IN TOUCH WITH INDUSTRY: ICAF INDUSTRY STUDIES 1997

GERALD ABBOTT, editor

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INDUSTRIAL COLLEGE OF THE ARMED FORCES
NATIONAL DEFENSE UNIVERSITY
WASHINGTON, DC 20319-5062

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At the end of World War I, British Prime Minister David Lloyd George remarked, "There were no braver nor more fearless men in any army, but the organization at home and behind the lines was not worthy of the reputation which American businessmen have deservedly won for smartness, promptitude and efficiency." The 1924 founding of the Army Industrial College was in large measure a response to this observation. Bernard Baruch charged the College at its founding to "preserve experience and keep *in touch with industry.*"

Since this beginning, the Industrial College of the Armed Forces has successfully prepared both military and civilian students for positions of senior leadership. Our curriculum, while adapting to changing times, maintains its core purpose of study and research of the resources component of national power. Special emphasis is placed on materiel acquisition and joint logistics. By conducting in-depth examinations of 18 industry sectors—both at home and abroad—the Industry Studies Program allows ICAF students to assess industry's ability to support our national security strategy.

The following pages comprise an assessment of each industry sector and are offered as part of the ongoing dialogue concerning the health of the industrial base. The 270 senior military and civilian students who contributed to this volume have brought a great deal of collective expertise and experience to the effort.

I would like to thank all the corporations and government activities worldwide that so generously supported this vital educational program.

John S. Cowings
Major General, U.S. Army
Commandant

ADVANCED MANUFACTURING

ABSTRACT

Current conditions suggest a resurgence of U.S. advanced manufacturing capabilities since 1990, but several potentially serious challenges remain, including financial pressures to reduce long-term research and development, barriers to technology deployment among smaller manufacturing firms, inadequacies in the current educational system, and declines or slower growth in productivity and wages. Because these problems detract from U.S. companies' ability to sustain global competitiveness, and because advanced industrial capabilities are an indispensable component of U.S. national wealth and power, government should assume an active role to achieve the following policies: Closer interaction between industry and educational institutions, strong support for government and industry partnerships that promote shared research and help develop new technologies, and economic initiatives that promote stable growth and capital investment in the manufacturing sector.

Mr. Barry M. Alexia, Hughes Aircraft Company
LTC Dewey L. Blyth, USA
Ms. Sharon K. Davie, Dept. of Defense
Col Randall M. Davis, USAF
LTC Thomas W. Feick, Jr., USA
Lt Col Robert Garcia, USAF
Lt Col Robert C. Halbert, USAF
Lt Col Kenneth P. Hasenbein, USAF
LTC Patrick L. Jenkins, ARNG
LtCol Christopher K. Joyce, USMC
LtCol Steven C. Miller, USMC
Lt Col Mark S. Overholtzer, USAF
COL Donald E. Plater, USA
Dr. Thomas J. Pojeta, Dept. of the Army
Ms. Mary Van Mullekom, Dept. of the Navy (HQMC)
CDR Kevin L. White, USN

Dr. Linda Brandt, faculty
CAPT Paul Moser, USN, faculty
Dr. Paul Needham, faculty

PLACES VISITED

Domestic

Caterpillar, Inc., York, PA
Cincinnati Milacron, Cincinnati, OH
General Dynamics Land Systems Division, Lima, OH
General Electric Aircraft Engines, Evendale, OH
General Motors Corporation, Warren, MI
Honda of America Manufacturing, Inc., East Liberty, OH
Hughes Aircraft Company, Dayton, OH
National Institute of Standards and Technology, Gaithersburg, MD
Northrup Grumman Corporation, Baltimore, MD
Saturn Corporation, Springhill, TN
TS TECH North America, Reynoldsburg, OH
W.L. Gore & Associates, Newark, DE

International

American Consulate General, Hong Kong
Hong Kong Productivity Council, Hong Kong
University of Hong Kong, Hong Kong
Motorola Semiconductors Hong Kong, Ltd., New Territories, Hong Kong
Hong Kong & Shanghai Bank, Ltd., Hong Kong
Li & Fung Group (Trading) Ltd., Kowloon, Hong Kong
American Consulate General, Guangzhou, China
Guandong Nortel Telecommunications, Shunde, China
Guangdong Provincial Economic Commission, Guangzhou, China
Guangzhou Otis Elevator Co., Ltd., Guangzhou, China
Heinz-UFE Ltd., Guangzhou, China
Shunde Whirlpool SMC Microwave Products Co. Ltd., Shunde, China
Shunde City Municipal Administration, Shunde City, China
American Consulate General, Nagoya, Japan
Mitsubishi Heavy Industries, Ltd., Aerospace Systems, Nagoya, Japan
Toyota Motor Corporation, Toyota City, Japan
Toyota Commemorative Museum, Nagoya, Japan
Sony Khoda Corporation, Aichi-Pref, Japan
Kintetsu Corporation, Nagoya, Japan
Daiei Corporation, Nagoya, Japan
Denso Corporation, Aichi-ken, Japan
Yamazaki-Mazak Trading Corporation, Aichi-Pref, Japan
Brothers Industries, Ltd., Nagoya, Japan
NGK Insulators, Ltd., Nagoya, Japan
Noritake Company, Ltd., Nagoya, Japan

INTRODUCTION

Although the U.S. economy is increasingly service-based, manufacturing continues to be a cornerstone of the nation's economy. Manufacturing accounts for 22 percent of the U.S. gross national product. Almost 21 million workers (17 percent of the U.S. work force) are directly employed in manufacturing. Additionally, every 100 manufacturing jobs support 60 additional jobs outside the manufacturing sector.

The manufacturing sector also conducts over 90 percent of U.S. nondefense research and development (R&D) and employs almost 75 percent of the nation's scientists and engineers. Manufacturing R&D provides the cutting edge for incorporating state-of-the-art technologies into new products, processes, and major improvements in productivity. As these innovations cycle through the economy, both the originating firms and society as a whole benefit from improved productivity, competitiveness, high employment, and a higher standard of living.

In addition to economic wealth, manufacturing industries are a key source of the materiels and technological capabilities needed to produce modern weapon systems and sustain sufficient military forces. Manufacturing is an important determinant of national power, both economic and military. Advanced manufacturing capabilities that require the interaction of highly trained humans, complex equipment, high technology, sophisticated management practices, and large organizations produce competitive world-class products and impact the ability of a nation to maintain security, project power, and influence world events.

This report focuses on the advanced aspects of modern manufacturing, its distinguishing features, and current industrial conditions. Industries are examined in a framework of three categories: (1) technology and equipment, (2) manufacturing processes, and (3) human and organizational aspects. Next, we address several challenges that potentially threaten the future of advanced manufacturing in the United States and the outlook for dealing successfully with those challenges. In the final section, we draw conclusions regarding government's appropriate role in addressing these challenges and recommend specific policy goals to improve the ability of U.S. advanced manufacturers to enhance national security in the future.

The diffusion of new technology shapes productivity through several channels: the purchase of technologically sophisticated machinery, equipment, and components; the acquisition of licenses or patents that enable one to use ideas developed elsewhere; or the simple borrowing of

ideas and expertise. But it is a firm's own innovative effort that allows the benefits of outside technology to be enjoyed.

Growth in Productivity

In advanced manufacturing, growth in productivity can be traced mainly to industries' own R&D expenditures—particularly in the machinery sector. Cincinnati Milacron, for example, has increased its capital spending significantly over the past three years in order to invest in modern equipment and systems. Through process redesign, the company is reducing machining and assembly operations, speeding up the production cycle, turning over inventory faster, and cutting rework and warranty costs.

Productivity growth in services and information technologies (e.g., transportation and communication services, finance, insurance, real estate, and business services), benefited considerably from the purchase of technologically sophisticated intermediate and investment goods from the manufacturing sector.

Yet the invention of new products and processes and their initial commercial exploitation generate fewer economy-wide benefits than their timely and widespread distribution. The economic performance of most manufacturing and service industries depends on adopting and using technological ideas and products developed elsewhere.

We believe that advanced manufacturing will continue to contribute its expertise to all industry sectors, thereby increasing their productivity, employment rates, and worker skills; and securing the future role of technology in shaping U.S. competitiveness at home and abroad.

The Evolution of Advanced Manufacturing

The United States, has emerged from the Cold War with two parallel industrial infrastructures—one for defense, the other for general commerce. Each sector relies on distinct technologies, production processes, and business practices. This legacy makes defense systems potentially unaffordable and encumbers our industrial competitiveness. The new world order demands a unified industrial base in which defense and commercial products share dual-use technology and are manufactured on next generation production processes that respond rapidly to changes in customer requirements and demand.

The continuing evolution of advanced manufacturing will create an open, flexible, and scaleable electronic infrastructure for manufacturing

in the 21st century. This infrastructure will provide standardized ways of accessing a wide variety of flexible production services over local area networks and the Internet. It is open because anyone will be able to offer services, and scaleable because it draws no distinction between services available on-site and those obtained from other divisions or outside companies. When fully developed, information technology will provide seamless access to flexible manufacturing services worldwide.

ADVANCED MANUFACTURING DEFINED

No single attribute or fixed set of elements inherently defines advanced manufacturing industries. Advanced manufacturing is better understood as an integrated system of the best human, organizational, and technological elements currently available. This report reviews a number of management techniques, business practices, organizational characteristics, technologies, processes, and human relations philosophies commonly found in advanced manufacturing organizations. Although each of these elements has important advantages, the essence of advanced manufacturing lies in how they are consolidated. Companies that effectively integrate these elements are the most successful creators, distributors, and supporters of world-class products.

Successful products take many forms, but all have the common characteristic of being the right product, in the right place, at the right time, competitively priced, and satisfying customers' quality expectations. Customer satisfaction, however, takes more than high quality today. Advanced manufacturers must also satisfy customers' demands for product differentiation. An industry's manufacturing processes and equipment must be flexible enough to build customer-driven product variations as efficiently as it produces cookie cutter copies. Customer demand is also highly changeable, and manufacturers must be agile enough to respond quickly to sudden shifts in customer demand to avoid debilitating losses of market share and large inventories of unprofitable product. A final distinguishing characteristic of world-class products is that they are created, used, and disposed of in ways that minimize damage to the environment. These product characteristics define advanced manufacturing more accurately than the mere list of techniques or technologies used to make the products. Thus, our definition of advanced manufacturing emphasizes both the integration of organizational elements and the value of its final products:

> Advanced manufacturing is an integrated combination of people, processes, machines, organizational structure, and management techniques that imbues products with globally competitive advantages that are measurable in terms of cost, quality, performance, customer satisfaction, and benign environmental impacts.

To achieve world-class results, a company does not necessarily employ every element of advanced manufacturing. Some companies may optimize certain elements to compensate for weaknesses in other areas. However, few firms succeed as advanced manufacturers unless they effectively integrate many of these elements. Customers can access markets anywhere in the world, and manufacturers must compete with each other on a global basis; that is, they must use manufacturing systems that are at least as effective as their competitors' systems. Instantaneous and ubiquitous global communications ensure that companies all over the world know which new technologies and business practices are most successful.

The key elements of advanced manufacturing evolve with time. The techniques and technologies that exemplify advanced manufacturing today may not be good enough to achieve world-class results tomorrow. Failure to keep pace with improved techniques and technologies guarantees a reduction in competitiveness. Thus, another characteristic of advanced manufacturing companies is the continuous search for, and implementation of, improved elements for their system.

Technologies and equipment associated with advanced manufacturing include machine tools, robotics, information technologies, and research and development. Advanced manufacturing processes address product development and production, quality, equipment maintenance, supplying manufacturers, and the environment. The organizational and human aspects of advanced manufacturing include the work force and organizational changes to ensure competitiveness.

CURRENT CONDITIONS

The manufacturing enterprise is undergoing significant changes in response to new market forces that are rendering mass production obsolete. These new forces include

- More intense global competition.
- Fragmentation of mass markets into niche markets.
- Greater cooperation among companies, to include competing firms.
- Increased expectations for customized products that do not sacrifice quality or reliability, and do contain costs.
- Greater social pressures that are shaping new ways that companies must conduct business.

To cope with these pressures, manufacturers have become leaner and more flexible. Compared with mass-production manufacturing, lean manufacturing develops new products using a fraction of the human effort, manufacturing space and inventory, investment tools, engineering hours, and real time. Flexible manufacturing processes allow them to adapt to changing conditions such as new technologies, customer preferences, regulatory constraints, monetary exchange rates, tariffs, and labor wages. Flexible, alert organizations adapt quickly, reducing the production cycle, and rapidly changing from product to product. The challenge for advanced manufacturing enterprises is to change quickly and economically. Doing so requires the appropriate application of systems, processes, and technologies to gain a competitive advantage.

Advanced Manufacturing Technologies and Equipment

Machine Tools. The machine tools industry is a critical part of the manufacturing enterprise. Advanced manufacturing relies on machine tools, not only for manufacturing consumer products, but for making the machinery of production. Machine tools shape, form, and cut metals, plastics, ceramics, and other material composites. They are often classified by functional category (e.g., drill press, punch, lathe) and by control device (manual, numerical control, and computer numeric-control). Computer numeric-controlled (CNC) machines use advanced software applications to reprogram automated movements easily and quickly. U.S. automotive and aerospace firms recently joined forces to facilitate their conversion to open, modular-architecture controls that make hardware replacement, upgrade, and interchange much easier.

The relatively small size of the machine tool industry in the United States does not reflect its significance to the nation's economic viability. The health of the industry often reflects the state of manufacturing. Accordingly, the United States lost its market share in the machine tool

industry when domestic production plummeted in the 1980s. This loss was exacerbated by improved foreign, particularly Japanese, machine tool products and services, and the high value of the dollar that hurt price competitiveness at home and abroad. Today, the U.S. share of the world's machine tool market is about 7 percent; Japan and Germany own the greatest market share. American machine tool manufacturers are generally small, family-owned firms with limited financial resources. Many were purchased by foreign firms during the domestic downturn of U.S. manufacturing during the 1980s.

Robotics. Robots execute specific functions in the manufacturing process (e.g., welding, lifting, and cutting). Robots typically replace and consolidate functions formerly done by humans, particularly repetitive or unsafe tasks, but also complex operations easily distorted by human error.

In the earlier stages of robotics development, some companies misapplied robots or overestimated their potential, resulting in low return on investment and high life-cycle costs. Most advanced manufacturers today conduct thorough cost analyses, identify training requirements, and integrate robots into their overall manufacturing systems. Over 72,000 robots are now at work in U.S. factories, and orders for new robots from U.S.-based companies have doubled since 1992, surpassing $1 billion.

Information Technologies. The role of information technologies in advanced manufacturing continues to grow. These technologies facilitate both materiel requirements planning (MRP I) and manufacturing resources planning (MRP II). State-of-the-art manufacturing execution systems (MES) are interactive, dynamic information systems that drive the manufacturing process from the point of order to delivery of the final product. Advances in simulations modeling support the design, virtual testing, and rapid prototyping of everything from automobile engines to aircraft, enhancing integration, and significantly cutting costs and approval-to-launch times.

Manufacturers continue to refine and exploit the vast potential of computer-assisted design (CAD) and manufacturing (CAM). These applications support rapid prototyping for design verification and preliminary testing, and the integration of design, production, distribution, marketing, and other functions. They also permit manufacturers to use secure electronic media to disseminate critical data

immediately within their companies and among their suppliers and overseas operations.

Research and Development. Six of the largest U.S. corporations collectively decreased their R&D by 30 percent between 1991 and 1994. Focusing on designing innovative products that offer a quick return on investment, U.S. firms have traditionally favored product-oriented R&D. Some leading-edge firms are investing more in process-oriented R&D. Firms are forming alliances with each other and with academic and non-profit researchers and the government to share R&D expenses. Government labs, for example, facing dwindling federal research funding, are collaborating with U.S. automakers on projects such as the Partnership for a New Generation of Vehicles (PNGV). A primary purpose of such initiatives is to link advanced technologies to manufacturing processes.

Advanced Manufacturing Processes

Product Development. Manufacturers are slashing the production cycle to reduce costs and enhance productivity. They apply integrated product teams, benchmark their competitors, and use sophisticated information technologies to help integrate processes to cut product development time and costs. Still, some major U.S. manufacturers lag behind their domestic and foreign competitors by a wide margin. Many U.S. manufacturers are world-class in design, but falter during production because they have not adequately integrated the design, engineering, and manufacturing process.

Production. Manufacturing in the United States is characterized by constant advances in production processes. One recent advance is the integration of personal computer-based human-machine interface applications and controls on a single, open-architecture platform. These systems enhance efficiencies by controlling inventories, tracking production, and documenting quality data.

Flexible manufacturing cells is a term used to refer to the integrated and automated machine tools and robots that produce high-quality, precision products around the clock. These cells can be programmed to support the production of various products by the same set of machine tools.

Quality. The Big Three automakers currently achieve about 120 defects per 100 vehicles, a vast improvement from the 1980s, when 750 defects per 100 vehicles was the norm. Quality control has shifted from the end of the production line to become an integral part of all aspects of product development. By incorporating quality measures throughout the manufacturing process, some U.S. automakers no longer have to hot-test engines before shipment. The International Organization for Standardization (ISO) oversees the quality certification of manufacturers around the world using standards such as the ISO 9000 series. ISO certification becomes critical to global competitiveness as more countries require certification as a condition for market access.

Maintaining Manufacturing Equipment. Manufacturers looking for every competitive edge are placing greater emphasis on maintaining their increasingly sophisticated equipment to minimize lost production time. Ease of maintenance has, in fact, become an important consideration in the design of manufacturing machinery. Equipment maintenance is carefully programmed into production scheduling and workers are more highly trained on maintenance procedures. The result is reduced downtime and higher-quality production.

Supplying Manufacturers. Cost pressures force manufacturers to minimize their parts inventories and outsource more production of parts and components. Since the purchase of parts and essential components (the supply chain) accounts for as much as 70 percent of the cost of many products, original equipment manufacturers (OEMs) are squeezing suppliers to cut costs, and some U.S. automakers require 5 percent reductions in parts costs each year. As a result, first-tier suppliers are outsourcing more engineering work and transferring cost pressures down to second- and third-tier suppliers. OEMs are developing partnerships with suppliers, helping them with productivity challenges, and sharing software technologies with them, to facilitate the communication of design specifications and production schedules. This communication facilitates timely parts delivery, minimizes costs associated with storage space and investment in parts, and supports flexible and agile manufacturing. OEMs are bringing suppliers into the earliest stages of product development to ensure that costs and specifications are integrated throughout the process.

Environmental Considerations. Environmental considerations have likewise assumed a greater role in manufacturing. Compliance

requirements affect productivity and influence where manufacturers locate their production. The ISO 14000 series of international environmental management standards has become a major factor in manufacturing operations because adherence is either expected or required, both domestically and internationally.

Organizational and Human Aspects of Advanced Manufacturing

Organizational Adaptations. Lean organizations are smaller and flatter, relying more heavily on empowered, self-directed teams and individuals to drive productivity and quality improvements. Firms are using teams and horizontal management models to integrate various manufacturing functions throughout product development and production. Automakers are achieving integration by having the chief engineer and plant manager co-chair product teams that include designers, suppliers, dealer representatives, and other key players. The result is much shorter cycle times, higher productivity, and greater responsiveness to market demands.

Collaborative trends between organizations are reflected in domestic and global alliances to share burdens, capitalize on strengths of respective partners, hedge against currency fluctuations, and comply with domestic content requirements of consumer nations.

The Work Force. U.S. labor costs and productivity are globally competitive, contributing to the influx of foreign transplant manufacturers in the United States. Rapid changes in the U.S. work force are characterized by declining labor union membership, greater use of lower-paid temporary workers, and the shift to, or concentration of, manufacturing plants in right-to-work regions. Union membership is currently at its lowest level in more than 50 years. Relationships between labor and management are increasingly cooperative and unions have been instrumental in achieving numerous productivity gains. However, remnants of an adversarial relationship persist, occasionally disrupting production and resulting in loss of market share that is difficult to recapture. Unions have hindered the efforts of some major U.S. manufacturers to outsource, forcing the use of higher cost in-house suppliers. Temporary employment has grown three times faster than employment as a whole over the past decade. Some manufacturers who have shifted from hourly to salaried work forces report that their employees are experiencing higher job satisfaction and lower absenteeism.

The ability of education to support advanced manufacturing in the United States varies widely by locality. Many manufacturers work with local schools and universities to develop required employee skills and improve worker quality. The degree to which manufacturers promote employee training is similarly varied. Many competitive manufacturers have embraced employee training, and the positive impacts on worker satisfaction and productivity are impressive.

The Globalization of Manufacturing

Global market forces are contributing to the increasingly "borderless" nature of the manufacturing enterprise. The national origin of products has less meaning once their parts are procured from multiple nations, to be assembled and manufactured in a different location, and finally customized for marketing in yet another locale. Flexible, agile manufacturers position various manufacturing functions to buffer the firm against changing labor costs and currency exchange rates, tariffs, regulations (such as local content requirements and environmental laws), and consumer needs. Some firms are avoiding large capital investments by outsourcing manufacturing processes such as product assembly to contractors who can quickly set up manufacturing facilities and produce quality products.

The higher-value aspects of advanced manufacturing are sought by developing nations such as China as a way to improve their standard of living and global stature. Developing nations often require manufacturers to establish higher-value manufacturing functions locally before granting them access to local markets. Although a proliferation of manufacturing has occurred throughout the world, labor-intensive and less technical functions are often performed in developing nations such as China. Manufacturers find it challenging, for example, to employ progressive labor techniques in China, since Chinese culture does not promote the teamwork that has been so vital to the success of Japanese manufacturers.

The manufacturing enterprise has declined in some nations, for example, Germany, as a result of labor, regulatory, and tariff conditions that are unfavorable for business. Once a major manufacturing power, Germany has moved much of its production to other countries, retaining only certain functions such as product development closer to home. Other nations, such as South Korea, are mounting aggressive campaigns to achieve world-class manufacturing capabilities.

Many Japanese manufacturers are now promoting what they call a "harmonious" approach to manufacturing. By balancing the human element with safety, the environment, and progressive business practices, they continue to promote a more comprehensive, holistic approach to manufacturing. Though challenged by an aging work force and fluctuating exchange rates, Japan has aggressively pursued the further globalization of its manufacturing prowess.

U.S. manufacturing capabilities remain fairly impressive across the full spectrum of advanced manufacturing. However, a shorter-term focus on the bottom line may erode America's manufacturing strength as fewer resources are dedicated to key functions such as R&D and employee training.

CHALLENGES

The overarching challenge for advanced manufacturing today is global competition. Like advanced manufacturing itself, the challenge of global competition is a composite of many elements that can vary from company to company and industry to industry. Thus, global competition not only presents a different face to different companies, it is also different when viewed from a national perspective. Whereas companies engage in global competition by struggling to sustain competitiveness against other companies, countries struggle to create internal environments that attract capital investment, often with many companies competing in the same industry. Ultimately, however, manufacturing success for companies or countries lies in their ability to integrate solutions to specific combinations of manufacturing challenges.

Advanced Manufacturing Technologies and Equipment

Research and Development. As noted earlier, short-term pressures for financial returns make it increasingly difficult for publicly owned companies to invest substantial sums in long-term R&D. Yet R&D remains a vital component of long-term competitiveness: it creates new products, processes, and technologies that often result in quantum gains in productivity. The challenge faced by many American companies is how to sustain adequate R&D budgets while simultaneously satisfying shareholders with high investment returns. Many companies are seeking

government partnerships or multicompany industrial alliances to pool R&D budgets and share the results.

A multitude of technical R&D challenges face the manufacturing community. These include telecommunications security and encryption, open architecture software for machine control, standards for the translation and transmission of electronic data, advanced materials research, and others. Developments in these areas will have major impacts on the global competitiveness of manufacturing enterprises.

Machine Tools. The U.S. machine tool industry supports a small number of large companies, such as Cincinnati Milacron, but the bulk of the industry is composed of small, family-owned businesses that assemble low-to-medium technology machine tools and manufacturing cells. While most of the large companies have the financial resources necessary to adopt new technologies, few of the smaller machine tool companies have sufficient risk capital to take on the investment and training costs associated with new technologies. For this reason, deploying new technologies and recapturing market share lost to overseas manufacturers is especially challenging for the majority of U.S. machine tool firms.

Advanced Manufacturing Processes

Product Development. Shorter product development cycles help manufacturers compete for market share and profits. First, the faster a company can develop a product, the more responsive that company will be to changing customer requirements and tastes. Second, rapid product development enables manufacturers to exploit new market opportunities. Third, shortening product development time reduces costs by using fewer engineering hours and less design overhead. The result is a price advantage over companies with longer product development cycles and the ability to profit from smaller production runs. Last, the cooperation that engineers, managers, and production workers need to achieve rapid product development demands a level of teamwork that also enhances product quality.

In the automobile industry, for example, where each day eliminated from the product development cycle saves over $1 million, manufacturers are taking steps to reduce product development time. Many of these manufacturers face the additional challenge of phasing out a large number of older CAD/CAM systems in favor of a single enhanced CAD/CAM system that can facilitate concurrent engineering,

supplier responsiveness, and faster product development cycles. For example, costly prototypes can be eliminated (or at least reduced) using the modeling and simulation capabilities built into new generation CAD/CAM systems. The challenge is the time and money it takes to convert a large organization over to the new methods. To be competitive with Chrysler, for example, Ford, needs to cut $1,000 from its product development costs. The Ford 2000 program is the company's answer. This program will cut development time by 30 to 40 percent. It includes concurrent engineering and a new CAD/CAM system that incorporates paper transmissions of data, fewer engineering steps, and a 50-percent reduction in prototypes.

Organizational and Human Aspects of Advanced Manufacturing

Work Force Education and Training. One of the most difficult challenges facing U.S. manufacturers is that many graduates of American secondary schools lack the basic skills in reading, math, and human relations needed to succeed in advanced manufacturing jobs. Companies often have to screen large numbers of resumes to find suitable personnel or conduct remedial training for the workers they hire. The challenge facing manufacturers is how to partner effectively with schools to prepare workers for manufacturing jobs.

Productivity. Improving productivity is a constant challenge for advanced manufacturers, who want to remain competitive in the global market. Productivity improvements originate from several sources. Research and development and process organization have already been mentioned, and the human work force is equally important. As the closest observers of the manufacturing process, workers are keenly aware of inefficiencies or areas that could be improved. The key challenge is to empower the work force to develop and implement its new ideas and methods. Incentives, such as awards, performance-based compensation, increased wages, and morale-building tactics, such as team work and worker access to decision makers, are important components in meeting this challenge. For example, the Saturn Corporation uses a system of risk/reward pay to encourage productivity improvements in its work teams.

OUTLOOK

U.S. advanced manufacturers are currently in a strong position, as many companies have adopted lean manufacturing processes and are slowly evolving toward flexibility and agility. These trends have certain implications for the Department of Defense (DoD). The trend toward leaner manufacturing builds our defense capabilities because it can more rapidly field new products and weapon systems during a national mobilization. However, the manufacturing technology for weapon systems may not always be adaptable to the equipment and methods used for consumer goods. A negative implication is the tendency for lean manufacturing enterprises to run at near capacity rates and with minimum inventory, suggesting little excess capacity or inventory available for surge situations.

The U.S. machine tools and capital goods industries are particularly vulnerable to economic downturns, as shown in the 1980s when Japanese tool makers took over a large portion of market share in this area. Although the 1990s have seen a resurgence in this industry few changes have occurred in the machine tool industry to improve the ability of small firms to survive the next downturn.

The outlook for R&D is somewhat more encouraging. Many industrial alliances and government partnerships are currently funded. Examples include the Partnership of Next Generation Vehicles and the National Institute for Standards and Technology's Advanced Manufacturing Technology program.

Educational institutions are receiving a great deal of scrutiny in the United States. However, it remains to be seen whether widespread reforms will be undertaken to improve the outlook for work force education. Current proposals for modest funding increases, national standards, and performance-based pay for teachers are too controversial and limited to assure an improved outlook.

GOVERNMENT GOALS AND ROLE

Although the role of government in manufacturing has varied over time, it is characterized by a wide range of activities and spans the entire spectrum of manufacturing from research and development to traditional manufacturing processes. In the United States, both industry and the

nation as a whole have common interests in promoting a world-class education system, technology, and economic stability.

The government plays an important role in securing an educated work force to support the growing and changing needs of manufacturing. To ensure continued viability in an increasingly competitive global manufacturing environment, industry requires workers with skills and knowledge in a range of academic, business, technological, and work place subjects. The government must promote closer interaction between industry and educational institutions that includes determining whether and how job skills can be required in school curriculums.

Government agencies have also provided grants to private industry to fund research on promising ideas. The nonprofit Manufacturing Technology Centers (MTCs) of the National Institute of Standards and Technology (NIST) help small- and medium-sized companies adopt state-of-the-art manufacturing technologies and management concepts. MTCs are being combined with several other NIST outreach programs to form the Manufacturing Extension Partnership (MEP) programs.

The degree to which government gets involved depends on many factors, but national security considerations have been a primary driver. When the country is embroiled in a national crisis or war, or when its leaders perceive other threats to national security, such as increasing foreign competition or development of new technology by a potential adversary, then government plays a larger role. Political considerations, such as what constituency is served when Congress supports a specific industry, or which congressional district will get jobs, also influence the level of support—as do philosophical differences among the various political parties and branches of government. Finally, the budget environment and the potential effect of government support for manufacturing on the budget deficit are significant factors in determining government's role.

The technology infrastructure of the United States is basically strong, but the complex set of interdependencies among industry, government, and academia on which this infrastructure relies is currently changing. Unless these partnerships are understood, uncontrolled arbitrary changes in the fabric of their relationships could lead to its unraveling with irreversible and undesirable consequences for the nation.

Dynamic changes have occurred during the past five years in both manufacturing and the political climate. Technology became a major issue in the 1992 presidential campaign. After the election, federal technology programs grew rapidly. The budget of the Commerce

Department's Advanced Technology Program (ATP) grew from $47 million in 1992 to over $400 million in 1995. The DoD received an appropriation of $500 million in 1994 to accelerate the application of defense technology to civilian needs through the Technology Reconversion Program (TRP). National labs were also given incentives to establish partnerships with industry. Even as this growth occurred, however, many in Congress sought to reduce or eliminate these programs—and the departments of Commerce and Energy—in an effort to reduce the size of the federal government.

As a general proposition, this report recommends that public policies concerning advanced manufacturing should be guided by a better understanding of the role of manufacturing in the economy and its relevance to the national interest. Those interests are closely interwoven: industry seeks a favorable climate for profitable investments, and the nation needs that investment to enjoy economic growth, security, and a high standard of living.

The government supports the manufacturing enterprise in the United States primarily by ensuring the nation's economic stability. The prudent application of fiscal and monetary policies that encourage low inflation, high savings, capital investment, and other benefits promotes the nation's advanced manufacturing enterprise and secures its defense.

CONCLUSION

The overall health of advanced manufacturing in the United States is very good. However, the nation cannot afford to rest on past successes, but must move toward greater innovation and risk taking to maintain its position in the global environment.

The joint involvement of industry, government, and academia is crucial to our success. Without it the United States will face increased competition from abroad—capable, perhaps, of displacing us in the global market place, leaving us with an industrial base incapable of responding in a time of crisis, and no mechanism for the sharing of ideas and technology that stimulate growth and produce a world-class economy.

Without doubt the 21st century will be a time of tremendous growth around the world. The United States must be prepared to influence and manage this growth, notwithstanding its demand for effort, cooperation, far-reaching thought, and sufficient funding. It is certainly within the nation's capacity to accomplish this task and continue its world leadership.

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AGRIBUSINESS

ABSTRACT

This report analyzes the U.S. agribusiness industry, beginning with a general description of the industry and its current condition, followed by an analysis of trends, outlooks, and conclusions related to five major challenges that this industry must carry into the next century: feeding a growing world population, ensuring food safety, leveraging technology, protecting the environment, and defining government's appropriate role. The report closes with recommendations to enhance the industry's already vigorous state. The content reflects recurring themes heard throughout our classroom studies, research, field visits in the United States and Russia, and interviews with government officials and industry representatives.

Mr. Bob Bemben, Dept. of the Air Force
LTC Mark Brown, USA
Lt Col Steve Cameron, USAF
Lt Col Barbara Chine, USAF
COL Eddie Coleman, USA
Ms. Denise Droneburg, National Imagery and Mapping Agency
Lt Col Don Fick, ANG
CAPT Jack McCorkle, USN
Ms. Leslie Nolan, U.S. Information Agency
LTC Pat Nolin, USA
CDR Roger Peoples, USCG
LTC William Phillips, USA
LtCol Ervin Rivers, USMC
Lt Col Laurie Ternes, USAF
LTC Gerald Walsh, USA
Col Donald Wurster, USAF

COL Thomas Grant, USA, faculty
Dr. James Currie, faculty
Dr. Nedra Huggins-Williams, U.S. Agency for International Development, faculty
Mrs. Judyt Mandel, Dept. of State, faculty

PLACES VISITED

Domestic

U.S. Department of Agriculture, Washington, DC
Agricultural Research Service, Beltsville, MD
Ottenberg Bakery, Washington, DC
Smithfield Farms, Smithfield, VA
Wampler-Longacre, Inc., Forestville, VA
Chicago Board of Trade, Chicago, IL
Chicago Mercantile Exchange, Chicago, IL
U.S. Senate Agricultural Committee, Washington, DC
U.S. House of Representatives Agricultural Committee, Washington, DC
California Dept. of Agriculture, Sacramento, CA
Blue Diamond Almond Association, Sacramento, CA
Calgene Research Institute, Davis, CA
Williams Rice Milling Co., Williams, CA
Domaine Chandon Winery, Yountville, CA
University of California Davis, Davis, CA
Agriculture Council of California, Sacramento, CA
California Cattlemen's Association, Sacramento, CA
California Dairymen's Association, Sacramento, CA
Lane Ranch, Clements, CA
Van Warmerdam Dairy, Lodi, CA
Rominger Farms, Winters, CA
J&S Food Brokers, Colonial Heights, VA

International

American Business Center, St. Petersburg, Russia
USDA Model Farm, St. Petersburg, Russia
Foreign Agriculture Service, Moscow, Russia
Russian Agrarian Institute, Moscow, Russia
Moscovski Agro-Combine, Moscovski Hamlet, Russia
Russian Farm Community Project, Moscow Oblast, Russia
Farmer's Market, Moscow, Russia
Meat Processing Plant, Shehapovo, Russia
Moscow Agricultural Academy, Moscow, Russia

INTRODUCTION

Agriculture is unique. Unlike other industries, nature limits its surge capacity; that is, weather dictates the timing of harvests, the availability of seeds, and crop yield. The demand curve for agricultural products is relatively inelastic, highlighting the fact that no substitute exists for food. Since hungry populations are more likely to create conflicts, the health of a nation's agribusiness industry is a key test of its stability.

One unforgettable day we found ourselves standing waist deep in a healthy field of California grain, listening to a young, next-generation U.S. farmer address the most pressing issues of his business. Another time we huddled before a poor, middle-aged Russian dairy farmer in the rural countryside near St. Petersburg. Her weather-beaten face flooded with tears as she spoke of hardship, U.S. generosity, future concerns, and hope. The visit to Russia was a sobering reminder of the dire consequences facing a government that ignores its agricultural industry.

Agriculture is a critical element of U.S. national power. The combination of good soil, modern technology, educated farmers, efficient food processing, and marketing contributes to a healthy population, strong economy, and an unequaled capacity to field and sustain fighting forces. U.S. agricultural exports have doubled in the past 10 years, creating a positive net trade surplus. Agribusiness contributes substantially to the U.S. economy: it commands a large share of the gross domestic product (GDP), employs a large segment of the nation's work force, and generates high levels of economic activity. In stark contrast, Russian agriculture is in an abysmal state, having declined markedly since 1991. This situation could have serious consequences for U.S. national security if, for example, Russia turns away from democracy to solve its agricultural crisis.

As we approach the end of the century, U.S. agribusiness is robust, efficient, and globally competitive. This previously subsidized and protected American industry has become a major contributor to the U.S. economy, and a necessary condition for meeting national security objectives. Agribusiness is well-positioned to surmount diverse new challenges in the global marketplace. It is also poised to reap benefits from potentially revolutionary policy changes and actual, rapidly emerging information age technologies.

This report analyzes the U.S. agribusiness industry, beginning with an overview of the industry and its current condition, followed by an analysis of trends, outlooks, and conclusions vis-à-vis five major

challenges. It closes with recommendations to enhance the industry's already vigorous state.

THE AGRIBUSINESS INDUSTRY DEFINED

A diverse global enterprise, U.S. agribusiness begins with traditional farming and its related suppliers and extends to processing, sales, food services, and a host of farm-dependent but nonfood-producing industries. Key industries facilitating agribusiness include trade, transportation, and finance. Top firms in the agribusiness food and fiber complex include tobacco producers and chemical manufacturers, food-related beverage and soup companies, and major food retailing and restaurant chains. Major components of the U.S. agribusiness industry include:

- ***Farm Input Suppliers***—Input suppliers include seed, feed, and equipment businesses, and the producers of chemical fertilizers, herbicides, and pesticides. Inputs extend beyond the farm to oil and fuel companies, and even to natural gas, which is used to produce nitrogen fertilizer. Input businesses also include support services, such as financial assistance and government research and education programs.
- ***Farms and Farmers***—Farmers remain the backbone of U.S. agriculture. One U.S. farmer grows enough to feed and clothe 130 people, and one milk cow supplies enough dairy products for 25 people for one year. Of the 130 people fed and clothed, 36 live outside the United States (Walker, 1997), and although 90 percent of U.S. farms are still family-owned, farms have generally decreased in number and increased in size. Today, the majority of farm outputs are produced by a few large farms that are more efficient and productive than small ventures.
- ***Food Processors, Retailers, and Service Outlets***—The growing food processing industry includes canning, cooking, baking, and packaging plants and other preparation activities that add value to raw food commodities. Food retailers provide consumers with a wide variety of processed and unprocessed foods. Food-service outlets are becoming increasingly popular as working families spend less time in the kitchen. Fast food restaurants dominate this sector of the industry.
- ***The Futures Industry***—Commodities exchanges located in New York and Chicago are the primary means of risk management in the

agribusiness industry. Exchanges provide a market for buyers and sellers to meet and exchange commodities, to discover prices, and seek stability. Agricultural products constitute about 25 percent of the contracts available for trade (CBOT, 1997).

- ***Exporters and Importers***—As U.S. agriculture moves away from subsidies and closer to global free markets, exporters and importers play an important role. American agriculture is twice as reliant on international markets as is the U.S. economy as a whole; and by the year 2000, agribusiness will be 2.5 times more reliant. According to Secretary of Agriculture Daniel Glickman, "In the long-term, trade —global markets—not commodity programs, will define agriculture's future."

CURRENT CONDITIONS

The United States enjoys sufficient natural resources to ensure its national security in the area of agriculture and is perfectly positioned to compete successfully for growing food markets around the world.

Agricultural Production and Sales—Healthy

The agribusiness industry presently accounts for 16 percent of the total U.S. GDP, employs 18 percent of the nation's work force, and generates over $1 trillion in economic activity each year (USDA, 1997a). Decreasing price supports under the 1996 Farm Bill could eventually alter production patterns for some previously subsidized commodities, but predictions call for a strong and stable future. U.S. production of wheat, feed grains, and soybeans is expected to remain relatively constant for the next several years, even with Farm Bill changes; and 1997 industry predictions for total red meat production are the same as 1996 outputs. The U.S. Department of Agriculture (USDA) expects a 5 percent increase in poultry production, and worldwide demand for U.S. broilers should remain exceptionally strong (USDA, 1997b).

Overall domestic agribusiness demand continues to grow steadily at about 1 percent per year, while agricultural efficiency increases almost 2 percent per year. As the result of this efficiency gain, Americans now spend less on food as a percentage of income than ever before—and less than other nations. The United States spends 9 percent of its income on food; by contrast, residents of India spend 53 percent of their income on food.

U.S. Agribusiness Exports—Expanding

The United States is the world's top exporter of agricultural products. In 1996, we exported over $60 billion in agricultural trade, with a surplus of $30 billion. Overall, an export growth of about 3 percent per year prevents any need to scale back agricultural production and provides a built-in reserve in the event of a national emergency (Tweeten, 1992, p. 1). The United States exports over a third of its harvests. The top U.S. export crops in 1995 were wheat, rice, cotton, soybeans, and corn. Top markets for U.S. agricultural products include Japan, the European Union, Canada, and Mexico. U.S. agricultural products also flow to a number of smaller, but growing markets, for example, emerging markets include China, Indonesia, India, South Korea, Mexico, Argentina, Brazil, Poland, Turkey, and South Africa (Aguilar, 1997. p. 1).

Export commodity and product sales figures for 1995 reflect the overall health and growth of agricultural exports. Bulk commodities export sales of $24.5 billion were up $6.5 billion—a hefty 36 percent over the previous year. Exports of high-value intermediate products rose to a record $11.2 billion, up 19 percent from the record set in fiscal year 1994. Consumer-oriented products had another record year with exports of $18.5 billion (USDA, 1996b, p. 2).

In virtually every foreign market, U.S. agricultural exports are subject to import duties and nontariff trade restrictions (FAS, 1997). The U.S. currently uses agribusiness to knock down these barriers, through programs such as Winrock International's Farmer-to-Farmer program in the former Soviet Union, that promote development of market economies. In addition, food is becoming an important policy tool for international pressure, approaching the same level of influence as military aid.

Farm Supports—Declining

In past years, the government paid farmers when the market price of their crop dropped below certain levels, specifying types and quantities of crops farmers could grow. The Federal Agriculture Improvement and Reform Act, commonly called "the 1996 Farm Bill," phases out these price supports and allows farmers to produce directly for the commodities markets largely free of government intervention. Aggregate net farm income is expected to be higher under the bill than it would

have been under the past legislation, despite higher government payments. However, since government payments are now fixed, farm income may become more variable from year to year in response to market supply and demand. Marketing alternatives to manage risk will become more important to farmers. President Clinton signed the 1996 Farm Bill with concern and hope: concern that it lacked an adequate safety net for family farmers and hope for improved U.S. competitiveness in world markets.

Farmer Risk Management—Increasing

As the 1996 Farm Bill shifts price risk management from the government to the private sector, farmers must rely more on futures contracts and options trading to survive. Small farmers have not traditionally participated fully in these markets because they lacked expertise and because of the complexity of modern commodities. Their lack of familiarity with these risk management tools could be problematic, especially at a time when county extension offices, a convenient source of information and expert advice to farmers and ranchers, are being widely reduced or eliminated. Proposed regulatory changes may offer some relief, if they can strike a balance between the need for regulation and investor protection and the costs to industry of complying with regulations. Proposed legislation would encourage agricultural options trading and ease the process of introducing new futures contracts, thereby reducing the time before new products can be traded. Even with these reforms, the average American farmer still faces a tough transition to this relatively complex method of managing risk.

Demand for Processed Foods—Increasing

The U.S. consumer's desire to spend less time in the kitchen has forever transformed food marketing. Demand for heat-and-serve, or home replacement meals and other processed foods is increasing. Shelf-stable foods, refrigerated dough, complete meals, and frozen or dehydrated foods—all satisfy part of this booming demand for new products. Firms have aggressively moved into prespicing, precooking, and prepackaging, all of which minimize the work done by consumers and retailers. This trend shows no sign of abatement and is rapidly spreading to international markets. Total U.S. trade in processed foods and beverages amounted to $54.2 billion in 1995 (USDA, 1997c, p. 34). This market is a huge growth area for agribusiness.

Food Service Business—Flourishing

The U.S. population eats away from home more than ever before. This "the most striking change in food consumption and marketing," accounted for 45 percent of all food dollars in 1992, compared with 25 percent in 1954 (Nagengast, 1994, p. 144). Americans currently spend 45 percent of their "away-from-home" food dollars at fast food establishments (Kinsey, 1994, p. 21). Not to be outdone, grocery stores are beginning to compete for the eating-out market by providing ready-to-eat take-out foods.

CHALLENGES

The continued success of U.S. agribusiness hinges on success in addressing five top challenges facing the industry today—feeding a growing world population, ensuring food safety, leveraging technology, protecting the environment, and defining appropriate government roles and goals.

Feeding a Growing World Population

Population growth poses both domestic and global challenges. If, as expected, the world's population doubles in the next 35 years, it will demand twice the current food supply. As populations increase, global food supplies depend on the ability of nations to leverage their agricultural potential. Nations that cannot feed themselves will be increasingly dependent on food distribution networks and imports from other countries. Currently the leading supplier of food to the world, the United States must prevent urban sprawl from increasingly swallowing its farmland. Encroaching development also brings other problems to farmers: greater property values, higher taxes, and environmental degradation.

More People. The current world population exceeds 5.7 billion. If the fertility rate remains at 3.8 children per couple, we may see over 50 billion human beings on earth by the end of the coming century. Even at lower birth rates, the large number of young people who have yet to arrive at childbearing age is likely to increase the population to 7.3 billion by the end of the 21st century. It is highly likely that the

population of the world will double before we see a significant downward trend in population growth rates.

Need for Increased Production. According to the USDA, 49 percent of the world's dietary energy supply is provided by two grains—wheat and rice (USDA, 1996, p. 11). Therefore, the global food supply depends not only on increased production in areas of the world with favorable soils and adequate water resources, but also on higher yields from wheat and rice cropping. However, the land area devoted to rice and wheat cultivation has stagnated the last decade, so increases in wheat and rice production must come from increases in yield per hectare. Meeting the estimated world need will require a 60 percent increase in production over the next century (Cassman, 1995, pp. 439-440).

Further, increased production in the United States will not help people in underdeveloped countries that lack an adequate transportation infrastructure. The food distribution systems in underdeveloped nations will be critical to the health and survival of their populations.

The United States is blessed with sufficient agricultural potential to satisfy the needs of a growing global population. Nowhere else in the world do soil and the climate intersect so favorably as in America. Ideal agricultural conditions abound in over 240,000 square miles of America's heartland, an area resistant to crop loss in all but the most devastating conditions.

Decreasing Farmland. Preservation of the land base for farming is vital to the future of agribusiness. Effective zoning, agricultural security areas, easements, and preferential tax policies are all useful tools for resisting urban sprawl and maintaining sufficient land base for farming (Pena, 1996).

Farmlands are also threatened by resource depletion, including the overuse of water and the desertification of formerly fertile, irrigated valleys. Fertilizers, salts (accumulated from irrigation), herbicides, and other chemicals used in agriculture can have lasting, deleterious effects on the land if they are overused or not properly applied (Brechin, 1996). As these issues affect the food supply, they are population issues; the wise husbanding of finite resources is necessary for humankind's long-term survival. The challenge for U.S. agribusiness is to increase productivity to feed America and much of the world using the same land now available and minimizing environmental damage (Avery, 1995).

Aquaculture. Some farmers have turned to aquaculture as a means of growing food in previously nonproductive areas. This fast-growing segment of U.S. agriculture enjoys relatively steady feed costs and high demand for pond-raised products (USDA, 1997d). The USDA believes that although the worldwide catch of wild ocean fish will decline or at best remain the same, farm-raised aquaculture will more than quadruple by 2025. The industry contributes just over 17 million metric tons of domestic aquaculture products currently, with the capacity to grow to 76 million metric tons by 2025. This young, vigorous industry may be one solution to keeping pace with population growth (New, 1990).

Conclusion. Population growth is a global issue with increasing national security implications for the United States. Nations that cannot grow their own food must develop an effective food procurement and distribution network. Those that cannot will either starve or disrupt regional stability. The United States has ample resources to feed its own population and an increasing portion of the global population, but it lacks a comprehensive plan to protect the resources that support this critical component of national power. U.S. agriculture must improve its efficiency and productivity to meet this demand, both for an increased share of the global economy and to ensure U.S. national security needs.

Ensuring Food Safety

The United States has one of the safest food supplies in the world, but food safety in this country is still a concern. Harmful microbes in food cause as many as 7 million illnesses and up to 7,000 deaths every year in the United States (FSIS, 1997). Food safety issues will likely increase as the United States turns more toward processed products and opens agricultural markets to foreign competition.

Foodborne Illnesses. The Center for Disease Control and Prevention estimated that the medical cost of foodborne illnesses in 1992 exceeded $5.1 billion (Roberts, 1994 p. 7). Much of the problem stems from improper handling and preparation, for example, the widely publicized 1995 *E. coli* illnesses that occurred on the West Coast after people ate undercooked hamburgers. The impact was greatest in Washington state, where over 600 people became ill, 144 were hospitalized, 30 experienced kidney failure, and four died (GPO, 1995, p. 2). The risk of food contamination increases with the number of times food is handled

during processing. Thus, food safety will become even more important as Americans consume increasing amounts of processed food.

The 1997 experience with contaminated strawberries from Mexico also highlights the need for additional food safety measures as the United States moves more aggressively into larger international agricultural markets. Another threat to food safety is some producers' reluctance to control pesticides and other chemical residues that can find their way into processed foods (Kramer, 1994, p. 171) .

Inefficient Safety Programs. Evolving over many years, the U.S. government's food safety program is a web of numerous regulations administered by various agencies with food safety responsibilities. "Currently, 12 federal agencies spend about $1 billion annually to administer 35 laws governing food safety and quality" (GPO, 1995, p. 50). Managing and coordinating this unwieldy responsibility continues to be a demanding task. Currently, there are over 50 cooperative agreements between federal agencies responsible for food safety (GPO, 1995, p. 51). With so many agencies involved in food safety, the current system suffers from inefficiency, redundancy, and potential lack of public confidence. Moreover, U.S. food safety programs historically were designed for contamination detection—not prevention. Fortunately, food safety reforms are in the works.

Inspection Reforms and New Technology. The new Hazard Analysis and Critical Control Program (HACCP) food safety system will allow both the Food and Drug Administration and Food Safety and Inspection Service to focus their programs on the most significant safety hazards, while ensuring that processing plants have systems and procedures in place that actively prevent food safety problems. The HACCP system is a scientific, process-based analysis of potential hazards, a determination of where those hazards may occur, and an appropriate action plan to implement preventive measures to avoid occurrence. This new program mandates modernized inspection programs, and greater cooperation and teamwork between agencies.

Modern technology can also provide better, cheaper, and faster means of increasing safety levels for our food supply. For example, fighting foodborne diseases with radiation offers great promise, if it can overcome the widespread tendency to ascribe a negative connotation to the term "radiation."

Conclusion. A safe food supply supports a healthy population and is vital to the competitiveness of U.S. agriculture products in a global marketplace. The United States continues to maintain one of the safest food supplies in the world, but foodborne illnesses occur frequently. As the U.S. diet includes more processed and imported foods, ensuring food safety poses a greater challenge than ever. Success depends on the combined efforts of a vigilant, better coordinated government prevention and inspection program, application of technological solutions, a safety-minded food service industry, and a well-informed consumer.

Leveraging Technology

Nations that leverage new technologies have a decided competitive advantage over those who do not. As long as the success of U.S. agriculture depends on its ability to compete globally, the industry must continuously adapt new technologies to increase crop yields, protect natural resources, and improve production efficiency. Two technological fields can make this happen: information technology and biotechnology.

Information Technology. Agribusiness is rapidly evolving as a consequence of the Information Age. Video livestock sales were an early application of information technology in Agribusiness. The results of video sales are impressive—in 1993, the Lower Middle Tennessee Cattle Association's video sales prices averaged 5 percent over average market prices. Producers using video sales can command these higher prices because the livestock are transported directly from the producer to the buyer in fresh condition, straight from the farm.

Though still in its infancy, precision farming is another promising information-technology application. This process uses a wide variety of data to understand the variability of a particular field—the better to manage every square foot of land. Using computerized systems, precision farmers simultaneously analyze crop yields, soil samples, topography, and rainfall to determine where in the field and how much fertilizer, herbicide, and pesticide inputs are needed to generate the desired economic results. Although the farmers we contacted told us that startup costs are high, the payoff will come in conservation and higher yields. For now, however, the technology of precision farming is ahead of the science, and every precision farming operation is its own experiment station.

Satellite imagery plays a major role, monitoring weather for early warning and evaluating probable impacts of events such as freezes,

droughts, fires, and floods can drastically affect crop production. Analysts also monitor crop production and give producers, distributors, and exporters an advanced look at the world market for various commodities and possible export opportunities.

One of the most rapidly expanding uses of technology and a valuable source of information is the Internet. Now used to trade commodities, predict weather, and access agricultural libraries and databases, the Internet educates farmers and consumers and links agricultural suppliers, colleagues, and customers.

Biotechnology. With its potential for increasing crop yields and meat production, biotechnology promises greater flexibility in growing environments, less use of chemical pesticides, and improved food nutritional content. Research advancements in the past two decades have permitted scientists to accelerate the development of precise agricultural product improvements through biochemical additives, hormone therapy, and gene amplification.

Those methods will continue to produce agricultural improvements in the coming years, but new research methods could provide even greater agricultural advancements. For example, scientists are beginning to examine transgenic research as a way of improving the next generation of animals and plants. Transgenic research alters the genetic composition of cells through techniques such as in-vitro manipulation of eggs and gene-characteristic transfer from one organism to another.

One of the most promising developments in plant research is the formulation of genetically inserted biopesticides, products that use naturally occurring organisms, rather than chemicals, to deal with bugs and weeds. Most of the products presently in use employ *Bacillus thuringiensis* (Bt), to destroy both pests and weeds. New Bt crops for 1996 include cotton with a genetic makeup that fortifies plants against the devastation of both bollworms and budworms, and corn hybrids that use a Bt gene that resists the European corn borer (Keller, 1996). In addition to insect resistant plants, Monsanto has genetically modified a number of crop plants—corn, soybeans, and sugar beets—to tolerate its "Roundup" herbicide. This natural tolerance allows farmers to kill weeds without harming the soybean plants.

The development of disease and herbicide-resistant crops represents only a scratch on the surface of surprises yet to come in the field of plant biotechnology. With the aid of modern computer technology, scientists are developing a better understanding of some of life's basic processes, and with understanding comes the potential to increase nature's bounty.

In addition, drought resistant crops, once thought impossible, may now be possible through the use of DNA probes and marker-assisted selection.

Some new research projects are breaking the barrier between animal and plant biotechnology. Researchers are using fish genes to provide built-in antifreeze for plants, to determine the possibility of producing year-round field crops; and a relatively new field of biopharmaceutical research is the effort to develop human vaccines from plants. Scientists are already transferring hepatitis and cholera genes into plants, and specialists have designed research to help solve other human ailments, from cancer to tooth decay.

While genetically altered animals might offer future medical benefits, the primary objective of current agricultural animal research is to establish whether transferred genes can improve productivity. Historically, public reaction to modifying animal products has hampered animal biotechnology research. The milk production hormone (bovine somatotropin) first met with skepticism—some grocery chains would not even accept ice cream from hormone-treated cows (NPA, 1990).

Private sector research is now the major investor in biotechnology, accounting for an estimated $8 billion of the $12 billion that the world spends annually on biotechnological research and development (ABSP, 1997). The challenge facing USDA and other government agencies conducting biotechnology research is to find the proper niche for government in this rapidly developing area.

Conclusions. Emerging technologies offer opportunities to strengthen economies, feed growing populations, and reverse or prevent much of the environmental damage caused by past agricultural practices. The economic benefits of new agricultural technology will go to the early adapter, and it is in our best interests to pursue aggressively new information and biotechnology advances. The federal government is a key technology change agent. New biotechnology advances cannot survive without significant government oversight and public assurances that new products are safe to consume and use. At the same time, government approval processes must be changed to facilitate technology development and use to ensure that the United States will remain competitive in this rapidly developing global arena.

Protecting the Environment

Environmental protection, a growing challenge for the agribusiness industry, is a source of conflicting goals. On the one hand, the United States must increase agricultural production to remain competitive and feed a growing population. On the other, the industry needs to conserve its valuable land resources and it faces increasing public resistance to agricultural practices that have traditionally allowed pesticides, fertilizers, and industry effluents to degrade water and air quality.

More than any other industry, agribusiness is tied to the environment and the use of natural resources. During our visits to farms, production facilities, wholesalers, and government agencies, we found consensus on the need to protect natural resources, but disagreement about how to accomplish that task and concern for the rising costs of environmental compliance. During these visits we also noted concern over scarcity of natural resources and agricultural pollution.

Scarcity of Natural Resources. During the last two decades, awareness of the critical need for environmental protection has slowly made its way to the forefront of the nation's strategic policy-making forum. Secretary of State Warren Christopher said in April 1996, "Our ability to advance our global interests is inextricably linked to how we manage the earth's natural resources."

The United States as a whole has adequate water supplies, but water resources and supply needs are not distributed evenly. Therefore, an abundance in the aggregate overshadows the fact that supplies are becoming increasingly limited in many areas. For example, a USDA report states that 96 percent of the annual renewable water supply in the Colorado River Basin is withdrawn for consumption before the river flows into Mexico.

A final concern is motivating farmers to enroll their environmentally sensitive (i.e., highly erodible) acreage in the Conservation Reserve Program and other conservation programs. Failure to protect these acres jeopardizes the success of conservation programs.

Agricultural Pollution. Like other industries, agribusiness seeks to reduce costs while providing a quality product. USDA spent an estimated $3.5 billion on resource conservation and other environmental activities in fiscal year 1994. The Environmental Protection Agency (EPA) reports that U.S. spending on pollution control and abatement rose from approximately $52 billion in 1972 to $108 billion in 1990.

EPA estimates that by 2000, those costs could increase to between $133 billion to $147 billion. In fiscal year 1991, EPA assessed a total of $87 million in fines and penalties and when you add in state and local penalties, the total increases to approximately $280 million. One facility we visited faced 5,000 alleged violations of clean water laws with estimated fines of $125 million.

Among industrial nations, the United States has high environmental standards and strict laws. While we agree with the need to protect the environment, we conclude that cost-benefit analyses based on realistic standards is the key to balancing production and protection. Further, as we move toward a global market, the United States must encourage other countries to raise their standards for environmental protection. Such action will level the playing field and help ensure global environmental protection and resource conservation.

Pesticides contribute to increased productivity in agriculture, but the use of some chemicals harms human and animal health as well as plant life. USDA reports that pesticide use has declined from 612 million pounds in 1982 to 574 million pounds in 1992. Although this reduction is good, we have also seen an increase in the toxicity of some chemicals. Consequently, a reduction in pounds used tells only a partial story.

Conclusions. While the high cost of U.S. environmental compliance programs may appear to reduce our competitive advantage, protecting and preserving natural resources is a critical element of long-term production efficiency. Environmental protection is a shared responsibility, but free market systems provide little incentive for curbing pollution. The government must continue to play a central role in ensuring that national resources are not destroyed for short-term profit. We must continue to pursue better water and land conservation policies, practice integrated pest-management procedures, and adopt low-impact farming and processing technologies. Our overall goal should be to raise U.S. agribusiness to the point at which it can produce sufficient food, consistently, with a "net zero" impact on the environment.

GOVERNMENT GOALS AND ROLE

Aside from the government's regulation of food safety—which is a clear-cut responsibility covered in our food safety section—the issue of government goals and roles vis-à-vis agribusiness involves a fine balance

between government support of national security interests, efficiency, and dependency. Too much government support for agriculture disrupts a free market's natural selection of the most efficient and competitive firms: too little support can potentially undercut national power by creating a dependency on other nations for basic nutritional needs. The relatively few politicians familiar with agriculture complicates the issue.

International. Russian agriculture, previously dependent on a state-operated collective farm system, has declined badly since 1991. Emerging private farms in Russia face fundamental land ownership issues, lack of capital and credit, lack of markets and state support, and scarcity of supplies and equipment.

Russia faces a tough learning curve as the wheels of democracy search for traction. While its recent financial policies seem to be stabilizing inflation, manufacturing enterprises have been slow to restructure and respond to market discipline. Overall output is weak, with wage and tax arrears growing. In 1996, real GDP fell 6 percent as industrial output slumped 5 percent and investment fell 16 percent (Dept. of State, 1996). Although dismal, these figures actually represent the smallest annual decrease in Russia's productivity since before 1991.

In 1993, the United States initiated a small Agribusiness Partnerships program with Russia designed to introduce modern technology and management techniques, leverage private investment, and stimulate investment. This $26 million trial program sought to stimulate Russian agricultural production by providing U.S. assistance to improve marketing, farm input supplies, distribution, storage, and processing primarily at the private farm level. The program ended in January 1997 with a mixed record of success. According to U.S. officials, program activities did not contribute much to the restructuring of the Russian food system or to accelerating development and promoting the growth of private enterprise. As a result, we must conclude that any increases in Russian agricultural production will depend on sweeping macroeconomic infrastructure changes, such as tax reform, legal code reform, and stimulation of capital markets.

Politically, Russia's agricultural future faces significant barriers. Much of its rich soil in the south is represented by the least reform-minded political sector. As a result, agriculture is not a high priority for the Russian government, and agricultural infrastructure is virtually nonexistent. Wide-scale land reform has not occurred, and the government is still divided over the issue of private land ownership. Between 1991 and 1994, 286,000 small private farms sprang up,

promising, it seemed, the prospect of full privatization of the Russian agrarian system. Since then, the number of private farms has decreased for lack of capital and credit, lack of state support, scarce inputs, absence of farming cooperatives, fear of risk, and general loss of confidence in the future (Strokova, 1997). Meanwhile, Russia now imports 25 percent of its food, a percentage that increases to 70 percent in urban areas like St. Petersburg and Moscow.

Visits to Russia did uncover some promising signs of progress with an interesting twist. A former physics instructor is organizing a new, privately owned Russian Farms Community Project, and a former music teacher operates a successful private farm. When asked about his change in occupation, the musician explained that creativity, not tradition, is what succeeds in Russia's struggling agricultural community.

Domestic Germ Plasm and Seed Banks. The chain from germ plasm to crops is fragile, and the threat is primarily in the laboratory, not in the field. The concern in human-caused or natural disasters should not be for losses in the fields, but for the loss of our entire capability to produce or reproduce strains of crops. A single fire at the University of California germ-plasm research facility, for instance, could virtually set the state's entire agricultural system on its heels. Such storage and research facilities across the nation represent centers of gravity for entire agricultural regions. Since this is a public need, protection of the entire system represents a legitimate government function. The government has the responsibility to maintain its ability to replenish the strain or reestablish the gene line for crops forming the underpinnings of our nation's agricultural strength.

Agricultural Stockpiles. On this issue, above all others, we remain divided. One school of thought views stockpiles as "batteries" for storing "energy" that can be used during periods of low annual output. The other asserts that we have no need for total food self-sufficiency in today's global economy. In times of shortage, the United States can rely on imports from other nations. Each argument has its merits.

Natural disasters in recent U.S. history illustrate the need for adequate stockpiles, but recent war mobilizations do not cause concern over missing stockpiles because neither Vietnam nor the Persian Gulf Wars disturbed the civilian economy from an agribusiness perspective (Cameron, 1997).

Economic theory lends some credence to the case for stockpiles. Free market systems work well when it comes to the allocation of

depletable and excludable goods, but public goods like national security meet neither depletable nor excludable tests—you can't measure the security provided by stockpiles per unit dollar (Baumol, 1994, p. 318). The vagaries of weather and the special nature of agriculture make the application of just-in-time techniques developed for other industries inappropriate for agribusiness. Some people view stockpiles as simply the equivalent of excess inventory in other industries. Proponents of stockpiles, however, argue that a stockpile's true worth can only be measured in the venue of its intended use—natural disasters, mobilization, and international diplomacy.

Education. The U.S. system of cooperative extension and support for land grant colleges is one of the solid underpinnings of this successful industry. We are concerned that the downsizing of USDA's agricultural extension service may adversely affect the industry; however, if those services are available on the Internet and other information outlets, the shrinkage may have no discernible impact. It's too soon to tell.

Government support of land grant colleges and their research is vital. For instance, not one single agricultural producer we visited in California failed to mention the necessity of the University of California's support for their the industry.

Educating the farmer is one task; educating those responsible for ultimately shaping agriculture's future—namely, politicians and policymakers—is another. At the turn of the century, most Americans could point to a relative or friend involved in farming. Today, it is difficult to find a politician with significant agricultural experience or understanding. In California—the number one agricultural state in the United States—legislators from urban areas increasingly outnumber those representing rural agricultural regions. The reason is clear: as the urban population is growing; the rural population is not. Los Angeles County stands as an ominous warning of urban interests displacing agriculture. Fifty years ago, it was the number one agricultural county in the state.

Promotion of a Free Market Economy. A result of the new Farm Bill is that farmers will need to become more actively involved, better trained, and more well-advised in the business of global trade and marketing. Now that they can respond freely to market and trade conditions, it remains to be seen if crops will be as predictable and cheap as they have been over the 60 years that the farm price supports existed. We anticipate more volatile commodity prices in the coming years, forcing

farmers and processors to spend more money on options and future contracts to protect prices (Hagstrom, 1996, p. 983).

The new trade and export provisions in the Farm Bill have already pushed exports to $60 billion in FY 96, a record $2 billion increase. Long-term projections for exports under the legislation should reach $66 billion for the first year of the 21st century and are currently right on track (Glickman, 1996). The economic challenge is to maintain the appropriate balance in free market agricultural production. The 1996 Farm Bill is based on economic competitiveness: the "ability to produce goods and services that meet the test of international markets while our citizens enjoy a standard of living that is both rising and sustainable" (Tyson, 1993).

Globalization of the U.S. Agricultural Economy. By knocking down trade barriers with other nations, the U.S. government has improved agriculture's global competitiveness. The agricultural export market has expanded, largely fueled by government's aggressive action to develop new overseas markets and reduce extensive trade barriers through international agreements. These factors contribute to our growing share of world agricultural trade, but the global market itself has dramatically increased with the greater demand for food.

USDA promotes U.S. agriculture in the global marketplace through a five-pronged program of international trade policy, market development, statistics and market information, commercial export financing, and agricultural linkages (FAS, 1997). This mission was made easier with the implementation of extensive trade liberalization policies through the Uruguay Round negotiations and the North America Free Trade Agreement (NAFTA).

Projected benefits to U.S. agriculture with implementation of the Uruguay Round negotiations are staggering—exports, employment, and income are expected to increase significantly, along with global trade opportunities, as access barriers to world markets are reduced and trade-distorting practices are minimized. Although not as economically significant to U.S. agriculture in the short run as the Uruguay Round negotiations, NAFTA is the starting point for a free trade zone throughout the Western Hemisphere.

With these expanded market opportunities come increased challenges, as other nations gear up to fight the "food wars." Other nations' agricultural industries still have access to powerful economic arsenals. Economic measures, such as export subsidies, export credit guarantees, and market development/agricultural promotion programs,

are used by most agricultural exporting nations, including the United States. With the high stakes involved and the intense level of global competition, the U.S. government cannot afford to lessen its support for our agricultural industry.

Conclusions. Russia's agriculture will continue to founder until it develops a stronger, more market-oriented economic, political, and legal infrastructure. Absent those reforms, Russia will become increasingly dependent on imported food that many Russians cannot afford. The risk to U.S. national security should this dependency occur is that working-class Russians may become sufficiently frustrated to support a more secure, but less democratic, form of government.

The need for government involvement in the support of a safe food supply stands clearly evident. Federal food inspection and safety laws and environmental and nutritional standards must continue to be strong. However, the federal government is not taking sufficient action to protect food security. Our seminar noted deficiencies in securing germ plasm banks and other single-points-of-failure in the research and development system.

Other issues are not so clearly evident. For example, this seminar was divided on the issue of stockpiles, though we agreed that current national policy regarding stockpiles derives more from omission than conscious direction. As fewer lawmakers understand the needs of agriculture, their education takes on increased importance. Concerning the free market economy, the 1996 Farm Bill appears to be a step in the right direction—eliminating price supports to encourage efficiency and productivity without dependency—but the first hard evidence will not appear until after this year's crop season. Government assistance in breaking down international trade barriers must continue. In short, while individual agricultural products are depletable and excludable, government intervention in the agricultural free market is necessary to protect agriculture's contribution to national security—a safe and secure food supply for our nation.

RECOMMENDATIONS

As we approach the end of the century, U.S. agriculture is robust, efficient, and globally competitive. However, agribusiness' ability to continue its support of U.S. political, economic, and military needs hinges on its successful resolution of five major challenges—feeding a

growing world population, ensuring food safety, leveraging technology, protecting the environment, and defining appropriate government roles and goals. As a first step, we offer the following recommendations.

Government

- Determine the role of government agricultural stockpiles in the U.S. National Security Strategy.
- Establish a federal, state, and local system to formulate and coordinate land-use policies that will ensure adequate land for agriculture.
- Ensure a safe, adequate food supply by protecting the nation's central seed banks and germ plasm from single-point disasters.
- Use tax structures, education, and other incentives to encourage the adoption of new technologies that increase agricultural production while protecting the environment.
- Sustain efforts to improve food inspection programs and streamline existing programs, by eliminating redundancies.
- Offer economic incentives, such as tax relief and grants, to farmers using information technology.
- Speed information to end users by linking national information systems to decentralized state and local networks that provide agricultural resources and access to global networks.
- Focus U.S. diplomatic efforts abroad to establish the broad macroeconomic infrastructures necessary for free market agricultural businesses to grow, before aiding specific agricultural projects.
- Continue to break down international barriers to free trade.

Industry

- Strengthen, not relax, food safety standards.
- Increase education and public relations efforts to ensure adequate political and public understanding of agribusiness' contribution to national security and requirements for its continued success.

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AIRCRAFT

ABSTRACT

The aircraft industry is essential to the nation's power and economic health. Although the market for commercial aircraft is growing, the requirement for large numbers of military aircraft is declining, compelling manufacturers to reevaluate their market strategies. Leading aircraft manufacturers in the United States and Europe are preparing for the future by sharpening their focus, identifying core competencies, and shedding excess capacity. Innovative approaches include cost reductions, outsourcing and offshore production, and the benefits of information technology. Many have formed alliances to counter the high cost and risk of aircraft production, and are collaborating in the development of new systems. Though U.S. companies lead the world aircraft market, aggressive competition from European manufacturers is forcing them to improve their response to customer demands for reliable and affordable aircraft. Continued innovation is needed to ensure that U.S. aircraft productivity matches or exceeds its European counterpart.

Lt Col James D. Allshouse, USAF
COL Abdeljebbar Azzaoui, Moroccan Army
Lt Col Timothy J. Carroll, ANG
Ms. Irma P. Finocchiaro, Dept. of the Army
CDR Gerald L. Francom, USN
Lt Col Chuck R. Friesenhahn, USAFR
CAPT Edward W. Gantt, USN
Mrs. Elinor J. Gonzales, Dept. of the Air Force
Mr. Cecil C. B. Hines III, Federal Emergency Management Agency
COL Vicente C. Ogilvie, USA
LTC James A. Page, USA
Lt Col Ernest H. Plott, Jr., USAF
COL Robert G. Richards, Canadian Forces
COL Mark E. Warner, USA
CAPT Colleen A. Watry, USN

Col John V. Bauman, USAF, faculty
Dr. Rolf H. Clark, faculty
Col Larry C. Franks, USAF, faculty

PLACES VISITED

Domestic
Aircraft Industries Association, Washington, DC
United Technologies, Pratt & Whitney, East Hartford, CT
Sikorsky Aircraft Company, Stratford, CT
Smithsonian Museum, Aircraft Refurbishment Facility, Suitland, MD
McDonnell-Douglas Corporation, St. Louis, MO
The Boeing Company, Seattle, WA
Shultz Steel Company, South Gate, CA
Douglas Aircraft, Long Beach, CA
Northrop-Grumman Corporation, Palmdale, CA
Lockheed-Martin Skunk Works, Palmdale, CA

International
British Aerospace Defence Ltd., Warton Aerodrome, UK
Rolls Royce Military Aero Engines, Ltd., Bristol, UK
GKN Westland/Agusta, Bristol, UK
Ministry of Defence UK, Bristol, UK
Aerospatiale, Toulouse, France
Airbus Industrie, Toulouse, France
Dassault Aviation, Argenteuil, France
SNECMA, Villaroche, France

INTRODUCTION

The U.S. aircraft industry is a major contributor to the nation's economic strength. Through the late 1980s, aircraft sales flourished, and the industry's trade surpluses helped balance losses in other industries. By the early 1990s, however, a reversal in the industry's fortunes had begun. The end of the Cold War resulted in a drawdown of the military worldwide. Reduced defense spending, a worldwide economic recession, and overcapacity from the boom years of the 1980s further depressed the demand for commercial and military aircraft. That trend has now been reversed: the U.S. aircraft industry produced over $112 billion in sales in 1996, with $38 billion in exports and a positive trade balance of $25 billion.

Several nations participate in this industry, but the market is dominated by U.S. and European manufactured aircraft. Accordingly, this report examines the three major production sectors of the U.S. and European aircraft industry—commercial fixed-wing aircraft, rotary-wing aircraft, and aircraft engines. We looked at each sector's military and commercial applications, capabilities in design and integration, use of advanced and composite materials, and key work force trends.

AIRCRAFT INDUSTRY DEFINED

Commercial Fixed-Wing Aircraft

The commercial fixed-wing aircraft industry includes small airplanes, medium regional aircraft, large jet aircraft capable of transporting 100 passengers or more, and large cargo aircraft. This report focuses primarily on large jet aircraft for passengers and cargo. Three companies dominate this mature, oligopolistic sector: Boeing and McDonnell Douglas in the United States, and Airbus Industrie in Europe. The recent Boeing-McDonnell merger leaves two major competitors in a market that produced over $46 billion in sales in 1996, and expects sales in excess of $56 billion in 1997. No other firms are expected to enter this market because of the extremely large capital investment required to develop and manufacture aircraft.

Current Condition. The commercial aircraft sector has rebounded from a low of 30 aircraft orders in 1993 to a projected peak of 1,400 orders in 1998. Product affordability, the driving characteristic in this market, has led to sweeping changes in the design and manufacturing process, most noticeably, a closer relationship between manufacturers, suppliers, and customers (airlines). To mitigate risk, manufacturers now include the

customer as an integral part of the design and manufacturing team. Manufacturers who partner with airlines stress involvement in operational activities, maintenance, modification, and "turnkey" services.

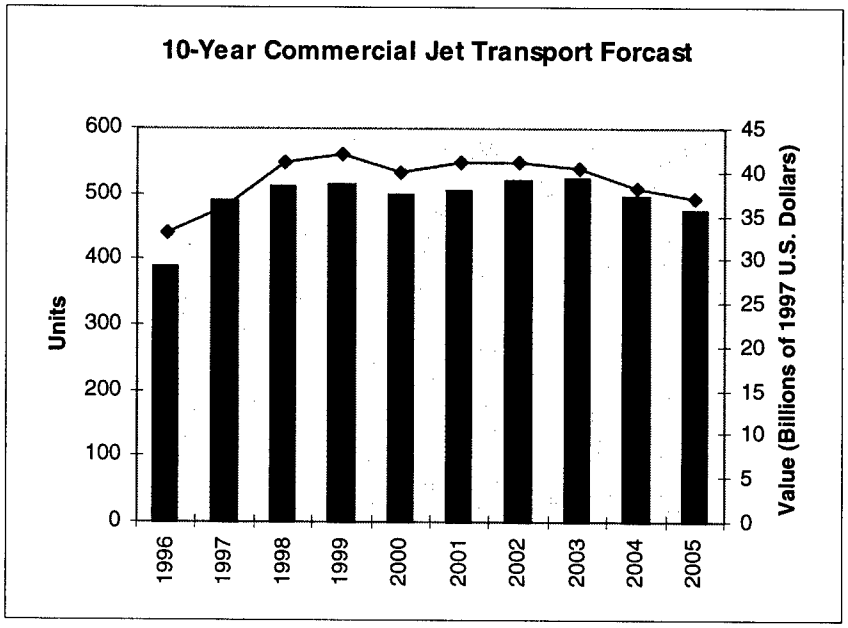
Other key elements of affordability include less product cycle time, fewer parts, competitive purchasing (i.e., "sourcing") among both internal and external suppliers, reduced time to market, and more efficient advanced manufacturing processes. Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) are revolutionizing product design and assembly. Aircraft are now designed on computers. The same electronic bits of information used to design the aircraft are used to program machines that make components—essentially moving from screen to machine with no one in between. In lieu of numerous sheetmetal pieces and fasteners, manufacturers are beginning to use single structures, that is, larger precision milled pieces bonded with high-strength adhesives, laser brazing, or stir welding techniques. These processes save production costs and expedite manufacturing.

As customer demands for long-distance air service change from hub airport operations to point-to-point airport connections, manufacturers are responding with longer range aircraft, such as the Boeing 777 and the Airbus 340, to satisfy their demands. Airbus is pursuing the market for even larger airplanes, by developing the A-3XX, a 600-plus passenger aircraft. Boeing has temporarily shelved its idea for the larger aircraft but could easily reenter the market. Its flexibility derives from a short design-to-production capability.

Challenges. Chief among the challenges facing commercial fixed-wing aircraft manufacturers is the merger of Boeing and McDonnell Douglas and its effect on the overall structure of the market. Maintaining access to key international markets is another major challenge for U.S. firms, particularly if foreign governments expect offsets—a share in production — in return for buying U.S. products. Finally, industry must seek ways to control the high cost of technology. The large research and development (R&D) costs associated with developing new commercial models will make it difficult to expand production significantly.

Outlook. After several lean years, commercial transport manufacturers are poised to capitalize on forecasts that contain a realistic potential for market growth (Fig. 1). U.S. firms seem to be focusing on worldwide production to mitigate risk and enhance market access, while European firms concentrate more on cost and customer satisfaction for market penetration. Competition in this sector will remain fierce as the two major companies seek to improve their market share.

To bolster profits in an industry with increasingly narrow product margins, aircraft manufacturers now contract for more product maintenance and services. Through innovative business relationships with traditional maintenance and repair firms, acquisitions, and proprietary repair processes, aircraft manufacturers are striving to increase profits across the aircraft's life cycle.



Source: Teal Group.

The industry's consolidation extends to suppliers. With fewer manufacturers, the need for numerous secondary and tertiary vendors diminishes with a trend to move more "offshore." The supplier base is shrinking substantially through attrition, mergers among suppliers, and acquisition. The trend throughout the commercial fixed-wing industry is toward vertical integration.

Military Fixed-Wing

The military fixed-wing sector includes fighter, bomber, transport, and training aircraft. Currently, three U.S. aircraft manufacturers dominate this sector: Lockheed Martin, McDonnell Douglas, and Northrop Grumman. Major European competitors include British Aerospace, Dassault Aviation (France), and various international partnerships.

Current Condition. U.S. production of fixed-wing military aircraft has fallen dramatically since 1990. Reductions in defense spending will likely continue so long as the threat of combat is uncertain, public support for costly defense systems is weak, and the idea of a more balanced federal budget is ascendent. The result is that "supply outstretches demand"—a condition that the industry has responded to with substantial corporate downsizing and numerous mergers. Most notable among the mergers is the formation of Lockheed Martin and the Boeing and McDonnell Douglas merger. Consolidation and mergers within the U.S. aircraft industry have reached beyond primary firms to the inclusion of numerous second-tier companies and subcontractors. The following chart (Fig. 2) depicts the results of recent mergers:

Major US Consolidations 1990-1997

Lockheed Martin
- Loral
  - •Unisys Defense
  - •IBM Federal Systems
  - •Ford Aerospace
  - •LTV Missiles
- •GE Aerospace
- •GD Fort Worth
- •GD Space Systems

Boeing
- •Rockwell Aerospace
- •McDonnell Douglas

Northrop Grumman
- •Westinghouse Electronics
- •Grumman
- •LTV Aircraft

Raytheon
- •E-Systems
- •BAe Corporate Jets
- •Texas Instruments
- •GM Hughes

Rolls Royce
- •Allison Engines

In spite of reduced demand and substantial downsizing, the U.S. military fixed-wing aircraft industry produced in excess of 200 airframes in the 1996-97 production cycle (Aboulafia, 1997a). Boeing teamed with Lockheed Martin to produce the F-22, which will succeed the F-15 as the premier U.S. air superiority weapon system in 2004. Current plans call for the production of 438 aircraft at a projected cost of $72 billion ("Agenda," 1997, p. 29). Boeing and Lockheed Martin are also contenders for the Joint Strike Fighter (JSF) project scheduled for 2001. As many as 2,978 JSF aircraft will be procured—which, at current-year prices, could cost $200 billion over the next two decades (ibid., p. 30).

