NISTIR 5225

The Technical Program of the Factory Automation Systems Division 1993

Howard M. Bloom
Larry W. Masters

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

NIST

NISTIR 5225

The Technical Program of the Factory Automation Systems Division 1993

Howard M. Bloom
Larry W. Masters

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

July 1993

U.S. DEPARTMENT OF COMMERCE
Ronald H. Brown, Secretary

NATIONAL INSTITUTE OF STANDARDS
AND TECHNOLOGY
Arati Prabhakar, Director

TABLE OF CONTENTS

FACTORY AUTOMATION SYSTEMS DIVISION
1993 PROGRAM DESCRIPTIONS

1. INTRODUCTION

This report describes the 1993 technical program of the Factory Automation Systems Division (FASD), one of five divisions within the Manufacturing Engineering Laboratory (MEL) at the National Institute of Standards and Technology (NIST). MEL supports the U.S. mechanical manufacturing industry through research and measurement services that are oriented toward a modern automated environment. The laboratory programs are organized into five areas: Automated Manufacturing, Precision Engineering, Robotics, Manufacturing Data Interface Standards, and Support for Manufacturing Technology Transfer. (See [JACK92] for a detailed description of the major technical programs in the Laboratory.)

The work of FASD contributes primarily to the automated manufacturing and data interface standards areas. The Automated Manufacturing efforts lead to the development of methods and systems for design, process planning, scheduling, production management and inspection. The Manufacturing Data Interface Standards thrust, which is expected to experience the greatest growth in the next decade of all Laboratory programs, develops the national standards for a "paperless" manufacturing and logistics support system. Data interface standards are an essential element in the U.S. industry's efforts to draw upon the principles of concurrent engineering, a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support [CARV91].

In recent years, the programs addressed by the Division's activities have been described through several key studies:

- The National Critical Technologies Panel [NCTP91] identified Flexible Computer Integrated Manufacturing (FCIM) and Systems Management Technology (SMT) as key technologies required for Concurrent Engineering.

- The Agile Manufacturing Forum (consisting of key U.S. industry leaders) developed a vision for 21st century manufacturing [AM92]. There were specific roles for NIST that related to technology and standards development.

- The FCCSET Advanced Manufacturing Initiative [AMI92] which has been developed identifies a key thrust in the area of "Integrated Tools for Product, Process, and Enterprise Design."

These reports along with the Department of Defense's Critical Technologies Plan [DCTP91] define a set of objectives in the areas of FCIM and SMT that will enable the vision of the 21st century manufacturing in the United States to be realized. These objectives have been organized around five key technologies:

- o Enterprise Integration - Develop enterprise software tools that make use of manufacturing process knowledge to promote integration concepts that apply across entire industry sectors.

- o Product Data Exchange - Implement standards-based application protocols for data exchange across manufacturing processes.

- o FCIM processes - Promote programs to understand the science of key generic manufacturing processes, with special emphasis on extending design across the product life cycle.

- o Communications and Networking - Demonstrate a robust integrated manufacturing environment with a distributed network utilizing network protocols to transfer data.

- o Database and Database Management - Develop FCIM data models and establish fully integrated product databases.

FCIM with all its associated technologies has clearly been identified as a critical technology in making U.S. industry more competitive internationally. Standards have also been identified as key enablers in the development of the "virtual enterprise" which allows for the broad base of U.S. companies to work together in producing world class products [OTA92]. New approaches are urgently needed to facilitate the timely development of responsive standards. The future will involve the concurrent development of new technology and corresponding standards that allow vendors to build products to meet the technology needs.

2.0 DIVISION OVERVIEW

2.1 Mission and Function

The mission of the Factory Automation Systems Division (FASD) is to provide a focus for national research and standards efforts related to information systems for manufacturing.

In recent years, information technology and information systems have become increasingly important in the manufacturing enterprise. Improved information systems are key elements in refining current manufacturing methods and in creating new technologies to develop products, reduce production costs, shorten commercialization lead times, and raise overall product quality. In carrying out its mission, the Division contributes to the strength of manufacturing

in the United States and to the ability of the U.S. to remain competitive in world markets.

