Needs of the Nation's Transportation System

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In *Technology for America's Economic Growth, A New Direction to Build Economic Strength* (February 22, 1993), President Clinton and Vice President Gore affirm the critical role of transportation in the nation's economy:

> **A competitive, growing economy requires a transportation system that can move people, goods and services quickly and efficiently. To meet this challenge, each transport sector must work effectively both by itself and as part of a larger, interconnected whole.**

Even though Americans enjoy an unprecedented level of personal mobility, significant segments of the nation's transportation system are under strain. Capacity constraints are increasing congestion, especially for heavily used highways and airports. Many believe that we have underinvested in the existing infrastructure and that it needs major renovation. Moreover, the negative environmental impacts of transportation activities — in terms of energy and land use, air and water quality, and noise levels — limit our options for improving the system and expanding capacity.

Balancing the demands for increased capacity, greater mobility, and environmental quality will require innovation and investment in transportation technology through a well-formulated research and development (R&D) process. Recent changes in the world have created the opportunity to redirect our resources from defense to civilian priorities, including transportation. This paper outlines some of the critical transportation needs to be met as the nation shifts its focus from the Cold War to a new vision of the future. It presents the technology and transportation policies of the new Administration and raises questions about the R&D programs and advanced technologies required to meet transportation needs. Finally, this paper concludes with a "charge" to the defense research and industrial sector to work with the Department of Transportation to expand R&D partnerships supporting transportation technologies.

NEW TECHNOLOGY AND TRANSPORTATION POLICIES

> **Investing in technology is investing in America's future: a growing economy with more high-skill, high-wage jobs for American workers; a cleaner environment where energy efficiency increases profits and reduces pollution; a stronger, more competitive private sector able to maintain U.S. leadership in critical world markets; an educational system where every student is challenged; and an inspired scientific and technological research community focused on ensuring not just our national security but our very quality of life (*Technology for America's Economic Growth*).**

Technology reinvestment is key to America's long-term economic growth. As called for in the Administration's technology policy and defense conversion initiative, resources formerly devoted to defense and other mission-oriented R&D are being shifted to civilian technology programs and "strategic" research aimed at meeting a wide range of critical national needs. This investment in technology development and commercialization will play a fundamental role in stimulating and sustaining an economy that is competitive, that creates high-quality jobs, and that protects the environment.

Because nearly one out of every six dollars of the nation's Gross Domestic Product (GDP) is now spent on transportation-related activities and services, efforts to improve transportation will be crucial to creating and sustaining economic growth. The Administration's technology policy specifically identifies the importance of the transportation sector, which will play a leading role in defense reinvestment and conversion:

> **Technologies that increase the speed, reliability, and cost-effectiveness of the transportation sector will also increase the economy's competitiveness and ability to create jobs** (*Technology for America's Economic Growth*).

The policy calls for increased investment in the following key areas:

- Upgrading America's existing highways and transit systems.
- Establishing a "clean car" task force to oversee cooperative research on a lighter, more fuel-efficient vehicle.
- Funding high-speed ground transportation system options, such as a maglev prototype and start-up costs for private or state/local government-sponsored high-speed-rail projects.
- Research and demonstration efforts for Intelligent Vehicle Highway Systems (IVHS) technologies.
- Research on new civil aviation technologies, including advanced aircraft and a global, satellite-based air traffic control system.
- Exploring new technologies for assessing the expected life of the transportation infrastructure, particularly nondestructive testing and inspection.
- Support for renewal engineering research programs that target both new materials and new construction methods that will lead to more durable infrastructure facilities.

THE TRANSPORTATION SYSTEM

Although the United States boasts one of the world's best transportation systems, a growing set of international and domestic demands challenges it at every level.

In the new global marketplace, greater emphasis is placed on timeliness, quality, and reliability in the delivery of goods and services. For U.S. industries to be competitive in this environment, they must be able to rely on a "seamless" worldwide transportation system — one that is efficient, safe, reliable, flexible, and intermodal.

