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CAD/CAM/CAE
Current and Future Environment (1988 - 1998)
Version 3.0
FINAL DRAFT

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The diffusion and adoption of new technologies across national, sectoral, and organizational boundaries has been a topic of considerable research. While the exact transfer mechanism remains a matter of hypothesis, it seems clear that the direction and speed of technology development and penetration is heavily impacted by environmental influences - be they organizational, macroeconomic, or microeconomic. This section of the report examines key aspects of the current and projected future environment which could influence either the direction or pace of CAD/CAM/CAE technology development or the adoption of these technologies by the U.S. Air Force. Most of the discussion will center around issues relevant to the Air Force Logistics Command (AFLC), except where noted.

Structued in six sections, the report compares and contrasts the aerospace industry with the Air Force for perspective and balance. Sections 2.0 and 3.0 contrast the respective current design and manufacturing environments. Section 4.0 examines associated procurements, prototyping, and R&D programs that could have significant impacts on the evolutionary path followed by both sectors. Sections 5.0 and 6.0 extrapolate into the future by examining future weapon system technologies and the plans of industry and the Air Force to respond to the growing technological challenge

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1.0 INTRODUCTION

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This section of the report examines key aspects of the current and projected future environment which could influence either the direction or pace of CAD/CAM/CAE technology development or the adoption of these technologies by the U.S. Air Force. Most of the discussion will center around issues relevant to the Air Force Logistics Command (AFLC), except where noted.

Structured in six sections, the report compares and contrasts the aerospace industry with the Air Force for perspective and balance. Sections 2.0 and 3.0 contrast the respective *current design and manufacturing* environments. Section 4.0 examines associated procurements, prototyping, and R&D programs that could have significant impacts on the evolutionary path followed by both sectors. Sections 5.0 and 6.0 extrapolate into the future by examining future weapon system technologies and the plans of industry and the Air Force to respond to the growing technological challenge.

2.0 CURRENT AIR FORCE DESIGN, MAINTENANCE, AND MANUFACTURING ENVIRONMENT

The 1987 Production Base Analysis Report (Reference 21) noted that AFLC was responsible for: managing some 883,000 end items; supporting 9,000 aircraft of 60 different types; and supporting 37,000 engines of 75 different types. A majority of this aircraft fleet is aging. The five Air Logistics Centers (ALCs) in conjunction with the Aerospace Guidance and Metrology Center perform major maintenance, repair, and modification of aircraft, missiles, engines, exchangeables, and other major end items.

ALCs are often subject to conflicting and competing demands in terms of: mission, turnaround time, economics, enviromental concerns, health and safety, and surge considerations. This surge requirement is particularly important, since data indicate that the industrial sector would have difficulty meeting mobilization goals in a time of national emergency. When considering automation opportunities, the ALCs must factor their surge requirements into any justification analysis.

2.1 Characteristics of Depot Workloads

Workloads at ALCs are difficult to analyze for automation opportunities because of current Air Force accounting conventions. ALCs currently rely on an "earned hour" approach to cost control, which aggregates costs only at the Resource Control Center Level instead of at the work station level. A work station perspective would better help to identify and evaluate high cost processes. A recent Air Force initiative called the Technology Insertion (TI) Program is structured to provide a greater level of cost insight into depot processes. The TI program is designed to achieve the following major objectives:

- improve wartime/readiness and surge posture
- increase technology consistency across AFLC/MA
- identify and prioritize "No/Low" cost process improvements
- identify and prioritize process improvements requiring major capital investments

- accomplish near-term productivity gains
- identify technology transfer opportunities
- improve production/process flexibility

Despite the lack of process specific data, recent studies have characterized the workloads at ALCs as being:

- complex and segmented
- generally low volume and quite variable
- composed of a large number of varying processes on a wide variety of end items

Even the process of weapon system improvement contributes to the complexity of the workload. The existence of different versions of the same aircraft, with their unique repair and maintenance requirements, negate any possible economies of scale.

A study completed in 1987 on the application of robots to ALCs (Reference 3) explored automation opportunities beyond the realm of robotics. Among the more interesting insights offered by this study are:

- major automation opportunities exist in the areas of item tracking/accountability and automated planning systems/group technology. ALCs expressed difficulties in areas of materials management and supply.

- direct labor automation is not likely to yield dramatic near term results.

- air frame activities do not lend themselves to discrete processes as easily as engine repair.

- automation initiatives face major institutional and personnel qualification hurdles.

- information management has great potential for improving productivity.

2.1.1 Current Mechanical Workloads

ALCs are currently engaged in engineering design (2D and 3D mechanical design), engineering management, engineering analysis (e.g., fracture mechanics, structural analysis), inspection/test and part/tool manufacturing. Detailed information on cost and/or time drivers awaits results from the Technology Insertion Program. Nevertheless, it is informative to consider the number of items locally manufactured by the ALCs to use as a base for evaluating the extent of ALC automation. In 1987, Ogden reported 187,769 items had been locally manufactured, while Sacramento reported 198,429. No breakdown was given for mechanical vs. electronic or numbers of duplicate items manufactured.

Despite its industry focus and early 1980s time frame, many of the cost/performance drivers identified in the Product Definition Data Interface (PDDI) Needs Analysis appear to be relevant to the ALC case. PDDI found three levels of drivers: general cost/performance drivers, airframe cost/performance drivers, and part class cost/performance drivers. General cost drivers included:

- human understanding of part/assembly requirements.
- managing and incorporating change in manufacturing.
- data conversion for automated manufacturing.

Tooling turned out to be a major cost driver in the airframe area, while part class cost drivers revolved around:

- sheet metal design and manufacturing.
- machined part structure.
- design and machining using new materials (e.g., composites).

2.1.2 Current Electronic Workloads

As weapon systems become more electronically dependent, the requirement for ALC electronic support is projected to increase substantially. Presently, ALCs are involved with printed circuit board (PCB) design, PCB repair/manufacture, automatic test equipment software (ATE) development, and digital and analog circuit simulation. The electronics test function has been identified and emphasized in a number of studies as a potential constraint to ALCs being able to meet their surge requirements.

Technology trends toward surface mounted devices and very high speed integrated circuits (VHSIC) is exacerbating this growing test problem. As systems become more complex, the tools available for organic support are proving deficient in providing the timely support demanded by the operational requirements of the newest weapon systems.

2.2 Current ALC CAD/CAM/CAE Technology Status

A survey was first conducted in the March 1988 time frame and updated in November 1988 to review the current posture of AFLC to manage and utilize CAD/CAM/CAE and CNC systems (References 12 and 33). Although the data appearing in the survey is somewhat inconsistent, it provides some indication of the general conditions facing AFLC.

Hardware

The number of systems provided on the summary slide and in detailed breakdowns are inconsistent. On a summary basis the hardware breakdown appears as follows:

CAD/CAM/CAE Hardware

Organization	No. of Systems	Vendor with Highest Percentage
MM	194	DEC (47%)
MA	152	CV (75%)
CR	4	Autotrol/Apollo (100%)
DE	4	Intergraph (100%)

NC Machine Hardware

MA	190	Cincinnati Milacron (10%)

NC Machine Controllers

MA	190	General Electric (16%)

More detailed breakdowns of current inventories and projected future buys appear in Tables 1 to 5. Table 1 gives some indication of the composition of the systems cited on Page 5. It also provides details on the capabilities of the equipment by providing the model number and date acquired. An examination of the other tables indicates that Sacramento ALC has an enormous advantage over the other ALCs in terms of numbers of CAD/CAM systems. At the same time, Table 3 shows San Antonio with a considerably greater number of CNC machines. Reasons for these discrepancies remain to be explored.

Software

CAD/CAM/CAE

The majority of software applications being utilized by survey respondents revolved around mechanical analysis and design (2D and 3D modeling, fracture mechanics) and electronic analysis and design (PCB design, schematic capture). Additional applications included engineering management and architectural functions (facilities management).

