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# **AUTOMATED MANUFACTURING RESEARCH FACILITY**

## **1994 ANNUAL REPORT**

**A Joint NIST/Navy Manufacturing Technology Program**

**Conducted in Collaboration  
with Industry and Academia**

**David C. Stieren  
Cheryl Albus**

U.S. DEPARTMENT OF COMMERCE  
Technology Administration  
National Institute of Standards  
and Technology  
Manufacturing Engineering Laboratory  
Gaithersburg, MD 20899

November 1994

NOTE: Identification of commercial equipment and materials in this report does not imply recommendation nor endorsement by NIST, nor does it imply that the materials and equipment identified are necessarily the best for the purpose.

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U.S. DEPARTMENT OF COMMERCE  
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Mary L. Good, Under Secretary for Technology

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# Preface

This document has been prepared as the AMRF Annual Report for federal fiscal year 1994. This document includes only the technical and operational information pertaining to the AMRF that is specific to this fiscal year.

Additional information regarding the background of the AMRF, previous year technical projects, accomplishments of the AMRF, AMRF publications, and AMRF videos can be found in the 1993 AMRF Annual Report. The 1994 Annual Report is an updated edition of the 1993 Annual Report.

Special acknowledgement should be given to John Meyer, Albert Jones, and Cheryl Albus for their efforts in compiling the 1993 Annual Report. Acknowledgement should also be given to the individual technical project leaders for their contributions to the project summaries contained herein, and also contained in the 1993 report.



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# Introduction

The Automated Manufacturing Research Facility (AMRF) was created at the National Institute of Standards and Technology (NIST) in 1982 in order to provide a national testbed for research and development in computer integrated manufacturing. Initially, the program focused on control architectures and interface standards for large, flexible automated manufacturing systems. In recent years, the emphasis has shifted to more narrowly focused projects relating to specific technologies, types of equipment, and automation subsystems. The program has been jointly sponsored by the Navy since 1983, primarily through the Navy Manufacturing Technology (ManTech) Program. The AMRF was the Navy's first Center of Excellence.

Since its founding, the AMRF has achieved several significant accomplishments. Among these include the development of over 25 commercial products, roughly 20 patents, and more than 25 national and international standards. Most of the AMRF efforts have been jointly funded by NIST, the Navy ManTech Program, other agencies, and industry. AMRF technical projects are conducted primarily within the Manufacturing Engineering Laboratory (MEL) of NIST. The projects have always involved the demonstration of developed technology, usually at the NIST facility, as well as an element of technology transfer. Due to its high level of visibility at NIST in a Washington, D.C., suburb, the AMRF has provided a "window-on-technology" for countless policy makers within government, industry, and academia.

Operating as a Center of Excellence through federal fiscal year 1993, AMRF projects have focused on the development and transfer of advanced automation technologies. These projects have been aimed at integrated manufacturing applications, primarily those associated with integrated production systems; intelligent controls and sensor-based automation; advanced quality and inspection techniques and methods; and engineering tools.

During the past year, fiscal 1994, the AMRF has been in a state of transition.

The AMRF transition has entailed shifting away from status as a Center of Excellence and moving toward more of a jointly sponsored, planned, and conducted program that consists of an array of individual technical projects. These projects cover a wide range of technologies, from enhanced control systems for machine tools, to integrated manufacturing engineering software tools, to advanced precision finishing systems.

The present emphasis of AMRF projects primarily involves two concepts: the solution of problems associated with Navy weapon system manufacturing, as well as the development of technologies to increase capabilities of weapon system manufacture. AMRF projects focus on

the development of advanced manufacturing technologies that are generic in nature such that they can be replicated in several scenarios throughout DOD and the industrial base. These solutions and technologies are developed by leveraging the expertise and resources available at the sites of NIST and the other collaborators of the AMRF, whether they are within the Department of Defense (DOD), industry, university, or combinations of these facilities.