New and expanded capabilities are being required of our nation's transportation system. For example, there is significant and growing evidence of capacity constraints and "gridlock" in a number of areas, particularly urban roadways and major "hub" airports during rush hours. High-growth regions are in need of improved suburban-to-suburban highway capacity. At the same time, many rural areas with scattered populations and geographical barriers lack basic transportation services for either passengers or freight. There are large segments of the population — the elderly, the disabled, the economically disadvantaged — who also have severely limited transportation choices.

Many sectors of the transportation industry are undergoing a major economic "shake-down." The manufacturing sector is facing mounting competition from foreign companies, particularly in the automobile and commercial aircraft markets. These pressures have already reduced America's passenger rail car, transit car, and shipbuilding industries to minimal levels. There also is concern over the long-term health and stability of the commercial airline industry in the face of overcapacity and sometimes cut-throat competition. These conditions have recently led to multibillion-dollar losses, at a time when flying is becoming the only realistic option for high-priority, long-distance travel. Nearly every other service provider sector — including freight rail, intercity bus, and long-distance trucking — has undergone similar pressures in recent years.

Recent legislation has underscored the importance of guaranteed access to transportation services by all segments of the population. The Americans with Disabilities Act, for example, mandates specific accessibility standards for public transportation facilities and equipment — not only for those with reduced mobility, but also for those with other disabilities such as hearing and vision. Many of these improvements will be based on human factors research and will lead to enhancements in safety and accessibility for all users of the transportation system. This will also benefit the nation's elderly, who are a growing proportion of the total population.

While increases in mobility and capacity are major goals, there is concern that such goals be attained in a manner that preserves the environment, promotes energy conservation, improves overall quality of life, and costs as little as possible. The long-range goal is to realize a "sustainable" transportation system, one which represents a harmonious balance among performance, cost, resource use, and social impact characteristics, enhancing the quality of life and supporting a sound national economy and vigorous international competitiveness. A sustainable system will provide superior personal mobility and safe, convenient access for all; efficient, economical, and reliable freight transportation; and a healthy transportation industry, including carriers, manufacturers, and suppliers. Finally, total transportation use of nonrenewable physical resources will be at a level that can be sustained into the indefinite future.

TRANSPORTATION ISSUES AND OPPORTUNITIES

Realization of a sustainable transportation system, and of our national and global transportation goals, will be a difficult, long-term undertaking. Yet technology can offer some productive avenues for achieving this vision. The transportation system's primary technology needs are described below in four categories: vehicles, infrastructure, traffic management, and environmental monitoring and mitigation.

Vehicles

Except for long-distance business travel, the private automobile is by far the dominant mode of passenger transportation in the United States. The total annual cost of automobile ownership and operations is estimated at $500 billion, or nearly 10 percent of the nation's GDP. However, although the automobile has improved significantly in the past 25 years in terms of safety, emissions, efficiency, comfort, and cost, a number of issues remain. Societal goals of environmental quality, transportation safety, and energy conservation often conflict with the desire for personal mobility, traditionally embodied by the private automobile. Many of these issues are also germane to other transportation vehicles, particularly aircraft.

Issues:

- There is persistent concern over the automobile's negative impact on air and water quality, noise levels, land-use patterns, and solid-waste-disposal capacity. For example, motor vehicles are responsible for about 20 percent of all U.S. carbon dioxide emissions. Commercial aircraft create similar concerns, particularly involving noise levels.

- Motor vehicle operations, especially the automobile, account for a majority of the petroleum used each day in the United States. And this is occurring at a time when over one-half of our petroleum needs are met by imports.

- Increasing automobile ownership and use contributes to America's mounting highway congestion, especially on urban and suburban roadways. There are now more automobiles in the United States than licensed drivers, and total vehicle-miles-traveled continues to grow twice as fast as the population.

- The fatality rate per passenger-mile is dropping, but each year there are still about 40,000 deaths and more than 1.5 million personal injuries associated with the automobile. Other safety concerns include road–rail crossings and aging aircraft.

- As revealed most recently by Desert Storm, the military requires access to significant maritime capacity on short notice. Yet both the size and the condition of the U.S. merchant marine are eroding.