Table 1. CAD/CAM/CAE Hardware
Organization vs. Vendor vs. Nos. of Machines
vs. Type of Machine vs. vs. Date Acquired

ORGANIZATION: CR - Competition Advocacy

EQUIPMENT	DATE ACQUIRED
5 - Autotrol/Apollo File Servers	1987
33- Autotrol/Apollo Workstations	31- 1987, 2 - 1988

ORGANIZATION: DE - Civil Engineering

EQUIPMENT	DATE ACQUIRED
4 - Intergraph 200 CPU/Fileserver	1 - 1987, 3 - 1988
14- Intergraph Interview 32-C Workstations	5 - 1987, 9 - 1988

ORGANIZATION: DS - Distribution

EQUIPMENT	DATE ACQUIRED
1 - DEC VAX 11/750 CPU	1981
5 - Intergraph Workstations	1981
18- IBM PC/AT Workstations	1987
11- Zenith Z-248 Workstations	1987
11- VICTOR 9000 Workstations	UNK
1 - Silicon Graphics Mini-Computer	1987

ORGANIZATION: MA - Maintenance

EQUIPMENT	DATE ACQUIRED
6 - Apollo DN580 Workstations	1986
4 - Hewlett Packard HP 1000 Workstation	1983
11- Hewlett-Packard HP 9000 Workstations	1984
3 - Hewlett-Packard PCDS Workstations	1987
13- Intergraph Workstations	9 - 1986, 4 - 1987
6 - Computervision Designer V Workstations	1982
26- Computervision Designer V-X Workstations	6 - 1982, 1 - 1985 13- 1984, 6 - 1987
23- Computervision CADDStation Workstations	9 - 1985, 14- 1986
1 - Computervision CDS 4201 Workstation/CPUs	1985
1 - Computervision CDS 3411 Workstation	1987
2 - Computervision CDS 3421 Workstations	1987
9 - Computervision Instaview	5 - 1982, 4 - 1986
25- Computervision Workstations (Other)	10 - 1982, 15 - 1987
1- Gerber Photo plotter/MA41 Workstation	UNK
1- IBM 4381 Workstations	1986

Table 1. CAD/CAM/CAE Hardware
Organization vs. Vendor vs. Nos. of Machines
vs. Type of Machine vs. vs. Date Acquired (con't)

ORGANIZATION: MM - Materiel Management

EQUIPMENT	DATE ACQUIRED
12- Apollo/Autotrol DN4000 Workstations	1988
36- Apollo/Autotrol DN3000 Workstations	1988
29- Apollo Workstations (Other)	1985-1988
1 - Apollo Network Server	1985-1988
2 - Apollo/Auto-trol File Servers	1987
31- Apple Macintosh Workstations	1987-1988
6 - Computervision CADDS 4X Workstations	1983
2 - DEC VAX 785 (CPU)	1987-1988
1 - DEC VAX 8800 (CPU)	1987-1988
1 - DEC VAX 11/780 CPU	1 - 1985, 1 - 1986
1 - DEC VAX 85/50 CPU	1987
3 - DEC VAX 8650 CPU	2 - 1987, 1 - 1988
2 - DEC VAX 8530 CPUs	1987
2 - DEC MICROVAX II Workstations	1 - 1987, 1 - 1988
42- DEC MICROVAX III GPX Workstations	6 - 1987, 36- 1988
3 - DEC MICROVAX Workstation (Other)	1987-1988
43- DEC GPX Workstations	1987-1988
1 - DEC VT-100 Terminal	1985-1987
1 - DEC VT-200 Terminal	1985-1987
225-DEC VT340 Terminals	1988
7 - FUTURENET Workstations	1986-1988
2 - Hewlett-Packard 9845B Workstations	1982
4 - IBM 5080 Workstations	1986
1 - Intergraph Workstation	1986-1988
5 - Sun Workstations	1987-1988
1 - Sun Server	1987-1988
1 - Tektronix 4015 Workstation	1986
1 - Textronix 4105 Workstations	1987-1988
4 - Tektronix 4107 Terminals	1985-1987
2 - Tektronix 4109 Workstations	1987-1988
1 - Tektronix 4115 Workstation	1986
3 - Textronix 4125 Workstation	1985-1987
8 - Textronix 4129 Workstations	2 - 1986, 8 - 1987-1988
3 - Tektronix 4207 Terminals	1985-1987
4 - Tektronix 4209 Terminals	1985-1987
4 - Textronix Terminals	1987-1988
11 - Zenith Z-248 Workstations	UNK

Source: Reference 33

Table 2. LIST OF CAD/CAM SYSTEMS (IN PLACE) - VENDOR VS. ALC
As of 4 March 1988

VENDOR		OC-ALC	OO-ALC	SA-ALC	SM-ALC	WR-ALC	TOTAL
APOLLO	MM	1	12	0	36	0	49+
	MA					+?	
CALCOMP	MM	0	0	0	1	0	1
CV	MM	0	0	0	6	0	
	MA	3	9	4	+?	4	26+
EVANS & SUTHERLAND	MM	6	0	0	0	0	6
H-P	MM	5	0	0	0	8	
	MA					2	15
IBM	MM	0	0	0	4	0	
	MA				1		5
INTEGRAPH	MM	0	1	0	0	0	
	MA					2	3
TEKTRONIX	MM	0	0	1	0	0	
							1
DEC	MM	1*	0	1*	60	0	
	MA	1					63
XEROX STAR	MM	5*	0	0	0	0	
Systems Eng. Lab.		1			1		7*
VALID ANALOG	MA				1		
SUMMAGRAPHICS	MA				1		
TOTAL		23*	22	6	111+	16+	178+

*INCLUDES BASE/SERVER SYSTEMS
+Data not detailed enough to determine manufacturer
?Number appears questionable

Source: Reference 12.

TABLE 3. LIST OF CAD/CAM SYSTEMS ON-CONTRACT OR ORDER - VENDOR VS. ALC
As of 4 March 1988

VENDOR	OC-ALC	OO-ALC	SA-ALC	SM-ALC	*WR-ALC	TOTAL
ALPHAREL	0	27	0	0	0	27
APOLLO	0	0	22	0	0	22
TEKTRONIX	0	0	7	0	0	7
DEC	7	0	1	24	0	32
TOTAL	7	27	30	24	0	88

* There is an indication that WR-ALC will be ordering DEC equipment on the SEWS contract.

Source: Reference 12.

TABLE 4. PRESENT INVENTORY OF CNC MACHINES AND CONTROLLERS BY ALC
As of 4 March 1988

CENTER	# OF MACHINES	DIFFERENT TYPES OF MACHINE MANUFACTURERS	DIFFERENT TYPES OF CONTROLLERS	NO LISTING	FUTURE PURCHASES
OC-ALC	35	15	10	--	--
OO-ALC	30	18	14	1	--
SA-ALC	62	22	12	--	4
SM-ALC	39	19	15	--	--
WR-ALC	22	17	14	1	9
AGMC	2	2	2	--	4

Source: Reference 12.

Table 5. Air Logistic Center vs. NC Machine Manufacturer vs. NC Controller

	Top 3 Machine Manufacturers	Top 3 Controller Manufacturers
OC-ALC	White Sunstrand - 10 Kearey Trecker - 4	Swing White Sundstrand - 9 Allen Bradley - 7 G.E. - 7
OO-ALC	Mazak - 4 Warner Swazey - 3 Leblond Makino - 3	Fanuc - 6 Allen Bradley - 5 Mazatrol - 4
SA-ALC	Cincinnati Milacron - 14 G.A. Gray - 7 White Sunstrand - 5 Monarch - 5 SIP - 5	G.E. - 17 Acramatic - 11 Dynapth - 9
SM-ALC	Mazack - 7 Wells - 5 Omni Mill - 4 Excellon - 4	Mazatrol - 7 Allen Bradley - 6 Heidenhain - 5 Excellon - 5
WR-ALC	Cincinnati Milacron - 7 Warner Swasey - 4 SIP - 2 DAC - 2	Cincinnati Milacron - 8 Allen Bradley - 4 Bosch - 2 G.E. - 2

Source: Reference 12

Numeric Control

The table below summarizes the extent of NC data currently residing on systems.

Numeric Control Data Status

ALC	# Part Programs	Formats	Retention Period	Potential for Reuse (%)
OC	1130	EIA	Unlimited	100
OO	1000	CV Binary Format APT Source - CV-ASCII Format Punched Tape -CV-ASCII Format	Unlimited	100
SA	550	APT Source CV-CL Data Tape image	2 years	100
SM	?	?	?	70
WR	1600	EIA (Mag. & paper tape) APT Source	Until not Manufactured	100

Only Ogden (OO) indicated significant progress with implementing BCL. Note that given the almost 200,000 items locally manufactured by an average ALC per year, these tables indicate a rather low level of current automation.