As the AMRF operates in today's state of existence, the objectives of its technical projects more broadly assume the overall objectives of the DOD ManTech Program: the reduction in life-cycle cost of weapon systems and/or the increased capability of weapon systems through the development, demonstration, and implementation of advanced manufacturing technologies. As mentioned above, the approach followed in achieving these objectives is through solutions which involve generic, enabling technologies that not only apply to weapon systems, but that also apply to industrial commercial products and processes. The AMRF continues to be a cost-shared program that leverages capabilities, expertise, and resources from several organizations in pursuit of these objectives.

While the AMRF remained active as a program in fiscal year 1994, there were no new-start projects that were funded. Fiscal 1994 involved the continued conduct and refinement of projects that began in previous years, some of which were completed in 1994, and some of which will be continued in fiscal 1995 and beyond.

In the future, the relationship that has been solidly established between NIST and the Navy ManTech Program through the AMRF is expected to last long into the next century. The future nature of the operational mode for the AMRF is unclear and is presently being planned and defined. However, the advanced manufacturing research and development; the successful demonstration of resource leveraging for multi-organizational objective accomplishment; and the transfer of developed technology into manufacturing implementation that have been produced in the AMRF for over a decade will surely provide the foundation for the program's next generation.

The logo for NIST (National Institute of Standards and Technology) is displayed in a bold, black, sans-serif font.

# Operations

The primary mission of the AMRF remains to develop and transfer advanced automation technologies that:

- increase production capabilities,
- reduce manufacturing and life-cycle costs,
- improve product quality,
- enhance flexibility of production systems, and
- shorten development and manufacturing times.

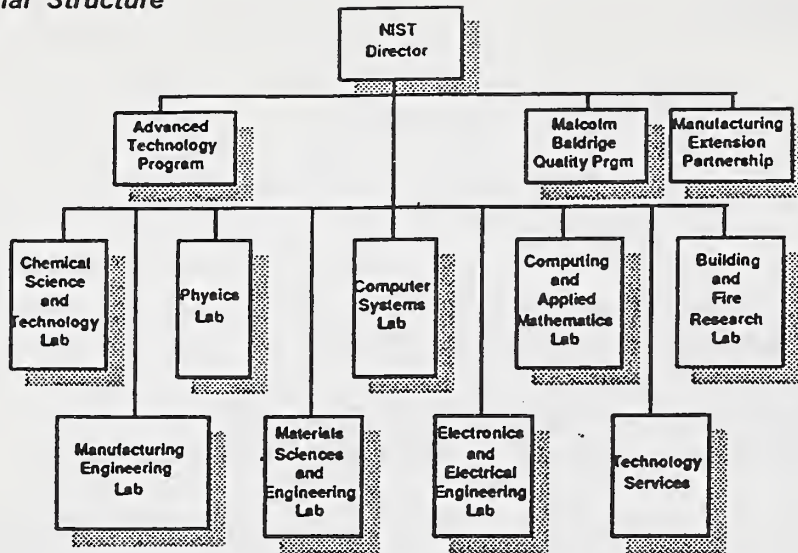
In addition to its primary mission, the AMRF also continues to perform a number of secondary functions on behalf of the program's Navy ManTech sponsors. These secondary functions include: providing assistance in solving specific, unique Navy manufacturing problems; serving as a focal point for other joint NIST/DOD manufacturing-related research and development projects; participating in Navy and DOD planning efforts associated with the DOD Manufacturing Science and Technology (MS&T) effort; providing a conduit of information and a window-on-technology with geographic proximity to Washington, D.C., for policy makers from the government, industry, and academia; and assisting with Navy surveys of other organizations to determine "Best Manufacturing Practices."

## Organizational Structure

In order to best understand the dynamics of how technical projects are conducted within the AMRF, it is necessary to describe the two primary organizations involved with the operation of the AMRF: NIST and the Navy ManTech Program.