The objectives of the Division are the following:

- o Perform research and development into advanced manufacturing systems and networking.
- o Test and develop computer software, manufacturing systems, and systems integration necessary for successful operation within the United States manufacturing community.
- o Assist industry to implement voluntary consensus standards relevant to CIM, including standards for networking, electronic data interchange, and digital product data sharing.
- o Make high-performance computing and networking technologies an integral part of design and production of products.
- o Conduct research to identify and overcome technical barriers to the successful and cost-effective operation of advanced manufacturing systems and networks.
- o Facilitate industry efforts to develop and test new applications of advanced manufacturing systems and networks.
- o Involve companies which both manufacture and use systems.
- o Provide training for industry on the effective use of new technologies.
- o Work with private industry to develop standards for the use of advanced computer-based training systems, including multimedia and interactive learning technologies, that will accelerate the efficient use of the advanced manufacturing systems.
- o Provide mechanisms for the exchange of information about advanced manufacturing systems and networking.

The scope of the Division's programs is the application of information technology and associated standards to a multi-enterprise environment [CARV91]. The vision of the future manufacturing environment (see Figure 1) involves creating the framework to support the "virtual enterprise." Independent enterprises operating as suppliers, system integrators, merchants, and customers are integrated by an information network into an effective system. Within each of these enterprises the various product-related functions and product life cycle stages are integrated through the sharing of product and process data,