Findings

As a result of the response to the survey, the CAD/CAM/CAE working group arrived at a number of findings. Among the most significant findings were:

- AFLC does not understand its CAD/CAM/CAE requirements.
- this lack of understanding has resulted in an inadequate command policy.
- the proliferation of different hardware and software types has resulted in many interface and communications problems.
- there are a lack of conventions and existing standards are not mature enough to bridge resulting gaps.
- MM and MA are not communicating.
- procedures are lacking or inconsistent in areas such as CAD storage or CNC machine operation.

AFLC realizes it has a problem and has begun to tackle these problems through the establishment of working groups on topics such as mechanical design, electronics, standards, and CAD/CAM acquisition. The next section will present a characterization of the current aerospace industry CAD/CAM/CAE environment for comparison purposes.

3.0 CURRENT AEROSPACE INDUSTRY DESIGN/MANUFACTURING ENVIRONMENT

Surveys and sources consulted for this report indicate that major defense contractors either lack or are also in the formative stages of establishing a long range CIM strategy. Two-thirds of the aerospace industry does not have a formal long range CIM plan established or a formal plan for migrating to a CIM environment. While industry's approach to the adoption of computer aided technologies has been characterized as being piecemeal (e.g., CAD, CAM, CAT, etc.), CAD is currently being utilized for over 30% of all design efforts today. Major findings from the surveys are presented under separate headings.

MACRO CALS Capabilities Survey - CALS Industry Steering Group - January 1988

Thirty-one of the top forty defense contractors, by dollar volume for 1986, responded to a survey designed to establish a baseline of computer-aided technology in production use by industry. Some companies had several separate divisions respond to the survey. Twenty-seven of the respondents named the Air Force as their major customer. Thirty-five respondents had billings of over $300 million in defense work for 1986. Survey findings of significance to this study include:

- 34% of the respondents are implementing digital interfaces with suppliers/subcontractors.
- 37% of the respondents have greater than 30% of their design, development, and manufacturing data in digital format.
- nearly one-half are planning to develop a relational common data model architecture.
- a majority have not achieved significant integration of analysis data with CAD systems, but there is a higher degree of integration in the electrical analysis area than in the mechanical analysis area.

- only 34% are transferring more than 20% of their digital engineering data directly to manufacturing.

- multivendor systems appear to be the rule for both mechanical and electronic design.

- 2D modeling is the predominant design technology being used.

- IGES is the only standard receiving widespread support.

- respondents felt major advances are needed in most of the major technology areas together with standards developments.

Automated Airframe Assembly Program (AAAP) State of the Art Document-July 1987

The survey, conducted as part of the above cited study by Northrop Aircraft and Price Waterhouse, was an attempt to also develop a CIM technology baseline measure of the aerospace industry. Sixteen organizations responded to the survey, including fourteen from the airframe manufacturing sector. Major relevant findings from this survey include:

- Two-thirds of the companies do not have a plan or commitment to develop a common data model for shared data (note the inconsistency with the prior survey).

- only about one-third of the companies use MAP/TOP standards.

- there is some hardware integration on the shop floor.

- data is interfaced between engineering and manufacturing rather than being integrated.

- most process planning is done manually.

- IGES is used mainly to transfer data internally, with only limited use to transfer technical data externally (to/from suppliers and subcontractors).

- approximately one-half of the companies utilize group technology concepts during the design process.

- approximately one-half of the industry has automated mechanisms to ensure that only one correct version of a drawing exists.

- most companies perform assembly modeling.

- industry uses coordinate measuring machines to inspect detail parts and tools, including composite parts.

- the process of feeding engineering analysis and test results back to the CAD system is largely manual.

- a majority of industry is performing manual drawing checks on paper drawings.

- a majority of industry creates and maintains engineering parts lists manually.

- a majority of industry utilizes different systems and procedures for tool process planning than they do for assembly process planning and a majority of the tool process planning is done manually.

- material specifications are created without interfacing to a CAD system.

- most companies develop their assembly schedules using an automated system.

- approximately one-half of the companies are considering just-in-time concepts for implementation in their factories.

- only 25% of industry is utilizing a Manufacturing Resource Planning System for material planning.

- less than one-half of the companies have fully automated manufacturing cells controlled by computers.

- communication between the shop floor and other functions is mainly accomplished manually.

- material control is largely automated.

The picture that one derives from these surveys is of an industry that is on the threshold of technological change. It appears that a majority of industry are ahead of ALCs in terms of the extent of penetration of CIM technologies. Nevertheless, industry also has many of the same problems in terms of issues such as: integration of design and manufacturing, multi-vendor hardware and software compatibility, lack of standards, etc. What emerges most starkly from considering these findings is a technology gap which does not appear to be overwhelming. The reasons for the smaller than expected gap are probably multifaceted. Some critics of defense contracting procedures contend that cost plus fee contracting creates disincentives for firms that would like to modernize their manufacturing processes. If this contention is correct, the pace of technology implementation may be slowed down by passive negative contractual impacts. These same critics point to the relative ineffectiveness of the MANTECH and IMIP programs to provide incentives to modernize plants, despite the completion of a few well publicized state-of-the-art facilities.

For more than two decades, DOD has supported the Manufacturing Technology Program (MANTECH) and, more recently, the Industrial Modernization Incentive Program (IMIP). One of the objectives for MANTECH is to improve the industrial base, by focusing on smaller companies, for spares production, maintenance, and repair through implementation of manufacturing technologies. IMIP is also intended to reduce production leadtimes and growth in costs, while improving surge support. Typical funded projects include: rearrangement of a factory into work cells and a CAD/CAM system to provide part drawings electronically to work cells; and development of a computerized system of quality assurance inspections and test throughout a manufacturing process.

MANTECH is a broad based program to provide new and innovative manufacturing technology at the factory floor level. Its initiatives are to be structured to:

- aid in insuring the economical production and operational support of superior weapon systems on a timely basis.
- insure advanced manufacturing processes, techniques and equipment are used to reduce AF system acquisition and support costs.
- foster greater use of computer technology in all elements of manufacturing and repair.

MANTECH is currently divided into 10 thrust areas, with the following funding profile for 1989: (Dollars in Millions)

	FY89
airframe production and productivity thrust	12.7
low observable structures/configurations manufacturing	0
propulsion system production	10.0
electronic integration and assembly thrust	13.9
AFLC maintenance and repair productivity	18.0
computer integrated manufacturing	22.8
strategic missile and launch system production	0
space systems manufacturing and production	5.5
tactical systems manufacturing and production	0
manufacturing science	9.2

These budget numbers provide some indication of where the Air Force believes there is both a need and the greatest opportunity to achieve returns from automation.

The computer integrated manufacturing (CIM) thrust is directed at proving, analyzing, and transferring fully computer integrated manufacturing planning, scheduling and control systems; automated factory-floor production systems; and the information management technologies required by such systems. Major projects include: an unattended machining cell in aerospace subtier vendor facilities, establishing an automated assembly capability within the airframe industry, revitalizing the machine tool industry, and the Integrated Composite Center (ICC).

The AFLC maintenance and repair productivity thrust will be discussed under the REPTECH program. In the area of electronic integration and assembly, the objective of the thrust is to provide reproducible manufacturing technologies that improve quality and reliability and lower the cost of advanced electronics that meet the requirements of military systems and subsystems. Areas of concentration include: VHSIC manufacturing capability, high production rate capability for gallium arsenide (GaAs), solid state microwave devices, and advanced methods for low cost, high quality traveling wave tubes.

4.0 ASSOCIATED PROCUREMENTS, PROTOTYPING, AND R&D PROGRAMS

Evolution of the Air Force and aerospace industry CAD/CAM/CAE environment will be influenced by many factors over the next ten years, some (such as the defense budget) difficult to predict. Yet, there are known factors which should be considered in deriving a concept for a future CAD/CAM/CAE environment. Significant procurements, prototyping, and R&D programs are considered here. Standards are addressed only superficially.

4.1 Associated Procurements.

CAD/CAM/CAE hardware and software procured now by ALCs may constrain their future options, given budget realities. The following procurements may have significant impacts on AFLC.

4.1.1 SEWS (Scientific and Engineering Work Station)

The SEWS contract was awarded to the Digital Equipment Corporation on 22 May 1987. It is an Air Force wide contract with the following restriction: "The requirement is for a new family of workstations (computers) configured primarily to support the computational and graphics needs of scientists and engineers who perform the research and development mission". Primarily intended for Air Force Systems Command, the contract is also being utilized to procure CAD/CAM/CAE hardware for AFLC. Available information indicates SEWS has a DPA limit of $114 million, all of which has been obligated or set aside ($10.5 million for AFLC sites). SEWS is intended to provide a Unix based family of compatible processors with distributed processing capability. There are three processors available: a VAX 8650 (with floating point accelerator, 16 MB memory, 912 MB disk storage); a Micro VAX II (with 16 MB memory, 527 MB disk storage, 95 MB streaming tape); a Vaxstation II/GPX (with 8 MB memory, 71 MB disk storage, and 95 MB streaming tape). It is our understanding that Warner Robins ALC is procuring hardware under the SEWS contract for both MM and MA requirements. Sacramento ALC has also purchased significant computer system hardware for MM under this contract. Sacramento has a contractor assisting with the integration of hardware and software for its engineering environment.