NIST, as an agency of the U.S. Department of Commerce's Technology Administration, is charged with the primary mission of promoting U.S. economic growth by working with industry to develop and apply technology, measurements, and standards. NIST carries out its mission through a portfolio of four major programs. These four programs include the Advanced Technology Program, which provides cost-shared grants to industry for development of high-risk technologies with significant commercial potential; the Manufacturing Extension Partnership Program, a grass roots effort helping small and medium-sized companies adopt new technologies; the Malcolm Baldrige National Quality Award, a highly visible quality outreach program; and an Internal Laboratory effort planned and implemented in cooperation with industry and focused on measurements, standards, evaluated data, and test methods.

## NIST Organizational Structure



AMRF technical projects are jointly conducted by NIST, the Navy and/or other DOD facilities, companies in industry or industrial consortia, academic institutions, or any of several combinations of these entities. Within NIST, the AMRF is no longer a central facility as it once was during its days as a Center of Excellence in the 1980s and early 1990s. Instead, the AMRF is a matrix-managed program that cuts across the borders of four technical divisions within NIST's Manufacturing Engineering Laboratory (MEL).

MEL is one of NIST's eight technical laboratories. MEL has the explicit mission of working with the diverse American manufacturing sector to develop and apply technology, measurements, and standards. The four technical research divisions of MEL focus on the following topics:

- Precision Engineering Division:
  - Large-scale coordinate metrology
  - Mid-scale and complex form metrology
  - Surface and microform metrology
  - Nano-scale metrology
- Automated Production Technology Division:
  - Acoustics, mass, and vibration
  - Sensor systems
  - Ultrasonic standards
  - Sensor integration
  - Force

- Intelligent Systems Division
  - Performance measures
  - Intelligent controls
  - Systems integration
  - Sensory intelligence
  - Unmanned systems
  
- Manufacturing Systems Integration Division
  - Applied systems
  - Manufacturing standards methodology
  - Manufacturing collaboration technologies
  - Engineering design technologies
  - National PDES testbed and apparel technologies
  - Manufacturing systems engineering
  - Systems integration for manufacturing applications

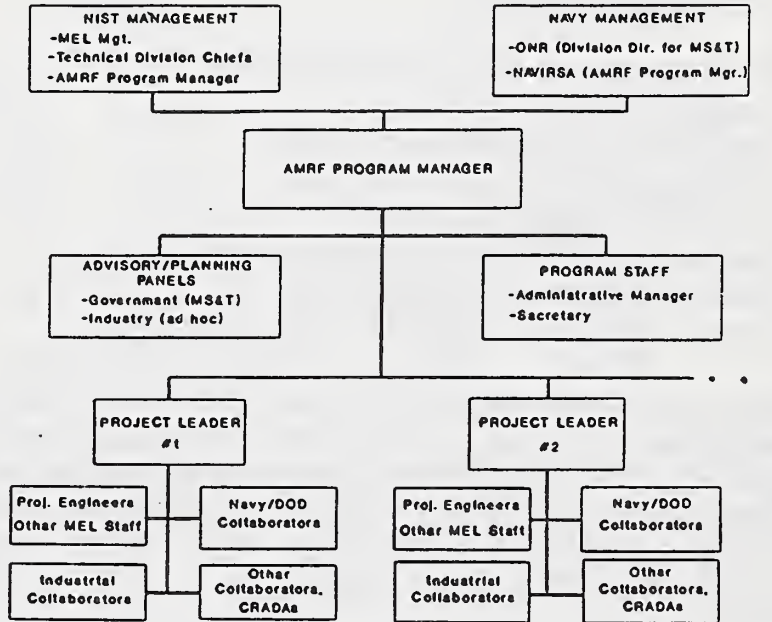
In addition to these four technical divisions, MEL has a Fabrication Technology Division that designs and manufactures components and equipment to service the needs of NIST in-house programs and other, external activities. This division has a wide range of precision production capabilities and specialty shops, including grinding, EDM, welding, optics production, and glassblowing. The Fabrication Technology Division also conducts a machinist apprentice program for training and certifying skilled machinists.