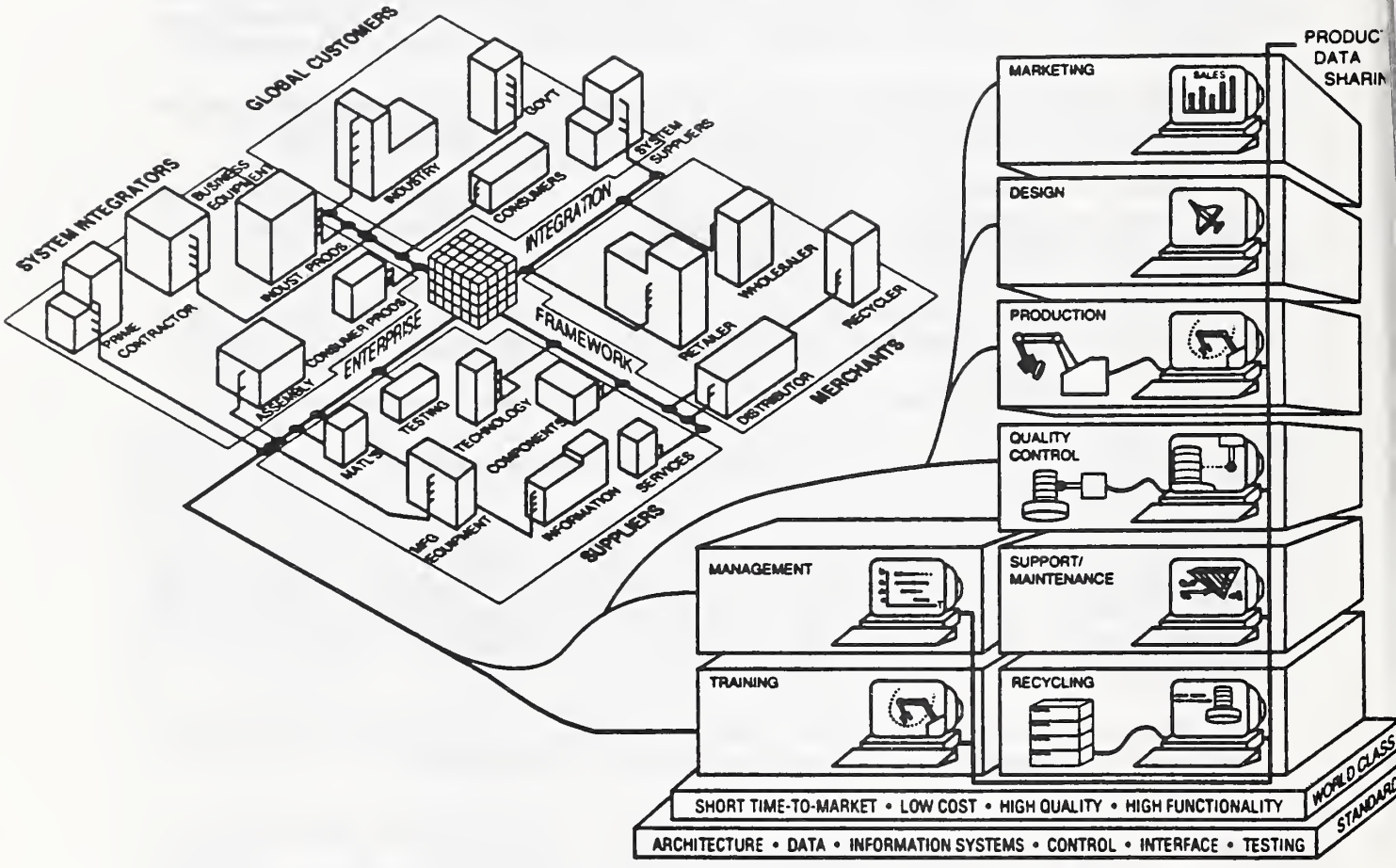

Figure 1. A Portrayal of 21st Century Manufacturing

although each stage maintains its own view of the product. Based upon standards, the inter- and intra- enterprise framework enables the integration of the product life-cycle processes such as design, manufacturing, marketing, maintenance, and improvement. This is commonly referred to as the practice of multi-enterprise concurrent engineering, through which the characteristics of world class products are achieved. These characteristics are short-time-to-market, low cost, high quality, and high functionality.

In order to meet the requirements of the industrial community, the Division has developed a paradigm to define the type of projects initiated by the Division. This paradigm consists of four major elements: (a) Active role in developing required standards, (b) Lead role in developing the testing and evaluation methods to ensure that quality standards are developed and implemented by vendors, (c) Perform research and development into the technologies required to develop the standards and implement the advanced manufacturing systems that conform to the standards, and (d) Work with pilot facilities in implementing the FCIM standards through the involvement of FCIM vendors.

2.2 Technical Programs

The scope of the Division's programs is the application of information technology to a multi-enterprise environment. More specifically, the Division's staff members apply their expertise in information technology and their knowledge of manufacturing to promote multi-enterprise concurrent engineering in the manufacturing of discrete parts.

The long range objectives of the Divisions's research can be categorized under the following five areas:

Enterprise Integration

- Employ a total systems approach to identify and develop enterprise software tools.
- Make available manufacturing process knowledge and computers able to simulate and model the entire manufacturing process.
- Promote integration concepts across entire industry sectors.

Product Data Exchange

- Initiate a major standards-based application protocol data exchange effort targeted at manufacturing to alleviate the lack of data exchange capability among computer-aided activities (e.g. CAD, CAPP). This activity provides extensive support to the development of STEP (Standard for the Exchange of Product Model Data), Draft International Standard 10303.
- Promote wide use of standard product data that is fully implemented at all levels of design and manufacturing.
- Make available testing methodology for vendor implementations.

FCIM Processes

o Promote programs to understand the science of key generic manufacturing processes.
o Develop new design tools and algorithms.
o Extend design to the entire product life cycle.
o Develop modular, flexible, reconfigurable, affordable production processes.
o Develop modular product design incorporating reconfigurability and upgradability.
o Apply integrated design architecture and product data to shop floor control, including collaborative design, knowledge base concepts for engineering design and manufacturing, use of design tools, and next-generation controllers.

Communications and Networking

o Develop a fully distributed network serving enterprise.
o Demonstrate robust integrated manufacturing environment.
o Establish a national, publicly accessible and interactive broadband communications network.
o Obtain and share information quickly and link information directly to the production processes.
o Implement seamless networking in the industrial base utilizing network protocols to transfer data between customers and contractors.

Database and Database Management

o Develop database models to support FCIM functions.
o Define generic database for enterprise integration.
o Establish fully integrated product databases for design, procurement, manufacturing, training, and administrative functions that utilize an industry standard distributed object-oriented database, enterprise integration framework and database modeling.

Typical outputs for the Division include:

- o Draft specifications for future standards
- o Journal papers describing research results
- o Prototype software systems that demonstrate proof-of-concept
- o Test methodologies for supporting standards implementations
- o Testbeds for use by NIST, industry, and academia

To help ensure that the work carried out by the Division is, to the extent possible, consistent with its programmatic objectives, the following criteria are used in helping select industrial and/or sponsor needs to be addressed by the Division:

- o The work is consistent with the FASD/MEL/NIST mission
- o The need is verifiable
- o Results of the work provide potential technological and/or economic impact to U.S.

o An achievable objective can be stated, or for high-risk tasks, the potential payoff is large
o Resources (funds) are likely to be available

2.3 Funding

For the past several years the Division budget has remained at approximately the $7.3 to 7.5M level. There are primarily two types of funding available to the Division: (1) NIST-supported such as base program, Director's Reserve, Competence, new initiative, and ATP (Advanced Technology Program) collaborative participation; and (2) Other Agency supported.