4.1.2 Software For Warner Robins ALC Engineering Central Computing Facility

Warner Robins ALC is currently soliciting proposals for off-the-shelf electronic/electrical, mechanical, facilities design, and engineering documentation software to be used by engineers within the Directorate of Materiel Management (MM). This software will run on a VAX cluster consisting of a VAX 11/785 and two VAX 8530s; a VAX 8650, 12 Micro VAX 3s; 42 VAX station 3/GPX workstations; 226 VT 241 terminals; and other peripherals. This detailed functional specification could be an indicator of what form an AFLC wide procurement may take. Support of PDES and EDIF are spelled out as requirements once they are accepted as standards.

4.1.3 Navy CAD II

The Navy is in the process of developing a major request for proposal (RFP) to acquire commercially available, "off-the-shelf" CAD/CAM/CAE equipment (hardware, software and services). A foundation for the buy has been derived by the Navy specifying an architecture, standards, and integration requirements. A flexible, open system architecture based on the use of engineering workstations (as the primary compute engines) in an office automation environment has been defined. Other special purpose computers will support database, communications, storage, scientific computing, and direct numerical control applications. Figure 1 illustrates the Navy's concept of the overall system architecture, while Figure 2 illustrates the hardware architecture. Systems will be required to fully support the IGES/PDES Standards and the POSIX operating system as they become available. Each of the Navy's individual systems commands will be responsible for defining its own internal design, engineering analysis, manufacturing and maintenance software requirements as well as the necessary level of integration between design, engineering analysis, manufacturing, and maintenance functions.

The scope of the software functionality delineated in the specification is extensive, including items such as: system software, a modelling and drawing