- The U.S. commercial shipbuilding, passenger rail car, and transit car industries have been virtually eliminated by their inability to compete against foreign companies.

- The U.S. commercial launch industry is facing strong competition from Europe and Asia, as well as from nonmarket competitors such as Russia, the Ukraine, and China. Both launch vehicles and the support infrastructure require a strong infusion of technology to maintain their competitive edge.

Opportunities:

- Recent advances in materials, structures, power and propulsion systems, and computer technologies now make it possible to design and develop vehicles embodying a quantum jump in functional characteristics compared to those in use today — the next-generation motor vehicle. The vision is of a vehicle that will significantly reduce emissions and fuel consumption without compromising performance or safety — and all at a reasonable cost. Development of this new concept is already under way. These same advances may also make it possible for high-speed guided ground transportation, such as maglev and high-speed rail, to supplement the automobile for intercity passenger travel.

- New carbon-fiber and advanced metal composite materials can be used in a range of vehicles for nearly all modes. Assuming that costs can be reduced, these materials offer potential advantages in weight, strength, durability, energy usage, and maintenance costs.

- Advanced aircraft concepts such as the hypersonic and "super-jumbo" passenger jets and the tiltrotor are being explored for commercial aviation use. The components and subsystems being proposed for these aircraft would incorporate the latest technological advances in structures and materials, propulsion, energy efficiency, and environmental characteristics.

- The aerospace industry has initiated technology development and test partnerships with federal agencies (NASA, Defense Department) in critical areas for propulsion, avionics, materials and structures, and space launch operations. These are "dual-use" in the sense that both government and private sector partners will benefit from more advanced, lower cost launch vehicles.

Infrastructure

The United States has approximately 3.9 million miles of public roadway, which accommodate 187 million vehicles traveling over 2.1 trillion miles each year. In urban areas, automobiles and transit buses account for over 92 percent of all work trips. The trucking industry carries over one-third of all intercity freight tonnage.

Public expenditures for construction and maintenance of the highway system are about $80 billion per year, requiring a work force of 800,000 people. Infrastructure expenditures for other modes are smaller, but still substantial. U.S. railroads spend about $5 billion each year on maintenance of way and structures and nearly $3 billion on non-equipment investments. Capital investment in airport renewal and improvement exceeds $4 billion annually. A single new urban rail transit system, high-speed-rail corridor project, or airport can cost $3 billion and up.

Given the size of the initial investment and the costs of maintaining this infrastructure, obtaining the best life-cycle performance is of great importance to users and to government at all levels. At the same time, the methods, tools, and materials used in infrastructure construction and maintenance change very slowly, limited in part by the desire to avoid the risk of unknown consequences and the need to minimize initial costs.

Issues:

- Increasing demand, coupled with constraints on new construction, are straining the capacity of urban and suburban roads. In many urban areas, "rush hour" no longer consists of two 2-hour periods during the workday, but can last for nearly 12 to 14 straight hours. One recent estimate suggests that congestion of Interstates and principal arterial roads adds about 8 billion hours in delay at an estimated cost of over $34 billion each year in the largest urban areas alone.

- Years of underfunded maintenance and repair work, a lack of innovation in structures and materials, and the wear and tear associated with increases in vehicle-miles-traveled and truck traffic have all taken their toll. About 265,000 miles of pavement are at or below acceptable engineering standards for cost-effective maintenance. About 134,000 bridges were rated as structurally deficient. In 1989 alone, more than 5,000 bridges were closed to traffic due to either structural deficiencies or repair.

- Many railroads operate on infrastructure planned and constructed over a century ago, with all of the inherent limitations of such a situation. There is a significant market for railroads, particularly for long-distance freight, which can be tapped with such promising new concepts as intermodalism and double-stack containers service. However, the investment costs of the improvements necessary to tap these markets can be high.

- The national ranges require substantial upgrades and expansion in order to establish easy access to space. This requires joint planning and costly investments in order to become a reality.