At the current time, the Division's fiscal-year budget is about $7.3M, with about $700K of Other Agency, year-end carry-over.

For NIST-type funding, the Division has $1.6M of base program funding (specified for AMRF-related projects and for chairing the IPO/ISO product data standards organizations), $500K of ATP funding, $130K of funding from another laboratory (on Metal Powder Processing), and approximately $430K for Director's Reserve.

For Other Agency funding, the Division has approximately $5M, including carry-over, with approximately $2M in the area of Product Data Exchange.

Most of the Division's funding is derived from technical and standards-related projects that are supported by other government agencies. Several of the projects are also supported, to some degree, with NIST funding where there is the possibility of leveraging the two funding sources in areas of common interest. Government agencies are listed below with the projects being supported (note that some are only carry-over):

Air/Force Mantech	Enterprise Integration Framework
ARPA	Manufacturing Research Testbed
	Persistent Object Base Evaluation
	National Process Planning Testbed
	Machine Tool Controller (collaboration with MEL Divisions)
Defense Log. Agency	PDES for Apparel
DoD/CALS	National PDES Testbed
Navy/Mantech	Factory Engineering
	Interorganizational Assessment of STEP (collaboration with Industrial Technology Institute, ITI)
	Conformance Testing for STEP (with ITI)
	Best Manufacturing Practices
	MAP/TOP Lab (collaboration with GM)
	Reverse Engineering (U.S. Navy)

	Reference Architecture for Control (coll. with Robot Systems Division)
	Intelligent Modules for CIM (collaboration with IMAR)
	Software Performance for CMM
	Learning and Process Control (coll. with Matls. Science & Engineering Laboratory, MSEL)
U.S. Postal Service	Postal Equipment Message Specification

2.4 Division Staff

The Division is located within the Manufacturing Engineering Laboratory (MEL), which is one of the eight technical laboratories at NIST. In addition to FASD, there are four other Divisions in MEL: Automated Production Technology, Fabrication Technology, Precision Engineering, and Robot Systems. There are two offices: Manufacturing Programs and Industrial Relations.

Divisions at NIST are organized into technical groups and program offices. In the case of any of the technical groups in FASD, the work includes not only advancing the state of the art in relevant technologies, but active participation in national and international standards bodies to ensure that such technologies can be implemented by U.S. industry under the overall framework of Flexible Computer Integrated Manufacturing (FCIM). As part of each group's mission, it is expected that efforts will be undertaken to provide the following functions: technology transfer of group's efforts to industry, conformance testing methods for vendor implementations of technology, training for industry on effective use of technology, and mechanisms for the exchange of information about the technologies.

The Division has a total staff of 52 that fall into the following categories: Technical Professionals - 41, Support and Administrative - 11. There are presently 6 supervisors - Division chief, deputy division chief, and four group leaders. There are nine top level professionals (i.e. ZP5 pay band level).

As illustrated in Figure 2, at the current time, there are four groups in the Division: Production Management Systems, Product Data Engineering, Integrated Systems and Machine Intelligence. In addition, there are two program offices: CALS/PDES Project Management Office and IGES/PDES/STEP Administrative Office.

The Production Management Systems Group performs research and development work to advance the state of the art for manufacturing systems and to identify open interfaces that will support interoperability, when these systems are used by different vendors. Examples of the types of systems addressed include control architectures, cell controllers, production scheduling, process planning, and off-line programming.