The AMRF Program Manager is located in MEL's Office of Manufacturing Programs. In addition to overseeing the operation of the AMRF, this office is responsible for managing selected cross-divisional and multi-organizational research and development programs sponsored by other agencies. Individual AMRF technical projects are conducted by the MEL technical research divisions in conjunction with direction from the AMRF Program Manager. The AMRF Program Manager reports to the Deputy Director of MEL and acts as a technical and managerial liaison between MEL and the AMRF's Navy ManTech sponsor. MEL planning and guidance for the AMRF is provided by the MEL Deputy Director, the four chiefs of the MEL technical divisions, along with the AMRF Program Manager.

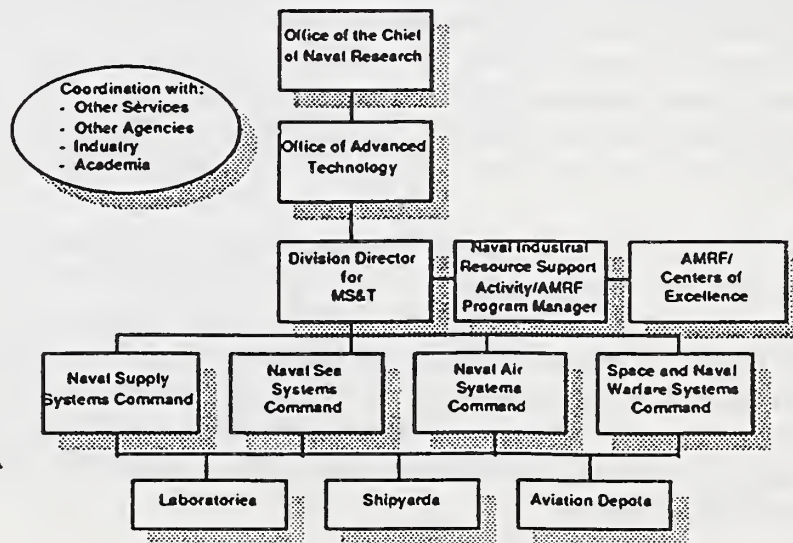
From the Navy perspective, the AMRF is considered to be part of the Navy ManTech Program, which is the primary source of Navy (DOD) funding for the AMRF. The Navy ManTech Program is managed within the Office of Naval Research (ONR). The AMRF interacts with ONR's Division Director for Manufacturing Science and Technology either directly, or through the Naval Industrial Resources Support Activity (NAVIRSA). NAVIRSA provides the Navy Program Manager for the AMRF. The AMRF also interacts directly with the Navy systems commands, laboratories, shipyards, and aviation depots in planning and conducting individual projects.

From the perspective of the rest of DOD, industry, and academia, the activities of the AMRF are conducted primarily on ad hoc bases.

**AMRF Program Organization**



**Navy/ManTech Program Organization**



# Technical Projects

As mentioned previously in this report, there were no new-start projects funded within the AMRF in fiscal year 1994. The conduct of technical project work in 1994 consisted of previous year projects that were either completed or continued. This is not an indication of lack of accomplishment by the AMRF—this is an indication of the state of transition which the AMRF experienced in this year.

In fiscal 1993, about 25 technical projects were underway. It is the completion or continuation of these projects that comprise the portfolio of primary technical work for the AMRF for fiscal 1994. Most of these activities are summarized in the AMRF 1993 Annual Report. Additional information on any of these projects, or copies of the 1993 Annual Report may be obtained by contacting the AMRF Program Office at NIST (tel: 301-975-6100; fax: 301-869-3750).

Two of the technical projects continued within the AMRF in 1994, which will also continue in fiscal year 1995, are summarized below.