Opportunities:

- Current technological advances in such areas as corrosion protection and control, structural composites and adhesives, and new pavement mixtures provide a strong incentive for innovation in infrastructure. Many of these new alternatives await only the effort to develop specific applications, demonstrate effectiveness and long-term viability, and reduce costs to a competitive level.

- Another area in which technology can contribute is the application of non-destructive inspection and testing — using magnetic and acoustic technologies, among others — to bridges, pavement, and other transportation infrastructure. These techniques offer benefits in terms of enhanced safety, infrastructure life, and maintenance.

- One concept long discussed but little used to date is that of "smart structures": roads, bridges, and tunnels with a network of embedded sensors that continually provide detailed information as to the structure's condition under both normal and abnormal circumstances.

- Automated highway inspection and maintenance based on digital imaging, sophisticated data analysis, and advanced robotics would have great value for roads throughout the nation.

- Innovative space launch infrastructure proposals have been initiated by several states and industry consortia. New land, air, submarine, and off-shore launch platforms could well be the key to a successful renewal of commercial space activities.

Traffic Management

Transportation users demand timely, reliable, high-quality service that is competitively priced. At the same time, growing congestion and near-gridlock, especially on urban roadways and at high-volume airports, make it difficult to guarantee the desired level of service. The traditional and relatively "easy" response, building more infrastructure, is no longer feasible in most cases. New solutions will have to be sought from other sources. One question often asked is whether R&D and technology hold any promise for increasing transportation efficiency without major investments in new infrastructure.

Issues:

- Congestion on urban roads imposes enormous social costs in terms of time, fuel, accidents, environmental impacts, and overall quality of life for all those affected by it. Similar concerns over traffic congestion arise at many hub airports.

- The share of total ridership held by mass transit has been declining in recent years, at a time when operating, maintenance, and capital costs are steadily rising.

- Future evolution of the air traffic control and commercial space launch systems will incorporate satellite navigation and communications and advanced automation. This presents an immense design and system engineering challenge.

Opportunities:

- Application of modern sensing, information, and communications, navigation, and surveillance technologies to traffic management has the potential to improve dramatically our transportation system's safety, capacity, and efficiency.

- Use of advanced computing concepts for such tasks as inventories, logistics, and scheduling can cut costs significantly. In freight, for example, electronic data interchange is leading to faster and cheaper shipments that require less paperwork and fewer pauses in the total process. New space-based tracking and telemetry systems could improve the cost and efficiency of commercial space activities.

- Coordination of traffic can achieve a more productive use of infrastructure capacity. Although current technologies have yielded significant improvements, the advances of recent years now offer a broader vision: direct information links among the infrastructure, vehicles, and operators to monitor and control traffic flows, provide information to vehicle operators and system managers, and conduct transactions.

- Still defined only conceptually and in terms of a small number of operational examples is IVHS, which can include virtually any new electronic technology that facilitates the coupling of roads and vehicles or that enhances a driver's awareness of the vehicle's current and anticipated operating circumstances. These technologies are also being applied to trains, ships, and transit buses.

- Full exploitation of satellite navigation and communications, advanced computing power, artificial intelligence, and expert systems could make the next-generation global air traffic control system dramatically different from the one now in place. This new system could considerably improve the safety and efficiency of air travel.

Environmental Monitoring and Mitigation

Every transportation mode has at least some negative environmental impacts. Whether viewed from a local, national, or world perspective, these impacts have been the subject of increasing public discussion over the last few decades. Some of the most serious concerns relate to urban air quality, land use, global warming, and noise, and have resulted in legislated constraints on transportation operations. For example, recent amendments to the Clean Air Act impose ceilings on federal-aid funding and vehicle-miles-traveled for regions that do not attain air-quality standards by the statutory deadlines.

Reducing transportation's environmental consequences traditionally has focused on improving the design and characteristics of vehicles and of the infrastructure. However, there exists yet another substantial challenge: improving our abilities to monitor the environment itself for noise, air or water quality, or the presence of pollutants. A similar situation exists with respect to the mitigation of transportation-related spills or other releases of toxic or hazardous materials. Physical, chemical, and biological approaches have been suggested and are in use. But these problems are far from solved.