McDonnell Douglas continues to hold the dominant position among U.S. military fixed-wing aircraft manufacturers. The company is currently producing more than a hundred C-17 cargo planes for the U.S.

Air Force, and expects to receive orders for 1,000 fighter/attack planes (F/A-18EFs) and 268 trainer aircraft (T-45s) for the Navy. In addition, McDonnell Douglas continues to produce F-15 aircraft for the U.S. Air Force and to fulfill overseas orders.

These projections are, however, tentative. The Quadrennial Defense Review (QDR) has recently submitted recommendations to Congress to reduce several aircraft programs by as much as 25 percent. The U.S. Department of Defense (DoD) has proposed holding production to the following limits: 339 F-22s, 548 F/A-18EFs, 2,852 JSFs, and 21 B-2s.

In Europe, the British Aerospace-led Eurofighter team, which includes Germany, Italy, and Spain, is actively developing the next generation European fighter. In addition, British Aerospace continues to produce the successful Hawk 200, a light fighter/attack aircraft from which the McDonnell Douglas T-45 Goshawk was derived; and Dassault Aviation produces Mirage fighter variants for foreign military sales. Dassault is also under contract to the French government to manufacture the Rafale fighter.

Challenges. As U.S. military aircraft manufacturers reduce their size and work force, they must diversify and find new markets to replace government programs. The shrinking domestic market compels them to improve their global competitiveness through aggressive marketing. They must consider new, perhaps international partnerships and embrace new products, new technologies, and new markets. Aircraft customers are demanding reliable, efficient, quality products at lower prices. This trend will continue as companies consolidate, and reorganize to compete in the global market. The market has clearly stated the challenge: the industry must rise to meet it.

Outlook. For now, production and profits have stabilized. Except for the F-22 and JSF programs, no new, large-scale programs have been proposed. Foreign military sales will play an increasingly vital role in sustaining the aircraft industry, and they will require the support of foreign policy objectives and diplomatic efforts.

Aircraft companies will continue to match airframe builders with leading defense electronics firms and systems integrators to maximize efficiency and expand long-term employment prospects. Their overall goal is to increase profits and enhance stock value. Business styles are also changing as partnerships between suppliers and customers become more common. Industry and government agencies need to follow this trend to ensure that the essential military requirements of future defense programs are clearly identified and met at minimal cost.

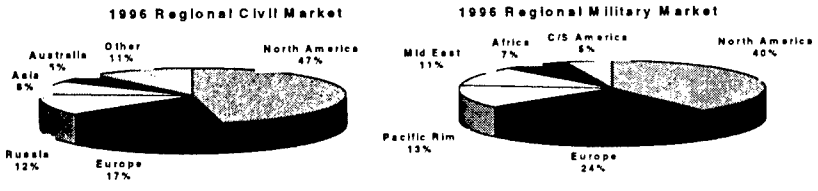
Large aircraft companies are clearly positioning themselves to compete in the global marketplace. They are merging their talents, integrating their processes, and sharing technology and engineering skills between military and commercial production.

Rotary-Wing Aircraft

Helicopters now under development are significantly improved over their predecessors. The rotary-wing market can be divided into the military and civilian sectors. The major U.S. manufacturers are Bell, currently with 22.3 percent of the world market and over 50 percent of the civilian market; Sikorsky, with 12.2 percent; and McDonnell Douglas, with 8.5 percent. Their competition is Eurocopter, a joint venture between France and Germany holding 11.5 percent of the market, Agusta of Italy with 5.1 percent, and a number of smaller contenders vying for market share.

Current Condition. The worldwide market for helicopters is predicted to remain the same in terms of the number of aircraft produced; however, the dollar value of production will increase as customers demand larger, multiengine turbine helicopters equipped with modern electronic systems. The civilian market for helicopter purchases will exceed the military market, but the value of military production will exceed the civilian value.

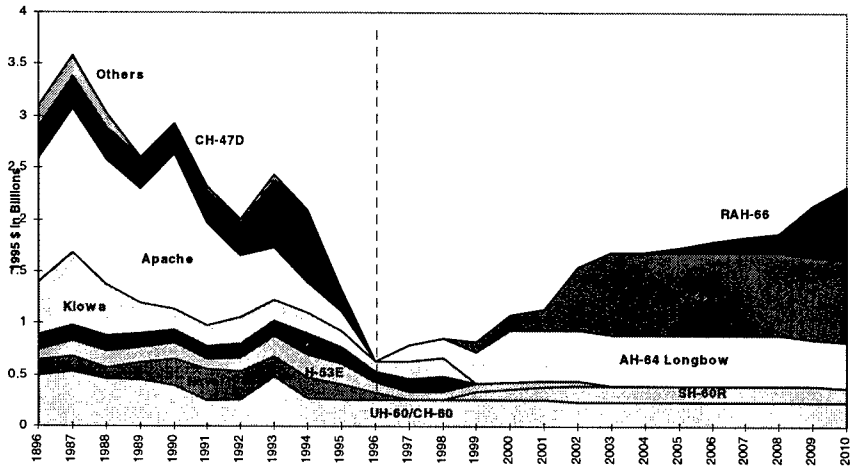
1996 Regional Helicopter Markets



Annual worldwide production of rotorcraft will decline until the turn of the century. In 1990, eleven rotorcraft models were in development or in production for the U.S. military—by 2,000 only four rotorcraft models will be in production.

A slow recovery should begin after the year 2000 when several new and more expensive aircraft models will enter the market. The value of annual production will begin to show upward trends, though the annual unit production may remain relatively flat.

U.S. Military Helicopter Market



Source: Sikorsky.

Challenges. The ultimate challenge that the rotary-wing aircraft industry faces is to produce helicopters that are cost competitive. The industry's primary objective is to produce a commercial mode of transportation that is similar to fixed-wing aircraft but at lower sustainment costs. The challenge for the commercial sector is to expand internationally in undeveloped markets, while the military sector, in the wake of reduced defense budgets, assumes more responsibility for research and development (R&D).

To remain solvent, the rotary-wing industry is exploring service and maintenance ventures to stabilize their financial base and provide sustenance for operations during production slowdowns. Manufacturers are also moving the manufacturing of components to overseas locations and shipping them to the United States for final assembly. This strategy reduces overhead costs and permits manufacturers to retain control of critical technologies.

Outlook. The rotorcraft industry's long-term outlook is for a slightly improving market. The value of military rotorcraft production in 2006 is forecasted to be $6.23 billion, compared to $3.96 billion for 1997. Forecast International predicts that the four major U.S. manufacturers will lose market share, dropping from 60 to 40 percent over the next 10 years with European, Russian, and Japanese manufacturers filling the increased world demand. The commercial market will drive the industry as defense budgets continue to shrink and new developmental programs slow down. The merger of Boeing and McDonnell Douglas will create the dominant firm in the industry. This prediction is based on current remanufacturing programs, the introduction of new commercial models, and the continued development and acquisition of existing programs. The future will be characterized by continued partnerships, modifications of existing systems, and a marked reduction of new programs.

All companies currently involved in the industry have growth potential that is based on the assumption of continued government procurements. Foreign market sales will grow if industry can keep costs down and satisfy customer demands. "If the industry is able to drastically slash the operating costs of their products, annual production during the next 10 years could be higher than forecasted, with more rapid rates of growth" (Colucci, 1997). Commercial sales alone will not be enough for growth in the rotorcraft market.

The primary emphasis of current and future helicopter designs is mission package performance. Mission packages are anticipated to cost more than the airframe. Past helicopter designs concentrated on building a platform and "strapping-on" mission equipment and avionics to conduct multiple operations. Newer designs evolve around mission requirements and embed these systems within the aircraft. These systems reflect the beneficial combination of digital and aerodynamic states of the art. This systems integration approach is producing a more technologically advanced helicopter that is adaptable to the rapid information changes necessary to satisfy user requirements without sacrificing capability.

Aircraft Engines

Aircraft engines represent a significant portion of the total cost of an aircraft. Manufacturing aircraft engines is capital intensive and the processes are technologically advanced. Production tools and machinery are complex, massive, and extremely expensive. The advanced materials needed to maintain engine performance are costly and often hard to procure—and this cost is complicated by the extensive time lag between

research and development and a new engine's return on investment. From initial concept through production, it may take 12 years to produce an engine at costs as high as two billion dollars. Such costs effectively bar the entry of new competitors; they also limit the research and development efforts of existing manufacturers.

Consequently, the aircraft engine industry is dominated by four strong, relatively stable companies: General Electric (GE) and Pratt & Whitney (P&W) in the United States; Rolls-Royce (RR) in the United Kingdom; and SNECMA in France. National distinctions are becoming less meaningful as companies develop alliances and partnerships across international borders. Competition is intense for market share.

The health of this segment of the aircraft industry is directly related to aircraft sales. Key market factors driving the industry:

- *Cost*—Engine manufacturers are being forced to reduce development and initial costs.
- *Environment*—Noise and emission controls are a major requirement in the industry as urban expansion moves closer to airports and "stealthiness" is a condition of survivability on the battlefield.
- *Performance*—All aircraft engine customers are demanding higher thrust, improved fuel efficiency, and lower weight.

Current Conditions. The aircraft engine industry is rebounding from a low in the early 1990s. In the past several years, companies have downsized and reduced overhead to respond to market realities. With the resurgence of aircraft sales in 1996 and a projected growth of the airline industry, aircraft engine sales are increasing. The defense portion of the industry, however, is declining. International sales will help maintain domestic defense production. Manufacturers are also benefiting from the need to replace aging equipment and to upgrade equipment to meet new environmental and noise abatement standards.

Traditionally, engine manufacturers have sold their products at or below costs, relying on sales of replacement parts and equipment to make profits. Increased reliability and maintainability of engines has diminished profit margins. To offset lost income and make better use of surplus capacity, engine manufacturers are competing for product support markets such as engine maintenance and repair.

Engine manufacturers are responding to market pressures by focusing on affordability rather than technological superiority. Historically, the aircraft engine industry hinged on technical innovation and produced significant advance in mechanics and materials technology. Enormous improvements in power, weight, and durability

were the key to aircraft performance. Government support may be required to underwrite the development of future propulsion systems, particularly in hypersonics and new engine technologies.

Challenges. The market for engines in the commercial sector is growing, driven by increased airline orders and pending environmental standards. The market in the military sector is dim, diminishing as a result of defense budget reductions. A bright spot in the military sector may be the possibility of increased foreign military sales, but this opportunity is moderated by intense competition among engine manufacturers.

Excess capacity is a common issue throughout the engine industry. This capacity may offer a business opportunity as it helps the industry absorb work from defense agencies seeking to downsize through outsourcing and privatization. Engine maintenance currently performed by military and DoD civilians will soon be put to bid and both Pratt & Whitney and General Electric have expressed an interest in competing for that work. Excess capacity is also an indicator of the industry's ability to surge—though that is not a concern for the foreseeable future. Other challenges are cost of ownership, reliability and maintainability, and exponential advances in engine performance.

The industry is pursuing new ways to maximize profits. As aircraft operators sharpen their focus and divest themselves of all but core competencies, engine manufacturers are also seeking to extend their services beyond traditional sales: they may offer after-market services such as maintenance and repair facilities to aircraft operators, or they may offer aircraft operators leasing arrangements for aircraft engines rather than direct sales.

Outlook. The four major engine manufacturers will continue to dominate the market. These firms carefully manage their organizations to meet expected demand, and their downsizing activities have left the industry with a reasonable capacity to meet surge requirements. Corporations will continue to develop new products in joint ventures that lessen their individual exposures to risk. It appears unlikely that mergers will occur between any of the four companies, though continued partnership arrangements are expected.

In the commercial sector, requirements for aircraft engines are anticipated to increase over the next several years. Markets will grow in response to the increase in air travel. Environmental regulation will drive engine and airframe changes over the next five years, including, for example, the retirement of certain models. At the same time, U.S. military engine purchases are expected to flatten or decline in the future.

After the year 2000, only three engines will be in production for U.S. fighters.

The substantial costs associated with research and development preclude radical changes in engine design, especially as current engine technology meets the commercial market demand for performance and affordability. Significant research and development for engines would involve either an increase in government sponsorship or a radical change in the market environment such as a significant increase in fuel costs. The propulsion requirements of even very large aircraft can be met with existing technologies.

OTHER IMPACTS ON THE AIRCRAFT INDUSTRY

Trends in Design and Integration

Computer design and manufacturing applications are radically transforming the methods, structure, and culture of the aircraft industry. Tremendous advances in the production of highly complex aircraft have already been made through the innovative use of information technology. Other results are lower development and production costs, reduced crew and maintenance training, and better definition of support and logistic requirements for the user. The powerful computer programs required in all facets of an aircraft system are becoming a separate deliverable item to the user.

Several computer-based aircraft design tools are available industrywide. Two of the more notable products are CATIA, developed by Dassault of France and used by Boeing, and Computervision, developed in the United States and used by Airbus partners.

CAD has significantly reduced manufacturing defect errors and has reduced dimensional tolerances far below previous manufacturing techniques. According to the Lockheed Director of Production Operations for the F-22 program, CAD led to the development of tools and parts designs for the stealth aircraft (Flight International, Feb 1997). CAD decreases defect rates and increases the rate of production—a prime factor in reducing costs and speeding delivery in both military and civilian programs. It also produces a strong database for coordination among subcontractors.

Although the use of these programs is becoming standard among prime and subcontractors, they now must be "designed" for easy product support. Several companies are offering full customer support packages, including logistics, repair, and maintenance, based on information in their CAD programs. More customers are looking at aircraft supportability and life cycle costs as a key discriminator during

competition. The use of CAD programs greatly enhances a company's ability to provide life-time support.

Use of these programs will increase in the future as companies move toward even more "virtual design" applications. From concept development to product support, CAD provides a competitive advantage to its users. Technology advancements, processing capability, and the design of secure protective measures will enhance the use of CAD well into the future.

Advanced Materials

Advanced composite materials are distinguished from their traditional counterparts by increased cost, performance, and manufacturing complexity. Specifically, composite materials consist of two or more substances (e.g., polymers, ceramics, and metals) combined to produce a material with specific physical characteristics for specialized applications.

Advances in manufacturing technology will increase the use of composite materials in aircraft programs. These materials increase range and performance with fewer parts and less weight; and they provide design flexibility and greater reliability with less waste and corrosion.

Investments in automated machinery support the greater use of composites in new manufacturing. Both the Airbus A340 and the Boeing 777 have maximized the use of new tooling to take advantage of advanced materials in their design of developmental aircraft. Companies that have not made or cannot make the large investments in automated processes must still rely on handmade piece work. The industry as a whole continues to research new methods to reduce the cost of the manufacturing process. For example, research departments are investigating methods of "blowing" composites into shape and cold curing to decrease cost and increase flexibility.

Several challenges still exist for the industry. A primary concern, for example, is the risk associated with post-mishap environmental, safety, and health concerns. Material fractionalization, decomposition, and exposure to extreme heat in aircraft accidents cause further damage to personnel and the environment. More research and development is required to ensure that adequate safety measures are developed.

Another challenge is the need to master composite repairs. Military aircraft require unique repair capabilities that must be undertaken in a variety of environments. Composite repair may also impact the structural integrity of civilian and military aircraft. Simple, "patch work" repairs could affect the high-strength, corrosion-resistant characteristics of advanced materials. Cost-effective repair and integrity testing procedures continue to be a challenge for the industry.

Cost, manufacturing methods, and material availability will also affect the future use of advanced materials. Additional R&D efforts are needed to find cheaper, quicker methods of producing composite structures—structures that provide even more design flexibility as they require less tooling and material preparation.

Advanced materials are now being used on every new aircraft program and will be used for repair and modifications on existing systems as well.

Information Technology

Information technology in the form of computer hardware, software, and special application programs has allowed the industry to increase efficiency, decrease manpower, and improve management of materials, personnel, and information. Improvements have resulted in competition between companies to maximize their profits and future strategic options on a global scale. Computers accurately manage and track resources, automate billing procedures and purchases, and perform other tracking and accounting functions. Large amounts of information are shared internally and externally through systems that do everything from measuring production line metrics to specifying configuration and interface control.

The aircraft industry is striving to incorporate information technologies wherever possible. Several companies have proposed detailed support and logistic plans for military and civilian aircraft. Without the technology necessary to perform real-time monitoring of requirements and assets, this technological advance would be an impractical undertaking.

The industry faces three basic challenges in the effort to upgrade its information systems: employee training, configuration control, and information security. Companies must make new investments in training even to master current software applications. Configuration control will be difficult as hardware matures and new technology is introduced. The security of databases and transmissions will become increasingly important as reliance on information systems increases. Companies need to recognize their vulnerability to intentional or unintentional intrusion into their databases.

The use of information technology is expanding. Concurrent engineering through information technology reduces time-to-delivery and manufacturing costs. Computer-controlled production tools increase quality, reduce waste, permit the manufacture of larger, one-piece parts, and allow greater flexibility to produce varied products with minimal changes to the line. Industry downsizing will drive the increased use of information technology to enhance employee productivity. Aside from

obvious applications to aircraft systems, corporate management will expand the use of automated systems in all administrative and marketing aspects of the industry.

Outsourcing

The aircraft industry is increasingly pressured to cut costs and reduce production time. Companies have responded by seeking innovative outsourcing relationships with select suppliers with the goal of reducing product cost and delivery time. Common functions are being outsourced to gain efficiencies and cost savings—data center operation and consolidation, networks, distributed computing, and application development—with selected key engineering functions integral to design retained in-house. The industry also dedicates in-house manufacturing resources to high value-added parts and increasingly outsources components of lower value that are less critical to the production process.

Lockheed Martin, for example, outsources fabrication: it buys 70 percent of its machined metal and composite components and subassemblies from outside contractors. Boeing is also increasing its outsourcing of parts production—from 48 to 52 percent, anticipating an annual savings of $600 million. The European Airbus consortium is restructuring into a single corporate entity. Over time, this arrangement may allow management to shift parts production from the four Airbus partners to competing firms, thus lowering costs and increasing its competitiveness.

Offshore Production

The growing movement toward global outsourcing and transnational ventures has led to a proliferation of international production structures. Aircraft firms can reduce costs by moving manufacturing to low-wage countries. This allows companies to establish a strategic foothold to secure future markets. Additionally, the industry can invite offshore suppliers to participate as risk-sharing partners, providing a valuable infusion of capital to finance major aircraft projects. The trend toward global production has raised concern over the loss of domestic manufacturing jobs. Labor unions concerned with the transfer of jobs to low-cost areas are demanding a stronger guarantee of job security.

The European Union

The fifteen nation states in the EU represent the world's largest market, our largest trading partner and our primary competitor.

The EU recently challenged the merger between Boeing and McDonnell Douglas. The two companies combined will have sales worth $36.5 billion, compared to Europe's Airbus Industrie sales of $8.8 billion. The most significant point of contention is Boeing's exclusive supplier deals with American Airlines and Delta Airlines which detract from Airbus's ability to compete in the next two decades.

The EU is also an advocate for increased transnational integration, leading to a unified European defense industry. Without European transnational consolidation and rationalization, European companies will be hard-pressed to achieve parity with larger, more consolidated American defense firms. European aircraft firms include state-owned and private companies. Private firms are concerned that consolidation with state-owned companies will subject them to political considerations, limiting their ability to implement cost-cutting initiatives and personnel reductions. European countries are at different points in the move toward privatization and hold different perspectives on how to preserve the European defense industrial base. A controversial issue is access to the European defense market—should it be limited to European companies or remain open to transatlantic trade with American companies?

The security provided by an autonomous national defense industry is an important sovereignty element that nations will not easily surrender. As governments promote deeper integration of the European defense industry, the pace set by private-sector companies in their search for cost-competitive intra-European partners will also be a significant indicator of whether the EU can provide a solid technical niche for success. It is clearly in the best interest of the European aircraft industry to rationalize and consolidate.

Subsidies

U.S. relationships with foreign competitors are strained by the question of government subsidies. Most aircraft firms receive support from their government in some form, but this support varies between countries. The debate centers on whether these subsidies skew competition and give companies of a given nation an unfair advantage. Having met with representatives from both sides of this controversy, we have determined that it should be downplayed as a serious source of competitive advantage. All parties benefit from government subsidies in either direct or indirect forms and, based on government's role in defense, this support is probably appropriate.

Personnel

Another major challenge to the aircraft industry stems from extensive personnel reductions. Streamlining efforts to reduce overhead costs and infrastructure led to significant layoffs from 1990 to the present. While this practice achieved lower costs, it has long-term implications that must be considered.

Management has chosen to protect current skills and preserve morale, but this approach may cost the industry its future technical viability. The percentage of the aircraft industry work force below age 35 dropped by over 8 percent between 1992 and 1996, while those between 35 and 54 increased by over 10 percent. Further, the high-technology manufacturing skills required by the industry are becoming even more specialized. Current practice protects experience at the expense of programs that would bring in new skills.

European companies have far more effectively reduced their work forces. Their average age has dropped and apprentice programs continue to draw students and skills to sustain the industry's future. Perhaps the difference is attributable to the social safety net that makes early separation programs more palatable to European workers. Most important, they have actively engaged labor unions as partners in streamlining companies and improving productivity.

Unless U.S. companies take action to balance the work force, a vacuum may be created that will reduce the industry's flexibility in response to market changes or mobilization requirements. Companies should continue hiring and training personnel in skills needed for tomorrow's technology, skills that will be very different from those employed today.

GOVERNMENT GOALS AND ROLE

It is essential to national security, economic security, and national pride that the government ensures the health and well-being of its aircraft industry. Historically, governmental rules, regulations, and policies have occasionally hampered industrial growth. Political objectives, both internal and external, can impede sustained growth in this industry. The government has a legitimate concern, however, in sustaining the domestic aircraft industry base, particularly since this industry contributes directly to the nation's security objectives.

Research funding is in steady decline for all defense related programs. Consequently, industry partnerships, both with domestic and foreign manufacturers, are becoming more common, allowing firms to minimize the risks of investing in the advanced technologies required to

continue aircraft advancement. International competitors are expanding their R&D funding even as the United States is reducing funding in this area. Although U.S. industries currently possess a technology advantage over foreign manufacturers, their prominence will erode unless government continues to support research initiatives.

Government restrictions and trade laws also impact the industry's ability to compete with international manufacturers who do not confront these barriers. As the defense budget declines, a strong market focus will be needed to retain world prominence in the military market and to sustain a "warm" industrial base for potential mobilization. Thus, our recommendations include the following:

1. Continue to support privatization and outsourcing of noncore defense functions. This action will allow DoD to focus on its primary mission, while encouraging a responsive aerospace industrial base.

2. Continue government efforts toward acquisition and regulatory reform within DoD. Regulatory changes can help streamline contracting and procurement activities, thus reducing bureaucracy and cost. The government should also focus on better alignment between military and civilian standards and specifications.

3. Foster a closer, partnership relationship with industry that will reduce production costs. DoD and industry should also work more closely together to streamline processes.

4. Support foreign military sales of aerospace products. U.S. foreign policy initiatives and global diplomatic efforts are greatly needed to sustain and enhance the aerospace industry through offshore sales.

CONCLUSION

The aircraft industry survived the financial crises of the early 1990s through mergers, consolidations, and aggressive efforts within individual companies to streamline, modernize, and rationalize operations. U.S. aircraft companies now contend with the emergence of strong overseas competitors. While the number of U.S. firms engaged in aircraft production and aircraft support has decreased substantially, significant challengers are emerging, particularly in Europe. At present, U.S. firms retain a significant lead; however, their competitors are demonstrating focus, initiative, and creativity in closing that gap.

Several trends have emerged from this highly competitive environment. Chief among these trends is the development of coalitions

and partnerships between various companies. What was once a mosaic of aircraft companies and subcontractors is becoming a more unified image. Alignments shift and change from program to program as companies seek out alliances to share risk, expand sources of financing, and enhance their competitive position. Companies are also looking to broaden their marketing base, both by pursuing after-sales support and developing innovative sales approaches.

U.S. manufacturers will continue to seek ways to exploit the opportunities this new environment offers. The government must support them by reducing barriers and promoting the flexibility essential to growth. The aircraft industry has done well in streamlining and "right-sizing." Now the same companies must sharpen their focus and relentlessly pursue improvement to retain their strategic advantage. European manufacturers will continue to privatize and consolidate to enhance efficiency. The resulting competition will be fierce and healthy for the global industry. Partnership between the U.S. and European Union firms may further increase productivity.

As for defense, military programs have traditionally produced technological advances that are eventually incorporated into civilian aircraft. Thus, DoD has funded much basic aircraft research and development. As DoD emphasis and funding decline, the government must consider whether it is still important to fund aircraft R&D—not immediately for defense programs, but to allow the U.S. military aircraft industry to maintain its technological advantage. A strong aircraft industry is needed to help preserve both our national security and the domestic economy. Its funding may be equally as important.

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BIOTECHNOLOGY

ABSTRACT

The U.S. biotechnology industry made significant gains in 1996. Industry revenues, health-related product approvals, market capitalization, and employee levels surged to new highs. A previously flat equity market produced a 132 percent single year gain in capital for the industry. Alliances and merger activity often with larger pharmaceutical companies, strengthened the industry. Legislative proposals and regulatory changes signaled government support for the industry while highlighting ethical concerns over its potential applications. The United States continues to be the dominant global leader in this strategic industry, with at least six times the strength of its closest rival, the European Union. Industry concerns for the 21st century include intellectual property rights, regulatory and legislative limitations, financing for research and development, infrastructure shortfalls, and public relations—the need to address the ethics of human biotech applications.

CDR David W. Costa, USNR
LTC Michael R. Clements, USA
LTC Charles J. Fowler, USA
COL Robert C. Harvey, USA
Ms. Robyn E. Hinson-Jones, Dept. of State
Mr. Edward C. Koenig, Dept. of the Air Force
CDR Fred P. McKenna, USN
Mr. Stanley D. Puchalla, Dept. of Energy
Mr. Thomas J. Robillard, Dept. of the Air Force
LtCol Daniel C. Shultz, USMC
Lt Col Michael P. Setnor, USAF
CDR James J. Sicari, USN
Lt Col William H. Toney, USAF
Lt Col John L. Trivette, USAF
Mr. Richard A. Zell, Defense Logistics Agency

Dr. Rita L. Wells, faculty
Lt Col Howard P. Andrus USAF, faculty
Ms. Patsy L. Gates, Dept. of the Navy, faculty
Dr. Joseph E. Goldberg, faculty
Dr. Alan G. Whittaker, faculty

PLACES VISITED

Domestic

Human Genome Sciences, Gaithersburg, MD
National Institutes of Health, Gaithersburg, MD
Columbus Labs, Baltimore, MD
USAMRIID, Ft. Detrick, MD
Med-Immune, Gaithersburg, MD
Genzyme Manufacturing, Allston, MA
Genzyme Transgenics, Framingham, MA
Massachusetts Biotechnology Research Inst., Worcester, MA
Altus Biologics, Cambridge, MA
Natick Laboratories, Natick, MA
Novartis, Research Triangle Park, NC
Novo Nordisk, Research Triangle Park, NC
Georgia Institute of Technology, Atlanta, GA
Center for Disease Control and Prevention, Atlanta, GA
Biogen, Research Triangle Park, NC
North Carolina Biotechnology Center, Research Triangle Park, NC
Army Research Lab, Research Triangle Park, NC
Genentech, South San Francisco, CA
DNA Plant Technology, Oakland, CA
Xoma, Oakland, CA

International

United Kingdom Ministry of Defense, London, England
Department of Trade and Industry, London, England
Pfizer, London, England
PPL, Edinburgh, Scotland
Moredun, Penicuik, Scotland
Thomae GmbH, Munich, Germany
European Molecular Biology Lab, Heidelberg, Germany
German Cancer Research Center, Heidelberg, Germany
Yissum, Hebrew University, Jerusalem, Israel
Volcani Research Institute, Rehovot, Israel
Weizmann Institute of Science, Rehovot, Israel
Hadasa Hospital, Jerusalem, Israel
InterPharm Laboratories, Tel Aviv, Israel
Teva Pharmaceuticals Industries Ltd., Kfar Saba, Israel
Orgenics Ltd., Yavne, Israel
Hazera, Kiryat Gat, Israel
Biotechnology General, Rehovot, Israel

INTRODUCTION

This study presents a succinct portrait of the biotechnology (a.k.a. biotech) industry in 1997, assesses its condition, and projects its future growth and relevance as a strategic national industry. Areas of analysis include industry structure, funding and financial status, business practices, marketing strategies, ethical and legal considerations, regulatory issues, national security implications, patents, and international competitiveness. In addition to a comprehensive literature review, the study group discussed biotech issues with many industry, government, and academic experts. Subsequent investigations included site visits to domestic and international companies representing the leading edge in biotech, significant government partners, key military organizations and industrial customers.

THE INDUSTRY DEFINED

The Science of Biotechnology

Hungarian engineer Karl Ereky coined the term "biotechnology" in 1919. At that time, the term meant all lines of work by which products are developed from raw materials with the aid of living organisms. Ereky envisioned a biochemical age that would have an evolutionary impact rivaling that of the stone and iron ages (Murphy and Perrella, 1993).

Today, biotechnology involves the use of living organisms and their cellular, subcellular, or molecular components to provide goods, services and environmental management. It combines the principles of bioscience with technological expertise, and often involves the integration of advanced disciplines such as biochemistry, cell biology, chemistry, genetics, chemical engineering, process engineering, and computer science (IBA, 1990). Biotech methods have increasingly played a more significant role in solving problems in health/medicine, industry, the environment, and agriculture over the past twenty years.

Health/Medicine. Using recombinant DNA technology (splicing desired genes from one organism for insertion into another), scientists combine the genetic elements of two or more living cells (Peters, 1993). The science of genomics, for example, contributes knowledge of the way genes function that facilitates development of more efficient methods for treating illnesses such as cystic fibrosis, cancer, sickle cell anemia, and

diabetes. Gene therapy (replacing malfunctioning genes with normal ones) constitutes a significant and growing specialty area within the industry.

Industrial/Environmental. Biotechnologists engineer microbes that digest compounds which pollute the environment (Treohan, 1993), or provide extremely efficient catalysts for industrial applications that produce a broad variety of solvents and chemicals.

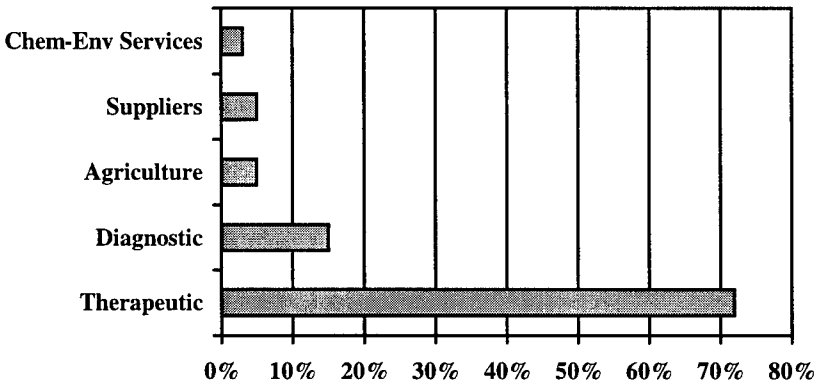
Agriculture. In agricultural applications, scientists have utilized biotech methods to develop disease and herbicide resistant crops, disease resistant animals and seedless fruits.

The Industry of Biotechnology

The biotech industry sector includes firms or subsidiary firms that produce genetically altered products for therapeutic or diagnostic health services, agricultural, chemical, and environmental uses. It also provides for licensing an array of scientific information pertaining to human, plant, and animal genomes.

Health care companies financially dominate the U.S. biotech industry (see Fig. 1). They comprise 87 percent of the domestic biotech market in therapeutics (disease treatment) and diagnostics (tools to identify human or animal diseases). Agricultural biotech companies (about 5 percent of the market) focus on the genetic modification of crops and livestock. Chemical and environmental firms with 3 percent of the market provide metabolites (e.g., enzymes) and related biological techniques for industrial and environmental applications. Biotech suppliers—another 5 percent of the market—offer support services to the industry, such as biological devices and dedicated software.

Figure 1.—Biotech Industry by Market Segment



Another important distinction concerns the types of firms that make up the 1,287 public and private biotech companies that currently exist within the United States. These include small research and development (R&D) firms with products in development but not in the market, "bioinformation" firms that sell gene discovery information to the industry, independent biotech companies (e.g., Genentech and Genzyme) that have successful product lines, and global firms (e.g., Pfizer, Novartis, Smith/Kline/Beecham) that operate their own internal biotech divisions. Several government organizations (e.g., National Institutes of Health, U.S. Department of Agriculture) strongly influence the biotech industry by providing scientific funding and research direction.

Notably, less than 10 percent of biotech firms currently provide products for the commercial market. Those companies not backed by the global firms typically lack the independent sales revenues necessary to finance their operations. Emerging biotech firms depend on private venture capital, equity markets, research collaborations, partnerships, licensing arrangements and royalties to finance their progress (Christensen, 1996). High research and development (R&D) expenses and long product lead times require a company to have significant cash to remain operational and these circumstances act as formidable barriers to companies seeking entry to this field. In many cases, "burn rates"—a colloquialism for R&D expenditures—can average millions of dollars per quarter. In the absence of new funding sources or successful patents/products, a firm's survival can be measured in months. This constant need for financing to support operations has driven many

biotech startup firms into partnerships with large pharmaceutical and chemical companies. Some of the seed money for the early biotech companies (e.g., Amgen and Genentech) came from major pharmaceutical companies, whose licensing agreements paid for seminal research and initial product development (Christensen, 1996). Nevertheless, the industry's actual and potential successes also promote considerable growth. By 2000, industry analysts project that sales for the U.S. biotech industry will reach $50 billion (BIO, 1997).

CURRENT CONDITION

A strategic industry facilitates increases in national wealth at a rate far greater than the industry's own expansion (e.g., America's railroad industry in the 1800s). Biotechnology shows promise as a future strategic industry for the United States, but has not yet achieved that mantle. Traditional business indicators, such as market growth, sales rates, and employment statistics only partially define biotech's condition. Biotechnology operates in an environment characterized by intensive and expensive research and concerns about intellectual property rights and ethical issues. Its development is long range, and it is highly regulated. This assessment accordingly includes trend analysis, (e.g., sales and production through-put), future potentials, the effects of government involvement, and barriers to market entry and growth.

Industry Comparison

Regulatory, capital and product development aspects associated with biotechnology clearly characterize its immaturity in contrast to other high technology industries. Of the eighteen industries under study within the Industrial College of the Armed Forces, biotech constitutes the "youngest" on the industry life cycle. Figure 2 compares biotech with some other, relatively new industries.

Figure 2.—Comparison of Biotechnology and Other High Technology Industry Life Cycles.

U.S. INDUSTRY	BIOTECH	COMPUTER	SEMICONDUCTOR	SOFTWARE
Life Cycle	Young	Maturing	Middle Aged	Middle Aged
Technology	Intense	Intense	Intense	Intense
R&D	Critical	Critical	Critical	Critical
Regulations	Heavily Regulated	Unregulated	Unregulated	Unregulated
Capital	Intensive	Moderate	Intensive	Moderate
Market	Global	Global	Global	Global
Product Development	Long Timelines	Short Timelines	Short Timelines	Very Short Timelines
Annual Sales[1]	**$9B**	**$80B**	**$45B**	**$97B**
Number of Companies[1]	1,308	2,134	300	35,384
Employees[1]	**108,000**	**350,000**	**236,000**	**546,000**
[1] 1995 Industry Data used in this comparison				
Source: DRI/McGraw-Hill, Semiconductor Industry Assoc., American Electronics Assoc.				

Industry Life Cycle Evaluation

Developmentally most biotech firms fall somewhere between *introduction* and *growth*. The following factors indicate that biotechnology remains in the "introduction" phase: (1) engineering and R&D comprise key functions, (2) many still constitute high risk ventures, and (3) their output consists of short production runs requiring high skill, extraordinary costs and a specialized sales channel.

Factors supporting biotech's transition to the "growth" phase include a (1) widening buyer group, (2) competitive product improvements over traditional alternatives, (3) increased mergers, and (4) increasing numbers of successful companies.

Biotech Industry Metrics

The biotech industrial sector is moderately concentrated—the top six firms represented 37 percent of all sales in 1996 (Lee and Burrill, 1996). Business measures posted by the biotech industry showed impressive across-the-board increases in 1996 (see Fig. 3).

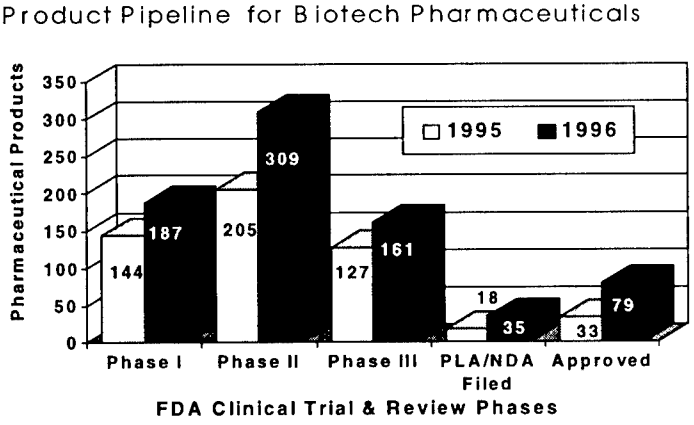
Figure 3.—Business Measure Increases in the Biotechnology Industry.

MEASURE	1996	1997	% Change
Revenues	**$12.7B**	**$14.6B**	**15%**
R&D Expenditures	**$7.7B**	**$7.9B**	**3%**
Equity Raised	**$3.5B**	**$8.0B**	**132%**
Market Capitalization	**$52.0B**	**$83.0B**	**60%**
Employees	**108,000**	**118,000**	**9%**

Source: Lee and Burrill, 1996, p. 14, 21.

With 87 percent of the sector linked to health care products, the biotech product "pipeline" for pharmaceuticals constitutes a dominant indicator. The number of biotech products included in the FDA approval process jumped dramatically within the last year (see Fig. 4).

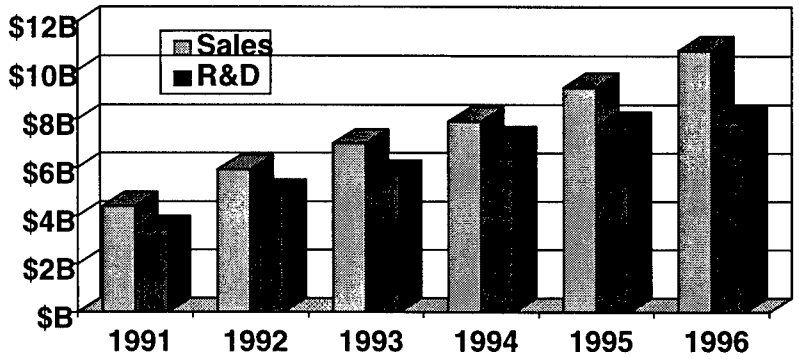
Figure 4.—Product Pipeline for Biotech Pharmaceuticals



Source: Ernst & Young Annual Reports on Biotechnology (1996-97)

The biotechnology industry continues to attract R&D investment and to generate revenues for successful patent holders despite the low number of product approvals in the early 1990s. Figure 5 below shows both sales and R&D growth for domestic biotech companies. These metrics buttress the conclusion that the biotech sector is moving into the growth stage of the industry life cycle.

Figure 5.—U.S. Biotechnology Industry: Sales and R&D Trends

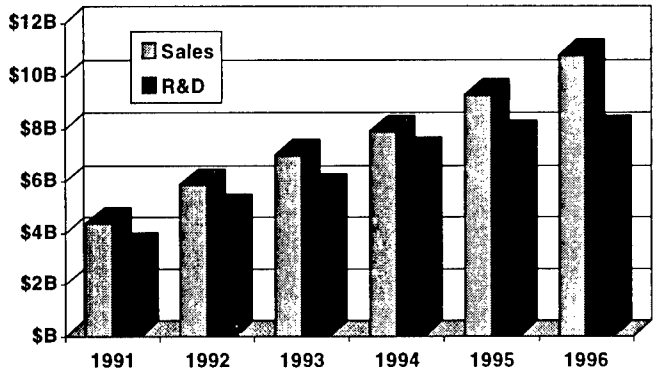


Source: Ernst & Young's Annual Reports of Biotech Industry (1992-97)

The notion of *patents* as *products* is an important and defining characteristic of the biotech industry. Many firms have refocused their attention; instead of generating off-the-shelf products, these firms are producing gene information and genetic process patents marketable to biotech producers. Biotech's increased demand for timely patents has prompted the U.S. Patent and Trademark Office to increase the number and sophistication of biotech patent examiners. In 1988, the office had 67 biotech patent examiners. By 1995, the number had more than doubled to 152 (BIO, 1997).

While the number of biotech companies has remained fairly constant over the last six years, the increase reveals one significant trend and conceals another. Figure 6 depicts a steady increase in publicly traded biotech firms (up 13 percent in 1996 alone). However, it camouflages the considerable consolidation activity that has accompanied this increase in which insufficiently capitalized but promising biotech startup firms have been acquired by larger companies.

Figure 6.—U.S. Biotech Companies: Sector Size and Ownership Trends



Source: Ernst & Young's Annual Reports of Biotech Industry (1992-97)

Geographic Concentration

As of 1996, 1,287 biotechnology firms were registered in the United States and 294 of these firms were publicly held. Geographic concentration is also a significant factor in biotechnology development; firms often locate within a specific area to take competitive advantage of major universities (e.g., Stanford, the University of California, Harvard, MIT) and government centers (NIH, CDC) that have already amassed considerable biotechnology expertise, research grants, and cooperative agreements. Of the reported firms, 373 are in California where they are anchored by strong academic research and grant activity (204 of these firms are in the San Francisco Bay area) (Lee and Burrill, 1996). Boston and Maryland also host large biotech clusters.

Barriers to Entry

Despite a considerable potential profit, those who would enter this maturing industry face a number of obstacles, including restrictive patent rights and the threat of litigation. In pharmaceuticals and agriculture, a few major firms hold key biotech process patents. New firms must obtain licenses (if they can) or develop alternative processes. Further, all biotech companies, particularly those tied to health care, face daunting legal challenges, among them:

- biotech patent suits,
- challenges from environmental and religious organizations seeking to block biotech products and procedures by claiming potential side effects or ethical considerations, and
- the absence of statutory limits on the punitive damages courts may award to plaintiffs for real or perceived human consequences of biotech drugs and treatments.

Still another barrier derives from the uncertain sources of venture capital. Equity financing declined by 30 percent in 1995 only to increase by 132 percent in 1996, illustrating the volatility and fickleness of current capital markets (Lee and Burrill, 1995 and Lee and Burrill, 1996). Biotech startups with unproven products are finding it harder to raise capital by initial public offerings as the investment community becomes more experienced with the industry. Alternative sources of essential funding (strategic alliances and consolidations with larger firms) must depend on technical breakthroughs to render the new firm profitable.

Other financial barriers are the high cost-to-market and delays on investment returns. Recent studies of the pharmaceutical development process indicate that between $200 and $350 million are needed to develop a new product from concept to market (BIO, 1997).

Biotech products have a high profit potential as health care applications which are also 87 percent of the market show. However, these applications may require as many as 12 to 15 years for product development.

Global Competitiveness

The European Union (EU) constitutes America's most significantly developed biotech competitor, although other nations have entered the field. Canada currently reports 350 biotech companies and Israel 87. Japan and Korea have a growing number of financial partnerships with European and U.S. biotech firms, foreshadowing the development of production facilities in the Pacific Rim. The European biotechnology industry has grown considerably in the past two years, increasing the number of firms more than a 20 percent each year, and producing a 60 percent rise in employment in 1996 alone. Figure 7 documents that growth and compares it to U.S. 1996 sector figures (converted to European Union currency).

Figure 7.—Growth of European Biotechnology Industry, 1995-1996.

Metric	Europe 1996	Europe 1995	% Change	US 1996
Revenues[1]	1.72B	1.47B	17%	11.68B
R&D Expense[1]	1.51B	1.25B	20%	6.32B
Companies	716	584	23%	1,287
Employees	27,500	17,200	60%	118,000
[1]All figures in ECU Billions				
Source: Ernst & Young (1997).				

Note that Europe's current rate of growth exceeds that of the United States. Several factors contribute to the recent European surge:

- Major European governments have boosted support of the biotech industry by increasing basic research funding and adopting more growth-oriented policies. Britain's science-based funding rose slightly (while spending for defense and other civilian projects declined) over the past eight years.
- The popular perception of biotechnology has improved, freeing both public and private institutions to invest more aggressively in the industry's support.
- European stock markets have lowered barriers to public listings of biotech related stock.
- Partnerships between firms from Europe and other nations have dramatically increased, providing capital and technical synergy.

We conclude that the governments of major European biotech countries (e.g., UK, Germany) have adopted strategic plans to become preeminent in biotechnology. Paradoxically, Europe is not only America's foremost biotech competitor, but also an important partner in the industry's development. European firms have many agreements with U.S. biotech companies. In fact, this bifurcation supports Porter's contention that nations don't compete, firms do (Porter, 1990). Although, transnational teaming can blur assessment criteria, the U.S. biotech industry is clearly the world leader in biotechnology based on its sheer size and substantive involvement in every biotech subsector.

CHALLENGES

Process engineering breakthroughs, such as mammal cloning and the growing array of approved products, indicate a rapidly advancing biotech industry. In biotechnology scientific excellence continues to

overcome technical challenges. Successive technological breakthroughs and associated media coverage produce a broad array of nontechnical challenges to biotechnology's growth, specifically with regard to intellectual rights and ethical, regulatory, and legislative concerns. This study identifies several major, often interconnected challenges facing the industry.

Research and Development Funding

Given that the product development process is long, complex, and expensive, and that the lag time between investment and revenue is lengthy, the industry must continually develop and shift strategies to sustain itself. One of the most research-intensive industries in the world, the U.S. biotechnology industry spent $7.9 billion in research and development last year, or almost $67,000 per biotech employee. Compared with an average of $7,651 per employee for all U.S.industries and $56,000 per employee for the top pharmaceutical companies. (BIO, 1997).

Infrastructure Concerns

Biotech industry leaders repeatedly cite the need for a trained work force as a primary concern for their companies. While doctoral level expertise appears readily available, companies are often short of skilled technicians to operate and monitor the sophisticated industrial processing machinery needed to move newly approved products into production. To meet this need, a national education policy is needed to promote scientific training and instruction in statistical process control and manufacturing process engineering at the college (bachelor or associate degree) level.

To transform the industry to mass production also requires many firms to find cost-efficient sites for biotech factories. Proximity to urban universities (an asset during development) can become a liability in the production phase if these sites also have high land costs, zoning restrictions, and insufficient infrastructure to transport and handle production materials in bulk.

Balanced Patent Protection

Cash flow remains the single biggest concern facing any new biotechnology firm. If cash represents the firm's life-blood, viable

patents are the heart muscle that draws and pumps cash into the company to finance production and further research. Because the industry's output is intellectual in nature, patent protection and licensing agreements remain vital to the industry's survival. An inordinate amount of industry attention and resources is focused on resolving patent suits instead of advancing scientifically. The challenge to industry is this: Can a level of patent protection be developed at both the domestic and international level that recognizes and rewards inventors while stimulating efficient scientific progression and its associated benefits?

Protecting Intellectual Property Rights

Within the United States, observance of intellectual property rights and resolution of disputes through litigation constitute standard operating procedure. However, domestic biotech firms increasingly must rely on international patent protection to underwrite R&D expenditures in foreign income streams. Many of the drugs and gene therapies produced by U.S. biotechnology companies can be marketed in advanced industrial countries (e.g., in Japan and western Europe), where patent protection appears adequate.

Elsewhere in the developing world, rising expectations for improved living standards, longer life expectancy, and better health care have increased demand for biotech products. The most likely future markets (India, China, and the nations of the Pacific rim) are notorious for their lack of rigorous patent protection in other high technology exports (e.g., computer software, electronics). Biotech agricultural products constitute a huge market opportunity for export, but possess the highest vulnerability (and probability) for patent piracy.

Conflicts arise over biotech process ownership, secondary and tertiary effects of genetically altered material, and establishing the governing body for resolution of patent disputes. Japan grants much narrower protection to biotechnology patents than does the United States. Significant differences also exist between the U.S. and European patenting systems. The United States grants patents to the firms it believes first made the invention, the European Patent Office grants patents to the first to file. The biotech industry will be increasingly challenged by the need to codify and enforce intellectual property statutes at the international level in a form consistent with domestic protections.

Public Relations and "Bioethics"

Although the media dutifully report biotech advancements with potentially tremendous health benefit consequences on an almost daily basis, this "good news" does not resonate with the public like the ethical fears raised over issues like cloning. Unfortunately, the industry has often contributed to this phenomenon by inflating expectations of rapid health and quality of life improvements. Unrealized expectations undermine industry credibility, sour the investment environment, and choke off needed sources of capital. A much broader public debate resulted this year from the success of mammal cloning. Arguments both profound and insipid found voice concerning the potential application of this new process to humans. President Clinton reacted by issuing a moratorium on federal funding for human cloning. Congress responded with proposed legislation that would make that funding moratorium law and the act of human cloning illegal. The possibility of legislation curtailing biotech research dramatically raises industry and investor concerns.

Although the biotechnology industry has established a voluntary set of guidelines with NIH, it has not yet adequately addressed its responsibility vis-a-vis its ethical leadership. A stream of ethical debates concerning biotech processes (e.g., research on human fetal tissues, *in vivo* genetic engineering, biotechnically modified food) illustrate the enduring nature and diversity of this challenge. Both individual and collective preemptive measures are needed to improve public understanding of the biotech industry and its benefits and to demonstrate a responsible approach to applied technology.

Regulatory Reform

Many of these challenges to the biotech industry give credence to the claim that its future viability lies in the hands of the Congress. During the 105th session of Congress bills have been introduced to spur investment, streamline product approval, fund research, and limit corporate liability as well as limit biotechnological research and practices. Thus, capital gains and other taxation reforms, tort reforms, and even administrative and regulatory reforms of government agencies may result in significant legislation affecting the biotech industry. These initiatives may determine the legal uses of biotechnology and the levels of funding available for basic research. Thus, public policy will have a key role in biotech's future profitability.

OUTLOOK

The United States' tremendous lead in the global biotechnology market—even with Europe gaining ground—enhances national security by fostering significant economic growth and providing unparalleled opportunities for enhanced health, agricultural productivity, and environmental quality. The government has not yet crafted a visionary program to spur specific biotech applications that can directly increase national security or provide for mobilization mechanisms.

Near-Term Predictions (Zero to Five Years)

The immediate business strategies of biotechnology firms must focus on the issues of capital financing, regulatory reform, intellectual property protection, and product pricing. Other critical strategies include promoting favorable government business policies and successfully addressing public concern over possible misuses of technology and other ethical questions.

Capital Development and Investment. Capital raised for biotechnology has generally increased over the last five years, including the 132 percent increase recorded in 1996. This trend should continue, aided by corporate alliances and acquisitions that consolidate smaller biotech firms through direct merger, acquisition, or licensing arrangements. Increased investor confidence in the sector will accompany the growing number of profitable products reaching the market, stabilizing firms that achieve commercial viability and increasing marketable securities.

Risk Management. The growth and sustainment strategies for biotech companies in the health care market will continue to focus on filling the development pipeline with numerous candidate products in various stages of investigation, clinical testing, and review. This variety of products in various stages constitutes the industry's version of diversification. This strategy staggers new product time to market and distributes new product risk throughout the development life cycle so that no single product setback completely undermines the company's value.

Alliance Strategies. Over the last five years, acquisitions and mergers have given way to the development of product-unique alliances and numerous other teaming strategies. These strategies serve to marry cash

and creativity and will continue to prove effective in the near term. Many large pharmaceutical companies, rather than relying on in-house development of their own biotechnology capability, seek to acquire new technology via license, merger, acquisition, alliance, or partnering. This strategy has dual benefits: it reduces the firm's cash flow (by avoiding basic development expenses) and enhances its selective engagement in emerging technological opportunities that merit investment.

Regulatory Reform. Many biotechnology and pharmaceutical companies cite reforms of the U.S. Environmental Protection Agency, the Food and Drug Administration, and the various USDA agencies as strategically important to the future of biotechnology. The industry continues to criticize the Food and Drug Administration (FDA) procedures as outmoded, obsolete, and grounded in legislation passed in 1902. Such procedures result in a process that industry often views as excessive, irrelevant, and largely responsible for preventing safe and effective products from reaching patients quickly. Fully 85 percent of biotechnology chief executives place FDA reform at the top of the list of actions that would positively impact biotechnology (Lee and Burrill, 1995). A critical legislative milestone occurred in September 1997, when the 1992 Prescription Drug User Fee Act expired. This legislation reduced FDA review time for new drugs and biologics. If not reenacted, the FDA review cycle must fall back to prestreamlined processes. According to industry estimates, joint FDA and industry proposals to modify and renew the legislation could reduce the product review cycle by 10 to 16 months from its 1996 average of 19.2 months (Lee and Burrill, 1996).

Public Outreach. To preserve investor and consumer confidence, ward off stifling legislation, address ethical concerns, and forcefully counter antibiotechnological propaganda and litigation, the industry must strive to accelerate public relations efforts. BIO, the industry's lobbying organization has undertaken the challenge of disseminating complex scientific information to the public by emphasizing its considerable potential for delivering quality of life benefits across the spectrum of human needs. Successful firms will continue to pay close attention to corporate investor relations by producing better explanations of R&D achievements, more realistic expectations of product performance and availability, and a more acceptable response to ethical application concerns.

Legislation. Price controls, vulnerability to uncapped product liability, and reimbursement reductions could reduce profitability and the long-term viability of R&D as investors seek a safer, more equitable market-based industry segment. Biotechnology firms will continue to advocate capital gains incentives, research credits, and other legislation to increase direct financial support to the development of the industry.

Long-Term Planning (to 2020)

The industry appears to have adequate financial capital to grow as it develops profitability. Industry growth and a future contributory role in national security remain tied, however, to prudent private sector management and proactive government policies.

The emerging and potentially competitive economic markets in China and India suggest that the United States and Europe would do well to ensure that the World Trade Organization adopts robust patent and intellectual property rights protections. Enforcement of patents in emerging markets will play a key role in sustaining the nation's leadership position through 2020.

Industry enlargement will continue to rely on the government to fund plentiful amounts of basic research, (e.g., NIH grants). The industry will mature more quickly and vigorously if legislators go beyond providing a "sense of Congress" in favor of biotech research to a funding resolution that truly reflects the industry's strategic potential.

The industry must grapple with improving the efficiency of its production while matching products to processes. Three different production sources—human, animal, and plant DNA—currently complete as the preferred source of products in the future marketplace. Bioinformation may likely become a segment of large biotech firms instead of an outsourced service as it is currently.

The industry faces the potential of crippling legislation should it fail to convince the public and legislative bodies that its benefits outweigh health and ethical concerns. The industry requires informed legislation that protects public interests without hampering responsible scientific advance.

The government should facilitate biotech's continued evolution into a strategic industry via the technology transfer process. This process promotes the evolution of fundamental laboratory discoveries into practical knowledge and useful products for the benefit of humanity (NIH, 1996). Federal laboratories are the largest source of biomedical technology transfer opportunities. Future advances in biotechnology,

pharmaceutical and health care industries, new biopharmaceuticals and drugs in development, fundamental discoveries in the life sciences, and novel disease treatments and diagnostics rely on their continued robust funding and support.

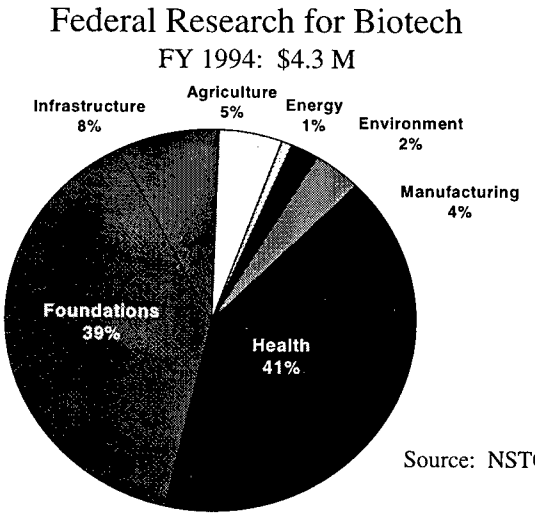
Long-term viability of the technology transfer process relies on use of Cooperative Research and Development Agreements (CRADAs), one of the newest and best mechanisms to protect a corporation's research investments. Congressionally established CRADAs permit government laboratories to provide personnel, services, facilities, equipment or other resources to improve R&D in other settings.

GOVERNMENT GOALS AND ROLE

Supporting the Biotech Industrial Base

The biannual congressionally mandated National Critical Technologies Review (NCTR) identifies biotechnology as a national critical technology essential to further the long-term national security and economic prosperity of the United States. The following sections will highlight key government agency contributions in promoting and sustaining the biotechnology industry.

Figure 8.—



Source: NSTC, p.2

Health and Human Services (HHS). As the parent department for the National Institute of Health (NIH), Food and Drug Administration (FDA), and Center for Disease Control (CDC), HHS has the primary responsibility for promoting the health of Americans and providing essential human services.

National Institutes of Health. Through its collaboration with government scientists and private researchers, NIH constitutes the vanguard for government activity in biotechnological developments. Basic research money flows through the agency to support pioneer biotech therapy, genetic research, gene mapping and sequencing, and other medical advances. NIH focuses on eliminating or reversing genetic defects in cells, developing serums and vaccines against disease, and improved drug delivery systems. In the 1980s, NIH researchers performed the first trial of human gene therapy, and currently play a key role in human genome discoveries. Scientists predict this new knowledge will lead to genetic tests to diagnose predilections for diseases such as colon, breast, and other cancers, and the eventual development of preventative drug treatments for individuals in families known to be at risk.

Food and Drug Administration. The FDA supports biotechnology research in five key areas: (1) testing therapeutics for safety and effectiveness; (2) evaluating the safety, purity, and potency of vaccines; (3) assessing devices, including computer models and other tools that assess biomedical materials degradation and interaction with hosts; (4) ensuring effectiveness of diagnostic assays, such as blood donor screening tests and procedures for measuring for infections or disease; and (5) developing methods for detecting food-borne contaminants and toxins. One of the most visible government agencies in the biotechnological arena, the FDA is best known for its responsibility to approve or disapprove new drugs, vaccines, and medical equipment for the protection of public health.

Center for Disease Control. As the nation's premier center for global health and disease monitoring, the CDC plays a key role in the nation's first line of defense against biological anomalies and emergencies. The CDC's public health surveillance system in the National Center for Health Statistics (NCHS) monitors mortality, and virulence of diseases such as AIDS, the Ebola virus, polio, diphtheria, and influenza. The CDC accomplishes its mission through extensive national and international networks and partnerships with state and local health care

institutions, the World Health Organization, and foreign governments. The CDC works closely with the biotechnology industry seeking cures for illnesses such as cancer and Alzheimer's disease, tracking and eradicating water and food-borne diseases, and stopping the spread of epidemics anywhere in the world (Jaret, 1991, p. 114).

U.S. Department of Agriculture. The USDA biotechnology research program focuses on agricultural problems associated with molecular biology. USDA views biotech as a tool to enhance the competitiveness of American agriculture—improving the quality, acceptability, and safety of its products while minimizing its environmental impacts and maximizing sustainability.

The fundamental nature of biotechnology's focus on living systems makes agriculture one of its natural development fields. Agricultural biotechnology promises myriad benefits: drought and disease resistant plants, improved land use, enhanced food product flavor, and fewer and better pesticides. The USDA's biotechnology agenda emphasizes the Plant Genome Research Program, which identifies and maps crop genes. Its discoveries will improve the prospect of future food security domestically and internationally.

Combating Biological Terrorism.

The United States faces a real and growing threat, namely, that terrorists may employ biological weapons against its cities and population centers. By "terrorists" we mean rogue regimes, state-sponsored terrorists, and extremists, with the latter to be found both at home and abroad. The impact of a biological accident or attack on a populated city would likely be severe, causing widespread panic and chaos, possibly inflicting mass casualties and destabilizing the government. In the event of a biological weapons attack or a biological accident, numerous government agencies (e.g., the DoD, CIA, and HHS) play critical roles in protecting the nation. Absent a crisis, government agencies work routinely with the biotech industry to support national security in mutually beneficial ways.

The Threat. The acquisition, development and use of biological weapons is well within the capability of many extremist and terrorist movements, acting independently, or through associations with foreign states. According to USAMRIID (1997), terrorist groups have already

conducted attacks or attempted to use chemical or biological agents against civilian targets:

- A cell of the German Baader-Meinhof gang was discovered with a culture of botulinum toxin.
- Two members of the Minnesota Militia were convicted of possession of a self-produced lethal biological agent (ricin).
- The Aum Shinri Kyo cult released a chemical agent (Sarin gas) in a Tokyo subway killing 12 and injuring thousands; and released anthrax from the top of a building, ostensibly in pursuit of a capability for biological warfare.
- Following the Gulf War, inspectors in Iraq discovered stocks of anthrax cultures. These cultures were labeled "American Type Culture Company, Parklawn Dr. Rockville, MD."

The United States and other nations lack the equipment and training that would be needed to handle biological warfare effectively. Required medical countermeasures (e.g., vaccines and antibiotics) are not readily available. Effective biological detectors (highly selective, specific, portable, and lightweight) are also not available, leading most analysts to conclude that the first indication of an attack would be the inflow of victims to local hospitals and health clinics.

The Agents. Biological agents consist of living organisms, for example, bacteria (e.g., anthrax, plague), viruses (e.g., smallpox, Venezuelan equine encephalitis), or poisons (e.g., ricin, botulinum toxin). Biological warfare agents can be produced in facilities much smaller and harder to detect than nuclear weapons plants. Biological agents can be dispersed in unconventional "weapons" such as through sprayers and crop dusters, and compact, off-the-shelf technology can be used to manufacture these weapons quite cheaply. For example, the residue of castor bean oil production is 20 percent pure ricin.

Biotech Solutions. Biotechnology offers several significant technological responses to biological warfare (BW). Both domestic and international entities have conducted investigative research into potential countermeasures:

- Bioengineered enzymes may neutralize BW agents as they contact enzyme-impregnated material.
- Simple organisms may be genetically altered to respond to the presence of specific BW agents, enabling a new class of biosensors.

- Vaccines specifically targeting BW agents may provide protection to those military and civil personnel most likely to be exposed.
- The Department of Defense is currently pondering the implications of vaccinating its entire force against anthrax. Aside from that measure, funding in biodefense developmental areas falls short of the need dictated by the BW threat. This gap has serious national security implications.

CONCLUSION

The biotech industry's high technological growth and business sector expansion over the last year denotes a life cycle transition from the introductory to the growth stage. In every major industrial nation, biotechnology appears at or near the top of its list of potentially key strategic industries, even as the industry struggles to record its first year of overall profitability. While in agreement with scientific and business pundits already conceding biotech to be the reigning technology of the 21st century, this study concerns itself with proposing the measures that will optimize and hasten that result.

> "This was the century of physics and chemistry, but it is clear that the next century will be the century of biology"
>
> Robert F. Curl
> 1996 Nobel Prize
> (Chemistry)

A consortium of public and private biotech stakeholders must proactively pursue a broad spectrum of actions that will preserve biotech's growth opportunities and national preeminence. The government must continue to expand funding for basic biotechnological research, the proven method for obtaining unexpected breakthroughs. Government agencies with a stake in biotech development (e.g., Agriculture, Defense, Commerce, State, Health and Human Services) must act as advocates for the biotech industry's advancement and fund developments related to their mission.

The DoD participates with industry on biotech developments in a number of isolated but commendable ways, but an overall cohesive plan that recognizes the potential for biotechnology to bolster military power has yet to be realized. In general, too few steps have been taken to leverage the U.S. advantage in biotechnology to meet national security resource needs. The present acquisition system thwarts "off-the-shelf" procurement and thus deters commercial firms from marketing to the Department of Defense. The DoD should form a steering group to

identify and establish programs facilitating the biotechnology industry's response to defense-related needs. Most urgently, the DoD should set priorities and enlarge the budget for seminal research and product development in biological warfare defense methods and equipment. Potential surge and mobilization requirements that the biotech industry can fulfill (e.g., advanced vaccine and enzyme production) must be studied and realized in practical strategies.

Government and industry representatives should cooperate to support legislation that promotes biotech advancement such as regulatory reform, business growth incentives, consumer protection, intellectual property protection, and bioethics. Industry, academia, and government have interlocking roles in supporting the biotechnology industry and answering the valid concerns raised by societal and religious interests. The guiding principle is to strike the proper balance between supporting the biotech sector and preserving the rights and safety of the public.

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CONSTRUCTION

ABSTRACT

The construction industry, a vibrant, healthy, and stable component of our nation's economy, is characterized by many small firms, fierce competition, and domestic market dominance. The industry is beginning an international expansion into new areas of economic opportunity. U.S. high technology, new construction methods, engineering design, and management are key strengths in obtaining a significant international market share.

Our nation's infrastructure is in need of substantial repair and capital development. Our roads, bridges, and facilities need improvement to support future U.S. economic strength. Faced with declining domestic and international resources, governments are employing new methods to finance infrastructure development. Privatization and Design-Build-Operate variations are vital to solving capital shortfalls. Using automated technology can enhance construction design, management, processes, and equipment, while simultaneously reducing bureaucracy and overhead.

Mr. André Bazemore, National Security Agency
LTC Gary Berry, USA
Ms. Tammy Famoso, Dept. of the Navy
Lt Col David Harrell, USAF
LTC Douglas Horn, USA
Lt Col Mark Johnson, USAF
Ms. Carol Kokinda, Dept. of Transportation
CDR Edward Morgan, USN
Ms. Ramonda Rawls, Dept. of the Navy
CDR Robert Schlesinger, USN
LTC Joseph Schmitt, USA
CDR Joseph Sensi, Jr., USN
Lt Col Scott Streifert, USAF

Dr. Hugh Conway, Dept. of Labor, faculty
Mr. Jeffrey High, Dept. of Transportation, faculty
Col David Price, USAF, faculty

PLACES VISITED

Domestic

Associated General Contractors of America, Washington, DC
National Institute of Standards and Technology, Gaithersburg, MD
National Association of Home Builders, Washington, DC
U.S. Army Corps of Engineers, Washington, DC and Vicksburg, MS
Port Authority of New York, World Trade Center, New York, NY
Parsons Brinckerhoff, New York, NY
Boston Harbor and Central Artery Tunnel Projects, MA
Sheet Metal Workers' International Association, Suitland, MD
Stromberg Metal Works, Inc., Beltsville, MD
Huber, Hunt and Nichols, Inc., (Seismic Retrofit), San Francisco, CA
California Transportation Department, San Francisco, CA
Bechtel Corporate Headquarters, San Francisco, CA
Bay Area Rapid Transit (BART) System, San Francisco, CA
Dames & Moore Group, Los Angeles, CA
Parsons Corporation, Pasadena, CA
Jacobs Engineering Group, Inc., Pasedena, CA
U.S. Army Corps of Engineers, Los Angeles District, Santa Ana Dam

International

Airport Authority, Hong Kong
Bappenas, National Development Planning Agency, Jakarta, Indonesia
Ministry of Public Works, Jakarta, Indonesia
Sudirman Central Business District Project, Jakarta, Indonesia
Ministry of Communications (Transportation), Jakarta, Indonesia
Mission Energy Company, Power Plants Project, Jakarta, Indonesia
National Resilience Institute of Indonesia (Lemhannas)
Department of Defence, Acquisition Organization, Sydney, Australia
Victoria Barracks, Heritage Restorations, Sydney, Australia
State and Regional Development New South Wales, Sydney, Australia
Transfield Construction Company Pty. Ltd., Sydney, Australia
Construction Project for Olympics 2000, New South Wales, Australia
Economic Development Authority, Adelaide, Australia
Australian Submarine Corporation Pty. Ltd., Adelaide, Australia
Russell Offices Redevelopment Project (Defence), Canberra, Australia
Trade Development Zone Authority, Darwin, Australia
Department of Transportation and Works, Port Proj., Darwin, Australia
Defence Housing Authority, Fairway Waters Project, Darwin, Australia

INTRODUCTION

A nation's ability to project and sustain political, military, and economic power is dependent on its national infrastructure. Infrastructure is a key output of the construction industry. Although substantial, U.S. infrastructure is aging, and our current efforts to modernize or replace significant portions of it are insufficient. We are concerned that funding is not available to perform the work that must be done. To determine the health of the construction industry, our study asked the following question: Is our nation's construction industry sufficiently healthy to assure a domestic capability in time of crisis? Can it compete globally, or will we eventually be dependent on foreign contractors to meet our needs? Is the U.S. work force sufficient in numbers, training, and skills to meet demand? Are construction machines and materials maintainable, reliable, efficient, and environmentally friendly?

To address these questions, we researched various aspects of the construction industry and interviewed and met professionals with varying backgrounds and roles in the industry, including representatives from local and national governments; professional, technical, and trade associations; unions and their training components; and both privately held and publicly traded companies.

This report summarizes our findings on the current status of the industry and the challenges that it faces now and in the future. It also includes predictions for its future and our view on the goals and role of government.

THE CONSTRUCTION INDUSTRY DEFINED

The U.S. construction industry is the nation's largest manufacturing sector and its second largest economic activity (CERF, 1993). In 1994, new construction and renovation made up 13 percent of the Gross Domestic Product (GDP) (Wright, Rosenfeld, and Fowell, 1995). The construction industry in the United States consists of a diverse group of subindustries. Many people and corporations can be involved in the construction of a single structure. The construction industry encompasses everything—from the initial design through the manufacture of necessary components, to final assembly—and builds or replaces structures on a wide variety of facilities and systems ranging from single family homes to power plants. It is this diversity that makes

the construction industry the nation's single largest employer (Reid, 1995).

The construction industry is characterized by many buyers and sellers. General construction has very low entry requirements; however, mechanical, electrical, and special trades construction require special skills and equipment. The industry is becoming increasingly international; major construction awards frequently cross international boundaries. The U.S. government purchases only a small percentage of construction each year, but its influence on the industry through policy and regulatory roles is significant.

Net profits for even the most successful design, management, and construction companies are lower than in most businesses, averaging about 2 percent. The industry experiences fierce competition at the bid box.

U.S. investment in construction research and development (R&D) is low. Japan and Europe use more design-build procurement, which requires that separate contractors design and build construction projects, and fund R&D at higher levels.

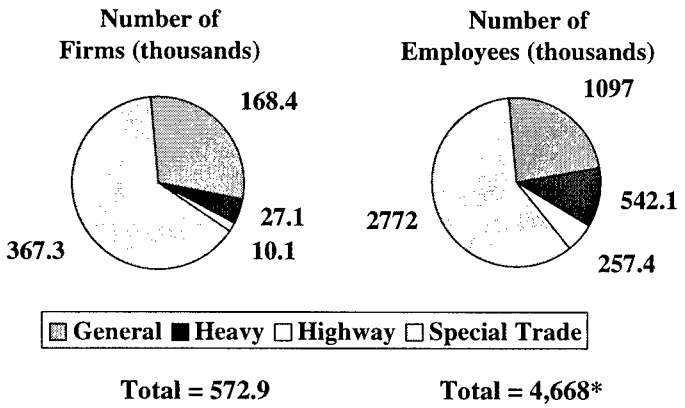
The official census of the U.S. construction industry is conducted every five years. The following data and Figure 1 are from the most recent census (U.S. Dept. of Commerce, 1992).

- There were 572,852 construction establishments in 1992.
- A total of 332,309 construction firms operated as corporations and had an average of 11 employees.
- Partnerships, proprietorships, and other forms of organizations totaled 240,543 in number. The average partnership establishment had 5 employees and the average individual proprietorship employed 3 people.
- Single-unit companies accounted for 98 percent of the total number of establishments and had an average of 7 employees.
- Only 2 percent of all establishments were multiunit companies; the average multiunit establishment had 69 employees.
- There are 5.1 million construction workers in the United States. They represent 4 percent of our total work force and the third largest occupational group tracked by the Labor Department (Bureau of Labor Statistics, 1997).

General building contractors are primarily engaged in the construction and renovation of residential, farm, industrial, commercial, and other buildings. Heavy construction contractors are primarily

engaged in the construction of highways, streets, bridges, railroads, pipelines, sewer and water lines, flood control projects, marine construction, power and petrochemical plants, and other nonbuilding construction projects. Special trade contractors include plumbers, painters, carpenters, electricians, brick layers, and roofers. This group includes those skilled workers who undertake work in either building or heavy construction.

Figure 1: Construction Industry Structure



Source: Bureau of the Census, 1992.

* Represents 1992 data for number of construction workers. 1997 Bureau of Labor Statistics data shows 5.1 million construction workers in the

CURRENT CONDITIONS

Current conditions in the construction industry include diminished dollars for public works, a stable private market, growing international opportunities, and new methods of construction, such as design-build. Aging infrastructure is a major concern.

General Financial Trends in U.S. Construction

Table 1 compares construction projects in production from 1985 to 1996 with a forecast of projects for the year 2000.

Table 1: Value of New Construction In Place, 1985-2000
(billions of 1992 dollars)

TYPE OF CONSTRUCTION	1985	1990	1993	1994	1995 (Est.)	1996 (Est.)	2000 (Proj.)
Private Residential	164.2	198.7	200.7	217.8	207.7	218.9	238.2
Single-family	87.5	118.1	127.1	140.3	126.3	135.1	146.4
Multi-family	35.3	21.0	10.3	12.8	16.1	17.7	19.6
Home Improvement	41.4	59.6	63.3	64.7	65.3	66.0	72.1
Private Nonresidential	167.1	164.1	124.7	128.2	136.2	141.0	142.5
Manufacturing	24.3	25.9	18.9	19.6	21.8	22.2	25.2
Office	38.8	31.2	14.9	15.8	17.4	17.6	17.4
Hospital/ Institutional	9.1	10.3	10.6	9.6	8.8	9.0	10.2
Commercial	33.8	37.2	26.2	29.1	32.0	33.6	28.9
Electric Utilities	27.1	11.1	12.4	11.4	11.6	12.1	13.5
Telecommunications	10.4	10.3	9.5	10.5	9.9	10.4	11.4
Other	23.6	38.1	32.2	32.2	34.7	36.1	35.9
Public Works	79.2	118.0	122.6	123.1	129.3	132.1	138.9
Highways	27.5	35.8	37.3	38.6	38.6	39.4	40.6
Educational	7.8	22.3	21.3	21.5	23.2	24.6	25.6
Other Public Building	*	18.9	19.3	17.8	19.0	19.8	21.0
Misc. Public Structures	*	9.3	11.4	11.6	12.8	13.4	14.8
Sewer Systems	8.4	10.3	10.1	10.7	11.0	10.2	12.2
Water Supply	3.9	5.1	5.8	5.6	6.3	6.5	7.3
Military	3.2	2.9	2.4	2.2	2.7	2.5	2.3
Other	28.4	13.4	15.0	15.1	15.7	15.7	15.1
Total construction	410.5	480.0	448.0	469.1	473.3	492.0	519.5

1 * These values included as part of "Other"; not calculated separately at this time.
2 1985 statistics were reported in 1977 $—GDP inflator of 2.166 was used to obtain 1992 $.
3 1990 statistics were reported in 1987 $—GDP inflator of 1.211 was used to obtain 1992 $.
4 The above statistics represent the "value added" figures associated with the construction industry. This technique for the most part provides the best measure of comparing relative economic importance. These figures are equal to the value of business done, including costs for subcontracted construction work and the costs associated with materials, components, supplies, and fuels.

(*U.S. Industrial Outlook for Construction*, 1985, p. 1-1 and 1994, p. 5-2; *Construction Review*, 1995-1996, p. v).

The U.S. construction industry consists of three sectors, private residential, private nonresidential, and public works.

Private Residential. The private residential sector is approximately 45 percent of new construction activity each year. The aggregate value of private residential construction fell by 5 percent in 1995, mostly from a decrease in single-family construction. Overall housing starts fell 7 percent in 1995 by from 1.46 million to 1.33 million ("Trends in U.S. Construction," 1995). An increase in interest rates in late 1994 and early 1995 precipitated this loss because the single-family home market is very sensitive to interest-rate fluctuations. Still, 1995, though not as high as 1994, was the sixth best of the past 15 years for new starts.

Multifamily homes increased 7 percent in 1995 with a total of 278,000 new starts (NAHB, 1997). This growth represents an increase in investment interest in this form of housing.

Private Nonresidential Building. A comparison between 1985 and 1993 shows a 25 percent decline in investment in private nonresidential building ("Trends in U.S. Construction," 1995). This decline from the post-World War II record set in 1985 represents a market correction of the phenomenal commercial building boom of the 1980s. The supply of commercial building space must be aligned with investor demand. Vacancy rates for commercial property (e.g., office buildings, stores, hotels, and warehouses) soared following the boom. As a result lenders are approaching investments in this area cautiously.

Public Works. From 1970 to 1977, public-sector investment in new construction was approximately 2.8 to 3.0 percent of the GDP. It has since dropped to about 2 percent of GDP (ICAF, 1996). Consequently the industry had a $50 billion shortfall in 1995, and a cumulative shortfall—since 1978—of approximately $500 billion.

Recent Trends

The internationalization of construction, the recent upswing in the use of design-build construction in the United States, the influence of information technology on the industry, and decay in the condition of U.S. infrastructure are recent trends worth noting.

International Market Place. While U.S. construction firms have traditionally focused on the domestic market, many now compete

successfully in the international market. Of the top 20 international firms (in terms of revenue earned in other countries) two are American. U.S. firms are gaining international market access by establishing foreign affiliates overseas. Local market knowledge is often the key to success in the international construction arena. U.S. contractors have worked on large, complex projects and their growing dominance in information technology puts U.S. construction firms in the running to gain a greater share of the international market.

The North American Free Trade Agreement, the explosive growth of the Pacific Rim countries, and the revitalization of the former Soviet Union are exemplary growth opportunities for the construction industry. U.S. companies maintain a dominant place in the international engineering and construction market; 40 percent of the top 200 international design firms have a base of operations in the United States. In addition, U.S. international construction firms, including their subsidiaries, won 49 percent of all international construction contracts in 1992 ("Construction Outlook," 1993).

Foreign construction firms garnered only 8.9 percent of construction contract awards in the United States in 1992. These figures signify that U.S. firms are maintaining their domestic superiority even as they pursue new international markets (Dept. of Commerce, 1994).

Access to capital and the cost of capital are major concerns of construction firms seeking entry into international markets. In developing, less stable countries, risk is a major contributor to the high cost of capital. To mitigate this high cost and assist U.S. firms in competing for access to developing markets, the Export-Import Bank of the United States provides loan guarantees to construction and engineering firms. These guarantees and others provided by the Overseas Private Investment Corporation help U.S. companies reduce risk and counter export credit subsidies that some governments provide (Moody, 1996). The easy availability of project funding can influence the selection of the funding source and the construction firm. As a result, many international firms have developed arrangements with banks that allow them to bring packaged financing to the deal. Emerging countries experiencing capital shortfalls will likely appreciate international firms that can offer design, construction, and financing options as a total package.