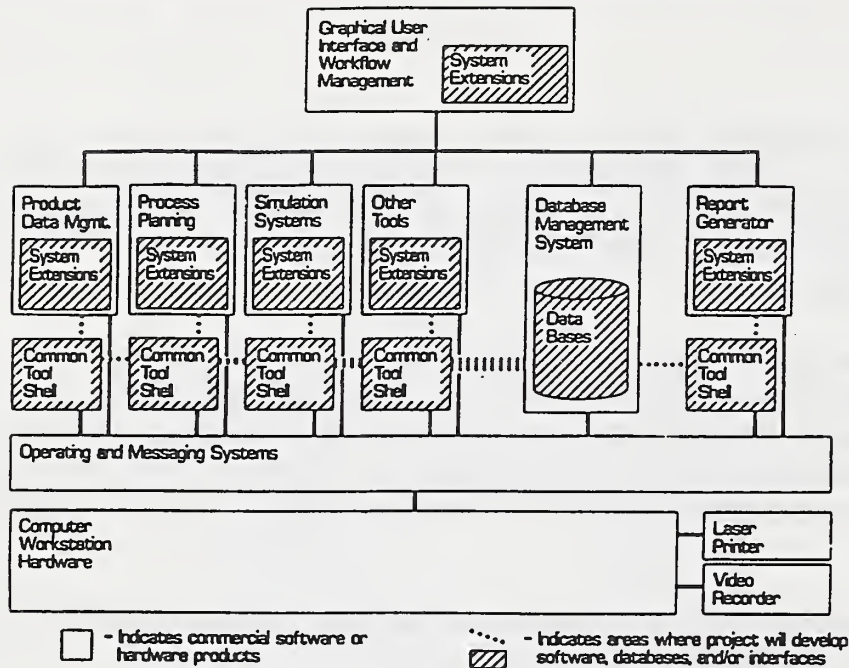
## Computer-Aided Manufacturing Engineering

The overall goal of the Computer-Aided Manufacturing Engineering (CAME) project is to lower manufacturing costs, reduce development and delivery times, and improve product quality through the development and implementation of advanced, integrated manufacturing engineering tools.

Emphasis is initially placed upon developing and integrating an engineering tool kit that will primarily consist of commercially-available tool products. The developed baseline tool kits will be installed at several collaborating facilities. They will be tested and analyzed in order to develop process capabilities databases and interface specifications for the integrated tool environment. A functional reference model of the manufacturing engineering process will be developed, and specifications for an integrated tools architecture will be completed.

A consortium of users, vendors, and researchers is being established to provide input and direction for the project's technical development plan. The consortium will provide the alpha/beta sites for technology testing, which will include NIST, military and industrial facilities.

## System Concept for the Manufacturing Engineering Tool Kit



The tools produced in this project will be used to increase productivity of engineers performing producibility analyses, designing manufacturing systems, evaluating quality costs, and conducting design trade-off studies. A recent study indicated that improved manufacturing and industrial engineering tools could save the DOD about \$300 million annually ("Manufacturing Systems Strategic Plan," Report of the Manufacturing Systems Committee, DOD Manufacturing Science and Technology Program, March 1993). The benefits realized from this project will be applicable to both Defense and commercial manufacturing systems. The developed tool kits will be used by internal DOD manufacturing sites, prime contractors and subcontractors, and commercial manufacturing facilities. Virtually all manufacturing organizations stand to benefit from improved capabilities in the areas addressed by this project.

## Enhanced Machine Controller

The purpose of the Enhanced Machine Controller (EMC) project is to produce an improved factory equipment controller by developing public domain open system interface standards and interchangeable software. The project will demonstrate such a controller incorporating various enhancements that improve the overall performance and operation of machine tools, robots, and coordinate measuring machines.