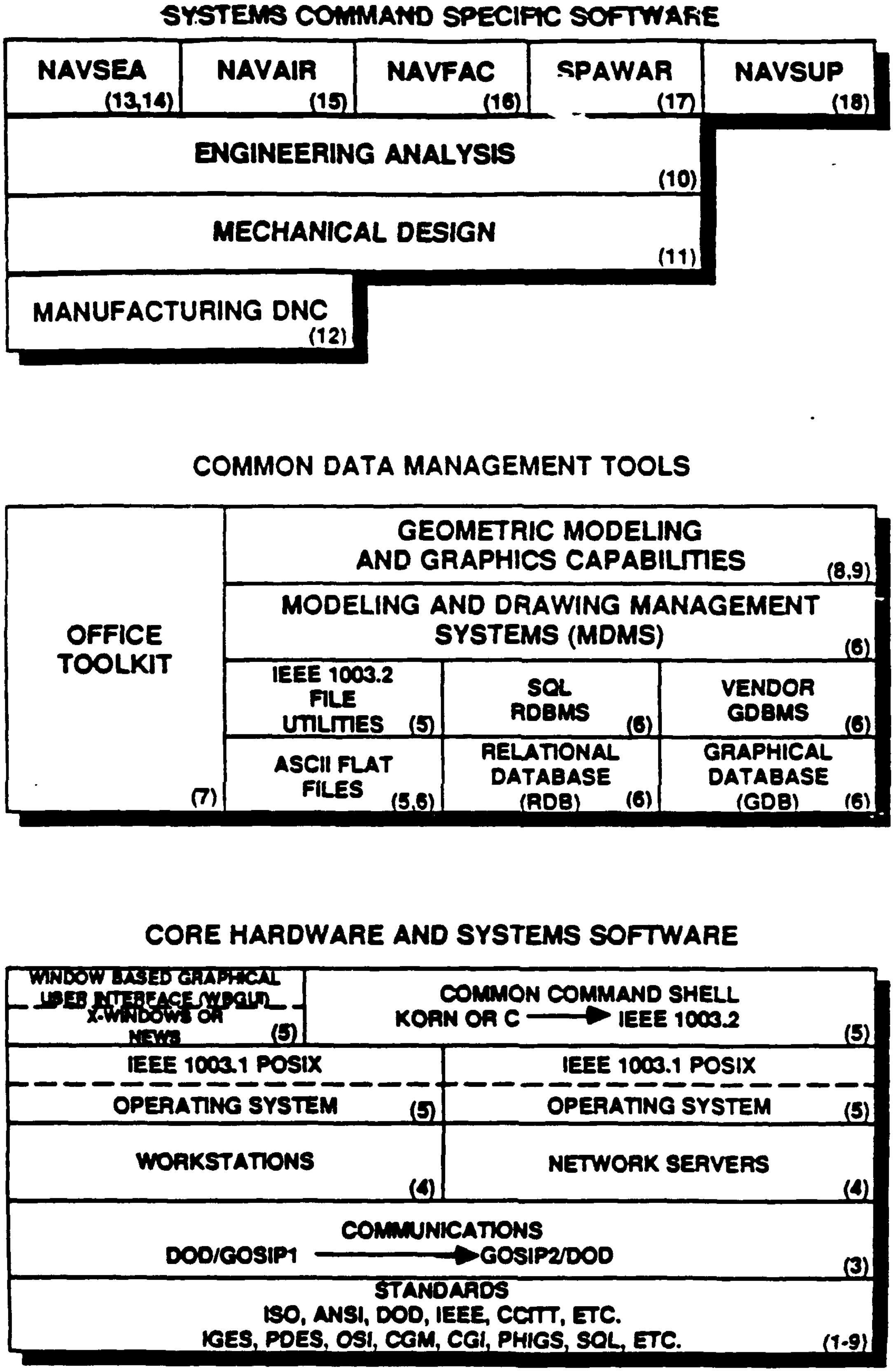

Figure 1. Navy CAD/CAM Systems Architecture

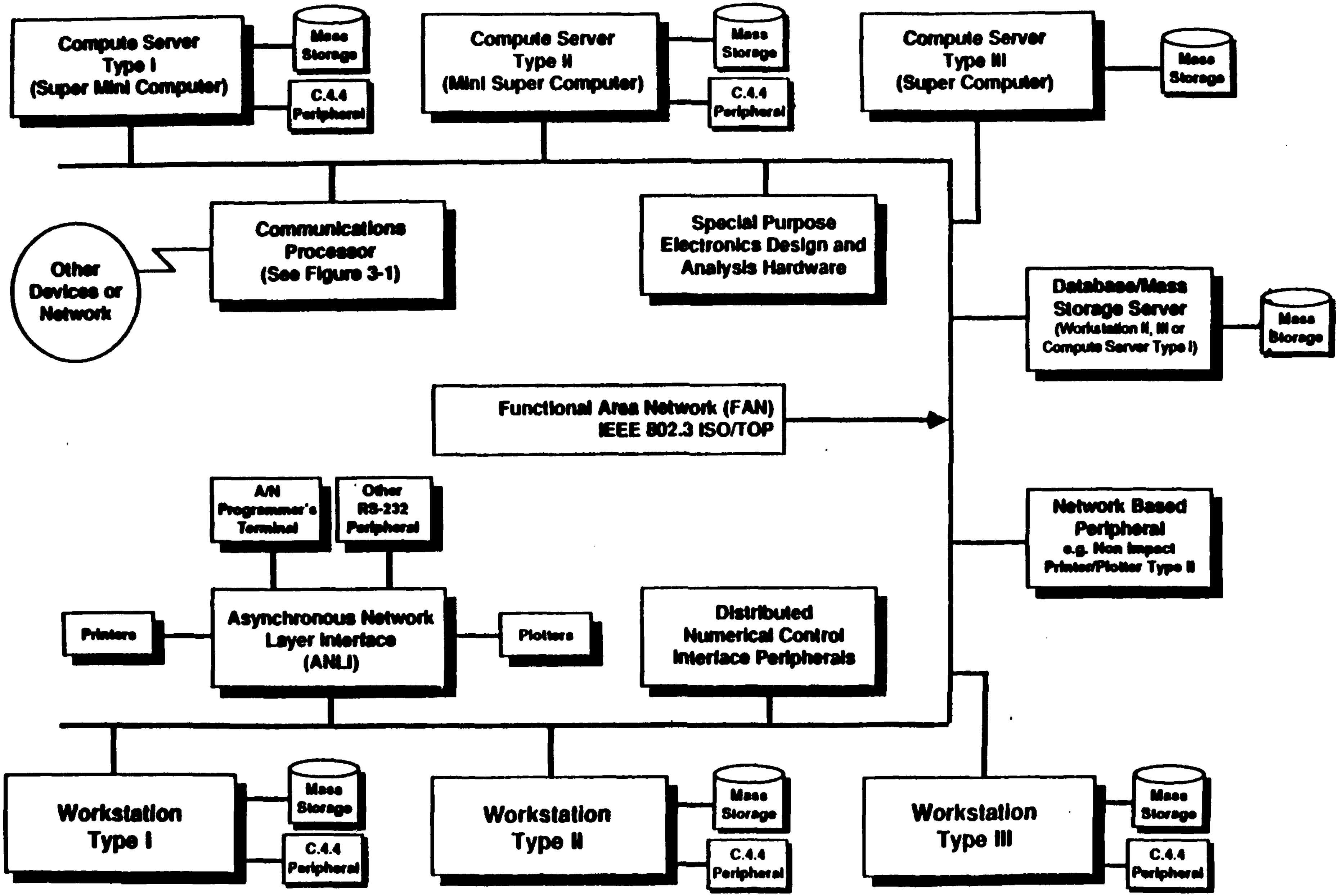

Figure 2. Navy CAD/CAM Hardware Architecture

management system, a geometric database management system, a relational database management system, an office tool kit, extensive geometric modelling and graphics applications (e.g., mold design and analysis, optics analysis), mechanical design applications, and manufacturing applications.

(Note: The material contained in this Section was garnered from source material dated 22 May 1987, See References 29 and 30.)

AFLC is monitoring the Navy procurement and is giving consideration to utilizing the specification as a possible model for its own 1990s command wide buy.

4.2 Prototyping Programs

Current sites for prototype automation projects are excellent candidates for future incorporation into the Air Force CALS PDD future concept. Several significant prototype programs are discussed next.

4.2.1 REPTECH

REPTECH (Repair Technology) is part of the MANTECH program managed by the Air Force Systems Command. Approximately 20% of MANTECH's budget is used for AFLC REPTECH programs. REPTECH is the major program for AFLC to acquire new technology in the depot maintenance and repair shops. Proven technology is transferred from R&D to functional processes and equipment (areas of engines, air frames, electronics, and inspection) on the shop floor through this program.

At the present time, most of the REPTECH projects involve either equipment specific robotic maintenance and repair applications, laser applications or automated inspection and test. They appear targeted at either labor intensive, repetitive, or safety related task areas. Examples of these types of projects include: automated deriveting, paint stripping, and integrated blade inspection systems (IBIS). Projects that appear to have broader information system components include: the Flexible Repair Center (FRC-automated repair center for engine cases), GMAP (geometric modeling applications interface program), and the parts replication system (laser scanning of parts and feeding of geometry into a CAD system). The GENESYS (critical component generation) system, currently undergoing reconsideration and reformulation, could also be significant if its scope continues to encompass an integrated engineering and manufacturing cell comprised of four modules: resource management, production planning, material substitution and part production. There appears to be some similarities between the initial GENESYS concept and the Navy RAMP program which will be discussed later.

4.2.2 Paperless Lantirn Automated Depot (PLAD)

This proposed project is an example of an attempt to expand an automated paperless manufacturing concept to the depot repair process. PLAD is planned to be installed at WR-ALC and is being sponsored by the AFSC Lantirn SPO. When implemented, automation will be extended to the areas of: performance measurement, personnel qualifications tracking, serialized asset tracking, environmental stress screening, and failure analysis. Embodying advanced robotics, automatic test equipment, and a sophisticated database management system, the integrated maintenance facility for this sophisticated, largely electronic piece of equipment may be a prototype of the future of electronic repair. Figures 3 and 4 show a typical lantirn shop flow and the data flow for failure analysis.

4.3 R&D Programs

Given the inherent risks involved with conducting research and development, potential impacts of R&D are probably the most difficult to project. Several potentially significant R&D programs are described next.

4.3.1 Navy RAMP Program

The RAMP program is a Navy initiative to apply CIM technologies to reduce the lead time and overall cost of spare parts, while increasing their availability and the number of part sources. It is intended to automate the entire