Design-Build. Application of the design-build process is growing worldwide. It is the delivery system of choice for more than 50 percent of nonresidential construction in the European Community and more

than 70 percent in Japan. From 1986 to 1992, the use of design-build grew by 172 percent in the United States. It now represents over one-third of new contract volume for the nation's top 400 contractors (Kreikemeier, 1996).

Approval of the Federal Acquisition Reform Act of 1996 (FARA) assures a solid future for the design-build process. FARA authorizes federal agencies to consider design-build as a delivery option and includes procedures for selecting the design-build process. All government agencies now have statutory authority to use two-phase selection procedures to procure the design and construction of a public building, facility, or work. Large federal agencies such as the General Services Administration, the Naval Facilities Engineering Command, and the U.S. Army Corps of Engineers are implementing design-build contracts. FARA has already led to increased use of design-build in the public sector.

Decaying U.S. Infrastructure. Although modest increases in federal government spending for highways and bridges have been projected, federal, state, and local officials believe more money is needed for U.S. infrastructure—and some alarming evidence supports their views (AGC):

- Fully 59 percent of the nation's primary highways are in fair, mediocre, or poor condition according to the Federal Highway Administration.
- The condition of the country's bridges is one of the most urgent infrastructure problems. The Federal Highway Administration estimates that $164.9 billion is required to fulfill bridge needs through 2010. Of this money, $103.7 billion is needed merely to maintain current conditions; the other $61.2 billion to accommodate backlog, improve bridge conditions, and handle increased traffic growth.
- The country's waterways and ports require extensive modernization to manage the increased volume and size of ships involved in commercial water transportation. To begin, more deep ports and waterways are needed (minimum 50-foot depth). Currently, only two ports on the east coast, Hampton Roads and Baltimore, have the depth to handle large commercial vessels. Dredging the country's ports and waterways will be required for the continued success of the United States as a maritime nation.

- Dam safety requires immediate attention. The results of an assessment by the U.S. Army Corps of Engineers and the Federal Emergency Management Agency listed 10,000 dams as "high" hazards and an additional 13,549 as "significant" hazards. A breach in one of these dams could cause substantial loss of lives and property.
- By the end of this decade, approximately 25,000 bridges (Jackson, 1996) and over 35 percent of the interstate system (U.S. House of Representatives, 1991) will reach the end of their design lives.

The Impact of Information Technology. Computers continue to revolutionize the construction industry's delivery time and design process. Most striking is the way network technologies have speeded the exchange of information between architects, engineers, and contractors, facilitating streamlined approvals and reviews. On one project, Bechtel Corporation teams in San Francisco, London, Delhi, Dubai, and Saudi Arabia used remote communication—virtual reality and computer-aided design (CAD) technology—to collaborate on project details.

Construction professionals have access to integrated databases, computer modeling, and computer labs via the Internet. Multimedia technology reduces the need for volumes of paper and photographs and expedites design and plan changes. Expert systems make one person's knowledge widely available to anyone facing complicated technical problems, anywhere in the world. Open system standards provide owners with cost-effective alternatives during the design, construction, and maintenance of their projects. The National Science and Technology Council has identified a national construction industry goal: a 50 percent reduction in construction project delivery time by the year 2004, with simultaneous reductions in project costs. In many cases, firms have decided that the speed and time saved by using information technology is key to meeting this goal (Wright, Rosenfeld, and Fowell, 1995).

CHALLENGES

The Construction industry's future challenges include adequately funding research and development, delivering infrastructure improvements for less cost, maintaining competitiveness in the global market, keeping a skilled work force in sufficient numbers to meet demand, and implementing global environmental standards.

Adequate Funding for Research and Development

R&D is vital to our nation's future productivity and to future cost avoidance. It can facilitate industry growth through improved materials, construction methods, construction machinery, technical design, planning, and virtual reality simulations.

The U.S. construction industry invests less than other comparable industries and less than its international competitors on R&D. Construction R&D in Japan and Europe is more coordinated than in the United States and more likely to focus on long-term, life-cycle performance. Public and private sector cooperation is the norm. Japanese and European private-sector construction firms move their innovations into practice faster than their U.S. counterparts. This ability in turn spurs even greater investment in R&D (CERF, 1993). In contrast, R&D in the U.S. construction industry has generally not been coordinated. To some extent, this approach to R&D reflects the fragmented nature of the industry itself. The federal government has also lacked coordination and overall objectives for construction R&D, though it has recently begun a coordinated approach (CERF, 1993).

The Civil Engineering Research Foundation (CERF), the National Science Foundation, the National Institute of Standards and Technology (NIST), and the National Science and Technology Council have recently taken leadership roles to provide a forum for public- and private-sector coordination. They have also developed joint goals and a strategic plan for the future. An illustration of this private and public sector R&D cooperation is CERF's recently launched Construction Materials and Systems Program (CONMAT). CONMAT is an industry-led effort with key government participation. The CONMAT program is a $2.1 billion research, development, and deployment plan to "help create the materials and systems for an entirely new generation of constructed facilities" (CERF, 1994). In addition, the Federal Technology Transfer Act of 1996 allows the U.S. Army Corps of Engineers to share federal laboratory research technology with other public- and private-sector representatives according to need and opportunity. The Corps of Engineers' Waterways Experiment Station and the Corps' Civil Engineering Research Laboratory (CERL) now provide their R&D findings in advanced technologies to construction and civil engineers.

The challenge is not merely to follow through on these promising starts but also to *increase* funding for R&D in both the private and public sectors.

Delivering Infrastructure Improvements for Less Cost

As the nation's infrastructure deteriorates, the industry must not only rebuild but fundamentally reform the way infrastructure is built, funded, used, and maintained. This reform is essential to help our nation achieve sustained economic growth and enhanced quality (CERF, 1996).

A world-class national infrastructure is essential to maintain our nation's role as the leading economic power far into the future. We can improve and/or build more infrastructure with less money only if robust R&D programs deliver new and improved building techniques, materials, and machinery.

The most difficult challenge to the construction and repair of our national infrastructure is paying the substantial bill. As the backlog of needed construction mounts, the United States makes use of innovative financing. The idea that private investors may own and operate all types of civil projects is a new trend and one clearly on the rise internationally. Budget constraints will no doubt increase it in the United States; privatization of public works will become an important way to provide infrastructure without government funds. The recent ICF Kaiser and Raytheon Infrastructure proposal to finance, build, and operate 23 miles of rail road linking Dulles Airport with the Washington, D.C. Metro System is one of many examples of privatized projects in the United States (Pae, 1997). Many projects in the Pacific Region, especially in Australia, are privately financed construction projects that promise a considerable return to their investors. Examples of private-sector participation in funding projects include the construction of toll roads, the Olympics 2000 facilities, light rail projects, power plants, and water purification facilities.

Privatization allows a firm to finance an infrastructure project in return for the proceeds generated from user fees over a period of time. State and local governments are beginning to use this method of financing their infrastructure projects with excellent results. Venture capitalists and other investors favor such projects because of their stability and their potential for large returns on investment. However, the federal government has not shown significant interest in promoting this promising infrastructure financing method.

Maintaining Competitiveness in the Global Market

As the market for construction becomes more international, the U.S. construction industry must strive to improve its productivity and future competitiveness.

The industry continues to use innovative equipment designed to reduce costs and improve productivity. Both Caterpillar and John Deere, for example, are using virtual prototyping and simulation to redesign construction equipment, making it easier and more comfortable to operate, easier to maintain and repair, and less conducive to repetitive stress injuries ("Cushier Controls," 1997; and "Construction Workers Are Game," 1996). Other firms are working on computerized remote-control operation for construction equipment and on software links to the Global Positioning System (GPS) so that construction sites can be surveyed so closely that bulldozers' blade positions can be determined during site grading operations (Churbuck, 1992; and "Satellite Technology," 1995). As this example shows, construction firms can use computer simulations to optimize equipment selection for a variety of specific tasks. Finally, Caterpillar has successfully tested a satellite communications system that allows contractors to track the status of Caterpillar equipment around the world, and the firm may begin to offer this service to customers as early as next year ("Software," 1997). These information systems facilitate the use of just-in-time parts and maintenance management.

Building materials remain a strong component of the U.S. construction industry. U.S. products are state of the art and in high demand internationally. Innovative new materials fueled by a more focused R&D effort promise to help the United States maintain this lead. Many research projects are underway to improve concrete's compressive and tensile strength, workability, and durability (Goldstein, 1996; Li, 1995; and "Materials: Recycling," 1996). Composite materials and new additives are key in this research. Stainless materials are the object of a innovative research agenda designed to showcase their corrosion resistance, durability, fire and heat resistance, strength, ease of fabrication, and impact resistance ("Stainless Materials," 1996). Research is also underway on wood connections, fire modeling, composite wood members, adhesives, finishing, and preservation. Composites will make it possible to use less expensive lower-strength wood for structural applications ("Wood Industry Targets," 1996). Finally, future R&D must show that composite materials do not cause

additional fire hazards and must test the effects of long-term environmental stress on composites.

Keeping Sufficient Numbers of Skilled Workers to Meet Demand

Our school systems, higher education, and trade institutions must prepare a work force that is productive and capable of handling the many new technical innovations available in the construction industry. The current construction work force is meeting the demand, but many predict that the future work force will be undereducated and underskilled. Alternative programs for educating youth to enter skilled trades may be required. Unions have provided outstanding apprenticeship programs, but these programs may not be sufficient to supply skilled labor for the future. Primary and secondary education must prepare young people to complete technical training successfully. Alternative approaches, such as the integrated high school and vocational schooling used in Germany, or technical preparation that aligns high-school and community-college programs, may be necessary. Career counseling that enlists local contractors to serve as advisors, mentors, and job providers would also be beneficial.

Becoming Better Stewards of the Environment

The construction industry must be a steward of the environment. The construction of modern buildings has made life better and easier for much of the world's population, but it also has significant effects on the earth's environment. "Buildings account for one-sixth of the world's fresh water withdrawals, one-quarter of its wood harvest, and two-fifths of its material and energy flows" (Roodman and Lenssen, 1995). Design and construction techniques must facilitate environmental remediation and preserve scarce resources including soil, water, and lumber.

In September 1996, the International Organization for Standardization (ISO) approved new environmental management standards, namely, ISO 14000. Organizations can manage the effect they have on the environment using these standards.

ISO 14000 provides codification of environmental management: it measures environmental risk, sets clear standards for the consumer, and recommends building product standards. The implications for the construction industry include standardizing environmental practices across international boundaries (sometimes raising standards in underdeveloped countries), changing criteria for environmental

remediation project selection, and new, environmentally friendly, building materials.

Accreditation and certification criteria for implementing ISO 14000 series remain elusive. Compliance is voluntary. It has not, for example, been determined whether or not the standards will be completely reciprocal between countries, and significant international concerns remain about how the standards can be integrated with various regulatory arrangements.

OUTLOOK

The future health of the construction industry, its ability to support national security requirements, and its response to these challenges, are addressed below.

Future Health of the Construction Industry

The long-range outlook for new construction within the United States should remain healthy and continue to grow modestly each year. If we can achieve a projected average annual growth rate of 2.4 percent in the GDP and a relatively steady interest rate on 30-year fixed-rate mortgages, then residential housing starts should continue to grow at the 5 to 7 percent rate per year. The current oversupply of commercial buildings will be absorbed by attrition, remodeling, and a growing economy. Thus, the nonresidential construction market is expected to pick-up stregnth into the next century. Reductions in federal infrastructure spending will be moderated by increased state and local government infrastructure investments and other privately funded capital projects. The need to repair and reconstruct the nation's infrastructure will be readily apparent from the way the outmoded systems impede transportation and commerce. The federal government will continue to fund such projects but increasingly exercise the privatization option.

Information Technology. Construction professionals will use virtual reality and simulation to troubleshoot and sell designs to clients. This marketing technique will favor high-tech performers over their not-so technically-adept competitors. Desktop graphics, super computers and large-screen theaters powered by super computers will be omnipresent. For example, Parsons Brinckerhoff's 4d Group already creates compact disc-based presentations that are part simulation and part walk-through

of proposed designs. Parsons, Bechtel and Dames and Moore offer similar presentations to prospective clients.

Virtual testing of construction assembly sequences and holograph-like three-dimensional projections over a glass tabletop will become commonplace and will revolutionize the industry (Phair, 1996a).

Design-Build's Future. The future of the design-build project delivery system appears bright. According to statistics compiled by the Design-Build Institute of America and F.W. Dodge DATALINE, from April 1995 to April 1996, the number of design-build contracts increased 103 percent over the previous year to $37.2 billion. One would expect this growth to significantly increase in the out-years as a result of federal government procurement under the new acquisition act. Recent trade publications show several state governments are now adopting design-build practices. The state of Utah recently initiated the largest federal construction design-build project to date, a $1.36 billion rehabilitation of Interstate 15 through Salt Lake City (Powers, 1997).

Support to National Security

That the construction industry supports our national security resource requirements has been amply demonstrated by the Logistics Civil Augmentation Program (LOGCAP). Brown & Root Corporation supported DoD's forward expeditionary base requirements in Somalia, Haiti, and Bosnia, and DynCorp is poised to do the same—after winning the $25 million, five-year follow-on contract. Many other corporations in the industry are similarly capable of stepping in to meet any construction mobilization shortfalls. There is no reason, given the health of the industry, to doubt its ability to respond to a future national emergency.

Responding to Challenges

Research and Development. CERF, NIST, and the National Science and Technology Council are using strong leadership to transform the U.S. construction industry's R&D efforts. Multinational collaboration, aided by modern information technology, will provide further benefits as researchers from all over the world develop new products in cooperation with one another. Construction and maintenance costs will drop as new materials, techniques, and equipment are used.

Delivering Infrastructure Improvements for Less Cost. The infrastructure will benefit from increased levels of construction research and development, especially as private interests are brought into civil and public works construction projects to replace inevitable reductions in the federal budget as these reductions are applied to investments in public works. Private funding of large conventional power plants in Indonesia is an indication of how countries will augment their infrastructure capital in future years. Application of the "Build, Own, Operate and Transfer" (BOOT) concept of development for public works infrastructure will continue to grow.

Maintaining Competitiveness in the Global Market. Markets in many countries that have been closed to foreign competition will open up due to U.S. government intervention with government counterparts and global and regional trade organizations. For example, U.S. firms recently gained contracts for a number of large governmental and private construction projects in Japan and Bechtel recently became the first U.S. company to negotiate a license to be the prime contractor for work in China (Moody, 1996).

U.S. firms are also gaining international market access by establishing foreign affiliates in overseas countries. Affiliates provide large companies with access to local construction markets and more reliable information about local market conditions. As "local" companies, they often avoid the experience of market discrimination that companies may encounter. This practice will no doubt grow as more international firms benefit from local access and knowledge.

Keeping Sufficient Numbers of Skilled Workers to Meet Demand. Mechanical, electrical, and special trades requiring advanced training or highly skilled workers may experience future shortages of qualified workers as construction techniques become more complex. U.S. construction companies and trade unions will continue to pursue qualified young people to enter technical career fields.

Demand for the most technical trades will grow along with new technologies, stricter environmental requirements, and increased use of composite materials. Union apprenticeship programs must continue to produce high-quality journeymen and school systems must expand their trade training programs.

The possible failure of our schools to graduate young people who are ready to practice a technical trade remain a potential vulnerability.

Becoming Better Stewards of the Environment. The international construction industry will use more environmentally friendly materials and methods. Both design and construction will use naturally occurring and recycled materials to reduce pollution, transportation requirements, and energy consumption. Debris minimization efforts will result in less materials packaging waste.

The ISO 14000 "green passport" will become a requirement for doing business globally. Visionary construction companies are already positioning themselves to obtain it for competitive advantage.

GOVERNMENT GOALS AND ROLE

Government regulations (federal, state, and local) will always impact the construction industry. Governments must ensure that quality construction is conducted under safe working conditions and that adequate and timely investment in the nation's infrastructure is achieved. In the past, government has pursued these goals by adopting the dual role of enforcer—of regulations and standards—and financier—the broker for national infrastructure repairs. To achieve these goals and enable U.S. firms to remain competitive in today's global economy, the government must accept changes in its traditional role.

Spurred by the construction industry, governments of the future will move from the role of safety and quality enforcer to that of partner. Partnerships are necessary between federal, state, and local governments to generate the funding strategies that will pay for managing and maintaining the nation's vast infrastructure. Government will also play a key role in the development of high-risk R&D. Only government can encourage the commercial sector to invest in R&D.

Safety

Public Law 91-596, the Occupational Safety and Health Act of 1970, led to the establishment of the Occupational Safety and Health Administration (OSHA) within the Department of Labor. In carrying out its duties, OSHA is responsible for promulgating legally enforceable standards that may require the adoption of one or more practices or processes to protect workers on the job. OSHA standards fall into four major categories: General Industry, Maritime, Construction, and Agriculture. With more than 1,000 mandatory construction standards incorporated into a thick OSHA guide, it is not surprising that the

construction industry says that OSHA standards and enforcement inflate construction costs.

The shrinking budget and congressional pressure to reform have convinced OSHA to use its limited resources in a more consultative capacity. Construction employers now have a choice between working with OSHA to improve their safety and health record or facing tough enforcement penalties. OSHA has a Construction Outreach Directorate that focuses on government, labor, and management partnerships. The directorate develops safety and health standards that relate directly to the construction industry. It offers special training sessions at plants, answers compliance questions, provides training videos, and interprets rules and standards. The situation is improved by a trend coming from the industry's side, namely, employers are promoting safety standards in order to reduce the cost of injuries. On the southern California Santa Ana Dam Project, Odebrecht Corporation raffles off a new truck to workers after every 30 accident-free days.

Quality Codes/Standards

> *To say that building codes are a complex and confusing body of regulations would be an understatement. Building code regulations are written, rewritten and interpreted by a legion of builders, manufacturers, architects, engineers, fire marshals and inspectors. To complicate matters there is no common language—there is no uniform building code in the United States. Some communities develop a unique code while others don't have a building code at all.* (Fisette, 1996).

The nation does have three regional, model building codes that cover commercial and housing construction. Their sponsors are the Building Officials and Codes Administration, Southern Building Code Congress International, and the Council of American Building Officials. Construction codes are built on standards such as product specifications and test and design requirements. Within one building code, as many as 350 standards may be referenced. The standards are not uniform among states, and local standards also vary from county to county within each state. This layer upon layer of regulations, codes, and standards adds substantially to the cost and scheduling of construction.

A case study by the National Association of Home Builders found that regulatory costs for building a Cincinnati starter home more than tripled in 20 years. State and local codes and standards also impact

construction lead times. Fully 83 percent of builders and developers reported noticing a substantial increase in regulations from 1984 to 1995. These regulations cost money and time; it now takes 25 months between the rezoning application and the issuance of a building permit for a single-family subdivision (NAHB, 1997).

The National Association of Home Builders is promoting statewide uniformity of building codes. There is also a push to use only commercial standards. The recently enacted National Technology Transfer Act states that the federal government must, with few exceptions, use private sector building standards in lieu of military specifications. This act eliminates the costly process of updating military specifications and adopts consensus standards in lieu of private-sector standards. Finally, the American National Standards Institute, which approves the standards of American organizations, is actively pursuing the adoption of international construction standards. This trend toward national and international uniformity will promote international competitiveness, decrease U.S. construction costs, and possibly improve the quality of work within certain regions of the United States. Government should assist and encourage this move toward uniformity to reduce construction costs.

Infrastructure Investment

The U.S. infrastructure needs repairs, upgrades, replacements and expansion. New infrastructure projects and repairs and maintenance on older structures are normally funded by the federal government and the states on a cost-sharing basis, with the largest share provided by the federal government (90 percent). Other sources of financing are low-interest federal loans, state and federal grants, state bonds, and privatization.

The privatization option allows a private firm to finance an infrastructure project in return for the proceeds generated from a public user fee over a period of time. States and local governments are beginning to use this method of financing their infrastructure projects. Strong partnerships are necessary between federal, state, and local governments to develop comprehensive infrastructure planning that will meet the country's needs well into the 21st century. The federal government must take the lead in developing incentives for state and local government partnerships that will generate new, efficient funding strategies to pay for rebuilding, creating, managing, and maintaining the vast network of infrastructure throughout the country.

Research and Development

Government should create incentives for contractor-funded R&D and should award contracts whenever possible to participating companies. Second, all levels of government should promote projects that employ new technologies to reduce cost or improve quality.

The federal government must be the catalyst to bring the very fragmented construction industry together through continued funding and support of construction engineering research with private and academic institutions.

Finally, Government must foster programs to promote the transfer of new technologies to the industry at large. CERL and Indiana State University's Internet Construction Technology Transfer Center and CERF's Worldwide Web site, CENET, are major steps in the right direction ("CENET," 1996).

CONCLUSIONS

The U.S. construction industry is a major element of this nation's economic might and contributes significantly to its ability to compete as a global power. The industry is healthy and well poised to grow in the future. Because of reduced government spending on domestic infrastructure, many larger firms will grow by competing successfully in an emerging international market. Private domestic construction coupled with innovative methods of constructing, owning, and operating infrastructure and facilities will ensure that the industry remains vibrant.

To compete internationally, U.S. firms must increasingly partner with local national companies and capitalize on their experience and insight into local market conditions. Developing countries facing the prospect of major infrastructure development will gain a measure of confidence by employing experienced U.S. construction managers to ensure project success.

The U.S. domestic market will continue to be characterized by small firms and fierce competition. The pressure on government to increase infrastructure improvements and repairs will continue, though large budgetary increases are not expected in the near future. Significant attention must be focused on reforming the educational and technical competence skills training of tomorrow's work force to ensure that domestic firms will remain dominant in the U.S. construction market.

With diminished infrastructure spending, the importance of improved methods and materials to reduce costs, extend a project's service life, and curtail maintenance costs increases significantly. Focused R&D can partially mitigate this difficult situation. Recent progress to coordinate private and government R&D efforts through such organizations as the Civil Engineering Research Foundation and the National Institute of Standards and Technology show much promise. R&D can also help the industry remain internationally competitive. An expanding international construction industry is good for the economy and helps develop key mobilization skills we would need in times of crisis.

Diminished government spending will lead to increased privatization and other innovative alternatives for funding, building, and operating U.S. civil facilities and infrastructure—traditionally the domain of the federal, state, and local governments.

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EDUCATION

The foundation of the state is the education of its youth.

Diogenes

ABSTRACT

Education is vital to a flourishing democracy—the cornerstone for active, involved citizenship. In a rapidly changing and increasingly competitive world, the economic advantage will belong to the nation that has the most adaptive, creative, and ingenious people. To garner this advantage for the United States, we must ensure a rigorous, high-quality education for all youth, and access to meaningful life-long learning opportunities for other citizens. Only by improving the synergy between our schools, higher education institutions, communities, businesses, and government can we harness the full diversity and energy of our citizens and meet the challenges of a changing economy and global industrial requirements. This transformation is a challenge for the education industry and for the entire nation.

COL Ben Anderson, USA
Mr. John Antonitis, Defense Intelligence Agency
CDR Wayne Cox, USN
LTC Robert Crear, USA
CDR William Crow, USN
Lt Col Larry Eriksen, USAF
Lt Col Ronnie Hawkins, USAF
Lt Col Charles Howe, USAF
BG Alojz Jehart, Slovenian Army
COL Sandra LaBelle, USA
Mr. Philip Marchese, Defense Logistics Agency
Mr. Steve Rome, National Security Agency
Mr. Thomas Tiernan, Dept. of State
Captain David Tyson, USN

Dr. Sid A'Hearn, faculty
Dr. John Bokel, faculty
Captain Susan Maybaumwisniewski USN, faculty
Dr. Susan Studds, faculty

PLACES VISITED

Domestic

Fairfax County Public Schools, Fairfax, Virginia
Jefferson High School for Science and Technology, Annandale, Virginia
University of Maryland, College Park, Maryland
Maryland State Department of Education, Baltimore, Maryland
District of Columbia Public Schools, Washington, DC
General Motors-United Auto Workers Training Facility, Pontiac, Michigan
Project Focus Hope, Detroit, Michigan
Educational Testing Service, Princeton, New Jersey
Carnegie Foundation, Princeton, New Jersey
Boston Renaissance School, Boston, Massachusetts
Chelsea Public Schools, Chelsea, Massachusetts
BBN Inc., Cambridge, Massachusetts
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McDonough City Magnet School, Lowell, Massachusetts
Minuteman Technical High School, Lexington, Massachusetts
John Hancock Financial Services, Boston, Massachusetts
Motorola University East, Mansfield, Massachusetts
Dr. Theodore Sizer, Coalition of Essential Schools

International

Ministry of Education and London, England
US Embassy Labor Councilor, American Embassy, London, England
London School of Economics, London, England
School Curriculum Assessment Authority, London, England
Enfield School, Enfield, England
Paris Learning Center, Paris, France
Department of Education, Paris, France
Organization of Economic Cooperation and Development, Paris, France
Industrial College, Schorndorf, Germany
Frech Company, Schorndorf, Germany
Heidelberg University, Heidelberg, Germany
DeutcheBundesbank, Frankfurt, Germany
Council on International Education, Bad Homberg, Germany

INTRODUCTION

Our nation's most precious resource is its people. Their knowledge and skills, intellect and productivity, contribute to maintaining our status as the world's only current superpower. Over the years, education played a central role in the United States's hold on a position of world leadership. As Hedrick Smith observes in his book *Rethinking America,* "A country's performance in the global game . . . begins in the mind-sets of its people — how people are taught to think, to deal with one another, to work together. In other words, the race begins in school" (Smith,1995, p. 98).

To assess whether our educational systems are successfully producing citizens with these attributes, we began by listening to and questioning an impressive array of expert practitioners, consultants, and social critics. This disparate group represented the full range of opinions from "the sky is falling" to "if it ain't broke, don't fix it." Next we sought to discover the linkages and commonalties between our own preconceptions and what we were learning. Hypotheses and prescriptions began to emerge. Eagerly, we began visiting real schools and workplaces in the United States and Europe; we talked with students, teachers, administrators, and trainers to test our ideas against the realities in which 60 million Americans engage in education on a daily basis.

Much of what we saw was thrilling. Pockets of genuine excellence exist, where real heroes work miracles on a daily basis with less than optimal resources. We began to look for ways to transplant these successes into the many schools in our nation that are failing or doing less than their best. It quickly became clear that, given the incredible diversity of America, the best solutions will come from community-based institutions and leaders who understand their local communities and the educational services they need.

We are convinced that real links are needed between schools and the larger society. Both are successful when they interact as a seamless whole, providing classroom and lifelong learning opportunities tailored to the needs of the community and the strength of the nation. Our analysis proceeded from that perspective; our recommendations reflect that belief.

THE EDUCATION INDUSTRY DEFINED

A broad range of societal institutions are part of the education industry. They all fit, however, into one of three categories that provide a convenient framework for descriptive data and observations about the status of education in 1997.

Elementary and Secondary Schools

In 1996, approximately 50.7 million students enrolled in America's public and private schools at a total cost of $308 billion, for a per-pupil cost of $6,084. Enrollment is expected to grow to 55.9 million by 2005, an increase of over 10 percent. Public schools educate nearly 90 percent of this total, a proportion that is expected to remain stable.

Public school students are served by approximately 140,000 schools employing over 2.8 million teachers and operated by over 15,000 local school boards with varying degrees of authority and autonomy, depending on the state. The configuration of the schools is endlessly varied. A popular pattern is to house kindergarten through fifth grade in elementary schools, sixth through eighth grades in middle schools, and ninth through twelfth grades in high schools. Variations from this pattern are based as much on space limitations and geography as on educational philosophy.

School districts also come in different shapes and sizes. In some states, they are organized at the county level; in others, at the community level. In some, they oversee all levels from K-12; in others, K-8 and 9-12 are separate districts — often with overlapping boundaries. Their student populations also vary greatly, from 1.1 million in New York City to districts in rural areas that educate fewer than 500 students.

This variety is simultaneously a strength and a weakness. It makes delivering a coherent, rigorous education throughout the nation difficult. The key problem is that each district may focus on different content and outcomes, depending on local politics, demographics, finances, job markets, and community values. The resulting diverse and uncoordinated curricula make it difficult for students to transfer between districts and for policymakers who want to compare the results across district or state lines.

Transitional Institutions

Transitional institutions are similarly diverse and encompass a multitude of school-to-work programs. They are located in secondary schools, or they may be apprenticeship programs, school or business training partnerships. Community and technical colleges, private vocational and proprietary schools, and traditional college and university programs also serve as transitional institutions. In total, over $200 billion are spent on these enterprises annually.

This segment supports retraining programs for workers in transition to a new career, whether voluntarily or due to corporate restructuring. The quality and availability of these programs and services concerns businesses, individuals, and public policymakers who can see that the twin forces of a globalizing marketplace and rapid technological innovation will force workers to make several job changes during their working lives. The ability of educational institutions to respond and adapt to this need for retraining will largely determine our position in the world economy. Historically, our European allies have done a much better job in training their noncollege bound youth. Yet current economic conditions require that they too, review their training programs for cost efficiencies, affordability to employers, and adaptability to the needs of a changing work force.

The Workplace

The third sector of the educational industry includes the whole range of employee training available in the workplace. Corporate spending on formal employee training totaled over $40 billion last year. Formal training consists of professional development courses, skill-building courses, and seminars. In addition, a significant amount of informal on-the-job training happens in the workplace. Its cost is difficult to calculate but is thought to be even higher.

Many large corporations here and abroad run their own training centers, and an extensive, highly competitive training industry has developed to service smaller companies. Several companies contract with community and technical colleges to develop specific programs for their needs. The workplace sector is marked by flexible, rapid adaptation to changing market needs — more so than the schools.

CURRENT CONDITIONS

Because the educational industry contributes best to the strength of our nation and its citizens when all its sectors are coordinated and linked, we evaluated the health of the industry by considering its overall success with certain critical issues.

The United States is a large and diverse country with a tradition of local initiatives and a distrust of "one size fits all" approaches. Consequently, it is not surprising that the effectiveness of the delivery of educational services varies widely. The energy and innovation that spring from such diversity are key components of the nation's strength. They also provide multiple ways to measure the current health of our educational systems.

To concentrate on what we believe are the key requirements of an educational system that can preserve and extend national strength, we chose six indicators. That is, we hypothesized that the industry is successful if it contributes to

- social cohesion and civility;
- provides universal access to a quality education for all students;
- imparts a rigorous curriculum with measurable results;
- offers a world-class education to both college and work-bound students;
- results in a competent, adaptable work force; and
- promotes partnerships among education, community, and business interests for life-long learning.

Maintenance of Social Cohesion and Civility

Most observers agree that the social fabric is seriously frayed. The appalling state of urban education has relegated large segments of America to a hopeless future outside the economic and civic mainstream. The gap between the "haves" and "have nots" is widening. Even college professors are experiencing a lack of civility in their classrooms.

Others have commented on the absence of effective civic and character education in our schools today. For example, the authors of *Winning the Brain Race* state, "We are producing a generation of young Americans that neither understands nor appreciates our democratic society" (Gerstner, et al., 1991). In France, a primary function of the educational system is to prepare good citizens who understand and appreciate the very essence of what it means to be French. Few can

disagree on the value added to society when children learn and demonstrate virtues such as honesty, integrity, responsibility, and respect for self and others. One of the greatest concerns of over 80 percent of employers is their inability to find young people with these characteristics to hire! Schools must be actively involved in the effort to preserve and shape our civil society, but the primary responsibility remains with parents. Schools should buttress and encourage the training in essential values, character, and civility that students receive at home and in local communities.

Universal Access to a Quality Education

The growing enrollments foreseen in public schools through the next decade will increase pressure on already straining budgets at the federal, state, and local levels. Currently, the federal government pays just 7 percent of the costs of public elementary and secondary education; states pay 48 percent, and localities pick up the remaining 45 percent. The amount paid at the state level varies greatly, however, from a high of almost 98 percent in Hawaii to a low of only 9 percent in New Hampshire. This wide range reflects differing philosophies among the states regarding the proper role for each level of government in managing public education. States in which the local governments shoulder the largest burden for funding public schools generally have the widest disparities in per-pupil expenditures and in the quality of programs and facilities offered. The trend since 1986 has been for states funding to decline and local funding to increase, with no change in the federal share. Inequities based on community wealth have increased accordingly. The result is that rural and urban schools are generally inferior to suburban ones, compounding the "haves" and "have nots" issue.

By contrast, school funding in Europe is centralized at the national or state level to minimize disparities. Spending decisions, however, are made locally; individual schools often prepare their own budgets reflecting their own priorities and needs. This model of local autonomy combined with state funding is worthy of emulation in the United States.

Since nearly all American colleges and universities charge tuition, problems of access are based primarily on the individual's ability to pay. For the 1994-1995 academic year, annual undergraduate charges for tuition, room, and board were roughly $5,962 at public colleges or $16,222 at private colleges. These figures represent inflation-adjusted increases over ten years of 23 percent at public and 39 percent at private

colleges. Scholarships and aid programs mitigate the problem somewhat. Scholarships have grown rapidly during the past decade, up from 9 to 14 percent of general expenditures at private institutions. Aid programs (Pell Grants, work-study programs, and various privately funded schemes) provide more than half of all full-time students with an average of $5,543, a substantial portion of tuition costs. It is worth noting that European nations that have traditionally provided a free higher education for their citizens are now considering the imposition of American-style fees.

A Rigorous Curriculum with Measurable Results

The competence of elementary and secondary school graduates can be hard to gauge. Nevertheless, current U.S. students are among the most tested students in the world, so it is not hard to prove almost anything positive or negative about their education. Long-term trends in reading achievement show improvement for many of the country's thirteen- and seventeen-year-olds and for some groups of nine-year-olds. However, much of the improvement made prior to 1988 has not continued among minority students, and some of it was actually reversed between 1988 and 1992. Students at all levels appear to have improved in basic computational skills, but older students show no improvement in advanced operations.

Extensive and well-publicized concern over student performance has caused several states to order additional mandatory academic courses at the secondary level and to make the passing of rigorous tests a condition for graduation, as is common in European schools. Other states are in the process of implementing similar standards. The tests and the degree of difficulty vary widely. In an attempt to bring some order to the standards, President Clinton has called for development of national tests to be used at the discretion of the states.

World-class Education for College and Work-bound Students

American secondary schools are structured to prepare graduates for college. The move toward more rigorous standards strengthens this tradition; it is no longer unusual for schools to require four years of English, math, science, social sciences, and three years of a foreign language. This course of study is decidedly more demanding than was the case as recently as five years ago, and it is an accelerating trend across the country.

This situation is not without its irony. Noncollege-bound students have historically been relegated to the high school sidelines; the focus on college preparatory courses will only deepen this alienation. Yet jobs in the 21st century are less likely to require a traditional college education than some other form of postsecondary training. Better communication between educators, policymakers, and employers is needed if schools are to provide a relevant education for the noncollege-bound. We have much to learn from the German apprenticeship system that does so well in preparing its students for meaningful work. The United States also has some excellent programs that are worthy of replication.

Provision of a Competent, Adaptable Work Force

Companies here and in Europe are making it clear that workers of the future will need a solid grasp of basic academic and cognitive thinking skills and the ability for complex problem solving. They will also need interpersonal skills and the ability to work in teams. In response to these needs, good schools are adapting their teaching strategies to develop these skills. More can be done, however. Most schools are still based on the active teacher/passive student model. Teachers themselves need extensive, focused, professional-development programs to learn how to align their methods with the needs of the workplace.

Education/Community/Business Partnerships for Lifelong Learning

Communications technology and rapid innovation are causing major changes in the marketplace. Globalization is here to stay. The traditional loyalties between worker and company are changing. Even in European nations with a tradition of lifetime employment with one company, the concept of a lifelong career is threatened. Workers must continually upgrade their skills to remain relevant, employable, and competitive in a global work force. In the United States, the institution that will bear the heaviest burden in this endeavor is likely to be the community college. The average age of its students is increasing as displaced workers return to learn new skills. More than one-half of all undergraduate students are twenty-two years old, and almost a quarter are thirty or older, fundamentally changing the colleges' mission. The best of these schools are forming partnerships with local employers to design specific training for the kinds of jobs being created. As the number of traditional college-age students has decreased, these institutions have expanded their

mission in order to survive. As a result, these colleges have reformed further and faster than any other type of educational institution.

CHALLENGES AND OUTLOOK

If the United States is to realize the relevant, universally accessible, world-class lifelong educational experience that we think is essential for the well-being of the nation, the industry has its work cut out — and many challenges.

Maintaining Social Cohesion and Restoring Civility

The widening gap between the "haves" and "have nots" has been well documented, and new evidence suggests that the gap between white and black is widening again. The Kerner Commission warned almost thirty years ago that "we are in danger of becoming two nations; one black, one white; separate and unequal." In April 1997, the Harvard Graduate School of Education reported that "the nation is headed backwards to a greater segregation of black students." A substantial growth in the size of other unassimilated minority groups is also evident and inequities in the quality of education are exacerbating the problem. The same Harvard report shows that Hispanics "now experience more isolation from whites and more concentration in high-poverty schools than any other group of students." Moreover, "school educational achievement scores in many states and in the nation show a very strong correlation between poverty concentrations and low achievement." Bridging this gap is essential for the well-being and strength of the United States.

Education's role as the key predictor for success and earning power throughout life is critical in this endeavor. It is important that all individuals have equal access to the school of their choice. Complementing the roles of parents and community, schools should provide the common social experience in which practical citizenship can be taught. Within reason, schools must teach civic responsibility and acceptable social behavior. Extensive use of magnet schools and experiments in allowing children to attend the public school of their choice in or out of their district are among reforms offering some solutions. Carefully constructed charter schools hold great promise for achieving a more common experience and a reversal of the disturbing

trend toward greater racial and economic isolation. We must ensure public schools are accessible to all.

Assuring a Quality Program

In all of our visits to schools both in the United States and abroad, the common thread in all excellent programs was the quality of the teachers. Although it has served us well historically, our teacher-preparation model is showing signs of severe strain. Women, education's traditional labor pool, now have other, often more attractive and remunerative choices. In addition, given the swelling enrollments in our schools and the imminent retirement of record numbers of teachers, the nation will need to recruit two million new teachers at the elementary and secondary levels over the next decade.

The industry must attract appropriate replacements to assure a quality education for all. There are few incentives beyond altruism to become or remain a teacher today. In fact, fully 50 percent of new teachers leave the profession within three years. Though studies show that the factors most contributing to teacher commitment are classroom autonomy in teaching techniques, influence over policy, quality of assistance to new hires, and a large spread between entry-level and end-of-career salaries, these elements are in short supply in today's public schools. Issues such as establishment of professional performance criteria, stringent hiring requirements, and periodic consequential assessment of performance are and should remain valid concerns for school boards. However, issues that bolster teacher commitment and identity as professionals are of greater long-term benefit to students.

After twelve to fifteen years of teaching, American teachers reach their maximum salary, typically earning twice what they made at the beginning of their careers. Few professionals in other industries would maintain their enthusiasm and commitment if faced with salary stagnation for the last fifteen to twenty-five years of their careers. We must find a way to reward teachers' performance throughout their careers. They should also experience the significant salary growth that is common in other professions and among teachers in many other nations.

Like other workers in this era, teachers in the United States need extensive opportunities for professional growth and development to help them meet the fast-changing needs of their students and businesses. But the way our schools are now structured hinders their opportunities. Teachers seldom have the opportunity to observe the best practices of their colleagues down the corridor because they are locked in the

isolation of their own classrooms. Opportunities to visit other schools, attend conferences in their subject area, or spend time collaborating with and learning from local businesses or community institutions are rare. Our teachers spend more time with students than their counterparts in most other nations. Most of our international competitors have a much more autonomous, professionalized, and well-paid teaching force. Failure to reform these practices will exacerbate the present difficulty in attracting the best and brightest to the teaching profession. One consequence of our inability to attract highly skilled professionals is that fully 30 percent of current secondary math and science teachers are not certified in their area of responsibility.

Another impediment to effective schools is the stultification and rigidity that our bureaucratic model for public education engenders. We are the only nation in which teachers make up less than half the employees in the typical school system. The heavy bureaucracy surrounding the myriad of school-related administrative functions hampers creative, effective, unfettered teaching by empowered, accountable professionals. This morass causes schools to lose sight of their true purpose and vision.

Formulating and articulating such a vision was a common thread of excellency in the schools that we visited here and abroad. Teachers, students, parents, and members of the broader community know the goals and are actively and collaboratively involved in them. Thus, successful schools do increase autonomy and accountability at the local school level. They either figure out how to work around their bureaucracies or how to leave them behind. Examples of the latter are "grant-maintained schools" in the United Kingdom and magnet charter schools in the United States; their existence should be encouraged. We believe that these types of institutions will grow substantially in number over the next decade, and we applaud this trend.

This development reflects the growing consensus that having a choice of schools is good for families who must then commit to a particular program. Such parents are more likely to become involved in their child's education. The competition between schools that results from choice is also a good antidote to the bureaucratic tendencies previously discussed. Diversity and decentralization are essential for responsive educational reform. School choice is the ally of the dynamic educator.

However, a word of caution: these programs should be part of the solution, not an exacerbation of racial and economic isolation. Families must not be allowed to use school choice as a mechanism to avoid

mixing with other economic or racial groups. Public officials and local citizens should remain vigilant to prevent such occurrences or perceptions.

While our colleges and universities are generally considered the best in the world, a disturbing trend developed over the last two decades. Institutions are relying more on part-time or adjunct professors and graduate students to avoid the costs of benefits and tenure — and to ensure that professors are free for research. This practice creates less stable college faculties, and a blurred sense of identity with the institution. As a result, many undergraduate students receive *no* classes from the either full-time or tenured faculty whose renown may well have contributed to their choice of this school in the first place.

A recent study by the Carnegie Foundation for the Advancement of Teaching proposes restructuring the reward system for college faculty to encourage them to see the teaching of undergraduates as a key part of their professional duties and to make their research of practical use to the communities they serve (Carnegie Foundation, 1997). We hope that this idea will spread quickly among all colleges and universities. It is in the nation's interest that its future leaders have a challenging, rigorous college education and access to renowned researchers.

Assessing Mastery of the Curriculum

Much has been written about the declining quality of U.S. students compared to their international counterparts. The truth is considerably more complicated. The majority of middle-class students receive a good, solid education, as long-term trends in SAT tests have shown. These students also do well on the new standards-based tests now in use in several states, and they are also likely to survive the current push to require "hard" academic courses in high schools at the expense of "soft" electives. In short, most assessment devices play to the curriculum of these suburban, largely college-bound students.

But imposing rigorous assessment measures on failing urban schools will not make them succeed. Without additional resources, better teachers, and a radical overhaul of school operations and relations with the broader community, we risk the danger that students will be set up for failure and for dropping out in even larger numbers. The industry — and policymakers — must ensure that higher standards are accompanied by the resources necessary to make them realistically achievable.

Educating the Non-college-bound

Our elementary and secondary schools are clearly geared to serve the college-bound student — more so than in any other industrialized nation. We could learn much from the apprenticeship programs that Germany uses to prepare its students for the workplace. A technical secondary school in the town of Schorndorf is an excellent example of this apprenticeship system. The school relies heavily on local businesses for up-to-date equipment on which to train its students, and clearly focuses on the particular trades in the region in which its graduates will be employed. In too many parts of America, students receive substandard instruction on outmoded equipment no longer used in industry or, worse yet, instruction for a trade in which jobs are declining or even disappearing altogether. This area of U.S. secondary education requires a major overhaul.

Fortunately, we do have domestic models from which to learn: Project Focus Hope in Detroit, Michigan; and the Minuteman Technical High School in Lexington, Massachusetts. Serving very different communities and clients, these schools provide training uniquely suited to the needs of their communities.

Project Focus Hope is part factory, part college, part vocational training center, food bank, child-care center and Montessori school. Built on the site of the 1967 riots, it was founded to train skilled workers for the manufacturing economy of Detroit. Through hard work, inspirational leadership, and partnerships with local companies, its strategy has been to tailor a training program to specific market needs. Project Focus Hope offers rigorous training on state-of-the-art equipment that replicates actual work situations. The product is the report card. For students not academically or attitudinally prepared, a seven-month preparatory program is required during which they must adhere to a rigid schedule of remedial education in math, computer courses, and workplace training. Project Focus Hope has a 90 percent placement rate for its graduates. While many unique factors contribute to the success of this private-sector program that may not work in public schools, the key components can be replicated: strong partnerships with local businesses and a straightforward program to train students in exactly the skills demanded by the market.

The Minuteman Technical High School is a public magnet school that has many of the same ingredients. Its students receive a solid academic preparation for college (with an emphasis on math and science) and firm, practical grounding in a "shop," such as robotics,

biotechnology, laser technology, electronics, structural engineering, veterinary science, auto mechanics, applied physics, or culinary science. Many of Minuteman's teachers are on loan from local companies. The school accepts all manner of students, gives them a rigorous program grounded in real workplace needs, and keeps open lines of communication with local employers. The program is replicable by energetic educators and communities with a vision and commitment to providing the best for all students.

The Minuteman model may not be right for every student, but all students ought to have such an option available to them. Project Focus Hope may not be the answer for every inner-city adolescent, but other cities would benefit by setting up programs closely linked to their local economies. These are the "best practices" we saw in U.S. education; the challenge is to create similar programs in other cities and towns.

Providing the Right Skills for a New Economy

Employers want workers who can get along with colleagues and who have the interpersonal skills to work in teams. As restructuring leads to fewer layers of management, more workers are empowered to make decisions in a team setting. This practice requires schools to rethink how they instruct students. The traditional "teacher talk, student listen" didactic model will not adequately prepare students for the level of interactive teamwork expected in the modern workplace. School districts and colleges need to train teachers to deliver instruction through collaborative activities. Good schools are changing their teaching methods to incorporate the latest research on the various styles by which students learn.

Employers want workers who can think creatively, solve complex problems, and learn quickly. The ability to find information and rapidly assimilate new processes is more important than simple knowledge. Good schools realize that the knowledge explosion makes it impossible to teach students all the facts about any subject. The influence of the Internet and its plethora of information makes teaching students how to sift and access information that is relevant to specific needs, and how to use that information to make informed decisions more crucial than ever.

The challenge for educators is to blend the employers' needs with the state policymakers' insistence on fact-centered standardized tests of student performance. The challenge for policymakers is to devise assessment measures that prove student competence based on academic achievement and actual skills needed in the workplace. Eventually this

challenge will be met as everyone begins to realize the importance of schools working closely with employers to guarantee national competitiveness. Local school and industry partnerships can contribute to overcoming this challenge.

Institutionalizing Lifelong Learning

Maintaining a cutting edge, quality work force in a highly competitive world requires frequent employee retraining with emphasis on technological innovations, higher-order problem-solving, interpersonal skills, teamwork, and flexible thinking. A commitment to life-long learning will be the hallmark of successful individuals, businesses, and nations. From an early age, parents and schools will need to ensure that children are comfortable with change and adept at meeting it positively and with confidence.

Our institutions will have to change to make lifelong learning available and relevant to all citizens. Fortunately, much of higher education is already grappling with ways to transform what is taught and to whom it is delivered. Since adult education is a major component of lifelong learning, these institutions can make a major contribution. Some of them, for example, Northern Essex Community College in Massachusetts, are forming strong partnerships with significant employers in their communities to design flexible courses tailored specifically to the needs and schedules of their companies. Some are part of a consortium of similar colleges formed to avoid duplication, act as an incubator for new ideas, and break new ground in the delivery of relevant, just-in-time knowledge. Extensive use of computer technology and distance or off-campus learning (and their promise of individualization and resource savings) will likely be hallmarks of other successful programs.

Lifelong learning will mandate a reevaluation of the traditional credentials that are a part of our system of education. A college degree no longer signifies possession of a body of knowledge that will carry its bearer through the rest of life. It is, rather, a marker, albeit a significant one, along the route of continual learning and education. We will have to devise new commonly understood credentials to signify other markers. The new ones will evolve from the joint efforts of industry, unions, educational institutions, and other individuals. These issues have already generated much discourse and experimentation, but the real transformation lies ahead.

GOVERNMENT GOALS AND ROLES

Functions of government are not neatly divisible between the federal, state, and local levels. All three play key roles in education. States and local governments share the responsibility for elementary and secondary school funding, curricula, and results. Decentralization best meets the diverse needs of the United States where rugged individualism, personal freedom (choice), and an entrepreneurial spirit are distinguishing characteristics. Each level of government makes policy, regulates legislation, collects and disseminates information, and funds public responsibilities.

An Intermediary for Quality

Six strategic issues in education require timely, balanced government intervention.

Citizenship. One of the primary goals of education is to attain full democratic participation by the citizenry. Socialization and issues of civility reinforce values, community involvement, cultural awareness, tolerance, and societal norms. The Summit on America's Future was a good start. This conference focused on volunteerism and called for every student to have an ongoing relationship with a caring adult (parent or mentor), a safe place to go and structured activities to do during nonschool hours, a healthy start as a youth, marketable skills gained through effective education, and an opportunity to give back through community service.

Global Competitiveness. A return to choice, equity, cognitive skills, and high standards of achievement is necessary to prepare our primary and secondary students for the lifelong learning needed to succeed in a technically oriented workplace. "Our public education," says Dr. Ted Sizer, "is not really very public" (Sizer, 1992). One can, for example, live anywhere in metropolitan Washington and use any public park or form of public transportation, but one cannot choose attendance at any public school. Because of the way local taxes are used to finance schools, the best schools serve the wealthy. Approximately 70 percent of the population attend lesser neighborhood institutions that perpetuate lower national capabilities through a growing divide between the "haves" and "have nots."

Standards and Assessments. Education is a local responsibility, a state function, and a national concern. Therefore standards and assessments are needed for schools, teachers, and students. We must avoid the risks associated with too much centralized control: piecemeal change with little coherence, excess direction and limited local initiative. The federal government should provide strategy, direction, and help to state and local governments. National goals, instructional content, performance standards, and assessment models provide an azimuth for state and local governments to adopt or modify, based on local needs.

Failure of Urban School Systems. School systems in Washington D.C.; Los Angeles, California; Baltimore, Maryland; and Boston, Massachusetts are failing. Urban dropout rates are higher than the national average (in some cases 60 percent). The earning power of dropouts is one-third that of a high school graduate, and one-sixth that of a college graduate; and additional social programs cost taxpayers $52 billion annually. Left untreated, megacities will become epicenters for a racial and economic rending of our national social fabric. Urban schools must become relevant to their constituents.

Inequities in the Education of Blacks and Hispanics. Nearly one-third of all twenty- to twenty-nine-year-old black men are in prison or on probation or parole. Nearly two-thirds of state prison inmates are high school dropouts. Hispanics now have the highest rate in dropout statistics — about 30 percent nationally. The urban poor do not have access to educational programs that would make them competitive workers. The history of unaddressed inequities and educational disenfranchisement is in stark contradiction to the basic tenets of the U.S. Constitution and an incredible waste of intellectual capital with debilitating social costs.

Inadequate Vocational Technical Education and Training. Many people are frustrated by education's failure to provide workers with the cognitive, interpersonal (team), and technical skills required in today's rapidly changing job market. Louis Gerstner, Jr., chief executive officer of IBM: "If we don't shape up our schools, we will soon be a Third World economy" (Gerstner, et al., 1995). School-to-work transition programs must attain parity with a four-year college education and meet the demands of the workplace. The German apprenticeship system, and the few domestic examples previously discussed, lead us to conclude

that improved vocational/technical high schools and community colleges can provide the necessary training and retraining.

RECOMMENDATIONS

Federal Government

Rather than exercising centralized control and prescribing standards, the federal government should set national goals, use national grants to pioneer help for high-risk or failing systems and groups, assess effectiveness for continuing and follow-on program work, and encourage decentralized control and local initiative. Consideration should be given to combining the efforts of the Department of Education and the Department of Labor to coordinate funds and programs and to focus efforts on enhanced technical and vocational training geared to the needs of the workplace. The "bully pulpit" should focus national attention on the part of education that is broken. Legislation should be enacted only if states do not take appropriate action on strategic issues.

State Government

States should set equity requirements and standards, and decentralize curriculum establishment and spending authority. State boards of education and legislatures should mandate the use of a state-level tax as the primary source for public school funding. These funds should be distributed according to a formula responsive to enrollment and special needs, thus ensuring equity in access and a quality education for all.

Local Government

Building coalitions with schools and industry, local governments should leverage local human resources and civic/commercial assets to increase equity while reducing expense. Individual contribution through civic involvement will increase a sense of community and promote social cohesion. Decentralizing curriculum development and spending authority, while holding individual institutions accountable for attaining standards, will optimize opportunities for community initiatives.

CONCLUSION

Education is the key to this nation's industrial success and national power. It enhances our quality of life, domestic tranquillity, and global competitiveness. The quality and success of the education industry is directly related to our esteem for learning. Good students possess a strong desire to learn, and good schools possess a strong and dynamic ethos of learning. They are led by people excited about education and driven by their belief in the education of all as a family. They are supported by a community steeped in the same ethos.

The incredible vitality, richness, and diversity of the United States calls for the same diversity in educational and training settings. In education, one size does not fit all. The education industry is most successful when it is seamlessly linked to communities, businesses, and families with a strong ethos of learning, and a commitment that others will have the same opportunity. Only such an educational environment will produce a responsible and productive citizenry who will continue their personal growth and encourage lifelong learning for all.

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ELECTRONICS

ABSTRACT

Electronics is a robust, rapidly growing industry which outperformed the U.S. economy as a whole in 1996. The industry has, in fact, had an increase in factory sales each year for the last quarter century. This report confirms the strength of the industry's long-term outlook and its ability to support the national security strategy well into the 21st century. It also reviews recent trends in the industry's converging computer, telecommunications, and multimedia sectors—and predicts that a more unified electronics industry will be on the cutting edge of the future. The multifunctional high-tech products that this industry will design and produce in the coming years will revolutionize the way Americans live, work, and play. The U.S. electronics industry is poised for phenomenal growth.

CAPT John Yaeger, USN
CAPT Steve Wellock, USN
COL Orhan Akbas, Turkish Army
COL Putthinat Vacharapanich, Royal Thailand Air Force
Mr. Don Briggs, Dept. of Transportation
Mr. Derek Stewart, General Accounting Office
CDR John Vinson, USN
LTC Carroll Pollett, USA
LTC Dave Washechek, USA
LTC Keith Lockard, USA
Lt Col Bill Sullivan, USAF
Lt Col Mary Cooper, USAF
Lt Col Harold Howell, USAF
Mr. Don Shultis, Dept. of the Navy

Dr. Donald L. Losman, faculty
COL Harold Tucker, USA, faculty
Dr. Kenneth B. Moss, faculty

PLACES VISITED

Domestic
3M Electronics, Austin, TX
Applied Materials, Austin TX
Defense Advanced Research Projects Agency, Arlington, VA
Dell Computer, Austin, TX
Harris Corporation, Melborne, FL
MITRE, Tysons Corner, VA
Motorola, Austin, TX
Oracle, Bethesda, MD
Raytheon, Boston, MA
SEMATECH, Austin, TX
Watkins-Johnson, Gaithersburg, MD

International
Ericsson Corporation, Stockholm, Sweden
Minister of Defense, Stockholm, Sweden
Stockholm International Peace Research Institute, Sweden
U.S. Embassy, Stockholm, Sweden
U.S. European Command, Stuttgart, Germany
5th Signal Command, Heidelberg, Germany
Deutsche Telekom, Bonn, Germany
U.S. Embassy, Bonn, Germany
International Business Machines, Mainz, Germany
Zentralverband Elektrotechnik und Elektronikindustrie (ZVEI),
Frankfurt, Germany

INTRODUCTION

The breadth and pervasiveness of the electronics industry touches virtually every aspect of our lives. The speed with which the electronics industry has become such a major part of the global economy is illustrated by the advances of the computer sector. Moore's law postulates that semiconductor capability doubles every eighteen to twenty-four months. As chips grow in capability, we may soon each have our own Cray supercomputer equivalent on one Pentium-like chip for less than $100.

Electronics applications range from the dramatic to the simple. The industry includes the production of visually stunning high-definition television; the life-saving tools of microsurgeons; instant cellular voice communications to remote and isolated regions; dominant weapons to deter war or to end it swiftly if it begins; computers to explore the origins of life and to discover cures for man's maladies. The electronics industry has not only designed new, highly complex software to support the nation's air traffic control systems; it has also produced the simple digital watch, the reliable toaster, and the automobile ignition system.

This report presents the industry's statistics, describes and examines the structure and performance of its major components, and reviews various issues, including an assessment of industry challenges, outlook, and potential government roles. The report is based on extensive library and Internet research; industry and government presentations; and visits to domestic and international firms, trade associations, and government organizations representing different sectors of the industry.

THE INDUSTRY DEFINED

The electronics industry has five components: computers; semiconductors; consumer electronics; defense electronics; and software. Each is characterized by rapid technological change, capital- and labor-intensive production, and global competition. The electronics industry generates approximately 6 percent of the nation's gross domestic product (GDP). It is the largest basic industry and the largest industrial employer in the United States. In 1996, factory sales of electronics equipment, components, and related products generated over $409 billion—a 9 percent increase over 1995 (EIA, 1997), and the industry continued to outperform the U.S. economy as a whole—1996 being the 26th consecutive year of factory sales increases. In 1996,

industry distributors' sales grew by 14 percent and continued growth was expected in 1997 (Carbone, 1997).

Fortune magazine declared 1996 to be a surprisingly profitable year for the Fortune 500 companies, whose overall profits grew 29.3 percent. Led by a 32.3 percent profit growth in the computer software industry and a 29.9 percent profit growth for computers and office equipment, the electronics industry shared in the profitability of these 500 companies ("500 Medians," 1997a). The electronics industry's 1996 growth surpassed traditional manufacturing heavyweights, including automobiles, chemicals, and textiles.

Computers

Computer makers comprise 21 percent of the U.S. electronics industry in terms of 1996 factory sales (EIA, 1997). The electronics industry as a whole and the computer industry are critical components of U.S. national defense.

Structure. Major commercial computer producers include IBM, Hewlett-Packard, Compaq, DEC, and Apple ("Fortune One Thousand," 1997). Major suppliers to the defense sector include Raytheon/E-Systems, Texas Instruments, Westinghouse, Lockheed-Martin (LORAL), and Rockwell.

The computer industry's commercial and defense sectors differ structurally in fundamental ways. The commercial sector is characterized by many sellers and a huge number of buyers. The defense sector has relatively few sellers and *very* few buyers. In addition to the Department of Defense (DoD), other buyers in the defense sector include the U.S. Transportation Department, the Department of Energy, national communications companies, and foreign governments. Computer export sales exceed imports as the industry continues to maintain its strong position vis-à-vis international competition.

Current Condition. A comparison of U.S. factory sales for 1995 and 1996 shows that sales increased in computers and peripherals from $74.5 billion in 1995 to $84.3 billion in 1996—a growth of 13 percent. Although this rate of increase exceeds that of all other companies, it is merely "typical" of the computer industry's growth throughout the 1990s.

Similar growth is expected in 1997. The World Bank predicts a rapid expansion of the use of personal computers and the Internet. Based on

1994 data, the World Bank estimates that there are between 150 and 350 personal computers per 1,000 people in 14 countries, including Japan, Germany, Britain, Canada, and the United States. Between 100 and 530 computers per 10,000 people are linked to the Internet in the 11 countries that are the largest Internet users ("Computer Revolution," 1997). Electronics dealers and distributors expect no downturn in this solid demand for personal computers and other end products. Many are, in fact, forecasting a 20 percent growth in sales of personal computers and networking accessories in 1997.

Outsourcing has become an important strategy for the productive capacity of the computer sector. An estimated 43 percent of all outsourcing, or "contract manufacturing," in the electronics industry occurs in the computer and business/retail segment. In the computer industry, dependence on manufacturing as a core competency is not as predominant as in other parts of the electronics industry. When demand is erratic, the computer segment can spread its risk by outsourcing manufacturing—guided, of course, by cost pressures and time-to-market constraints ("Riding the Rising," 1997). It should also be noted that the U.S. computer industry is internationally competitive, with worldwide revenues expected to more than double by 2002.

Semiconductors

The semiconductor sector is often described as "packaging" and "manufacturing." Packaging is the creation of circuit interconnections and a fit operating environment for integrated circuits, and manufacturing is the semiconductor production process.

Structure. Major U.S. semiconductor and equipment manufacturers include INTEL, Texas Instruments, Applied Materials, National Semiconductor, Advanced Micro Devices, and LSI Logic.

The semiconductor industry has experienced a decade of remarkable change during which individual semiconductor firms shifted from a vertically integrated, monolithic, nation-based structure to a more horizontally integrated cooperative structure. Multinational partnerships and alliances now dominate the $100-billion global industry. The semiconductor sector varies: at the low end, simple commodity semiconductors are produced; at the high end, application-specific semiconductors. Each segment has specific, often different marketing demands and business traits. International alliances among semiconductor companies are common, especially between Japanese and

U.S. firms. U.S. firms were among the first to move production facilities offshore to take advantage of cheaper labor and facilities. The United States and Japan have, in practice, divided the semiconductor sector; the United States leads in microcomponents sales, the Japanese in memory. Their dominance is due in part to the high cost of entry into the technological realm. The United States is expected to continue concentrating on specialized, high-value products—microcontrollers, microprocessors, and integrated circuits—while the Japanese firms concentrate on commodities such as SRAMS and DRAMS ("Globalization," 1996).

To remain a world-class competitor, the U.S. semiconductor industry must maintain a full complement of capabilities, including leading-edge research and development, fabrication, equipment making, manufacturing, testing, marketing, and servicing. Because only volume production and sales across a number of product markets separate the front runners from the rest of the pack, the U.S. semiconductor industry cannot rely exclusively on the computer industry to drive its growth. The semiconductor industry must make its own timely response to the growth in consumer electronics (e.g., high-definition television); telecommunications; aerospace; and other end-user industries.

Current Conditions. The fastest-growing semiconductor segments are those in high-end, computer-based applications. Market penetration and growth will depend on the continued evolution of these end-use demands. The current major categories of semiconductors include microprocessors; logic; memory; bipolar digital; analog; and discrete chips. Major end-use semiconductor categories are consumer goods, for example, computers, automobiles, communications, industrial equipment, and other products ("Globalization," 1997).

The semiconductor business has historically been cyclical. Although the industry's Fortune 500 companies showed a bare 1.1 percent increase in profits during 1996, five of the top nine (i.e., Texas Instruments, National Semiconductor, Advanced Micro Devices, and LSI Logic) experienced double- and triple-digit profit *declines* compared to 1995, mostly as a result of significant unit price reductions. On the other hand, both Intel and Applied Materials (a semiconductor equipment manufacturer) showed substantial profit increases, and the forecast for 1997 is more optimistic (*Fortune*, 1997).

Consumer Electronics

The best description of consumer electronics items may simply be "anything that blinks, beeps, buzzes, or vibrates." An extensive list of such items can now be found in almost every American home. Three types of products account for roughly 25 percent of all sales, namely, audio products; television sets; and video recorders.

Structure. Considering sales by both foreign and domestic manufacturers, the consumer electronics market is expected to reach $70 billion in 1997 (CEMA, 1997). However, at $11.3 billion, the U.S. share of this market is only 16 percent, based on factory sales (EIA, 1997). Consumer electronics is, therefore, a low profit margin, mass-production industry whose products are viewed merely as commodities. Accordingly, many American firms are exiting the field. The resulting gap is being filled by imports.

Current Conditions. During 1996, consumer electronics sales increased by 6 percent over 1995. Consumer electronics exports have grown from approximately $2.8 billion in 1991 to $3.1 billion in 1993, to over $4.2 billion in 1995. Opportunities for growth are clearly manifest. Many Americans are buying third-and-fourth generation consumer electronics and are only interested in the newest technology, but opportunities to sell "older" models or current technologies abound throughout the world. The former Soviet bloc nations, China, and Central and South America are virtually untapped markets precisely as they push to improve their economies and the conditions of their people. U.S. manufacturers, sellers, and distributors of consumer electronic items have significant export opportunities.

Defense Electronics

As a customer, the defense industry's market share of the electronics industry has declined, yet its reliance on electronic components has increased. Electronic subsystems are critical components underlying the accuracy, maintainability, and reliability of national defense. They are a growing percentage of weapon systems costs. Defense electronics run the full spectrum, from microprocessors and information systems to communications and weapons-guidance devices, and from sensor-based systems to collection, recording, fusion, and analysis systems.

Structure. In the past, defense electronics was a monopsony market: one buyer, the U.S. government, and three categories of suppliers—the numerous sellers having been aggregated as hardware producers, systems integrators, or systems engineers. Today, as defense spending declines, the electronics industry has become responsive to, and more reliant on, commercial markets. This condition has forced the defense industry to consolidate and sellers to integrate, creating a small number of vertically integrated megacorporations. This development has been accompanied by a shift in focus, with the government looking to the commercial electronics industry for standards, growth, and viability.

Other characteristics also differentiate the defense electronics hardware market from the commercial sector. Procurements tend to be larger and less frequent, with fewer, costlier systems than in the commercial sector. The technology cycle of fifteen to twenty-four months is unequally matched with an acquisition cycle of eight to twelve years. The increase in vertical and horizontal integration, and a continued consolidation among larger companies, results in substantial barriers to new entries. Companies of less than $1 billion per year in revenues have difficulty competing with the merging companies. Smaller companies must either merge with others or exit the defense arena. Reduced domestic and international procurements require less capacity, leading to industrywide consolidations. Important mergers within the last year include Raytheon and E-systems, Lockheed-Martin and Loral, and the proposed McDonnell Douglas and Boeing merger. The resulting megacorporations are horizontally and vertically aligned to provide hardware, systems integration, and systems engineering to both commercial and government customers. No wonder that the smaller firms are having increasing difficulty in their bid to be prime contractors.

The defense sector maintains a favorable balance of exports over imports and continues to be a strong international competitor. Note, however, that this advantage faces a potentially serious challenge as NATO allies consider instituting a "buy-European" policy.

The commercial electronics sector and its growth are at the heart of the commercial off-the-shelf (COTS) concept of defense acquisition. This trend started in the early 1980s in response to the difficulty of finding electronic components for aging weapons systems. It has spawned a new acquisition strategy including COTS, the demise of military specifications, and an increased reliance on commercial standards. To a significant degree, the new strategy takes us from our previous monopsonistic relationship to a more commercial one. The government customer must rely on the technology and innovations of the

commercial market, right down to the planning and fielding of new weapons systems. Megacorporations are in fact a defensive response to this market change; their large size ensures their ability to respond to commercial customers and to satisfy defense requirements, thus ensuring their viability.

Current Conditions. Total defense electronics sales (estimated in 1989 dollars) are between $38 and $45 billion a year. This range reflects a significant decline in government expenditures since 1989, and procurement is likely to remain stable at these levels throughout the 1990s.

Revenues driven by foreign military sales will probably decline over the next five years as western European markets continue to wither. For the largest buyers of U.S. defense electronics in the Middle East—Israel, Egypt, Saudi Arabia, Kuwait, and Turkey—revenues are likely to remain flat or decline slightly (in constant dollars). However, in the Far East, gains are expected, particularly in Taiwan, Singapore, and China. In South Asia, primarily India and Pakistan, the industry looks for only modest increases.

Software

U.S. software firms represent one of the most productive, vibrant sectors of the electronics industry. Major firms comprising the software industry include IBM, Microsoft, Oracle, Netscape, Silicon Graphics, Computer Sciences, Novell, Intuit, C-Cube Microsystems, and Lotus. According to *Business Week's* assessment of the top 50 best performing businesses in all sectors in 1996, Microsoft and Oracle ranked two and eleven, respectively. The assessment was based primarily on overall sales, profit growth, and total return to shareholders. This outstanding showing attests to the incredible strength and vibrancy of U.S. software firms.

Structure. In 1995, computer software firms led all other categories of electronic industries with nine new start-up companies. This growth is indicative of the industry's low entrance barriers. Start up in the software business is made even easier by the proliferation of the Internet where new companies can easily make their software products available to the public. U.S. software firms had total sales in 1996 amounting to about $125 billion.

Current Conditions. The U.S. commercial software industry continues to ride the crest of the information tidal wave, robustly matching new and more enhanced software to every leap in hardware capability. In international competition, the U.S. software industry dominates the marketplace, with a significant 75 percent share of the world's market for prepackaged software sales. In Europe, U.S. software companies held 60 percent of the market last year (Mowery, 1996). More than half of all major U.S. software companies earn greater than 50 percent of their sales revenues in international markets. Although currently there is no credible challenge to U.S. domination of the software industry, foreign competition is growing. Some countries, for example, India, have built internal capabilities that make it less expensive for U.S. firms to obtain software coding for routine software designs developed from India. South Korea has also aggressively expanded its software production capability in recent years and expects to continue this expansion into the next century. This foreign competition raises a potential concern for the long-range future of U.S. programmers. Another important concern for the software industry stems from overseas piracy. Some analysts estimate that the United States loses about $9 billion in sales each year to software pirates.

CHALLENGES

The electronics industry will continue to be a major influence on the U.S. economy and defense in the 21st century. This period will be characterized by explosive technological changes and intense competition in an increasingly global economy. The challenge for the U.S. government and the electronics industry is to harness these technologies to increase productivity and competitiveness, while simultaneously retaining a military capability that can be used effectively (along with other instruments of national power) to pursue U.S. national interests.

The increased globalization of the market place combined with the galloping pace of technological change represent significant challenges. In its *Future Warfighting Capabilities*, the U.S. Department of Defense identified high-performance electronics as a key to modern warfare and conflict prevention. Clearly, the nation's defense strategy relies heavily on electronics. Yet defense makes up only about 2-to-3 percent of the electronics industry's total business. This decrease in market power means that military needs are no longer the primary driver for

technological progress in electronics. As industry's focus shifts to commercial markets, both government and industry will be challenged to ensure that the industrial base retains its capability (and if necessary, its capacity) to support defense surge and mobilization requirements.

Rapid advances in technology (e.g., increases in integrated circuit or chip density) have fueled tremendous growth in the electronics industry. However, such galloping technology presents major challenges in the form of reduced development time and briefer product life cycles. New, leading-edge technology becomes obsolete in twelve to eighteen months (if not sooner) as new advances are developed and introduced. Thus, a particular technology dominates the market only briefly, and the time available for recapturing initial investments is also shorter—with less return on investment (ROI). As this trend continues, industry will be challenged to provide a sufficient return on investments, notwithstanding the product's shorter life cycle. If ROI is not commensurate with the risk, either procurement prices will rise, or industry will retreat from defense involvements. Shorter product life cycles also create significant supportability challenges; long-lived defense systems may contain electronic components that quickly become obsolete and are no longer produced.

The electronics industry (in the United States and abroad) has addressed the ROI challenge by increasing collaboration among companies and research institutions (such as colleges and universities). Companies may try to increase ROI by decreasing their research and development (R&D) costs. Investors also identify R&D costs as an indicator for potential ROI. While the industry realizes the necessity for ongoing R&D, investors often penalize companies that invest too heavily in R&D instead of focusing on short-term maximum ROI. Maintaining a viable R&D base while satisfying shareholders will be a key challenge for the electronics industry in the 21st century.

A recurring theme in the electronics industry is the shortage of technically trained and well-educated personnel. Two specific concerns are the shortage of qualified personnel for semiconductor manufacturing and the dearth of academically qualified software engineers. At the same time, trends such as vertical integration and concentration, are increasing the complexity of electronic systems. These systems are also more likely to increase their capability through software upgrades than through new hardware. Therefore, a major challenge for this industry will be to retain access to the technical workforce and engineering expertise needed to cope with increasingly complex, software-intensive systems.

As electronic systems become increasingly more complex and interconnected, industry will need to ensure that products are useful and provide added value. Determining how to add value and in what features will require an understanding of the environment in which the customer operates. Thus, another key challenge for the electronics industry will be understanding the customer's requirements—getting people to focus on the customer versus the technology.

OUTLOOK

The long-term outlook for the U.S. electronics industry is good. Its strength should be sufficient to support the U.S. national security strategy well into the 21st century. The industry is, in fact, poised to grow even stronger as its major components—the computer, telecommunications, and multimedia industries—continue to "converge." Some analysts have labelled this convergence as the infocommunications industry, but firms in the electronics industry have also embarked on other strategies such as partnering with each other—teaming with academia, and consolidating—that should further enhance the industry's ability to support national security.

Convergence

The continued convergence of the telecommunications, computer, and multimedia sectors should result in multifunctional products of increased value to the user. Convergence has been and will continue to be driven by a number of advanced technologies, including digital and wireless communications, advanced fiber-optics technology, and smaller, more powerful computer chips. The combination of these and other technologies has created an infrastructure that greatly facilitates this.

As products that were once separate, physical items are consolidated, one product can suddenly perform multiple functions. The advent of digital communications, for example, will make the distinctions between computers and televisions irrelevant, since each will incorporate the other's functions. Consumers will be able to read electronic mail on television or watch a movie from a personal computer. Likewise, the replacement of traditional copper lines with fiber-optic telephone lines and cables will give consumers greater bandwidth, thus allowing vast amounts of data to be accessed simultaneously and quickly

through multiple media. Wireless communications, via satellite, are already being included in video cameras and display monitors to create "telemedicine." Thus, medical personnel transporting an injured victim to the hospital by ambulance can describe and even show the victim's injuries to a doctor at the hospital. The doctor can, in turn, transmit life-saving instructions to the medics long before the ambulance actually arrives at the hospital.

The Telecommunications Act of 1996 should promote further convergence in the electronics industry, as this Act virtually eliminates cross-market barriers and relaxes antitrust laws and other rules governing companies that provide telephone services, cable television systems, and Internet and online computer services. Competition has already intensified among these companies as they obtain entry to each other's markets, giving rise to a growing debate over whether the United States is headed for a computer or TV-driven world. Ultimately, this debate will be decided by consumers—the people who spent $19 billion on computers and $10 billion on TV sets last year.

Partnering

Precompetitive collaboration, or partnering, appears to be a growing trend in the electronics industry as companies seek to share the enormous costs of research and development and to reduce the cost of technology. This activity should be viewed favorably by the antitrust authorities. Although partnering is occurring in all sectors of the industry, it appears to be most prevalent among companies involved in the semiconductor sector. This sector, with the backing of federal funds, began a major partnering effort in 1987. Known as SEMATECH, this consortium currently has ten member companies—IBM, Intel, Lucent Technologies (formerly AT&T), Hewlett-Packard, Advanced Micro Devices, Motorola, Rockwell, Texas Instruments, Digital Equipment, and the National Semiconductor Corporation.

SEMATECH's primary mission is to solve the technical challenges that would otherwise prevent the United States from being first in the global semiconductor industry. Fiscal year 1996 marked the last year of government subsidies to SEMATECH. However, the consortium plans to continue its current arrangement because it has proven to be a cost-effective way for companies to share the risks and the rewards of developing semiconductor manufacturing technology. According to SEMATECH's 1995 annual report, industry and government have invested $1.7 billion in SEMATECH since its inception. Approximately

70 percent of those funds were reinvested in the companies that make up the U.S. equipment and materials supplier infrastructure.

Partnering to gain market share also appears to be a growing trend among electronics firms. For example, Motorola, IBM, and Apple are jointly funding a design center for the advancement of computer microprocessors. This design center is reportedly the largest of its kind in the world. In addition, Applied Materials, Intel, and Motorola have formed a partnership to develop improved semiconductor materials; and Dell and Unisys recently partnered to provide 1,600 new computer servers to the Social Security Administration. As companies aggressively compete for market share, it appears that the partnering trend will continue.

Teaming wth Academia

Electronics firms are continuing to strengthen their position in the marketplace by teaming with educational institutions. This initiative supports an ample supply of "knowledge workers" with the necessary skills to produce cutting-edge products. Currently, the electronics industry is having a hard time finding sufficient numbers of qualified "high-tech" workers. To deal with this problem, SEMATECH and the Austin (Texas) Community College are developing a two-year curriculum in semiconductor training with a goal of producing hundreds of qualified graduates to support the semiconductor field. Other firms are seeking to fill job vacancies by implementing various strategies to upgrade the skills of their existing work force. The Harris Corporation, for example, provides in-house training courses to employees who wish to upgrade their skills and compete for higher-level positions in the company. Harris also provides financial reimbursement and time off for employees to attend courses at the community college level. This trend of industry teaming with academia is critical to the industry's ability to compete successfully in the global market.

Consolidation

To remain profitable in the face of shrinking defense budgets, a number of defense electronics firms have consolidated, mostly through mergers. Another impetus to consolidation is the nonlinear cycling of technological advancements and defense acquisition schedules. There is a clear "disconnect" between the technology cycle (eighteen to twenty-four months) and an acquisition cycle of eight to twelve years.

Consequently, electronics firms involved in developing technology for major military weapons systems take longer to realize a return on their investments, an unappealing situation for their shareholders. As investments become more costly, smaller electronics firms must consolidate to survive. The future health of defense electronics depends on successful, efficient consolidation and, for many, expansion into commercial markets to ensure profits for investors.

GOVERNMENT GOALS AND ROLE

Because the strength of the U.S. electronics industry is expected to hold steady into the foreseeable future, we can anticipate a fairly limited role for government involvement. Government's role in the recent past was much stronger. The Telecommunications Act of 1996 dramatically changed the ground rules for competition among companies involved in telecommunications and, indeed, in all aspects of electronics.

With the Telecommunications Act, the government set a new course: it accepted competition as the basic charter for all involved in the telecommunications, multimedia, and computer markets. The Act unleashes competitive market forces that will provide electronic firms continued opportunities for success. On the international level, however, the government may still serve the electronics industry in two areas. It can help ensure fair and open trade policies, and it can help protect the industry's intellectual property rights.

Open Trade. The United States and many of its trading partners, for example, the European Union, have agreed on policy that allows mutual market access. However, further work is needed to ensure that the United States does not fall back on unnecessary protectionism. To the extent possible, all barriers that keep foreign companies from fairly competing for U.S. market share should be lifted. We should, for example, rethink the nation's "Buy America" policy, which appears to contradict U.S. efforts to support worldwide free trade. Major provisions of the Federal Communications Commission Act, which limit the amount of foreign participation in the U.S. electronics industry, may also need to be repealed. The Helms-Burton Act also appears to nurture protectionist sentiments overseas. Free and open trade with virtually no barriers to competition has contributed to the strong market position currently enjoyed by U.S. electronics firms and this policy should continue.

Protect Intellectual Property. The United States must continue to protect the intellectual property of the electronics industry, primarily copyrighted software, from international piracy. Dialogue with member nations of the North American Free Trade Agreement and the World Trade Organization make this challenge a high priority. Strong corrective action against countries that violate intellectual property rights is critical to maintaining an industry that today accounts for over 70 percent of the world's software market.

CONCLUSION

The electronics industry will continue to be a major contributor to America's military and economic power. This industry provides the value-added products and services that the United States and other nations increasingly rely on to improve productivity and raise living standards. In addition to physical products, the electronics industry spawns faster and more insightful problem-solving methods—for its own needs and across numerous other industries—all of which lead to more robust economic growth.

The rapid growth in technology that characterizes the electronics industry requires both government and industry to rethink the way electronic systems are acquired. Shorter development times and product life cycles also drive industry to rethink how it captures and retains market share. An increased focus on providing value-added products to the customer will require an increased understanding of the customer's basic needs. The convergence trend will continue to increase the functionality offered by electronic equipment and its ability to operate anywhere and to interact successfully with other producers' equipment. This trend (both in the commercial and government sectors) will increase the need for the industry's developers to understand customer requirements from a system-of-systems perspective. That is, we must treat products as interconnected systems rather than as stand-alones, with each component contributing to the overall performance capability defined by the systems architecture.