FACTORY AUTOMATION SYSTEMS DIVISION

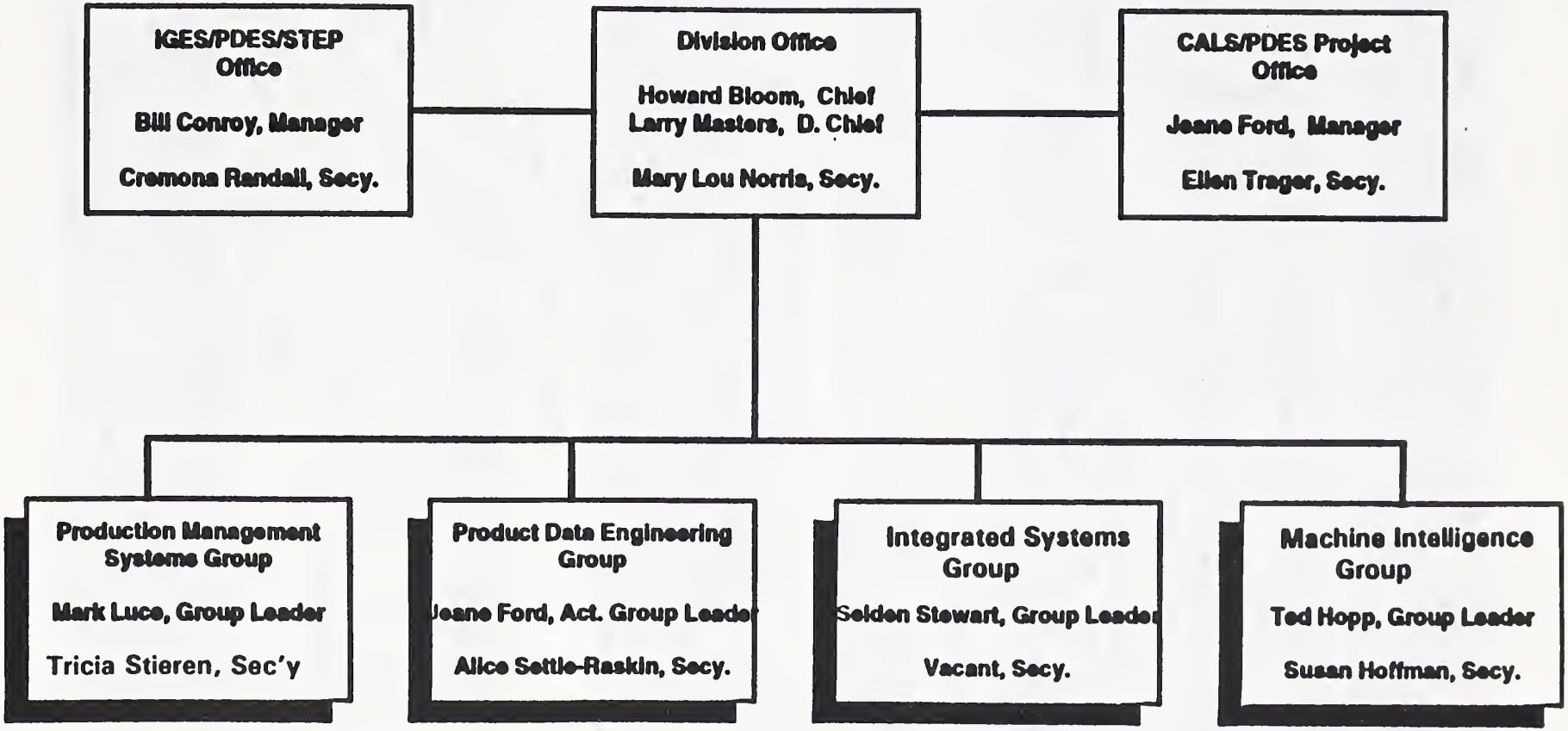

Figure 2.

The Product Data Engineering Group performs research and development into the technologies required to develop a standard product data model. Such technologies include product data modeling, data access and storage, software tools, and testing procedures.

The Integrated Systems Group performs work to advance the knowledge and understanding of information technology (computers, software, and networks). There are both research and applied components to the activities of the Group. The research includes technology transfer through standards development and work in distributed systems, configuration management, and enterprise integration.

The Machine Intelligence Group performs research and development in such areas as metal powder production, apparel product data exchange, inspection software performance testing, and inspection methods with an increasingly focused effort in mechanical tolerancing and related issues.

2.5 Facilities

The Division makes use of a variety of facilities in carrying out its program. The following is a list of the facilities grouped under the Division's five key technology areas:

Enterprise Integration

o The Computer-Aided Factory Engineering (CAFE) laboratory is just being initiated and will contain a collection of workstations with a variety of CASE tools and software systems that are being integrated into a CAFE environment. The laboratory will promote the application of information technology to the design and engineering of factories.

Product Data Exchange

o The National PDES Testbed (NPT) testing facility, in place for several years for validation testing of STEP part models, will be available for performing conformance testing and interoperability testing on any Application Protocols (APs) as they are defined. In addition, early validation testing capability will be available through a broad range of toolkits obtained from industry.