Issues:

- Our current abilities to monitor the impact of transportation activities on the environment, as well as methods to deal with spills and other releases of hazardous materials, are inadequate.

- Modeling and simulation capabilities are not sufficient to support the development of solutions and the formulation of policy.

- Reliance on fossil fuels, especially petroleum, contributes significantly to transportation's environmental impact. The choice of fuels also affects the nation's overall energy reserves and balance of payments, at a time when over one-half of our petroleum is imported.

Opportunities:

- Technologies for sensing a wide variety of chemical and physical phenomena, both remotely (even from space) and locally, exist in profusion. Their application would improve our ability to understand, monitor, and control the environmental impacts of transportation, especially for activities such as hazardous materials mitigation.

- Advanced environmental sensors also could improve the quality and reliability of the data being collected. In turn, this could lead to more sophisticated modeling and simulation of numerous aspects of the problem: transportation activity, vehicle emission characteristics, atmospheric chemistry, and diffusion of pollutants.

- Although less work is being done now than in the 1970s, research continues on more environmentally benign fuels and power sources that might have transportation applications. These include fuel cells, hydrogen, compressed natural gas, advanced batteries, and even solar-powered vehicles.

PARTNERSHIPS: COUPLING THE RESOURCES OF GOVERNMENT AND INDUSTRY

At the level of technology development, the fundamental mechanism for carrying out this new approach is the cost-shared R&D partnership between government and industry (*Technology for America's Economic Growth*).

Yielding the necessary innovations in transportation will require productive collaboration among all levels of government, private industry, the National Laboratories, and universities. Such partnerships have the potential to accelerate innovation, yielding a more flexible and responsive transportation system and a stronger position in global markets for U.S. industry. As called for in the Clinton–Gore technology policy, most R&D projects will be cost-shared and industry-led.

Collaborative research and development is needed to analyze the evolving needs of the transportation system, identify technologies that hold the greatest potential for meeting those needs, and apply the technologies to transportation improvements. Although it is natural that the Department of Transportation should take the lead in transportation R&D, DOT commands just 1 percent of the total federal R&D budget. Most of this research supports the Department's operational and regulatory missions, and not the nation's long-term transportation needs. Moreover, although DOT's proposed R&D budget for FY 1994 ($727 million) represents an 11 percent increase over the previous year, a substantial portion of this increase is earmarked for specific projects such as IVHS corridors and maglev.

Despite these restrictions, the Department can make a substantial contribution to America's reinvestment in civilian technology. One of DOT's key roles will be to identify the defense-conversion opportunities in transportation and to match transportation needs to emerging resources. Many long-term transportation needs already are being addressed by the new Administration, which has proposed significant R&D increases for maglev and high-speed rail, IVHS technologies, civil aviation, and infrastructure testing and inspection. Still other transportation opportunities remain to be defined, developed, and realized.

Transportation holds potential for defense industries looking for new commercial products and markets. There is a long and fruitful history of successful dual-use applications of technologies to defense and civilian transportation, including the jet engine; radar; advanced materials; satellite-based communications, navigation, and surveillance; synthetic vision; and advanced remote sensors. Yet the transportation sector is competitive, fragmented, and highly decentralized, responding principally to market-driven forces. The fractures in the transportation market — along the lines of industry, geography, personal mobility preferences, and environmental concerns — result in underspending on R&D.

Realizing the full potential of R&D and technology to improve our transportation system will require the dedication, energies, and resources of the entire defense research and industrial sector. This sector's challenge will be to work with the Department of Transportation to improve government–industry cooperation in support of transportation technology: to deploy its tremendous skills and capabilities to meet America's evolving transportation needs.

QUESTIONS FOR DISCUSSION

- What currently are the most promising dual-use, military–commercial transportation technologies?
- What future technologies might have both civil transportation and defense applications?
- What are the market challenges in commercial transportation applications of dual-use technologies?
- What are the institutional, organizational, and cultural barriers to government–industry cooperative R&D?
- What is DOT's role in fostering technology partnerships?
- What is the role of the National Laboratories in transportation advances and innovations? Of the defense industry? Of universities?