The products of the electronics industry will provide content as well as the ability to manipulate data and information. Therefore, the industry will continue to challenge America's educational system to provide a highly skilled and well-educated work force. Otherwise, companies will go elsewhere. The ability of the United States to pursue its national

interests effectively in the 21st century will increasingly depend on how successfully its industrial base can transfer the rapid advances in sensor, computing, and telecommunications technologies from the commercial sector to defense needs. This condition in turn will be largely determined by the nation's ability to use highly educated and trained people to maximum advantage in the workplace.

Today's electronics industry is characterized by explosive technological change and by intense competition in an increasingly global economy. The challenge for the United States is to harness these technologies to increase productivity and competitiveness while retaining an effective military readiness that can help influence the outcome of world events. Meeting this challenge requires the concerted effort of industry and government. The primary role of government should be to foster a domestic and global environment that allows the U.S. electronics industry to flourish.

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ENERGY

ABSTRACT

For the past twenty years, the energy picture in the United States has been colored largely by the oil shortages of the 1970s. The next twenty years are likely to be framed by an increasingly difficult clash between economic growth and environmental protection. This report recommends scientific study to better estimate the health and environmental effects of energy production methods and use, including a reevaluation of nuclear energy; public debate on the alternatives, and taxes to compensate for adverse environmental effects. Moreover, to ensure the global effectiveness of these measures, we suggest treating them as national issues first. We propose a concentration of federal research and development in basic energy research and development in basic cnergy research with greater international collaboration; and we urge government to discontinue the strategic petroleum reserve and accelerate the deregulation of natural gas and electricity. Finally, we suggest alternative strategies for supplying the nation's defense energy needs.

LTC Maynard Austin, Jr., USA
BG Mohamed Bakr, Egyptian Army
Lt Col Rich Caltabellotta, USAF
Col Ed Carr, USMC
Ms. Jean Cenac, Defense Information Systems Agency
LTC Bill Ford, USA
CDR Rick Kowalewski, USCG
Lt Col Tim Lampe, USAF
Mr. John Moore, Defense Logistics Agency
Lt Col Mike Muolo, USAF
LTC Brian Osterndorf, USA
Mr. Jim Sutton, Dept. of the Army
Ms. Diana Swain, Agency for International Development
CAPT Dave Thomas, USN
LtCol Bob Weidert, USMC

Dr. Maureen Crandall, faculty
CAPT Gary Crahan, USN, faculty
CAPT James Reid, USN, faculty

PLACES VISITED

Domestic

CONSOL, Inc., Blacksville #2 Mine, Morgantown, WV
PECO Peach Bottom Atomic Power Station, Wayne, PA
PECO Conowingo Hydroelectric Plant, Conowingo, MD
PECO Muddy Run Pumped Storage, West Holtwood, PA
Solarex, Frederick, MD
Montgomery County Solid Waste Resource Recovery Facility, Dickerson, MD
PEPCO Dispatch Center, Bethesda, MD
U.S. Department of Energy, Washington, DC
Shell Oil Company, Houston, TX
Shell Deer Park Refinery, Deer Park, TX
Enron Corp., Houston, TX
Enron Steam Cogeneration Plant, Houston, TX
Enron Methanol Company, Houston, TX
Houston Industries, Inc., Houston, TX
Exxon Corp., Houston, TX
Chevron Drilling Technology Center, Houston, TX
Halliburton Company, Houston, TX

International

Shell International Petroleum Ltd., London, UK
Enron Europe Ltd., London, UK
National Power, plc, Swindon, UK
Enron Gas Processing Facility, Teesside, UK
Teesside Steam Cogeneration Plant, Teesside, UK
Ruhrgas AG, Essen, Germany
Rheinbraun AG, Essen, Germany
RWE Lignite-Fired Power Plant, Frimmersdorf, Germany
International Energy Agency, Paris, France
TOTAL, Paris, France
Electricité de France, Paris, France
EdF Nuclear Power Plant, Nogent-sur-Seine, France

INTRODUCTION

Energy touches our lives most directly by lighting and heating our homes, powering our appliances, and fueling our cars. (figure 1.) It offers comfort, freedom, mobility, and a generally high standard of living. But energy is not something we buy to own. In fact, energy is important not as a product but as *a factor of production*. Energy is a basis for competitive advantage.

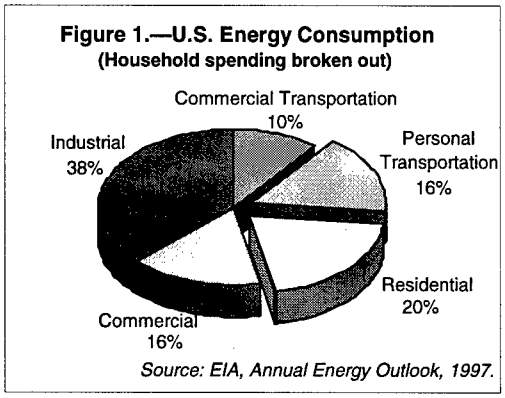


Figure 1.—U.S. Energy Consumption
(Household spending broken out)

Source: EIA, Annual Energy Outlook, 1997.

The United States spends over $500 billion for energy each year, or about 8 percent of the Gross Domestic Product (GDP). Most of that is spent not by individuals but by industry, businesses, and commercial transportation—within the production cycle.

The public dialog on energy is largely shaped by the tension between economics and the environment and is open to considerable controversy. But public perceptions of the issues has nearly as much influence as reality does on the direction of the industry and federal policy.

In making policy, one aims to discover the right balance between the purposeful use of energy and its unintended consequences. The problem is complicated by the scope of national interests, which of necessity includes the environment, safety and health, national defense, economic efficiency, and economic security. But the central policy question is always the same: where and how should the federal government intervene, if at all?

Our research concentrated on the national security implications of this question. We met with industry leaders, production workers, independent analysts, and government regulators to examine the structure and behavior of the energy industry, its performance, and the forces that drive change. We also examined existing public policies, and the general scope of their intended and unintended effects. What we found was a system of many dimensions, beginning with the nature of the industry.

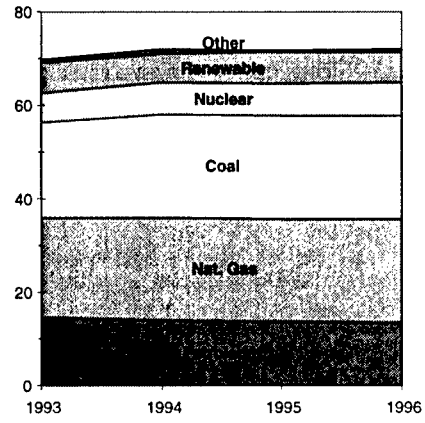
THE ENERGY INDUSTRY DEFINED

The energy industry is a highly aggregated construct that stretches the definition of "industry" considerably. For economic analysis, an industry is a group of firms producing products that directly compete (Porter, 1990). In this respect, energy is perhaps a dozen or more distinct industries.

Energy industries are naturally organized by raw materials and technology. Thus, we distinguish the fossil fuels (coal, oil, and natural gas), nuclear energy, and the renewables (solar and wind). (figure 2.) Some competition across these industries is natural, but it is often constrained by the capital investment required to substitute fuels. More important, the large, vertically integrated companies of the past have very nearly disappeared. The production and delivery cycles are increasingly disaggregated, and firms or subsidiaries of larger firms now compete separately in the traditional drilling and mining, manufacturing, transportation, retail, and service sectors.

Figure 2.—U.S. Primary Production

(Quadrillion Btu)



Source: EIA, Annual Energy Outlook, 1996.

Exploration and Production

Crude oil production is a global industry. Oil deposits are widely distributed and shipping is relatively cheap. Eight major multinational firms are based in the United States, along with 3,000 to 4,000 smaller firms, none of which is large enough to influence the global market price. Oil grades are differentiated by sulfur content, wax content, and specific gravity, and the value of each grade is predictably reflected in relative prices.

Natural gas production is essentially a continental enterprise. Transportation is generally by pipeline, and United States and Canadian reserves are substantial. The top ten operators supply about 40 percent of U.S. production; the top one hundred supply 80 percent. Natural gas has many different chemical constituents, but the market place seldom

differentiates products. Price is fairly volatile, but is disciplined by that of its chief competitor: oil.

Coal mining generally supplies a national market. The U.S. coal industry is moderately concentrated. With 1,200 companies overall, some 56 percent of the total output is from the ten largest producers. Four-fifths of our production goes to electric utilities, where coal holds over half of the market; the remainder is divided between industrial use and export. Coal is differentiated primarily by heat content, sulfur content, and transportation distance.

Refining and Processing

The oil refining industry in the United States is led by eight major oil production companies who share 46 percent of the U.S. market with several dozen independent refineries. The refining process not only separates but also transforms chemicals. So "slate," the refinery's product, includes many nonenergy products, such as asphalt, wax, plastic derivatives, and lube oil. Slate also varies with demand. Transportation fuels comprise the largest share of this industry, and gasoline is the main profit driver. Because products are basically undifferentiated in the wholesale market, refiners compete in process efficiency.

Natural gas processing, though similar to oil refining, is generally a smaller-scale operation that separates natural gas liquids, such as propane and butane, cleans and purifies gases for shipment, and converts natural gas into products like methanol that are then used in reformulated gasoline.

Power Generation

Electric and natural gas utilities have a long history of monopoly and regulation, but are now immersed in liberalization and deregulation. Utilities have, until now, been vertically integrated. Today, they still generally provide the energy source (power plants or gas supply), and usually own and operate the "pipes and wires" for transmission and distribution.

Nonutility generators range from federal hydropower plants to solar, wind, geothermal, steam cogeneration, biomass, and waste-to-energy plants. Some of this power is produced on a small scale for local use; most is supplied to the electric grid. In the case of waste-to-energy and biomass, energy is a byproduct of waste disposal, so it is sold at market rates. In other cases (e.g., wind, solar, or steam cogeneration), utilities

may be required under present law to accept the generators' output, even at above-market rates.

Marketing and Distribution

Natural gas marketing is a relatively recent development. Marketers serve wholesale and some retail customers, and now compete with utilities. Their parent companies are large multinational corporations usually based in the United States or Canada and often in the oil business. The top eight regional marketers accounted for 47 percent of sales in 1995, and mergers are rapidly concentrating the industry further. Product price varies with seasonal demand.

Electricity marketing has been the province of utilities and regional power-marketing administrations that market government-owned hydropower. Commercial electricity marketing began only recently at the wholesale level, and is often intertwined with natural gas to form a broader "energy marketing" or "Btu marketing" initiative.

Gasoline is marketed through retail stations. This part of the oil industry is modestly concentrated in major brand names, and typically even these stations are owned/operated under local franchise. Gasoline is differentiated by fuel additives, company reputation, or vehicle servicing, but customer loyalty is easily corrupted by trimming a few cents per gallon in price. The market is characterized by monopolistic competition.

CURRENT CONDITIONS

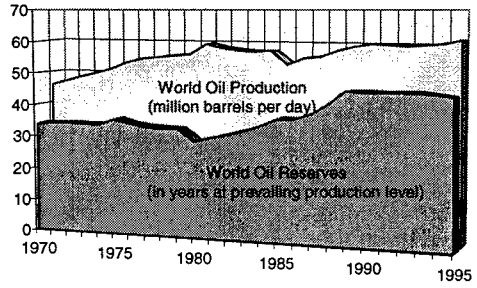
Patterns in the energy market reflect geography, national resources, politics, jobs, a nation's research base, and trends in the economy. So it is not surprising that the performance of energy industries is aligned with many of the elements of national power. Yet we found that many of the basic trends in the energy industries of the United States roughly mirror those in other countries, particularly in the European Union.

Industry performance plays out in terms of supply, demand, efficiency, capacity, prices, and public interest. We begin with an apparent paradox: the unusual relationship between production and reserves.

Energy Supplies Increase with Use

Only twenty-five years ago, it was widely believed that we had only thirty years of oil reserves left in the world. Had that been true, we should have almost depleted our reserves by now. (figure 3.) "Reserves," however, are really a function of economics and technology, and in the last ten years, oil companies have cut the cost of finding and extracting oil by 30 to 40 percent. Proven world reserves of both oil and natural gas have gradually risen to about 40 and 60 years, respectively, as additional reserves have more than offset production. We have more, because more is accessible. It is by no means certain that this trend will continue, but the historical record is pretty persuasive—growth in the supply pool has so far outpaced demand. An apparently counterintuitive situation has, in practice, become the industry norm.

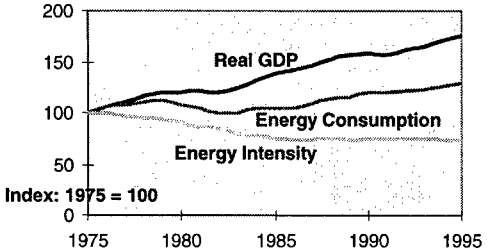
Figure 3.—Oil Production and Reserves



Source: Arthur Anderson, World Oil Trends, 1996.

Against this backdrop of growing reserves, the oil crises of the 1970s imposed a certain discipline on our use of energy. Since then, gains in efficiency and energy conservation have almost steadily reduced the energy intensity of the U.S. economy by about 1.7 percent per year. That is, we need less fuel per dollar of GDP. (figure 4.) This condition is good for the economy and even better for prices. But growth in the GDP means that we will need more energy to run the economy. Fortunately—and characteristically—we produce most of it ourselves.

Figure 4.—Historical Changes in Consumption, & Energy Intensity



Sources: Economic Report of the President (1996); and EIA, Annual Energy Outlook (1996).

A Mix of Energy Sources and Capacities

Countries tend to use a mix of energy sources derived from their natural resources, then make up the difference with oil because it is the most portable product. We produce 87 percent of the natural gas we consume, and 83 percent of the electricity, with most of the rest imported from Canada. We are a net exporter of coal. And given the resources we have, along with the cost of transportation and the nature of delivery, the U.S. energy market is fundamentally a competition within U.S. industry. In that context, capacity is important, and we found that circumstances are changing here.

Crude oil production in the United States is at near capacity, and companies' oil inventories have gradually declined to about 60 days of consumption. Meanwhile, U.S. refineries today are operating at 94-to-96 percent of capacity. The slate of refined products has been altered to match demand, and the mix could be changed to deliver, for example, twice the amount of jet fuel that is currently produced. But only so much jet fuel can be made from a barrel of crude oil, and foreign refineries are already operating at similarly high levels. Under most scenarios for surge production, refineries are the key bottleneck for oil products.

Natural gas is being produced at about 86 percent of capacity in the United States, and Canada also has abundant reserves and capacity. The upstream production industry is not, however, the key factor for surge. Natural gas is stored in several large salt caverns to meet peak seasonal needs. Storage and pipeline capacity limit its throughput.

Coal production has already exceeded domestic consumption, with net exports the result. Rail transportation is the limiting factor for increasing delivery. Most coal is used for generating electricity, but any increased electricity demand can usually be met through a variety of generating sources (e.g., gas, oil, renewables) for most regions.

Electricity generation currently has considerable excess capacity; peak loads are the most significant constraint. Electricity is unique in the sense that supply and demand must be balanced in real time. By nature, it has no online storage capacity. Some generating units are kept running as a "spinning reserve" to meet sudden peaks in demand, but this energy otherwise is wasted, not stored. The only way to *store* excess electricity is to *use* it—as is done with pumped storage, compressed air, or cooled water—for later regeneration (and further losses in efficiency).

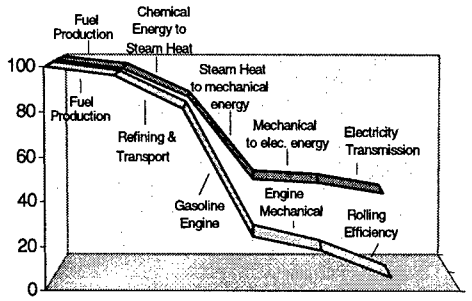
On the whole, excess capacity is declining, with some identifiable bottlenecks. But in such a large system, the supply remains quite robust, with many opportunities to develop energy efficiency.

Efficiency and Deregulation

Much of the energy in fuels never makes it to the point of useful *work.* Consider electricity: after losses in generation, transmission, and distribution, only about 30 to 35 percent of the energy content of fossil fuel is still available for use. And the efficiency of a gasoline-powered car is even more striking—95 percent of the original energy is lost through refining, conversion of the gasoline into mechanical power, and rolling resistance. (figure 5.) Physical and practical limits have to be admitted, but there is still plenty of room for improvement.

Figure 5.—Efficiency Losses

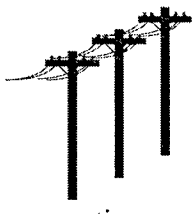
Electricity Generation vs. Gasoline Automobile



Source: Energy: A Conceptual Approach - Van Koevering (1986)

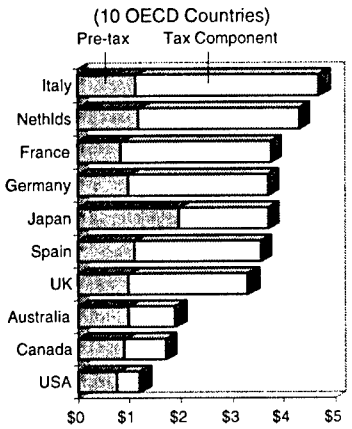
Efficiency gains—anywhere in the life cycle—stretch the supply. They reduce fuel costs, and the depletion of natural resources; they also reduce industry's vulnerability to disruption. Not surprisingly, most energy-related research and development is seeking greater efficiency in some part of this life cycle. The more tantalizing of these efforts may be the prospect for a breakthrough in the technology for electric vehicles, because electric motors have a 2:1 work advantage over heat engines from the same Btu content of the fuel. Electric cars are comparatively more efficient than gasoline-powered ones. And they don't just move the source of pollution (as some contend); they cut it in half.

A significant development in the energy industries is deregulation of the natural gas and electricity markets. Electricity alone comprises a U.S. market of over $200 billion—more than the United States spends on telecommunications (Brennan, Palmer, Kopp, Krupnick, et al., 1996).



Although, federal law is the regulating authority, the process of deregulation is occurring on the state level at varying rates. By unbundling the production, generation, and marketing of energy from the "pipes and wires" that carry the

Figure 6.—Gasoline Prices & Taxes, 1992



Source: DOE, Sustainable Energy Strategy.

product, deregulation can open the industry to competition, which should reduce prices, perhaps as much as 20-to-25 percent on average. Lower prices will, in turn, stimulate higher demand and further reduce slack in the system.

Firms are positioning themselves for deregulation through mergers and alliances to extend their experience, diversify their assets, and achieve economies of scale. The major challenges are how to deal with "stranded investments," including plants and equipment or long-term contracts incurred when utilities operated with regulatory oversight under a different set of rules; and how to deal with special system needs, like peaking power or cold-start capability, that are difficult to price.

Real energy prices in the Unites States are about 30 percent less than they were in 1980. Retail prices for gasoline, in particular, haven't been lower in real terms in the last sixty years (American Petroleum Institute).

New technology and competition have driven costs down. But the market is still oddly distorted. For example, the costs for generating electrical power range from about 1-2 cents per kilowatt hour to 30 cents per kilowatt hour, based on local costs to generate. In captive, regional markets, these variations can be averaged into the utilities' rate structures. The wide disparity in retail prices across different utility service areas are vestiges of a regulated market.

Gasoline prices are also "distorted" in a more subtle way. Gasoline taxes in the United States are about 35 percent of the total retail price—rates that are far below those in every other industrialized Western nation. (figure 6.) Some researchers have suggested that this "distortion" is perhaps a third of the amount needed to compensate for the costs imposed on society from driving, including costs for road maintenance, bridge repair, traffic management, congestion, and pollution.

This observation leads to a broader concept of pricing and to a more difficult political terrain. But it also highlights the significant pressure that external conditions place on the industry.

Safety and Environmental Concerns—Two Externalities that Shape the Market

Though not a market force, the environment plays an increasing role in the generation and use of energy resources. Fossil fuels generate acid rain, greenhouse gases, smog, and ozone. Hydropower disturbs fish and the aquatic environment, while coal mining disturbs the land and oil transportation (sometimes) pollutes water. Nuclear waste, mining, and underground gasoline tanks may contaminate groundwater; and even wind power can be hazardous to eagles. However, the magnitude and economic effects of the damage are not always clear. How much does it cost, and what is a reasonable cost to avert it?

Polls report that 40-to-70 percent of the public are willing to pay more for "green" energy (and in several market trials, consumers did indeed elect to do so). Nevertheless, the public may not be willing to pay directly and across-the-board for cleaner energy. The four-cent gasoline tax in 1993, for example, lost public support and was eventually repealed. Public sentiment is often indirectly channeled through regulatory agencies and their permitting processes. But regulators are not consistently able to design programs that are economically efficient and some have unintended effects. The permitting process can also be obscured by delay, changing requirements, and special-interest tactics that preclude rational deliberation. Thus, private sector decisionmaking (e.g., whether to build or close refineries or upgrade hydroelectric plants), may be distorted or suspended as a result—precisely when action would make the best economic sense.

One major trend seems certain to affect the energy industry over the next several decades: carbon emissions, or greenhouse gases. Emissions are clearly rising, while atmospheric loading and temperature are also rising over the longer term. Concentrations of carbon dioxide, for example, are 30 percent higher than they were one-hundred years ago, and the average world temperature is estimated to be about one degree warmer.

Most developed countries are committed to reducing CO_2 emissions to 1990 levels by the year 2000. But 1990 levels do not represent an equilibrium condition. Carbon dioxide levels in the atmosphere will continue to rise, though no one knows the level at which it becomes critical to global climate change.

CHALLENGES

The most vexing problem for energy policy is, in our view, an emerging collision between economic growth and the environment. Many in the industry argue that the environmental effects of energy production are overstated, or that the connection between energy use and its alleged environmental damages are not scientifically demonstrated. Some also suggest that the focus ought to be on the global community, since the United States contributes only about 20-to-25 percent of the total environmental impact from energy use. All of these have positions have some merit, but the underlying issues are more complicated.

Insisting on Clean Energy

It is inherently difficult to establish the social costs of pollution. How do you quantify environmental damage? As many agencies have attempted to do this economic analysis with widely varying results, a range of approaches, each with its own shortcomings, is used for managing risk.

Reducing risk "as low as reasonably achievable" (ALARA), or mandating specific technologies (such as scrubbers) are arbitrary solutions that may raise costs unreasonably or even inhibit the development of technology. Capping emissions is a more flexible policy, but one that can be equally arbitrary. After all, if we can't quantify the harm, a cap may be too low or too high. In economic terms, this strategy is inefficient at best.

Global issues are even more problematic. For example, significant competitors to U.S. firms may not be subject to agreements on CO_2 limits. The effects of unilateral action will not be proportional to the costs (Harding, 1968)—and the disparity affects competitiveness on a broad scale. Collective action is likewise complicated by issues of equity and enforcement.

Searching for a Safe Energy Option

The public has serious concerns about nuclear reactor safety and waste disposal. But these concerns are perceptual problems, not technical ones (e.g., Cohen, 1990). The science and technology of nuclear energy are well understood, and the risks of nuclear energy have been more thoroughly explored than those of any other technology in common use. The probabilities of an accident involving nuclear

technology are infinitesimally small, in particular in the West; and the industry's overall mortality risk is dwarfed by the risks of many everyday activities. Why then do people fear nuclear power, which is virtually risk-free, while they accept coal-fired power, which causes an estimated 30,000 deaths per year (Cohen, 1990)? The answer simply reflects the way people perceive and differentiate risks.

The challenge is how to balance risk. Society as a whole has limited resources that can be expended for risk reduction. And ultimately, risk management is more a function of society and politics than of technology. Estimating the magnitude of risk is a task for quantitative risk analysis. Deciding the limits, or amount, of "acceptable" risk is predominantly a social and political judgment, affected by a nation's natural resources and the public's perceptions of risk.

Managing Market Risk

In the oil, natural gas, and even electricity industries, producers and buyers have engaged quite successfully in the futures market to manage the risks associated with price volatility. Even the big oil-producing states of Alaska and Texas use the futures market to dampen the effect of price drops on tax revenue. Their success raises an exciting question, namely, whether and to what extent the U.S. Department of Defense can use the same remedy.

The Defense Fuel Supply Center already shares in the profit its suppliers may obtain from futures market transactions. It does not, however, use the futures market directly. And while its current procedure for price-setting (nine to twenty-one months in advance) helps stabilize budgets across the board, it doesn't recognize price elasticity of demand or opportunity costs at the field-unit level. In the larger sense, economic efficiency is not achieved.

We also considered whether hedging might be increased as part of an (oil) energy security policy. It seems to be a reasonable extension of what the oil-producing states are already doing to hedge their risk. But at a national level, the issues have another dimension: the larger risk for the futures market is its dependence on producers to supply the product. While the New York Mercantile Exchange has never failed by producer default, it's also never been used as a national security instrument. Since the market depends in the end on good faith, it seems inherently too fragile to counter a threat that may be based on a breakdown in international relations. The alternative is to reconsider the threat.

Limiting Dependence on Imported Oil

In 1995, for the first time ever, we imported over half the oil we used, and this import share is projected to continue rising. Policymakers worry about our dependence on imported oil, but is it really a problem?

A poignant history of exposure to oil embargoes and price shocks has led the United States to maintain a strategic petroleum reserve (SPR) equal to about sixty-to-seventy days' supply of imports (or about a year's supply of Middle East imports). The transportation sector is the most vulnerable to an oil shortage; it consumes almost two-thirds of the 18 million barrels of oil that we use per day, and no easy, immediate substitute for oil exists for this sector.

Nevertheless, some things have changed. While U.S. oil production is declining, the world supply has increased and become more evenly distributed. The Middle East now produces less than 30 percent of the world market. Oil exporters are driven by an urgent need for revenues. And we have learned that price controls tend to exacerbate a contraction of supply.

Still, we can't insulate ourselves from the volatility of supply or price. It makes little difference what proportion of U.S. imports come from the Middle East; it's a global market. The SPR protects U.S. suppliers, but using the reserves would be a politically charged and short-term solution, during which the world economy would still be exposed to potentially serious disruption.

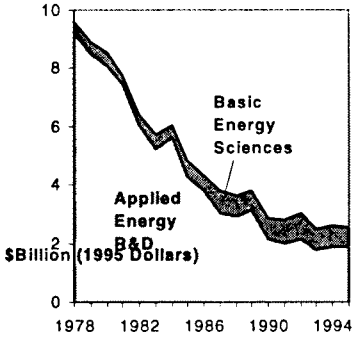
The bottom line: imported oil is less of a problem than it used to be, and we can do little about it anyway.

Declining Federal Investments in Research

Since the late 1970s the federal investment in energy-related research has declined 75 percent in real terms. (figure 7.) The question is: Is that bad?

Federal spending on research and development (R&D) stimulated the development of new technology, especially in areas that industry neglects to avoid market failure. Thus, a decline in R&D investment presents an obvious challenge for the energy

Figure 7.—DOE Energy R&D Funding



Source: U.S. Dept. of Energy, 1995.

industries. Perhaps, but our investigation indicates that this assumption as a misleading portrayal of the situation.

First, the baseline year for the decline (1978) was an extraordinary peak. Over the longer term, R&D spending on energy alternatives and issues in the 1990s appears to be adequate. It may be argued that high spending levels in the 1970s reflected a transient threat that is now diminished. More basically, one may ask why it's important that R&D spending on energy remain constant. The *overall* federal investment in research *has not declined* over the past twenty years, and the energy industry has benefited greatly from gains in information technology (IT), though IT research is not "credited" as energy research.

We need to consider the effects of related research, and even the gains from policies such as deregulation or replacing design standards with more flexible performance standards. These developments contribute to technological advance without direct federal investment. We also need to consider the real possibility that federal spending might *displace* private-sector spending on R&D, with uncertain net benefit. In fact, private industry's spending on R&D rose 36 percent in real terms over the past twenty years while federal spending declined over the same period.

Spending is a natural center of gravity for a governmental organization. Yet these questions suggest that the spending issue may be largely a distraction. The fact that we are spending less on energy research tells us very little about the outcomes we are aiming to achieve.

OUTLOOK

Firms in the energy industries commonly have planning horizons of five years or less. The environment, after all, is very dynamic. Even the U.S. Department of Energy tends to make significant corrections from year to year in its long-range forecasts. The pace of change notwithstanding, some useful observations can be made about the next five-to-twenty years. Some of these observations are interrelated with current public policy; others present fairly macrolevel, independent variables. Collectively, they provide the context for the alternative policy choices that we will explore in the next section.

Macro Trends

Population Growth and Industrialization. Growth in developing countries will accelerate the consumption of the world's resources, and double the use of energy in the next twenty years. The resulting competition for resources will affect energy prices, particularly oil, and clearly accelerate the environmental impacts of energy production and use.

Global Climate Change. As previously noted, climate change is a very complex phenomenon. Natural forces may dampen the trend or amplify it. But scientific evidence will continue to accumulate, and over the next twenty years we expect a better understanding of the issues. It is also quite possible that the public will perceive a crisis during this time that could change the economics of energy.

Environmental Controls. Regulations on local and regional pollutants such as sulfur dioxide and nitrous oxides will probably be strengthened, leading to increased market pressures to move from coal to natural gas or renewables, or perhaps nuclear power for generating electricity. At the same time, these controls will impel the development of clean coal technologies. In fact, we expect these forces to suppress coal prices and seriously constrain the profitability of the coal industry as a whole.

Trends in Technology

Technologies that improve energy efficiency are likely to continue their steady development, although—given historical trends—they are unlikely to outpace growth in GDP or offset increased energy usage. Electric vehicles could (if mass produced and marketed) improve energy efficiency, reduce pollution, and uncouple the transportation sector from oil. But technical and economic challenges remain to their deployment, not least of which is the need for a large, new retail infrastructure for recharging their power supply.

Oil Substitutes. Alternatives to oil are already available, technologically. Coal, for example, which is also a hydrocarbon, can be processed into petroleum products (at competitive prices when oil costs about $30 to $35 per barrel). But coal gasification plants won't be built without a current market, subsidy, or substantial lead time. Synthetics from natural gas face similar hurdles.

Nuclear Fusion. Nuclear power has long promised clean, safe energy with a virtually unlimited supply of fuel. But commercial fusion power is still at least thirty-to-forty years away. Although the United States, Japan, and Europe are collaborating on fusion research and engineering development, U.S. funding has been scaled back considerably.

Deregulation

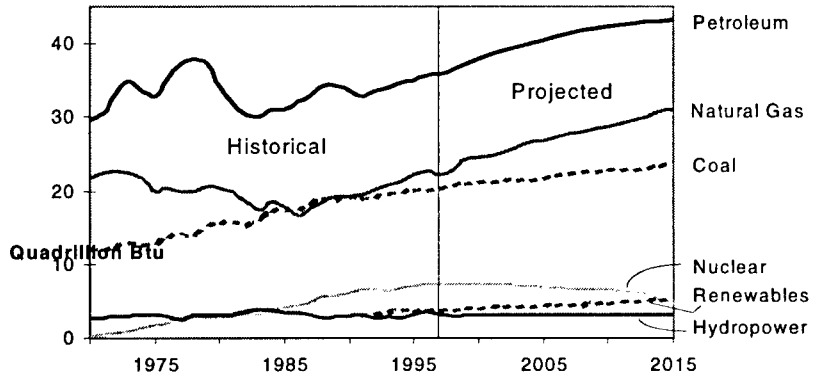
Electricity deregulation will probably unfold quickly once it has been demonstrated in major markets, for example, in California. The resulting increase in competition should reduce prices substantially. Lower prices will in turn stimulate higher demand, and increase the use of coal-fired plants (now operating at about 40 percent of capacity), at least in the near term. By 2015, we may need another 250 gigawatts of new generating capacity, as many nuclear, coal, and hydroelectric plants reach the expiration of their current licenses.

Deregulation Issues in Europe. The European states will likely struggle to open and deregulate their energy markets for almost another decade. Great Britain is perhaps the farthest along, but the European Union's member states are generally handicapped with large, influential monopolies; persistent social issues including unemployment; historical concerns with security; skewed distribution of natural resources; stagnant rates of productivity and energy consumption; and conflicts between EU and sovereign priorities. Collectively, these differences will continue to be divisive—limiting the competitive advantage of European firms in general.

Trends in Production and Consumption

Given current trends (figure 8.) and existing policies, energy consumption in the United States is likely to increase by 1.0 percent per year over the next twenty years. At the same time, we expect some differences by sector. The magnitude of the trends and the shifts by fuel sector, though, will depend on economic growth, relative energy prices, and new technology.

Figure 8.—U.S. Energy Consumption by Fuel



Source: Energy Information Administration, 1997.

Oil. The U.S. energy industries will probably reduce their production of oil by 1.1 percent annually as proven reserves are depleted faster than new deposits are found. By 2015, the nation may import over 60 percent of its oil. In this case, oil will remain a vital national interest. Prices will likely remain about $20 per barrel (in 1997 dollars). A large rise in oil prices could stimulate the search for substitute fuels and significant investments in electric or other alternative-fuel vehicles.

Natural Gas. Production of natural gas is expected to accelerate 1.7 percent per year to meet increased demands—especially for generating electricity. Natural gas still competes with electricity, however, in both residential and industrial sectors, and deregulation will narrow the price difference. U.S. growth in natural gas production will also be moderated by the availability of cheap gas from Canada, provided that its pipeline capacity is expanded to meet demand. Reserves will probably continue to rise, and new finds will more than offset production for at least the next ten years. Though natural gas is relatively clean, CO_2 emissions are an environmental concern. Gas may be clean but it is still a hydrocarbon.

Coal. U.S. coal production is expected to rise by 1 percent per year, roughly mirroring the expected rise in U.S. coal consumption. Considerable progress has been made in cleaner coal technology, and several promising new production technologies are under development. But coal combustion still produces more carbon dioxide than other fossil

fuels. It is an open question whether the cleaner coal technologies will be sufficient to overcome these drawbacks.

Renewables. Wind and solar power have shown considerable progress both in production technology and affordability, but low fossil fuel prices have prevented them from obtaining commercial viability. Renewables offer at least two intrinsic advantages over fossil fuels: they tap energy "income" (while fossil fuels deplete energy "capital"), and their environmental effects are comparatively benign. Over time, these advantages will make renewables more economical, winning them an increasing share of production. At the same time, investment in renewable energy resources offers prospects to U.S. firms for capturing significant international markets, particularly in developing countries.

Hydropower. Water, the major and most conventional form of renewable energy, presents a more contradictory trend. Though hydropower is cheap to generate, it is very expensive to build, and relatively few natural water resources remain undeveloped in the United States. Moreover, the social and environmental effects of hydropower projects sometimes overwhelm the economic benefits. Licenses for 24 gigawatts of capacity will expire between 1995 and 2010, and many plants will have to meet new requirements. Some have already been shut down to restore natural water flow. Overall, we expect hydropower's contribution to the nation's energy supply to decline.

Nuclear Power. Although nuclear power could be a wild card in the future energy equation, its production is more likely to be discouraged. About 40 percent of our nuclear generating capacity is scheduled for relicensing (or retirement) by 2015. However, relicensing rules were published in 1995, and many of these plants are still generating electricity at very competitive rates, which could make license renewal more attractive. The final decision may hinge on resolution of the nuclear waste disposal issue. The prospect for new nuclear power plants is probably more controversial. Four new reactor designs, with simplified construction and operations, will be certified and available commercially by 1999. But public opposition, federal regulation, and extraordinary capital requirements discourage commitments by industry. Given current trends and policies, we do not anticipate any new nuclear plants in the United States within the next twenty years.

The effect of these trends on the structure of the energy industries over the next ten to twenty years will at least partially determine their

role in the U.S. economy and national defense capabilities. We expect increasing concentration at the upstream end of the energy industries, increasing competition at the retail level, and increasingly complex business relationships among the industries' various players. The federal government will certainly play a role in shaping the market, but its effect will clearly depend on the goals and strategies it chooses, and its effectiveness in pursuing them.

GOVERNMENT GOALS AND ROLE

The government can influence the direction of the energy industry as a consumer, an investor, a regulator, or as a direct player in some part of the production cycle. Its choices are commonly influenced by people's biases and a variety of organizational challenges. But in general, we believe that federal intervention is justified only when a market failure exists *and* a policy response is available that can effectively target and correct the failure.

Current Strategy

The current national energy strategy presents a useful starting point. Grounded in the *National Security Strategy of Engagement and Enlargement*, it focuses on three strategic goals:

- Maximize energy productivity to strengthen our economy and improve living standards;
- Prevent pollution to reduce the adverse environmental impacts associated with energy production, delivery, and use; and
- Keep America secure by reducing its vulnerability to global energy market shocks.

We think these goals are conceptually valid, and correctly represent the major federal interests in a cheaper, cleaner, and more secure energy supply. We acknowledge some intrinsic conflicts in these areas, but balancing competing interests is the goal of public policymaking.

To accomplish these general goals, the administration pursues five strategies. It seeks to (1) increase the efficiency of energy use, (2) develop a balanced domestic energy resource portfolio, (3) invest in science and technology advances, (4) reinvent environmental protection, and (5) engage the international market. We think these strategies, and the research programs they engender are too diffuse. They look as

though they were developed from the bottom up, as rationalizations rather than motivations. The result is a government too involved in allocating resources that market forces could distribute more effectively. Consider first the approach to R&D, which spans all three energy goals.

Research and Development

The U.S. Department of Energy (DOE) sees itself as a science agency. With a $15 billion budget, 16,000 employees, and several large, contractor-operated labs, most of its resources are concentrated on nuclear weapons programs (which are peripheral to our interest here) or energy research. But the general approach to federally funded research is misguided.

DOE's research portfolio includes almost a hundred general areas of technology. Each program is justified by a description of economic externalities. But there is no apparent reason why, for example, we spend $35 million on coal combustion and $19 million on super conductivity technology. Further, when DOE calculates the cost-benefit ratios of these programs, it ignores private-sector costs, and makes no attempt to estimate the results that might be achieved without federal funding.

Industry clearly has the primary responsibility to advance the technological base of our economy. Where time horizons are long, risk is high, or benefits distributed, industry tends to underinvest in R&D and government tends to take over. But these criteria could justify federal spending far beyond available resources and are not a useful guide for discriminating among our investments. We propose, instead, the following guidelines:

- Concentrate the federal investment in basic research in which the private-sector interest is most remote, the federal role is unequivocal, and the return on investment is potentially high.
- Engage other countries in collaborative research.
- Divest most applied research except perhaps for a few projects in emerging technologies. Let industry fulfill this need based on market conditions.

Production Goals

Energy productivity, or efficiency, is inherently an interest of the private sector, as long as there is competition. Thus, the deregulation of natural gas and electricity and the privatization of government facilities

should provide a natural environment for optimizing economic efficiency. Antitrust issues are sometimes raised in this context because a deregulated industry will tend to consolidate. There is, however, little evidence that monopoly markets will develop. We recommend that any federal impediments to deregulation be removed quickly; and that all remaining federal hydropower plants and power-marketing administrations be privatized.

Environmental Protection

Environmental effects are obvious externalities in the marketplace, so they are clearly within the scope of federal interest. But how should we deal with them? We propose four steps:

- Prepare a credible estimate of the scope and magnitude of environmental impacts. (The National Academy of Sciences or the National Science Foundation can help with this task).
- Estimate a monetary equivalent for the damages, based on broad public discussion and debate.
- Formulate some form of environmental tax to compensate for these damages and to put all energy sources on an equal footing in the larger context of costs and benefits.
- Establish clear connections between these taxes and programs that will be used to prevent or repair these damages (to maximize public support), then phase in the program, monitor, and adjust.

Greenhouse gas emissions and global climate change present a special case. Given the "minor" contribution from U.S. energy sources, we are legitimately concerned that limiting U.S. emissions would be a costly solution with trivial benefit. However, given the possible irreversibility of damage, and the unique position of the United States in leading international collaboration, we recommend that the United States

- Begin by addressing the domestic and national implications of this problem. Developing nations are more likely to pay attention when the industrialized nations demonstrate that emissions can be reduced without destroying the economy.
- Engage the international community in a broader, collaborative effort, with U.S. firms in a leadership role. These firms may be

in a good position to transfer/market technologies to other parts of the world.

Nuclear power presents both safety and environmental issues. Again, we need to provide credible estimates of risk. If, as we expect, the gap remains between perceived and scientifically derived risks for nuclear power, we recommend that the United States act, as France has done by compelling example:

- Promote the regrowth of nuclear power as a national security issue.
- Correct the distortion of public information.
- Absorb some of the risks of nuclear power—through insurance guarantees or some other mechanism, if necessary.
- Streamline the requirements for the construction and operation of nuclear plants.

Energy Independence

While in the short term (the next ten years), the United States will not be self-sufficient in energy resources, we are confident that the market will respond to demand. Thus, the threat to our economy is probably exaggerated as well. We do not find tangible economic or security benefits that justify the cost of maintaining the strategic petroleum reserve. We recommend that the Department of Energy discontinue and sell off the strategic petroleum reserve.

Defense Acquisition

As a large-volume buyer of energy, the U.S. government should take better advantage of the futures market for the most efficient distribution of resources. To that end, we should test several hedging strategies for the Defense Fuel Supply Center, including paper hedging, shared hedging with contractors, and physical hedging the SPR. Simultaneously—or as an alternative—we should explore outsourcing the federal fuel supply system to one or more energy marketers.

CONCLUSION

The energy industries, by and large, are competitive domestically and internationally, and the observed level of competition is increasing. In many areas, U.S. firms are the international leaders in technology.

Research is continuing to advance technological innovation, with many promising opportunities remaining. Energy reserves are rising while prices and energy intensity continue to decline. Vigorous competition is driving smaller profit margins and squeezing out excess production capacity to some extent. But overall, industry capability to respond to global competition or a national security emergency appears quite robust, and comparatively stronger than in most other countries in the world.

U.S. dependence on foreign oil is continuing to rise even as the security threat from imported oil is fading. The global marketplace now provides a powerful cushion against possible disruptions in supply, and in any event, the United States is more self-sufficient than its competitors.

The environmental effects associated with energy production and use pose the most intractable challenges for the industry and for policymakers. Trade-offs between the environment and economic growth present tough political choices, and global effects may present even tougher diplomatic hurdles. Nevertheless, the impacts are increasingly evident, and all industrialized nations appear to be confronting them.

The current national energy strategy appears sound at the highest level, but its particular strategies are too vague and its research programs too diffuse. As this strategy is implemented, it tends to spread resources around and avoid difficult choices. We do not advocate more spending or greater governmental control. Instead, we propose a more consistent, credible, and flexible approach to estimating and compensating for market externalities; and generally greater use of market mechanisms to achieve economic efficiency.

A Revised Outlook

Our initial "Outlook" for the energy industries was based on current conditions and policies—a logical starting point for assessing the trends and exploring alternative approaches. But if federal programs and policy directions change as we have proposed, the effects could be significant. In that event, we would expect, the following changes:

- greater understanding and visibility of global climate change,
- substantially higher consumer prices for fossil fuels,
- increased tax revenues for environmental restoration,
- suppressed growth in energy consumption overall,

- declining U.S. production of coal, oil, and perhaps natural gas,
- declining imports of oil,
- increased private sector R&D funding to sustain the fossil fuel industries,
- higher growth in renewables, and a revitalized nuclear industry,
- greater likelihood for commercialization of electric cars,
- more support for nuclear fusion research, and a
- larger international market share in clean energy technology.

Finally, we see a diminishing and more concentrated role for the federal government—partly intended, and partly because we have little choice. The momentum of deregulation and international competition will drive industry decisionmaking, and fiscal constraints will curb federal investment and oversight. The government's key role will be to provide basic research, international coordination, and the basic framework for resolving the inevitable conflicts among economic, environmental, and security interests. We do not underestimate the political pitfalls in this approach. But we think that it is the only approach that will take us in the right direction.

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ENVIRONMENT

ABSTRACT

The environmental industry is a labyrinthine collection of services, equipment, and resources. The remediation of waste media may be the most visible and dominant aspect of the industry, but interest in pollution prevention technologies and processes continues to grow—spurred by the promise of economic and resource conservation benefits. Remediation activities dominate the market, however, and serve to obscure the long-term benefits of pollution prevention technologies and processes. This report addresses the entire span of the environment industry, but focuses on pollution prevention. Given the potential for environmental degradation and resource depletion as potential sources of conflict and threats to U.S. national security, public sector planners must understand the dynamics of pollution prevention in order to encourage industry and consumers to move "up the pipe" from remediation to prevention. Pollution prevention is part of preventive defense, and an opportunity for international market growth.

CAPT Jerry Faber, USN
Lt Col Bill Gain, ANG
LTC Bill Grisoli, USA
Ms. Ginny Guzzi, Defense Intelligence Agency
COL Svein Hansen, Norway
LTC Greg Kaufmann, USA
COL Don Meno, USA
LtCol Chuck Mugno, USMC
Mr. Steve Peterson, Dept. of State
Lt Col Gene Powell, USAF
CDR Lane Pritchard, USN
Mr. Steve Siegel, Dept. of the Army
COL Eli Stern, Israel Army
Lt Col Bud Vazquez, USAF
Ms. Holly Wise, Agency for International Development

Dr. Greg Foster, faculty
Col Rick Lorenz, USMC, faculty

PLACES VISITED

Domestic

ADPA/NSIA Environmental Symposium, New Orleans, LA
Bechtel Group Inc., San Francisco, CA
Concurrent Technologies Corporation, Johnstown, PA
Custom Print, Inc, Arlington, VA
E. I. duPont de Nemours and Company, Wilmington, DE
EPA Regional Headquarters (Philadelphia, San Francisco)
Fluor Daniel, Inc., Irvine, CA
Foster Wheeler Environmental Corp., Livingston, NJ
General Atomics, San Diego, CA
ICF Kaiser International Inc., Fairfax, VA
Lucent Technologies Inc., Basking Ridge, NJ
Marine Corps Base, Camp Pendleton, CA
McDonnell-Douglas Aerospace, Huntington Beach, CA
Mitretek Systems, McLean, VA
National Institute of Standards and Technology, Gaithersburg, MD
Naval Station, San Diego, CA
State Pollution Prevention Offices (DE, MD, PA)
Regional Water District, San Francisco, CA
Virginia for the Environment Conference, Lexington, VA
World Bank, Global Environment Facility, Washington, DC

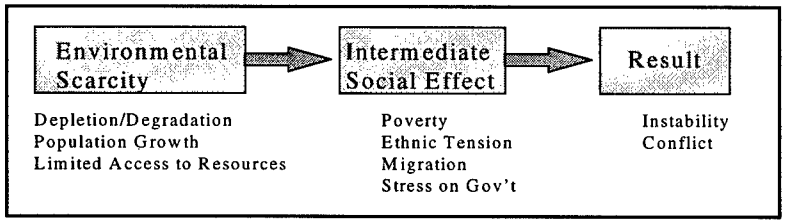
International

ABB Environmental Services Inc., Zurich, Switzerland
Battelle Research Center, Geneva, Switzerland
International Organization for Standardization, Geneva, Switzerland
World Trade Organization, Geneva, Switzerland
Dames and Moore Group, Frankfurt, Germany
HSG Philipp Holzmann, Frankfurt, Germany
IABG, Ottobrunn, Germany
Intel Corp., Munich, Germany
The Green Party, Environmental Working Group, Bonn, Germany
USEUCOM Environmental Conference 1997, Berlin, Germany
OECD, Paris, France
Lyonnaise Des Eaux, Nanterre, France
UN Environment and Industry Program (UNEP), Paris, France
Ministries of the Environment (France, Germany, Switzerland)
Regional Environmental Center, Budapest, Hungary
American Embassies (France, Germany, Hungary, Switzerland)

INTRODUCTION

In "The Coming Anarchy," Robert Kaplan (1994) identifies the environment as "*the* national-security issue of the early twenty-first century." Population growth, resource scarcity, immigration patterns, sustainable development: such pressures on the environment contribute increasingly to social disruption and friction. The resulting political tensions stress poorly prepared governmental structures and ultimately contribute to inter- and intrastate conflict and instability (Fig. 1). The ability to forecast possible points of conflict drives two recently adopted agenda—"environmental security" in the U.S. Department of Defense (DoD) and "environmental diplomacy" in the State Department.

Figure 1.—Effects of Environmental Scarcity



Note: Though this figure implies a linear relationship, the reality is that these various aspects of environmental security are interactive.
Source: Homer-Dixon (1996)

Engaging governmental, public interest, and private groups to identify means of resource conservation and development and generating financial support to execute such strategies, lie at the heart of our environmental security policy.

The U.S. and global response to such issues, however, must draw on initiatives other than those traditionally applied to social, economic, and security challenges. The private sector, though bound by domestic and foreign regulations, leads the response to environmental challenges. This report examines a mix of public and private engagements in this area. It looks at environmental security concerns, appraises the competitiveness of the U.S. environmental

industry in the global marketplace and focuses specific attention on pollution prevention (P2) and its market potential.

THE INDUSTRY DEFINED

The environmental industry defies easy definition; commonly used standard industrial classification codes are woefully inadequate for this purpose. Environmental businesses span many media, types of work, and outcomes. The network of people and organizations involved weaves a global web. Each player has a specific agenda and an allegiance to constantly shifting alliances. Nonprofit organizations may not be "business" members of the industry; however, they directly influence business decisions, and their role cannot be ignored. Thus, we developed the following consensus definition to frame our analysis: **the environmental industry encompasses those manufacturing processes and services dedicated to developing, marketing, and applying processes and technologies to prevent pollution, resolve process deficiencies, manage waste, and support remediation.**

This definition is in general accord with existing literature, and embraces a focus on pollution prevention (P2). P2 holds the most promise for sustaining resources, thereby protecting world stability and providing for future generations. Constant process improvement and innovative resource use are critical to continued growth and sustainable development. Until the economic benefits of investments in sustainability are clear to manufacturers and governments, however, both will continue to focus on remediation and services in lieu of prevention.

The Policy Setting

The popular conception of environmental issues often fails to go beyond ozone holes, landfills, Love Canals, polluted air and water, and the specter of nuclear radiation. For others, chaotic possibilities associated with natural resource scarcity, deforestation, and nuclear accidents define the field. To the casual observer, conservation and recycling are the mantras of the general environmental community. Yet beneath this dominant view of the environment is a vast, amorphous tangle of organizations, businesses, and government agencies, all trying to grasp the complete ramifications of worldwide environmental abuse and resource scarcity while attempting to ensure a viable world of plentiful resources. Internationally, environmental security is enmeshed

in national security and foreign policy. This concept underlies the present administration's goal of sustainable development, with its requirement for resource stewardship. Remediation efforts are important, but they deal primarily with the aftermath of resource use. Both developed and developing countries must now begin to approach their natural resources from the other end—by adopting a P2 ethos.

Flashpoint for Conflict

Former Secretary of State Warren Christopher's emphasis (1996) on environmental seccurity derived from the pervasive, insidious impacts of natural resource scarcity on global stability. In 1996, Deputy Secretary of State Strobe Talbott said, "The health and welfare of Americans are bound up with the quality of the land, air, and water everywhere in the world. Even if the ill effects of [environmental] scourges do not reach our shores and our lungs and our drinking water, they can still harm our interests because struggles over land, water, and other resources can lead to instability in regions of critical importance to the United States."

Deputy Under Secretary of Defense Sherri Goodman (1996b) has identified a twofold environmental challenge to effective preventive defense. One challenge is "to understand where and under what circumstances environmental degradation and scarcity may contribute to instability and conflict, and to address those conditions early enough to make a difference. The second is to determine where military environmental cooperation contributes significantly to building democracy, trust, and understanding." Current Secretary of State Madeleine Albright (1996) also has reinforced the administration's view of the environment as a major issue in foreign affairs.

The Middle East exemplifies the seriousness of this issue. The ethnic and religious causes of the Arab-Israeli conflicts are evident, but beneath the surface lie important environmental causes as well. King Hussein of Jordan, for example, underscores the importance of water in the region when he states, "The only issue over which Jordan might go to war is the issue of water." After Israeli independence in 1948, three small demilitarized zones were established in 1949 near the freshwater Sea of Galilee. Immediately, all sides undertook water projects—wells, aqueducts, dams, and river diversions—to secure water supplies. Between 1949 and 1967, these projects precipitated literally *dozens* of skirmishes, raids, and attacks, including specific attacks on water

installations and aqueducts. Water rights received specific language in the 1994 Peace Treaty between Israel and Jordan.

Other examples of environmental flashpoints for social unrest, instability, and conflict include the following: half the drinking water in Russia is not only contaminated, but *untreatable;* ethnic tension in the Assam region of India results in part from deforestation; and soil erosion contributes to economic and social problems in the Philippines and sub-Saharan Africa.

CURRENT CONDITION

The U.S. Environmental Industry

U.S. industry has been increasingly involved in environmental protection since the creation of the U.S. Environmental Protection Agency (EPA) in the early 1970s. Figure 2 delineates the structure of the environmental industry to date.

Figure 2.— An Overview of the Environmental Industry, 1997.

The business segment, "Process and Prevention Technologies," encompasses pollution prevention, waste recovery, and materials efficiency. However, P2 technologies and services also occur in other business segments. For example, in the "Environmental Energy Sources" segment, renewable energy technologies (e.g., photovoltaics) reduce the amount of pollution caused by the burning of fossil fuels for electricity.

Business activities in the U.S. environmental industry engage over 30,000 private companies, generate over $170 billion in annual revenues, -and employ over 1.2 million workers. The United States is the world's largest environmental market. According to Environmental Business International, the U.S. environmental industry represents one of the largest accumulations of technical, engineering, manufacturing, and management skills in the world (Ferrier and Noble, 1995).

But its potential is enormously underused. First, the U.S. environmental industry overwhelmingly focuses on remediation rather than pollution prevention. Remediation is an "end-of-pipe" solution that seeks to contain the effects of pollution already created. More effective, permanent, and socially beneficial solutions lie in pollution prevention—that is, the application of processes and technologies that prevent or curtail the creation of pollution. In 1994, over 80 percent of the $170 billion environmental industry focused on control and remediation; less than 12 percent was for avoidance, or P2.

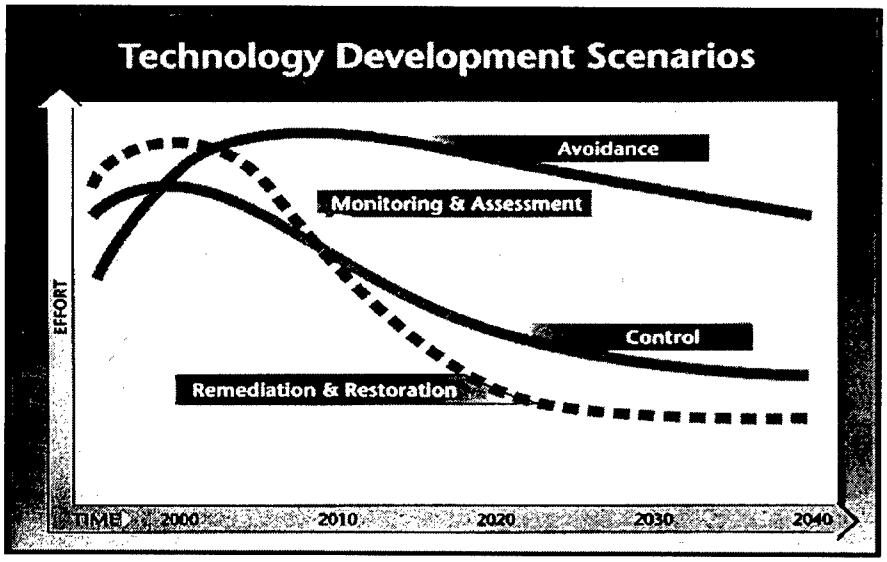
The second area in which the U.S. environmental industry is underperforming is trade. Despite a growing global market for environmental technologies and services, only 6 percent of the industry's revenues are generated outside the United States. In 1994, some $242.5 billion of the $408 billion global environmental market was located outside our borders. Yet our exports in this area were only $10 billion, and virtually zero in the area of P2.

These statistics suggest that the industry needs to focus on the economic benefits of P2. Controlling the waste after generation consumes over 90 percent of state and federal environmental budgets. Industry, which in 1996 accounted for over 66 percent of pollution prevention expenditures, is discovering that cleaner manufacturing processes produce less waste and add to cost savings and competitiveness. Waste not only degrades the environment; it is also economically inefficient. Thus, the U.S. environmental industry is moving toward pollution prevention technologies as the future trend. P2, unlike remediation, explicitly recognizes resource limits. To facilitate sustainable development, P2 focuses on full resource use and

conservation, modifing manufacturing processes to achieve maximum materials efficiency and finding alternative uses for remaining wastes.

Others must be convinced that investing in pollution prevention technologies will benefit a company's bottom line. The environmental literature suggests that P2 will continue to grow in importance. The Clinton administration's key environmental road map, *Technology for a Sustainable Future* (1994), projects a decline in remediation investment about the year 2000, while pollution prevention grows through 2010.

Figure 3.—Technology and Development Scenarios



The indications are clear: emerging financial analysis indicates probable economic benefits of investing in P2; government policies and private sector initiatives recognize the need for a shift from remediation and control to P2; and commonsense stewardship for the future seems to demand such a shift.

Government Regulations

The regulatory process in place since the early 1970s has fostered adversarial relationships among industry, environmentalists, and government while presenting a barrier to the advancement of P2. Much of this problem stems from the nature of congressionally mandated

"command and control" regulations, designed to facilitate accountability and enforcement by making it easy to identify violations and violators.

Such regulations, however, can impose heavy compliance costs on industry, which spent over $140 billion on pollution abatement in 1994 forecasts for the year 2000 put this cost at $190 billion. Such costs significantly affect manufacturing, processing, and location decisions. Still, industry's regulatory concerns center on the validity of scientific data and the lack of cost-benefit analyses. Compliance outlays are increasingly out of line with benefits, resulting in increased costs and lower competitiveness. For example, most of the gains in air pollution abatement occurred before 1985 (Jaffe et al., 1995), yet business spending on this problem has increased at an accelerated rate since then (Press and Mazmanian, 1997).

Empirical data to support the assertion that compliance with environmental regulations hurts competitiveness, however, is lacking. In even the most regulated industries, compliance costs account for only 1 to 3 percent of total production costs. Nor is compliance with environmental regulations a factor in layoffs. Environmental regulations have actually led to a net increase in jobs disproportionately weighted to traditional blue-collar sectors. Finally, there is no demonstrated link between environmental regulations and net exports or foreign investments. Pollution-intensive companies have indeed migrated from countries with strict controls to ones with lax controls, but this movement owes as much to the "demand-pull" of developing countries that want to create an industrial base and to businesses that want cheaper labor and closer access to raw materials, as it does to regulatory "push." Indeed, "industrial greening" advocates note that as firms adopt improved environmental control technologies and the stricter practices inspired by regulations, they discard old, inefficient technologies for more innovative, cost-saving tactics that boost performance and output.

But if the regulatory threat to competitiveness is exaggerated, the disadvantages of sticking with a command and control regime are not. Diverging trends between the rising costs of compliance and diminishing rates of return suggest that end-of-pipe solutions have reached their limits; the "low hanging fruit" has been picked. Further, the combination of medium-specific and end-of-pipe remedies may not be the best approach to environmental hazards about which we still know little. For instance, as we learn more about water pollution, we realize that a great deal of the problem lies with agricultural and other runoff from nonpoint sources that are not easily reached by command and control regulations.

Finally, the command and control approach may embody opportunity costs that impede innovation and competition. For instance, single-media, end-of-pipe, technology-based standards virtually dictate how industry must comply with pollution abatement requirements. Consequently, industry has no flexibility or incentive to try other processes or technologies that could yield better results. Command and control regulations also impose competition-inhibiting entry barriers. Firms seeking access to an industry must meet the latest and most stringent technology, record-keeping, and other costly environmental standards. Existing firms have either already absorbed these costs or they have been grandfathered into the regulations and are exempt. Technology-based requirements may discourage new entries by forcing firms to adopt scales of operation that are incompatible with their plans or budgets.

These trends underscore the need for an alternative regulatory approach. To satisfy public and other environmental interests, it is unlikely that enforceable standards composed of measurable exposure limits and ways to identify and punish violators will entirely disappear. Such standards can be made more palatable to industry, however, if firms are also given flexibility, encouragement, and market incentives to find and adapt the best P2 tactics. Recognizing this need, EPA has instituted a growing array of partnership programs focused on demonstrating that voluntary goals and commitments can achieve environmental results in a timely and cost-effective way.

Economic Considerations

Minimizing the creation and emission of waste is rapidly becoming the best means for complying with federal regulations. When compared to the cost of pollution cleanup and the potential for heavy fines, waste reduction methods are the most economical way to care for the environment. Recycling and waste reuse have proven to be important techniques for fighting the high cost of pollution remediation. Reusing industrial by-products, for example, rather than disposing of them can lead to significant savings. It reduces or eliminates the need to pay for costly shipping and disposal fees. Individual recycling within the home also has more than economic impact. In addition to reducing landfill requirements and providing a source of additional revenue, local recycling programs have the added benefit of developing environmental awareness and building pollution prevention habits within each household. Children are now growing up with an understanding of

pollution and conservation, and these attitudes will ultimately have a great impact on the future. These future corporate employees will enter the work force with an enhanced appreciation of environmental matters. Most citizens, politicians, and corporations understand the need to avoid polluting the environment for future generations. However, many second- and third-order effects are only now coming into play as a result of a one-sided emphasis on pollution enforcement, including closing factories, the loss of jobs, and increased costs that ultimately result in higher taxes or higher costing goods.

Recycling programs, for example, once the model of efficiency and revenue production, have become burdens for local budgets. In the past, funds generated from selling recycled plastic, paper, and metal were enough to sustain the program and provide an additional source of revenue for communities. Then the market for recycled materials flooded, and the amount paid for these materials decreased significantly. Consequently, many recycling programs have gone from profits to deficits.

Emerging financial analysis, however, presents an increasingly positive picture: firms willing to invest in environmental technologies can achieve beneficial results. In an important 1996 study of the 300 largest public companies in the United States, ICF Kaiser International showed that "when public companies improve their corporate environmental practices, they are able to increase shareholder wealth by up to five percent (Feldman et al., 1996)." The study concluded that "adopting a more environmentally proactive posture has, in addition to any direct environmental and cost-reduction benefits, a significant and favorable impact on the firm's perceived riskiness to investors and, accordingly, its cost of equity capital and value in the marketplace."

In the current industrial and regulatory environment, hard choices must ultimately be made between environmental investment and its impact on the structure of the firm. Pollution prevention investment is likewise constrained until further data are developed or compliance and performance standards emerge that would dictate such investment.

Global Dimensions

The increased attention that U.S. diplomatic and defense policymakers are giving to environmental issues will almost certainly help accelerate the growth of the global environmental business market. EBI predicts that this market will grow from $408 billion in 1994 to over

$540 billion in 2000: a 33 percent increase, though the U.S. share will shrink slightly, from 40 to 38 percent. Western Europe and Japan will remain the largest markets, but their respective shares will also shrink. Relatively speaking, the largest expansion will occur in the developing markets of Asia and Latin America, where high economic growth rates will compel governments, and societies generally, to invest in environmental protection. A similarly urgent need for environmental protection is evident in Eastern Europe, but prospects for investment there, under current conditions, are not bright. Economic growth to support such investment is unlikely, the institutional structures to regulate the environment are lacking, and massive crime and corruption will scare away investors.

U.S. firms face stiff competition to boost their share of the global market. Among 17 environmental companies that had over $1 billion in revenues in 1994, only three the first, fourth, and seventeenth—were U.S. companies. The leading U.S. firms specialize in waste management, a market that is leveling off at home. Leading European and Japanese firms, on the other hand, specialize in water—in part because water is a critical need in such densely populated regions; in part because the privatization of water utilities has given European firms unique opportunities to develop new processes, technologies, and management systems that increase their attractiveness in the global marketplace.

Pollution prevention presents the best option for U.S. firms to gain a future market niche despite aggressive and established challenges from Europe and Japan. EBI evaluated environmental business segments for competitiveness and determined P2 most open to gaining market share, primarily because all countries rate poorly in this area (Ferrier and Noble, 1995).

China. Rapid growth without the benefit of environmental safeguards has resulted in serious pollution in China. China's environmental problems compromise its progress toward sustainable development and pose the greatest threat to the global environment. Despite China's immense size, its natural resources are quite limited. It has only 7 percent of the world's fresh water and arable land, 3 percent of the world's forests, and only 2 percent of the world's oil resources (Christopher, 1996). Alternative energy sources, managed conservation, and P2 are keys to the future health and stability of this nation and the world. China must address its air and water pollution and soil degradation as well.

In the initial phase of recent industrialization, China's government was not committed to financing r mediation or the costs of P2 in its state-owned industries, nor did it provide incentives for pollution control to emerging private industries. With the cost for this pollution an estimated 10 percent of GDP, the government has realized that natural resource scarcity and contamination will increasingly constrain the country's drive to modernize. Thus, it has projected an increase in environmental investment, from the current level of 0.7 percent of GDP ($17 billion annually) to 1.5 percent of GDP (approximately $40 billion) by the year 2000. Estimates conclude, however, that between 5 and 10 percent of the GDP will actually be needed to overcome current problems (Zimmerman et al., 1996).

Opportunities for environmental business growth in China are outstanding. U.S. firms are not yet highly competitive in China. Distance, the size of most U.S. environmental firms, a strong domestic market, and competition with firms underwritten by foreign government subsidies have inhibited U.S. efforts there. These factors may exclude all but the largest firms, and legislation restricts the Agency for International Development, the Overseas Private Investment Corporation, and the Trade and Development Agency from operating in China and from helping U.S. firms gain greater access to the country's vast market.

U.S. industry has considerable opportunity, but it requires the dedication of additional public resources, an integrated and consistent foreign policy toward China, and a targeted analytic approach. Failure to seize this opportunity will soon result in irreversible damage to the global environment and a remediation bill that we will be forced to shoulder along with the other nations of the world.

Latin America As Latin American countries progress toward representative democracy, greater economic stability and citizen involvement in business are pushing environmental issues to higher levels of visibility and concern. Each nation has selected a unique mixture of voluntary and regulatory methods to meet its objectives. Environmental regulation of industry, business, and agricultural activities has increased. As a result, U.S. companies are strongly competitive in that region.

To date, most pollution prevention efforts have focused on reducing discharges from existing facilities with limited changes to production processes. As old infrastructure is replaced, the focus shifts to less polluting processes. Three principal factors are intensifying this

interest in pollution prevention: (1) domestic nongovernmental civic and political groups with an environmental agenda; (2) external lending agencies, such as the World Bank and the U.S. Export-Import Bank, which make environmental considerations a condition of approval for funding; and (3) trade and business groups affected by the North American Free Trade Agreement or the International Organization for Standardization agreements that make environmental standards a condition for trade.

A number of U.S. lending institutions are engaged in Latin America. Through the first half of 1996, Bank of America arranged one-third of the commercial bank financing; Citicorp and Chase Manhattan were also active. In addition, most major governmental organizations, such as the U.S. Department of State, the Agency for International Development, and the EPA are involved in projects in Latin America. The challenges that face U.S. businesses in this area largely revolve around funding and culture. Argentina, Brazil, Mexico, Chile and Venezuela, are the emerging markets most promising for U.S. industry penetration. Firms with advanced technology, financing, project management, access to local partners, and the expertise to design, finance, and deliver complete environmental solutions that enhance sustainable growth will compete successfully in Latin American markets.

Europe. Europe's environmental policies and industries have benefited by adopting the best features of U.S. experience and avoiding our mistakes. Europe has moved aggressively on the regulatory front, but it has also embraced a more cooperative compliance process than the U.S. In this context, two important themes emerge. First, European governments, industry, and private interest groups seek to set standards and enforcement procedures through consensus. This process helps clarify environmental protection goals and objectives and makes all parties more accountable to the public. It also eliminates much of the litigation that inflates costs and slows the process of environmental protection in the United States. Second, the consensus process obviates the need for U.S.-style command and control regulations. It substitutes market incentives; for example, Switzerland is introducing a new pollution tax that requires businesses to internalize the costs of pollution and select the most efficient antipollution measures. The flexibility in this framework also appears to be driving Europe toward pollution prevention faster than P2 is moving in the United States. Europe's buy-back policy, for example, where manufacturers are responsible for

the safe disposal of their products after consumers are finished with them, is gaining slow but steady acceptance.

Meanwhile, the U.S. military in Europe is actively advancing the environmental security component of DoD's preventive defense policy. Increasingly, U.S. military personnel are on the ground working with the host nation militaries to confront a wide range of environmental issues. A prime example of this policy is reflected in the declaration signed by the defense heads of Russia, Norway, and the United States. This declaration ensures the conservation and sustainable use of the Arctic environment and underscores the vital importance of cooperation among military organizations to prevent and solve environmental problems caused by their activities. The immediate focus is on nuclear waste issues in the Barents Sea and Russia's practice of dumping excess and damaged nuclear reactor sections (and sometimes spent reactor fuel) in this area. In addition to this issue, approximately seventy decommissioned submarines are in drydock on and around Russian naval bases, many with spent nuclear fuel on board. Lockheed-Martin and Kvaerner, a Norwegian company, are forming a partnership to respond to follow-on phases of this declaration. While the declaration was initially remediation oriented, the follow-on focus is on P2.

Environmental Management Standards

The recent promulgation of the International Organization for Standardization's 14000 series of environmental management standards (EMS) will impact the future competitiveness of U.S. industry. An outgrowth of global concern for environmental issues in relation to trade, EMS are voluntary standards and guidance documents that include environmental management systems, ecolabeling, environmental auditing, life cycle assessment, environmental performance evaluation, and environmental aspects in product standards.

At least three aspects of these standards are the source of heated discussion. First, they are management, not performance, standards. EMS do not set requirements for environmental compliance, performance standards, or specific P2 requirements. Second, the EPA is examining the possibility of granting regulatory relief from certain requirements and inspections if a manufacturer is certified and audited under ISO 14000 provisions. A great many U.S. companies support this possibility, because it offers relief from numerous, overlapping requirements. Finally, ISO 14000, though still in the initial stages of release and implementation, is rapidly being incorporated by the larger,

multinational conglomerates and other firms that routinely conduct international business. Subcontractors may have to be ISO 14000 certified if the parts they supply are vertically linked. In fact, significant economic issues are involved here for small subcontractors. Here if nowhere else EMS will significantly affect a firm's environmental and economic performance.

The European preference for the Eco-management and Audit Scheme (EMAS) involves similar issues. EMAS is a voluntary system in which the European Union's member states formally recognize manufacturing facilities in Europe that meet a relatively detailed EMS and auditing protocol. ISO 14000 was an outgrowth of EMAS; however, EMAS is a more stringent rule than ISO 14000, and it is currently the preferred standard, especially among German firms. The full ramifications of this relationship between EMAS and ISO have yet to be determined.

Finance

Locating and securing financing is an increasingly critical factor in deciding who wins and loses, both domestically and in export opportunities. Environmental firms that come to the table with a complete financing package for P2 projects, products, and services have a better chance of concluding a deal than those still looking for appropriate financing. Financing requirements typically fall into two categories: trade finance and infrastructure projects.

Trade Finance. Most U.S. sales/exports and investment transactions are handled by commercial banks that provide working capital loans, trade finance, and other services. The U.S. government offers several programs, particularly to small businesses and new exporters, and also helps them identify and access other financing sources.

Infrastructure Projects. Another, more complicated, area of financing involves large-scale projects, such as wastewater treatment facilities. Financiers (commercial banks and equity funds) seek financially viable projects that will generate sufficient revenues over time to cover the cost of the project and provide a reasonable rate of return. Pollution prevention projects often have difficulty meeting this important criterion for several reasons: It is often difficult to ensure that a project will generate a steady revenue flow; currency risks—depreciation or devaluation—can be a major hurdle; and finally, P2 projects compete for

capital with other infrastructure projects that offer similar or better returns and less risk. Traditional projects often have better returns because the full costs of environmental degradation and cleanup have not been incorporated into the financing package. Less risk is assumed because the technologies involved, though environmentally damaging, have a proven financial and performance track record that newer, more environmentally sound technologies have not yet demonstrated. For most successful environmental infrastructure projects, funds are obtained from a multilateral development bank, a sovereign guarantee, or the project sponsor.

These complexities may initially deter private investors. But a number of financing mechanisms are emerging that will help increase market penetration and level the playing field for environmental technologies, both domestically and overseas. These sources, which include the U.S. government and international development banks, can often provide the leverage needed to surmount these hurdles and galvanize private sector financing.

U.S. Government. Numerous agencies provide financial support to U.S. firms involved in P2 sales or investments. The Export-Import Bank is the primary governmental agency financing export sales through its programs of export credit insurance, loan guarantees, and direct loans. The bank also offers various enhancements such as longer pay back periods for environmental projects. The Overseas Private Investment Corporation supports U.S. private investment in developing countries and emerging markets by providing investment insurance, loan guarantees, and direct loans for small businesses and cooperatives. The Trade and Development Agency provides grant funding for feasibility studies, consultancies, and other services related to major projects in developing countries and emerging markets; and the U.S. Agency for International Development provides seed money for a number of environmental funds. The Small Business Administration (SBA) supports small businesses by guaranteeing commercial loans for facilities and working capital, providing trade financing, and co-guaranteeing loans.

Multilateral and Bilateral Finance. U.S. firms can also bid on projects sponsored by the World Bank and regional, multilateral development banks (MDBs), including the Inter-American Development Bank, the Asian and African Development Banks, and the European Bank for Reconstruction and Development. MDBs make loans to governments or

agencies if they can obtain a sovereign guarantee. These loans generally cover the hard currency portion of the project. MDBs are increasingly emphasizing the environment; their new Global Environmental Facility is now the single largest program providing technical assistance, grants, and concessional funds for investment projects that return global environmental benefits. In addition to these multilateral development banks, a number of institutions in the host country and bilateral institutions can also offer financing support for environmental projects.

The Road to Pollution Prevention

Many P2 benefits can be derived through relatively inexpensive process changes. Reorganized production lines, more innovative use and storage of inputs, and creative leveraging of information technologies are good management practices that cut waste and lower costs. New technologies, however, are also part of the equation for eliminating pollution at the beginning of the production cycle. Indeed, several firms are developing and applying such processes and technologies to reduce cost.

Intel, for example, has voluntarily set environmental goals that are stricter than called for by regulations. A modification in the process for producing circuit boards uses a new soldering technique that requires no cleaning. This "no clean" process uses no water or solvent. Other initiatives at Intel will help eliminate five toxic chemicals identified by the EPA for elimination or reduction in manufacturing processes.

The Advanced Technologies Group of General Atomics Corporation is developing several P2 techniques with military application. Their "cryoiracture" process is a safe destruction method for obsolete chemical weapons that will also apply to explosives and toxic chemicals in non-defense applications. Their "hydrogen fluoride ion cleaning system" works on a cleaning line for aircraft gas turbine engine parts. The U.S. Air Force uses this technology, and realizes over $100 million in savings every year from reduced labor and resource savings.

Monsanto, a representative of the chemical production sector, is shifting its technology from the creation of chemical pesticides and fertilizers to biotechnology products and bioengineering solutions that will yield larger crops.

In addition to such company-based innovations, a clear trend toward partnerships is emerging in the environmental arena. These partnerships are between private organizations, between governmental agencies and private organizations, and/or between various

governmental agencies. The partnering of a government agency and a private sector firm is illustrated by the Commerce Department's Market Development Cooperator Program (MDCP), which invests in innovative marketing export projects. A private-private partnership between McDonald's and the Environmental Defense Fund (EDF) is helping McDonald's address its solid waste disposal problems.

There also appears to be an emerging trend for technology firms to merge with financial firms to improve competitive advantage. A good example of this trend is the recently announced merger of the French environmental firm, Lyonnaise Des Eaux, with the financial firm of Compagnie De Suez. The merger provides critical support to each firm's business sectors, as the new entity's infrastructure proposals can now be offered as integrated packages of technology, financing, and management. Finally, the 1996 Memorandum of Understanding among the Department of Defense, the Department of Energy and the Environmental Protection Agency on cooperating for environmental security is a key example of intragovernmental partnerships.

GOVERNMENT GOALS AND ROLE

The government's role in the environmental arena has been discussed throughout this report. The government is already deeply involved in the environment from many perspectives: regulations and compliance, finance, partnerships, preventive defense, environmental diplomacy, and economics. However, the efficacy of the government and its many agencies is not always evident to serious perception. The view within government is that its various agencies are well-coordinated to handle both domestic and global environmental issues.

An entirely different perspective on the government's involvement is painted by many private industry and nongovernmental organizations. Significant criticism was leveled by these groups at the seemingly disjointed initiatives and actions taken by government agencies. While there was general agreement that individual agencies have effective programs within the specific scope of their responsibility, the larger issue of integration across government agencies is one that needs to be addressed. More generally, the adversarial relationships that have characterized many activities among government, industry, and

nongovernmental organizations in the past need to be overcome through increased collaboration and trust.

KEY FINDINGS AND RECOMMENDATIONS

Law and Economics Drive Environmental Practices

New regulatory strategies focused on market incentives should be undertaken in the United States. Such strategies have been partially tested, with the most promising being tradable discharge permits—government-issued, or auctioned, credits that firms in compliance with environmental regulations can sell to firms that are not. A new generation of regulations centered on such incentives could help shift the emphasis from control to prevention, bring more industries into compliance at a higher threshold, and eliminate the artificial restraints regulations imposed on innovation and competition.

Sources of International Finance for P2

The availability of funding sources and vehicles should not be an obstacle in the establishment and development of an international P2 market. The U.S. government, multilateral institutions, and the private sector have established financial mechanisms that are capable of supporting U.S. and foreign industry initiatives in this market. The key issue now are to educate the private sector and governments to the range of financing options available; to use these funds to develop and implement successful P2 projects; and to monitor and assess the adequacy of these financing mechanisms to promote P2.

Promoting P2 Technologies

Research and development in environmentally clean technologies, especially P2, should be actively pursued by both the U.S. government and private industry. Policies that promote P2 technology, such as government-sponsored research and financial incentives for the private sector, should be enacted as a necessary step toward sustainable development.

Enhancing Global Cooperation

As U.S. foreign policy focuses on the environment as a potential source of conflict, the United States must also be prepared to help at-risk nations develop public and private institutions specifically to monitor and control environmental threats. The creation of uniform standards and effective enforcement mechanisms will not only help the environment, but will also create a level playing field for business interactions. The ISO 14000 series is a first step in this direction.

Mobilization Impacts

The U.S. government must plan and develop partnerships with industry and public organizations to meet surge requirements during mobilization periods. Complex, environmental regulations can be a key area inhibiting the nation's surge in production and construction during mobilizations. It is not likely that environmental regulations can or should be ignored. Federal agencies will probably be more flexible than state and local authorities, as they are now claiming more responsibility and ownership than in the past. A current bright spot in this area is the trend toward integrating P2 into new production processes. It may well be that not all surge requirements can be mitigated by P2; therefore, we can expect delays or legal claims after the surge.

CONCLUSION

The environmental industry is growth oriented. The incorporation of environmental concerns into our diplomatic and security policies can help the U.S. environmental industry identify new business opportunities. However, these goals can only be realized with increased public-private partnering. As emerging nations build new capital infrastructures, the exploitable P2 market provides a significant growth opportunity for superior U.S. technologies. Economic analysis and demonstrated performance supports the benefits of pollution prevention investment and numerous financing options exist for such investment. Pollution prevention—P2—is clearly the wave of the future.