FCIM Processes

o The Rapid Response Manufacturing Facility (RRMF) is being established as part of the Division's interaction with the ATP Rapid Response Manufacturing program (i.e. National Center for Manufacturing Sciences, NCMS, consortium). This will be a STEP-based manufacturing machined parts facility. This facility will make use of knowledge-based systems to allow for

intelligent integration of the manufacturing process. Critical research into knowledge representation schemas will be required in order to develop the set of knowledge-based rules for each of the major manufacturing processes. There will be an integrated network of design workstations, machine tools, in-process and post-process inspection systems, and process planning/NC/Inspection programming systems all sharing information from a common knowledge-base system.

o The Process Planning Testbed was established to encourage open collaborations between process planning researchers from government, academia and industry. The Testbed will service information management and communication needs of the process planning community by providing on-line access to relevant information bases, and mailing lists, and by conducting regular workshops. It will also provide a suite of system development and integration tools, along with databases containing sample populations of process plans, factory models, and designed parts to facilitate integrated process planning system development. The testbed will serve as a conduit of information on issues and advances in the field of process planning, and help unify development approaches adopted by academia, industry and government research programs.

o The Design Laboratory provides a wide range of design analysis tools and "design for x" tools that have been integrated into a design workstation environment. A variety of CAD systems are available for use. These systems will be integrated over the FASD network into the AMSANT (Advanced Manufacturing Systems and Networking Testbed). The design systems will all have interfaces to STEP application protocols. A library of design knowledge for various applications will be available for use.

o The Algorithm Testing System (ATS) Laboratory provides the ATS as a mechanism to test the performance of curve- and surface-fitting software used on coordinate measurement machines.

2.6 Major Customers

In carrying out its mission, the FASD has established a special relationship with standards organizations, R & D institutions, other government agencies, industry end-users, and vendors (see Figure 3). FASD works with its partners by providing testing methodologies, integration technologies, and feasibility demonstrations in support of the development of standards, technologies and world class products.

The ideal project involves partners from all the defined aspects. Part of every project should be the creation of a special