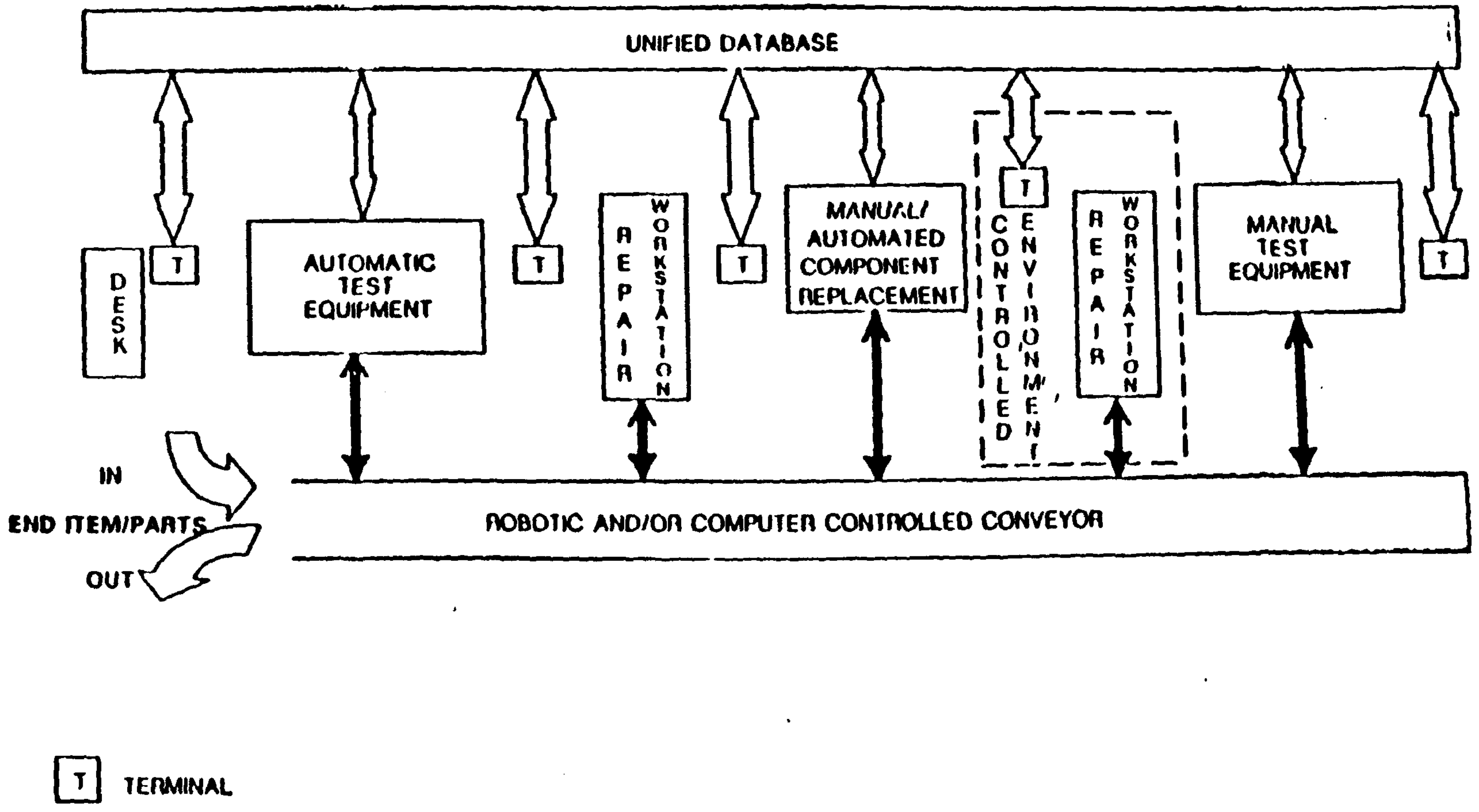

Figure 3. Typical Lantirn Shop

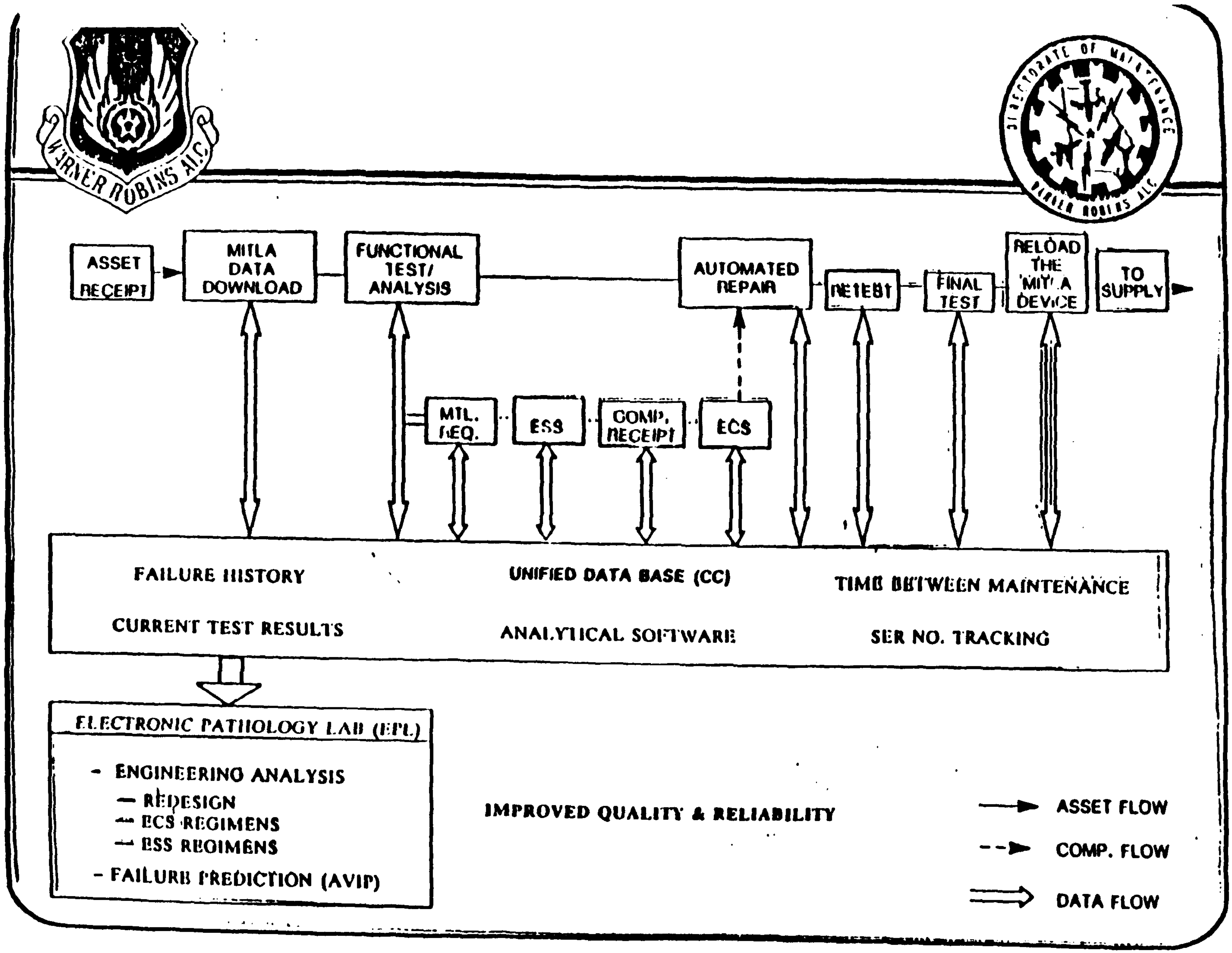

Figure 4. Automated Lantirn Failure Analysis

production process from order entry to flexible machine tool and shop equipment scheduling to actual fabrication.

Expected to be operational in the early 1990's, the RAMP Test and Integration Facility will have two prototype cells - one for small mechanical parts and one for printed wiring assemblies. RAMP is intended to produce very small lots of out-of-stock or out-of-production parts, on demand, in about 30 days.

The RAMP concept relies on being able to predict what parts will be needed most often so that the systems main database can be stocked with electronic parts technical data packages. Note that the ability to do this type of prediction for AFLCs was called into question by some members of the AFLC CAD/CAM/CAE working group. The answer to this question from an ALC standpoint may be the key to the future applicability of this program, or a modified GENESYS, to the Air Force. Once these data packages have been stored, RAMP is intended to considerably reduce the procurement administrative lead time and the manufacturing administrative lead time associated with acquiring parts.

Key design and implementation issues associated with the program revolve around the issues of: maximizing the use of off-the-shelf software, integrating the software so that all interfaces are functional, and anticipating/paralleling PDES development to minimize any major database restructuring. Other key risk elements to be addressed include: the data transfer process and mechanism, manufacturing process planning, and some aspects of the flexible manufacturing system (FMS) automation.

4.3.2 Next Generation Machine-Workstation Controller

This $100 million program focuses on revitalizing the U.S. controller and machine tool industry by developing and commercializing a Next Generation Controller (NGC) family of machine workstations. NGC is an AFSC MANTECH program geared to developing a single advanced controller, with an open architecture and modular design, that meets the needs of a broad range of manufacturing applications and can be scaled in terms of cost and performance. Examples of applications targeted for NGC applications, include:

- 5-axis milling, dimensional measuring, robotic part loading
- 4-axis turning
- composites fabrication
- grinding
- gear machining
- finishing surfaces and edges
- ultrasonic, optical inspection

NGC subscribes to the MAP version 3.0 specification as the standard for the basic NGC, but will ensure that the controller has a sufficiently open architecture to support alternate protocols. Other capabilities embodied in the NGC include:

- a new native programming language
- a graphical programming capability
- graphics based task planning
- automatic task planning
- a control equipment interface

From a data format standpoint, it is desirable that NGC accept a standard feature-based format into its task planning module. It is stated in the initial requirements specification for the NGC that:

> "Current data exchange formats do not meet the data requirements for NGC in the task planning role. The evolving Product Definition Exchange Specification (PDES) does have provisions for feature and management data. However, the PDES provisions for feature data is geometry-based and may fall short of expectations in the area of features". (Reference 10, P.71)

4.3.3 National Institute of Standards and Technology (NIST), formerly National Bureau of Standards

NIST is currently engaged in major research impacting on automated manufacturing. Major focus areas appear to be: distributed data management systems (e.g., IMDAS), robotics, sensors, process planning, and standards development. One of the goals of NIST research is to produce interface standards between machines, eventually allowing plug compatible systems to be configured.

Standards development is one of the major responsibilities of NIST. Evolution of standards will also play a major role in the environment faced by both the aerospace industry and the Air Force in CAD/CAM/CAE. Among the standards of particular significance are:

- IGES/PDES/STEP
- MAP/TOP/GOSIP
- UNIX/POSIX
- EDIF/VHDL/IPC
- SQL
- IRDS

5.0 FUTURE AEROSPACE INDUSTRY DESIGN/MANUFACTURING ENVIRONMENT (5-10 YEARS)

The future of the aerospace industry will largely be shaped by progress in several key technologies. Many of these technologies require additional advances in CAD/CAM/CAE technologies and/or techniques to assist in their development. A five year study by the Aerospace Technical Council of the Aerospace Industries Association of America (AIA) reviewed the developmental status of over 100 technologies. The council identified eight key technologies based on selection criteria which compared their potential leverage, their potential payoff and the scope of new potential applications. Each of the technologies targeted will briefly be discussed, with their design/manufacturing issues highlighted.

Composite Materials

Composites, given their very attractive strength to-weight ratio, are predicted to result in more fuel-efficient aircraft, lighter missile and spacecraft structures, reduced manufacturing and labor costs and more innovation in vehicle design. Advanced automated design and manufacturing techniques are required to deal with the unique properties of composites (e.g., directional properties, low ductility, fiber/matrix interface). Additional work is also required to simplify the repair process.

Very Large Scale Integrated Circuits (VLSI)

Electronic micro-miniaturization is a trend that has revolutionized aerospace electronics. AIA felt that in order for the U.S. to remain competitive and to regain some lost competitiveness development is required in: submicron process technology, manufacturing processes and equipment, CAE/CAD/AI application to VLSI design, advanced VLSI and multi-VLSI packaging, built in test functionality, interconnection technology, and materials R&D (GaAs).