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FINANCIAL SERVICES

ABSTRACT

With an innovative and competitive financial services industry and with the nation's public finances in their best condition since the 1960s, the financial underpinnings of the U.S. economy and national defense are secure. The U.S. industry is the preeminent and worldwide leader in financial services, a technological pacesetter and market innovator. The government can ensure continued U.S. leadership in the global economic community by pressing for more open markets and legislating increased harmony among regulatory regimes. It also has an important leadership role to play in the coming international struggle to regulate trade and electronic cash on the Internet. Financial markets are operating in a new economy marked by technologies and global boundaries that are increasingly beyond the scope of regulatory authorities to understand or control.

Mr. Daniel Allen, GTE
CDR Michael Boyer, USNR
Mr. Stephen Brundage, Dept. of State
LTC Donna Dacier, USAR
Lt Col John Daly, USAF
Lt Col Daniel Dunaway, USAF
Mr. David Haas, Dept of State
COL Abdul Hadi, Malaysian Air Force
CAPT Lawrence M. Jones, Jr., USN
LTC Jeanine Lugo, USA
CDR Timothy Mulcare, USN
Lt Col George Reasonover, USAFR
LTC Martin Thomas Spainhour, USA
COL Metodija Vanevski, Macedonian Air Force
Mr. James Walke, Federal Emergency Management Agency
LTC Roy Wallace, USA

Dr. Irene Kyriakopoulos, faculty
Dr. Robert Pirog, faculty
COL Glen Lause, USA, faculty

PLACES VISITED

Domestic

Lockheed Martin Corporation, Rockville, MD
Senate Banking Committee, Washington, DC
NASDAQ, Washington, DC
Export-Import Bank of the U.S., Washington, DC
Board of Governors, Federal Reserve System, Washington, DC
T. Rowe Price Associates, Inc., Baltimore, MD
Alex. Brown & Sons Incorporated, Baltimore, MD
Washington Capital Development Corporation, Washington, DC
World Bank Group, Washington, DC
Chicago Board of Trade, Chicago, IL
Chicago Mercantile Exchange, Chicago, IL
Chicago Board of Options, Chicago, IL
Chase Manhattan Bank, New York, NY
Paine Webber, Incorporated, New York, NY
New York Stock Exchange, New York, NY
New York Mercantile Exchange, New York, NY
Prudential Securities Incorporated, New York, NY
Federal Reserve Bank, New York, NY
Bankers Trust, New York, NY
Morgan Stanley, Inc., New York, NY

International

U.S. Embassy, Paris, France
Smith Barney, Paris, France
Banque de France, Paris, France
Aerospatiale, Paris, France
U.S. Mission to the European Union, Brussels, Belgium
European Commission, Brussels, Belgium
U.S. Embassy, Athens, Greece
Euromerchant Bank, S.A., Athens, Greece
Ministry of Development, Athens, Greece
Bank of America, Athens, Greece
Hellenic Telecommunications Organization, S.A., Athens, Greece
Council of Economic Advisors, Athens, Greece
Bank of Greece, Athens, Greece
Athens Stock Exchange, Athens, Greece
Economics Department, University of Athens, Greece
Capital Market Commission, Athens, Greece

INTRODUCTION

The financial services industry is crucial to national security and an indispensable element of the nation's economic strength. An effective financial services industry pools its resources in efficient capital markets and directs them to their most productive use. The great breadth and depth of our financial markets and the vitality and innovation of the financial services industry provide the United States with a significant economic advantage over any current or emerging competitor nation.

This report sets out to study the current condition of the financial services industry, the challenges it faces, and its links to national security. Its authors conducted independent research, interviewed guest speakers, and took advantage of domestic and international travel to explore a wide range of topics including the reform of banking legislation, the role of the Federal Reserve, the growth of the mutual fund industry, reform of social security, and market valuations of defense firms.

Internationally, we investigated the changing role of the World Bank and the potential challenge of a single European currency to the preeminent financial position of the United States. We followed with special interest the industry's use of technology to cut costs and offer new products such as electronic banking and electronic cash. We raised questions about future trends, especially where financial services technology interfaces with the public and other institutions. Issues such as the privacy, security, and accuracy of financial transactions directly affect the widespread acceptance and use of new and emerging technologies.

Finally, we wanted to understand industry's response to vulnerabilities inherent within new technologies, to competition from emerging economic powers or power blocs, and to global crime (e.g., counterfeiting).

THE INDUSTRY DEFINED

Financial Services is a rapidly evolving industry. Increased competition from nonfinancial institutions, new information technologies, rapidly declining processing costs, and continuing deregulation have accelerated the pace and scope of change. The industry fulfills a number of key functions in the larger economy. It determines methods for (1) making payments; (2) pooling financial

resources; (3) transferring economic resources over time and distance; (4) managing risk; and (5) providing price information (Crane and Bodie, 1996).

Financial services is a heavily regulated industry at both the state and the federal levels. The nation's "financial infrastructure" comprises a complex set of laws, accounting standards, exchanges and clearing facilities, as well as the state and federal regulatory framework (Merton and Bodie, 1995). While nonfinancial firms (such as Ford Motor Credit and AT&T Leasing) are increasingly active in certain product niches, the sector is dominated by traditional financial services firms.

Depository Institutions

The failure of many savings and loan institutions in the late 1980s and increased competition from nonbank financial institutions led to a major consolidation within the banking sector. In fact, the number of commercial banks and savings and loan institutions has declined in each of the past eight years. Depository institutions are regulated by the Office of the Comptroller of the Currency, the Federal Deposit Insurance Corporation (FDIC), the Federal Reserve Board, and state regulatory agencies. Unlike accounts in other financial institutions, deposits in banks and savings institutions continue to be insured by the FDIC.

Securities Firms, Mutual Funds, Venture Capitalists

Securities firms mobilize corporate capital by helping corporations issue debt and equity securities and by selling these securities to individuals and institutions. Mutual funds pool financial resources from individuals and institutions and use professional management to select and purchase debt and equity investments. These pooled resources are then easily transferred over time and distance. Mutual funds have become an attractive way for individuals to invest in stock and bond markets; and they offer, at least theoretically, some safety through diversification of assets and professional management of fund portfolios. Venture capital firms also pool and transfer resources by providing equity financing to new and fast-growing companies. These firms are increasingly active overseas where they have assumed some of the roles traditionally performed by bilateral and multilateral donors, such as the World Bank.

Futures Trading

The futures industry consists of individuals and firms engaged in the offer, purchase, or resale of futures—or options contracts—for their own account or others. It performs risk management and price discovery. The futures industry also includes exchanges, such as the Chicago Board of Trade, and exchange clearinghouses.

Insurance

The insurance sector, with over $2 trillion dollars in current assets, is composed of more than 100 insurance companies selling directly to the customer or through a designated agent or brokerage house. Insurance companies are approximately half "mutual" (owned by policy holders) and half publicly traded companies. The two primary types of insurance are life and property and casualty.

Federal Reserve

The Federal Reserve is the independent executor of monetary policy. In addition to its regulatory functions, it focuses on monetary aggregates in an attempt to promote maximum employment, production, and purchasing power within the economy.

As the Federal Reserve gauges and interprets national economic data, it directs its open market activities to achieve a federal funds target rate that it believes will adjust volume of reserves in the depository system necessary to optimize employment, prices, and interest rates. Because interest rates directly affect the cost of all financial instruments, the policies and actions of the Federal Reserve are of prime concern to the financial services industry.

CURRENT CONDITION

Most of the financial services industry has enjoyed record levels of sales and profits in recent years. However, the futures industry has seen its market share seriously erode as other nations (e.g., the United Kingdom and France) aggressively promote new exchanges that offer more flexible regulatory regimes than those in the United States. Despite competition from mutual funds and other financial services, commercial

banks posted record profits in 1996. Banks have used regulatory changes, increased mergers, and technology to reduce overhead, cut costs, and develop new fee-based services. Securities firms have benefited from a record number of new stock issues in 1996, increasing corporate earnings and strengthening the demand for stocks and mutual fund shares. Venture capital firms did a record number of initial public offerings in 1996, raising $11.8 billion in fresh capital for business start-ups.

U.S. banks and securities firms are among the strongest performers in international finance. As a result of restrictions on interstate banking, U.S. banks have relatively small assets compared to foreign banks, yet they are consistently among the most profitable. In 1995, for example, Citicorp, the largest bank in the United States but only the thirty-second largest bank in the world, had the second-highest net income. And among the top 100 banks in the world in 1995, U.S. banks had the highest rate of asset and capital growth. Of the world's ten largest securities firms, six are American, and in recent years, U.S. securities firms have outperformed their closest rivals in Japan by large margins in all areas of performance: asset growth, capital growth, net income and revenue growth ("Survey of World Business," 1996).

Explosive growth in the assets managed by mutual funds is expected as the baby boom generation begins saving for retirement and as individuals of all ages seek higher returns in a low-interest rate environment. Today this industry has over $3 trillion in assets, almost half of which are in equity mutual funds—those that invest in common stocks (Woolley, 1996). Assets have tripled since 1990. There are now two stock mutual funds for every three stocks listed on the New York Stock Exchange, and trading by mutual funds accounted for 43 percent of the overall dollar volume on the New York Stock Exchange in 1996. According to Federal Reserve data, in 1995 the value of household stockholdings was $5.5 trillion compared to a total of $4.2 trillion in home equity—the first time in decades that stocks represent a greater portion of Americans' wealth than their homes (Woolley, 1996). While the share of equities in overall household wealth has risen sharply in the decade of the 1990s, rising from 18.6 percent in 1990 to 31.1 percent in 1996, it is still behind the level of the 1960s when equities accounted for 44.8 percent of household wealth (Wyatt, 1996).

Insurance companies have suffered increased competition in recent years, resulting in flatter premiums and an overall contraction of the industry. The number of insurance companies has actually declined. The insurance industry has forced competition from major corporations who

have established subsidiaries to underwrite their own insurance needs and from better-informed consumers who prefer less expensive term insurance over traditional whole life policies, which are more profitable for insurance companies. In response, the companies have consolidated business functions and cut costs through mergers and acquisitions. These responses have improved the range of investment options; insurance customers can now request mutual funds, annuities, and guaranteed investment contracts.

The excellent performance of firms dealing in traditional financial services attests to the vitality and strength of this industry. Another way to assess its condition is to ascertain how well these services are being performed in the U.S. economy as a whole. By a number of measures, the financial services sector is performing well. For the example, the cost of capital for U.S. firms is at a forty-year low (Coy, 1997). For individual households, innovations in the securities industry and regulatory and legislative changes have made more credit available—and to a wider range of the population. These changes make homeownership more affordable and put consumer credit in the hands of individuals that creditors had traditionally shunned as too risky. On the downside, the relaxation of credit standards may be partly responsible for a surge in credit card delinquencies and personal bankruptcies. Some groups continue to complain of a lack of affordable credit for business start ups and first-time home buyers.

The financial services industry has been the pacesetter in using new information and communications technologies to cut costs and spur product innovation. Innovations in financial services help firms and consumers use capital more efficiently and better mange risk ("Survey of Finance and Technology," 1996). For example, international comparisons of the relative efficiency of investments (unit of output per unit of investment) show that investments by U.S. firms are 33 percent more efficient than the investments of their closest international competitors. The structure of U.S. financial and equity markets is cited as one of the principal reasons for these results (Lewis, 1996).

The financial services industry has also been among the first to exploit the commercial possibilities of the Internet. A 1996 Booz Allen & Hamilton Banking Survey predicted that 285 banks would be "on-line" by December 1996, and nearly 900 banks would be transacting services over the Internet by December 1997. Equities trading is a natural Internet application, and during 1996 on-line trading became a staple service offered by the major brokerages. At the end of 1996, roughly 800,000 customers were trading on-line and that number is

expected to grow to 1.3 million by 1998. Insurance companies see the Internet as having a significant impact on their industry. In a survey conducted by IBM, 75 percent of the insurers surveyed believed that the growth of the electronic marketplace will have a greater impact on the industry than all other competitive factors, including insurance deregulation and increasing competition from banks.

CHALLENGES

The U.S. financial services industry is the most competitive in the world, and it has been a key factor in the strong performance of the U.S. economy in recent years. However, major changes in the economic environment will soon challenge the industry to find new and more efficient ways to perform its role within the global economy. The most significant challenge for the industry—indeed the nation—involves financing the baby boom generation's retirement—including reform of the Social Security System. Other challenges also loom: the emergence of a single European currency and monetary policy; the growing threat of global financial crime; and the larger role for private banks, mutual funds, and the financial markets in channeling investment to developing countries.

Social Security

The financial health of the Social Security System will play a key role in financing the baby boom generation's retirement. Although the program currently enjoys a significant funding surplus, expenditures to satisfy promised benefits will exceed projected revenues within fifteen years. Demographic forces, including aging boomers, declining birth rates, and increasing life expectancies are converging. Soon, the ratio of workers to retirees will be 2 to 1, rather than 3 to 1 as it is now.

In 1993, President Clinton appointed a thirteen-member Advisory Council to review and monitor the Social Security System with an emphasis on its need for long-term financing. The Advisory Council developed three recommendations that would have had significant effects on the financial services industry, but was unable to reach consensus on any one of the recommendations. Their recommendations included extending the benefit computation period from 35 to 38 years; raising the age of eligibility for full retirement benefits from 65 to 67, and eventually to 70; and establishing new rules to tax more of an

individual's Social Security benefit. The Advisory Council also outlined three methods for balancing Social Security finances:

- The first method calls for the federal government to invest all social security funds directly into the stock market, thus making Uncle Sam the world's largest stockholder.
- The second method would establish a new 1.6 percent tax on Social Security wages and require people to invest in a half dozen or so government-sponsored stock funds.
- The third method would require workers to save 5 percent of Social Security wages in accounts holding publicly traded securities. It would also require the government to borrow as much as $7 trillion to repay money it invested rather than distributed to retirees, and increase the current 12.4 percent tax by 1.52 percent (to 13.92 percent) to fully fund this solution.

Counterfeiting

Many government and financial experts view counterfeiting and money laundering as major challenges to the financial services industry over the next several years. According to some estimates, the counterfeiting of U.S. currency has doubled in the last four or five years. It is the most popular target for international counterfeiting because it is widely used abroad and lacks updated security features.

High foreign inflation rates and the relative stability of the dollar contribute to its increasing use outside the United States, especially in Russia and the Commonwealth of Independent States. OfU.S.$380 billion in circulation, the Federal Reserve estimates that 60 to 70 percent may be circulating outside the United States. Excluding two changes introduced in 1990 and 1993, the dollar's overt security features have not changed substantially since 1929 (GAO). Widespread counterfeiting undermines confidence in our currency, and if done on a large enough scale, could have a negative effect on the U.S. economy and threaten national security.

New financial services that incorporate emerging information technologies introduce new and complex challenges. Concerns about security, privacy, and accuracy have impeded rapid adoption and acceptance of electronic commerce. As electronic commerce proliferates, governments must determine how to tax on-line transactions so that they do not erode the conventional tax base. If electronic cash can potentially alter the way the money supply is measured, it could reduce the government's role as the controller of the money supply.

A Single Currency

The development of a single European currency and its effect on U.S. and global prosperity is another challenge facing the financial services industry in the coming years. Under the Maastricht Treaty, the European Union's participating nations will begin the shift to a single European currency (the Euro) on January 1, 1999. They will also designate a European Central Bank responsible for monetary policy within countries joining the European Monetary Union (EMU).

Whether the EMU will have a positive or negative effect on the U.S. economy and the financial services industry will depend on the extent to which the monetary union fosters a stronger European economy. In this decade, Europe's sluggish economic performance has acted as a brake on U.S. exports, and continued recession and record unemployment in Europe could threaten its support for an open global trading system. Many believe that the answer to Europe's long-term economic difficulties lies in market-oriented reforms, especially of labor markets, which the EMU does not address. However, under the monetary union, member governments will forgo the ability to pursue independent monetary policies, and the use of fiscal policy to counter unemployment will be severely restricted. European governments may then be forced to undertake economic reforms that are long overdue. If so, a more competitive and prosperous Europe may result, with beneficial consequences for both U.S. traders and investors. U.S. financial services companies are already active and well-positioned in Europe to take advantage of these developments. Indeed many are predicting a decade of economic reform and corporate restructuring on the continent.

The EMU and the Euro may affect the role of the dollar as the world's primary reserve currency. Since the breakdown of the Bretton Woods System in 1973, the dollar's share of official currency reserves has gone from 76 percent to about 65 percent (Summers, 1997). Under the EMU, the European Central Bank will need dollar reserves only to defend the value of the Euro, as it will be unnecessary for each national central bank to defend the value of each national currency. While this may lead to a reduction in the total amount of dollar reserves held in Europe, the process is expected to be gradual and will ultimately depend on the success, not of the monetary union, but of the larger European economy. In any event, official government holdings of U.S. currency account for less than five percent of the continent's total financial assets;

therefore, the actions of private investors will be more significant than those of European authorities.

Global Challenges

Another challenge facing the financial services industry arises from the new openness of developing countries and former socialist economies to foreign investment, and their return of large industrial sectors to private ownership. This development has unleashed a flood of private capital to developing countries, estimated at $224.8 billion in 1996—five times larger than the funding released from multilateral development banks and bilateral donors.

Although they are a powerful boost to economic development, these massive flows of private capital are changing the traditional relationships between the governments of developing countries and the Bretton Woods institutions (i.e., the World Bank and the International Monetary Fund) which heretofore dominated the flow of capital and technological knowledge to the developing world. As the 1994 peso crisis demonstrated, these capital flows move in both directions, and impediments not only devastate the local economy; but also, at least potentially, destabilize world financial markets. A substantial fraction of the local stock and bond markets in many countries is controlled by foreign investors, often operating through mutual funds. The judgments of these fund managers and international financial markets can be swift and unforgiving for the local economy if government policy and economic performance fail to reach expectations.

OUTLOOK

The outlook for the U.S. financial services industry is highly positive. Depository institutions have successfully emerged from the savings and loan crisis with record profit levels. Banks have amassed capital reserves well above international standards and the financial services sector in general has become a technological pacesetter and market innovator.

The industry's future will be shaped, however, by strong demographic forces, higher rates of savings and investment, and funding crises in "pay-as-you-go" pension schemes. Whatever decision is made on social security reform, the financial services industry is almost certain to benefit as more income is channeled to investment vehicles offered by

the industry. Opinion is divided concerning an ultimate solution to the social security crisis, but within the financial services industry, a surprising level of skepticism prevails regarding plans to privatize social security by allowing individuals to invest their social security contributions in the stock market. This skepticism is shared by Federal Reserve Chairman Alan Greenspan, who does not believe that moving trust fund investments out of government bonds and into stocks will fix the retirement system's finances, and could actually depress investment returns (Berry, 1996). In any event, a slight upturn in the savings rate and the flow of funds into long-term, retirement-related investments in mutual funds indicate that the baby boom generation, slowly but surely, is beginning to save for retirement.

The outlook for financial services can also be up or down depending on further changes in government regulation. Congressional deadlock on banking reform combined with increasingly activist and competing regulatory bodies has already led to the defacto repeal of Glass-Steagal restrictions on commercial banks. The Federal Reserve and the commercial banks are seeking new ways to assure the safety and soundness of U.S. banks by developing regulatory and management approaches based on the level of risk in loan portfolios (Rivlin, 1996). Changes are also likely in the regulation of futures markets as this industry faces further declines in its global market share. Petitions for regulatory changes in the U.S. futures markets will be internally driven.

As overall trade in financial services is liberalized, attempts to harmonize financial regulations will be made, especially between financial and futures markets among the principal countries. Since U.S. regulations tend to be among the strictest in the world (consider, for example, regulations concerning financial disclosure for firms listed on the U.S. stock exchanges), these efforts at harmonization could result in some lessening in U.S. standards.

The gradual opening of foreign markets to U.S. financial services and economic reforms and corporate restructuring in Japan and Europe will present extraordinary opportunities for U.S. companies. They can also expect to be particularly active in Europe over the coming decade if, as expected, a single currency leads to the kinds of corporate consolidations that the U.S. industry experienced in the 1980s and early 1990s. The deregulation and opening of financial services and insurance firms in Japan has already benefited U.S. firms and presages a wider move across Asia where the financial services sector has generally suffered from excess government regulation and a flight from foreign competition.

While changes in the foreign regulatory environment will present great opportunities to U.S. firms in the short term, they will eventually give rise to stronger, more competitive overseas rivals. In areas that have been deregulated for some years (such as futures trading), European futures markets and trading firms have become increasingly competitive and are taking market share from the U.S.

The eventual role of the Euro in the international monetary system and the disposal of excess dollar reserves held by European central banks will be the subject of G-7 and transatlantic consultations in the coming months and years. Already, G-7 finance ministers and central bank governors, including the U.S. delegation, have expressed support for the Euro. During the first months of the EMU, a large volume of capital will no doubt move in and out of the Euro area with possible fluctuations in the exchange rate between the dollar and the Euro. Although the Maastricht treaty is not clear on who should act in the event of an exchange rate crisis, the G-7 can be expected to set at least an informal range for the value of the Euro vis-à-vis the dollar (Henning, 1996). Both private sector and government sources have indicated that American and European central banks will cooperate to ensure an orderly disposal of excess dollar reserves held in Europe.

As noted earlier, U.S. investment funds are seeking diversification and higher returns in developing economies newly open to private foreign portfolio investment. The scale of these capital movements is likely to remain very large, especially in China and other fast-growing Asian and Latin American economies. Beyond potential losses to U.S. investors, this situation also contains the risk of a potential collapse of local economies and even negative repercussions for international financial markets. The International Monetary Fund and its principal shareholders, including the United States, are rushing to catch up with these developments, particularly in the wake of Mexico's financial crisis two years ago (1995). This event dramatized the extent to which developing countries rely on private capital and the favor of global financial markets. To avoid a repeat of the Mexico crisis, the Fund has stepped up its surveillance of key developing economies and now prods developing countries to increase access to the status their public finances. It has also established an escrow fund of $28 billion to lend on an emergency basis should another crisis develop.

As the information technology revolution continues to advance, the financial services industry is developing electronic commerce applications that embrace new technologies and integrate them into standard business practices. Electronic cash and Internet commerce have

the significant potential to change how commerce is conducted. Cash changes hands 300 billion times a year in the United States, and the general care and feeding of our currency drains tens of billions of dollars from the economy merely to pay for its printing, shipping, safeguarding, vending, collecting, and counting. The technology of the information age has given us electronic cash or smart cards as an alternative to cash. This alternative is the first to truly replicate the instant and unaccounted transfer of value that is the function of cash. Smart cards are credit cards, debit cards, key cards, and others made with enhanced internal microprocessors capable of holding more information than traditional magnetic stripe cards. The card can be used as an electronic purse that can be loaded with "value" that is stored in the card's memory until it is needed to purchase goods or services.

The Internet, too, is rapidly being transformed into a thriving component of the global marketplace. The Internet, now used by a critical mass of businesses and consumers, is possibly the most revolutionary development for commerce in this century. Many retail outlets have created web pages offering product information and sales over the Internet; by the end of 1997, over 900 banks are expected to be on-line. As many as 800,000 people executed on-line stock trades in 1996, and that number is expected to top 1.3 million in 1997.

The financial services sector is similarly well positioned to support national security requirements insofar as the range and depth of financial markets are needed to provide the government with flexible and relatively low-cost access to world capital markets. Military strength, of course, and the financial strength and overall industrial capacity of the United States, play key roles in deterring potential aggressors. The support for national security that comes from the financial services sector goes beyond resources and capabilities (including the capabilities of the financial services sector which is the most competitive in the world). It is rather the support of being able to trust sound public finances and the political will of elected authorities to allocate the necessary national resources to defense in peace and war. Thus, the recent progress toward achieving a balanced budget relieves the pressure of government borrowing on financial markets and encourages lower interest rates and higher stock and bond prices. Fiscal restraint and a prudent monetary policy are accomplishing a level of employment gains and price stability that have not been seen since the 1960s.

Nevertheless, prospects for financing the defense industry are mixed. The reliance of defense firms on investor and market sentiment to raise capital makes the financial health of these firms a direct condition of the

nation's ability to raise adequate amounts of funds for researching and developing new weapons. Without financial capital, defense firms cannot fund research, capital improvements, or technologies to ensure the economic viability of important defense industries. To measure earnings potential, the financial services industry predominately watches the defense budget because the relationship between the government and the defense industry is not a normal free market (Gansler, 1996). The defense industry is highly regulated; the government plays a direct role as both buyer and producer—and sometimes as supplier. Above all, the government sets the allowable profit margins the defense industry can realize on the products it sells to the military.

In the early 1990s, defense stocks rose significantly despite a declining defense budget because the defense industry was making money through a strategy of cost cutting and consolidations. The second half of this decade may tell another story. Defense's capital and research accounts have already been cut to zero, and its consolidation options are also largely exhausted. Therefore, the defense industry will have difficulty competing for investor dollars against firms in the civilian sector where most of the high-tech research and development will take place. In terms of national security, we cannot reasonably expect the defense industry to stabilize until the defense budget does.

In sum, the secular forces of aging baby boomers, increased life spans, and the rapid growth of defined contribution retirement plans all point to future increases in equity investments. The convenience and daily liquidity offered by mutual funds suggest that mutual funds will play an increasing role as the investment vehicle of choice. They will also play a key role in assisting the boomer generation to assume a larger individual role in financing retirement—with or without the so-called privatization of social security. In addition, as official development assistance recedes and private international capital flows increase, mutual funds will increasingly be the conduit in which capital is transferred from savers in the developed world to economies in developing countries.

The problems and opportunities associated with the growth of the mutual fund industry affect the future of this nation and its economy even if the implications of this growth are unclear at present. As more and more of the nation's wealth becomes tied up in the stock market, what will happen during the next bear market? Contrary to popular belief, no mass exodus from stock mutual funds occurred during past bear markets, and throughout the 1990s investors have been rewarded for remaining invested despite several market corrections. Following the

1987 stock market crash when many calls to mutual fund companies went unanswered, mutual fund companies upgraded their phone systems and greatly expanded their menu of customer services. Companies have also expanded consumer education and the Securities Exchange Commission has introduced changes to mutual fund reports so that investors can better understand the risks associated with particular funds. The Federal Reserve constantly monitors the financial markets and during the crash of 1987, its quick action in providing liquidity and assuring banks that it would continue to do so calmed the markets and fostered a quick rebound.

The capital available in mutual funds is, moreover, an essential source of investment in the nation's technological base. In an era of declining or stable defense budgets, this capital becomes an increasingly important source of new technologies that may have important commercial and defense applications. As the government becomes more open to using commercial technology, this private source of capital will become a determining factor in the modernization and vitality of the nation's armed forces.

GOVERNMENT GOALS AND ROLE

Government regulators are concerned to strike a balance between safety and efficiency in financial markets. Increasingly, regulators must also assess the impact of their actions on the international competitiveness of the American financial services industry. At the same time, a system of state and federal banking regulators with multiple regulatory bodies such as the Federal Reserve and the Office of the Comptroller of the Currency has led to confusion and even competition among regulators, particularly at the federal level. Regulation is an important factor in the overall competitiveness of U.S. financial services firms. On the whole, U.S. regulations ensure important protections for investors; due diligence, disclosure, and full financial accounting have helped make U.S. financial firms the most competitive in the world. Other parts of the financial sector, however, such as the commodities exchanges, believe that current U.S. regulations are making them less competitive internationally as other nations develop markets based on fewer regulations.

The principal focus for government regulators in recent years has been the reform of the National Banking Act of 1933 (the Glass-Steagall Act), which prohibits Federal Reserve System member banks from

"affiliating with entities that are engaged principally in underwriting or otherwise dealing in securities" (Fed. Reserve Bd. of Gov., 1994). As recent attempts in Congress to rewrite the National Banking Act have thus far failed, regulators have moved ahead to reduce the prohibitions. In 1996, the Federal Reserve Board removed some of the barriers that separate banks from securities affiliates; that is, it gave commercial banks more freedom to market and develop investment products in competition with investment banks that dominate securities underwriting. At the close of 1996, the Office of the Comptroller of the Currency issued rules allowing national banks to apply for expanded powers to underwrite and sell securities and insurance and to market financial products not previously tested by banks.

The argument for the repeal of Glass-Steagall centers on the contention that the existing prohibitions address the inadequacies and irregularities of a system that no longer exists. Technology, financial globalization, and market innovations have created an economic environment that is vastly different from conditions operative in the 1930s. The Federal Reserve Chairman favors certain relaxations, but warns against rewriting legislation that may undermine the authority and ability of the Federal Reserve System to conduct monetary policy, assure an effective payment system, and address crises.

During the last decade, commercial banks have faced stiff competition from nonbank financial services firms, as increasing numbers of depositors turn to mutual funds as their preferred savings vehicle. Further, with investment houses enabling investors to draft checks against investments, banks see themselves competing on an uneven playing field. Investment bankers and securities dealers, on the other hand, seek to continue current prohibitions, citing what they believe is an inherent conflict of interest should banks be allowed to engage in underwriting activities. These objections focus on an assumption that banks would actively promote the securities they underwrite, rather than offer their customers disinterested advice. Investment houses are also concerned that banks might attempt to persuade troubled commercial loan customers to issue securities as repayment. An additional concern, shared by current and former heads of the Federal Reserve (Greenspan and Volker), is the degree to which the Federal Reserve financial safety net (deposit insurance and access to credit at the discount window) will be extended to nonbanking affiliates.

On another front, the Secretary of the Treasury is currently weighing a proposal to allow banks to own and be owned by commercial

companies (as is the case in Europe and Japan). Stiff opposition to this proposal exists, however, in the Senate Banking Committee.

Another critical and often unappreciated role of the government involves the collection and dissemination of economic statistics—the numbers on price and wage inflation, housing starts and industrial production that move billions on the financial markets each day. Both government and private-sector officials have expressed doubts over the reliability of current statistics (on price inflation and productivity for example). The consequences of inaccurate statistical data for economic policy and the nation's prosperity are obvious. The Boskin Commission as well as other economists believe that the Consumer Price Index systematically overstates inflation, which leads to excess government expenditures and reduced revenues.

Government and the private sector are also concerned that no statistical measures seem adequate to capture output and productivity in the rapidly expanding information and services sectors of the economy. Monetary authorities are beginning to manage interest rates more cautiously, given the gaps in economic statistics and signs that the information-based economy and the competitive pressures of deregulation and globalization may be altering long-standing relationships between output, employment, and price stability.

As part of a general reduction in government expenditures, Congress and the administration have reduced the demand for statistical surveys. The Federal Reserve has filled in some of the missing statistics, but cannot be expected to gather large amounts of economic data. Others have suggested a joint industry and government approach to the problem of (1) identifying appropriate measures to assess output and productivity, and (2) collecting those statistics on a reliable and cost-effective basis.

The government will play a large role in determining whether electronic commerce fulfills its promise to provide lower cost transactions to millions of consumers around the world. Although regulators are quick to point out that they cannot establish regulations for that which does not exist (for example, an electronic cash system without links to existing regulated financial institutions), the Federal Reserve is studying the potential implications of electronic cash on how money supply aggregates are measured and how the electronic system may affect monetary policy. Internationally, the United States has aggressively promoted a free trade approach to the Internet. The Clinton administration and Congress have made proposals for duty-free Internet commerce.

CONCLUSION

The U.S. financial services industry is the preeminent leader in the world today, a technological pacesetter and market innovator ready to penetrate newly opened financial markets. As other nations catch up, they may experience the same phenomena (e.g., nonperforming loans, corporate mergers, increased automation, and product innovation) that shook the U.S. economy during the 1980s. Thus, the American financial services industry is well positioned to bring its unmatched expertise to bear in foreign markets. Second, as more nations turn to market-based solutions to solve their economic needs, they are but copying American financial institutions and practices. This condition also opens up new opportunities for the entire range of U.S. financial services companies. Other parts of the industry, including U.S. stocks, futures, and regulators, will be increasingly called upon to provide technical assistance to other governments as they reform their financial infrastructure.

The dollar remains the world reserve currency of choice and the preferred medium for international commodities transactions (such as oil), which helps finance our debt and foreign trade. Although some believe that a single European currency may one day rival the dollar as a reserve currency, the dollar's privileged position in world finance developed over much of this century and persists despite a significant drop in the U.S. share of total world output in the decades since World War II. Beyond economic factors, the dollar's status also reflects this country's unmatched political and military power. According to Under Secretary of the Treasury, Larry Summers: "[T]he relative position of the dollar in the system is likely to depend more on developments in the United States than in Europe or Japan. If the United States maintains strong and credible policies, the dollar will remain a sound currency. The fate of the dollar is still largely in our own hands" (Summers, 1997).

Our government needs to ensure continued U.S. leadership in the global economic community. In its address to the world, it must press for more open markets; at home it must seek increased harmony among all regulatory regimes affecting financial services. The U.S. government will likely determine how the international community will regulate electronic cash and international trade on the Internet. It should insist that international financial and law-enforcement authorities enact additional measures to combat new (Internet-related) and traditional financial crimes, such as counterfeiting and money laundering.

The financial services industry has entered an era of rapid change and extraordinary money flows into financial markets. New products and services are proliferating at an astonishing rate. Impelled by the profit motive, financial services firms are restructuring, rapidly incorporating new technologies, reducing their overhead costs, and providing more competitive services. In many respects, our financial institutions are operating in an economy that is beyond the ability of their regulatory institutions to fully comprehend. Traditional econometric models do not accurately portray the interplay of economic forces in the new economy.

What is clear is that information technology permeates all levels of financial services and represents a significant and growing share of the total U.S. economy. Today's financial services industry is completely dependent on this technology. Its mastery permits U.S. markets and financial services to operate beyond traditional models with great vitality and creativity. The American financial services industry will continue to be a major contributor to the economic dimensions of national security and power.

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HEALTH CARE

ABSTRACT

A healthy population is a national resource that contributes to the overall productivity of the American economy. Health care is part of the service sector and an instrument of national power—a fundamental support of the national security strategy for the citizens and the Armed Forces. The challenges facing the health care industry in the public and defense sectors are congruent. Access to affordable, quality care is fundamental to any health care delivery system. In this era of constrained and competing resources, the need arises for a general public policy debate about the future of health care and the possibility for, and direction of, a gradual, but comprehensive reform. The greatest challenge to military medical capability is maintaining the resources, structure, modernization, and sustainability of medical assets, including the right people, training, and equipment. But an even greater challenge to the industry is to remember that the patient and human need are its "raison d'être."

LTC Larry E. Campbell, USA
Dr. Dennis M. Conlon, Dept. of the Navy
Ms. Mary E. Forbes, Dept. of Defense
CDR Marshall A. Hall, USN
CDR E. Scott Hebner, USN
Mr. Austin P. McHale, III, Dept. of State
COL Dimiter Minchev, Bulgarian Army
Lt Col Michael J. Muzinich, USAF
Mr. Michael J. Safina, Dept. of the Navy
Col James H. Sammons, Jr., USAF
COL Patricia A.H. Saulsbery, USA
Lt Col William R. Saunders, USAF
CDR Daniel J. Snyder, USN
LTC Robert M. Speer, USA

COL Arthur W. Hapner, USA, faculty
Dr. William A. Knowlton, Jr., faculty
Dr. Samuel S. Rea, faculty

PLACES VISITED

Domestic

Highmark Blue Cross Blue Shield, Pittsburgh, PA
University of Pittsburgh Medical Center, Pittsburgh, PA
- Center for Biotechnology and Bioengineering
- Center for Biomedical Informatics
- University of Pittsburgh Cancer Institute

US Army Medical Research and Material Command, Ft. Detrick, MD
- US Army Medical Research Institute of Infectious Diseases
- US Army Medical Material Agency
- US Army Medical Material Development Activity
- US Army Medical Research Acquisition Activity
- Medical Advanced Technology Management Office
- Defense Medical Standardization Board
- Air Force Medical Logistics Office
- Navy Medical Logistics Command

National Naval Medical Center, Bethesda, MD
Uniformed Services University of the Health Sciences, Bethesda, MD
Baxter International, Deerfield and Round Lake, IL
Allegiance Healthcare Corporation, McGaw Park, IL
Siemens Medical Systems (Imaging Systems Grp.), Hoffman Estates, IL
Cook County Hospital, Chicago, IL
American College of Healthcare Executives, Chicago, IL
American Medical Association, Chicago, IL

International

Guy's and Sir Thomas's Medical and Dental School, London, UK
British United Provident Association, London, UK
Royal Defense Medical College, London, UK
Disaster & Emergency Med. Ctr., Sodersjukhuset, Stockholm, Sweden
Surgeon General, Swedish Armed Forces, Stockholm, Sweden
ADA Aktiebolag, Stockholm, Sweden
Apoteksbolaget AB, Defence Section, Stockholm, Sweden
University of Heidelberg, Kopfklinik, Heidelberg, Germany
USAEUR, Command Surgeon, Heidelberg, Germany
USEUCOM, Patch Barracks, Stuttgart, Germany
Siemens AG, Erlangen, Germany
Hoechst AG, Frankfurt, Germany

INTRODUCTION

This report assesses the health care industry from the perspective of national security. In that framework, health is an element of national power and a support of national security strategy and policy. It has domestic and international environmental components that are intricately woven into the values of the nation. The military, economic, and political forces and resource constraints on this industry are described in the context of its current condition, challenges, and future prospects. In response to an increasingly interdependent world, the Secretary of Defense has outlined the need for America to fulfill a global leadership mandate based on sound defense policies and budget priorities.

Health care is part of the service sector. Though not a traditional instrument of power, health care acts as a military force multiplier as its application to members of the Armed Forces protects their military preparedness in both peace and war. Technological innovation, leadership, and the quality of our Armed Forces present a formidable power. This showing involves health promotion and physical fitness as well as the development of soldier enhancements in the field. Military medicine has touched some aspect of every American's life, either directly or indirectly, through medical research and development. Readiness support for combat troops and the U.S. Department of Defense (DoD) beneficiary mission comprise the military health care mission. Factors affecting the civilian health care sector also influence the military health care system. The two go hand in hand.

Economic forces are significant—not only from the perspective of resources spent and generated by the industry, but also as money spent by the government for its citizens' health, most notably, Medicare and Medicaid spending. The impetus to balance the budget and the funding crisis that looms over Medicare (the coming explosive growth of the senior citizen population) are primary concerns. Competition for the scarce resources in health care's share of the economic pie will continue to be fierce.

Political dreams for some type of national health insurance began with Theodore Roosevelt in the early 1900s. The Clinton Administration's 1994 comprehensive health-care reform initiative was a revolutionary but unsuccessful attempt to change a massive system that now touches everyone in the United States. Further efforts by the 104th Congress to reduce the rate of growth of Medicare were also stymied. Clearly, however, with the future health and direction of the nation at stake, a gradual but comprehensive reform is needed.

THE INDUSTRY DEFINED

The health industry consists of public, private, and nonprofit organizations that deliver health care. Medical equipment and device manufacturers, pharmaceuticals, and administrative services also make up the industry. The focus of this report is on direct care, that is, on delivery systems serving the civilian and defense sectors. Types of delivery system organizations include hospitals; nursing homes; specialized health care facilities; and managed care organizations (such as health maintenance organizations, preferred provider organizations, and physician sponsored organizations. Community hospitals are in transition as average length of stay decreases and medical procedures in general are shifted to the ambulatory setting. Technology, information networking among health care organizations, and the expansion of managed care contribute to this hospital transformation. In response, the hospital industry is decreasing inpatient bed capacity. Between 1985 and 1995, the number of U.S. hospital beds declined by 12.8 percent (AHA, 1996).

The health care system in the United States is a market-based system that generates about $1 trillion per year in goods and services or 13.6 percent of the Gross Domestic Product (GDP). In 1995, health expenditures in this country reached $988.5 billion or $3,621 per person annually (HCFA, 1997). These numbers are the highest worldwide, both in dollars per capita and as a percentage of the GDP. In comparison to Japan, Sweden, Germany, Canada, and the United Kingdom, the United States spends over $250 billion per year more than the next most expensive system. Health care in the United States also uses more technology than other developed nations and has a unit cost per hospital bed that is 62 percent higher than Canada, the next highest country (Bok, 1996). That the cost per incident of hospital care has remained relatively stable over the past three years is related to the influence of managed care in containing real prices (Heffler et al., 1996).

Purchasers of health care include individuals, business, labor, and government. Government or public-sector spending has increased at a higher rate than the private sector. Medicare and Medicaid programs accounted for $0.33 of every health dollar spent in 1996 (Aston, 1997). The slower growth in private health insurance spending is related to the growth of managed care with its focus on preventive care, the

elimination of unnecessary services, negotiated discounts, and smaller copayments (HCFA, 1997).

In 1995, over 4.2 million workers (or full-time equivalents [FTE]) were employed in the hospital setting (AHA, 1996), and growth in health services employment was an important source of job creation, particularly in the private sector. Growth in home health services led the industry but this market may soon be saturated. It has also been identified for Medicare cost containment and regulatory oversight (Heffler et al., 1996). Over the past decade, as measured in the aggregate nationally, the number of hospital FTEs has declined. This decline is attributed to efficiencies in response to managed care, capitation, and other fixed reimbursement plans (AHA, 1996).

Defense Health Care

The Defense Department's Military Health Services System (MHSS) provides medical services to active duty members during war and peace and extends health care to the families of active duty personnel, military retirees, family members, and survivors. Among the nation's largest health care systems, the MHSS provides benefits to about 8.2 million people at a cost of over $15 billion annually (U.S. House of Rep., 1997). Its primary mission is to maintain the health of the 1.7 million active-duty personnel and to deliver care during times of war.

The Defense Health Program (DHP) uses over 100,000 military members and 43,000 civilians in 417 clinics and 115 medical centers and hospitals worldwide. The DHP also manages an insurance-like program called the Civilian Health and Medical Program of the Uniformed Services (CHAMPUS) and a nationwide managed-care program called TRICARE to provide medical and dental services.

Since 1987, base closures and realignments have reduced U.S. military hospitals by 35 percent; yet the number of eligible beneficiaries decreased only by 9 percent. In addition, the composition of the beneficiary population is now more than 50 percent retirees who often require more care than active duty personnel. Demand has begun to exceed the MHSS capacity to deliver care (OSD, 1997).

In operational terms, the services are jointly responsible for meeting the medical requirements of the combat theater through training, supplying, and equipping a medical force that can be mobilized and deployed as needed to support two, nearly simultaneous major regional contingencies (MRC). The echelons of medical support in the theater range from combat lifesavers to hospitalization. The role of medicine

during field operations requires the professional staff to seek dedicated training to maintain their level of competence—whether on board a ship, within a temper tent, or near an airfield. Efforts to provide the proper medical coverage at the right time and place are not Service specific. Rather, the closest and most appropriate medical unit will provide the required level of casualty care. Operational medicine is the heart of health care for our soldiers, sailors, marines, and air force personnel.

CURRENT CONDITION

Access, cost, and quality remain the key parameters for discussing the health care industry, whether one's framework is the civilian or the defense health care system.

Civilian Health Care

Access to health care in America is related to health insurance, which for the nonelderly is related to employment. In 1994, 63.8 percent of the nonelderly were covered by an employment-based insurance plan. In 1995, 40.3 million nonelderly adults or 17.4 percent of the population was uninsured. This group consistently includes young and middle-aged adults who do not have access to public or private insurance. Over 52 percent of these Americans work full time. About 25 percent of retail, self-employed, and service workers are uninsured. The trend of growth in the service sector, increased use of independent contractors, and part-time workers, will increase the number of uninsured. Those who lack health insurance often lack primary care as well, which leaves many minor problems untreated. Often such minor problems will erupt into larger, more serious problems that lead to costly emergency visits. Hospitals provide emergency care to the uninsured and are partially compensated through tax subsidies and cost shifting to other third-party payers. Under current financing trends of capitation, fee scheduling, and discounting, the provision of care to the uninsured has become even more expensive for hospitals (AHA, 1996).

Medicare (federal) and Medicaid (federal and state) programs were implemented in 1965. Medicare offers health insurance for retirees age 65 and over, and Medicaid covers the indigent and certain chronically ill individuals. Medicare spending, one of the nation's largest entitlement programs, was $197 billion in 1996, and current projections are that this expenditure will grow at 9 percent a year. Unless Congress takes

corrective action, the Medicare insurance trust fund will be exhausted in 2001 (GAO, 1997). Recent proposals have emphasized moving both Medicare and Medicaid program recipients into managed care plans as a mechanism to decrease costs and control access for these patients (Salisbury and Fronstin, 1996). As of November 1996, 4.7 million Medicare beneficiaries were enrolled in managed care—an increase of 30 percent (Fried, 1996).

Managed care consists of integrated networks of providers, hospitals, long-term care facilities, ambulatory care centers, home care, medical insurance, and ancillary services. While not new, this type of service is rapidly growing within the industry. Traditional indemnity insurance was essentially patient risk sharing, without cost controls—if costs escalated, then premiums were raised. Managed care offers prospective, at risk financing, that motivates health care providers to find lower cost practices and trim excess use. In recent years, competition has dramatically altered the health care market, primarily through the growth of managed care and vertically integrated health care networks. These strategies have concentrated market power in fewer and fewer companies. Competition has its benefits: it brings efficiencies into the system and slows the overall rate of growth in health care costs. However, the system has other needs besides competition: it must also balance between cost, access, and quality of care (Schactman and Altman, 1995).

As health care costs have risen since the 1970s, health care providers are being challenged to reduce costs. Consequently, providers must apply fundamentally sound business practices to the health care market, including measures to integrate services, reduce inventories and excess capacity, and limit procedures. Trends include the following:

(1) The increased development of integrated health care service networks occurs primarily between delivery and financing systems. Other members of the industry, however, such as medical equipment manufacturers, are now becoming involved in management services. These integrated organizations focus on ways to work with their customers to increase the system's efficiencies. For example, they help hospitals redefine internal processes to reduce operating costs.

(2) Average inpatient length of stay is declining at community hospitals as a result of managed care practices, technological innovation, and advances in surgical intervention. In turn, shorter stays create an excess of hospital beds. Community hospitals nationwide experienced a drop of 3 percent in bed days last year, yielding an overall hospital occupancy rate of only 60 percent (Aston, 1997). Economic figures for

the first quarter of 1996 indicate a continued declining adult occupancy rate of 2.3 percent. If, as expected, this trend continues, hospitals may experience as much as a 34 percent decline of inpatient days by 1999. This outcome will create tremendous market pressure on hospitals to further reduce excess bed capacity (Sensenig and Heffler, 1996).

(3) Patients express a greater willingness to try alternative medicines and therapies to prevent sickness or self-treat. In 1990, Americans made approximately 425 million visits to providers of these alternatives as compared to 388 million visits to primary care physicians. Most of these visits were for chiropractic, acupuncture, vitamin therapy, and massage services that are generally provided at a lower cost (Campbell, 1997). Patients as well as managed care programs appreciate the cost and treatment benefits of these alternatives. In addition, these visits reinforce an increasing focus on community wellness.

(4) State governments are increasingly involved in the provision of benefits under private health insurance plans. They have enacted legislation requiring employers to provide health insurance for certain benefits. These benefits usually involve mandatory minimum hospital stays and mandatory diagnostic testing for Medicaid recipients and health insurance providers (Davis et al., 1990). Alternatively, Oregon has begun a test program to limit or ration health care services in response to cost concerns.

Defense Health Care

Military preparedness or capability must include a fit and ready force that has the necessary force structure, modernization, and sustainability to respond when needed. Because the combat service support role of health services is critical in both peace and war, the Office of the Assistant Secretary of Defense (OASD) for Health Affairs (HA) developed the Joint Health Service Systems (JHSS) Vision 2010. This strategic plan covers Command and Control (C2), hospitalization, primary care, evacuation, preventive medicine, logistics, blood supplies, combat stress control, dental services, and veterinary issues. The enhanced capability of C2 in medical services will have dramatic effects on medical services and information systems during war time. JHSS Vision 2010 is a jointly focused strategy that employs a light, mobile and more capable force designed to provide essential care in theater and definitive care in the United States. Strategic lift capability is essential to support this strategy.

The DoD currently faces several military health services challenges, one of which is the continuing pressure to downsize the MHSS. Government-mandated studies such as The 733 Study (OSD, 1994a) have recommended reducing personnel and facilities—by as much as half in some cases.

Service experts believe, however, that these studies did not fully address the military's medical needs, particularly readiness requirements. Concerned that the day-to-day forward deployment and overseas missions of the Sea Services may not be fully resourced, the Navy developed the Total Health Care Support Readiness Requirements (THCSRR) model to define minimum Navy operational medical personnel requirements in both peace and war time. The THCSRR demonstrated a requirement to retain about 95 percent of the Navy's medical end strength (Weber, 1994). The Army, likewise, developed a model: the Total Army Medical Department Personnel Structure Model (TAPSM). The Army used the TAPSM to validate the Army medical department's personnel requirements and to develop its human resource needs by reviewing its mission. This mission includes combat health support, command and control support infrastructure, and worldwide sustaining base health care services. Similarly, the Air Force developed the Air Force Medical Services Reengineering and Rightsizing Initiative to determine its requirements.

The OASD (HA) also convened a triservice working group to develop a model that would fully define operational medical requirements. The result was a comprehensive analysis of medical requirements that demonstrated that the medical force structure could be reduced by 10 to 30 percent per Service, but recommendations of 50 percent were not feasible (OSD, 1994b).

DoD efforts to outsource the medical supply and delivery responsibilities previously performed by the military show encouraging results in the peacetime environment. The Prime Vendor (PV) program continues to yield tremendous savings in the warehousing and handling costs previously borne by an inefficient centralized system. This program also shortened the logistics pipeline and increased reliability in acquisition. The program has become a critical peace and war time partnership with private industry.

In peace time the outsourcing program is responsive to the needs of the military customer, but it must also be able to deliver needed materials during surge periods. This requirement raises some legitimate concerns. Studies indicate that the PV program will not be able to meet the medical material needs of two, nearly simultaneous major regional conflicts (Sherman, 1995).

In 1995, DoD responded to pressures to provide accessible, cost friendly, quality care to its beneficiaries by implementing its own managed care plan—TRICARE. This plan provides the resources necessary to meet peacetime health care demands, thus preserving the capability to deploy active medical personnel in support of operational missions. TRICARE has four primary goals: predictable low-cost health care for all beneficiaries; enhanced access to the health care system; appropriate and timely treatment; and customer satisfaction with health care. TRICARE provides beneficiaries with various coverage options (OSD, 1997).

TRICARE uses managed care support contracts, including a provision for resource sharing, to reduce costs. Under resource sharing, the contractor has wide latitude to provide personnel, equipment, and supplies to a military treatment facility. It is too early to determine whether or how much cost savings the Defense Department will realize via TRICARE.

CHALLENGES

All individuals have a fundamental right to health care. However, its burgeoning cost and the increasing demands that a large aging population puts on the system challenges that premise. Per capita spending on health care varies internationally but the United States spends considerably more than other industrialized nations. Differences among countries include alternative means of supplying and pricing health care, and wide-ranging institutional designs and incentive structures. Generally, health care spending is weakly related to other social, environmental, and cultural factors that influence health status (OECD, 1995).

Civilian Health Care

The looming Medicare insolvency is one of the nation's largest budgetary concerns. The political aspects of restructuring Medicare make congressional and administrative leaders reticent to propose or enact reform much beyond the edges. Moreover, increasing revenues or reducing other programs to support Medicare begs the question of why one element of the population should have greater access to health care than others (Reischauer, 1997).

The aging of the U.S. population is becoming a financial and policy issue beyond the Medicare discussion. The average per capita health care spending for adult males ages 30 to 34 is $1,528 annually, while it is $4,454 for those ages 50 to 54. In 1994, male and female adults older than 65 years, numbered 33.2 million, almost 12.7 percent of the U.S. population. By 2030, this number is expected to climb to 70 million or 20 percent of the population (Health, 1996).

- Access to affordable, high quality health care is an increasing problem—and not one restricted to the elderly: the gap is widening between those who can afford health care and those who cannot. The logical conclusion of this realization is that health care access is implicitly rationed. For example: The scarcity of organ transplants (i.e., hearts, livers, lungs), results in a complex regional system of allocation in which a person in most medical need will be passed over in favor of someone who lives in a region with more available organs.

- Many of the uninsured seek and receive treatment only in emergency conditions—which is clearly a rationing of preventive care. Such rationing not only results in sicker people and more deaths, but in higher costs. Preventive care is less costly than emergency care.

- Insurance companies, through the use of capitation and coverage decisions, ration care to control costs. If, however, the patient is willing to pay out-of-pocket, nearly any procedure is available. And this problem has its contrary: In a world of limited health care resources, providing services to patients with self-inflicted illnesses presents a medical ethics dilemma.

The Council on the Economic Impact of Health Care Reform has voiced concern about the consolidations and acquisitions occurring in the managed care portion of the industry. It is, for example, occurring outside the context of an overall national policy and without the benefit of public debate and scrutiny. In fact, the long-term implications of these competitive managed care systems require monitoring, evaluation, and public debate (Schactman and Altman, 1995).

Defense Health Care

Of the numerous challenges facing the military health system, the greatest challenge is to maintain the force structure, modernization, and sustainability of medical assets. That is, the right people, training, and

equipment must be available for deployment. Even as the private sector is experiencing fundamental shifts in its perception of health care, so the DoD must be aware of the effects each of these shifts will have on its ability to meet peace and war time medical needs. Do defense medical personnel in the reserves contain an appropriate mix to support war time needs? Does the reduction in available U.S. civilian hospital beds put returning military casualties at risk? Further, equipment and supplies for medical readiness must be available globally through strategic prepositioning or through industry surge capability.

A second challenge for the military health services is how well the PV program will work during wartime. The delivery of medical supplies must be timely, but lift capabilities are limited. At such times, medical assets will compete with the priority movement of troops and munitions. So far advanced warnings of deployments have allowed the vendors as required from other PV distribution centers or manufacturers. That luxury may not exist, however, in a two, MRC scenario (Lloyd, 1996). The key strategic question is this: Can the PV system sustain timely delivery of medical supplies and meet its major obligations to the domestic commercial sector? An answer is clearly needed.

Currently, PV surge contracts are not required to maintain the additional inventories or raw stocks that would be required for timely production and sustainment of supplies beyond initial deployments. In 1996, recognizing the potential shortfall, DoD completed an Industrial Base Program Crisis Production Survey to determine the medical industry's material shortfalls in the event of a dual MRC scenario. The survey analyzed input from industry on 7,651 medical items. Of the items analyzed, 4.3 percent (334) were not available within the required time period of 120 days; 2.2 percent were not available during the entire course of the conflict; and industry provided no data on 18.0 percent of the items surveyed (Sherman, 1996). Consequently, DoD has no assurances that industry partners maintain sufficient stocks to support a two MRC strategy (Sherman, 1997).

Turning next to quality of life, surveys indicate that health care is a major concern for military personnel, retirees, and family members. But the implied expectation of lifelong military health care is no longer realistic, and beneficiaries are now being faced with previously unanticipated choices and expenses. As TRICARE has not yet been fully implemented, its effect on quality-of-life issues and cost effectiveness are unknown as is its impact on military preparedness. The seriousness of this challenge warrants that it be fully realized and carefully monitored continuously.

The challenges facing the effective delivery of health care in the public sector and defense community are congruent. Burgeoning costs and access issues influenced the development of integrated service networks that have become the dominant model for health services delivery. Vertical integration places under one management umbrella those organizations that provide different levels of care. For example, acute care hospitals, long-term care facilities, ambulatory care centers, home care, and health maintenance programs represent the continuum of health care. These organized delivery systems will play a major role in preventing further fragmentation of care and in focusing the forces of change (e.g., technology, information, demographic shifts, restructured work force, and the demand for value). Organizations that have vision, leadership, and flexibility will be successful (Conrad and Shortell, 1996). The military health services system has the capability to seize this challenge and lead the way.

OUTLOOK

In the absence of comprehensive health care policy, the hard decisions are made de facto by insurance companies, hospital administrators, and health care professionals. The result can be an uneven distribution of health care that leaves some individuals without a health safety net and the costs of health care unchecked. These industry conditions support the following trends and/or emphases.

Medicare. Medicare's condition of pending insolvency is not expected to change, at least in this fiscal year. Medicare spending, as currently structured, will grow at a faster pace than the economy as a whole. According to the Clinton administration, over the next five years, spending on an unchanged Medicare program will grow at an annual rate of 8.9 percent; the economy, by 4.9 percent. But a program of Medicare's size cannot grow significantly faster than the economy unless drastic reductions occur in other government activities or significant tax increases are used to maintain benefits (Reischauer, 1997).

Consumer-oriented. Patients are becoming more proactive about their medical care. Tools such as the Internet provide people with the means to research their own symptoms, diagnose themselves, or electronically communicate with providers worldwide for a diagnosis. The increasing

availability and use of nonpharmaceuticals (e.g., herbal remedies) and a growing variety of nonprescription drugs encourage this trend.

Preventive Medicine. HMOs, hospitals, insurers, and the government will continue to emphasize preventive medicine. The majority of acute care is associated with preventable illnesses and disease. Smoking-related illnesses and alcohol and drug abuse, for example, cost more than $81 billion annually, and diseases related to the HIV syndrome cost approximately $75,000 per patient over the patient's lifetime (Public Health Service, 1990). Immunization programs, diagnostic testing, and education continue to lead the way in implemented health care reform.

Integrated Service Networks. Managed care delivery systems will remain the dominant model for health services delivery. Recent experience has demonstrated the major role that these systems have had in transforming the industry and preventing the further fragmentation of care. As their dominance continues, they must also demonstrate their ability to deal with vulnerable populations. Medicare and Medicaid programs are likely to move large numbers of patients into managed care settings; in response, these systems must be committed to functioning as an integrated clinical delivery system that provides coordinated, wide-ranging, and accountable health care services to all who need them.

Technology and Biomedical Research. The U.S. is the undisputed leader in technology-based biomedical science and research. Revolutionary advances in this realm include image guided therapy that permits physicians to see "through and into patient bodies"; trackless, less invasive surgery using ultrasonic waves instead of touch; surgical robotics; genetic engineering; gene therapy; and continued advances in the pharmaceutical industry. Genetic engineering, in particular, is changing the practice of medicine from "diagnosis and cure" to "predict and prevent." The public will expect these diagnostic and therapeutic technologies to be widely applied to enhance their general welfare. In addition, the application of these technologies will be expected to result in cost-effective treatment and to result in more efficient and reliable outcomes for patients (Shortell et al., 1996).

Information and Information Technology. The integration of information technology in the health care system also accelerates the growth of managed care. Advancements in information technology, such as telemedicine, affect the method and outcome of health care delivery.

Specific medical treatments and therapies tailored to individual patient needs require improved access to providers and patients by phone, electronic mail, and expanded access to a global patient database. Information networks facilitate sharing among the health care team, empower patients, and, in general, make health care information available to all. Informed consumers will make responsible choices, which will, in turn, increase the responsiveness of health care providers. This cooperative attitude is rare in the current health care delivery system (Shortell et al., 1996). Civilian and military communities will use information technology to integrate the health care industry.

Changing Demographics. Changing demographics and increasing economic diversity in the United States will continue to drive new approaches to health care. Minority populations increased 40 percent in the United States between 1980 and 1992. Cultural differences in definitions of health and illness, needs and expectations, and care seeking behaviors will also affect the future of integrated health delivery systems. Family and community concerns will be more prominent, and Western-style medicine will no doubt integrate allopathic and naturopathic healing elements. The more significant, perhaps even the critical driver of change, will be the additional health care and financial burdens that poverty will place on a resource-constrained government (Shortell et al., 1996).

A Changing Work Force. The health services work force will continue to undergo changes in education, job description, and working conditions—in all areas of medicine and allied health professions. The trend in medical schools of training physicians in primary care rather than elective specialty training will continue with the long-term goal that providers will be multiskilled and flexible in meeting patient needs. In addition, physician assistants and nurse practitioners will be asked to expand their roles—to become more involved in disease prevention, health promotion, and chronic care (Shortell et al., 1996).

Outpatient Care. As care delivery focuses on the continuum of care, the site will shift from primary care clinic to ambulatory surgery to the home. The traditional role of the acute care hospital is changing to that of providing care for a very sick group of patients for a short period of time. Hospital staffs, primarily nurses, are downsizing and now focus on preparing patients for discharge with continuing care provided at home. The key is providing a continuum of care and health professionals will

need to have multiple skills and the flexibility to provide the needed services.

Return of Rising Costs. Low or stable health care inflation may soon end. A study by the National Coalition on Health Care projects that health care costs will rise 6.4 percent annually beginning in 1997 and continue to rise over the next five years. Managed care plans have exhausted the easy ways to save money, HMO enrollments have slowed, and many health plans now have mandated coverages. Americans will continue to seek and expect the latest and best treatments and drugs irrespective of costs (Modern Healthcare, 1996).

Continued Outsourcing. Efforts to streamline and outsource the defense sector medical needs will continue. The most *recent Quadrennial Defense Review* confirms that the Defense Health Program expects to outsource selected patient care, medical training, and installation support (QDR, 1997).

Mobilization Planning. To ensure the mobilization capability of war, the military health services system must continually reassess and manage the risks inherent in the use of the Prime Vendor/Just-in-Time (JIT) delivery system. DoD can identify and coordinate surge requirements with industry on a continuing basis. It is, for example, critical that DoD operate as a "mature" customer that adequately identifies, updates, and funds its mobilization and surge needs. A close working relationship with industry is essential to ensure that industry will respond effectively during surge periods. Industry must meet the expectations of its stockholders and remain competitive; consequently, it will not maintain excess capacity or capability unless it is adequately reimbursed by government.

Over the past thirty years, health care has been primarily influenced by new technology with limited direct public policy intervention, such as Medicare legislation and prospective payment reform. Technology will continue to influence the future of the U.S. health care system and its military counterpart. Additional forces—the information revolution, increasing social and economic disparities, and a restructured work force, among others—will play a role. Forces now in play have created a fragmented system of care; whether this fragmentation will continue into the future remains to be seen (Shortell et al., 1996).

GOVERNMENT GOALS AND ROLE

The role of government, generally, is to provide for the common defense and promote the general welfare of its citizens. Health is an element of national power that also underlies the national security strategy for citizens and the Armed Forces. But the development of public policy related to the health care industry must be balanced against the realities of constrained resources.

The nation has struggled to provide for the health of all its citizens. Medicare and Medicaid ensure care to certain segments of the population. The questions here are how much government intervention in the health care industry is appropriate, what will the country tolerate, and how do the civilian and military health care systems compete for financing? The civilian and defense systems are, at least on one level, in fiscal competition.

In the grand framework of policy and strategy, political, economic, and military forces are squeezing the U.S. health care system. Market forces and government intervention have created the current fragmented system: the most advanced and technologically intensive health care in the world is also one that denies some of its potential clients access to even basic primary care. Yet the United States has focused on providing high-quality services that are available and affordable to everyone when those services are truly needed (Bok, 1996). The nation cannot abruptly refocus a nearly trillion dollar portion of its economy without tremendous disruption. The following recommendations offer a health industry blueprint for the evolution of a national health care policy from a civilian and defense perspective that focuses on cost, quality, and access.

Civilian Health Care

Medicare Solvency. The President and Congress should establish a nonpartisan commission to evaluate the Medicare program and explore all options to produce a quality, cost-efficient program of health care delivery. This commission should be established under legislation similar to the Base Realignment and Closure Commission with recommendations going to Congress for an up or down vote and acceptance or rejection by the President. All financing mechanisms and options, to include means testing, age of eligibility, and the recision of Medicare's first payer status, are to be considered. Coverage options

should include preventive health services, chronic care needs, and nursing home care.

Cost Containment and Cost Avoidance. From the clinical perspective, the policy should promote health and wellness programs. Keeping people well is less expensive than treating acute and chronic illnesses or injury complications. Exercise programs, vaccinations, immunizations, diagnostic screenings, smoke-free workplaces, and behavior modification classes effectively reduce medical expenses. Environmental protection and individual lifestyle choices will move to the forefront.

Another key component of the education process is to focus not only on lifestyle choices, but also to talk about health and the health care system. Individuals and communities must plan for their futures and reestablish baseline expectations for health care.

The expanded use of information technology in the business of health care will help bring down administrative costs. This tactic has great potential for record keeping (electronic medical records) and outcomes monitoring and measurement. In addition, its use for complex reporting requirements can cut labor costs and decrease fraud, waste, and abuse.

In addition, the policy should encourage coordinated efforts for an over-arching research direction for health care involving industry, academia, patients, providers, and government.

Incremental Reforms. Health care reform policy must surely include a push for incremental legislative health care reform beginning with safety nets for vulnerable populations. These populations include the poor, children, and those at risk for illness, disease, or injury who do not have the independent resources or financial ability to receive necessary treatment and care. A health care safety net combined with individual responsibility will contribute to the nation's welfare. The area of tort reform needs close scrutiny, particularly attorney's fees and punitive damages. The bottom line, however, is to care for the patient and make the patient, not the legal system, whole.

Continued Government Streamlining. Pharmaceuticals and other medical devices require tough regulatory testing and approval to ensure public safety; but streamlining the regulatory process can often provide these life-saving devices and drugs to terminally ill patients. The Food and Drug Administration (FDA) has made substantial reforms in improving the process times for new drug and medical device approval, and

continued emphasis on these methods will benefit the safety and health of all Americans.

Defense Health Care

As previously established, military medicine faces its greatest vulnerability in sustaining surge and mobilization policies to ensure the nation's capabilities in war. First, though, the Department of Defense must retain the active and reserve force structure necessary to support combat troops. It should carefully scrutinize all proposals to reduce medical force structure and facilities. Second, it must ensure that adequate medical materiel and pharmaceuticals are available to support the medical force structure in wartime. Reliance on the prime vendor program has slashed these inventories, for both peace and war.

Strategic Planning. Using the various services' medical sizing models will ensure that adequate active and reserve medical strength and supplies are maintained to deploy and support operational missions. These models are analytical tools used to determine adequate force structure requirements. They can be resourced through the Planning, Programming, and Budget System (PPBS).

Working with Industry. Defense must establish a professional working relationship with industry to develop plans and policies to meet logistical mobilization requirements. In particular, DoD must establish plans and policies to ensure the adequacy of war reserve requirements, and identify critical needs. Government must define and prioritize medical mobilization requirements to procure resources appropriate to levels of risk. The key in an era of constrained resources is finding the balance between acceptable risk and expenditures.

Industry has the technology, facilities, and transportation assets to support the Joint Health Services System strategy. DoD should determine the acceptable degree of risk and the most cost-efficient means to develop contracts with major medical distribution firms. And it should explore expanding agreements with international vendors. Large multinational medical conglomerates and manufacturers are potentially valuable allies and could be used for overseas medical resupply.

Because the prime vendor program supports a significant customer base on a lean stockage level, an accurate, real-time knowledge of inventory is essential. Under the previous inventory accounting practices, visibility of retail and wholesale depot stocks were available.

Today's transition to Prime Vendor/Just-in-Time management has restricted DoD access to such information. Future contracting efforts should include provisions for commercial asset visibility (Lloyd, 1996).

Information Technology. Maximal use of available information architecture will strengthen all aspects of the military health services system and reduce duplicative systems and technologies that pertain to medical and logistics support. The need to develop legitimate, joint information technology to support clinical practice, administration, and financial management has priority. Services should avoid duplicating emerging technologies such as telemedicine.

CONCLUSION

The U.S. health care industry is in the midst of a major transformation. Contributing factors include the burgeoning health care costs (13.6 percent of GDP), threats to Medicare solvency, an aging population, 40 million uninsured Americans, and technological advances. Three major transitions in the industry have been: the move to improved business practices and cost controls (e.g., reducing excess inventory and capacity, managed care organizations); increased reliance on technology; and increased government intervention. These trends will continue to transform the industry and the economic, political, and military forces affecting national power.

The almost trillion dollar health care industry cannot afford to ignore cost considerations. Insurance companies and politicians now make decisions that in the past were in the sole purview of the provider, such as length of hospital stay. Rationing, both implicit and explicit, is practiced every day by health care providers. A decline in the number of hospital beds must be carefully evaluated in the defense context. Will we need additional beds for returning service members, or will the hospital treatment of wartime casualties be similar to that of the general public?

As the government struggles to balance the budget, additional funding to support the existing health care system will cut into all other discretionary spending, not just defense. The aging population, unrealistic patient expectations, new expensive technologies, the trends toward cost containment, and intense scrutiny of the industry will all continue to stress the system. While Americans believe that all citizens have a basic right to the best possible health care available, they are reticent to pay for it. Congress must find the will to restructure Medicare

legislatively. Unless or until it ensures the solvency of this system, its credibility in the larger debate will be at risk.

The challenges for the civilian and defense health sectors are formidable, but not insurmountable. Constrained resources are the basis for a general public debate about access, quality, and cost of health care for all citizens. How can we reconcile free market forces with the need to care for the indigent? Under what conditions, if any, is rationing acceptable? A broad plan of incremental reform is needed to address these issues.

The demand of citizen consumers for health care value and measurable outcomes is also here to stay. The health care industry must be ready to deal with an informed and responsible consumer on the individual patient basis and on the bill-payer level. The government and the Department of Defense must be recognized as discerning buyers. Methods of cost containment, incremental reforms, and governmental streamlining are as necessary to the future of the health care industry as are clinicians and administrators who are committed to the patient's well being as their central focus.

The DoD health care mission is to provide health care in peace and war and to be ever ready to respond when needed. Changes and trends in the private sector significantly influence the provision of health care in the defense sector. Maintaining adequate and appropriate medical end strength, proper risk management of medical and logistic requirements (in conjunction with industry) for surge and mobilization, and the greater integration of information systems will help ensure the military health services readiness to fulfill its objective of providing world-class health care—anywhere, anytime.

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INFORMATION

ABSTRACT

The ability to access and use information is a prerequisite for economic prosperity and national power. As information systems permeate all aspects of business, society, and warfare, they enhance the productivity of U.S. industry, change the way people live, and contribute to a revolution in military affairs. Maintaining U.S. leadership will require the utmost in technology and business acumen in a dynamic economy with accelerating product life cycles and increasingly sophisticated global competition. Projections indicate the information industry is well poised for the challenges of the 21st century, facilitated by government advocacy of open markets, deregulation, privatization, establishment of global trade rules, and a vision for the future. However, additional effort is required in developing a world class education system for the 21st century work force and establishing policies for data assurance. The industry is well prepared to support U.S. security needs. The nation that leads the information revolution will also be a most powerful nation.

Lt Col Edward Alexander Jr., USAF
CAPT Dennis DuBois, USN
LTC Alexandru Grumaz, Romanian Army
CDR Gerard Harms, USN
Mr. Mark Horton, National Security Agency
Mr. Charles Keightley, Defense Intelligence Agency
LTC(P) Hugo Keyner, USA
LTC Arthur Kron, USA
COL Richard Ledbetter, USA
Lt Col Raymond Michael, USAF
Lt Col Charles Pinney, USAF
Mr. Arnold Regan, Dept. of the Air Force
Mr. Richard Scott, Dept. of the Army
LTC Stephen Spataro, USA
CAPT(sel) Gracie Thompson, USN
Lt Col Robert Vaughn, USAF

COL Stephen Thacher, USA, faculty
COL Richard Altieri, USA(ret), faculty
Dr. Jeremy Kaplan, faculty

PLACES VISITED

Domestic

AT&T Network Operations Center, Bedminster, NJ
BBN, Arlington, VA
Bell Atlantic, Washington, DC
Federal Communications Commission, Washington, DC
Lucent Technologies, Arlington, VA
Microsoft, Washington, DC
National Cable Television Association, Washington, DC
AirTouch Communications, San Francisco, CA
Apple Computer, Cupertino, CA
Chancellor LGT Asset Management Co., San Francisco, CA
Hewlett Packard, San Jose, CA
Intel Corporation, Santa Clara, CA
Netscape Communications, Mountain View, CA
Oracle Corporation, Redwood Shores, CA
Rational Software, Santa Clara, CA
Silicon Graphics Inc., Mountain View, CA
Sun Microsystems, Menlo Park, CA

International

First Pacific, Asia Link, Hong Kong, PRC
General Datacom, Hong Kong, PRC
Hewlett Packard, Hong Kong, PRC
Hong Kong Telecom, Hong Kong, PRC
Consulate General of the U.S., Guangzhou, PRC
Guangzhou Harris Telecom Co. Ltd., PRC
Guang Dong Nortel, PRC
Guang Dong Posts and Telecommunications Administration, PRC
Motorola (China) Electronics Ltd., PRC
Shunde Whirlpool SMC Microwave Products Co. Ltd., PRC
The People's Government of Shunde City, PRC
Asian Technology and Information Program, Tokyo, Japan
Ministry of Posts and Telecommunications, Tokyo, Japan
National Panasonic, Tokyo, Japan
Nippon Telephone and Telegraph, Tokyo, Japan
Nippon Motorola Ltd., Tokyo, Japan
Sony Corporation, Tokyo, Japan
Japan Intellectual Property Association, Tokyo, Japan

INTRODUCTION

The Information Age is fostering new technologies, triggering a convergence in telecommunications and computing, and creating new dimensions in national security. Knowledge is power, and access to information has become a prerequisite for economic growth and national status (Nye and Owens, 1996). Information systems are increasingly permeating all aspects of business, society, and warfare. They are helping other industries manage their businesses, improve productivity, innovate, and grow. Information technology is also changing the way people live—not only where and how they work, but also how they fight. A successful revisioning of Military Affairs depends on the ability of U.S. forces to gain an advantage over its adversaries through the superior employment of information and information systems. The ability to collect, process, disseminate and use information faster than others will be the competitive advantage in the calculus of global power for the foreseeable future.

Information systems have become a strategic resource as important as land, labor, and capital. Currently, the industry represents 10 percent of the U.S. gross domestic product (GDP), with projected growth to 20 percent by 2004 (Gilroy and Randall, 1996). The industry is clearly strategically important, even critical to U.S. prosperity and security.

The engine driving this competitive advantage has been the convergence of computers and telecommunications. This convergence has created an explosion in value-added services and new products unimaginable just a few short years ago—and the explosion continues to accelerate at a staggering rate. Can U.S. industry stay in front of this juggernaut, and will it still be the leader in 2020? Can the U.S. Department of Defense (DoD) continue to assimilate these galloping technologies faster than its adversaries?

This report assesses the health and status of the information industry as a strategic industry. It analyzes trends in profitability, productivity, and international competitiveness in an increasingly global marketplace. It also identifies numerous challenges that it will face as it seeks to continue its preeminence.

THE INDUSTRY DEFINED

The information industry consists of three sectors: computer systems, telecommunications, and information/value-added services. The computer

sector includes the full range of hardware and associated peripherals from supercomputers, mainframes, and minicomputers to microcomputers, personal computers, and laptops. It also includes prepackaged systems, applications, and utility software. The telecommunications sector, which transports and distributes data, includes local and long-distance carriers, third-party resellers, cellular and mobile radio, satellite and data communications, and networking services. The transport media range from copper wire, fiber-optic cable, and coaxial cable to microwave, cellular, and satellite communications. The information services sector includes traditional services (e.g., data management, financial services, and customized software) and many new and evolving value-added technologies and services (e.g., multimedia, tele-medicine, and electronic commerce).

CURRENT CONDITIONS

The global information industry is one of the largest in the world, with revenues in 1995 of approximately $1.4 trillion (Kelly and Minges, 1997; DOC, 1995). The computer, telecommunications, and value-added services sectors represent 24 percent, 56 percent, and 20 percent of the industry respectively. It is also one of the fastest growing industries; its relatively mature markets (e.g., fixed telecommunications services and the U.S. personal computer market) sustain growth rates of 7 to 12 percent annually, and its new markets (e.g. the Asian computer market, multimedia products, and wireless communications) grow at a phenomenal 40 to 50 percent per year. This dynamic industry is characterized by an almost continuous introduction of new products with ever shortening product life cycles.

Though the United States holds a commanding share of the global market, the rest of the world has also recognized the importance of information and is aggressively entering the information age and nurturing emerging national capabilities. The U.S. industry is challenged to sustain its preeminence in the face of increasingly sophisticated international competition. Continued rapid growth will depend more on new markets, value-added services, and wireless communications than on personal computers and copper wire.

Computer Sector

In the computer sector in 1995, the U.S. industry controlled 75 percent of both the $233 billion computer hardware market and the $105 billion

packaged software market (DOC, 1995). U.S. exports, which dominate foreign markets except for the Japanese hardware and peripherals market, are increasing and represent more than 50 percent of market revenues. The largest markets are North America, Europe, and Japan. The fastest growing markets are Asia (less the Japanese hardware market) and Latin America. That the U.S. industry continues to dominate the software export market reflects the relatively small international presence of European and Japanese vendors. However, the United States is losing market share in hardware exports to Canada, Mexico, Singapore, and South Korea—primarily as a result of U.S. industry's strategy of producing peripherals and parts in low-cost, overseas labor markets.

The current robustness of the market has been spurred by the Internet and intranets, local area networks (LANs), and emerging value-added capabilities (e.g., in-house on-line communication networks). The computer sector maintains its global competitive advantage through shorter time to market, superior infrastructure, higher quality software, pricing, and performance. These strategies are the results of a very competitive domestic market, industry downsizing, and investment in advanced technologies.

The computer sector has experienced significant consolidation. Price competition in software has resulted in a few large software companies and significantly fewer niche firms. Computer hardware has become increasingly commodity-like with little brand loyalty. To maintain and gain market share, companies have been forced to offer lower priced, high performance systems. As a consequence, hardware makers have undergone multiple restructures, consolidations, mergers, and global alliances—simply to maintain productivity and profitability in a low profit margin, commodity-like market. U.S. firms, primarily computer hardware firms, have also established overseas subsidiaries, particularly in Asia, to better serve overseas markets, circumvent tariff and nontariff trade barriers, and to benefit from lower wages. Additionally, they have formed domestic and foreign alliances to cooperate on technology and joint development, manufacture, and marketing.

Telecommunications Sector

Global telecommunications services revenue exceeded $600 billion in 1995 with another $188 billion in equipment revenue (Kelly and Minges, 1997). U.S. telecommunications services employ over 900,000 people and generate about $215 billion in revenues (Gilroy and Randall, 1996). Telecommunications is the third largest industry in the world in terms of

market capitalization and ranks with computers as the fastest growing export sector. Sales of telecommunications services grew by 7 percent in 1995, twice the rate of the global economy. From 1990 to 1995, the telecommunications industry in industrialized nations grew at annual rates of about 4 percent while this sector in developing nations has been growing at a rate of nearly 10 percent a year (ITU, 1997). While industrialized countries represent the bulk of global telecommunications activity, the developing countries of Korea, Brazil, Mexico, and Argentina rank in the top ten markets based on revenue. U.S. companies represent 11 of the largest 20 corporations in terms of revenue.

The U.S. telecommunications industry is undergoing dramatic change. The Telecommunications Act of 1996 has deregulated the industry, allowing local and long-distance providers, cable companies, and Internet providers to enter each others' markets. Increased competition will improve services and reduce consumer costs. While the long-distance carriers have become more efficient due to domestic competition, local providers and cable companies have not yet completed the transition from their former business models. It remains to be seen whether these companies can be competitive in a deregulated and global marketplace.

The international market is also moving toward privatization and competition. As many as sixty-nine members of the World Trade Organization (WTO), representing 94 percent of the world telecommunications market, reached agreement on 15 February 1997 to open their national markets to competition starting 1 January 1998. Historically, opportunities for foreign investment have been limited by the fact that most countries had state-owned monopoly carriers. As the WTO Agreement helps bring this era to an end, opportunities for establishing foreign subsidiaries or combining in joint ventures will increase, resulting in lower prices and the greater availability of new services.