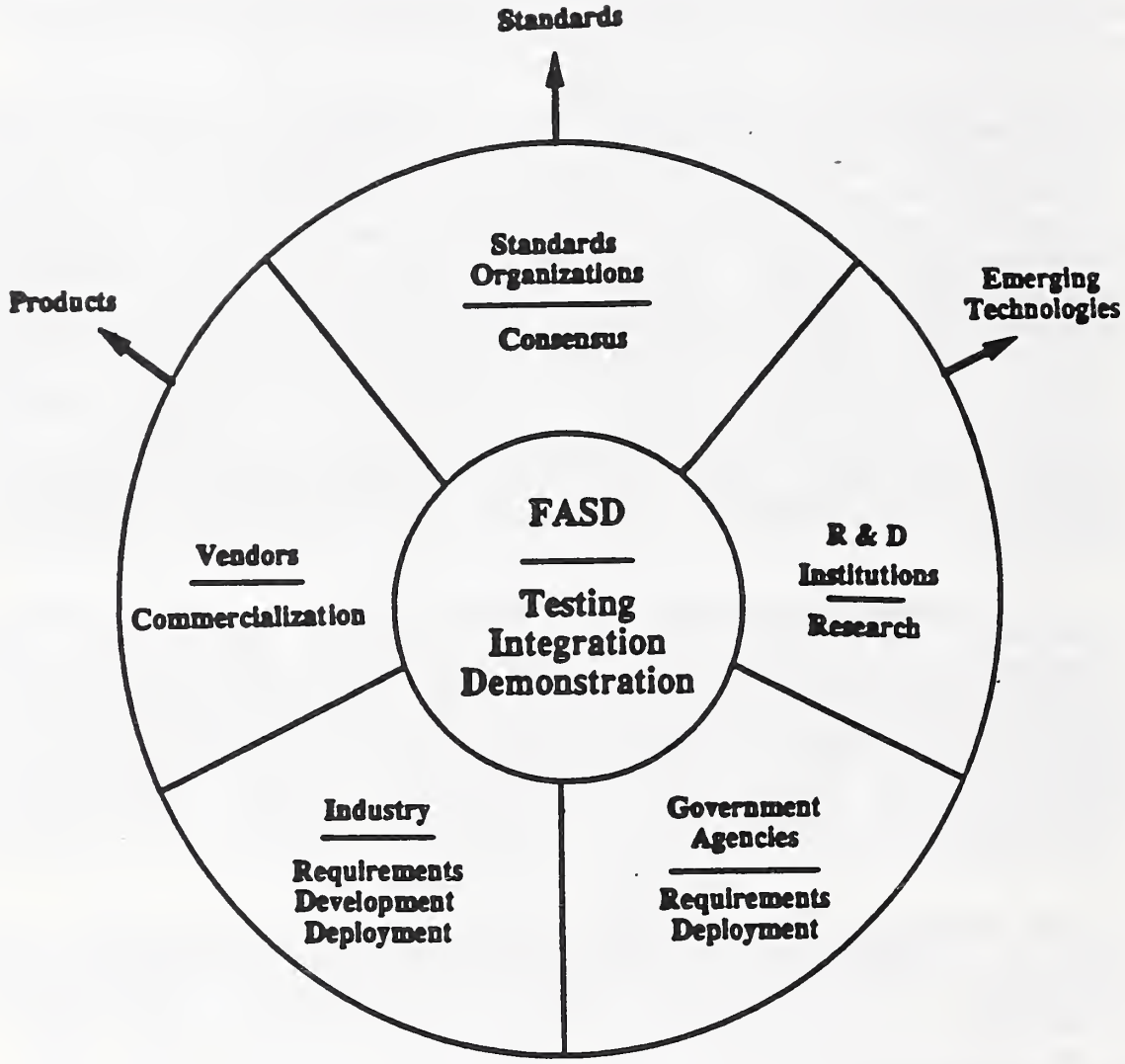

Figure 3. The Factory Automation Systems Division, (1) in a partnership with standards organizations, industry, other government agencies, and research and development institutions, (2) provides testing methodologies, integration technologies, and feasibility demonstrations (3) in support of development of standards, technologies, and products.

relationship through Cooperative Research and Development Agreements (CRDAs) involving industry, Memorandum of Understanding (MOUs) involving standards organizations, joint funding involving other government agencies, and grants involving research institutions. These special relationships have greatly contributed to the success of the programs and to the production of quality standards, new technologies and world class products.

2.7 Interactions with Other Organizations

Table 1 contains a list of Cooperative Research and Development Agreements (CRDAs) in effect during FY93.

2.7.1 Standards Organizations

Manufacturing and product-related standards have become internationally important in trade agreements. A June 1991 meeting between U.S. and European Community representatives led to the following joint communique: "International standardization and openness of conformity assessment were an indispensable means of eliminating or avoiding the creation of technical barriers to the international trade." Recently, both government and industry have realized the importance of accelerating and participating in the development of standards because standards impact the ability of U.S. industry to be globally competitive. The Office of Science and Technology Policy stated in a report published in September 1990 that the Administration's strategy to implement U.S. technology policy includes encouraging "increased U.S. participation in multi-lateral international standardization efforts through the standards activities of the National Institute of Standards and Technology." Accordingly, a key customer of the Division has become the U.S. standards community. Division staff members serve in chair positions and on technical development committees, and they provide support for secretariats.

The following is a list of national and international standards organizations with which the Division interacts, along with the names of staff members who serve in key capacities.

National

AAMA (American Apparel Manufacturers Association) CIM Standards Committee (T. Hopp; T. Lee)

ANSI (American National Standards Institute)
- B89: Dimensional Metrology
  - B89.3.2: Measurement Methods (T. Hopp; S. Feng; M. Algeo)
  - B89.4.10: Coordinate Measurement Machine Software (T. Hopp; M. Algeo)
- Electronic Product Data Harmonization Organization

CIMSB (CIM Standards Board)
X3: Information Processing Systems
X3T.2: Data Interchange (E. Barkmeyer)
X3H2.1: Remote Database Access
X3J16: Programming Language C++
Y14: Standards for Drawings and Drafting Practices
Y14.5.1: Mathematics of Dimensions and Tolerances (T. Hopp; M. Algeo; S. Feng)

IGES/PDES Organization: Product Data Standards and Technology
Chair: B. Conroy
Editor: J. Wellington
Exec. Asst.: M. Zeltman
Application Validation Methodology
Architecture, Engineering Construction
Composites
Dictionary/Methodology
Drafting (A. Barnard)
Electrical Applications
Finite Element Analysis
Form Features
Geometry
Implementation Specifications (Chair: J. Fowler)
Implementors
Interoperability Testing Methodology
Manufacturing Technology (S. Ray)
Materials
Mechanical Product Definition
PDES Development Methods
PDES Visual Presentation
Product Life Cycle Support
Product Structure
Qualification and Integration
Recommended Practices
Software Products
Standard Parts
Technical Publications
Test Case Design
Testing Methodologies
Tolerance (Chair: J. Crusey; S. Feng)