Software Development

In terms of maximizing leverage on aerospace capabilities, database management systems, multilevel security systems, and artificial intelligence are singled out for further development in the software area. Other software technologies mentioned include: automated software generation tools, software for parallel and distributed processors, formal validation methodologies, and application specific high level languages.

Propulsion Systems

Current propulsion programs include the National Aerospace Plane, the Advanced Launch System and Integrated High Performance Turbine Engine Technology. Despite these programs, AIA sees a need for further development in: gas turbine power plants, rocket engines, engine architectures, fuels, and materials. Advanced automated design, manufacturing, test and analysis techniques are recommended for further development before new prototypes can be produced.

Advanced Sensors

Advances have been made in high-performance infrared detectors, radar transceiver components and laser sensors. Further progress requires work in design for producibility tools and methods, CAD tools to ensure first-time success, automated manufacturing and in-process test technologies.

Optical Information Processing

This technology involves the use of light, as opposed to a charged electron flow, to store and manipulate data. Optoelectronics, a combination of optical and electronic methodologies is being pursued as a near term option, while researchers work on development of an optical transistor for the longer term. Innovative, low cost manufacturing methods will be required to make this technology a commercial reality.

Artificial Intelligence

AIA postulates that artificial intelligence will revolutionize a variety of aerospace products by the turn of the century, as well as the way in which those products are manufactured. Before that goal can be reached, research is required into: software validation methods for expert systems, advanced computer hardware, and improved modeling techniques for decisionmaking under uncertainty.

Ultrareliable Electronic Systems

The increasing complexity of system design requires that much greater attention be devoted to development of methodologies for producing provably correct designs for ultrareliable systems. Fault-tolerant architectures, hierarchical maintenance and self-healing systems are still evolving. Advances in this area require improvement in other electronic technologies, along with progress in: packaging and manufacturing technology (SMT, VLSI, VHSIC, MIMIC); methods for designing and testing error-free systems and environmental screening, advanced CAD tools for simulation, and self-healing and automated maintenance technologies.

Industry Surveys

It is clear from the above discussion that advances in key aerospace technologies are intimately linked to advances in CAD/CAM/CAE. As these technologies become proven and implemented on new or existing vehicles, CAD/CAM/CAE and CIM technologies and methods should become more prominent throughout the design and manufacturing cycle. The foregoing extrapolation is largely borne out by the major findings of the industry surveys presented below (Reference 3 and Reference 32). Most of the projections below were made by major airframe companies.

o by 1995, a majority of the industry will have a plan or a commitment to develop a common data model for shared data.

o most companies will be using MAP/TOP to support applications in production

o by 1995 most companies will have an integrated environment between engineering and manufacturing

- over 80% of industry will be utilizing group technology concepts and its spin-offs
- there will be a definite trend toward use of simulation software for assembly modeling
- automated mechanisms will exist to ensure correct drawing release
- 20% of companies will have a common Bill of Material for manufacturing and engineering
- 75-100% of engineering drawings will be created utilizing CAD.
- a majority of industry will have technical databases linked to CAD systems so the feedback of analysis and test results will no longer be a manual process.
- a majority of companies will be using 3-D computer graphics to design most of their engineering drawings.
- industry will utilize automated product configuration management techniques.
- a majority of companies will utilize computer aided process planning linked to a computer-aided design system.
- 85% of industry will be considering just-in-time concepts for implementation
- a majority of companies will be utilizing a MRP II System for material planning and over 90% will utilize a computer-based system for capacity planning purposes
- most companies will have fully automated manufacturing cells controlled by computer, with automated communication between shop-floor and other functions.

- most companies will achieve an 80 to 100% implementation of CIM technologies between 1997 and 2002.

6.0 FUTURE AIR FORCE DESIGN/MANUFACTURING ENVIRONMENT (5-10 YEARS)

Developments in the technologies discussed in Section 4.0 will eventually impact AFLC as they are transferred to operational weapon systems. Many of these technologies have direct counterparts in Air Force R&D programs, as either part of the Project Forecast II effort or as part of the Air Force Science and Technology Program. Project Forecast II was a major AFSC initiative to prioritize technologies and advanced systems concepts necessary for the Air Force to carry out its missions in the twenty-first century. Thirty-nine technologies and thirty-one advanced systems concepts falling into the broad categories of propulsion and power; materials, structures, and vehicles; weapons technology and countermeasures; electronics/electro-optics; information and computation; and systems acquisition and support were programmed for funding.

The Air Force's Science and Technology (S&T) Program is structured to: respond to the technical needs of the field commands; encourage and support new technologies that might revolutionize future warfare; and provide sufficient depth and breadth in the aggregate to help the U.S. achieve technological superiority over potential adversaries. Project Forecast II technologies have a 10-20 year time horizon for implementation, while the Science and Technology Program incorporates some technologies with a shorter time horizon.

Some of the technologies advocated under Project Forecast II include:

- high performance turbine engines
- wafer level union of devices
- photonics
- full spectrum, ultra resolution sensors
- fail-soft, fault-tolerant electronics
- survivable communication networks
- smart skins
- high-temperature materials
- advanced manufacturing technology
- unified life-cycle engineering

- smart built-in test
- distributed information processing

A review of the Air Force's Science and Technology Program confirms the institutionalization of many of the Project Forecast II initiatives in either next generation systems (small ICBM, ATF, Brilliant Weapons, heavy lift space vehicle) or in future systems (aerospace plane, tactical VSTOL Aircraft, directed energy weapons, sparse array spacecraft, battle management system). Note that the Science and Technology program is being restructured to explicitly support the R&M 2000 plan in the areas of reliability, maintainability, and producibility. This restructuring could have major impacts on the CAD/CAM/CAE environment, due to the areas that R&M 2000 will concentrate on:

- fail-soft, fault-tolerant aircraft hardware and software
- built-in-test to eliminate false alarms
- computer-aided design systems that permit early tradeoffs among performance, producibility and supportability

Ultimate impacts from these advanced technologies on depot processes is difficult to quantify. However, most sources seem to agree that there are certain trends which have gained considerable momentum, including:

- an accelerating trend toward two levels of maintenance (replace in forward areas, repair at depot). More sophisticated maintenance will be done at the depot.

- weapon systems will continue to be more electronically/software intensive requiring an increasing degree of sophistication in the depot work force.

- VHSIC testing requirements will introduce new expensive Automatic Test Equipment into the depot. Testing and software maintenance will challenge the resources of depots, despite the trend toward built-in test.

- dedicated memory located in electronic modules on the weapon system will record logistical and failure information. This information will need some form of processing and central storage.

- design of unmanned, unattended, or minimally attended electronic systems will continue to increase. The depot will be able to download test, diagnostic, and operational software to these systems.

- capability for fault tolerance and self repair may effect some reduction in the number of depot returns.

- line replaceable modules (LRMs) will replace line replaceable units (LRU's) in avionics systems.

Given these technology and operational trends, it is interesting to note how one ALC hopes to posture itself for the future. San Antonio ALC (SA-ALC) developed a 30-year plan with the following objectives and time frame.

- establish flexible and automated manufacturing cells and link these cells to form a Flexible Manufacturing System, 1988-1994.

- incorporate diagnostic technologies into the technical support base for test equipment, 1989-1994
  - develop computer aided design architecture 1991-1993

- pursue "just in time" concepts to ALC acquisition/distribution process, 1988-1997.

- transfer VHSIC technology, 1989-1994.

- automate labor intensive work in MA, 1988-2005.

- establish ALC as a technological leader in NDI, 1988-1995.

- transfer fiber optics technology, 1989-1994.

- restructure ALC organizations to take advantage of information technology, 1989-1995.

Among the technologies projected by the ALC to support its future workload are:

- artificial intelligence
- advanced NDI
- VHSIC
- advanced materials
- software
- laser systems
- automation and robotics
- advanced manufacturing
- engineering data systems
- CAD/CAM systems

The strategic vision established by this ALC is of an increasingly sophisticated technology related workload dependent on advanced technologies and automated information systems for support. This vision appears to be consistent with the strategic objectives and strategies outlined by the Air Force Logistics Command (Reference 22). Major objectives outlined in the cited document include:

- instill quality in basic processes and workforce to ensure responsive and productive logistics support

- focus efforts on improving the industrial base responsiveness

- integrate advanced technologies in logistics applications

- emphasize logistics considerations in all acquisition programs including modification, repair, and replacement

- integrate the development and management of Air Force logistics studies, processes, systems, and research priorities

- maximize the military capability of allied and friendly nations to meet mutual security objectives.