Domestic and international deregulation are not the only factors stimulating competition. Emerging wireless technologies are spawning new market opportunities and revolutionizing the telecommunications sector with "anytime, anywhere, any media, digital communications." This phenomenon has inspired innovative entrepreneurs to develop wireless voice, data, and video technology so that subscribers can be mobile, but "connected" to their homes and central offices. The exploitation of new digital protocols, coupled with recent regulatory changes, has led to fierce competition among cellular, personal communication systems (PCS), mobile satellite services, and wireless network providers. Wireless video and other broadband services are creating new niches in the industry, especially in video entertainment, programming, and broadcasting.

The pace of cellular phone growth, and wireless technology in general, is growing at an extraordinary rate. In 1983, there were fewer than 1 million cellular phone users worldwide. Today there are over 137 million, with projections of over 400 million by the year 2000. The growth rate in the United States and other developed nations has been about 45 percent a year since 1994. Total wireless services in the United States in 1994 exceeded 31.1 million subscribers. By 2005, this nation will have at least 136.3 million subscribers to voice, data, or video wireless services. A majority of these subscribers—96.5 million—will subscribe to wireless voice (OTA, 1995).

The largest wireless market is voice; however, mobile data communications is the fastest growing. The U.S. market for wireless data communication was $756 million in 1994 (OTA, 1995). Wireless revenues are projected to reach $60 billion by 1999, including $7.8 billion for mobile data communications. PCS, digital cellular systems, and wide area networks (WANs) promise to be the industry front runners.

Future competition will increasingly be based on price and services (bundling). As deregulation and wireless technologies increase competition, per unit revenue is expected to decline. Profits will depend on new services, expanding global markets, and reduced costs as companies restructure and downsize.

Information Services/Value-Added Sector

By 1994, the United States was also the world leader in the information services/value-added sector with 46 percent of a $282 billion market (DOC, 1995). Although current numbers are not available, it is likely that the U.S. share is even larger today as a result of its leadership in Internet use and the introduction of Internet driven innovations. The industry's formerly distinct sectors—computers, communications, consumer electronics, and content (the latter including still and motion video, text, and audio information)—are evolving, interconnecting, and converging in completely new ways. Such developments are a response to consumer demands for useful, accessible, real-time, interactive, and cost-effective digital information.

Convergence is best represented by the dramatic growth of the Internet and Internet applications. From 1995 to 1996, the Internet in the United States nearly doubled from 6.6 million host computers to 12.8 million hosts with approximately 35 million users (Kantor and Neubarth, 1996). North American use of the Internet has surged 70 percent (Chandrasekaran, 1996). One in four people in North America over age 16

now use the Internet, twice the number 18 months ago. Expansion of the Internet in Europe in 1996 nearly overwhelmed the telephone companies. The Internet, which now reaches every continent, is expected to double every year until 2001, at which time it will connect an estimated 100 million people (Gregston, 1996). The major barrier to Internet growth is the lack of adequate telecommunications infrastructure and the cost of upgrading it.

Digital convergence has been swift to follow the increase of processing power, global networking, and improvements in wire and wireless transmission technologies. These technologies have enhanced consumer electronics with increased processing power and functionality. Convergence affects the creation and distribution of whole new categories of interactive content, such as interactive voice response systems, video-based shopping, multimedia games, interactive personal services, electronic commerce, and tele-medicine. The future portends even greater interactivity, virtual reality, and other as yet unimagined value-added content.

In sum, trends indicate that the U.S. information industry will continue to be among the fastest growing segments of the economy. All sectors continue to experience significant growth and are clearly competitive in the global marketplace.

CHALLENGES

The U.S. information industry faces a promising future of prolonged growth. However, foreign industry is also developing its technology and becoming more competitive. As it, too, begins to penetrate more global information markets, the U.S. industry will need the utmost in technology and business acumen to stay ahead of this increasingly sophisticated foreign competition. An environment of dynamic demand, accelerating product life cycles, and increasingly short-lived technological leads, this competition is but one of numerous challenges that must be addressed to ensure the future health of the U.S. information industry. These challenges are grouped into four categories: ensuring competition and free trade, maintaining U.S. technological lead, development of a 21st century work force, and providing an enabling infrastructure.

Ensuring Competition and Free Trade

Sustaining U.S. global competitiveness requires creating a domestic and international environment of privatization, deregulation, and free trade to ensure a level playing field and open competition.

Trade Protectionism. Many governments nurture their domestic information industries by erecting tariff and other trade barriers to protect them from competition (DOC, 1995). These restrictive policies adversely affect U.S. exports and global competitiveness. The U.S. government has forcefully and successfully tackled the issue of closed markets at the bilateral and multilateral levels. The North American Free Trade Agreement (NAFTA) has reduced and eliminated many tariffs, and in 1996, President Clinton and the Asian Pacific Economic Council (APEC) committed to the elimination of tariffs on information technologies by the year 2005. More recently, the United States also helped conclude the Information Technology Agreement (ITA) at the WTO Ministerial in Singapore. The ITA will eliminate tariffs on computer hardware, software, and most telecommunications equipment by 2000, thus promoting economic growth and new jobs (DOC, 1997a).

Domestic Deregulation. The United States has made major strides in deregulating its telecommunications industry. As a result of the Telecommunications Act of 1996, all local and long-distance carriers, Internet providers, and cable and utility companies have an opportunity to enter the local, long-distance, and international markets. The issue is who will open these markets first. Currently, the local providers are striving to maintain a competitive advantage in their markets even as they prepare to enter the long-distance market. The challenge here—for the industry and government—is to ensure the opening of the local markets in a fair and equitable manner.

International Deregulation. The recent WTO pact is a significant step in the deregulation of global telecommunications. However, the issue is much the same—who opens their markets first. It appears that the U.S. has traded access to its lucrative current markets in exchange for eventual access to global markets that are not yet deregulated or privatized. U.S. long-distance firms should be very competitive because they have experienced competition in the U.S. market. However, they now face immediate foreign competition in the U.S. market, while their entry into foreign markets is delayed both formally by the WTO

Agreement and informally by the slow pace of dismantling foreign monopolies. In the information industry, even a few months of uneven access to markets can have a significant effect on long-term competitiveness. The challenge in this situation is for industry and the U.S. government to monitor the progressive states of the WTO agreement to ensure that U.S. industry is not unfairly penalized.

Maintaining U.S. Technological Edge

Maintaining the nation's preeminence in information systems requires more than anticipating the next technological advance. It requires the synergistic combination of government and industry investment in research and development (R&D), an environment of innovation and creativity protected by the fundamental rules of law and intellectual property rights, and ready venture capital. Even though numerous countries have some of these ingredients, the United States, exemplified perhaps by Silicon Valley, brings these ingredients together to create a synergistic environment of leading edge technologies and products. The challenge is to preserve this unique environment despite changing national and international conditions. The industry and the nation must strengthen its R&D investment and enforce intellectual property rights.

R&D and Innovative Environment. To sustain its global preeminence, U.S. firms must maintain their advantage in leading edge technologies despite increasing foreign competition. Much of the current U.S. technological advantage stems from its relationship to the DoD's history of basic research in telecommunications, integrated circuits, signal processing, "ARPAnet" and other technologies (Burr, 1995). However, in response to tighter budgets, DoD has reduced its investment in research and implemented a strategy to rely more on commercial R&D. Corporate R&D dollars are also being squeezed by competition, which reduce profit-per-unit, and by shorter product life cycles, which reduces the time investors have to realize a reasonable return on their investment. The concerted efforts of foreign countries to develop their national industries also reduce the U.S. technological lead. Additionally, technology is being disseminated rapidly around the globe. Silicon Valley, a mecca for the best and brightest technical talents from around the world, attests that its technology is not simply U.S. technology. Rather it is international technology that resides in the United States. Many leading edge corporations, based in the United States, have

worldwide operations. This situation challenges the traditional concept of national competitive advantage.

In this highly competitive environment, industry must maintain or increase its investment levels, especially in light of the DoD's reductions in technology spending. The U.S. government must reinstate and invigorate its policy of investing in basic technologies.

Intellectual Property Rights. The piracy and unlawful disclosure of intellectual property, from trade secrets to copyrighted material and software, is adversely affecting U.S. innovation, investment, and trade. Economic espionage costs the United States an estimated $240 billion per year. Piracy is estimated to cost the $105-billion a year software industry over $50 billion a year in lost revenue (Wasch, 1994). Unfortunately, copyright infringement has escalated with advances in information technologies and the growth of the Internet. Copyrighted works need maximum exposure to generate profit, but piracy deters its owners from risking their investment until appropriate protections are in place (DOC, 1997b). As a result, innovation is stifled, the exchange of information is undermined, billions of dollars are lost, and the U.S. competitive advantage erodes.

Vigorous enforcement of IPRs and the rule of law is essential to protect U.S. investment in critical technologies and to provide an innovative environment. At U.S. urging, negotiations to protect and promote the competitiveness of the information industry were undertaken and approved during the Uruguay Round of General Agreement on Tariffs and Trade (GATT). The GATT Trade-Related Aspects of Intellectual Property (TRIPS) provisions will for the first time protect computer information as literary works and establish minimum legal standards that will help fight piracy. The new rules will provide important international legitimacy to the United States in its continuing challenge of protecting IPRs.

Development of the U.S. Work Force of the 21st Century

The foundation for sustaining U.S. technological leadership and power is the development and nurturing of a highly skilled work force for the 21st century. Improving primary and secondary education, training the noncollege-bound work force in relevant 21st-century skills, and providing everyone with universal access to the latest in information and information systems. This system must be refurbished without damaging the traditional U.S. hallmarks of innovation and creativity.

Education and Training. Education and training may be the Achilles heel of the U.S. information industry. While the United States still has the best university system in the world, many believe the K through 12 education system is producing children who are falling behind their peers in the rest of the world. Increasingly, U.S. firms are unable to find high school graduates equipped with information systems skills. Instead, they are going abroad in search of the best talent. Already the industry is experiencing a shortage of critical computer skills (IDC, 1997). Several firms suggested that Singapore produces workers better prepared for computer component manufacturing than the United States does, and several U.S. companies are having software programs written in places like Russia and India.

Maintaining U.S. leadership in the 21st century requires improving the educational and vocational skills of the work force to ensure that high paying, value-added jobs stay in the United States and contribute to economic prosperity and national security. A partnership between industry, government, and educators is essential to create a world-class educational system tuned to the needs of 21st century industry. And for the same reasons, a new paradigm in vocational training is also needed. The stigma that vocational training is where the "also-rans" go is counterproductive and does not reflect the true nature of the market. High-tech, nonacademic skills are in demand. A strong industry and government partnership would ensure that future workers develop the educational and vocational skills they need to contribute to continued U.S. competitiveness.

Universal Access. The 1934 Communications Act established universal access to basic telephone service for all Americans. Deregulation and a raft of new services have created two new challenges with Universal Access, namely, who pays and for what services. Deregulation has created many new players who don't currently contribute to the Universal Access Fund. For example, Internet service providers and wireless providers can circumvent local access charges. In addition, the Telecommunications Act of 1996 expanded universal access to include all schools and libraries. However, the emergence of new technologies has spawned contention over how much capability (bandwidth) should be universally provided. Some people fear that new classes of information "haves" and "have-nots" will emerge unless we extend today's open policy to the new technologies. To facilitate the development of a world-class education system, the United States needs

to guarantee universal access to the latest in information and information systems.

Providing an Information Infrastructure

Sustaining U.S. competitiveness requires an enabling infrastructure that includes the National Information Infrastructure (NII) and the Global Information Infrastructure (GII). These standards ensure that information systems are interrelated and interoperable—without inhibiting innovation or preventing the development of explicit data security and data assurance policies.

National and Global Infrastructures. The NII, with its promise of high speed and high bandwidth communications, offers a quantum improvement in the ability to move information and enhance innovation and competitiveness. But, the NII will cost almost $2 trillion over the next 20 years (Corbin, 1995). The challenge for public- and private-sector customers will be investing in the key infrastructures required to deliver a backbone that will effectively handle convergence of the industry. While the U.S. government has provided a vision and some R&D, investment for the NII will come primarily from the private sector (Burr, 1995). This approach, although inefficient, allows more diversity and innovation into the system and prevents premature closure on potentially poor choices. The government should remain as a facilitator, advocate, and coordinator, providing incentives and precompetitive R&D dollars.

Standards. Standards are critical to the interoperability of information systems. Yet, the absence of standards also contributes significantly to the industry's innovation and growth. Hence, the challenge to define standards that facilitate interoperability without inhibiting innovation. The undercurrent of strong industry participation in standards development is the industry's fear that even with supposedly open standards, those who have not been part of the development process may lose a competitive opportunity. Choosing standards may entail choosing industry winners and losers. Corporations also recognize that much of their competitive advantage stems from maintaining product differentiation and market niches. Therefore, efforts to set standards have sometimes been met with resistance as each firm tries to maintain an advantage (Yoffie, 1996). Standards should continue to emerge, not

only from standard-setting organizations, but also from competition and market acceptance of new and evolving services.

Data Security, Integrity and Privacy. Society increasingly and routinely relies on advanced information systems, perhaps without realizing the vulnerability of unprotected systems. Information security and privacy are vital to the continued growth of the industry and the national security of the United States. This complex issue pits the needs of the government to protect the public (law enforcement) against the individual's right to privacy. Solutions that meet the needs of the individual often intensify the difficulties facing law enforcement and vice versa. Resolution appears to be heading toward encouraging the use of encryption. A solution would allow government or third-party "honest brokers" to hold encryption keys. for law enforcement purposes while permitting the export of sophisticated encryption technology and creating a win-win for industry, citizens, and law enforcement.

Additional issues regarding the safety, security, and integrity of sensitive data range from personal information to corporate planning information and trade secrets. While third parties are developing market niches in security services, it is not clear that the information industry, or U.S. industry as a whole, has adequate economic incentives to provide the necessary levels of protection. The economic cost of lawsuits and industrial espionage is relatively low compared to the cost of providing protection. However, cost analysis alone ignores the societal costs of lost or misused information and the long-term consequences for economic growth and national security. If industry is unable or unwilling to bear the true economic costs, it is incumbent on the government to establish policy and standards.

Information Warfare. Information warfare is an extension of data security and integrity issues. It occurs when anyone delays, denies, disrupts, destroys, or steals information. The same technologies that the information age uses to provide new tools to national defense can be used to conduct military, economic, and industrial warfare and espionage. The capabilities that governments, corporations, and individuals can use to exploit dependencies and vulnerabilities have significant implications for information security and U.S. national security. Exploitation of these vulnerabilities can lead to loss of intellectual property, delays in getting to market, neutralization of strategic plans, and loss of confidence in products and services. Most U.S. companies are poorly equipped and trained to protect one of their

most valuable assets—their intellectual property. Often they write off the cost of industrial espionage and commercial warfare as a business expense rather than institute appropriate protections. Policy and standards should clearly be established.

OUTLOOK

The information industry's short-term outlook reflects a highly competitive industry poised to capitalize on the exploding demand for information and information systems. The growth engine for the foreseeable future will be the Internet and the networked consumer and corporation as well as broadband and wireless communications. The rate of growth of the industry will be paced by the growth of available bandwidth to support the many new and evolving business and consumer applications.

Computer Sector

In the computer sector, exports of computer systems are expected to grow 7 percent annually through 2000 (DOC, 1995). The world market for packaged software will grow 10 to 12 percent annually, increasing from $105 billion in 1996 to $153 billion in 2000. This growth will be fueled by economic recoveries in Western Europe and Japan and the rapidly expanding markets of Asia and Latin America, which are growing over 20 percent per year.

International competition in the computer sector will come primarily from Japan, and to a lesser degree, from other Asian countries. Japanese computer hardware firms pose the strongest challenge, having reached parity with the United States across a wide range of products and technology. Recently Japanese companies significantly increased exports of computer systems. The emerging Asian countries of South Korea, Taiwan, and Singapore are not yet able to challenge U.S. dominance in the high performance market. However, they are developing a formidable, low-cost manufacturing capability and a significant R&D program. Eventually they may be able to challenge U.S. dominance in high end products. European and Japanese firms will increase their competition in software, but only in their domestic markets. The competitive advantage of the United States in packaged software seems insurmountable for the foreseeable future.

The engine of economic growth in the computer sector has shifted from the personal computer (desktops) and stand-alone applications to the

Internet and networked computing. Business networks and on-line consumers offer tremendous profit potential and will become a new focus of investment and innovation. The industry is split on whether to continue developing higher performance, lower cost systems connected to the Internet, thus further penetrating the home personal computer (PC) market, or to take advantage of the Internet by developing simple, inexpensive network computers (NCs) to reduce life cycle costs. The industry will pursue both approaches for the foreseeable future. But, whether the PC or NC finally prevails, further penetration of the U.S. consumer market will require significantly reduced prices, below the $1,000 barrier, and significantly more user friendly and maintenance free systems for the average consumer.

The computer industry's low price margins will make it ripe for another round of mergers and acquisitions as PC companies join forces with each other or their suppliers to create a cadre of global players. Coexisting with the industry giants will be a number of smaller firms satisfying particular niche markets. The dominant firms will have the advantage of economies of scale and the ability to generate substantial revenue even with low profit margins. Thus, they will have continued resources to invest in critical R&D. Some additional consolidation is also likely in the software sector. If the larger companies can't produce the required technological advances, they will try to buy specific niche firms (Kehoe and Taylor, 1995).

Telecommunications Sector

The telecommunications sector, growing over 7 percent a year, will likely exceed $1.25 trillion in revenue by 2000 (Kelly and Minges, 1997). The key to future profitability is low cost, universal access to broadband digital data. Deregulation and privatization, a result of the 1996 Telecommunications Act and of the 1997 WTO Agreement, should result in more competition and investment, lower prices, and improved products and services. In developed countries where competition has been introduced, the growth rate in traffic per subscriber has jumped from 5.6 percent to 9.3 percent annually. The results are even more dramatic in developing countries with growth rates jumping from 5.2 percent to 11.7 percent annually.

U.S. firms are in a solid position to compete overseas. Compared to their competition, U.S. companies are more productive, having achieved more efficient economies of scale from their infrastructure investments. On one measure of efficiency, namely, revenue per employee, the top three

companies worldwide are U.S. companies (DOC, 1994). As overseas markets open, U.S. firms will have much to offer in knowledge, skills, and advanced services.

Market-driven pressures to compete successfully will result in consolidations and alliances among industry members and the bundling of services (to include the emergence of more resellers), and interconnectivity across geographic markets and between wireline and wireless markets. The U.S. local phone companies and long distance carriers have been slow to enter each other's markets or international markets directly, choosing instead to establish strategic alliances or mergers with existing providers. This practice is also true in the international realm, although it appears that foreign providers are moving into the United States more quickly than U.S. providers are moving into foreign markets. Foreign countries have been more cautious about opening their markets to competition. Their caution is reflected in the phased implementation of recent WTO agreements, which provides immediate access to U.S. markets but only gradual access to foreign markets. It is difficult to determine who will come out ahead as a result of the WTO agreement. U.S. firms are better structured to compete, but the short-term advantage foreign firms will have in their early access to the U.S. market could have long-term effects.

The biggest change will be the emerging role of wireless providers who are beginning to challenge entrenched providers. Direct broadcast television is competing with cable companies to provide home entertainment. Cellular companies (and soon space-based PCS systems) are challenging the phone companies. Some proposed space-based systems will offer broadband services that will compete as backbone providers. Inherent in these systems will be low-cost, universal access that could eliminate the paradigm of urban customers subsidizing high-cost service in rural areas.

The true impact of wireless communications can only be appreciated when one considers that more than 50 percent of the world's population has never made a phone call (Ness, 1997). This poor showing is primarily a function of the high cost of installing infrastructure and the physical constraints that geography imposes on traditional wire services. Wireless communications will carry voice, data, and fax services to a far greater number of the world's inhabitants. Providing wireless services to new markets such as countries of the former Soviet Union and China may open up regions that have never before been connected to much of the world's information.

The biggest stumbling block to this emerging technology is the need for a standard protocol to replace multiple competing and incompatible

formats. Eventually, a standards-based architecture will be required to achieve an effective national and international system that is seamless and transparent to its customers.

Services/Value Added Sector

Exports of services are growing 22 percent per annum and are projected to continue, fueled by the convergence of the computer and communications industries (DOC, 1995). U.S. firms are in an excellent position to take advantage of recent global growth in electronic commerce and business-process reengineering and outsourcing trends in Europe and Japan. The fastest growing markets will be in Asia with privatization and modernization increasing demands for U.S. information services. Speed and agility to meet changing needs will be the key to continued market success.

Convergence is already having a significant impact on the industry as the engine of growth moves from the PC to the Internet, spawning numerous new hardware devices, software applications, multimedia products, and services. The "content revolution' will significantly change lives in fundamental ways, including the way people communicate, conduct business, and entertain themselves (Gates, 1995). The medical world will benefit from several meaningful applications such as tele-medicine and virtual reality "surgery." Future applications will allow surgeons to perform diagnoses and follow-ups of patients at remote locations. The variety and sophistication of such value-added services will increase dramatically during the next decade.

U.S. competitiveness will depend on the continued convergence of computing, communications, and content. To capitalize on the synergy of these sectors, additional mergers of communications and content companies are likely.

Long-Term Outlook

The long-term outlook for the information industry is excellent and the United States should still be the dominant global player in 2020. U.S. firms, by almost any measure, are extremely competitive in the global marketplace. Many exciting technologies are only now coming to fruition such as virtual reality, photonics, nano-technology, and artificial intelligence; and new products are and will continue to be introduced with increasing frequency as a result of the Internet. Continued maturation of the NII should lead to even more exciting innovations.

International competition will continue to grow, challenging U.S. dominance. Access to information is recognized as the sine qua non of economic growth and national power, and other countries are taking steps to catch up. Some developing countries will likely skip the industrial revolution and move directly to an information-based economy. These countries are seeking advanced technologies and nurturing their domestic industries. The key to continued U.S. leadership will be time-to-market, continued innovation, and equal access to foreign markets.

While it is expected that many industry challenges can be sorted out in the near term, the state of the U.S. education system is a long-term challenge. To ensure a healthy industry and economic prosperity requires developing and sustaining a highly skilled, value-added work force for the 21st century.

National Security and Mobilization

The U.S. information industry is and will be robust and capable of simultaneously satisfying defense requirements and commercial demands. Because of the increasingly global nature of information systems and the international reach of information companies, the industry tends to have a global rather than national focus. Many firms have global operations, global markets, and gladly employ people and resources wherever it makes corporate sense. As a result, many are less focused on national issues like the U.S. industrial base, defense mobilization and surge requirements, and the continued viability of a U.S. skilled labor force and to maintain profitability.

Reduced DoD spending is significantly contracting and restructuring the defense industrial base. Many second- and third-tier vendors have opted to leave the defense business, defeated by decreasing sales and the complexities of government procurement. In the information industry, the DoD no longer drives the market. To preserve its ability to mobilize and build forces quickly, the DoD must accelerate its efforts to conform to the commercial marketplace by procuring commercial off-the-shelf items and adopting "best commercial practices." This transformation is essential so that defense can capitalize on rapidly changing, market-driven technologies and products and apply them to military systems and the ongoing Revolution in Military Affairs. The ability to count on and to cooperate with industry in times of crisis will depend primarily on how well the DoD can satisfy its requirements with commercially available systems and tap into commercial pipelines and nodes to procure them.

In telecommunications services, the NII and the GII must have sufficient capacity to support global military operations and national mobilization during a crisis or war. While the NII should be predominately a private investment, the U.S. government should ensure that sufficient capacity exists to support unique military needs. It should be global, mobile, secure, survivable, and sufficient to provide high bandwidth requirements. This standard might require a construct similar to the current civil reserve airlift fleet. In this system, the DoD pays to augment the system to satisfy its unique requirements and for reserve capacity for use during times of crisis.

The growing magnitude of the information industry, relative to potential DoD needs, is challenging traditional concepts of industry's roles in national security. Mobilization may simply mean providing more on-demand services and helping the DoD acquire additional equipment from the local electronics retailer. The point that must be recognized, however, is that the domestic information infrastructure is critical to nationwide mobilization in a crisis.

GOVERNMENT GOALS AND ROLE

The Information Revolution has quickly become one of the most powerful and important trends of the late 20th century. Increasingly it is permeating all aspects of society, business, and warfare; and projections are that it will continue to dominate well into the 21st century.

The U.S. information industry is essential to future U.S. economic prosperity and national power. Consequently, the U.S. government must devise, formulate, and implement comprehensive information policies simply to remain globally competitive. For the most part the government has done a superb job, particularly in advocating a level playing field. Thus, this report recommends only minor adjustments and notes two issues that have significant consequences for the industry and require prompt attention and explicit government policy—education and data assurance. These issues will be addressed in more detail as part of a comprehensive review of the four industry themes: (1) ensuring competition and free trade; (2) maintaining the U.S. technological edge; (3) developing the U.S. work force of the 21st century; and (4) providing an enabling information infrastructure. U.S. national security needs will also be addressed.

Ensuring Competition and Free Trade

The U.S. government has already played an active role in enhancing the global competitiveness of the U.S. information industry and establishing it as a global leader. It has, for example, increased free trade through NAFTA, APEC and WTO agreements on free trade and market liberalization, and begun the process of deregulation through the 1996 Telecommunications Act and conclusion of the WTO initiative on deregulation and privatization of global telecommunications. These efforts have eliminated barriers to free trade and helped create a level playing field for U.S. products in the global marketplace. Government vigilance and enforcement are still required, however, as countries nurture their national industries and are slow to open their markets to U.S. competition. Deregulation of the $600-billion telecommunications sector will require particular vigilance. International deregulation negotiated under the WTO is uneven and has the potential for putting U.S. firms at a competitive disadvantage by opening lucrative U.S. markets to foreign competition before foreign markets are open to the U.S. industry. In the information age, a competitive advantage of just a few months can quickly become insurmountable.

Maintaining the U.S. Technological Edge

To sustain its leadership position, U.S. industry must support continued research and development even as increased competition drives profit margins down. Industry should also look toward increased partnerships and joint ventures to invest in critical, long-range technologies. For its part, the government should continue R&D in basic technologies, increase R&D tax incentives, and relax antitrust laws to permit critical joint ventures and partnerships for investing in capital intensive, long-range technologies.

The U.S. government's role in establishing the rule of law and intellectual property rights has been effective and appropriately gauged. However, many cultures still don't appreciate the significance of IPRs and the theft of intellectual property remains a lucrative business and a cheap way for countries to catch up technologically. Thus, the government must continue its vigilance, in lock step with the WTO, and vigorously enforce the agreements.

Developing the U.S. Work Force of the 21st Century

Among its top policy priorities, the government, in partnership with industry and educators, should include the development of a skilled 21st century U.S. work force. A comprehensive solution to current educational deficiencies is required, and the establishment of a world-class K to 12 program is most strongly recommended. Nothing less will provide the education and skills required by U.S. businesses in the 21st century. The next, equally important step is the establishment of a new paradigm in vocational training to eliminate the stigma of vocational training as the place for nonacademic achievers and "also-rans." High tech, nondegree skills are in demand. These developments will require a strong partnership with industry to ensure that students have access to the latest technology. Educational reform will ensure that high paying, value-added jobs stay in the United States to bolster U.S. competitiveness, economic prosperity, and national security.

Universal access should also be a key component of the strategy to develop the U.S. work force of the 21st century. All schools, libraries, and other learning centers should have access to the latest information and information technologies, including high bandwidth services. Access will lead to familiarity and proficiency; the current delay in the delivery of universal access is attributable to the issue of who pays. The government must find a formula that requires all providers of information services to contribute to a new universal access fund.

Providing an Information Infrastructure

As the number one infrastructure policy issue, the government should quickly explicate its expectations concerning security and data assurance, as vital information resources must be protected given the absence of a concerted industry effort in this area. In this case the marketplace is failing to reflect the true economic costs of lost, stolen, destroyed, or corrupted data. Virtually every area of society is affected by information technologies, and increasingly peoples' lives are represented by a digital compilation of their medical, employment, banking, and consumer records. Loss of confidence in information could have consequences similar to the loss of confidence in banking in the 1930s. It could also undermine emerging on-line businesses and consumer services. Allowing the export of third-party key escrow encryption devices was a major step toward a secure transport of data. But protecting sensitive databases from corruption, interruption, and destruction is still needed. Data assurance and

data protection will also help protect the United States against the future possibility of information warfare.

Standards for interoperability and transparency are complex issues. Standards are required for interoperability, but they can also inhibit innovation, the engine of industry growth. Future standards should provide for interoperability *and* innovation and new technologies. For now, standards should continue to emerge not only from organizations committed to standards, but also from the empirical results of competition and the marketing of new services. The government should continue to advocate national and international standards, standards proven by the marketplace.

The government's present policy is appropriate regarding the NII and GII. It should continue to facilitate their development by providing vision, tax incentives, and investment in the necessary basic technologies. Financing and building of the system should be a private undertaking, except for those investments required to provide government access to secure, mobile communications during national crises.

National Security and Mobilization

The U.S. information industry will continue to be strong and vibrant well into the 21st century. To fully leverage this industry for defense, the DoD must accelerate its efforts to conform to the commercial marketplace. To ensure priority access to high-capacity, secure, survivable, global communications during times of crisis the U.S. should consider establishing a Civil Reserve Air Fleet-like program with telecommunications service providers.

CONCLUSION

The information industry is strategically important to U.S. prosperity and security. It permeates all other industries and enhances U.S. productivity and global competitiveness. It is also critical to the nation's defense capabilities.

In the short and long run, the information industry is poised to capture a dominant share of the exploding demand for new products, the evolution of the Internet, and the many other new and exciting technologies on the horizon. And it is clearly well prepared to face the issues and challenges of the 21st century. The government has provided major new opportunities for growth through its advocacy of the NII, its opening of foreign markets, and its establishment of global rules regarding IPRs. Significant

government efforts are required to develop a world-class education system for the U.S. work force and to provide explicit policy on data assurance and data security. The DoD is also challenged to align its policies and business practices to tap the strength of this industry.

The nation that leads the world in the use and dissemination of information and information technology will be a formidable world power. For the foreseeable future, the United States will be such a power.

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LAND COMBAT SYSTEMS

ABSTRACT

The end of the Cold War and consequent easing of international tension suggests that the United States now faces less possibility of long-term or large-scale military conflict. This perception and the call for reaping a "peace dividend" from the fall of Communism in Europe convinced decisionmakers to reduce the defense budget and the size of U.S. military forces commensurate with the perception of a reduced requirement for armed forces. This general demobilization and the accompanying shift of resources away from defense procurement results in a significantly smaller Land Combat Systems industrial base that must look to government for a rationale to ensure its survival. In the absence of a strong vision, this industry will continue to shrink—possibly at the risk of extinction.

Col Jawad Al-qattan, Army, Kuwait
LtCol Robert Biggs, USMC
Lt Col Wendy Campo, USAF
COL Michael Chapman, USA
CAPT James Freihofer, USN
Mrs. Andrea Garcia, Defense Systems Management College
Lt Col Dave Herres, USAF
COL Jacques Malavergne, DGA, France
COL George Montgomery, USA
LtCol Nicholas Petronzio, USMC
Ms. Bonnie Pyett, Civ, Dept. of the Navy
LTC Michael Ramirez, USA
LTC Larry Roberson, USA
Mr. Michael Stephany, Dept. of the Army
COL Young Mo Yang, Army, Republic of Korea

Col Kenneth Dunn, USMC, faculty
COL Robert Garcia, USA, faculty
COL Paul Severance, USA, faculty

PLACES VISITED

Domestic
Defense Advanced Research Projects Agency, Arlington, VA
Letterkenny Army Depot, Chambersburg, PA
United Defense Ltd. Partnership, Chambersburg, PA
United Defense Ltd. Partnership, York, PA
Saturn Corp., Springhill, TN
Stewart & Stevenson, Sealy, TX
Picatinny Arsenal, Dover, NJ
General Dynamics Tank Plant, Lima, OH
Oshkosh Truck Company, Oshkosh, WI
AM General, South Bend, IN
Tank-Automotive Command, Warren, MI
General Dynamics Corp., Sterling Heights, MI

International
Tatra Truck Corp., Koprivnice, Czech Republic
Austrian Defense Academy, Vienna, Austria
Schiebel, Vienna, Austria
Vickers Defense Systems, Newcastle, UK
Royal Ordnance, Nottingham, UK
Krauss-Maffei Wehrtechnik, Munich, Germany

INTRODUCTION

If we desire peace, one of the most powerful institutions of our rising prosperity, it must be known that we are at all times ready for war.

George Washington

Forewarned, forearmed; to be prepared is half the victory.

don Miguel de Cervantes

In the aftermath of the Cold War, the United States determined that a smaller military establishment is warranted and that it could expect a significant savings, a "peace dividend" to follow from the new order. The result is that the United States began a military demobilization, not unlike that experienced after major conflicts. With dramatic reductions in the defense procurement budget (67 percent in real terms since 1985), demand for hardware plummeted. In some areas industrial capacity is nearly idle, and the number of contractors and subcontractors has shrunk dramatically. Production lines that remain open in the Land Combat Systems area do so only with government participation in the industrial process. As policy drives downsizing and the commercialization of defense programs, emphasis is placed on dual-use technologies, single process initiatives, and acquisition reforms. These technologies are expected to achieve cost savings that will allow the Department of Defense (DoD) to "get the most bang for the buck," for our remaining forces.

The Land Combat Systems Industry Study Group focused on the structure, health, and outlook of the sectors that comprise this industry and limited its scope to tracked and wheeled vehicles that provide combat, combat support, and transportation functions in support of military forces. The most significant issues are the following:

- the extent to which downsizing threatens the viability of the military to mobilize, surge, and conduct strategic operations in support of the survival and vital interests of the United States.
- the future role of the military in national power.
- the extent to which policies for achieving near-term savings affect long-term security.
- the competitive disadvantage of firms involved in defense contracts relative to an increasingly open global marketplace.

- the extent of systems, supplies, and equipment needed to sustain the force.
- the market share and other requirements needed to sustain the industry.
- the extent that excess capacity must be maintained to support mobilization and surge capacity.
- the role played by depots and government-owned/commercially operated (GOCO) plants, and
- the effect of acquisition reforms on the industry.

The decisions that policymakers endorse today regarding the Land Combat Systems industry will impact the nation's ability to fulfill its mission as an "engaged" world leader. Assumptions that future conflicts will be short, "come as you are" affairs may be correct, but misjudgment in the pursuit of short-term savings could be disastrous in a complex, technically oriented, and economically interdependent world. This report outlines current conditions in the industry, risks and challenges for tomorrow, and steps that government and industry can take to meet those challenges.

LAND COMBAT SYSTEMS INDUSTRY DEFINED

The Land Combat Systems study focuses on two major segments of the Land Combat industry: tracked vehicles and wheeled vehicles. While the study group also considered other segments such as towed artillery, small arms, and land mines as important elements of land combat, this report is confined to tracked and tactical wheeled vehicles and the policies related to their production.

Tracked Vehicles

Tracked vehicles are designed to perform functional mission requirements in almost any terrain and to survive all known and projected threats within reasonable risk limits. Today's domestic tracked vehicles include M1-series Abrams tanks, Bradley Fighting Vehicles, M109A6 Paladin Self-propelled Howitzers, M88A2 Hercules Recovery Vehicles, Armored Combat Earthmovers, and the Multiple Launch Rocket System. Proposed systems include the Grizzly Obstacle Breacher, the Marine Corps' Advanced Amphibious Assault Vehicle, and the Crusader advanced artillery system.

Advanced technology is applied to these vehicles to achieve additional survivability and lethality. For example, protective layers of steel, aluminum, titanium, or composite protective materials improve survivability; while advanced optics, communications, and laser capabilities supply the cutting edge in lethality—a must in today's technologically advanced and rapidly changing environment. Integration of modern command and control systems, sensors, and fire-control technology significantly enhances both survivability and lethality. It also allows smaller crews to determine precise enemy locations and target them with lethal first-round hits, often before the enemy knows an adversary is in the area.

Improved protection often carries penalties in terms of weight that challenges the systems' maneuverability on the battlefield. Increases in size and weight also affect the deployability and strategic reach of military power in an era characterized more and more by CONUS-based, but globally employed forces.

Determining the correct balance between defensive measures and high-technology offensive capabilities requires careful government-industry coordination. Because the technologies involved in tracked vehicles are not applicable to traditional commercial-vehicle manufacturing and because combat systems rely on specialized materials and processes that are not easily available once the military force is reduced, the Land Combat Systems industry can lose its critical capabilities and associated skills. Trends toward industrial consolidation, internal restructurings, mergers, and acquisitions characterize the post-Cold War industrial setting. This risk must be weighed as we look to future requirements for tracked vehicles.

The costs associated with maintaining or losing these capabilities is significant but offset by potential savings in human and equipment survivability and, of course, victory rather than defeat on the future battlefield.

Tactical Wheeled Vehicles

Tactical wheeled vehicles support combat operations by transporting personnel, equipment, petroleum products, critical supply items, ammunition, food, and water. They also provide mobility for command, control, and communications systems and serve as platforms for weapon systems, such as machine guns and TOW missiles.

Domestically produced tactical wheeled vehicles include a number of platforms that fall into three main categories according to carrying

capacity: light, medium, and heavy. These categories include the following systems:

- The light High-Mobility Multipurpose Wheeled Vehicle (HMMWV) currently in production at AM General Corporation at South Bend, Indiana.
- The Family of Medium Tactical Vehicles (FMTV) in 2.5 and 5-ton versions produced by Stewart & Stevenson Corporation, Sealy, Texas.
- The Heavy Equipment Transporter, the Heavy Expanded Mobility Tactical Truck, the Palletized Load System, the Logistics Vehicle System, and a number of special-purpose vehicles currently in production at Oshkosh Truck Company, Oshkosh, Wisconsin.

The wheeled fleet of military tactical vehicles, unlike their commercial counterparts, must traverse terrain and distances similar to those encountered by combat forces. This travel must be accomplished at speeds that accommodate the full spectrum of the vehicles' combat missions in diverse and demanding climatic conditions—from arctic environments at sustained temperatures of minus 50° F to desert, off-road environments, such as those in the Middle East, with sustained temperatures in some months hovering around 130° F. Although survivability features were not as high a priority for tactical wheeled vehicles in the past as for tracked vehicles, the threat of land mines and other systems are changing this criterion. But the design and survivability requirements for tactical wheeled vehicles are still less than they are for tracked vehicles. On the other hand, load capacity, off-road mobility, reliability, and simplicity of operation and maintenance are fundamental to supporting combat forces.

Tactical wheeled vehicles have more in common with commercial vehicles than do armored tracked vehicles. Their design is less subject to change with the changing nature of threats and more amenable to using off-the-shelf components and production technologies developed for commercial vehicles. The latter can sometimes satisfy military requirements with little modification. Experience has shown, however, that even rugged commercial vehicles—for example, those designed for mining, construction, and other heavy applications—fall short of military performance requirements in most cases. This realization prevents complete transition to a "single process" in firms that try to meet the requirements of both commercial and military operations.

CURRENT CONDITIONS

The world situation changed tremendously with the demise of the bipolar arrangement of the Cold War era. Loss of a clearly defined military threat drove policymakers to lower defense procurement budgets worldwide. Industrial plants that once busily produced the tools necessary to win the Cold War now operate at minimum capacities, scrambling to remain viable and competitive in a globalizing world economy. Many are out of business, and others fight for survival. The tracked vehicle sector, for example, has consolidated from three to two primary contractors, and only one of these produces main battle tanks.

The Department of Defense is also changing the way it does business. Most notable is the reduction of U.S. military forces by about 35 percent from Cold War levels. Base closures and withdrawal of major forward deployed forces to CONUS are an important part of the cost-saving effort. The stand down of units, equipment storage, and the transfer of major combat and combat-support end items to allies through defense cooperation and foreign military sales (FMS) have also taken place. Acquisition reforms and a rapid transition to commercial cost-saving practices in defense-oriented procurement are the wave of the present. Overcapacity in military depots and commercially operated industrial lines, and our inability to adapt facilities to other commercial business, is costly and threatens the survival of these capabilities.

New production requirements are dramatically lower than they were in the 1980s, particularly in the area of tracked vehicles. For example, General Dynamics Land Systems' (GDLS) Lima, Ohio, Tank Plant is currently running one shift to provide ten M1A2 tanks per month—and these are remanufactured and upgraded current tanks. As recently as the mid-1980s, the plant produced 70 per month, using three shifts. The facility could surge to 28 to 30 tanks per month with two additional shifts, but GDLS plans to produce at the current rate through 2001. The remanufacture of 600 tank chassis is programmed for the proposed breacher and bridging programs. This contract, added to current M1 business, helps the industry maintain its short-term ability to acquire replacements for attrition and a warm production base should a surge capability be needed in the near term.

The U.S. tactical wheeled-vehicle inventory is rapidly approaching the end of its projected service life, and several replacement and remanufacturing efforts are underway. These developments are discussed further in the Outlook section of this report.

Role of Government Requirements

The following characteristics describe the current condition of the combat vehicle industry relative to government requirements:

- In the Land Combat Systems industry, as with other elements of the economy, firms producing products to meet national security needs are increasingly global in their outlook.
- Failure to heed the government's call to realize efficiencies reduces competitiveness in the international marketplace and threatens the survival of firms relying on defense contracts (and potential alternate sources). Such failures also threaten the survival of critical skills and capabilities in other areas of the industry.
- According to management, GOCO facilities are placed at a competitive disadvantage because they must maintain overcapacity in those facilities.
- Some overcapacity may be critical to surge and mobilization requirements should assumptions about "come-as-you-are," short-term war scenarios prove realistic in the long run.
- Vehicle manufacturing as an overall industry in America is increasingly conducted by foreign or international firms with foreign ownership of companies such as GM Trucks, Mack, Freightliner, and soon the Ford heavy truck business. This circumstance raises the question of how responsive foreign-owned or international firms will actually be during a mobilization.
- Reduced procurement has resulted in virtually no government leverage on the truck market. Military procurements comprise a mere 1 percent of the 569,594 trucks produced in the U.S. market annually.
- Companies that supply parts and components reside largely in the third tier of contractors. Many operate globally and produce high-technology products; some do not maintain manufacturing operations in the United States. Because they don't depend on defense for any substantial part of their sales, most are only marginally affected by changes in defense policies and declining defense budgets.

These suppliers also produce many of the dual-use technologies listed in the DoD's "Critical Technologies Plan." These technologies and products introduce an increasing measure of

dependence on foreign industry and sources that affects the defense industrial base as a whole. They also add the element of risk associated with internationally shared research and development (R&D) technology. This dependence is an emerging trend in Land Combat Systems that may increase as it has in other defense industries.

- In Land Combat Systems, as in most defense industries, the government is caught in a dilemma: it can achieve short-term cost savings or it can concentrate on preserving potentially critical industrial and mobilization capability.

Industry Responses

In response to shrinking defense procurements, surviving contractors in the Land Combat Systems industry are exploring every means possible to cut costs and increase efficiency.

Downsizing. The primary method for achieving business efficiencies is downsizing. Reduced government demand has forced contractors to reduce personnel dramatically in every category. The only exception is the number of people needed to ensure compliance with government acquisition policy, which in some firms may be as much as 40 percent of the administrative staff. Work force reductions of over 50 percent across the board are not uncommon. The result is hiring freezes that bar younger entrants to the industry and raise the specter of a "graying" work force that is not being replenished by a new generation of workers. Thus, downsizing represents a further threat: namely that we may not have the critical skills and capabilities needed to mobilize and surge in the event of conflicts. As the current work force nears retirement, its collective experience and skills will be difficult to recover.

Consolidations, Mergers, Acquisitions, and Diversification. As the demand for Land Combat Systems declines, mergers constitute an important means for some firms to remain viable. In the most significant example, FMC's Defense Systems Group in San Jose, California, and HARSCO's BMY Combat Systems Division in York, Pennsylvania, combined in 1994 to form the United Defense Limited Partnership (UDLP), which is now the largest U.S. manufacturer and systems integrator for self-propelled artillery, tank retrievers, and armored combat vehicles.

In addition to UDLP, the other main producer of tracked military vehicles in the United States is GDLS, the producer of the M-1 series main battle tank. To compensate for the loss of tank orders, the company has diversified its product line. It recently acquired Teledyne Vehicle Systems and Lockheed-Martin Defense and Armament Systems to expand its business into the production of engines and combat information systems. GDLS also plans to compete for production of the Marine Corps' Advanced Amphibious Assault Vehicle (AAAV).

The primary producer of heavy wheeled vehicles for the Department of Defense is the Oshkosh Truck Company, which has strengthened its position in the international market by acquiring the Pierce fire truck manufacturer in Appleton, Wisconsin. This acquisition broadened the company's overall business base, achieved overall economies for the government, and strengthened Oshkosh Truck's worldwide business competitiveness.

Other Pressures

In addition to the trends previously discussed, a shrinking supplier base and an excess of industrial capacity further constrain the current operations of the Land Combat Systems industry.

Shrinking Supplier Base. Very low production rates in the Land Combat Vehicle sector have had a major impact on the industry's supplier base. Some suppliers were forced out of business by the low demand, while others were dropped by primary contractors intent on streamlining operations. In some cases, the primary contractors provided management and financial assistance to critical suppliers to keep them minimally viable. With fewer vendors, it may not be possible to contain prices or maintain the availability of supplies, particularly in the event of a defense mobilization or under conditions that require increased production.

Excess Capacity and Associated Overhead Costs. Current U.S. production facilities were built to produce sufficient goods to cover WWII and Cold War production needs and some have remained primarily to maintain a mobilization surge capacity. However, current DoD policy hinges on the notion that surge capacity is no longer a factor because future conflicts will be of short duration. If that is in fact the case, then the nation has an excess industrial capacity that is both expensive and wasteful. Most facilities operate at 60 percent or less of

their capacity, and some are operating at only 10 percent of their potential. In facilities designed for high-volume assembly lines, small work forces are now producing individual vehicles and tanks.

Current manufacturers involved in defense-related production, such as tanks and armored systems, compete with military depots for business. Some of them operate government-owned facilities that are larger than required for their operations and therefore represent overhead costs for these firms. These overcapacities in depots and GOCO facilities place defense firms like UDLP and GDLS at a distinct competitive disadvantage. The GOCO facilities have fixed overhead costs not shared by worldwide competitors whose commercially owned facilities must be tailored to the needs of their companies. Thus, excess capacity is the single most important impediment to competitiveness in the industry, other than the declining defense budget itself. While overhead costs cannot be denied, the Land Combat Systems Industry Study Group believes that the additional expense is minimal compared to the savings that would be realized from building, buying, or leasing tailored facilities, rather than using GOCOs. It appears that the impact of this overhead is purely theoretical. It's more likely that defense contractors would leave the business rather than undertake the costs of obtaining tailored commercial facilities to manufacture defense peculiar end-items to avoid the overhead associated with GOCO facilities.

CHALLENGES

The U.S. now faces competing and contradictory goals. On the one hand, it wants to cut military forces and drastically reduce the defense budget. On the other, it wants to maintain a technologically superior force to sustain our national survival and vital interests. To achieve the first goal, government must reform acquisition procedures and industrial structures to restrain the costs associated with smaller runs of highly specialized products. All of the mergers, downsizing, and collaborative efforts described in the previous section will be needed. To achieve the second goal, it must continue to produce or upgrade its land combat systems using leading-edge technology to ensure the continued superiority of the smaller force.

Reducing demand always results in increased unit production costs—as does the use of new technology. How is it possible to achieve these goals for less money? Acquisition reform in conjunction with industrial restructuring, mergers, collaborative efforts, diversification,

and other means may change production scales and allow some savings. However, they also reduce the surge capability that resides in industry and that we have repeatedly used to advantage in our military history. Its loss is a risk that must be weighed in any discussion of the cost-benefits of reform. Nothing is more costly than losing the next war. The greatest challenge in the Land Combat Systems industry is for the nation to determine how it will achieve short-term savings without endangering the future. Our assumptions about the nature and duration of future wars must be accurate, because the cost of being wrong is unacceptable.

The Military Budget

The budget is not likely to increase in real terms for the foreseeable future. The Army RDA accounts also decreased from $20.8 billion in fiscal year 1990 to $10.6 billion in 1997. Cost increases in an industry burdened by low demand, excess capacity, high overhead, long lead times for major end-items and critical components, a diminishing supplier base, and a graying work force are challenges not easily overcome in the current fiscal environment so long as no readily identifiable threat to our security can be detected by the public. Restructuring; implementation of managing a limited inventory; integrating commercial components, single-process initiative concepts, and dual-use technology exploitation; teaming labor and management; and relying on international and civilian orders to increase production are a few of the measures that government and industry are pursuing to mitigate the effects of declining military budgets.

Supplier Base

The decrease in defense production was naturally followed by the decreases in the size and viability of the supplier base, and for a number of reasons. First, the defense industry couldn't afford to keep all suppliers, so many firms concentrated their efforts on maintaining only the most efficient. Second, some suppliers left defense contracting because they couldn't stay in the industry without special attention on the part of industry or government. Finally, DoD had, and still has, no direct connection to the supplier base to fully assess its condition. To complicate matters further, the increasingly international climate of today's business ensures that many suppliers, particularly third-tier contractors, are not American companies and don't have production facilities in the United States. This circumstance raises questions about

the reliability of suppliers' support for U.S. interests in an emergency. The extent of our dependency on foreign sources is a new and emerging trend in the Land Combat Systems industry, although it is a well-established trend in commercial industry as a whole.

Problems with the supplier base, coupled with demand to meet unique military specifications, may greatly increase the lead time needed for future production and degrade the quality of future systems. While acquisition reform holds some promise for correcting these problems, it can be very slow to materialize and, by itself, is unlikely to sustain the supplier base that is critical to the long-term viability of our systems.

Regulatory Constraints

Manufacturers faced with increasing competitive pressures in national and global marketplaces are attempting to increase productivity, efficiency, and profitability. Some are attempting to diversify into related industrial fields that can better sustain both their commercial and government lines. Current restrictions, however, often hamper these efforts and may result in greater cost to the government. For example, GOCO facilities, such as Letterkenny Army Depot and the Lima Tank Plant, both have high overhead costs related to significant excess capacity. Regulations require that total overhead costs be spread evenly over both government and commercial work in each facility. Consequently, efforts by contractors to increase the efficiency of GOCO facilities are accompanied by overhead costs that place them at a competitive disadvantage. This competitive disadvantage makes it increasingly difficult to survive in either sector.

Restrictions on exports place necessary hindrances on industry. Unlike some foreign competitors, our defense industry can't sell to everyone interested in our products. Important technical transfer issues are at stake that could jeopardize the capabilities and safety of our forces. A potential result is that the Land Combat Systems industry will offer scaled-down versions of its products that don't represent state-of-the-art capability. In such cases the outcome is obvious; potential buyers will take their business to less inhibited competitors.

Antitrust Laws

U.S. defense firms are sometimes hampered by antitrust laws that place them at a disadvantage internationally. These laws inhibit American firms from engaging in some domestic cooperative ventures,

while their overseas competitors are not subject to such restrictions. While the intent of antitrust legislation is to ensure competition in the marketplace as an incentive for lower prices, such savings are not possible if competitors are driven from the scene by insufficient business. In both cases, the government loses. Finding the appropriate national policy in the area of antitrust legislation will be a challenge for the government in its drive for lower costs and a smaller, more capable military.

International Industries and Markets

The Land Combat Systems Study Group visited a number of foreign producers of combat vehicles. The firms were selected to provide a mix of characteristics. Some were modern plants employing the latest production technologies, others were established plants using older methods and techniques. All were capable firms facing many of the same challenges that U.S. defense firms are facing: adjustments to the post-Cold War military posture, falling defense budgets, downsized military forces, a diminished supplier base, and the encroachment of the commercial sector.

European companies, like American firms, view international marketing as indispensable to survival. Continual improvement in competitive advantage is their goal. Frustration with American isolationist tendencies tops the European list of impediments to successful cooperation and partnership efforts. Foreign competitors view the "buy American" statutes of the United States as unreasonable barriers to trade. They also see the cost of developing partnerships with American business as a cost-prohibitive option for entering the U.S. market.

The European view is that the United States currently enjoys a 75 percent market share in European defense procurement, putting U.S. firms in a better position than their European counterparts in the global defense marketplace. Europeans hope to compete successfully for a larger share of that market. Such competition should not be difficult, since the United States doesn't have a monopoly on high-tech, quality defense products. Frustration with "buy American" policies, the cost of shipping U.S.-produced systems back to U.S. firms for upgrades and remanufacturing, and poor parts support from U.S. manufacturers cause European countries to look elsewhere for hardware and service at a time when U.S. firms need all the business they can get. Thus, for example;

- In the Czech Republic, the Tatra Truck Corporation of Koprivnice produces heavy trucks that are designed for off-road travel through the use of a unique suspension system based on a "central backbone" construction with swinging half-axles;
- In Munich, Germany, the Krauss-Maffei Wehrtechnik builds the Leopard II main battle tank;
- In Newcastle, England, the Vickers Defense Systems produces main battle tanks, light tanks, armored repair and recovery vehicles, and other specialized items, with joint ventures in the United States and Germany; and
- In Nottingham, Royal Ordnance produces artillery.

All European firms producing Land Combat Systems are operating at inefficient levels, but Tatra appears to have the greatest challenge. The company is struggling to deal with the overhead and inefficiencies of a large plant left over from the command economy of WWII Germany and Communist rule. Tatra's main cost-cutting initiative has been division of the firm into separate business areas, each responsible for developing product diversity and for expanding its own business base. The plant has also integrated a line of diverse products to shore up its position resulting from low-rate truck production in the wake of the Cold War.

OUTLOOK

The production base for Land Combat Systems is in jeopardy. Current production lines are operating well below capacity, and as current new production contracts expire—for example, the limited run of M1A2 main battle tanks, the Family of Medium Tactical Vehicles (FMTV), the HMMWV, and other heavy trucks to transport heavy and outsized cargo—these production lines may be permanently ended. For companies like Oshkosh, whose military products are based on specialized heavy-duty commercial designs used in construction, mining, and exploration, a "warm" base may remain that can be readily adapted to defense mobilization purposes, provided that commercial demand remains sufficient to sustain the company's overall business position (Oshkosh has decreased its defense business from 90 to 40 percent in the last three years). Completion of new production tanks and light/medium trucks could result in expensive gaps or loss of production capability altogether. Estimates indicate that if tank production ends at the Lima

Tank Plant, it would take five years to reconstitute the ability to produce or remanufacture them.

Short-Term Outlook (One to Five Years)

Upgrade programs will clearly remain the primary source of production for the nation's only remaining M1 tank line located at Lima, Ohio. The production of new M1A2 tanks will give way to the remanufacture of older M1A1 versions. The production of low-rated FMTV end-items will necessitate remanufacturing some Army medium trucks through the 2.5 ton Extended Service Program (ESP). Because the Army's FMTV design does not meet Navy/Marine Corps size/cube/weight requirements for shipboard and fly-in-echelon transportability, Marine medium truck assets will also be included in this remanufacturing effort. This program, as well as the contract for the new AAAV, is the subject of fierce competition among surviving firms in the U.S. defense industry. Thus, both the wheeled and tracked vehicle segments of the industry are actively seeking foreign buyers. Foreign competition for contracts will remain strong as demobilization continues on an international basis.

Projected near-term business appears sufficient in the tactical wheeled vehicle segment to maintain production for the short run. The capture of any international sales would go a long way to offset overhead rates and help maintain sufficient production capability during the coming five years.

A new emphasis on defensive systems may create additional upgrade business for both wheeled and tracked vehicle contractors. Capitalizing on modern design technology, including computer-based reliability, real-time interactive computer models, tactile feedback devices, computerized design-model translators, and computer-aided design systems with seamless data-sharing capability may reduce research and development (R&D) costs sufficiently to develop future vehicles and incorporate sophisticated upgrades.

Long-Term Outlook (5 to 20 Years)

One of the main themes in industry is that the future is not defined beyond current multiyear procurement contracts. Industry leaders cannot predict the total truck requirement is over the coming decade. The recent presidential budget submission is empty in the out-years, and no one knows what the overall strategy will be. This uncertainty affects

research and development (R&D) spending, since the requirement and aim of that effort cannot be defined. The government policy of procuring in "chunks" rather than in accordance with a long-range strategy has caused manufacturers to move away from reliance on defense contracts as much as possible. It has, that is, decimated the number of contractors and subcontractors.

With similar effect, the less glamorous tactical wheeled vehicle programs are routinely decremated in favor of attack helicopters and armored combat vehicles. Predictably, the Army finds itself in the situation where it must buy trucks in "spurts," when the trucks are not in direct competition with more glamorous systems. This ploy has the obvious effect of creating chronic gaps in production that prevent program stability and lead contractors to question the desirability of their involvement in tactical wheeled vehicle programs.

Although some programs, such as the Advanced Amphibious Assault Vehicle, the Future Main Battle Tank, the Heavy Bridge System, the Crusader Advanced Field Artillery System, the Future Infantry Fighting Vehicle, and the Advanced Cavalry Vehicle may be contracted for in the coming years, the Land Combat Systems industry assumes continuing decline in defense spending well into the future. Production of new, upgraded, and remanufactured vehicles will not rebound from current minimum sustaining levels. In fact, the consensus of the Land Combat Systems Industry Group is that at least one current producer may become uncompetitive as the others assume all contracts for the remanufacture and upgrade of existing systems. At the least, U.S. systems will not compete successfully in the FMS market through failure to maintain market share, rising overhead costs associated with unused capacity, retaliation for protectionist measures, and failure to invest sufficiently in R&D to maintain technological superiority in our systems.

New generation combat vehicles (e.g., Future Main Battle Tank and follow-on HMMWV) are in direct competition with other expensive defense programs such as the B-2 bomber, F-22 fighter, and sorely needed strategic sea/airlift capabilities. The view from industry's vantage point is not promising enough to hold on to the limited contractor base that now exists. Sound business reasoning suggests that industry take every possible action to cut costs and remain profitable so long as they can hope to survive this extremely competitive market. The remaining contractors may forgo defense business entirely and focus exclusively on the potentially more profitable commercial sector.

In short, the ability of the United States to maintain a viable industrial base capable of ensuring our national security interests is at

risk. Some lines are sure to shut down, and only firms that have diverse but related market shares in transferable commercial systems will survive. For example, those possessed by Stewart & Stevenson before they produced the Family of Medium Tactical Vehicles, will find entry barriers low enough to reenter the market when the need for trucks reemerges. In the absence of stable, long-term production schedules, such companies will be relied on to convert to defense production periodically in the future.

Main Vulnerability

The declining defense budget works its greatest damage on the supplier base. Some contractors have eliminated 70 percent of their supplier base to cut costs as much as possible. Most have cultivated only the most reliable suppliers, eliminating less productive ones and intervening in the internal affairs of the remaining suppliers to ensure their continued viability. Their intent is to develop long-term, lasting relationships with selected vendors to secure the little business that remains. Contractors now ask vendors to share in the overall risk associated with the industry to a degree unheard of in past years. The practice of maintaining multiple vendor sources is no longer affordable. This circumstance carries greater risk in the event of prolonged war and mobilization than was ever the case during the Cold War period.

Future Surge Capability

As industry streamlines its operations and eliminates excess capacity, surge capability is also eliminated. Today's surge capability is constrained to what the current workforce can produce on current production lines operating and to the level of production that the suppliers can support. Most facilities operate one shift with a reduced number of workers. Major expansion of output will require hiring and training sufficient workers to increase the number of workers on the current shift and to place additional shifts on line. As this is a time-consuming process, it is unlikely that the mobilization would be timely, no matter how necessary. And the situation will only get worse. The Department of Defense cannot afford to use a flawed assessment of the nature and duration of future conflict—not in an atmosphere that emphasizes business savings at the expense of mobilization and surge capacity.

Commercialization and Internationalization of the Industrial Base

Increasing reliance on the commercial sector and continued pressures to internationalize business threaten the overall reliability of our industrial base during times of future conflict—or at least call this reliability into question. Remanufacturing, upgrading, and technical insertion programs for foreign owners of American manufactured systems such as tanks, artillery, and trucks will drive some American manufacturers to consider offshore operations to meet this potential international market. Both domestic and foreign producers are exploring the virtues of international partnerships. The possibility of gaining a competitive edge in the global market or cutting development costs by using internationally available technology motivates U.S. firms to form partnerships with foreign counterparts. When "buy American" statutes are attached to procurement practices, partnerships are the only way that foreign firms can enter U.S. markets. The current production of M1 tanks in Egypt and proposals to produce American systems in Turkey are early examples of this transition to offshore locations, as is the trend to rely on foreign resources and vendors that do not fall under U.S. mobilization policies.

GOVERNMENT GOALS AND ROLE

DoD must provide the assessment and vision necessary to ensure that the Land Combat Systems industry remains capable of meeting its future requirements. A consistent vision of the future coupled with reforms in government and industry is needed to ensure the lowest cost to government and a competitive advantage for U.S. manufacturers.

Government Sponsorship of American Manufacturers

The national governments of our competitors are much more actively involved in obtaining sales for their defense industries than our government is. The initiatives of senior foreign leaders increase sales, reduce overhead, and help maintain the viability of foreign defense industries with which our own industry competes for survival. Though American firms receive little active support from their government leaders, international sales such as airport fire trucks and HMMWVs help companies like Oshkosh Trucks and AM General maintain the

minimum production rates that keep our defense industrial base warm. Maintaining America's 75 percent market share of European defense procurements would go a long way toward sustaining our domestic defense industrial base, particularly if the government would actively seek additional overseas sales through joint efforts of the State and Commerce departments.

Acquisition Reform

The time for acquisition reform is long overdue. In fact, we have a long history of reform initiatives that goes back as far as the American Revolution. However, the severe drawdown of U.S. military forces following the end of the Cold War has become a catalyst for real reform. We are slowly seeing a streamlining in acquisition regulations and specifications. In spite of this momentum, however, resistance to change is deeply entrenched. While high-level government officials and industry leaders endorse reform as part of the drive to maintain military capability and corporate profitability, mid-level government employees are slow to make the transition to new modes of operating. Industry continues to run into bureaucratic inefficiencies. Some defense contractors have made great strides using the Single Process Initiative (SPI). Its use resulted in significant savings in the production process of one company yet 40 percent of the company's administrative staff is still needed to document compliance with acquisition reforms, at a cost of about $1 million annually.

The most important challenge for government leaders in the legislative and executive branches is to revise the budget process to allow multiyear funding that is not subject to annual manipulation. This reform alone would stabilize programs and result in the greatest cost-savings. Annual budgeting and the changes associated with it is the single most costly factor in defense programs. It inhibits proper business planning by defense contractors and dissuades further measures such as plant automation that would result in even further savings. Failure to vigorously pursue this reform wastes the taxpayer's money and damages the capability of their significantly reduced military forces.

CONCLUSION

> *We must always be ready, so that if an enemy approaches us with a sharp sword, we do not meet him armed only with an ornamental rapier.*
>
> Carl von Clausewitz

The Land Combat Systems industry is taking steps to remain viable despite continuing defense spending cutbacks as the nation and the Western world demobilize following the Cold War. The industry is downsizing, consolidating operations, integrating its commercial and military lines, and competing fiercely for a dwindling number of production and remanufacturing contracts. Firms producing wheeled vehicles have the advantage of being able to transfer some of their capabilities to the commercial sector. Those producing tanks, armored vehicles, and self-propelled artillery, however, have few expectations beyond the end of their current multiyear contracts.

The remanufacturing and upgrading of current systems and technical programs and limited opportunities for foreign military sales are currently sufficient to maintain production lines, but at minimum sustaining rates. Further cutbacks will result in a smaller industrial base and force some competitors to exit the defense business. In spite of improved production efficiency and drastic reductions in the work force, higher unit costs resulting from increasing overhead in idle facilities; inconsistent, low rates of government procurement; and erosion of a strong supplier base place our defense contractors at a disadvantage relative to their counterparts in domestic and international markets.

While companies involved in producing Land Combat Systems are generally profitable, current profits are at the expense of lost mobilization and surge capacity. Although no long-term national vision has been articulated for the industry, the consensus in Washington is that a peace dividend can be achieved and the federal debt reduced—based on the premise that future wars will be short "come as you are" affairs using existing equipment and supplies. Surge capability is less important in a scenario that assumes the conflict will end before a mobilization can be mounted. Policymakers would then expect industry

to replenish its spent stocks in three years—before the eruption of another conflict. The validity of such assumptions is critical to our national security: Is it wise to trade surge and mobilization capability for short-term savings?

The nation must develop a comprehensive national security strategy that provides a clear vision for the defense industry so that it can profitably manufacture the material means to ensure our national interests. We must decide between alternatives: to continue producing tanks and other systems at very low rates of production or to adopt a new strategy that relies on the comparative advantages of the United States and its closest allies to meet our collective military hardware needs. In other words, instead of maintaining several costly and underused tank production lines in the West, we should perhaps allow the nation with the greatest competitive advantage in making armored vehicles to build tanks, while another with the greatest advantage in technology (perhaps the United States) produces electronics and defensive countermeasures for incorporation in major end-items.

In the absence of a comprehensive policy, expanded use of dual-use technology, commercial practices, depot/industry work-sharing, vehicle upgrade programs, and aggressive foreign military sales are keys to near-term survival of the industry. An ironclad partnership between government and the industrial survivors of the current demobilization is essential to the security of our nation and its success in future combat.

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MUNITIONS

ABSTRACT

Current defense planning is predicated on the overlap of two short (less than 90 days) major regional contingencies. We believe the current U.S. munitions stockpile, coupled with the production of precision weaponry, appears marginally adequate to meet this requirement. However, trends point to a time in the near future when the U.S. Munitions Industrial Base (MIB) might not be capable of sustaining the quality and quantity of munitions required in a prolonged national emergency such as a short war "gone long." Clearly, the munitions industry is at a critical juncture. It can be allowed to atrophy or, in partnership with government, adapt and remain a viable element of our nation's defense. Prudent ways must be found to keep a minimal MIB capability aimed at producing preferred munitions, leveraging the stockpile through weapons enhancements and streamlined logistics systems, aggressive research and development (R&D) funding, greater global competitiveness, and ensuring a postconflict rapid munitions replenishment.

Col Larry Bramlitt, USAF
LTC Donald Browne, USA
CAPT Paul Bruno, USN
Lt Col James Diehl, USAF
CDR John Fraser, USN
Mr. Donald Gregory, Dept. of the Air Force
Lt Col Tim Hershey, USAF
Lt Col William Holway, USAF
LTC Roy Johnson, USA
LTC William Laymon, USA
BG Musa Megdadi, Jordanian Army
CDR Martin Moke, USN
Mr. Gary O'Connell, Dept. of the Air Force
Mrs. Barbara Sisson, Dept. of Energy

Mr. Roger Cubby, faculty
Col Barry Smith, USAF, faculty

PLACES VISITED

Domestic

Aeronautical Systems Center, Eglin Air Force Base, FL
Atlantic Research Corp., Gainesville, VA
Department of Energy, Germantown, MD
Hughes Missile Systems Co., Tucson, AZ
InterContinental Manufacturing Co., Garland, TX
Lockheed-Martin-Vought, Grand Prairie, TX
Armament Research Development and Engineering Center (ARDEC),
Picatinny Army Arsenal, Dover, NJ
Sandia National Laboratories, Albuquerque, NM
Texas Instruments, Lewisville, TX

International

Ministry of Defence, London, UK
British Aerospace, Stevenage, UK
GEC-Marconi, London, UK
Hunting Engineering, Ampthill, UK
Office of Defense Cooperation, London, UK
GIAT, Bourges, France
Aerospatiale, de Magny les Hameaux, France
Directorate for General Armaments, Paris, France
Office of Defense Cooperation, Paris, France

INTRODUCTION

The U.S. munitions industry is a critical element of national power that must be nurtured and sustained. Failure to maintain a vibrant munitions industrial base (MIB) will significantly compromise the nation's ability to deter aggression and protect its vital and strategic interests. Unfortunately, the vitality of the MIB—specifically its capability to support present and future U.S. strategic objectives by providing ammunition, precision-guided munitions, missiles, and weapons of mass destruction (hereafter referred to collectively as munitions)—is threatened. Reductions in munitions demand erode its capacities, as do conversions of munitions manufacturers to nondefense production, reduced production of high-tech weapons, and growing global competition.

This report defines the MIB, assesses its current condition and challenges, projects its future health and describes the government's goals and roles in its future. The report concludes its summary of the status of the U.S. munitions industry, with recommendations important to the continuation of a strong MIB—an industrial base capable of supporting U.S. military forces well into the 21st century.

Members of the munitions industry seminar read extensively on the MIB and visited contractor plants and government installations in the United States, the United Kingdom, and France. They also discussed issues relevant to its three major sectors with representatives of the Office of the Secretary of Defense including the Assistant Secretary of Defense for Industrial Affairs and Science and Technology, the U.S. Army Single Manager for Conventional Ammunition, and the Munitions Industrial Base Task Force. The three primary sectors of the MIB are: ammunition—bombs, bullets, mortars, mines, projectiles, explosives, and rockets; precision-guided munitions (PGMs)—conventionally armed guided missiles, smart bombs, and torpedoes; and weapons of mass destruction (WMD)—nuclear, biological, and chemical weapons. The contents of this report reflect the insights gained from firsthand observations of these systems and discussions with munitions experts.

THE MUNITIONS INDUSTRY DEFINED

The U.S. MIB consists of a small number of munitions plants, arsenals, depots, and technology centers. Specifically, it has three active government-owned, government-operated facilities, six active

government-owned, contractor-operated facilities, and fewer than 50 contractor-owned, contractor-operated facilities. The MIB also includes the individual services' facilities responsible for the storage, maintenance, and distribution of the current munitions stockpile—valued in excess of $40 billion.

Today's MIB is changing dramatically in composition and sophistication. Forcing this transformation is the need to remain competitive in a munitions market characterized by an 80 percent reduction in defense spending, growing preferences for upgrades versus new acquisitions, greater demand for high-tech electronics, and increasing global competition (GAO, 1996a). The result of these trends is the near extinction of mammoth munitions production facilities whose blast furnaces and labor-intensive production operations forged massive arsenals of relatively simple munitions for global wars. Emerging in their place are flexible, high-tech munitions production and storage facilities. As facilities modernize, they employ a smaller, highly skilled work force in the limited production and modernization of munitions, primarily PGMs. Today's MIB employs a wide variety of sophisticated production technologies and methods, as it must to maintain a competitive edge in the global market. These technologies and methods include nuclear physics, advanced computer-aided software engineering, stealth (low observables) technology, optics, advanced and agile manufacturing, composite materials, metallurgy, metal machining, guidance and navigation systems, fuzing, microelectronics, propellants, and explosives.

With regard to nuclear weapons, the Department of Energy's (DOE's) Office of Defense Programs is responsible for ensuring the safety, security, and reliability of the nation's nuclear weapons stockpile. As the sole supplier of nuclear warheads to the Department of Defense (DoD), DOE oversees an extremely broad range of activities including basic scientific studies and experiments; manufacturing operations involving nuclear materials, high explosives, and high-technology electronics and mechanical components; testing, surveillance, assessment, and certification of weapons; and storage and transportation of weapons and hazardous materials. DOE's Office of Defense Programs performs its mission with 2,000 federal employees overseeing the work of about 25,600 contract personnel who, in turn, manage and operate the government-owned weapons complex. The Defense Programs budget is about $4 billion per year.

The chemical weapons stockpile is considered obsolete, too costly to maintain, and a growing safety hazard. Furthermore, the superior conventional firepower of the U.S. military, complemented by its arsenal of nuclear weapons, has diminished the need for chemical weapons. Thus, the United States has made the unilateral decision to dispose of its chemical weapons stockpile. To date, this stockpile consists of 30,000 tons of chemical agents stored in approximately three million mines, rockets, projectiles, bombs, spray tanks, and one-ton storage containers. All of these weapons are stored in one of six facilities in the continental United States or at Johnston Atoll in the Pacific (NRC, 1994).

CURRENT CONDITION

At the end of the Cold War, demand for munitions dropped dramatically—as illustrated by the Army's 74 percent reduction in war reserve requirements and a decline in DoD munitions requirements from 2.5 million to 650 thousand gross tons. Massive quantities of munitions returned from Europe and Operation Desert Storm have also placed considerable strain on the Army's ability to store, manage, and dispose of the wholesale munitions inventories for all the services. The magnitude of the Army challenge was reflected in the 1996 identification of $31 billion worth of excess munitions, of which $22 billion were usable (GAO, 1996b). Today, while shortages in specific types of munitions exist, the services generally believe these shortages can be corrected with substitute munitions and planned procurements.

Not surprisingly, the drop in demand caused DoD procurement of munitions to be cut in half. International demand also fell as a result of the end of the East-West confrontation, poor global economic conditions, and increasing dependence on domestic munitions production. Though these more recent changes in the global munitions market are important, the actual decline in the U.S. MIB began long before the implosion of the Soviet Union. Since 1978, the number of government owned and/or operated, as well as private munitions companies, have declined by over 50 percent (MIBTF, 1994). Although some of this decline was the result of government downsizing and industry mergers, the predominant cause has been manufacturers leaving the munitions business for more stable and profitable markets. In one contemporary instance, a manufacturer of critical missile technology entered the automobile airbag market and in less than five years, this new production activity had become its primary

source of revenue. An even greater loss in the number of commercial lower-tier companies exacerbates the MIB's overall decline. The manufacturers of subcomponents for major prime contractors, forced by low production rates and single-year procurements, look elsewhere for revenue sustaining products (GAO, 1996a). Another threat to the current and long-term strength and stability of today's MIB is its aging work force. During years of downsizing and consolidations, younger engineers and technicians were often the first to go. As munitions manufacturers seek to restore a portion of their previous work force and begin new munitions production they discover that available engineers and technicians are reluctant to join the MIB because of its instability and because greater pay, prestige, and growth potential are available in other industries. These conditions are especially true for high-tech munitions manufacturers who must compete for the same computer and software engineers being sought by the flourishing information systems industry.

Drastic reductions and fluctuations in demand have created excess production capacity, which increases unit costs since the expenses of idle plant capacity must be covered by the remaining production. In addition, high R&D investment requirements, loss of skilled labor to other industries, and the need to be more cost-efficient force the remaining munitions industries to be more cooperative with each other. Joint ventures (domestic and international) and outsourcing the production of component parts are ways to use each other's core competencies, while minimizing the risks and costs to all. Finally, to elicit public and government support for the MIB, some manufacturers have formed advocacy organizations such as the Muitions Industrial Base Task Force (MIBTF, 1994).

DoD has adapted to changes in the global political and domestic MIB environments by adopting a new munitions planning strategy. This strategy, based on the assumption that the next war will be "come-as-you-are," abandons past reliance on domestic surge production and mobilization capacity. Instead, this new DoD munitions strategy places greater reliance on the ability of the existing stockpile to meet all munitions requirements through two major regional contingencies (MRCs). It also seeks to leverage the firepower of this stockpile through increased development and acquisition of precision strike munitions. MIB production capacity will be called on only to *replenish* the stockpile, not to meet the demands of fighting the MRCs (GAO, 1996a). However, this new strategy's reliance on precision munitions renders obsolete a majority of the current stockpile.

As a result of the new strategy, the DoD munitions program is a complex mix of select R&D, slow stockpile modernization, and environmental and safety programs. The ability to maintain an effective, safe, and affordable mix of munitions (i.e., high- and low-tech) depends on having a domestic core of technological and production capability, while participating in a global munitions market with friends and allies. The organization at least partially responsible for the attainment of this goal is the U.S. Army's Single Manager for Conventional Ammunition (SMCA). Since 1977, this organization has stored, managed, inspected, tested, and disposed of munitions common to all the services, with each service managing its own stock of service-unique munitions. The SMCA is also charged to preserve an adequate domestic production capability. It therefore attempts to balance "warm" production lines through low-rate buys and "cold" (layaway) facilities for later use if required.

In compensation for the decline in domestic munitions requirements, the U.S. MIB puts greater emphasis on foreign sales to sustain its production operations. The international MIB is characterized by a mixture of munitions manufacturers representing the full spectrum of quality, ownership (private versus government), technological processes and final product, and joint ventures. From the perspective of the United States, the world munitions market is not a level playing field. Some foreign competitors are heavily subsidized by their governments and engage in certain practices to win contracts that could be deemed unethical or illegal for U.S. firms. These practices can put the U.S. MIB at a competitive disadvantage. A trend, especially in Europe, is for nations to forego self-sufficiency. Instead of producing the full spectrum of their national munitions requirements, some nations are focusing their limited resources on gaining preeminence in selected munitions areas and importing items they do not produce indigenously. This trend could result in very significant competition for the United States in high-tech munitions categories as other nations focus their limited resources in specialized areas of munitions production.

The performance of U.S. munitions industries in the international market is complicated by a growing demand for industrial offsets (i.e., the insistence that at least some of the work involved be accomplished within the nation purchasing the munitions). No longer satisfied with low-tech industrial offsets ("bending metal," low-tech production processes, etc.), foreign buyers are becoming increasingly insistent on getting the technology involved in end-item, high-tech manufacturing. U.S. companies have been forced to develop sophisticated offset packages. A

munitions subsidiary of a major American automotive producer, for example, was able to offer auto parts manufacturing as an offset against the purchase of munitions.

CHALLENGES

The volatility in international relations, coupled with military downsizing and shifts to high-tech weaponry, create many challenges for the U.S. military industrial base. The following are among the most significant.

Optimizing the Stockpile

Among the major challenges is determining the optimal quantity and quality of munitions, consistent with requirements and resources, necessary to fight and win two MRCs. In stockpile optimization, the potential loss of life and the result (losses) of exposing high-value combat systems to combat (e.g., aircraft carrier, B-2 bomber, and M1A1/2 Abrams tank) must be considered in conforming to a munitions strategy that allows one to use suitable substitutes on the battlefield. DoD's ability to pursue stockpile optimization is severely compromised by its lack of oversight. No single DoD munitions manager knows the services' constantly changing requirements, or what they possess in their munitions storage facilities. As it is difficult to determine the amount of excess munitions in the DoD inventory, limited resources are wasted caring for munitions no longer needed, and optimization of the stockpile cannot be achieved (GAO 1996b).

Rates of Production

Another concern is how quickly low-rate production items can fill stockpile shortages, especially after a major conflict. The prolonged reliance on less-modern munitions is also questionable. For example, the primary 155 mm howitzer munition—the Dual Purpose Improved Conventional Munition (ICM) round—is currently at 50 percent fill in the stockpile. Even at full production rates, it takes over three years to replenish one MRC's expenditure of this key artillery munition. Further, as the U.S. munitions industry strives to increase exports, the United States and its allies may rely on the same defense firms to replenish their

respective stockpiles. Competition among allies for scarce munitions resources may create severe tension and require delicate negotiations. In any case, the time required to replenish the stockpile will undoubtedly increase. Assuming that experiences similar to the Gulf War are repeated, and armed forces resist using less modern munitions, it may be that little or no modern munitions will remain for use in a second MRC.

Increased Privatization

Budget pressures and DoD downsizing will continue to drive major reductions and restructuring in government-owned and maintained infrastructure. While seeking to divest itself of munitions plants, equipment, and labor, DoD will transfer these activities to private industry. Private industry may accept responsibility, but only if these activities are as profitable as other industries—operating at a loss for the sake of the nation will not be an option. Unless the privatized plants are profitable, the U.S. munitions industry will further erode.

Fewer Suppliers

The dwindling size of the MIB results in a smaller competition base for government and private industry. It also increases the single-source acquisitions of full systems (prime) and suppliers (subcontractors). The risks of this situation are higher costs, single-point failures, and limited flexibility (production times, costs, and capabilities). On the other hand, fewer suppliers may lead to stronger long-term commitments from the remaining industry in the form of more focused R&D, dedicated infrastructure investments, and the economic efficiencies of larger production lots.