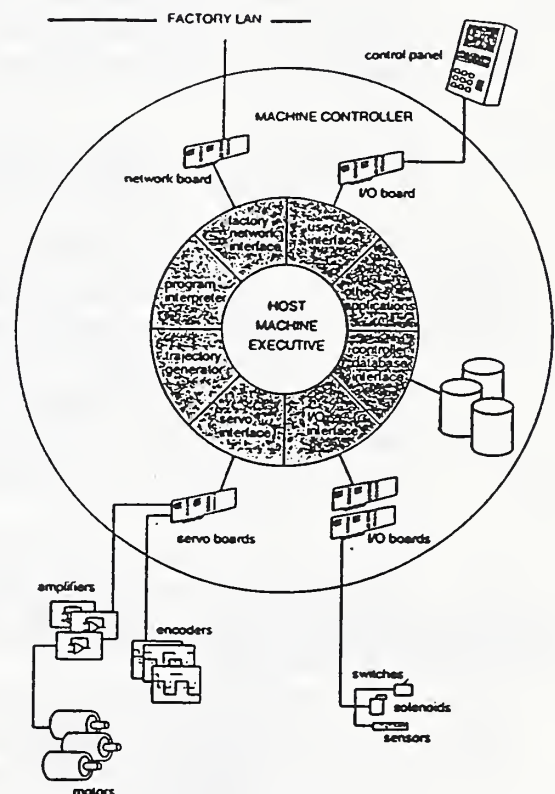
NIST is working with machine tool builders and users, control component suppliers and software vendors to validate and refine an open architecture specification, as well as to implement several prototypes with machine enhancements. While EMC will use commercially available hardware for the controller servo board and discrete input/output (PLC) interface, EMC will also incorporate NIST-developed public domain software to provide the basic functions of the machine controller. The critical machine controller functions will be implemented in software and will be in the public domain. The interface specifications for the controller will be published so that each module can easily be replaced by a functionally equivalent module developed by the user or a third party software/hardware control component manufacturer.

The EMC concept will be demonstrated by developing two different prototype controllers, one for machine retrofit applications and one for high end controller (HEC) applications. Both prototypes will be tested at multiple beta sites involving several applications and controller enhancements to rigorously test the systems in real production environments. A number of workshops have been conducted for EMC with interested representatives from industry and the government, and the beta test sites are being finalized for the project.

EMC was begun in fiscal year 1992. Preliminary versions of both a shop floor controller and a laboratory development controller have been demonstrated. These systems have also been upgraded to enhance robustness and ease of operation. Work is underway for development and testing of the open architecture specifications on the lab controller. Progress is also being made on the integration of enhancements to the shop floor controller, including touch probing, complex path generation, and thermal compensation.

The potential benefits from EMC are great. EMC 2 will be based on widely available, low cost computing platforms. It will enable machine builders, users, and system integrators to cost effectively customize their equipment in order to optimize equipment performance. The modular, open nature of EMC will facilitate reductions in training and maintenance costs, and it will also make retrofits a more practical alternative for many factory machines.

### MACHINE CONTROLLER CONCEPT



## Other Projects/Activities

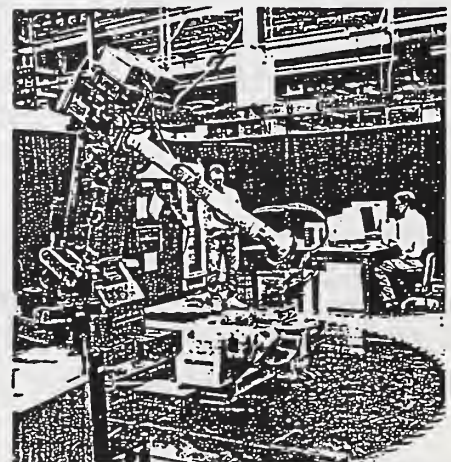
In addition to the continuation of the two projects summarized above, the AMRF conducted a number of activities associated with its secondary functions as described in the Operations section of this report. These functions included, but were not limited to, the following:

- working with the Design and Manufacturing Institute at Rensselaer Polytechnic Institute on selected areas of research pertaining to electronics manufacturing,
- working with the Electronics Manufacturing Productivity Facility to define and develop education and training programs for electronics manufacturing industry employees,
- working with the Industrial Technologies Institute (ITI) on the development and implementation of a program for the conformance testing of STEP applications,
- working with the Institute of Advanced Manufacturing Sciences to develop and implement a manufacturing modernization training program,
- developing a reverse engineering production system with NADEP North Island, CA, and
- assuming primary responsibility for organizing and conducting the national Manufacturing Technology Needs and Issues Conference held at NIST.