Strategies advocated under integration of advanced technologies include:

- implement widespread use of digital data within AFLC
- develop the capability for AFLC to maintain and manage modular electronics hardware and software
- implement use of artificial intelligence technologies
- support advanced materials and structures
- exploit information technology to optimize the command structure
- Seek out and advocate technologies that reduce the cost of ownership and/or increase quality and combat capability
- prepare for the rapidly expanding reliance on software in weapon systems

CALS is critical to the ultimate realization of these visions.

7.0 CONCLUSIONS

Current Air Force Design, Maintenance, and Manufacturing Environment

The generally variable nature and low volume of depot processes coupled with the need to maintain and modify increasingly sophisticated hardware and software, while ensuring a surge capability, makes the Air Force environment distinct. AFLC is looking to CAD/CAM/CAE/CNC technology to assist it in meeting its mission, despite the complications of its environment. Data regarding the current base of CAD/CAM hardware indicates a predominance of early 1980's computervision machines in MA while MM has acquired significant quantities of late-1980's DEC equipment. This equipment is not evenly distributed across all ALCs. Sacramento appears to have a large advantage in terms of CAD/CAM equipment, while San Antonio holds an advantage in number of CNC machines. Given the level of local manufacturing done at ALCs and the amount of digital data residing at the ALCs, there appears to be a rather low level of overall automation.

AFLC realizes that it has a problem and is attempting to tackle it through a series of working groups. The initial survey of the working groups found that:

- AFLC does not understand its CAD/CAM/CAE requirements, which has resulted in an inadequate AFLC wide polity
- a proliferation of different hardware and software types has resulted in many interface and communications problems
- MM and MA are not communicating
- procedures are lacking or inconsistent in areas such as CAD storage

Current Aerospace Industry Design/Manufacturing Environment

It appears that a majority of the aerospace industry are ahead of ALCs in terms of the extent of penetration of CIM technologies. Nevertheless, two-thirds of the aerospace industry does not have a formal long range CIM plan established. Industry also has many of the same problems as ALCs in terms of issues such as integration of design and manufacturing, multi-vendor hardware and software compatibility, lack of standards, etc. What one finds is a technology gap which does not appear overwhelming.

It should be noted that DoD has been supporting the modernization of the defense industry through a number of initiatives, including the MANTECH and IMIP programs. Two of the major Air Force MANTECH thrusts are in the areas of AFLC maintenance and repair productivity (REPTECH) and computer integrated manufacturing (CIM). The funding profile for REPTECH and CIM in 1989 was $18.0 million and $22.8 million respectively.

Surveys of major airframe manufacturers and defense contractors provide some interesting insights into the industry's design/manufacturing environments. Among the significant findings of the surveys consulted were:

- between one-third and one-half of the companies interviewed are planning to develop a common data model
- data is being interfaced between engineering and manufacturing rather than being integrated
- 2D modeling is the predominant design technology used
- IGES is the only standard receiving widespread support. It is used mainly to transfer data internally, with only limited use for transferring data to/from suppliers and subcontractors
- multi-vendor systems appear to be the rule for both mechanical and electronic design
- approximately one-half of the airframe manufactures have automated mechanisms to ensure that only one correct version of a drawing exists

- o the process of feeding engineering analysis and test results back to the CAD system is largely manual
- o a majority of airframe manufactures creates and maintains engineering parts lists manually
- o less than one-half of airframe manufacturers have fully automated manufacturing cells controlled by computers

Associated Procurements, Prototyping, and R&D Programs

Significant CAD/CAM/CAE procurements, prototyping, and R&D programs may influence the evolution of both the Air Force and aerospace industry. Two procurements which will influence the Air Force are SEWS and the Navy CAD II buy. SEWS has resulted in a significant presence of DEC equipment in AFSC and in several AFLC-MM organizations. Both Warner Robins and Sacramento ALCs are basing their MM engineering systems on DEC hardware. Meanwhile, AFLC is developing a strategy for a major 1990s AFLC wide buy. It now appears that the Navy CAD II specification may serve as a model for this projected procurement.

Current sites for prototype automation projects are candidates for inclusion in a PDD future concept. REPTECH projects of possible interest include: the Flexible Repair Center at Oklahoma City-ALC, the Geometric Modeling Applications Interface Program, and the GENESYS (critical component generation) system. GENESYS, currently undergoing reconsideration and reformulation, could be significant if its scope continues to encompass an integrated engineering and manufacturing cell comprised of four modules: resource management, production planning, material substitution and part production. The Paperless Lantirn Automated Depot at Warner Robins ALC is also worthy of monitoring as a forerunner of the future of electronic repairs.

There are a number of R&D efforts worthy of active monitoring. The Navy's RAMP program is an initiative to apply CIM technologies to reduce the lead time and overall cost of spare parts, while increasing their availability and the number of part sources. RAMP relies on being able to predict what parts will be needed most often so that the system's main database can be stocked with electronic parts technical data packages. The ability to do this type of predicting in the Air Force environment has been called into question and remains to be resolved.

Two other R&D programs with a wider scope than RAMP are the Next Generation Controller Program (NGC) and the work of the National Institute of Standards and Technology (NIST). The NGC program is geared toward revitalizing the U.S. machine tool industry by leapfrogging the capabilities of foreign competitors. Output from this effort will impact the way machine tools are programmed, the content and form of process plans, and the network architecture of integrated factories. NIST, along with its responsibilities in standards development, is engaged in major research in distributed data management, robotics, sensors, and process planning. One of the goals of NIST research is to produce interface standards between machines, eventually allowing plug compatible systems to be configured.

Future Aerospace Industry Design/Manufacturing Environment

The future of the aerospace industry will largely be shaped by the technologies embodied in next generation systems and aircraft. Many of these technologies require additional advances in CAD/CAM/CAE technologies and/or techniques to assist in their development. Key technologies identified by the Aerospace Technical Council of the Aerospace Industries Association of America are: composite materials, very large scale integrated circuits, software development, propulsion systems, advanced sensors, optical information processing, artificial intelligence, and ultrareliable electronic systems.

As these technologies become proven and implemented, CAD/CAM/CAE and CIM technologies and methods should become more prominent throughout the design and manufacturing cycle. Surveys of major airframe manufacturers and major defense contractors indicate that these sectors are projecting major advances in their implementation of CAD/CAM/CAE technologies. Examples of these projections follow:

- by 1995 a majority of airframe manufacturers will have a plan or a commitment to develop a common data model for shared data

- by 1995 most airframe companies will have an integrated environment between engineering and manufacturing

- most companies will achieve an 80-100% implementation of CIM around the year 2000

- 75-100% of engineering drawings will be created utilizing CAD. Most of these drawings will be prepared with 3-D graphics

- over 80% of the airframe industry will be utilizing group technology concepts and its spin-offs

- most airframe companies will utilize computer-aided process planning linked to a computer-aided design system and automated product configuration management techniques

- MAP II systems will be utilized for material planning and will be linked to capacity planning systems

- most airframe companies will have fully automated manufacturing cells controlled by computers, with automated communication between shop-floor and other functions.

Future Air Force Design/Manufacturing Environment

The Air Force is committed to maintaining its technological superiority in the most cost-effective manner possible. Initiatives such as Project Forecast II and R&M 2000 advocate further development of CAD/CAM/CAE technologies. New weapon systems will rely on unified life-cycle engineering, in which CAD/CAE systems permit early tradeoffs among performance, producibility and supportability. As weapon systems become more electronic/software intensive photonics; fail-soft, fault-tolerant electronics; smart built-in test; and automated test equipment will become increasingly important. CAD/CAM/CAE technologies will also play an important role in designing, modifying, and maintaining these sophisticated electronics, along with the new materials inherent in high performance airframes and turbine engines.

AFLC has included as one of its major strategic objectives the need to integrate advanced technologies into logistics applications. Strategies advocated to meet this objective include:

- implement widespread use of digital data within AFLC
- develop capability to maintain and manage modular electronics hardware and software
- implement use of artificial intelligence technologies
- support advanced materials and structures
- exploit information technology to optimize the command structure
- seek out and advocate technologies that reduce the cost of ownership and/or increase quality and combat capability
- prepare for the rapidly expanding reliance on software in weapon systems

Individual ALCs have begun to respond to these needs and some have even developed long range plans. One of these plans projects a need for the ALC to rely on artificial intelligence, laser systems, robotics, advanced manufacturing, engineering data systems, and CAD/CAM systems to meet its future workload. Momentum is driving the Air Force toward an increasingly sophisticated technology related workload dependent on advanced technologies and automated information systems for support.

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