Declining Force Structure

The estimates of munition needs for the two MRC scenario have not decreased, yet the number of weapons delivery platforms (e.g., ships, aircraft, tanks, artillery, and guns) has significantly decreased. Thus, the combat commanders-in-chiefs (CINCs) have placed precision-guided munitions (PGMs) at the top of their preference lists to compensate for the loss of delivery platforms and to sustain their combat efficiencies. This shift has created a significant increase in excess "dumb" munitions and a shortfall in PGMs. Increased production of PGMs appears to be

the answer to the shortfall; the current budget does not, however, allow them to be produced in the quantities the CINCs require. Thus, the challenge is to convert some of the huge "dumb" munitions stockpile into inexpensive "near PGMs"—an 80 percent solution to the goal of an all-modern stockpile.

Smaller Production Runs

In order to be profitable some munitions production facilities are being scaled for smaller, continuous runs. This approach limits the capacity to produce larger volumes, if required, and sacrifices economies of scale. Further, these smaller production runs are being accomplished in facilities designed for flexible manufacturing where capital investments have alternate commercial capabilities (e.g., build "bullets and butter" within the same facility). While this approach may provide for greater flexibility and efficiency to the producer, it might not be responsive to the needs of the MIB in the event of a national emergency. Another challenge with small runs on dedicated production lines is the necessity that the lines cycle between "hot" and "cold." Once the facility produces the required quantity of munitions, the line shuts down until the next production requirement. This approach results in expensive idle capacity, higher costs, and may lead to quality control problems with production startups.

Maintaining the Technological Edge

With a defense strategy that relies on quality more than quantity of munitions, it becomes imperative that the U.S. MIB maintain a technological edge. According to Paul Kaminski, former Under Secretary of Defense for Acquisition and Technology, the services can "maintain the edge" using current DoD programs such as Federally Funded Research and Development Centers (FFRDC), Advanced Concept Technology Demonstrations (ACTD), international armament cooperation (including R&D), and the rapid fielding and training of modernized munitions. The edge is sharpened by the availability and capability to employ advanced munitions (Kaminski, 1996b). One agency that is bringing new technology to bear in defense systems is the DoD-sponsored Defense Advanced Research Projects Agency (DARPA). The munitions community should work with DARPA to adapt new technologies to munitions problems. Of major U.S. defense sectors, the munitions industry has one of the weakest connections to the

commercial market because of limited private-sector demand. Modernized munitions require a concerted effort by the government to maximize the R&D community's "return on investment."

Demilitarization

As DoD downsizes and older munitions become obsolete, unserviceable, or unusable, they must be demilitarized. Over 400,000 tons of conventional and over 30,000 tons of chemical munitions currently require demilitarization, at an annual cost in excess of $100 million. The tonnage of conventional munitions requiring demilitarization will likely double over the next three years (Kaminski, 1996a and 1996b). The challenge is to destroy these munitions promptly, efficiently, and safely. Environmental restrictions curtail or eliminate the most cost-effective means of disposal—open-burning and detonation. The costs associated with demilitarization are a drain on the DoD total obligation authority for munitions. The demilitarization of the conventional stockpile costs over $90 million annually, while the multiyear cost of destroying the entire chemical weapons stockpile will be more than $11.9 billion (Dept. of the Army, 1995).

Globalization of the Munitions Industry

The size and diversity of its MIB has made the United States a world leader in developing munitions. Its history of fair pricing, high performance, on-time delivery, and supportability has earned it an enviable reputation in the global market. Nevertheless, competition U.S. firms will face increases as other nations enter the shrinking market. An illustration of this growing competition is Western Europe's plans to strengthen its own munitions industry.

To remain competitive and provide "industrial offsets" for foreign customers, the U.S. MIB is now engaging in joint ventures with international partners. Some within the MIB are uncomfortable with joint ventures because they can expose elements of the U.S. industry to the political whims of a foreign government. To illustrate their concern, they point to Canada, America's longtime ally, and its refusal to provide the tritium critical to sustain the U.S. nuclear arsenal. Others within the MIB see joint international ventures as a necessity for survival in a dwindling, highly competitive market. The challenge for the U.S. government is to ensure that its technology-transfer policies strike a balance between the MIB's need to engage abroad for survival and the

national interests in protecting domestic production capabilities, technological advantages, and unilateral flexibility in world affairs.

According to information received from European defense contractors, several barriers inhibit partnerships between U.S. and foreign defense contractors. These barriers include U.S. funding instability created by the annual budget cycle, a perceived lack of U.S. commitment to international programs, and frequent congressional actions that affect programs without due regard for international implications. The European MIB faces the same challenges as the U.S. industry. However, consolidation of the European MIB will occur strictly within Europe rather than also with U.S. companies as long as the U.S. market and program funding are perceived as unstable and risky. In the future, the U.S. MIB may find itself competing with a European consortium unless the barriers to greater U.S./European defense industrial cooperation are removed.

Operations Other Than War

The growing trend of military involvement in Operations Other than War for example, peacekeeping, disaster relief, drug and immigration enforcement—places a demand on scarce MIB resources for new and creative munitions. Nonlethal munitions are needed to give U.S. forces more tools for their employment along the "gradual conflict intensity continuum" from humanitarian disaster relief operations to high intensity conflict (Zinni and Ohls, 1996). These munitions are "explicitly designed and employed so as to incapacitate personnel or equipment, while minimizing fatalities and property damage" (Stanton, 1996, p. 59). Examples include adhesive snares, foam rubber bullets, rubber-eating chemicals, sponge grenades, and sticky foam. A growing demand for nonlethal weapons resulted in a reprogramming of $5.3 million of 1996 fiscal year procurement resources, authorization of $37.2 million for them in the FY 96 Defense Authorization Act, and another $37 million are being sought in the FY 97 budget. The challenge for the MIB in this strong support for nonlethal weapons is to meet the needs of the armed forces by developing and producing a new generation of nonlethal weapons without significantly compromising the MIB's primary role—which is to supply the lethal firepower needed to fight and win the nation's wars.

Nuclear Weapons

As the Cold War ended, shock waves of change created a requirements undertow for the U.S. nuclear weapons arsenal. As a result, DOE shifted its emphasis from developing and producing new nuclear weapons to dismantling and maintaining a smaller, aging nuclear weapons stockpile. Having significantly reduced the stockpile, DOE no longer manufactures new-design nuclear weapons, and has closed or consolidated some of its former industrial weapons production facilities. In contrast to the 1980s, when roughly 1,000 new warheads were produced each year, DOE is now dismantling approximately 1,000 warheads per year in compliance with the first Strategic Arms Reduction Treaty (START I).

In addition to these dramatic stockpile reductions, post-Cold War policies created significant new challenges to the preservation of U.S. nuclear deterrent capabilities. The President's 1994 Nuclear Posture Review (NPR) stipulates that the United States will no longer perform underground nuclear tests, produce fissile materials, or produce newly designed nuclear warheads. This statement also introduces for the first time the challenge of ensuring the safety and reliability of the nation's smaller nuclear weapons stockpile over an indefinite life span. DOE must accomplish this task without relying on underground nuclear explosive testing, which in the past served as the ultimate fallback for ensuring reliability and safety. These changes mark a shift from the traditional focus on designing, testing, and manufacturing successive generations of new warheads every several years, to one of identifying and implementing programs and policies needed to ensure the continued viability of the stockpile.

Securing a source of tritium is another challenge that DOE managers have been facing since 1988 when they last produced tritium from a nuclear reactor process at the Savannah River Site near Aiken, South Carolina. Tritium, a radioactive isotope of hydrogen, is a required component of weapons earmarked for the stockpile. Possessing a relatively short half-life of 12.5 years, tritium decays at the rate of approximately 5 percent per year and does not exist in adequate quantities in nature to support the stockpile program. Hence, it must be produced to meet weapons requirements. DOE estimates that it can maintain the current tritium supply required for the projected START II stockpile level and the mandated five-year reserve until about the year 2011, by recycling existing tritium supplies from dismantled weapons. However, the United States will need to establish a source of tritium after that time. Because

creating a new tritium production capability takes about 10 to 15 years, DOE is currently exploring two different options for satisfying this need, namely a commercial light-water reactor option and an accelerator option.

Munitions Visibility

During the Persian Gulf War, "mountains" of munitions were shipped to Saudi Arabia and back to the United States, at enormous cost, because DoD lacks an efficient in-transit visibility (ITV) munitions tracking system. If predictions are correct and the next war is "come as you are," the logisticians will be called on to maximize the global movement of limited munitions and thus provide U.S. forces the firepower and flexibility to win their battles. The ITV of munitions from factory to foxhole will be critical to their success.

While the importance of ITV is widely acknowledged within DoD, there remains the seemingly insurmountable challenge of integrating the myriad wholesale and retail automated munitions logistical systems to gain worldwide visibility of critical munitions assets. The challenge to achieve Total Asset Visibility (TAV) linking the wholesale and retail munitions systems of the services can be overcome with increased funding priority using proven, commercial off-the-shelf technologies. The establishment of a seamless munitions system could provide a decisive force multiplier to the armed forces. Returns on investment in TAV and ITV can be expressed in terms of reduced time to service the customer, greater flexibility on the battlefield, and lower costs for storage and transportation. Unfortunately, budget shortfalls have hampered the services' ability to field a common, seamless munitions TAV/ITV system. The future effectiveness in managing a smaller, more robust munitions stockpile will demand investment in these essential technologies to maximize munitions support on the digitized battlefield of the 21st century.

OUTLOOK

No consensus exists concerning the adequacy of the U.S. munitions stockpile to meet current and future requirements. Some argue that the stockpile is inadequate for one MRC, not to mention the two MRC requirement (MIBTF, 1994). Others believe that "sufficient" munitions do exist for the two MRC strategy and that any shortages can be covered by

planned procurements and the substitution of less modern munitions. Note that the perception of "sufficiency" in this belief has been achieved by a "lowering of the bar;" DoD has dropped its munitions requirements by 74 percent since 1990 (GAO, 1996b). This perception of sufficiency, coupled with a decision to rely totally on the existing munitions stockpile to fight two MRCs, has all but eliminated the chance that funding would be appropriated to develop a comprehensive MIB surge and mobilization capability.

The huge U.S. munitions stockpile consists largely of older, less capable munitions, and has a limited quantity of "preferred" precision-guided munitions. In today's resource-constrained environment, DoD's approach to this shortfall includes making more effective use of the current stockpile—thus avoiding the production of preferred munitions from scratch. For example, the Joint Direct Attack Munition (JDAM) program uses Global Positioning System (GPS) guidance kits to greatly improve the accuracy of 1,000- and 2,000-pound "dumb" bombs. This solution is, in effect, an "80 percent" solution to building new guided bombs. Another novel approach includes the use of GPS capable fuzes that can track the trajectory of older artillery rounds to target. By knowing precisely where the round impacts, accurate adjustments in targeting can be made allowing for more hits with fewer rounds expended. Yet another "80 percent solution" is to adapt modern launch platforms to accept older rounds—for example, by using a sleeve with the new 120 mm mortar to allow the expenditure of older 81 mm munitions for live-fire training. This solution avoids the costs of new 120 mm munitions; it also avoids the expense of demilitarizing a portion of the 81 mm stockpile.

Looking at the next one to five years, as the DoD continues to downsize, the strength of the MIB will be further eroded by the continued departure of its second- and third-tier manufacturers. Lacking sufficient production runs to ensure profitability, these manufacturers of munitions pieces and parts will leave the industry, possibly forever, in search of stable and profitable markets elsewhere. At the same time, the remaining high-tech munitions manufacturers will likely continue to consolidate as they seek to reduce overhead costs, streamline operations, obtain economies-of-scale, and remain competitive with already merged munitions manufacturers and international competitors. For the munitions themselves, greater emphasis will be placed on the continued development of high-tech weapons with greater accuracy and lethality to compensate for lower quantities of munitions. The application of state-of-the-art information systems will also be sought to introduce efficiencies in the

logistics chain and improve selections that will optimize the combat employment of scarce munitions assets.

In the realm of nuclear weapons, DOE's near-term approach to meeting the challenges of the post-Cold War environment is detailed in its Stockpile Stewardship and Management Plan—the "Green Book." This plan establishes two core programmatic responsibilities: Stockpile Management, which includes immediate tasks needed to sustain the stockpile; and Stockpile Stewardship, which includes longer-term challenges, including research programs and improved computational capabilities needed to certify the weapons in the absence of nuclear testing. DOE has also begun to reconfigure the weapons complex by consolidating weapons production activities into the remaining production sites and laboratories. Current plans call for the remaining production sites to continue to "downsize in place." By 2002, the complex will be sized to sustain a stockpile commensurate with START II goals (with a hedge for the larger stockpile capacity of START I), and it will provide surge-production capability adequate to address reliability and other issues that may develop.

Looking fifteen to twenty years ahead, it is likely that this century's consolidations will lead to next century's MIB. The 21st-century MIB will be characterized by a small number of high-tech munitions manufacturers who will produce smaller and more transportable munitions with greater lethality. The "kinetic solutions" of bombs and bullets will begin to give way to the more cosmic approaches, such as directed energy and high-powered microwave weapons. During this same time period, it is possible that a world superpower or coalition of nations could emerge, rivaling U.S. power. If so, it would reopen the quality versus quantity debate and force a reevaluation of the munitions strategy to use existing assets to fight two MRCs.

Continued congressional support will be key to the future vitality of the U.S. MIB. As downsizing and corporate consolidations drive the closing of munitions facilities, care will have to be taken not to lose the support of those members of Congress who champion MIB issues as a sign of their commitment to a strong national defense or loyalty to their constituents. Among other political factors that will affect the MIB will be a call for both nonlethal weapons and weapons that are less threatening to noncombatants. The current world concern over landmines has already threatened the continued existence of this class of munitions. As the U.S. military becomes increasingly involved with international police work,

greater reliance will be placed on nonlethal weapons as a means to apply coercive leverage with minimal death and destruction.

Despite defense drawdowns and decreasing demand, the U.S. MIB remains the world leader in the production of sophisticated munitions. As the global munitions market continues to shrink, it is likely the U.S. MIB will benefit from attempts by nations to leverage the firepower of their older weapons systems by purchasing a smaller number of highly sophisticated munitions. In fact, U.S. global leadership in munitions is likely to continue as a result of its proven ability to achieve greater production efficiencies and adapt to changes in government policies, reduced production, and greater foreign competition.

Throughout its history, the U.S. munitions industry has demonstrated a remarkable resilience in dealing with the ebbs and flows of government defense spending and the ever-changing status of global threats. Today's MIB is no different. While the challenges are real, a vibrant MIB can be sustained well into the 21st century through industry restructuring, reliance on advanced production techniques, and better stockpile management. The world munitions market may become even more competitive during this time, but the U.S. MIB should remain a preeminent force in this market because it consistently delivers timely performance at reasonable costs.

GOVERNMENT GOALS AND ROLE

As the MIB continues to adjust to the realities of defense downsizing and greater competition abroad, it will be increasingly important that government recognize it has primary responsibility for sustaining this vital national industry. Specifically, the government must engage and support industry more actively and remove impediments to the MIB's efficiencies and competitiveness abroad. As suggested by one executive of a major munitions manufacturer, government's role should be to create a favorable business environment. This environment can be achieved through policies that encourage investments, share in the costs of research and development, and create a level playing field in the foreign munitions market.

International

The government needs to streamline its technology transfer policies to assist U.S. MIB competitiveness abroad, while continuing to protect

critical munitions technologies. In the highly competitive international munitions market domestic companies often lose the initiative because of the bureaucratic requirements of government. International business can be lost if foreign competitors are able to consummate contracts before the U.S. government gives U.S. companies permission to pursue a sale. At issue is not government's technology-transfer restrictions, but its ability to provide a timely decision on transfer requests. The government does not need to loosen its technology-transfer standards, it simply needs to provide a mechanism for prompt government decisions.

While the globalization of the munitions industry appears to be a reality in today's munitions environment, the United States must also retain the flexibility to act unilaterally in world affairs. Thus, U.S. policies on joint ventures with foreign MIB firms should be fully supported as an economic means to acquire the best quality munitions at the lowest costs. As part of this initiative, the government needs to develop a database system to monitor components of critical munition items to limit vulnerability to foreign interference during the production and purchase years of a munitions contract. Greater use of multiyear contracts would encourage foreign companies to pursue joint ventures with their U.S. counterparts. U.S. budget instability is the greatest barrier to greater industrial cooperation.

Domestic

The United States must achieve an optimal balance between national munitions requirements and declining defense resources. Achieving this balance can be compromised by a variety of opposing institutional interests (congressional influences, service differences, competing civilian and defense requirements for resources, and the parochial views of autonomous groups within DoD and the various services). Obtaining balance in the U.S. munitions stockpile is also hindered by inconsistencies in statements of the national munitions requirements.

Despite these problems, DoD still wants it all. Notwithstanding a shrinking defense budget, it wants munitions that are cheaper, can seek and attack specific target types, have great range and lethality, and are safer to transport and store. Further, the entire package must be accomplished within an economic environment that is reluctant to provide "up-front" R&D funding or go beyond low rate production. Meanwhile, the government refrains from coming to the rescue of the domestic MIB—trusting, instead, that market forces will drive the needed transformation.

New DoD policies and attempts at acquisition reform, such as the use of performance specifications versus military specifications, have helped munitions industries meet marketplace demands; however, more can be done. For instance, greater reliance on multiyear funding would facilitate volume orders and help the MIB achieve economies of scale. It would also be an incentive for industry investments in infrastructure, people, and R&D. Multiyear contracting would also help reverse the trend of munitions subcontractors leaving the MIB to seek the stability that comes with long-term contracting. As part of this recommendation, DoD also needs to simplify the approval process for multiyear contracting, thus allowing munitions manufacturers the flexibility to secure the required production resources, at minimum cost.

Another DoD initiative would make use of "bumper-to-bumper" warranties. This practice places the burden of quality on the manufacturer, eliminates the need for extensive government oversight, and ensures a long-term commitment of the manufacturers to remain in the MIB. Such warranties also facilitate government downsizing by giving depot repair and maintenance responsibilities to the manufacturer. As for the munitions manufacturers, extended warranties provide an incentive to make investments in plant and personnel. Manufacturers would also be better able to retain the technical expertise critical to U.S. surge and mobilization capabilities in a national emergency.

While continued acquisition reform would help strengthen the MIB, sustaining a viable MIB is dependent on the DoD's development of a long-term R&D investment strategy. This strategy should seek to stimulate munitions R&D by removing obstacles and providing incentives to industry, while focusing on investments to maintain U.S. MIB competitiveness in the global market. More importantly, the DoD R&D program should seek to leverage the firepower of the warfighter through development of sophisticated weaponry. Any strategy developed should also be a reflection of a partnership between the government and the munitions manufacturers in sharing the R&D risks and costs.

As DoD places greater reliance on the existing stockpile to fight and win two MRCs, it must do a better job of determining the optimal mix of munitions in the U.S. arsenals—across all services. To meet this end, it is recommended that a DoD single munitions manager (DSMM) for all conventional munitions be established to champion the full spectrum of munitions issues and to provide a "single voice" in the munitions acquisition process (in place of the armed services' four voices). Such a consolidation would provide DoD more price and performance leverage

with the MIB, while giving industry the larger orders they desire for production investment and stability. The DSMM would develop a strategy for maintaining the U.S. MIB infrastructure and advocate investments in infrastructure and human resources. Other responsibilities would include stockpile management and demilitarization, environmental and safety compliance, R&D investment recommendations, and the prompt development of a seamless in-transit visibility. During future DoD and Joint Staff discussions on the tailoring of U.S. forces, the DSMM could provide a munitions perspective on any potential decisions. Clearly, the establishment of a DSMM would provide needed leadership, focus, and vision at a crucial time in the life of the U.S. MIB.

CONCLUSION

The structure of the Munitions Industrial Base is at a critical juncture. The MIB can be allowed to atrophy or, in partnership with government, become a viable element of national defense. Based on the two MRC strategy, the quantity and quality of the munitions stockpile, if coupled with the production of precision weaponry, appears marginally adequate for the current global threat environment. Trends within the industry suggest, however, that even in the near future the MIB might not be able to sustain the quality and quantity of munitions needed to respond to a prolonged national emergency. The future vitality of the U.S. MIB is threatened by reductions in munitions demand, the conversion of munitions manufacturers to nondefense production, reduced production of high-tech weapons, and growing global competition. DoD and industry must find prudent ways to keep a minimal MIB capability aimed at providing the full spectrum of munitions production capabilities.

For the munitions industry, this solution includes seeking production efficiencies through mergers, divesting excess capacity and overhead, adopting advanced production techniques, seeking opportunities to invest in dual-use technologies and joint ventures (domestic and international), and developing programs to attract and retain the necessary human resources. For government, it means leveraging the current stockpile through weapons enhancements (the "80 percent" solution), better stockpile management and in-transit visibility, streamlined requirements determination, greater use of multiyear contracting, and the establishment of a single manager within DoD for all nonnuclear munitions. Together, DoD and industry must form a partnership for the joint development of an

aggressive R&D program capable of providing for the long-term strength of the U.S. MIB. The munitions industry must be able to provide sufficient assets to fight and win two MRCs. More than that, it must ensure an industrial base capable of rapid postconflict munitions replenishment. Nothing less will fit the needs of the 21st century.

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SHIPBUILDING

ABSTRACT

United States shipyards build the best military ships in the world. However, the demand for naval vessels is currently very low, and it is unlikely to increase. Large military oriented yards have substantial capacity beyond national security requirements. Historically, political influence has ensured their survival, but future budgetary constraints may supersede this political influence. Several yards are attempting to reestablish themselves in the commercial market, but excessive overhead, lack of market identity, inefficient management, outdated production, and marginal capital investment and foreign subsidies make it difficult for them to compete in the international marketplace. The United States must choose between continued reliance on reduced military procurement and government support or on efforts to create a level playing field. On such a field, U.S. shipbuilders could improve productivity and efficiency as needed to develop a competitive position in a nonsubsidized international environment.

LTC Bruce A. Berwick, USA
Lt Col Thomas Cronin, USAF
COL Edward A. Hamilton, USA
COL Mary A. Hammond, USA
Mr. Donald E. Hartzell, Dept. of the Army
Lt Col Robert A. Herris, USAF
BG Iphemele Kgokgothwane, Botswana Army
CDR Duane M. Lafont, USN
CDR Kevin P. McNamara, USN
Ms. Claire E. Rennick, Dept. of the Army
LTC Bradley E. Smith, USA
CDR Christy J. Wheeler, USN
CDR Walter J. Wright, USN

CAPT Jeffrey W. Schneider, USN, faculty
CAPT James D. Harris, USN, faculty
CAPT Paul W. Kinneberg, USN, faculty
COL Bill Miller, USAR, faculty

PLACES VISITED

Domestic

Alabama Shipyard/Atlantic Marine, Mobile, AL
Avondale Shipyards, New Orleans, LA
Bollinger Shipyards, Lockport, LA
Carderock Division, Naval Surface Warfare Center, MD
Central Gulf Lines, New Orleans, LA
Halter Marine Group, Gulfport, MS
Ingalls Shipbuilding, Pascagoula, MS
Intergraph, Arlington, VA
Newport News Shipyard, Newport News, VA
Supervisor of Shipbuilding, Conversion and Repair, New Orleans, LA, Pascagoula, MS, and Newport News, VA
Textron Marine and Land Systems, New Orleans, LA

International

Archipelago Sea Naval Command, Turku, Finland
ILS, Raisio, Finland
Kvaerner Masa Yards, Ltd., Helsinki, Finland
Kvaerner Masa Yards, Ltd., Perno, Finland
Finnish Maritime Administration, Helsinki, Finland
Finnish Naval Headquarters, Helsinki, Finland
Finnyards, Ltd., Rauma, Finland
Masa Arctic Research Center, Helsinki, Finland
Technical Research Centre of Finland, Helsinki, Finland
Ministry of Business and Industry, Copenhagen, Denmark
Odense Steel (Lindo Shipyard), Odense, Denmark
Association of Danish Shipbuilders, Copenhagen, Denmark
Danish Shipbuilders Association, Copenhagen, Denmark
Danish Shipowners Association, Copenhagen, Denmark
Blohm & Voss AG, Hamburg, Germany
German Shipbuilders Association, Hamburg, Germany
Kvaerner Warnow Werft, GMBH, Rostock, Germany

INTRODUCTION

The United States is a maritime nation. The majority of international goods continue to move between the United States and its trading partners via the sea. The U.S. Navy possesses unequaled ability to protect those sea lanes and carry out other national security objectives, largely because of the high quality of naval vessels produced by U.S. shipbuilders. However, Navy downsizing, potential military budget cuts, low-rate procurement of new naval vessels, and noncompetitiveness in the commercial market threaten the survival of major U.S. shipbuilders.

Six U.S. shipyards construct virtually all large U.S. government vessels including all major U.S. Navy combat ships and account for over 95 percent of the U.S. Navy's shipbuilding budget. These yards are privately owned and directly affect the nation's maritime security. They provide vessels in peacetime, and most of the country's upsurge in times of national emergency.

This report examines the health and viability of the U.S. shipbuilding industry in these six yards. Though they certainly do not make up the entire domestic shipbuilding industry, they employ approximately 65 percent of the nation's shipyard workers and impact U.S. maritime security unlike any other single group. How these major shipbuilders confront the challenges in their future will affect the entire industry and the role that government must take to ensure the nation's defense and economic competitiveness. The analysis of two critical areas, military construction and commercial competitiveness, suggest that modernization and changes in management styles and labor practices will be as important as government and industry partnerships in the future of this industry.

SHIPBUILDING DEFINED

The U.S. shipbuilding industry consists of government and privately owned or commercial shipyards. Government-owned yards currently perform only ship repairs. "First tier" commercial shipyards design, manufacture and maintain large (over 122 meters) military and commercial ships, while "second tier" shipyards design, manufacture and maintain smaller vessels. There are currently seventeen first tier and numerous second-tier yards operating in the United States.

The Big Six

The six shipbuilders examined in detail in this report are all first tier yards and are commonly referred to as the "Big Six." They account for nearly all large ships built for the U.S. government since 1989, including Navy combatants, fleet support vessels, and several varieties of cargo carriers for the Military Sealift Command and the U.S. Army. The following brief descriptions identify the Big Six and assess their current status.

Avondale. The Avondale shipyard in New Orleans, Louisiana, employs more than 5,000 workers and is currently the largest private employer in Louisiana. Current government contracts include a Coast Guard icebreaker to be delivered in 1998 and five strategic sealift ships (T-AKRs) with final delivery scheduled in 2000. Avondale also won the contract for the initial LPD-17 amphibious assault ship and has an option to build another T-AKR for the Military Sealift Command (MSC).

One of Avondale's business goals is to reach a 50/50 split between commercial and government work by 2000. Capital improvements in the past two years include construction of a covered facility in 1995 and purchase of a new $2 million Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) system. The yard will deliver two converted commercial product tankers (each 38,000 dead weight tons (dwt)) in June 1997 and is discussing the construction of six 135,000-dwt Alaskan-trade tankers with ARCO and British Petroleum. It is also awaiting approval of Title XI funding for a contract to build six 42,000-dwt product tankers for Maritrans/Crowley.

Bath Iron Works. Bath Iron Works (BIW) of Maine has not built a commercial ship since 1984 and has no commercial contracts pending. After building *Perry*-class frigates and Aegis cruisers in the 1980s, the yard won the contract for the designing and building of the *Arleigh Burke* Aegis destroyer (DDG-51) in 1985. Bath's 8,000 employees will ultimately build eleven of these ships, with delivery of the last ship scheduled for 2002. By that time, BIW should be starting construction on the LPD-17 amphibious assault ship, which is part of its partnership with Avondale.

General Dynamics bought BIW in 1995 for $300 million. It plans to invest approximately $100 million in capital improvements over the next ten years, including a new dry-dock. BIW is also hoping to expand its shipyard into the Kennebec River with the cooperation of a state-owned port authority.

Electric Boat. Headquartered in Groton, Connecticut, Electric Boat (EB) is also a division of General Dynamics and the leader in the design, development, production, and support of nuclear submarines. EB is the second largest employer in Connecticut and the largest employer in Rhode Island, where it has a facility at Quonset Point. The yard presently employs 8,540 workers (down from 23,000 in 1990) and another layoff of 1,500 workers will occur in late 1997. EB has designed fifteen of nineteen classes of submarines and eighteen of nineteen submarine propulsion plants. It is the sole, current supplier of the *Trident* class ballistic missile and *Seawolf* fast-attack submarine, with contracts running through 1998.

EB recently teamed with Newport News Shipbuilding to construct the first four of the Navy's New Attack Submarine (NSSN). Acting as the lead design yard, EB will construct the engine room module, command and control modules, and seven other sections of the ship.

Ingalls Shipbuilding. Ingalls, a division of Litton Industries, is the largest employer in Mississippi with more than 12,000 workers. Current contracts for construction of eight Aegis destroyers and three *Wasp* class large-deck amphibious ships will keep Ingalls busy until 2001. It recently lost a bid to build the Navy's LPD-17. Ingalls is the only Big-Six yard to successfully enter the foreign military sales arena, delivering three SA'AR 5 corvettes to the Israeli Navy.

Ingalls also builds commercial marine structures, including barges and oil and natural gas production platforms, and is investigating a possible return to cruise ship construction. However, it presently has no active or pending commercial shipbuilding contracts.

National Steel and Shipbuilding Company. The National Steel and Shipbuilding Company (NASSCO) entered the ocean-going ship market in California in 1960. In the years since, it has delivered fifty-six commercial ships including roll-on/roll-off (RO/RO) vehicle carriers, container ships, bulk carriers, dry cargo ships, and ferries. Over 40 percent of U.S. product tankers were built at NASSCO. Its government contracts have included amphibious ships, fleet auxiliaries, sealift RO/ROs, hospital ships, and cable repair ships—a total of 38 vessels. NASSCO currently has contracts to construct a combat stores ship (AOE-6 class), to convert three Maersk L-class container ships to RO/RO sealift ships, and to construct up to six T-AKR sealift ships for the Navy with the last delivery scheduled for 2001.

NASSCO is an active player in development programs under the Maritime Technology (MARITECH) program. It has also signed agreements with ARCO Marine to design a new crude oil carrier. Teaming with Totem Ocean Trailer Express, Inc., it is designing trailer ships for vehicle shipments between Tacoma, Washington, and Anchorage, Alaska. NASSCO is also pursuing entry into the cruise ship market with American Classic Voyages of Chicago and American Hawaii Cruise Lines as partners.

Newport News Shipbuilding. Newport News Shipbuilding (NNS) is the largest privately owned shipyard in the United States. Located on 550 acres along the James River in Virginia, it employs over 18,000 workers, down from 30,000 in 1990. It is the only U.S. shipyard capable of building nuclear-powered aircraft carriers and, with Electric Boat, one of two yards capable of building nuclear-powered submarines. It has government contracts to build two *Nimitz* class carriers, delivering the final one in December 2002. As previously mentioned, Newport News recently signed an agreement to team with EB on the construction of at least four new attack submarines. It is also a competitor for the Navy's Arsenal Ship, teaming with Lockheed-Martin and Ingalls.

Newport News is attempting to reduce its reliance on U.S. government contracts and enter the international commercial and military markets. Its stated goal is to achieve a 60/40 split between U.S. Navy and commercial work by the year 2000. NNS currently has contracts to build nine medium-sized double-hulled tankers for Mobil Oil and two foreign shipping companies, under Title XI loan guarantees. The company is also aggressively marketing its fast frigate design (FFG-21) to foreign navies, but has yet to secure an order.

CURRENT CONDITIONS

The competitiveness of the U.S. shipbuilding industry began to decline over a hundred years ago, but some of the most significant events to impact the industry began in the early 1980s. Until that time, Construction Differential Subsidies (CDS) allowed U.S. shipbuilders to obtain commercial orders in the international market, while a slow, but steady requirement for military vessels retained high quality production for the fleet. When President Reagan eliminated the CDS program in 1981, commercial ship building in the U.S. evaporated. It was, however, replaced

by the President's goal of a 600-ship Navy and an abundance of military contracts which allowed most shipbuilders to stay in business.

The end of the Cold War made the 600-ship goal obsolete and led to a rapid and continuing downward trend in overall military procurement. U.S. yards suddenly found that while they had focused on government contracts for the past decade, they had also isolated themselves from commercial shipbuilding markets, developments, and technologies. The result is an industry that must fight for scarce government contracts while it searches for a new identity in a highly competitive commercial market.

Current naval contracts and options on those contracts are worth nearly $18 billion and will carry the primary military shipbuilders into the 21st century. The Big Six prefer government work: they are organized for government procurement methodology and construction requirements, understand its stringent documentation requirements and quality control inspections, and they are accustomed to working through hundreds, perhaps thousands, of change orders. Change orders usually result in a better end product, but add inefficiency, time, and cost to the construction of military vessels.

These government construction and management processes create a work environment that is not conducive to competition in either the military or commercial international environment. The comments of domestic and international shipbuilders and shipowners imply that major U.S. shipbuilders have not been able to shift from a government focus to a commercial customer focus. It remains subject to high costs and long design and delivery times—and to excessive overhead and inflexible management that cannot react rapidly to customer demands. The industry recognizes these shortfalls and is investing in new technologies to improve its productivity and competitiveness.

The Big Six have improved their productivity in recent years through investment in automated manufacturing technology. Capital investment by these yards accounted for nearly 40 percent of the industry's costs of $168 million in 1994. In addition to the CAD/CAM systems investment (which all have made), computer-controlled welding and cutting machinery has been installed in all yards. The amount of reliance on automation varies widely among yards, however, and generally does not compare with the extensive technologies found in foreign shipyards. None of the Big Six has the true Computer Integrated Manufacturing (CIM) capability that we saw demonstrated in several European yards and in some U.S. second-tier companies. The addition of covered facilities, use of burn-through primers, and increased preoutfitting using modular construction techniques have also contributed to increased productivity.

The recent reappearance of commercial contracts and recapitalization programs have been driven by the expanded Title XI loan guarantees and MARITECH programs. Title XI effectively constitutes a U.S. subsidy program for commercial shipbuilders and its generous financing arrangements have been very successful in attracting commercial customers. Avondale, NASSCO, and Newport News are now building commercial vessels or have commercial contracts pending Title XI approval, and all six yards participate in MARITECH projects to enhance their technological base and design capability.

Based on this experience, the Big Six object to the Organization for Economic Cooperation and Development (OECD) shipbuilding agreement because it eliminates subsidies in the signatory nations. Under the OECD agreement, U.S. Title XI loan guarantees would be reduced from the current maximum of 87.5 percent of vessel construction costs and a 25-year financing period to the internationally accepted levels of 80 percent of costs and a 12-year financing period. According to the Big Six, implementing the OECD at this time would substantially hinder their efforts to reenter the commercial sector. They also fear that despite OECD enforcement procedures, foreign governments will continue to find ways to subsidize their own yards or suppliers.

The Big Six are currently using their political influence as the American Shipbuilding Association (ASA) to lobby Congress against ratification of the OECD agreement, a position not shared by other U.S. shipyards. To date the United States, which initiated negotiations within OECD at the request of the U.S. shipbuilders, including the Big Six, is the only member nation that has not ratified the agreement. The major shipbuilding nations think that U.S. ratification is vital to the agreement, even though this nation controls less than 20 percent of the global commercial market. Though the U.S. market share is small, OECD members believe that only the United States can provide the leadership necessary to ensure the compliance of all signatories. Our failure to implement the agreement injures the nation's credibility among this same group.

Foreign yards produce most of the world's large, commercial vessels. Asian shipbuilders dominate construction of bulk carriers and tankers while European yards lead the market in more sophisticated ships such as cruise liners, ferries, and container ships. European shipbuilders' opinions are mixed on the ability of U.S. yards to compete in the commercial market, but all agree that U.S. shipbuilders are not competitive internationally in the construction of large commercial ships.

Of those U.S. yards that continue to build large ships, the Big Six capture the lion's share of the work. However, lack of experience in the commercial market and government-focused management makes it difficult for them to compete. Some others, for example, Alabama Shipyards, are making inroads in the transition to commercial work through aggressive marketing and customer focus, though they too are currently dependent on Title XI loan guarantees to secure contracts and are still working below capacity. In general, as we saw in European yards, firms with a commercial emphasis invest heavily in design and production techniques that give their customers maximum flexibility—they are organized to respond rapidly to customer demands.

U.S. yards often fail to meet these criteria for organizational flexibility. They are typically divided by function into several departments such as Production Engineering and Planning, Quality Control, Material Control, and Testing and Safety. Thus they tend to be top heavy, with a management to labor ratio of 1:3. The Japanese, on the other hand, operate with much flatter organizations. They tend to organize their yards by product orientation with two departments: Hull and Outfitting. The resulting management to labor ratio is about 1:7. The U.S. tendency for multiple management levels is indicative of the higher complexity of U.S. shipbuilding projects, and the nature of government work. To compete internationally U.S. yards must address both management and productivity issues.

This discussion of current conditions in the U.S. shipbuilding industry would be incomplete without mention of the second-tier Gulf Coast shipyards that conduct both government and commercial work. In general, these yards possess energetic, aggressive companies, which work double-time to find and please customers. They prefer commercial work and are anxious to showcase their design and production capabilities, while downplaying the difficulties of working on both government and commercial contracts. This aggressive, competitive culture is certainly a major factor in their current success.

CHALLENGES

U.S. Navy/Government Shipbuilding

Their professed goal and efforts to reenter the commercial market notwithstanding, in reality, the Big Six are bent on survival through the turn of the century or until they win the next government contract.

Avondale and Bath recently gained at least partial security for the future with their contract to build the LPD-17, but others find their order books becoming very bleak as they approach the turn of the century. They must compete for and capture the next project. To do this, they must control prices and maintain quality—a combination that up to now, has met with mixed success.

U.S. Navy ships are the best in the world, but they are also the most expensive. Thus, cost was a major factor in the Navy's decision to acquire only five or six warships per year through 2001. After that, the shipbuilders foresee a substantial increase in procurement as the Navy begins to replace ships due for retirement. Unless shipbuilders take extraordinary measures to increase productivity and control costs, the Navy may not be able to afford the next generation of warships, or at least not enough of them to hold the current force structure stable and support the survival of the major shipyards.

But to control cost, the industry must improve productivity through technological modernization and by applying commercial management techniques for maximum responsiveness and flexibility. Commercial shipbuilding can provide the model on which to build this experience. It will not, however, work without a corresponding change in the military's procurement culture.

Navy technical specifications and standards are generally more stringent and expensive than commercial standards. Valid combat requirements generally drive these standards, though the military is making an effort to move toward commercial standards wherever feasible. Another primary driver of high costs is the uncontrolled generating of thousands of change orders during construction. Navy program offices must make every effort to minimize changes if they are serious about controlling costs. The increased use of CAD/CAM systems should help in this effort through more rapid and effective planning before construction begins, a benefit that also applies to the commercial market.

Commercial Shipbuilding

Second-tier yards, which focus on commercial work, are aggressively pursuing contracts, and business is booming in response to the recent surge in off-shore oil exploration. The energy boom has also spilled over into the first-tier yards that build deep-water production and service platforms. However, apart from construction related to the oil industry, worldwide shipbuilding over-capacity and possible over-production by Asian yards

makes the competition for commercial contracts for large ships even more intense.

And, as mentioned earlier, the U.S. yards' lack of significant commercial experience and low productivity rates impact on their competitiveness. One of the greatest handicaps, however, to competing internationally, is a business culture that is geared to government contracts rather than responsive to commercial customer needs. The greatest challenge facing U.S. shipbuilders who want to be truly competitive is the requirement for a changing management climate to increase responsiveness and flexibility.

Foreign yards, for example, constantly emphasize timing—from rapid design to guaranteed delivery dates. For them, improved responsiveness comes through modernizing techniques that increase productivity; they also use teamwork to design, develop, and produce major ship components. Teaming with other domestic or international shipbuilders enlarges their pool of resources and helps them explore worldwide business opportunities. This approach may prove essential for U.S. yards to carve out their commercial niche.

Nevertheless, the position of many, if not most, of the international shipbuilders in the commercial market has depended on government subsidies. These subsidies clearly distort the international marketplace when it comes to the cost of procuring a ship. Most commercial shipbuilders would benefit from an elimination of subsidies and the Big Six should embrace, rather than reject, this approach. U.S. yards need to position themselves to compete in a nonsubsidized market. They need, above all, to improve flexibility and productivity. The scope of these changes depends, of course, on how seriously the yards want to compete.

Until recently, there was little incentive for the Big Six to move seriously into the commercial market. And even today, the incentive may be too weak to overcome the optimistic conviction that naval military construction will increase in the early 21st century. Lucrative government contracts have made the Big Six very profitable, and military work defines their core competency. But they cannot ignore the commercial market; in the event that future government procurements do not materialize, commercial work will be essential to their survival.

Modernization

American shipyards are making moderate efforts to upgrade production processes through automation, CAD/CAM techniques, and facility improvements. Productivity improvements help control costs on

government shipbuilding contracts and are part of any serious attempt to compete in the commercial market. However, the average U.S. yard still has a long way to go before it can compete with the fully integrated shipyards of Asia or Europe. In Denmark, Finland, and Germany, yards that are clearly on the leading edge of technological innovation and computer integrated manufacturing must still invest heavily in research and development for process control and productivity enhancement to remain competitive. The challenge for the major U.S. shipbuilders is how to pay for necessary capital improvements while fighting for scarce government and commercial orders.

Current production in most U.S. first-tier yards requires labor-intensive engineering and building techniques. They add significant time to ship construction and amount to lost opportunity and higher costs for commercial shipowners, as compared to the production schedules in foreign yards. The Navy, too, would gain significantly from the cost-savings that would result from improved production techniques, especially as acquisition budgets continue to decline and more ships reach the end of their life cycle. Major yards must pursue continued improvements to meet commercial demands and control the growing costs of government vessels.

Labor

With dwindling numbers of government contracts and the labor-intensive characteristic of most U.S. yards, a major challenge faced by shipbuilders is how to retain sufficient numbers of qualified workers to handle surges in construction. This need is particularly acute when the skills are shipyard specific, such as the skills of welders, pipefitters, and marine electricians. Higher wages for jobs generated in the oil industry pulled many qualified welders from Gulf Coast shipyards. Since orders for oil platforms and service ships were slower than oil field requirements, Gulf Coast shipyards were caught short of skilled workers. Some turned of necessity to foreign labor as a quick source of qualified personnel.

Some yards have initiated recruiting and training programs through local school systems. These programs not only produce skilled workers, but also generate loyalty to the sponsor. It is an excellent way to grow the required labor force, provided that a long lead time solution is feasible.

Any skills shortages in the work force are exacerbated by the high number of employees required in each U.S. shipyard. In a 1993 study, a European shipyard determined that the man-hours required to build ships in U.S. yards is substantially higher than in most locations overseas (Fig. 1). A higher degree of automation and robotics is present in foreign yards

than here—and both have been integrated in improved process engineering.

Figure 1.—Shipbuilding Productivity in Three Markets. (Man-hours/Compensated Gross Ton)

	EC	JAPAN	U.S.
Best	26	20	60
Average	44	23	82

Worldwide, the number of shipbuilding workers has been steadily declining (Fig. 2). However, total productivity from that smaller work force has increased substantially, particularly in the regions that show the greatest investment in automated processes. While system upgrades may eliminate some jobs, effective retraining can minimize that impact while increasing overall productivity. Automated systems also increase flexibility for surges in production since it is easier to run machines for longer periods than to train skilled laborers.

Figure 2.—Shipyard Employment, 1976-1995.

	1976	1992	1995
OECD – Europe	333,330	83,880	80,296
Japan	175,000	56,000	51,000
United States	171,600(1982)	123,800	106,000

OUTLOOK

Resourcing the National Security Strategy

The shipbuilding industry must fill two requirements in order to support current U.S. national security strategy. First, the industry must have the capacity to increase its production of sealift and combat ships to meet the challenge of any future threat. Second, the industry must produce sufficient numbers of capable ships at an affordable cost to ensure that the military can perform its maritime missions.

The traditional context of surge, which implies long lead times to a protracted conflict, no longer fits into our current rapid response strategy. Since the construction time of modern warships is long (over three years

for an Aegis destroyer), forces on hand will need to respond to the regional contingencies envisioned in the national strategy. Shipyards will have a role in replacing battle losses and repairing damage, but any future conflict will likely be a "come as you are" war. However, it may be necessary for the United States to increase production rates gradually to meet the threat of an emerging regional or global competitor. In this case, the existence of a surge capacity in shipbuilding becomes an important deterrent to potential adversaries who might otherwise engage in a naval arms race.

The shipyards of the Big Six are operating at well below maximum capacity and are in a strong position to meet any required increase in production. The physical space, equipment, and expertise are readily available to increase annual rates of production, though a rapid increase in the labor force may be difficult to produce. The current backlog of work at the Big Six will ensure that these conditions remain stable at least through the turn of the century.

The Navy will buy only five to six ships per year through 2003, while the QDR projects maintaining a fleet of approximately 300 ships.

Figure 3.—Current Plans for Navy Shipbuilding, 1998-2003.

	FY98	FY99	FY00	FY01	FY02	FY03
CVN-77			AP		1	
NSSN	1	1		1	1	
DDG 51	3	3	3	3	1	2
SC21						1
LPD 17		1	2	2	2	2
AOE(X)						1

A 35-year service life for these ships means that the Navy would annually need eight to ten new ships each year to sustain the size of the fleet. Although extending service life to forty years—something that is technically feasible in existing newer ships—could reduce this figure. Current rates of procurement are well below that level because warships are extremely costly, and the defense budget is tightly constrained. Barring unforeseen change, the Navy will shrink, and no increases will occur in the order book for ships.

Current military contracts are spread across the major shipyards, resulting in some assurance that each has enough work to stay afloat for the near term. However, it also ensures that ships will continue to be constructed at inefficient rates of production with the government paying a premium to retain a surge capacity in ship construction. These budgetary

and force structure pressures can only be relieved by increasing the procurement budget (unlikely), reducing operational requirements (unlikely and perhaps imprudent), or by finding ways to increase the productivity and efficiency of U.S. shipyards.

Short-Term Outlook

The short-term outlook for the Big Six is solid. Each of the yards has a backlog of work that will ensure its survival and profitability for the next three to five years and, in some cases, beyond. In particular, Avondale and BIW will increase their activity with the LPD-17 contract. However, none of the yards are currently working near capacity. All have downsized to match the workload, and more downsizing is likely to occur.

In the commercial arena, ship contracts are modest and do not use a significant amount of the industry's over-capacity. Construction of off-shore oil exploration and support facilities will continue to be in demand for at least the short term, but again this does not use a significant amount of total capacity. Competition for future shipbuilding contracts will continue to be keen and new projects will probably be on a small-scale. It is unlikely that U.S. shipbuilders' position in the global commercial market will change significantly in the next five years.

Long-Term Outlook

The long-term outlook for the industry is less rosy. It hinges on adjustments within the industry, developments in military procurement, and the market for commercial ships. In both the military and commercial sectors, some observers suggest that a construction boom will start around the turn of the century. This "bow wave" prediction is based on the current Navy fleet size, the traditional service life of U.S. Navy and commercial ships, the current slow replacement rate for both, and the upcoming requirement for double-hulled commercial oil tankers. If either boom materializes, the long-term outlook for the industry will improve. If not, low-rate naval procurement and a soft commercial market may force a restructuring of the industry. One or more of the Big Six may be forced to leave the military shipbuilding field, or the nation will pay higher costs to keep them in business.

An increase in Navy ship construction would be a tremendous boost for U.S. yards. It might also have more than one driver. It could, for example, be in response to events affecting U.S. security or it could reflect a consensus, political or otherwise, that maintaining the Navy at 300 ships

is prudent. Regardless of the reason, procuring eight to ten ships per year would ensure the survival of all six yards. In this case, commercial contracts would not be a significant factor for their survival, and the yards would likely remain focused on military work.

However, fiscal realities and the trend in military force structure do not support this "bow wave" prediction. It is unlikely that the military will substantially increase the acquisition of new ships in the next fifteen to twenty years. This circumstance makes commercial markets even more important for the long-term viability of U.S. yards and retention of shipbuilding infrastructure.

An increase in demand for commercial vessels could assist U.S. shipyards if buyers find the over-capacity of U.S. yards more attractive than waiting for a foreign competitor. To capture a suitable share of the market, however, U.S. shipbuilders would still need to invest in modernizing their facilities and production methods, and modify management styles to serve commercial customers.

Even with these improvements, commercial competition will not be easy. Substantial global over-capacity with potential over-production, in commercial shipbuilding will continue to increase over the next ten to fifteen years, particularly in Asia. The South Koreans are apparently planning to become the number one shipbuilder in the world and the expansion of their facilities continues. Even more significant, the Chinese are just beginning to enter the market and appear to be putting substantial resources into shipbuilding infrastructure.

U.S. yards are not in a position to capture a significant share of the market. The chief impediments to commercial success for the Big Six are a corporate outlook and culture that has focused them on the Navy market for over a decade. As pointed out in the 1996 ICAF Industry Study, the prospect of winning the next Navy contract has a paralyzing effect on shipbuilders that limits their willingness to make all of the changes necessary to be competitive.

This observation is not a criticism of the management of the Big Six. The decisions they make on modernization and investment are reasonable given their operating environment. The incentive for primary military shipbuilders to move seriously into the commercial market has not been evident. As pointed out by one European shipbuilder, American shipyards can make profits of up to 15 percent on military contracts involving no risk, while European yards must struggle to make 4 percent on commercial contracts. However, given that huge uncertainties now affect the long-term future of both military procurement and the commercial market, shipbuilders do need to focus on improvements that are complementary to

military and commercial customers. The dual nature of this need is a key to controlling the costs of military ships while developing the responsiveness required for other customers.

Political and Social Factors

Shipbuilding is an intensely political industry. The Big Six are critical drivers in the economies of their respective regions. They include the largest private employers in Louisiana, Maine, Mississippi, Rhode Island and Virginia, and the second largest in Connecticut. Their payrolls have a significant impact on regional economic activity. Elected officials pay close attention to the health of shipyards in their states and fight hard to protect them.

When a ship contract is awarded, the economic impact is substantial, concentrated, and members of Congress are quick to rise to the defense of the yard in their district or state. This political scrutiny is particularly intense when the primary customer for a shipyard is the military. An excellent example is the political activity associated with the award of the LPD-17 contract. The competition pitted Avondale (Louisiana) against Ingalls (Mississippi), and the congressional delegations lined up accordingly. Even after the award, the subsequent U.S. Government Accounting Office (GAO) protest, and resolution of the Navy's contract, congressional involvement is still high and may spill over to other current or future Navy contracts.

The high stakes involved have also created other players in the political process. Shipbuilders are represented by two trade groups that lobby actively in Washington. As mentioned earlier, the Big Six are represented by the ASA. The Shipbuilders' Council of America (SCA) represents the remaining U.S. shipbuilders. The SCA seeks to level the playing field by eliminating government subsidies and, hence, presses ratification of the OECD shipbuilding agreement. Conversely, the ASA argues for keeping government assistance, and opposes the OECD agreement. Labor unions are also involved and lobby to protect their members and expand their influence. In short, the success of shipbuilding firms depends at least as much on politics and the ability to influence the political process as it does on business practices and economics.

Industry Posture

An assessment of the industry's overall posture depends on which segment of the market is considered. The U.S. government will buy

military ships exclusively from U.S. yards. There is no indication that this situation will change anytime in the foreseeable future, nor should it. The commercial sector is another matter. U.S. yards command lass than 2.0 percent of the global market and much of that business is generated by government intervention in the form of loan guarantees and cabotage laws. If an upswing in the commercial market occurs, U.S. builders are not in a position to take advantage of it. They are outmatched by foreign firms in terms of infrastructure, technology, and commercial vision. Improvement must be made in all three areas if the Big Six plan to be competitive on a global basis. The issue is whether or not they can make these changes and sustain their lead in combat ship production.

GOVERNMENT GOALS AND ROLE

The primary goal of the U.S. government is to ensure that sufficient capacity exists to meet national security requirements, including programmed acquisitions and unplanned contingencies. In shipbuilding, this pertains directly to government-owned vessels, primarily for the military. Currently, there is tremendous over-capacity in the industry that can meet our national security requirements, though cost is a growing concern.

The acquisition system needs to continue its move toward more streamlined processes, fewer military specifications, less documentation, and less supervision. The "off the shelf" approach being used in the Smart Ship program and the performance-based specifications of the Arsenal Ship are examples of acquisition initiatives with tremendous savings potential. For maximum effect, the military's acquisition culture should accept commercial standards and minimize change orders.

As acquisition reforms help control system costs, the procurement system must continue to award contracts based purely on merit. Though this insistence may force some major players to move away from government contracts, the remaining shipyards are likely to be more responsive and efficient as workloads rise. The political reality is, however, that shipyards fall within the districts of key members of Congress who have a serious interest in their welfare. "Add-on" procurements may ensure that government contracts continue for each of the Big Six. And, for those who join the hunt for commercial work, the government also has a role.

The U.S. government has several alternative courses of action for dealing with commercial shipbuilding. It can continue to protect the

industry by subsidizing commercial ship construction through Title XI loan guarantees and maintain protective cabotage laws while parceling out government contracts to ensure continuous production. This approach will probably ensure that the United States will not improve its current standing in the global shipbuilding industry. However, it will guarantee the survival of most, if not all, major shipyards.

An alternative approach would be for government to facilitate the industry's competitive position in the international market. This approach requires several actions. Congress must ensure that no impediments are raised against domestic or international teaming. Teaming is a recurring theme among European yards striving to attain a competitive edge. It allows companies to pool resources and find the most effective way to develop and market the best product. However, this approach will have limited impact so long as subsidies still exist. This study group believes that ratification of the OECD agreement and subsequent elimination of subsidies is necessary to permit aggressive shipbuilders to compete with other firms on an equal basis.

A primary goal in a free market economy is to compete internationally on an even playing field. In the shipbuilding industry, subsidies make the field very uneven. The OECD agreement is an opportunity for industry to make a significant step toward equal competition. The U.S. may lose some domestic advantage in the short run, but the long-term implications for the overall industry are positive. As one of the European shipbuilders explained, "Competitive yards exist only in competition, and subsidies kill competition."

The Big Six account for less than 2.0 percent of the global commercial market, yet they hold the world's shipbuilding industry hostage through congressional lobbying. The rest of the U.S. shipbuilding industry is anxious to compete against international companies without having to compete against their governments. However, the Big Six—unsure of their ability to compete in the commercial market—have little incentive to drop the Title XI advantage. Nevertheless, the only way the U.S. shipbuilding industry can compete internationally is to force competition on an equal basis. Congress should pass the enabling legislation to implement the OECD shipbuilding agreement.

CONCLUSION

Shipbuilding is a strategic industry, specifically in the area of military requirements. The U.S. shipbuilding industry today builds the world's best

warships, but at significant cost. The capacity is sufficient within the six primary shipbuilders to meet current and anticipated government requirements. In fact, the excess capacity available is sufficient to meet any contingency. Maintaining sufficient numbers of skilled workers to run the yards remains a concern.

Over-capacity and declining rates of government procurement are driving some members of the Big Six to seek commercial contracts. However, U.S. shipbuilders are not currently competitive with foreign shipyards. A serious move toward competitiveness will require dramatic improvements in productivity through automated design and manufacturing processes. Equally important, the management culture that has grown up around bureaucratic government procurement and construction programs must be revamped.

The commercial marketplace requires aggressive marketing, quick response to customer demands, and a high degree of flexibility. These characteristics are largely absent in the current climate surrounding the Big Six shipyards. Furthermore, there is little incentive for U.S. shipbuilders to move seriously into the commercial market. Government contracts, executed under conditions of very low risk, have made U.S. shipyards some of the most successful yards in the world in their core competency: building warships. It is unlikely that any major U.S. shipbuilder would voluntarily abandon this core competency to compete in an inhospitable environment with no guarantee of favorable returns. And in fact no commercial shipbuilder is making the huge profits we see and expect in other fast paced, high technology industries—even those that are heavily subsidized.

Subsidies distort the commercial market by pitting governments against each other rather than letting their companies face off on an equal footing. The OECD shipbuilding agreement offers an opportunity to eliminate the subsidy dilemma. This agreement was initiated by the United States and has since been ratified by its OECD partners. It's time for the United States to put the agreement into force.

The U.S. shipbuilding industry is ready to meet the nation's maritime security requirements in the near future notwithstanding its poor showing in the commercial market. This condition has its dangers, however. It lacks the competitive spirit and production efficiencies that make companies commercially competitive, hence it continues to drive costs up and could one day price the nation out of its maritime leadership role.

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SPACE

ABSTRACT

Space systems facilitate a multitude of services and applications for government, industry, and consumers. The possibilities increase as the space industry shifts from a government to a market dominated industry. Efficiency, economy of scale, standardization, and "better, cheaper, faster" products are characteristic of the industry's new space systems development, production and operation. Services provided by space systems today (e.g., telecommunications), are driving change and market demand. New applications are envisioned for the future as access to space becomes more reliable and affordable. Such access will eventually be routine. International cooperation between nations on civil programs, and international partnerships in commercial ventures, are becoming the rule for space activities, that increasingly serve political and social as well as economic purposes. The industry has come of age.

Ms. Delia E. Donatelli, Dept. of the Air Force
COL Charles S. Fowler, USA
Lt Col Susan A. Goodrich, USAF
Lt Col Lawrence M. Jackson, II, USAF
LTC Scott A. Loomer, USA
Mr. Patrick J. McDaniel, Dept. of the Air Force
Mr. Kevin P. Meiners, Office of the Secretary of Defense
CDR Melinda L. Moran, USN
Mr. Stephen L. Motley, Dept. of State
Lt Col James V. Painter, USAF
CDR Steven E. Petersen, USN
CAPT Robert S. Riche, USN
Mr. David E. Rogers, National Imagery and Mapping agency
Lt Col Douglas G. Schwaab, USAFR
LTC Jed A. Sheehan, USA
Lt Col John D. Wright, USAF

Mr. David A. Lasko, faculty
CAPT Daniel W. McElroy, USN, faculty
Col Mary S. McCully, USAF, faculty
Ambassador Roman Popadiuk, faculty

PLACES VISITED

Domestic

Naval Research Laboratory, Washington, DC
National Aeronautics and Space Administration, Washington, DC
45th Space Wing, Patrick AFB, FL
Astrotech, Titusville, FL
Kennedy Space Center, Cape Canaveral, FL
Lockheed Martin, Bethesda, MD
Applied Physics Laboratory, John Hopkins Univ., Baltimore, MD
National Imagery & Mapping Agency, Bethesda, MD
Orbital Sciences Corporation, Gaithersberg, MD
NAVSPACECOM, NASC, Dahlgren, VA
Motorola, Crystal City, VA
Space and Missile Systems Center, El Segundo, CA
Hughes Space and Communications, El Segundo, CA
Boeing-North American, Space Systems Division, Downey, CA
Aerospace Corporation, El Segundo, CA
McDonnell Douglas, Huntington Beach, CA
TRW, Redondo Beach, CA
Lockheed Martin Astronautics, Denver, CO
Space Imaging, Thornton, CO
Boeing Missiles & Space Division, Huntsville, AL
Marshall Space Flight Center, Redstone Arsenal, AL
US Army Space and Strategic Defense Command, Huntsville AL

International

European Space Agency, Paris, France
Center National D'Etudes Spatiales, Paris, France
Aerospatiale, Les Mureaux, France
Delegation Generale de Armamente, Paris, France
Aerospatiale, Cannes, France
Alcatel, Paris, France
Societe European de Propulsion, Paris, France
NSAU, Kiev, Ukraine
Yuzhnoye/Yuzhmash, Dnepropetrovsk, Ukraine
NPO Khartron/Kommunar, Kharkov, Ukraine
Paton Institute, Kiev, Ukraine
Physics and Technology Institute, Kharkov, Ukraine
Kharkovsky Military Academy, Kharkov, Ukraine

INTRODUCTION

The theme of this year's space industry study is "space as an enabler." Our task was to gauge the health of the industry and look at what changes space and space systems have made possible or more effective—or will make possible or more effective in the future, in government, industry, business, and other aspects of daily life. We accomplished this through research and visits to industry and government agencies, reviewing products and services provided today and planned for the future.

The space industry affects all elements of national power. It is essential to national defense and a key contributor to the nation's economy, power, and prestige. Since Desert Storm, the military applications of space systems are well known, but their economic, political, and cultural aspects are more subtle.

Politically, opportunities for space exploration and exploitation provide common ground for cooperation among nations. Economically, U.S. corporations are aggressively developing space businesses and participating in international consortia to guarantee access to foreign markets. Space exploration and space science and technology, contribute to the technical capability of society as a whole, and provide the means to expand knowledge and understanding of the universe in which we live.

But space has a more direct impact on daily life by providing worldwide access to information through telecommunications satellites. The passage from the "industrial age" to the "information age," is an evolution accomplished by space. Private sector investment and exploitation accelerate this transition.

> *The space market is about to enter a period of peak growth and activity, largely centered around the commercial satellite communications market. The last three years of the 20th century will see the first generation of mobile communications satellites to be launched on a mass scale; a rapid expansion in the number of high-power, direct-to-home TV broadcast satellites; and the introduction of Ka-Band satellites designed for the Internet and high-speed multimedia communications* (Caceres, 1997).

THE INDUSTRY DEFINED

> *For three years we have entered the industrial era of space; before that it was an adventure* (Aerospatiale, 1997).

Both domestically and internationally, the space industry is moving from a government-dominated industry to one driven by market forces. Although government will continue to play an important role, the commercial sector will now drive this industry. U.S. National Space Policy supports this trend:

> *The fundamental goal of U.S. commercial space policy is to support and enhance U.S. economic competitiveness in space activities while protecting U.S. national security and foreign policy interests. Expanding U.S. commercial space activities will generate economic benefits for the Nation . . .* (White House, 1996).

The space industry is comprised of the work force and equipment necessary to exploit the space medium. It produces hardware, software, and systems capable of using space to provide unique services. Industry products include launch vehicles, satellites, ground stations, and user equipment. The services provided are system operations, system integration, and applications. System operations and integration provide the means to support applications, the largest value-added segment of the industry. It is this segment that defines the strategic value of the industry. It generates products and profits and facilitates future opportunities for commerce and industry in space and elsewhere.

Stakeholders

Buyers. Government is no longer the major customer for space industry products, though a demand still exists for "unique" defense systems. Some products and services formerly developed by and for government are now available commercially. The number of commercial customers is growing as new opportunities are enabled through space exploitation.

Suppliers. Industry consolidations have created a few large hardware suppliers that dominate the industry, for example, Lockheed Martin, Hughes, Aerospatiale, NPO Yuzhnoye, Matra-Marconi, although there are still opportunities for small niche firms. The launch vehicle market is global with few suppliers. Sufficient numbers of launch vehicles exist to meet present demand, with a large potential source in the newly free

states of the former Soviet Union. New developments are planned to meet future demand.

Service Providers. Services are based on providing tailored application data and information to users. The spectrum of service providers includes companies such as Lockheed-Martin and Aerospatiale at one end, which develop, launch, integrate, and operate their systems. At the other end of the spectrum are new companies that rely on other firms to build and operate hardware and software while they market innovative service applications. The competition to offer customers one-stop turnkey operations is one factor driving some corporate mergers and acquisitions and reducing the number of space prime contractors.

Applications

Space services fall into five major areas. First are the military applications that have driven the industry since its inception. These applications include surveillance, reconnaissance, communications, navigation, meteorology, and geodesy. Civil and commercial applications are in the areas of space and science exploration, environmental and earth monitoring, transmission and relay of information, and research and space experiments. Existing and projected civil and commercial applications include the following:

- wide band data transmission and mobile communications,
- modernized air traffic control, navigation, and precision-instrument landing systems;
- cargo tracking and inventory management;
- advanced atmospheric research and weather forecasting;
- urban and transportation systems planning and development;
- precision farming;
- energy exploration and utility network maintenance;
- disease vector tracking;
- natural disaster prediction and response planning;
- automated credit/financial transactions;
- environmental resource and pollution management;
- land surveying and real-estate marketing;
- microgravity life-science and advanced materials research; and
- vacation travel planning.

International Activities

International cooperation is a key element in both civil and commercial space activities. On the civil side, both economics and politics encourage cooperative efforts in space exploration and development. The International Space Station (ISS) is a prime example, involving the cooperation of 15 different nations, including the United States, Russia, Japan, Canada, and 11 member nations of the European Space Agency (ESA). Additionally, Ukraine and Brazil have announced their intention to join the program. While the initial incentive for cooperation was simply to pool limited resources, the determination to demonstrate that nations can work together on peaceful initiatives is sustaining the effort.

New commercial endeavors, such as Motorola's Iridium and Boeing's Sea Launch, will be owned and operated by international consortia, as will Space Imaging/EOSAT's remote imagery satellites. International ventures serve the commercial sector by providing a broad investment base and assured access to international markets.

CURRENT CONDITION

Worldwide, government spending on civil and military space is expected to remain fairly flat, while the commercial market grows at a rate of 20 percent per year. Internationally, the total 1997 government military and civil space budget is approximately $38 billion. The U.S. portion is $27 billion which includes about $13.5 billion each for civil and military space programs; $5 billion is from Europe and $2 billion from Japan. The global commercial space market is valued at $5 to $10 billion, and increases to about $65 billion when the value of all satellite-based services are factored in (Anselmo, 1997).

U.S. aerospace work force productivity has greatly improved due to U.S. industry restructuring. Since 1991 sales revenues per employee have increased by over 40 percent. The industry is financially healthy and has regained its historic level of 3.3 to 4.1 percent profit on sales, with space providing over 25 percent of total aerospace sales. With current commercial demand for space industry products, the growth in employment levels is creating some modest shortages in qualified technical workers, particularly in software specialties.

Space Launch

Expansion of the commercial sector of the U.S. space industry began with passage of the 1984 Commercial Space Launch Act, and accelerated when the Federal Communications Commission began granting licenses to operate constellations of satellites in low-earth orbit—thereby responding to the demand for telecommunications satellites. The demand for satellites increased the demand for launch vehicles, and has led to commercial investment in launch vehicles and facilities.

Though reliable, U.S. space launch systems are complex, costly to operate, and require lengthy processing prior to launch. Few major upgrades have occurred since development of the Space Shuttle. As a result, ESA's Ariane launch system is the market leader for commercial launches with over a 60 percent share of the global market; the U.S. has a 30 percent share.

Although the U.S. Titan, Delta, and Atlas launch vehicles, and Russia's Proton and China's Long March, all have a launch backlog of over a year, U.S. industry experts agree that reducing launch costs is essential to future industry growth. In 1994 the Clinton Administration recognized this need and supported several new initiatives to accomplish this, including new spaceports, launch vehicle upgrades, and new launch vehicle concepts (Radzanowski and Smith, 1996).

Spaceports. Current launch infrastructure at Cape Canaveral AFS and Vandenberg AFB has been in place since the 1960s. It is costly to operate and needs continual modifications and upgrades. Projected demand for commercial launches is spurring development of new commercial launch facilities. The U.S. has five spaceports in various stages of development—primarily for small-to-medium launch vehicles. They are in Alaska, California, Florida, New Mexico, and Virginia. Others are planned in Brazil, Norway, Canada, Sweden, Kenya, and Australia. Many see this development as a major step in the transformation of space into a market dominated by private industry (Caceres, 1997).

Some novel launch concepts include Orbital Science's *Pegasus*, a rocket launched from an L1011 aircraft, used to place 1,000-pound (lb.) payloads in low earth orbit; and *Sea Launch,* which is being developed by Boeing Commercial Space in partnership with Russia's RSC Energia, Ukraine's NPO Yuzhnoye, and Norway's Kvaerner. Sea Launch will use Ukraine's Zenit rocket to launch payloads weighing up to 13,000 lbs into geosynchronous transfer orbit from a platform at sea. The launch

platform is a modified off-shore oil drilling platform provided by Kvaerner, along with a command, control, and assembly ship that ferries the rocket and payload. The first sea launch will occur in the Pacific, from the equator, in summer 1998 (Mehuron, 1996).

Launch Vehicles. New launch vehicle developments include the Air Force Evolved Expendable Launch Vehicle (EELV), the National Aeronautics and Space Administration (NASA) Reusable Launch Vehicle (RLV), and ESA's Ariane 5 which is due to launch in September 1997.

The Air Force has Lockheed-Martin and McDonnell-Douglas under contract to develop concepts for an upgraded family of boosters to replace the medium-lift Delta and Atlas boosters and the heavy-lift Titan. The goal is to reduce launch costs by 25 to 50 percent. The EELV would place 2,500 to 45,000 lbs into low-earth orbit. A single development and production contract will be awarded in 1998 (Mehuron, 1996).

NASA awarded a contract to Lockheed-Martin in July 1996 to build the X-33 Advanced Technology Demonstrator to demonstrate the next generation's RLV technologies. Lockheed Martin believes the X-33 could reduce the cost of placing a payload in space by an order of magnitude—up to $400 million per launch (Blackwell, 1996).

Satellites. Spacecraft production is no longer solely a "craft" manufacturing process. Mass-production techniques are now employed, leading to reductions in cost and development time. Spacecraft performance is also improving. For example, the development of gallium arsenide solar panels has nearly doubled the electric power supply potential on satellites. Present trends in spacecraft development will make space systems more affordable. They include

- shorter development time,
- lower costs,
- lighter platforms,
- longer life,
- modular packaging, and
- increased power.

Over the past four years, Hughes has achieved a 10 percent annual improvement in commercial production efficiency and cut cycle time about 30 percent through process improvements, while incorporating new technologies to extend satellite service life and performance. Hughes is the market leader with 40 percent of spacecraft production. Second, with a 25

percent market share, is Aerospatiale/Matra Marconi, which pursued improvements similar to those of Hughes. Both the French and Ukrainian spacecraft industries have standard spacecraft series to achieve high-rate production. They report an ability to produce large satellites in 18 to 24 months.

Research advances in microengineering technology for producing integrated machine components promises to provide a cheap mass-production capability for highly redundant, ultralight-weight spacecraft systems. Small spacecraft production is now a research priority of space-faring nations, including Ukraine's space agency. Lighter spacecraft can be less costly to launch, and therefore, more marketable.

Applications

Space services support many industries in a variety of ways, as shown by the following examples.

Information. Space has enabled explosive growth in the information industry. Services using space assets include

- Satellite telecommunications—voice and data communications relays between points located anywhere: land, sea, air, and space.
- Navigation/location—signals from U.S. and Russian global positioning satellites can determine precise locations anywhere: land, sea, air, and space.
- Broadcast systems—broadcasting uplinked information to any receiver within the transmission "footprint," for example, direct television broadcasting.

These services also support military operations. Some services are provided by government systems. In other instances commercial assets may be leased, or commercial services purchased, by governments.

Agribusiness. Space resources enhance "precision farming," that is, make it possible to tailor soil and crop management to fit the exact soil conditions found in each field. Three types of satellites support precision farming: remote sensing and weather imaging, communications, and positioning. Services provided to farmers include data collection from satellites and other sources, locational information, and data analysis (Johannsen, 1995).

Biotechnology and Health Care. Space research and space sensors support the health care industry in a variety of ways. Remote sensing, for example, allows one to predict the distribution of disease vectors through measurements of observables associated with a particular pathogen; and to grow protein crystals in space for use in designing drugs to treat specific diseases (NASA, 1996a). Research in the microgravity condition of outer space enables "a deeper understanding of important physical, chemical, and biological processes by observing phenomena which are normally obscured by gravity in Earth-bound laboratories" (NASA, 1996b).

Energy and Environment. Space assets improve both the development and management of energy supplies and the environment. Space-based radar and multispectral sensors detect geomorphological features associated with energy supplies. Remote sensing also provides estimates of greenhouse gasses, spills, and contamination on a global basis. Other uses include fishery and forestry management. New remote sensing technologies may enhance the search for additional reserves of nuclear and fossil fuels.

Transportation. Communications systems support in-transit visibility—a concept revolutionizing the way industries inventory parts and supplies. This visibility has made "just-in-time" supply lines possible, reducing or eliminating the need to maintain large inventories. The Global Positioning System (GPS) has become a navigation standard. GPS receivers are found on most ships and are starting to emerge on airplanes, trucks, and automobiles. The FAA has awarded a contract to develop the GPS-based Wide Area Augmentation System that will modernize the Air Traffic Control System. Shipping and airline industries also use satellites for long-range communication, and to collect weather data to control delivery schedules (Dooling; Birkland).

CHALLENGES

There is unlimited potential for new space services and applications for government, industry, and consumers. The primary challenge, and limiting factor today, is reliable, affordable access to space.

Reliable, Affordable Access to Space

If the market for launch services is to expand, launch systems must be improved to reduce cost, increase reliability, increase capacity, and reduce ground processing time and personnel. Although U.S. launch systems are considered reliable, approximately one-in-30 launches fail. This risk, coupled with the high cost of space systems, pushes insurance liability costs as high as 25 percent of the system's costs (Simonoff, 1992). If these efforts are successful, risk and liability costs should be reduced accordingly, and further commercialization of space can proceed in earnest. As Lauer (1996) describes it:

> *Once a credible case can be made for providing safe and routine commercial access to low Earth orbit, and minimal amounts of orbital business infrastructure and crew accommodations are available on a long-term basis, . . . High-value products . . . manufactured in LEO will play a major role in opening the space frontier . . . and providing an increase in wealth and improvement in the average standard of living for generations to come.*

Government Policy

Other, less limiting, but still important challenges affect the expansion of space services and applications. In space, technology and trade converge. Space systems incorporate much of today's most advanced technology. Space industry functions in the highly political international arena, where technology and trade policies may conflict. Challenges in this area include the following:

- balancing national security needs with commercial and international activities,
- supporting research and development (R&D) and seeding new enterprises,
- cooperating and competing in the international market, and
- allocating and managing space resources on an international basis.

Balance. As commercialization proliferates in the space industry, products such as detailed imagery and positional/navigational and weather information will become globally available to friend and foe. The positive benefits to such access are many. For example, access to

satellite imaging allows the United Nations to create environmental databases that can help reduce famine and mitigate the effects of natural disasters; high-resolution imagery can support and reinforce peace-keeping forces by providing unbiased evidence of whether agreements limiting military operations are being honored. A powerful negotiation tool during the Dayton peace talks draped high resolution satellite imagery over digital elevation data to "overfly" the proposed boundary lines, allowing visualization of proposed agreements.

Partnerships between governments and the commercial community are needed to leverage commercial technology and capabilities rather than having to rely only on costly, unique government space systems. Military systems should be operable within civil and commercial systems so that they can be leveraged when mobilization is required. Although many of these systems are developed and owned by international consortia, military coalitions representing the same consortia would benefit from the interoperability of these systems. In any case, the military needs to prepare to operate in an environment where many nations depend on these systems for both military and nonmilitary purposes.

Supporting Research and Development. Continued robust funding for space technology development and the seeding of new enterprises is critical for future competitiveness. It seems to be a trend that when government budgets are cut, funding for R&D is reduced disproportionately. To compound the problem, R&D reductions occur simultaneously in both government and industry, and the remaining R&D funding is typically applied to projects with short-term payoff. Industry has relied heavily on government funding for R&D and for supporting commercial enterprises. The evolution of the space industry to a commercially driven industry will change this relationship. Government must encourage commercial developments of space, and industry must wean itself from government support. The challenge is to balance R&D risks between government and industry so as not to jeopardize the development of new technologies and enterprises.

Global cooperation and competition. Governments worldwide are facing fiscal constraints that limit funds for space activities. As a result, in areas of space science and exploration, governments are pooling resources to support major efforts. The International Space Station (ISS) is an example. Originally a costly U.S. program threatened with cancellation by Congress, it now survives as a cooperative effort that will be completed in 2002. The ISS will provide an international platform in

which to conduct space experiments in biotechnology and life sciences, as well as in material sciences and other areas. Successful experiments could lead to manufacturing in space, creating new economic opportunities. The challenge, however, is in successfully developing the ISS as an international cooperative effort.

Policy is a challenge in international cooperation and competition. For example, U.S. reluctance to launch a French commercial satellite 30 years ago led to the development of the Ariane launch system, which is now the United States' strongest competitor in the commercial launch market. And today, the United States faces another challenge with government control of GPS. International dependency on this data has grown so much that the international community must seek alternatives to ensure fair access to this information. The duplication is creating competition where cooperation might be more beneficial.

In areas where competition is desirable, formal trade barriers are often an obstacle to the development of competitive global markets. Prices and services vary widely from country to country. To the extent that price differentials are artificially maintained, free markets are inhibited. The challenge is to standardize services and develop common pricing schemes to promote growth and competition.

Allocating and managing space resources. The international character of the space industry presents a challenge. For example, the scarcity of the frequency spectrum and its allocation has served as a bottleneck to the rapid growth of satellite communications. This problem has grown in recent years with additional service providers seeking access to space. As a result, there is fierce competition for heavily populated radio frequency bands.

Another concern is competition for the limited number of slots for geostationary (GEO) communications satellites, particularly in Asia where there has been rapid growth in recent years. There is no international body authorized to enforce compliance with allocations.

Controlling accumulation of space debris may become a problem with the proliferation of satellites in low and middle earth orbits. Although currently manageable, as space-faring nations continue to launch satellites and expendable boosters, the potential of space debris collisions with operating satellites will continue to be of concern. Mitigation approaches to slow the growth of debris include deorbiting in vehicles in low earth orbit at the end of their usefulness and moving expiring satellites out of collection orbits. A total solution will require international action.

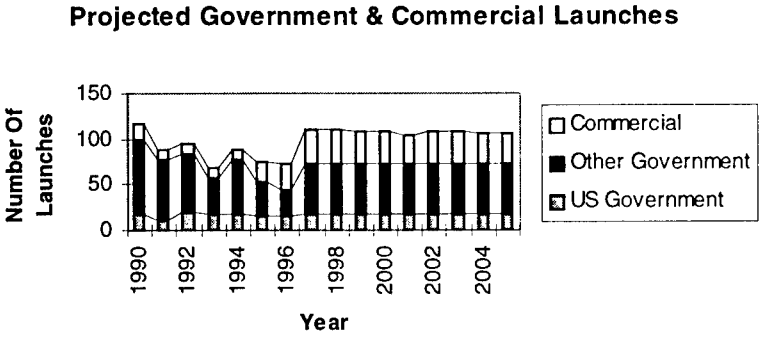
OUTLOOK

Despite these challenges, the short- and long-term outlooks for the space industry are positive. The trend toward international partnerships for both civil and commercial space ventures is likely to increase in the future. Cost-sharing spreads the risk and the burden for complex projects that might not be feasible otherwise. Partners also supply complementary expertise and market access. The market for space systems is beginning a massive expansion that is also driving expansion of the launch industry.

Space Launch

The challenge of reliable, affordable access to space is being met by the launch industry. In the past, government civil and military space programs drove the requirements for launch vehicles. Starting this year, a robust commercial space communications enterprise will significantly increase the number of launches worldwide. The increase will be far more than any single nation is currently launching through its combined civil and military programs.

Figure 1. Past launches and predictions for future launches, for the US, other governments, and for the commercial sector.