During 1994, the AMRF also developed the plans for projects which will be conducted in fiscal year 1995. As fiscal 1995 begins the following is the portfolio of primary active technical projects in the AMRF, along with descriptions of each:

- CAME, described above and in the AMRF 1993 Annual Report
- EMC, described above and in the AMRF 1993 Annual Report
- Advanced Deburring and Chamfering System, described in the AMRF 1993 Annual Report and below
- Robotic Paint Removal System, described below
- Cross-Organizational STEP Adoption Tool, described below
- National Advanced Manufacturing Testbed, described below

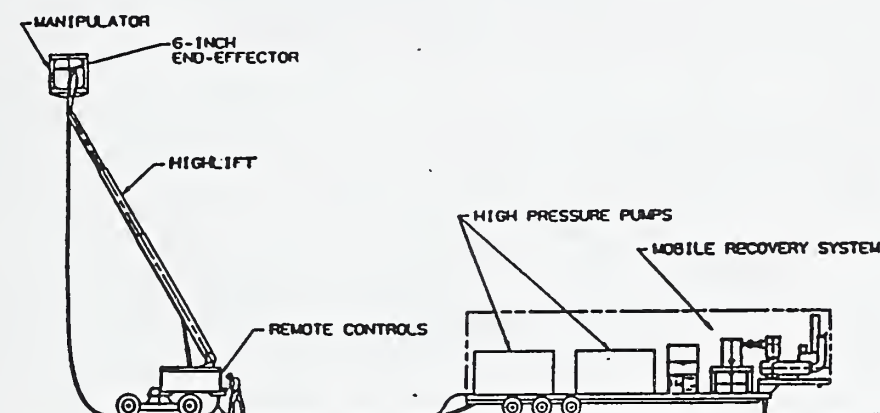
**Advanced Deburring and Chamfering System (ADACS):** The objective of the ADACS project is to develop an automated part finishing system, specifically to perform deburring and chamfering operations, that will be used on tightly tolerated components found in aircraft engines. ADACS, which was active at NIST in 1993, is a joint project between NIST, United Technologies Research Center, and Pratt & Whitney, also with significant involvement from NAVAIR.



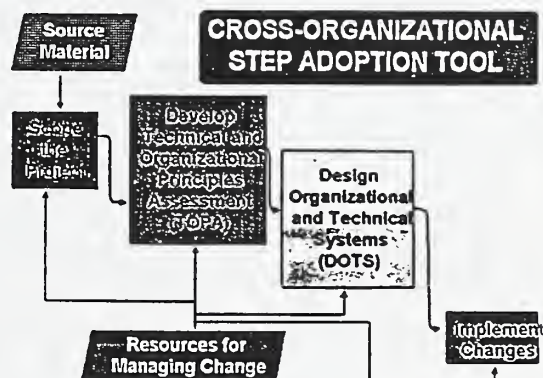
ADACS has already demonstrated a working prototype system at Pratt & Whitney, and it is anticipated that ADACS will achieve completed industrial implementation in 1995.

**Robotic Paint Removal System:** The objective of this project is to integrate robotics, control systems, and sensor technologies into the development of an automated and environmentally safe system for the removal of paint from the hulls of marine vessels. This project, which was begun in 1993, has already produced an initial prototype system which has undergone testing at a Naval shipyard facility. During 1995, the prototype system will be refined and enhanced in preparation for transfer to and implementation at one or more shipyards, including Puget Sound and Pearl Harbor.