(US Space Command, 1996; Calhoun-Sengler, 1997)

The lowest portion of each bar in Figure 1 shows the number of projected U.S. government launches by year. The middle portion shows all other governments' projected launches including a high estimate of future Russian launches. The top portion represents projected commercial launches. The predicted commercial launch requirements are

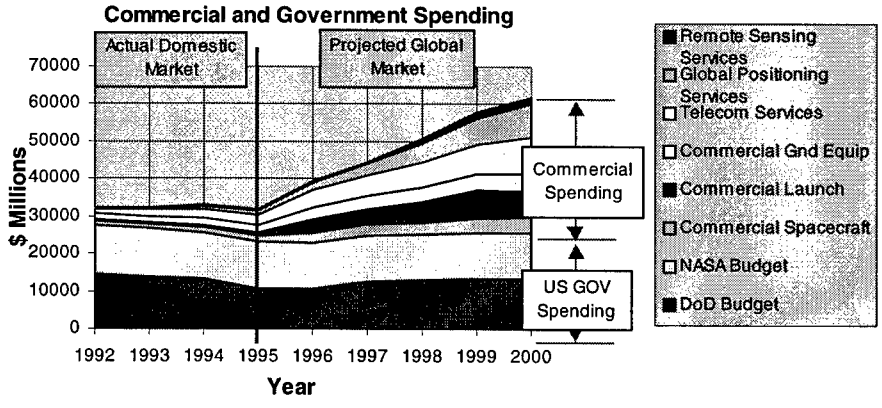
approximately double the forecasted U.S. government launch rate. This market will have a dramatic impact on this industry in the United States and on the government's ability to influence it. In the future, military and civil programs may purchase launch services as easily as they now purchase airline services.

The EELV and RLV programs, Ariane 5, and Zenit/Sea Launch are on-track to close a 25-year delay in launch vehicle development. The EELV, Ariane 5, and Sea Launch will support projected government and commercial launch demands until the next generation RLV system can be brought on-line. If the RLV goal of reducing launch cost by a factor of ten is achieved, studies indicate demand could increase by a factor of five to 20. This development would make new space market segments (e.g., space business parks, tourism, and space manufacturing), economically feasible.

Potential demand is stimulating private investment and competition for commercial launch services. Hughes and Loral Space Systems have contracted for future launches using commercially developed ELVs, namely, McDonnell-Douglas's Delta-III and Boeing's Zenit/ Sea Launch. Both of these launch systems are scheduled to begin service in 1998.

The U.S. government's launch commercialization initiatives, since 1984, have resulted in technical innovation and process improvement that is apparent throughout U.S. industry. Similar changes are apparent with ESA's investment in Ariane 5, which will keep Europe competitive in launch services in the GEO satellite market. Other competitors include Ukraine's Zenit, Russia's Proton, and China's Long March.

Figure 2. Projected growth in commercial investment in space systems and services compared with projections forU.S.government spending on civil and military space programs.



The predicted growth in commercial launch services is shown in Figure 2, with predicted growth in spacecraft, ground systems, and primary services. The first and second segments reading the scale from bottom to top, show actual and projected Department of Defense and NASA spending on space programs. This funding is expected to remain fairly constant for the foreseeable future. Segments above NASA show actual and projected worldwide commercial spending for space systems and services. Within two years, commercial spending in the global market will exceed U.S. government spending, which accounts for about 70 percent of worldwide government spending on space programs.

Spacecraft

Commercial investment in communication satellites is expected to reach $34 billion between 1996 and 2000, and it will continue to fuel spacecraft innovations (Atkins, 1997). The challenge of "better, faster, and cheaper" has become a driving force behind domestic and foreign government and commercial satellite development. NASA's Near Earth Asteroid Rendezvous (NEAR) and Lewis spacecraft would have been inconceivable just three years ago. The Motorola Iridium spacecraft is designed for a production rate of one satellite per week with only three weeks required for manufacturing and testing (Harding, 1997).

The number of GEO communications satellites is expected to rise about 25 percent worldwide over the next three years. Pacific rim countries and the United States will each own approximately 40 percent of these systems (Caceres, 1997). Hughes Space and Communications, Lockheed Martin, and Space Systems/Loral are under contract to build over 70 percent of these systems.

Current commercial plans call for several communications systems in low-earth orbit and medium-earth orbit. Most of the companies involved are new ventures or corporate spinoffs: Motorola's 66-satellite Iridium system, Globalstar's 48-satellite system, Orbital Science's 38-satellite Orbcomm, GE Americom's 24-satellite Starsys, the UK-based ICO Global Communication's 24-satellite ICO (Caceres, 1997), Teledesic's 288-satellite system and the 1997 deployment of the Iridium and Orbcom constellations. These and other proposed systems could increase the investment to $42 billion by 2001 (Cole, 1997).

Ground stations for commercial satellite operations are incorporating advances in automation that will reduce ground segment costs and work force requirements. The ground segment of older satellite systems typically accounted for nearly 50 percent of the total system cost (Atkins, 1997).

Applications

Present services are expected to continue to expand in the future. The market for commercial applications of the Global Positioning System may reach $8 billion per year by 2000, with a continued growth potential of $26 billion per year, dwarfing expected military equipment sales.

The remote sensing market exceeded $2 billion in 1993 and is expected to grow at a rate of 15 to 20 percent per year (Calhoun-Sengler, 1997). Eight U.S. companies have applied for licenses under the 1994 presidential directive that relaxes the 30-meter resolution limit for U.S.-licensed remote imagery systems to one meter. Most proposed ventures are international partnerships which provide combined expertise in launch vehicles, satellite designs, and imaging systems. Several are in advanced stages of design and construction with first launches scheduled for 1997. Numerous countries and foreign companies plan to offer one meter resolution imagery. Applications in mapping, planning, geologic exploration, environmental monitoring, and other areas imply a vast potential market for these ventures.

Space has become integral to, and a catalyst for, information age societies. The "convergence of technologies in computers and telecommunications is changing the world as radically as the industrial revolution did over 200 years ago" (Information Industry Study, 1996). Information systems technology is improving the design, production, performance, and operational control of space systems, while space systems are providing global "wireless" data transmission and supplying multispectral sensor data for information systems.

The rapid growth of information systems will continue to increase commercial demand for space products and services well into the next century. Over half the world is still waiting for a dial-tone—space systems can provide network connectivity in remote regions in less time and with less funding than needed to build comparable ground infrastructure.

GOVERNMENT GOALS AND ROLE

Government policy is a key element in promoting or impeding the commercialization of space. It should be used to stimulate development of a strong private sector which can provide key elements of U.S. political, economic, and military power in the future. Some critical elements for fostering the necessary commercialization are the following.

National Security. A reality of national security strategy today is the knowledge that potential opponents will probably have access to high-resolution imagery, satellite communications, weather and navigational information systems similar to ours. These systems are no longer the sole domain of military and intelligence agencies. The proliferation of private, commercial systems and the siting of ground receiving stations around the world will make dissemination control difficult, if not impossible.

This situation concerns the United States and other nations. For example, there is little doubt that if Saddam Hussein had had access to imagery of the quality expected from the new commercial systems, the Coalition forces in the Gulf War might have lost the element of surprise in their attack through the western Iraqi desert. The United States and other nations cannot assume that they will enjoy this advantage in future conflicts. In many respects, this situation is no different from the Cold War when both the United States and the Soviet Union had considerable satellite reconnaissance capabilities.

Space systems are increasingly internationally owned and capable of supporting both commercial and military applications. It is important to develop the technological and operational doctrine that will ensure their effectiveness for military missions. Other national security needs that must be addressed as the military becomes more dependent on commercial assets inspire the following suggestions:

- Consider investing in commercial telecommunication satellite systems, similar to the Civilian Reserve Air Fleet (CRAF) policy for airlift. This investment would provide cost-effective SATCOM services for federal agencies in peacetime and military mobilization surge capacity in a national emergency situation.
- Purchase launch services commercially, but ensure existence of sufficient excess launch capacity to support space mobilization

requirements. This requirement could be accomplished either through stockpiling ELVs or through launch agreements.

Research and Development

Categorize proposed R&D projects according to market relevance, that is, near-term market potential; long-term market potential; and unique to government. Industry should be given incentives to develop the near-term market, government-industry partnerships can develop the long-term market, and government funding will be needed to supply government's own needs. Funding support for new initiatives in space would encourage R&D that has potential commercial applications. Burden-sharing between government and industry can minimize risk and liability and maximize available capital for bringing new technology to market. The RLV program is an example of how government can seed new enterprises in the future. Management of the program is radically different from most government programs and has teamed industry and government in a cooperative venture: in this case, NASA and Lockheed Martin are shairng the costs of the initial technology demonstration effort. Private-sector financing will be required for full-scale development of the operational RLV. If successful, the RLV will be owned and operated by industry, and it would greatly facilitate future space initiatives. The U.S. government should become one of many customers for its services, with agreements on priorities in national crisis.

Promote cooperative international efforts between governments and scientific communities to achieve synergies and minimize duplication. For example, the Ukraine's National Academy of Sciences is conducting world-class research in many areas of interest to the United States.

International Cooperation and Competition

To facilitate commercialization, restrictions should be minimized. If restrictions on U.S. industry are stricter than the restrictions on its competitors, then U.S. companies will not be competitive in the global market. Standards, on the other hand, need to be as high as possible for both market and national security interests.

Establishing a single U.S. government agency with responsibility and authority to establish and oversee space policies and to coordinate between requisite departments and agencies would facilitate space development and protect national security interests. Several government departments and agencies currently have a role in formulating and implementing space

policies, and in affecting commercial ventures, often with conflicting interests (e.g., the departments of Defense, State, Commerce, Transportation, and Energy, among others).

It is important from a scientific and diplomatic standpoint to capitalize on opportunities for international cooperation. NASA is an important source of new and innovative applications for space industry and opportunities for international cooperation. The Human Space Flight mission, which includes the International Space Station (ISS), is a major component for breakthroughs in fundamental science, technology, and biomedical research. The ISS also sets a precedent for nations cooperating in peaceful pursuit of a common goal. We need to ensure continued investment. The Mission to Planet Earth studies the environment and strives to discover patterns to predict and respond to environmental concerns and natural disasters. The Space Science and Solar System Exploration missions are the seeds for long-term future endeavors that can only be imagined at this point in time. Continued investment in these areas is important to ensure that scientific and technical advancement will continue and secure our environment for future generations. If we compromise investment in these areas, we will likely compromise our future.

International Regulation of Space

International partnerships are increasingly important in commercial ventures—just as international cooperation is a necessity in the civil sector. In addition, cooperation in space has many diplomatic advantages. As the space industry becomes more international and space itself more commercial, international standards will be needed to help allocate and manage space resources and assets. Laws and an international space policy will also be needed along with the authority to enforce the law. It would be prudent to prepare now for this eventuality.

CONCLUSIONS

The space industry is developing into an international, market-driven industry. Both civil and commercial space programs are increasingly international, cooperative ventures. Traditionally, space activities have been predominantly government supported, but soon commercial activities will dominate. Market forces are now driving developments, which, if successful, will make access to space reliable, affordable, and routine.

Industry is becoming innovative and highly productive, shifting from producing costly "one-of-a-kind" systems to using mass production techniques to achieve economy of scale.

Access to space, that is, the cost and availability of launch, is currently the largest constraint to the growth of commercial, civil, and military space systems. The EELV and RLV programs are currently on-track for resolving this issue, as are new launch facilities that will increase capability and availability. The U.S. government will become just one of many customers for launch services.

Space industry is an integral part of the information age economy. Applications of space services have already led to an impressive array of industrial applications, for example, in health care, financial services, retail inventory management, agriculture, urban planning, aviation, telecommunications, ground transportation, energy, and emergency management. These and other new applications will continue to expand the commercial demand for space services, with demand most likely outweighing supply.

The U.S. space industry is and will remain capable of supporting the future needs of the military for information dominance and for precision strike and focused logistics across the spectrum of military operations. Commercial services will play a greater role in military operations as it becomes more cost effective for government to buy or lease commercial services rather than acquire dedicated military systems.

Governments should work to stimulate business partnerships both domestically and internationally. Government resources should be used judiciously in stimulating technology development and seeding new commercial enterprises.

The U.S. government's commercial space policy encourages the growth and competitiveness of the space industry. However, to facilitate and sustain this growth, a high level policy-making body is needed to consolidate interagency needs, formulate and guide effective space policy, and address national security issues.

Space services are now provided primarily through international partnerships. The growth of international space partnerships will complicate future policy formulation and require greater U.S. government participation in international regulatory institutions. It may be a propitious time to pursue formation of an international regulatory body for space.

Let us bind the [world] *together with a perfect system of roads and canals. Let us conquer space* (John Calhoun, 1816).

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STRATEGIC MATERIALS

ABSTRACT

A fundamental shift in thinking has occurred concerning the strategic and advanced materials industry in the United States. Historically, our concerns, policies, and programs were directed at items that were critical in a national emergency and difficult to supply. With the end of the Cold War and the increased globalization of national economies, a broader concept of strategic and advanced materials has emerged. The new perspective recognizes that national security planning encompasses the general welfare of a society, which includes economic and political considerations in addition to military considerations. This broader perspective on national security is evident in many countries. However, because each country has a different state of economic and political development, the role of the strategic and advanced materials industry in each country is different.

Lt Col Rick Bean, USAF
Ms. Barbara Binney, Dept. of the Army
Ms. Barbara Bonessa, Dept. of the Army
Mr. William Dates, Dept. of the Army
Mr. Paul Gross, Dept. of the Navy
COL Steve Hamilton, USA
Ms. Judith Kaufmann, Dept. of State
CDR Keith Koon, USN
LTC Britt Mallow, USA
COL Gale Pollock, USA
Lt Col Dave Razzo, USAF
Lt Col Mark Stephens, USAF
LtCol John Valentin, USMC
CDR Roger Whorton, USCG

COL Dave King CAF, faculty
Lt Col Lynn Scott USAF, faculty
Dr. John Starron, faculty

PLACES VISITED

Domestic
Bombardier Aerospace Group, Montreal, Quebec, Canada
National Research Council, Montreal, Quebec, Canada
Noranda, Montreal, Quebec, Canada
Spar AeroSpace, Montreal, Quebec, Canada
Federal Reserve Bank, St. Louis, MO
McDonnell Douglas Aerospace, St. Louis, MO
Monsanto, St. Louis, MO
National Imagery and Mapping Agency, St. Louis, MO
Systems & Electronics, St. Louis, MO
University of Missouri-Rolla, Rolla, MO
Washington University, St. Louis, MO
Zoltek, St. Louis, MO
World Bank, Washington, DC

International
ARMSCOR, Pretoria, South Africa
Chamber of Mines, Johannesburg, South Africa
Council for Scientific and Industrial Research, Pretoria, South Africa
Iron and Steel Institute, Pretoria, South Africa
Ministry of Minerals and Energy, Pretoria, South Africa
National Productivity Institute, Pretoria, South Africa
Standard Bank, Johannesburg, South Africa
Brazilian AF Aerospace Technical Center, Sao Jose dos Campos, Brazil
Butantan Institute, Sao Paulo, Brazil
Companhia Brasiliera de Alumino, Sao Paulo, Brazil
Companhia Siderurgica Paulista, Cubatao, Brazil
Ford Brazil, Sao Paulo, Brazil
INBRAFILTRO, Maua, Brazil
National Space Research Institute, Sao Jose dos Campos, Brazil
Perelli Tire, Santo Andre, Brazil
Port of Santos, Santos, Brazil
TECTELCOM, Sao Jose dos Campos, Brazil
Tiete Parana Development Agency, Sao Paulo, Brazil

INTRODUCTION

This report focuses on an evaluation of a nation's strategic materials and the governmental policies affecting them. It analyzes the United States, Canada, Brazil, and South Africa to develop a perspective on how strategic materials influence their status and security.

Materials contribute to the wealth and power of nations. In fact, Morganthau and Thompson (1985) list raw materials as one of the relatively stable factors that influence the status of countries. The importance of particular materials will change over time, but some materials are so interwoven with the history of civilization that they are associated with history itself (e.g., the stone, bronze, iron, and more recently, the silicon, ages).

Materials may be generally classified as minerals, organics, or advanced materials. The latter classification includes those that are transformed or combined by human labor to achieve a useful state. Much of this report will focus on mineral materials because of their naturally occurring distribution and their importance to the gross domestic product (GDP).

The globalization of industry and the essential contribution of raw materials are clearly evidenced by the following:

> The commuter slipped behind the wheel of his Detroit built sedan. Switching on an ignition system built with Zambian copper and Ghanaian aluminum, he drew on power from a battery of Missouri lead and South African antimony to start an engine of Pittsburgh steel strengthened by South African manganese and hardened with chrome from Zimbabwe. The car rolled on tire treads blended from natural rubber from Liberia and synthetic rubber from an Algeria petrochemical base. The exhaust from Nigerian gasoline was cleansed by Russian platinum. The commuter switched on a radio with its invisible traces of cobalt from Zaire and tantalum from Mozambique, heard a newscaster's report on the Communist-led coup in a small country in South Africa. "What's that to me?" he thought" (Sinclair and Parker, 1983).

THE INDUSTRY DEFINED

"Strategic materials" is not an industry in the traditional sense of the word. Nevertheless, materials are required in manufacturing industries and manufactured items are essential in service-based industries. Whether these materials are "strategic" or not, is a matter of perspective. A material strategic to one nation may be insignificant to another. For the United States, strategic materials have generally been defined as materials essential to military, industrial, or civilian needs in times of national emergency. However, this definition is ambiguous; it depends on how "essential" is interpreted and "national emergency" defined. More recently, the term "strategic" has been more broadly interpreted to include elements necessary for the general welfare.

Key Resources

For this report, we define strategic materials as key resources that transcend individual industries in their application. Strategic materials are obtained from several primary sources: the extraction of natural materials (minerals) from domestic or foreign sources, and from the creation and production of materials, also from domestic or foreign sources. Advanced materials are a subset of produced or created materials. These advanced materials may also be strategic.

Advanced Materials. Advanced materials contain two sectors, the specialty metals (titanium and beryllium), and the advanced composites: polymer, ceramic, and metal matrixes, and high thermal conductivity composites.

The specialty metals are found in many military applications such as airframes, turbine engines, optical systems, armored vehicles and nuclear weapons. Titanium provides high strength, and corrosion resistance, while beryllium is critical for its combination of low density, high stiffness-to-weight ratio, and thermal conductivity. Uses for titanium would probably increase significantly if prices were reduced by 40 percent—a reduction that industry is trying to accomplish through continuous processing techniques. Currently, the U.S. is a net exporter of specialty metals and maintains a strong position in total world production.

The polymer composites are the most mature of the advanced composites. The U.S. polymer industry receives annual revenue of approximately $2.3 billion dollars, 51 percent of the worldwide market.

Ceramic composite technology is less mature than the polymer industry. Ceramic matrix composites are primarily used as cutting tools. The U.S. percentage of advanced ceramic revenues is approximately 22 percent of the $15 billion in total worldwide revenues.

Metal matrix composite technology is even less mature than that of ceramics. Its small, unstable market is considered precompetitive. Metal matrix composites are used to reduce life-cycle costs and improve the performance of gas turbine engines. Although the worldwide revenues within this sector are only $55 million annually, the U.S. industry's share is $30 million or 55 percent—a dominant position.

High-thermal conductivity composites are the least mature of the advanced materials, and its industrial base is also precompetitive. The use of these composites is limited to very technical and unique applications with expensive production costs.

View from the United States. The United States holds a dominant share of the worldwide production capacity and revenues in several sectors of the advanced materials industry. Although it must rely on some imports, particularly for raw materials such as petroleum, natural gas, silicon and graphite, U.S. dependence on exports is quite low. The U.S. technology and industrial base for advanced materials is sufficient to meet expected requirements for the next 10-to-20 years.

Based on our decision to compare the United States, Canada, Brazil, and South Africa, the balance of this report focuses on the supply of natural strategic minerals and the governmental policies and decisions affecting them in these four countries. That is, it evaluates the influence of strategic and advanced materials on the security and status of nations by comparing attitudes and behaviors relative to these resources in Brazil, Canada, South Africa, and the United States.

CURRENT CONDITION

United States

Though much of the world's strategic mineral wealth is located outside the United States, within its boundaries over 90 minerals are mined and processed. The United States exports more than 60 different minerals and is especially rich in nonmetallic minerals. Although, the U.S. is one of the two top producers of nonfuel minerals, there are still

many materials that the United States imports from foreign countries (Kessel, 1990).

Minerals are imported for a variety of reasons, often because it is economically advantageous to do so. In many cases, foreign ore deposits are richer than domestic deposits, closer to cheap energy sources, and mined by cheaper labor. The industrial demand in some mineral rich countries is lower than the available supply, making them ideal exporters. The growing interdependence of the world's supply of resources is very apparent. Table 1 depicts the U.S. reliance on imports for several minerals and their primary sources.

Canada

Canada's great wealth of land contains some of the world's largest reserves of natural resources. This country is the world's top producer of uranium, zinc, and potash; the second largest producer of nickel, sulfur, asbestos, and cadmium; the third-largest producer of aluminum, platinum, titanium, copper and gypsum; the fourth largest in cobalt and molybdenum; and fifth in gold and lead.

Canada is the largest exporter of raw minerals and mineral products in the world. These items are 16.2 percent of Canada's exports, and are collectively a major factor in its continuing trade surplus of over $10 billion. The mining industry is large, growing, and vital to Canada's economy. The Canadian government estimates that for every job created directly from the mining industry at least one indirect job is also created in the economy. Mines are opening or reopening each year in Canada — 21 in 1995, 24 in 1996, and 25 in 1997. By the year 2000, the government predicts an average of 20 new mine locations per year. This activity will create over 20,000 direct and indirect jobs throughout the country (Canadian Mining Facts).

The mining and mineral processing industry contributes $23 billion to the Canadian economy annually — about 4 percent of its GDP. Exports of raw materials from Canada increased by over 40 percent between 1993 and 1995, from $29 to $40 billion, thus ensuring that Canada will remain

Table 1.—U.S. Mineral Materials Ranked by Net Import Reliance, 1995.

Commodity	Percent	Major Sources (1991-1994)
Arsenic	100	China, Chile, Mexico
Columbium	100	Brazil, Canada, Germany
Graphite	100	Mexico, Canada, China, Madagascar
Manganese	100	South Africa, Gabon, France, Brazil
Mica	100	India, Brazil, Finland, China
Strontium	100	Mexico, Germany
Thallium	100	Belgium, Canada, UK
Yttrium	100	China, UK, Hong Kong, Japan
Bauxite and Alumina	99	Australia, Jamaica, Guinea, Brazil
Gemstones	96	Israel, India, Belgium, UK
Flurospar	92	China, South Africa, Mexico
Tungsten	87	China, Germany, Bolivia, Peru
Tin	84	Brazil, Bolivia, Indonesia, China
Cobalt	82	Zambia, Norway, Canada, Zaire
Tantalum	80	Australia, Germany, Canada, Thailand
Chromium	78	South Africa, Turkey, Zimbabwe, Russia
Potash	74	Canada, Belarus, Germany, Israel, Russia
Barite	65	China, India, Mexico
Iodine	62	Japan, Chile
Nickel	61	Canada, Norway, Australia, Dominican R
Antimony	60	China, Mexico, South Africa, Hong Kong
Stone (dimension)	57	Italy, Spain, India, Canada
Peat	55	Canada
Magnesium Compounds	50	China, Canada, Mexico, Greece
Asbestos	46	Canada
Zinc	41	Canada, Mexico, Peru, Spain
Diamond (dust, grit, powder)	36	Ireland, China, Russia
Selenium	33	Canada, Philippines, Japan, Belgium, UK
Silicon	33	Norway, Brazil, Canada, Russia

the world's largest exporter of minerals and mineral products (Canadian Mining Facts).

Brazil

Brazil, one of the world's leaders in mining, has reserves of at least 18 billion tons of high-grade iron ore (one third of the world's total). It is

also a leading source of the world's iron with annual production of over 130 million tons of metal from over 200 million tons of ore. Brazil's bauxite output exceeds 11 million tons per year with reserves of 2.5 billion tons (the largest in Latin America). Brazil ranks fifth in aluminum production at 7.5 million tons. Annual manganese production runs at 2.6 million tons. Brazil is second in the world for tin production and reserves. Fully 90 percent of the world's niobium is located in Brazil. Chromium, copper, zinc, lead, nickel, cobalt, molybdenum, and titanium are abundant. Silver, quartz (about 95 percent of the known supply), and a wide variety of gemstones are plentiful. Brazil's gold reserves (35,000 metric tons), are the fifth largest in the world (EIU). Brazil is also fifth in the world for uranium and was the eighth nation to master the technology to enrich it for fuel (perhaps enough for weapons).

Brazil is the world's most significant producer and principal supplier of columbium to global markets. In 1994, it produced about 79 percent of the world's total supply of columbium concentrate, alloys, and oxides. Brazil was third in tantalum concentrate production in 1994, following Australia and Malaysia.

South Africa

Although government and industry sources provide somewhat inconsistent information on the South African economy, it is generally agreed that the minerals industry contributes 10 to 12 percent of the nation's GDP. At least 80 percent of all mineral production is exported, with mineral sales accounting for over 60 percent of the nation's export revenue. According to the Ministry of Mines and Energy, exports totaled US$17.6 billion in 1995, of which US$6.4 billion (36 percent) was for gold. Gold has been the main source of foreign currency for South Africa for many years. In 1980, when gold prices peaked, gold mining directly contributed 17 percent to the GDP. Gold mining currently contributes just under 5 percent directly to GDP, though indirect contributions may raise that closer to 10 percent. The South African minerals industry supports over 600,000 jobs, approximately 4 percent of all jobs in South Africa.

According to recent official estimates, South Africa has the world's largest reserves of six major minerals: alumino-silicates, chromium, gold, manganese, the platinum group metals and vanadium. For another 10 minerals, South Africa ranks in the top five nations. The South African mining industry collectively is the world's largest producer of gold, the

platinum-group metals, vanadium, and alumino-silicates, and ranks in the top five for 10 other minerals, as summarized in the following table.

Table 2 — South Africa's Role In World Minerals Production 1992.

Mineral	Unit	Production	World	
			%	Rank
Alumino-silicates	kt	231	35	1
Antimony (metal content)	t	3, 951	10	4
Chrome ore	kt	3,364	30	2
Diamonds (gem and industrial)	k car	10,177	11	5
Ferrochromium	kt	771	21	2
Ferromanganese	kt	536	9	4
Fluorspar	kt	260	7	5
Gold	t	613	28	1
Manganese ore	kt	2,464	11	4
Platinum-group metals (metal)	kg	152,891	54	1
Titanium metals	kt	751	20	2
Vanadium (contained V_2O_5	t	25,052	42	1
Vermiculite	kt	170	36	2
Zirconium minerals	kt	230	29	2

CHALLENGES

Several challenges affect each of these countries and their continuing ability to provide mineral resources to the world. Among them are protecting the environment, coping with growing federal deficits and insufficient capital investment, inadequate or outdated infrastructure, and the globalization of the marketplace. Both the United States and Canada legislate and enforce environmental regulations. Although Brazil and South Africa articulate the need to protect their environment, policy is lacking and enforcement haphazard.

Another challenge shared by these nations is their growing federal deficits. A very small portion of the national budget is available for capital

investment. Both the United States and Canada can easily borrow funds from foreign investors to finance their debt; however, borrowing is uncommon in Brazil and South Africa because the annual interest on capital is almost 50 percent. Officials in South Africa are unwilling to subject their countries to the rules and regulations that accompany funding from the World Bank. By contrast, in 1996 alone, Brazil requested and received approval for projects valued at over one billion dollars from the World Bank.

Brazil's financial challenges are massive. Since his election in 1994, President Cardoso has implemented comprehensive, market-oriented reforms of the public sector, and he is privatizing state-owned industry, and eliminating barriers to foreign investments. It will not be easy for Brazil to abandon long-standing practices of government intervention in the market economy, but the effective dismantling of its inefficient state structure is essential to its long-term survival and industrial competitiveness (Onis, 1989).

South Africa's major challenges revolve around maintaining its new government. Foreign individuals and organizations hesitate to invest until they can be satisfied that the South African government is stable. Among its many problems are violence, unemployment (at almost 50 percent), widespread poverty, and lack of education. The young government of South Africa must overcome many obstacles.

OUTLOOK

The threats inherent in mineral resource dependency are many, beginning with resource depletion, potential shortages, disruptions, economic fluctuations, or interdiction.

However, a nonfuel mineral dependency is not as threatening as it appears and no nation is completely self-sufficient in today's global economy. Globalization constrains national leaders from using historical market controls to leverage their positions. Today's world is interwoven with trade dependencies. Developing nations with vast mineral resources depend mightily on uninterrupted trade revenues. They are also the greatest importers of manufactured goods from the United States, comprising our fastest growing market (Castle and Price, 1983). Only eight of the world's 180 countries produce significant food surpluses. In fact, the United States could statistically hold a greater monopoly on food production than OPEC does on oil (Paone, 1992). As the Institute

for National Strategic Studies noted in its 1996 Strategic Assessment: "purely national economies no longer exist.' Economic interdependence has reached an unprecedented level; no nation can stand alone.

The idea of strategic mineral cartels, price controls, and embargoes evokes images of gas lines from the 1973 and 1979 oil crises. The actual likelihood of such materials blackmail is remote. The success of cartels depends on a number of complex factors, and requires not only political, but also economic solidarity, which is difficult to maintain in today's environment (Tilton, 1977). The market's reaction to both price fixing and embargoes is the greatest deterrent to these tactics. As with any commodity, demand falls with price increases and other sources, alternative products, and conservation can frequently fill the void. In today's global market, the producer, rather than consumers, is injured when other producers gain market share.

Could we survive a cutoff of strategic materials? The answer is yes. Kenneth Kessel studied the effects of a yearlong cutoff of the "big four" strategic materials from South Africa: manganese, cobalt, chromium, and platinum. He found that, given the current U.S. position, induced shortages would be almost entirely absorbed by supplies in transport pipelines, industry inventories, and modest conservation. In no cases would shortages affect defense needs. Within six months to a year, new production and substitutions would more than offset the problem. Duration of the cutoff is the determining factor, whether in peace, crisis, or war.

Materials shortages are not critical in all war emergencies (Gill, 1984). The biggest threat would be a large-scale war that endures longer than our most recent experiences, but falls short of a multiple-year war that would allow for market and technology mobilization.

Resource depletion is likewise not as critical as some suggest. The projections on which this theory rests are based on current known mineral reserves and estimates of future consumption built on today's rates. But these methods are flawed. Reserves are only known if exploration, usually commercial ventures, finds them. Companies don't often spend much capital to look for reserves they don't yet need. Second, both reserves and consumption rates are based on current technology, while the impact of future innovation is impossible to calculate. Finally, depletion does not account for the fact that, except in nuclear processes, elemental materials are not used up in production processes. They are simply transformed. Future recycling technologies may offer far more opportunities for reuse (Tilton, 1997).

Technology and innovation have other possible impacts on material availability. Besides recycling, future technology may offer new

exploration and extraction methods, more efficient uses for materials, new processes to use poorer grade ores, and improved conservation methods. There may also be new sources of mineral deposits, such as deep seabed, lunar, asteroid, or extra-planetary (Haag, 1997). Finally, new artificially structured materials, like advanced ceramics and composites, will undoubtedly replace many of our current construction and component minerals. Current technology in this area can virtually build new materials one atom or molecule at a time, giving advanced materials properties like none found in nature (Committee on Materials Science, 1989).

Recycling

Recycling and reuse are options to consider in lieu of new materials. Industries in the United States practice recycling when it is economically beneficial to them or when government legislation, focusing on environmental impact and protection, requires them to do so.

Canada has a much stronger national policy and programs for recycling than does the United States. The Canadian government subsidizes the recycling industry, including environmental research and development. Canada, like the United States, has no program specifically directed to recover and reuse strategic materials.

Brazil has recently added several articles to its Constitution that call for reclaiming environmentally degraded areas. Other resolutions require mining operators to act in an environmentally alert manner. Still other efforts address antipollution efforts. However, we found no policy in Brazil that specifically addressed the recycling of materials.

Recycling has great implications for energy and material resource conservation, waste reduction, and pollution prevention. The use of recycled materials has increased partly as a result of escalating prices, but also because of environmental concerns and energy costs. Thus, there are many success stories. Every ounce of gold that has ever been mined and refined is still in use in some form (National Mining Association, 1996). The secondary recovery of aluminum (7.8 billion pounds in 1994) uses 5 percent of the energy required to produce the same amount of aluminum from ore. Steel, our most recycled material, had a recycling rate of 68.5 percent in 1995. In 1995, automobile recycling rates were nearly 75 percent, leading to the recovery of large quantities of steel, aluminum, copper, lead, zinc, platinum (especially for catalytic converters), plastics, and glass. Virtually 100 percent of all titanium produced is reclaimed and reused.

There is still room for improvement. Of the 84 minerals listed in the 1996 Mineral Commodity Summaries, fewer than one third are recovered from previously used applications. The remaining two-thirds are either not recycled or the recycling effort is insignificant.

GOVERNMENT GOALS AND ROLE

The articulated goals of Brazil, Canada, South Africa, and the United States are very similar. Each recognizes the necessity of having active, competitive industries to compete in the global economy and promote the general welfare of its citizens. Similarly each of these nations is struggling with a history of spending in excess of revenue. Although foreign investment is essential, obtaining investment capital is more difficult for Brazil and South Africa than for the United States or Canada. Each nation recognizes the need for research and development. Methods for addressing these needs differ because of the different capabilities and styles of government among the countries.

United States Perspective and Policy

Two trends mark the U.S. perspective and policies: economic vibrancy and unmatched military hegemony. The United States is experiencing one of its strongest economic periods in the past 20 years. Unemployment is 5 to 6 percent and inflation is running less than 5 percent per year. Stock markets have shown steady and consistent growth for the past seven years. These positive effects have occurred within a significant period of industrial restructuring, and government downsizing. However, the country continues to run substantial annual budget deficits, though with decreasing trends the past few years. Now that Congress and the administration are committed to achieving a balanced federal budget, consumer and investor confidence are soaring to an all-time high as evidenced by the stock market's substantial growth in the past two years.

The end of the Cold War finds the United States as the lone superpower in the world with no known adversary capable of challenging or threatening its leadership or national security. The absence of any visible threat calls into question many of the programs that support our defense and national security. The nation is selling off defense resources such as the national stockpile and terminating numerous other programs now considered unnecessary. Other than stockpiling, there is no specific

U.S. policy or strategy for minerals, metals, or strategic and critical materials.

Following World War II, the United States actively supported science and technology by providing substantial funding for basic and applied research programs. Although much of this funding supported defense initiatives, the benefits were apparent in the spin-offs to commercial applications. The 20-year period following the Second World War was a renaissance for invention and commercial development. Funding for government-sponsored research in 1953 was $2 billion; the total budget was $74 billion.

Since 1994, as a response to the need to balance the federal budget and in accord with world changes, funding for science and technology programs has declined. Funding in fiscal year (FY) 97 is about $43.4 billion, in constant year dollars, or 9.7 percent less in real terms than FY 1994 funding levels. These figures include basic and applied research across the entire federal government, and all development programs except those managed by the Defense Department and the Department of Energy (National Academy of Science, 1997). These funding levels are surprisingly low in view of many foreign governments' efforts to increase their nondefense R&D. Foreign governments have recognized the connection between technology and successful economic growth (DOC, 1996).

Early in his administration, President Clinton announced that his technology policy would target economic growth. It contains four elements:

- initiatives that will help develop, commercialize, and deploy new technology;
- fiscal and regulatory policies that promote these same activities—ranging from R&D tax credits to changes in government procurement policy;
- investments in scientific and technical education and training; and
- projects that will help build critical transportation and communications infrastructure.

A recent report confirms the administration's long-term support for federal government investment in research and development. It also acknowledges the environment of reduced discretionary budgets, and indicates that in today's constrained resource environment, the

administration's objectives can be obtained more efficiently by allocating funding for federal science and technology (FS&T).

The administration proposes consolidating the FS&T budget across all disciplines and agencies. This consolidation would allow projects to be ranked so that resources will be available for new and promising investment opportunities (Committee on Criteria for Federal Support, 1995). In addition, the current administration seeks to provide incentives for R&D in the private sector through legislation and regulation.

Canadian Policy Initiatives

Canada has suffered recent economic difficulties caused by deficit spending, accumulated debt, and substantial interest payments on the debt. Canada's expenditures have exceeded revenues for more than 20 years. Accumulated debt exceeds 70 percent of the GDP. Many economists believe that a legacy of many years of liberal social programs has taken its toll on Canada and its economy.

Recently, the Canadian government embarked on an ambitious recovery program, "Investing in growth." Its purpose is to promote economic growth and create well-paying jobs, and it has three policy initiatives: First, reduce the deficit and debt to GDP ratio; second, ensure stability and sustainability through social program reform. Third, and finally, provide Canadians and Canadian businesses the support they need to take full advantage of their modern economy (Canada Dept. of Finance, 1996).

These initiatives should improve Canada's competitiveness and trade posture in the global economy. The Canadian federal government is working quite hard to reduce the deficit and put the economy back on a steady path to recovery. Its approach—of addressing economic recovery vigorously through support and collaboration with Canadian businesses — strongly influences its minerals and metals policies.

Canada has formally articulated its minerals and metals policy (Partnership, 1996). This policy is an outgrowth and evolution of the October 1994 Whitehorse Mining Initiative and September 1995 National Resources Canada issue paper for "Sustainable Development and Minerals and Metals." Canada's federal government considers managing mineral and metal science and technology a core responsibility. This policy describes the role of science and technology and government's responsibilities.

The policy is written to reflect an overarching concept called "sustainable development." Sustainable development is defined as

"development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Natural Resources, Canada). The policy accommodates environmental concerns and enfranchises the aboriginal population within the broader arena of the minerals business. The Canadian government's science and technology goals are to

- promote enhanced productivity of the industry through collaborative efforts;
- provide a window and access point for Canadian companies—particularly small- and medium-sized firms—to acquire international science and technology;
- evaluate external technological developments to assess their usefulness and value to Canadian operations in the minerals and metals sector;
- promote the transfer of technologies within Canada to transform research into exploitable know-how and promote the sharing of expertise among all participants;
- provide Canadians with the geoscience, knowledge, and infrastructure to enable exploitation of domestic and foreign markets;
- facilitate collaborative approaches to national problems;
- share Canada's scientific and technological experience with the international community to implement sustainable development for minerals and metals;
- promote the development of environmental protection and pollution prevention technologies; and
- work with industry to realize more employment and revenue benefits from mineral and metal resources through valued-added manufacturing of mineral and metal-based products.

This policy provides the framework for developing and applying science and technology to enhance Canadian industry's competitiveness and environmental stewardship. The role of the government is clearly defined as a catalyst and facilitator to form partnerships with industry, provincial and territorial governments, international organizations, other countries, and academic institutions involved with science and technology. This policy supports the economic reform initiative and seeks to provide Canadian business with access to the technical information that ensures competitiveness in the global economy.

By 1998 the federal government plans to invest $250 million through its Technology Partnerships Canada program. These funds will be used to leverage additional investment from the private sector. Rather than serving as a grant to firms, these funds will be replenished by income and profits from the products developed using the new technology.

Brazilian Perspective and Policies

Two initiatives by the Brazilian government provide insight into their intentions. First, Brazil's geological survey contributes to strengthening the nation's mineral resources by actively pursuing programs to map Brazil and develop databases with geological and economic information. The government has concentrated its efforts on the basic geological mapping of the nation's minerals so that these valuable resources can be used productively.

Brazil's second significant venture was a $160-million loan acquired through the Inter-American Development Bank in 1995 to modernize this industry with new technology. This initiative broke with the government's 1980s legacy of not investing in technology improvement projects. Failure to fund science and technology programs has handicapped Brazil's industry, rendering it inefficient and less competitive in the global marketplace. Brazil's economy can't grow and compete unless these programs are sustained. The loan has precisely that objective: support industry to compete in the global market. The loan also funds needed and overdue R&D proposals by universities and research institutes. Brazil's extensive network of mineral research colleges and firms serve as a key resource supporting this initiative.

These initiatives are consistent with Brazil's continued efforts toward economic stabilization and a market driven economy, and its desire to shift industry from government ownership to operation in the private sector. Under President Cardoso, Brazil revised its Constitution to permit foreign ownership of mines, to increase government's transparency, and to improve the rule of law.

South African Perspective and Policy

As South Africa's major industry and employer, the minerals and mining industry is at the center of the South African debate to balance rights and realign resources. A government policy initiative, the Tripartite Discussion Document, states that government's role is to coordinate research essential for stimulating development of the

country's mineral resources that aren't within the normal business and risk limits of private industry (Draft Mineral & Energy Policy). The paper defines the government role in research and development as consisting of the following tasks:

- direct research and development in areas of high need, particularly health and safety, small-scale mining, and beneficiation;
- provide matching grants for funding research and development projects;
- restructure the Safety in Mines Research Advisory Council (SIMRAC) to improve research management and oversight, and undertake occupational health research;
- manage government funds spent on joint research and development projects with industry;
- establish a mining and mineral processing research and development commission to make use of the best facilities, promote collaborative research activities and technology transfer, and ensure that minerals-related research and development is conducted in accord with the country's science and technology policy and national objectives; and
- ensure the SIMRAC's funding remains at a sensible level.

Some of these issues will pose difficult obstacles for the mineral industry, particularly with regard to the state's authority to direct research and development. The Chamber of Mines has commented on the draft policy on behalf of the mining industry. Industry welcomes the potential contribution that such R&D can make, provided that it is user-driven and complementary to private-sector activity. However, industry questions the government's strategic role and ability to formulate R&D policy. It also takes exception to the proposal in which government would intervene and add value to the relationships that industry already has with academic and research organizations. It concurs, however, with the government's cooperative role in health and safety research and that it should be funded by the government (Mining and Minerals Policy). These issues will be difficult to resolve. The established mining companies will be slow to give up authority in this area. In addition, industry funded the high risk research that allows deep-shaft mining (to 5 kilometers) under extreme environmental working conditions. They will be reluctant to share this technology.

The South African government wants to move the country to a market economy, and the mining industry is a major element of that effort. The

major issue is how to enlarge the ownership of the mineral wealth currently controlled by a small group of companies so that its benefits are shared with all South Africa's citizens. The government will try to use public policy to level the playing field. This role seems appropriate for a government in a country where the majority was disenfranchised for so long. Many remnants of apartheid are still factors in the lucrative mining industry.

CONCLUSION

Many commonalties exist among the United States, Canada, Brazil, and South Africa concerning strategic materials. All discussions we had in Canada, Brazil and South Africa, whether with government officials or private industry and business representatives revealed similar concerns. All recognize the advantages of free international markets, insist that sustainable development is a necessary focus of any mining efforts, and describe the advantages of government involvement in long-term research and development. Brazil and South Africa are struggling to upgrade infrastructure and decrease costs and production inefficiencies.

Each country has different approaches for achieving its goals. The common thread is the goal: to achieve or maintain economic stability and the benefits that accrue with it. All four countries are actively negotiating new markets, for example, through NAFTA (the United States, Canada and Mexico), MERCOSUR (Brazil, Argentina, Uruguay, and Paraguay) and SADC (Southern Africa Development Corporation). Canada's very proactive approach focuses heavily on collaborating with industry to ensure the global marketability of its products. South Africa is developing and debating a policy that would expand ownership beyond the small group which has historically controlled the minerals industry. Another priority is to develop a value-added component to its minerals industry rather than simply exporting raw minerals. Brazil is privatizing enterprises, obtaining foreign funding to invest in infrastructure and R&D, and charting a course to exploit its mineral resources. Although the United States actively negotiates new markets, it has reduced its financial support and commitment to R&D which has traditionally been a key to its successes.

Despite a drastic decrease in R&D funding in the United States, it still invests more than Canada, Brazil, or South Africa in this enterprise because of the size of its GDP. Further, R&D has decreased in all four countries at the industrial level. Many corporations indicate that investor

insistence on quarterly improvements in the bottom-line threatens continued advancement and productivity enhancements. South Africa is struggling, yet still invests in R&D. South African researchers have many international patents, but unfortunately its industrial base is too weak to manufacture many products. Brazil has obtained external funding for its R&D programs and hopes to improve its competitiveness in the world economy. Canada closely links R&D to industrial productivity. It seeks to decrease product development time and uses rapid testing and evaluation programs. The United States stands alone in its thinking that support for industrial R&D is "corporate welfare" and inappropriate in today's economy.

There has been a fundamental shift in thinking concerning the strategic and advanced materials industry in the United States. Historically, our concerns, policies, and programs were directed at items needed in times of a national emergency and whose sources of supply were potentially at risk. The end of the Cold War and the increased globalization of national economies has inspired a broader perspective on strategic and advanced materials. The new perspective recognizes that national security encompasses planning for the general welfare of a society and includes economic and political considerations in addition to traditional military requirements.

This broader perspective on the industry and national security was evident in each of the countries included in this project. However, each country is in a different state of economic and political development, which supports our conclusion that "strategic" is a matter of perspective subject to changes over time. The new millennium will present additional changes and challenges and perhaps redefine the parameters used to discuss "strategic materials" in each nation.

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TRANSPORTATION

ABSTRACT

Today's transportation industry is market competitive, exploits the efficiencies of intermodalism, information technology, and automation, and is evolving through globalization toward a seamless worldwide network. Challenges to its future evolution lay ahead. Improvements are needed to modal transfer mode infrastructure at ports, terminals, and airfields, as well as to employment policies and procedures. The federal government will continue to influence the evolution of the nation's commercial transportation industry. Leading the way in national transportation planning, following a customer/supplier policy wherever practical, and retaining and operating an adequate rapid initial response military lift capability represent the best course for future government interaction with transportation.

Colonel Regulo Anselmi, Venezuelan Air Force
LTC Mike Brown, USA
Mr. Dave Carlson, Dept. of Navy
LTC Bob Coxe, USA
Colonel Vladimir Goncharov, Russian Federal Frontier Service
Mr. Jay Henn, National Aeronautical and Space Administration
COL Steve Howard, USA
LtCol Chris Kauffmann,USMC
CDR Joe Kernan, USN
CDR Frank Klein, USN
Mrs. June Kunsman, Dept. of State
Lt Col Terry McCarthy, USAF
Lt Col Joe Niemeyer, USAF
LTC Bob Radin, USA
Mr. Jack Russell, National Security Agency
Lt Col Wilma Slade, USAF

Mr. Bill Jones, FEMA, faculty
Mr. Jim Tarrant, Dept. of State, faculty
COL Jon White USA, faculty

PLACES VISITED

Domestic
AMTRAK, Washington, DC
United Parcel Service, Burtonsville, MD
Port of Baltimore, MD
Federal Express, Memphis, TN
CONRAIL, Pittsburgh-Philadelphia, PA
Union Pacific Intermodal Container Transfer Facility, Long Beach, CA
Long Beach Port Authority, Long Beach, CA
Alameda Corridor Transportation Authority, Carson, CA
DYNCorp Services, Fort Worth, TX
American Airlines, Fort Worth, TX
Burlington Northern Santa Fe Railway, Fort Worth, TX
AMTECH, Dallas, TX
Alliance Development Corp., Alliance, TX

International
Aalsmeer Flower Auction, Aalsmeer, Netherlands
Rotterdam Rail Service Center, Rotterdam, Netherlands
Van der Vlist Special Transportation, Groot Ammers, Netherlands
European Transport Systems Division, Moerdijk, Netherlands
Royal Nedlloyd N.V., Rotterdam, Netherlands
Rotterdam Port Authority, Rotterdam, Netherlands
Sea-Land Delta Terminal, Rotterdam, Netherlands
U.S. Army Military Traffic Management Command-Europe, Rotterdam
Ministry of Defense, Paris, France
Societe Nationale de Chemins de Fer (SNCF), Paris, France
Intercargo, London, UK
Baltic Exchange, London, UK
Sea Container Services, Ltd., London, UK
Maersk Lines, London, UK
EURO Tunnel, Folkestone, UK / Calais, France
Ministry of Defence, London, UK
Ministry of Transport, London, UK
British Airways, London, UK
Heathrow Airport Authority, London, UK

INTRODUCTION

Throughout this nation's history, transportation has played a crucial role in projecting economic as well as military power. Over the last 20 years, four major influences have dramatically transformed modern American transportation. Deregulation and intermodalism have helped recast the nation's transportation service network into a lean, competitive industry continually pushing toward increased efficiency. Combined with applications from new technology, these influences have wrought a fundamental transformation of America's transportation capabilities. The evolution of modern transportation has spawned a revolution in American industrial business practices. Overnight delivery, just-in-time logistics management, and obsolescence of many material warehousing and inventory concepts characterize the profound impact modern transportation has had on the economic and military elements of national power.

Transportation capacity and capability issues form a major component of U.S. strategic logistics and mobilization concepts for defense. Logistics and mobilization planning must now consider the emerging globalization of commercial transportation, with its potential impact on American strategic mobility.

This report of the Industrial College of the Armed Forces 1997 Transportation Industry Study analyzes the interaction of transportation, the global economy, and military force projection. It examines the state of the transportation industry, the intermodal transportation improvements contained in proposed legislation, and the industry's capability to meet national defense needs. Lastly, the study explores major transportation issues that affect national defense, and develops recommendations for future government action to ensure the preservation of a robust American transportation capability.

THE TRANSPORTATION INDUSTRY DEFINED

Transportation deals with moving people and goods from a point of origin to a point of destination (Muller, 1995). In the United States, transportation is a major industry comprising 11 percent of the gross domestic product (GDP). The modern American transportation industry is characterized by capital-intensive firms operating under small profit margins.

The prevalent modes of transportation examined in this study are air, road, rail, and maritime. Each mode offers comparative advantages, depending on the type and amount of goods to be shipped and their destinations. American transportation moves approximately 11 billion tons of goods each year. Roughly 10 billion of those tons are shipped domestically. The 1995 market share for each mode moving domestic freight is shown in Table 1 by volume, ton-miles, and revenue.

Table 1.

(%)	Air	Road	Rail	Water	Intermodal	Other (pipe, etc)
Volume	0.1	45.5	24.4	3.5	1.4	15.1
Ton-Miles	0.4	26.5	39.0	14.1	2.2	17.7
Revenue	4.3	78.9	7.2	1.5	1.8	6.3

Intermodal transportation, a special focus of this industry study, is "the concept of transporting passengers and freight in such a way that all the parts of the transportation process, including information exchange, are efficiently connected and coordinated, offering flexibility" (Muller, 1995, p.1). The intermodal transportation industry includes the following elements:

- all participating carriers with their logistics management capabilities;
- applicable information technology;
- pertinent infrastructure elements such as airport/seaport facilities, terminals, intermodal transfer points;
- intermodal freight containers and associated material handling equipment;
- direct government support/participation/intervention; and
- the human capital needed to operate this industry.

Intermodal movement depends on standard *containers* for shipment of goods. More and more nonbulk general cargo now moves in standard 20 or 40 foot containers for overseas shipments (domestic intermodal freight also moves in 45- 48- and 53-foot containers). Container ship capacity is measured in 20-foot equivalent units (TEUs), based on the original 20-foot container standard. Containers offer the shipper many advantages, including greater security, reduced damage, lower shipping costs, and improved speed to market. Firms such as Sea Containers Services design and build specialized containers to handle bulk, liquid, palletized, and platform/flatbed-mounted cargoes and general freight. Containers allow

carriers to transload goods among road, rail, and maritime modes quickly and efficiently.

Specialized port facilities, material handling equipment, information systems technology, and skilled labor are needed to realize the benefits of intermodal shipment. Modal transfer nodes such as seaports, railyards, and trucking terminals are being completely reengineered to provide seamless and continuous handling of freight from ship to rail to truck. "Containerports" have developed in all major world harbors, and are now being built inland to serve the growing domestic intermodal freight industry. These ports feature special purpose cranes for dockside container transfer from ship to trucks and/or dedicated intermodal freight trains of "double-stack" container well cars, for movement to and from customers. Information exchange systems let customers and carriers track each shipment with up-to-the-minute accuracy. Containerization has proved a major catalyst to modern intermodal transportation.

The *globalization* of commercial air and sea transportation is also shaping the modern transportation environment. "Globalization," the emergence of integrated markets and industries operating in multiple countries, expands with the development of high speed communications and transportation technologies and applications. In airline and maritime transportation, global competition produces mergers and expansions into full logistics support services with worldwide access by huge corporations. Both mergers and international alliances seek to reduce costs in these very competitive industries where excess capacity is the norm. Customer demands for faster, more frequent and lower cost services drive new industry structures to reduce costs, manage competition, avoid regulatory and labor constraints and respond to customers.

CURRENT CONDITION

The modern American transportation industry is quite healthy in the aggregate. A capsule summary of latest available comparative data on industry profitability by modal segments (1995) is provided in Table 2.

Table 2.

	Air	Road	Rail	Maritime
Operating Revenues ($billion)	94.3	55.3	32.3	15.0
Operating Profits ($billion)	5.9	2.6	4.4	0.8
Operating Profit Margin (%)	6.2	4.7	13.6	5.0
Net Profit Margin (%)	2.5	2.1	6.5	1.5

Growth in transportation productivity has occurred annually since 1989, and its rate of change has also increased by 1 percent per year (DOT, 1996). While the various modes differ greatly in terms of speed, capacity and cost, intermodalism helps to integrate them into a virtually seamless network.

Conditions by Modal Segment

Air. Fueled by a healthy GDP, airline revenue passenger miles exceeded 540 billion in 1995, with aircraft load factors increasing to near 70 percent, a record high. Air freight traffic is increasing steadily with nearly 17 billion revenue ton-miles flown in 1995 (Air Transport Association, 1996). Increases in fuel and labor costs were offset by increases in load factor and decreases in unit cost. The result was the first net profit for the U.S. airline industry since 1989.

U.S. air carriers have always competed favorably in the international air transport arena. Since 1979, U.S. air carriers have flown an average of 40 percent of the world's total passenger traffic and revenue passenger miles (DOT, 1996). Nonetheless, international and domestic airlines continue to move toward business alliances to improve their market share and global access. In 1997, United Airlines, Lufthansa, Thai Airlines, Scandinavian Air System, and Air Canada created the "Star Alliance," the largest global commercial air alliance to date (*Time*, 26 May 97). American Airlines and British Airways are negotiating with the United States and British governments to create a competing alliance, in the same fashion as the already established KLM/Northwest Airlines alliance.

Road. Three major segments comprise the U.S. trucking industry. Truckload (TL) carriers haul full loads of 10,000 pounds and more, moving directly from dock to user with no intermediate stops at terminals. Less than truckload (LTL) carriers haul loads of generally less

than 10,000 pounds—cycling through a sequence of pickup, terminal consolidation, haul, break bulk (destination sorting), and delivery. Small package carriers, such as United Parcel Service (UPS), specialize in loads typically under 150 pounds.

The trucking industry is steadily profitable, yet firms strive constantly to improve their operating ratio (relationship of revenues to expenses). Since trucks are usually the mode of choice for general or intermodal freight delivery to end customers, operating expenses for trucking firms are significant. The operating ratio for Class I and II motor carriers has averaged 96 percent since 1995 (ATA, 1997).

While trucks continue to capture the largest share of the nation's freight transportation market by volume and revenue, intermodal freight traffic volume is declining as a result of increased competition from railroads. In response to that competition, TL carriers are teaming with railroads to ship general freight to destinations beyond 500 to 600 miles. Both trucking firms and railroads are creating pools of 45- 48- and 53-foot containers to service the expanding domestic intermodal market. Each mode maximizes its efficiencies and reduces individual operating costs.

Rail. Measured by revenue ton-mile, railroads haul nearly 40 percent of all U.S. freight (ATA, 1997). Deregulation and intermodalism have proved a tremendous boon for the railroads; intermodal traffic now accounts for 15 to 20 percent of total revenues of most Class 1 railroads. Railroads are also expecting to recapture LTL traffic lost to trucks since the late 1960s. The operating patterns of regularly scheduled high-priority intermodal trains are making rail service economically competitive with long-distance LTL trucking firms. Another aggressive marketing strategy of large railroads is their willingness to create alliances with short-line railroads, such as the CONRAIL EXPRESS program. These alliances give shippers the best service aspects of both railroads but only one bill to pay.

The U.S. rail freight network continues to consolidate. In the West, Union Pacific began its merger takeover of the former Southern Pacific in 1996, gaining rough parity with its principal competitor, the recently merged Burlington Northern Santa Fe Railway. In the East, CSX Transportation will purchase the Consolidated Rail Corporation, CONRAIL, then sell 58 percent of it to its principal competitor Norfolk Southern Railway to create true, widespread, physical rail competition in the Northeast.

AMTRAK, the nation's passenger rail network, continues to face financial challenges. AMTRAK is aggressively pursuing LTL traffic markets to generate new revenue by combining express freight and mail service on its regularly scheduled passenger trains. Whether AMTRAK can succeed with this venture is yet to be seen.

Maritime. The U.S. maritime commerce industry is a study in contrasts. Its companies enjoy significant success in domestic and international maritime commerce, particularly intermodal shipping. In 1993, Sea-Land Services carried more TEU containers than anyone else worldwide, namely, 922,581. American President Lines (APL) was fourth worldwide, carrying 631,439 TEUs in the same period (Muller, 1995). Both Sea-Land and APL have joined the growing trend toward global alliances. Sea-Land and Maersk Lines of Denmark have allied to gain increased access to Latin American and Asian markets. APL has joined with Nedlloyd Lines of the Netherlands, Orient Overseas Container Line from Hong Kong, and Japan's Mitsui OSK Lines to form the "Global Alliance," a joint venture optimizing the carriers' market share and operations worldwide.

Very few of the ships owned by U.S. companies are U.S. flagged. In 1995, only 292 of the 25,000 oceangoing vessels over 1,000 gross tons—less than 2 percent of the world's merchant fleet—were actively sailing under a U.S. flag (MARAD 1995, 36). Foreign-owned vessels dominate the market with low-wage crews. Reduced safety requirements, lower taxation, and lower labor and training costs have driven most U.S.-owned ships to flag-of-convenience registries to hold down costs.

To maintain sufficient U.S. flag vessels for national defense mobility needs, the U.S. government once paid operational differential subsidies (ODS) to American ocean shipping firms to offset the cost of doing business under the U.S. flag. The Maritime Security Program (MSP), created 8 October 1996, replaced ODS. MSP is a 10-year incentive program to ensure that a fleet of U.S. flag commercial ships and U.S. citizen crews will be available when needed to carry critical supplies during national emergencies or war (Hershberger, 1997). MSP targets 47 commercial cargo vessels for inclusion:

- 21 TEU containerships sized to carry 3,000 or more TEUs,
- 15 TEU containerships sized to carry fewer than 3,000 TEUs,
- 5 lighter-aboard-ship (LASH) vessels,
- 3 roll-on/roll-off (RO/RO) ships, and
- 3 car/truck carriers.

The Voluntary Intermodal Sealift Agreement (VISA) is part of MSP. VISA is a sealift readiness program providing the Department of Defense (DoD) with assured access to critical surge and sustainment sealift capability for national defense contingencies and similar access to the U.S. maritime industry's worldwide intermodal systems. It also gives DoD the use of existing commercial integrated transportation systems (Hershberger, 1997).

With very few U.S. flag vessels available, VISA will sustain the ships and merchant marine for crisis support. By allowing a non-U.S. carrier (Maersk) in alliance with a U.S.-owned partner (Sea-Land) to participate in VISA, this program breaks new ground in exploring whether transportation industry alliances can be leveraged to improve military support.

Value-Added Logistics

As corporations reduce inventories, they place greater pressure on transportation firms to manage movement times in terms of minutes rather than days. Production lines depend on transportation firms to deliver production material to the assembly line "just-in-time." As production companies divest themselves of costly overhead, they have outsourced many of the warehousing and transportation functions necessary to support production and distribution. Transportation firms have begun to fill this void by providing value-added logistics.

Two examples of firms offering value-added logistics are Federal Express Corporation (FedEx) and the Van der Vlist Group's European Transport System Division of the Netherlands. In Memphis, FedEx operates its "Premium Service" warehouse, at which it manages inventory for a number of commercial firms and the U.S. Department of Defense. FedEx's Premium Service guarantees delivery of any item it manages anywhere in the world within 48 hours. Using the FedEx Premium Service, customers can reduce operating costs by eliminating excess inventory.

In Moerdijk, Netherlands, the European Transport System provides value-added logistics for firms like Daewoo of Korea and Komatsu of Japan. These overseas customers ship unassembled construction equipment to the Netherlands, reducing transportation costs. Once on site, European Transport Systems assembles, tests, and forwards the construction equipment to purchasers throughout Europe. Companies such as DYNCorp Services in the United States and the Netherlands' Royal

Nedlloyd N.V., among others, are also expanding traditional transportation services to provide value-added logistics.

Automation

Automation is playing an increasingly important role within the transportation industry. Its use throughout the transportation process has already lowered labor costs and improved overall efficiency. The most notable example of automation in the intermodal transportation industry today is Sea-Land Services' ECT Delta Terminal container facility in the port of Rotterdam, The Netherlands. Within Delta Terminal, all ground container movements are made by driverless trucks controlled by a central computer. Large container ships can be fully offloaded in less than half the time, with less than half the labor that would be needed at a nonautomated facility. While the continuously operating Sea-Land terminal is the first of its kind in the world, ports from the United States and Asia have expressed interest in this technology application. While not all ports can make the investment of capital and land necessary to build an automated container terminal, the cost savings justify the investment. These terminals will attract an increasing percentage of intermodal container traffic because their operating costs are much lower.

Information Technology Applications

Electronic data interchange (EDI) is a process by which transportation-associated paperwork is automated and standardized to make shipping transactions uniform. EDI helps carriers supply their customers with timely, accurate, and simplified billing records for the entire movement and handling of goods. It also reduces cargo movement time at transfer points and increases overall transportation efficiency. Ports benefit from EDI with accelerated gate movements and customs clearance, greater terminal security; cheaper, more accurate data entry, and improved management of container operations (Muller, 1995). EDI is also used to locate shipments more quickly. This adds to customer service and satisfaction. Companies like UPS and Federal Express compete on the basis of this value-added feature. Clerks use computers to communicate with the shipper to find out where the package is in the transportation pipeline, when it will arrive; and if it has arrived, who signed for it. FedEx's proprietary on-line network, Cosmos, tracks the status of every package flowing through the FedEx distribution network—from the minute the shipment is ordered to the moment it is

delivered. The Cosmos network helps FedEx achieve a 99 percent on-time delivery rate.

Automated equipment identification (AEI) uses radio frequency technology to communicate vehicle tracking information and automated shipping data to a host computer (Muller, 1995). These systems normally use "tags" (transponders) to store and transmit cargo data in addition to the use of one- and two-dimensional bar codes. AEI provides improved container identification, vehicle inventory and management, and automatic container/trailer weighing capabilities (Muller, 1995). AEI equipment lets the carrier know where a container or transportation vehicle is throughout the transit phase. Used in conjunction with electronic data interchange, AEI also expedites material handling at modal transfer nodes and shipment delivery points.

Information systems technology is a key enabler of intermodalism, and it also provides the means to manage assets effectively to produce "just-in-time" delivery as a competitive, reliable service to customers.

CHALLENGES

Infrastructure and Equipment

Intermodal movement depends on containerization. Global carriers are concentrating movements to fewer, larger transfer points worldwide to take advantage of economies of scale. As such, ports like Rotterdam, Hong Kong, Singapore, and Los Angeles/Long Beach are being serviced by increasingly larger containerships. Industry standard 4,000 TEU PANAMAX ships (PANAMAX is the largest ship of its type that can transit the Panama Canal) are being joined by post-PANAMAX ships of over 6,000 TEU capacity. In order for ports to remain competitive in the world market, they must be able to accommodate increasingly large containerships. Port authorities and state and local governments must invest in infrastructure that can handle the large volume of traffic that these huge ships generate as they offload cargo. Port improvements may include

- dredging deeper channels and berths, along with building new wider-span cranes portside, for post-PANAMAX ships;
- large transfer cranes with spreader bars capable of lifting 80,000 pound containers;

- marshaling areas to stage intermodal trains up to two miles in length;
- access to interstate highways for local moves by trucking companies.

Gridlock and Congestion

With few exceptions, intermodal transfer points are located in highly populated areas. Commercial traffic must compete over limited road space with daily commuter traffic. Solutions to this problem are very expensive and do not keep pace with traffic growth. In California, Long Beach and Los Angeles are addressing their traffic problems through the Alameda Corridor Transportation Project. The Alameda Corridor initiative will consolidate all traffic from 90 miles of rail lines into a single 17-mile corridor physically separated from highway traffic. The project will allow an increased number of intermodal trains, each over one and a half miles long, to move from major transcontinental rail lines to the ports' intermodal facilities quickly without disrupting commuter traffic. The $2-billion price tag for 17 miles of new construction is not uncommon, as construction costs in urban areas skyrocket. In the Netherlands, a similar problem confronts the Dutch flower industry as it moves freshly cut flowers to markets worldwide. Traffic congestion on the six mile route from the flower market at Aalsmeer to the airport is so dense, the market is considering building a private tunnel to avoid the traffic. Since the flower industry generates five percent of Dutch GDP and the Port of Rotterdam another 15 percent, traffic congestion could have a serious impact on that nation's economy.

Airlift Sustainability

The combination of higher aircraft load factors and global alliance market sharing may produce adverse impacts on U.S. military airlift plans requiring activation of the Civil Reserve Air Fleet (CRAF). Purchase of wide-body airliners by U.S. airlines has diminished, for two reasons:

- Most routes can be economically covered by modern twin-engine commercial airliners. As older wide-body aircraft are sold or retired by commercial airlines, such vital aircraft may no longer be available to CRAF.

- Domestic carriers involved in global alliances may choose to rely on the international partner's wide-body fleet, negating the need to buy and maintain additional wide-body fleet assets International-flag wide-body aircraft may not be made available to CRAF when needed.

Current high load factors for aircraft, combined with frugal airline purchasing policy of aircraft replacement rather than fleet expansion, may mean fewer aircraft available to CRAF when it is activated. Analyzing projected aircraft purchase plans may help indicate if such a problem is imminent.

Labor

The National Labor Relations Act (NLRA) guarantees the rights of workers in the United States to form unions and to engage in collective bargaining, but does not apply to railroads or airlines. The Railway Labor Act (RLA) of 1926 deals with labor disputes in the railroad and airline industries. Its main purpose is to prevent strikes that might endanger the economy or create a national emergency. Proponents of change say that railroads and airlines should be brought under the NLRA, which governs all other industries and labor organizations. The advent of intermodalism offers strong support to this argument. The United States is taking steps to adapt its regulations toward intermodalism. Integration, relaxation, or elimination of government labor laws and policies will have a great impact on future transportation work force employees.

The 1991 Intermodal Surface Transportation Efficiency Act

The Intermodal Surface Transportation Efficiency Act (ISTEA), Public Law 102-240, signed 18 December 1991, authorized $151 billion over a six year period for improvements in the nation's transportation infrastructure. This money was primarily for highway construction and improvements, but the legislation also emphasized intermodal connections that would enhance the nation's transportation infrastructure. A major objective of ISTEA was to develop a transportation system that would provides "the foundation for the Nation to compete in the global economy, and . . . move people and goods in an energy efficient manner." The intent of ISTEA was to place the decision-making authority for regional transportation issues with metropolitan planning organizations (MPOs) at

the community level. Highway programs received the majority of funding, but ISTEA also included support for mass transit as well as other transportation programs. Most funding for federal transportation programs comes out of the Highway Trust Fund, which is fed by taxes on the sales of motor fuels.

ISTEA has shortcomings, however, which adversely impact the intermodal transportation improvement process it was supposed to foster. Neither state governors nor highway builders like the money and power sharing ISTEA has forced upon them. Funding formulas within ISTEA created "donor states" who contribute more in gasoline taxes to the Highway Trust Fund than they get back.

In 1994, the National Commission on Intermodal Transportation reported that "ISTEA's emphasis on local and state decision-making means that projects of national significance, which sometimes largely provide benefits beyond local and State jurisdictions, may not receive appropriate funding." An excellent example of how regional transportation issues are inadequately addressed by ISTEA is the freight rail situation in Chicago. Although this traffic results in major congestion, the Chicago MPO has yet to develop intermodal freight projects with ISTEA funds (with the exception of one Clean Air Program approved in 1995). A recent effort by the MPO to improve this record has identified 47 new project proposals.

In its 1996 audit of Intermodal Freight Transportation, the General Accounting Office identified numerous ISTEA execution shortfalls:

- the Department of Transportation's (DOT's) failure to track public/private project investments (as required by law);
- DOT's failure to track how states used authorized ISTEA funds;
- projects that are too narrowly focused—caused by inexperienced MPOs;
- lack of balanced planning between intermodal freight and other transportation issues; and
- other funding issues.

The ISTEA legislation is up for renewal in Congress in 1997, and several alternatives to the original concept have been proposed.

OUTLOOK

The global economy exerts substantial influence on the transportation industry. Corporations' national identities begin to blur as the drive to

improve efficiency crosses once-traditional corporate, and then national, boundaries. Mergers and alliances improve global access, reduce overhead, and lower personnel costs. Modern economic reality indicates that transportation industry of the future will be transnational.

Given this environment, can the U.S. transportation industry still support U.S. national security resource requirements? In the aggregate, our study's assessment is that it can.

Since deregulation, the American transportation industry has evolved, and continues to evolve, to help move people, resources, and goods as quickly and as efficiently as possible. Economics has done more to foster the drive to improved efficiency than any other impetus, yet the transportation system has shown it can also augment military lift assets to respond to national defense needs. The Desert Shield/Desert Storm operations of 1990 and 1991 offered the first substantial test of the newly evolving national (and global) transportation industry to support U.S. national security requirements in a surge/mobilization scenario. Again, in the aggregate, the performance of the industry in helping the government meet those requirements was superb.

Potential impediments to meeting surge/mobilization needs of the future reflect the unique needs of the U.S. military as a transportation customer in a mobilization environment. These potential impediments include:

- the loss of excess commercial transportation capacity;
- loss of qualified labor, particularly merchant mariners on which the U.S. sealift mobilization plans depend;
- theater port-of-debarkation (POD) offload capacity and capability (i.e., the lack of standardization among ports; some ports in an affected theater may not be adequate or sufficient); and
- failure to adapt to technological advances in transportation.

The post-Cold War reshaping of U.S. military power into a predominantly U.S.-based force makes the transportation link even more critical than at any other time in modern history. Some of the potential problems are mitigated by the robust initial mobility resident in U.S. military transportation forces, but others may be exacerbated by defense budget reductions. Efforts to save money in national defense may lead to characterizing programs and personnel not directly operating weapons systems as lower priorities and therefore subject to cutbacks. For example, while organic transportation management capability does not constitute a weapons system, but the drawdown or loss of resident expertise in "in-

theater" transportation procedures and capabilities may hamper effectiveness in meeting urgent defense mobilization requirements in those theaters.

Near-Term Industry Outlook

In the near term, intermodal transportation will continue evolving as global economic forces, new technology applications, and governments' regulatory actions continue to act on it (Muller, 1995). Plant rationalization among newly merged or allied carriers will characterize the next five years. The tangible effects of global alliances among air and sea carriers will become more apparent, as will surface transportation combinations of road and rail companies to maximize operating efficiencies and cut costs associated with domestic intermodal freight transportation.

Transportation companies will continue to expand their role by providing value-added logistics. This strategy prepares a win-win situation in which customers cut overhead costs by reducing or eliminating inventory, and transportation firms generate revenue by using their established networks to serve customer requirements. The net result is the more efficient use of resources, which translates to lower costs and better customer service.

Automated information systems and networks will increase to improve materials handling, transportation dispatch and routing, and customer service. Use of information systems technology such as EDI and AEI will proliferate among carriers. The competitive advantage these systems provide, and the shippers' demand for such capability, will necessitate their use throughout the marketplace.

Significant government intervention in the transportation industry during this time will likely come in two areas: ISTEA follow-up legislation, and decisions on future funding for AMTRAK.

Long-Term Industry Outlook

Between 2000 and 2020, transportation will complete its evolution into a global network and attain its goal of rapid, efficient customer service with intermodalism as the integrating agent. The industry will provide increased service along newly developing north-south global trade routes. "Bigger is better" will characterize long-haul transportation, with larger ships, aircraft, and ground vehicle combinations likely to be introduced. Carrier concentration through mergers and alliances would, however,

peak, if government intervention (i.e., regulation) to preserve competition becomes necessary.

Time will continue to drive cost. All "low-hanging fruit" solutions to minimize stopovers at modal transfer nodes will have already been implemented. The search for greater cost efficiency will require substantial up-front expenditures. Improvements to modal transfer nodes in terms of material handling speed and efficiency will become paramount. Reducing the "bottleneck" effect at these parts of the transportation infrastructure will be viewed as the next significant cost-saving area. Additional efforts to lower costs through better fuel efficiency, increased automation of existing services and processes, loss of excess capacity, and work force reduction will occur. In the latter case, difficulties with organized labor are also likely to result from these actions.

Significant government intervention during this time will deal with needed roadway and air traffic control infrastructure improvement. It may also be forced to deal with a possible return to regulatory policies, should transportation (particularly surface and air) provided by the merged/allied carriers be perceived by shippers as essentially non-competitive.

Response to Challenge

The U.S. transportation industry is acutely aware of the current environment in which it operates. Deregulation has provided the free market environment for transportation to operate, making increased efficiency and customer service worthwhile goals. Narrow profit margins force carriers to even greater levels of efficiency. Intermodalism, fostered in no small part by deregulation and by new technological applications, has proved a vital tool in achieving greater efficiency and service levels for customers worldwide.

Economic Response. Given this playing field, our study estimates that the U.S. transportation industry will surmount these challenges as long as a deregulated environment continues to exist. Improvements to modal transfer node infrastructure will become an economic necessity for many regions of the United States within the next 20 years. This economic necessity will lead to improvement programs far quicker than will "national security" or any other factor. Indeed, in areas such as the Los Angeles/Long Beach port region, such improvements are necessary and ongoing now. Lessons learned from the Alameda Corridor Transportation project, particularly in the area of regional community cooperation, can provide a critical blueprint for other regions of the

United States. Large-scale government expenditures for transportation, such as the Interstate Highway System program, are unlikely to occur in the fiscally constrained future (though an eventual upgrade to the nation's air traffic control system is a likely candidate).

Legislative Response

On 12 March 1997, President Clinton submitted the proposed ISTEA follow-on legislation to Congress. The National Economic Crossroads Transportation Efficiency Act (NEXTEA) proposes a $175-billion funding plan for the nation's surface transportation projects from 1998 to 2003 (DOT news release, 13 March 1997). A basic review of Title V of the proposed NEXTEA legislation identifies a new "Transportation Infrastructure Credit Enhancement Act" for 1997. This proposed act is designed to encourage development of large, capital-intensive infrastructure projects (including publicly owned freight rail facilities and intermodal facilities) through public-private partnerships. These projects must have financing payable in whole or in part by user charges such as tolls. This program represents a change from ISTEA and specifically includes funding avenues for intermodal freight projects. It would also provide an economic incentive for private/public cooperative infrastructure improvement.

GOVERNMENT GOALS AND ROLE

Common themes on the role of government in the transportation industry are very apparent, despite the articulation of vast regional and modal differences. Unquestionably, government deregulation has been the largest catalyst for the evolution of the modern U.S. transportation industry. From a purely market perspective, one would surmise that less government in transportation is better, but that is not the case. The public's stake in transportation includes access to service and availability of assets in a crisis. The federal government is responsible for national defense, and transportation is a critical element of that defense. Therefore, the government relationship with transportation will always be close. We believe the proper roles of the federal government with respect to transportation are as follows:

- Government must retain an adequate, quick-response worldwide military lift capability. The civilian transportation sector cannot

provide the dedicated unique capabilities offered by afloat prepositioned forces; military airlifters, such as the C-17 and RO/RO ships capable of moving combat vehicles and other military specific equipment; and combat theater transportation and logistics management. Power projection depends on the capacity for rapid initial response to crises, and that capacity resides with the military.

- Government must also identify its unique "customer" requirements to industry. Transportation and mobility requirements for national defense must still be generated using mobilization contingency scenarios. DoD efforts like the Joint Staff's Strategic Mobility Joint Warfighting Capability Assessment (JWCA) help define those requirements by determining the proper mix of military and commercial lift assets needed to execute national defense strategy. From these estimates, the government sets forth its unique "customer" requirements to the transportation industry. Then, government/industry cooperative ventures (e.g., CRAF and MSP) help to meet the broad scope of "customer" requirements comprising overall national defense mobilization strategy.
- The federal government must provide adequate economic incentive for commercial air carriers to participate in the CRAF Program. Participating air carriers, like all other elements of the transportation industry, operate on narrow profit margins. The loss of aircraft assets (and corresponding revenue) by commercial carriers to a future CRAF activation could be mitigated by rewarding participants with increased peacetime federal government business (e.g., city-pair transport contracts). The government may also need to review the entire CRAF process in light of the creation of global air alliances and the operating impact they will have on participating commercial air carriers.
- Some situations remain in which the authority of the federal government as arbitrator and lawmaker will be needed to settle disputes or challenges brought about by uncontrolled free-market activity or impending industrywide labor disputes. The Surface Transportation Board's recent activity in "encouraging" CONRAIL, CSX, and Norfolk Southern railroads to reach a restructuring solution for viable rail freight competition in the

Northeast is one such situation. Ensuring AMTRAK's ability to compete commercially in the LTL express freight transportation market allows AMTRAK to generate additional revenue for itself, which otherwise would come from subsidy. Whether the federal government should intervene in transportation labor disputes involving single firms, such as the 1997 American Airlines strike, is a different case.

- Government needs to develop a national transportation program to support infrastructure changes that will facilitate the nation's economic prosperity. A strong central government role in national transportation planning is needed to support efficiencies in all modes of transport. Many European commercial firms are optimistic that the European Union will fill this requirement as it gains strength. ISTEA and NEXTEA legislation are steps in the right direction. Simply adding additional traffic lanes to the nation's already congested highways is not the solution. Both intermodal freight and passenger transportation must be aggressively improved—an outcome best achieved by a strong national transportation plan and program.

CONCLUSION

Deregulation, intermodalism, globalization, and technology have all played major parts in the dramatic evolution of the U.S. transportation industry in the last 20 years. Now, speed, reliability, and quality are the drivers of the ever more efficient worldwide commercial transportation networks of today and tomorrow. Our study observed a vibrant, competitive economic sector which, along with information systems technology, has revolutionized the whole concept of industrial operations.

The transportation industry is a global one, operating on narrow profit margins and heavy capital investment, and relying on volume to remain in business. It is moving to fewer, larger companies or to alliances operating from fewer, larger ports. Often these companies operate in a multinational alliance as they compete for market share.

The various modes of the U.S. transportation network are, in the aggregate, very healthy. Pure competition has improved the efficiency of the individual modes, and has bred cooperation between modes to build an effective seamless intermodal network for the future. U.S.-flagged ocean

shipping will, however, continue to require federal government support to ensure a credible initial-response sealift capability.

Information technology also drives improvements to the transportation process. Electronic data interchange, automated equipment identification, and automation reap time and cost-savings. Modal and intermodal technology is also improving, though eventual upgrades to modal transfer node infrastructure will be needed to secure U.S. competitiveness in global transportation.

Our study recommends the following long-term federal government action with regard to transportation and national defense:

- continue to own, operate, and maintain an adequate rapid initial response military lift capability to support power projection;
- identify and address national defense transportation requirements with industry from a unique "customer" perspective (e.g., CRAF, MSP/VISA);
- weigh carefully the effects of any possible future industry regulation;
- examine Civil Reserve Air Fleet policies and economic incentives in light of global changes to commercial air carrier operation;
- continue to act as arbiter of last resort when needed (e.g. Surface Transportation Board actions); and
- develop a strong national transportation plan and program. Improve the ISTEA concept with NEXTEA legislation offering government support of private/public sector cooperative infrastructure improvement projects for freight and passenger intermodal transportation.

Our study is firmly convinced that the transportation industry can support the military requirements of U.S. national strategy. In the 20 years since deregulation, the transportation network has developed the capability to provide unparalleled worldwide service. Its continuing evolution is indeed revolutionizing U.S. industry as a whole.

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Industrial College of the Armed Forces
National Defense University