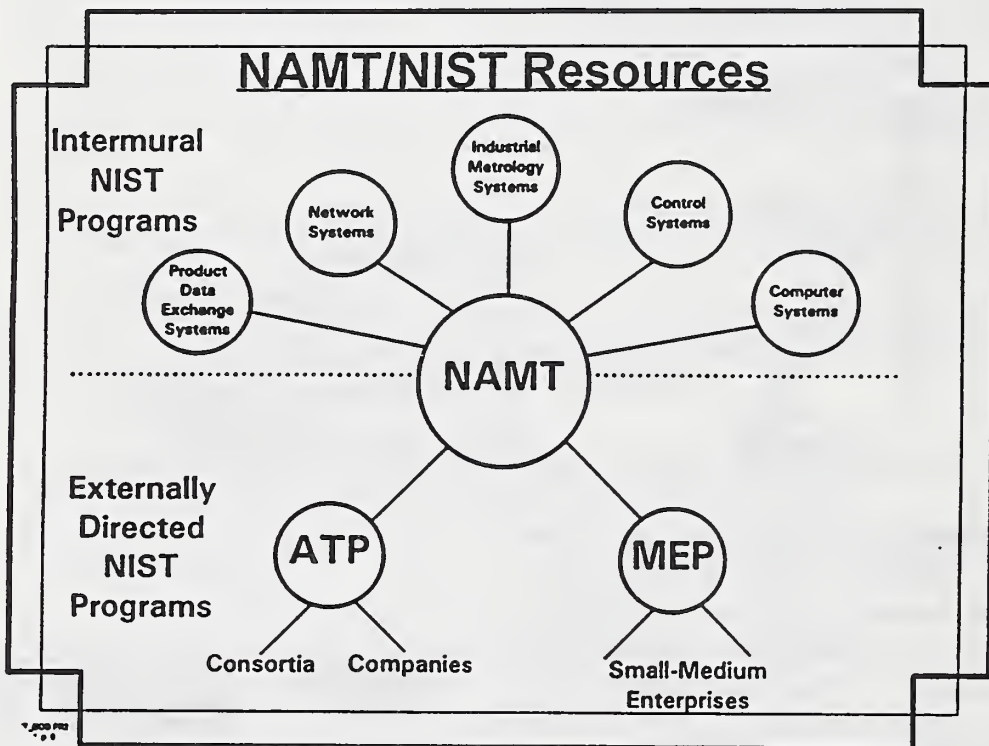
### NAVY WATERJET DEMONSTRATION SYSTEM



**Cross-Organizational STEP Adoption Tool (COSAT):** COSAT, which is managed by NIST and conducted in conjunction with ITI, is a project whose objective is to simplify and optimize the ability of manufacturing firms to reengineer their product development processes. COSAT will accomplish this objective using a methodology developed at ITI in 1990 known as High Integration of Technology, Organization, and People. COSAT takes this methodology, which is a structured means of analyzing the organization and people implications of factory floor manufacturing technology, and applies it to integrated product and process development.



**National Advanced Manufacturing Testbed (NAMT):** NAMT is a large, multi-organizational effort that is in its early planning stages. The objective of the NAMT is to create an advanced manufacturing testbed that will focus on testing and developing with strategic military and industry partners the standards, measurement techniques and selected technologies necessary to configure into a unified whole a confederation of disparate supplier systems that are distributed geographically. This includes the development of a common basis for controlling production; exchanging technical product design, manufacturing and support data; and integrating the business data for order entry, scheduling, and inventory. NAMT, which will consist of a virtual and distributed environment, will result in reduced research and development costs, and more rapid transition from initial concept to final product.



Finally, in addition to the primary projects described here, there are several other AMRF technical projects which may be active in fiscal year 1995. These projects potentially include additional work with ITI on STEP conformance testing, a project for the development of a generic sensor interface for machine controllers, and a project to integrate real-time scheduling software with shop floor data collection systems.