International

ISO (International Organization for Standardization)
TC10: Technical Drawings
TC10/SC1: Basic Conventions
TC184: Industrial Automation Systems and Integration
TC184/SC4: Industrial Data and Global Manufacturing Programming Languages (Chair: B. Smith; J. Wellington)
TC184/SC4/WG2: Parts Libraries
TC184/SC4/WG3: Product Modeling (J. Crusey)

TC184/SC4/WG4: Qualification and Integration (M. Mitchell)
TC184/SC4/WG5: STEP Development Methods
TC184/SC4/WG6: Conformance Testing Procedures (M. Mitchell)
TC184/SC4/WG7: Implementation Specifications
TC184/SC4/WG8: Manufacturing Management Data (S. Ray; K. Senehi)
Joint WG9: Electrical/Electronics Applications
TC184/SC5: Architecture and Communications
TC184/SC5/WG1: Reference Models

ISO/IEC (International Organization for Standardization/International Electrotechnical Commission) Joint Technical Committee 1

JTC1/SC22/WG11: Language Binding Techniques (Editor: E. Barkmeyer)

2.7.2 Consortia

To compete with European and Japanese industries, U.S. companies have increasingly joined together to form research and technology consortia. The Division has been working with consortia in the development of precompetitive technology and also for accelerating the development of standards. Consortia accept NIST as a neutral government agency, as a testbed for technology transfer into the companies, and for development of test methodology for controlling the quality of the output. The Division interacts with the following consortia:

Name	Program/Project
PDES, Inc.	National PDES Testbed
AAMA	PDES for Apparel Industry
Powdered Metals Consortium	Metal Powder Processing
CAM-I	Systems Integration
MCC	Enterprise Integration
Sematech	Systems Integration
European Strategic Prog. for R&D in Information Technology (ESPRIT)	US/EC Collaboration on Manufacturing System Research

2.7.3 Industry (Users of Manufacturing Technology)

Large manufacturing companies continue to view the Division as a means of technology transfer of new research into their own laboratories for further development. In addition, the Division uses the interaction to better understand U.S. manufacturing needs. The Division has joint research efforts with the following companies:

Name	Program/Project
Boeing	Manufacturing Systems
GM/EDS	IGES/PDES/STEP Administrator
IBM	National PDES Testbed
GM	Manufacturing Systems Integration
Industrial Technology Institute (ITI)	STEP Conformance Testing and Interorganizational Assessment for STEP Adoption

2.7.4 Industry (Producers of CIM Technology)

The Division has become a mechanism for demonstrating new technologies that are available from CIM (Computer Integrated Manufacturers) vendors. In addition, the prototype systems developed through the Division's testbeds are made available to vendors for future development of actual products. The following vendors are users of the Division's facilities:

Name	Activity
Control Data	Information modeling system software donation
D. Appleton Co.	Information modeling system software donation
DEC	VAX 8810 computer system, workstations, and software donation
Graphael	Object-oriented database software donation
HP	Workstation loan (expected)
IBM	Workstations and CAD software loan
ICAD	CAD software donation
ITC Integrated Systems, Inc.	Advance the development and application of tool management within the MSI (Manuf. Systems Integration) architecture
ModaCAD	Apparel CAD software donation
Ontologic	Object-oriented database software donation
Oracle	Relational database software donation
Prime/CV	CAD/CAM hardware and software donation
Pritsker	Scheduling and control software donation
Quantum Access	CD-ROM Retrieval Software donation
Savoir	Emulation of control systems software donation
Serviologic	Object-oriented database software donation
Systems Integration Specialist, Co.	Participate in the development of standards relevant to OSI protocols
Versant	Object-oriented database management system and software donation (expected)

2.7.5 Universities

The Division is developing a new role in its relationship with university researchers. Through the sponsorship of other government agencies such as ARPA or DLA, universities have been

funded to work on critical problems relating to engineering design and manufacturing. The Division is helping to integrate the work and to transfer the results of the work among the participating universities. The outcome of this activity is more effective sharing and utilization of government-sponsored university research results. The universities listed below are participating in joint research with the Division.

Sponsor/Project	University
ARPA/Manufacturing Research Testbed	Carnegie Mellon University, Cornell University, Purdue University, Rensselaer Polytechnic Institute, Stanford University, University of Utah
ARPA/Persistent Object Base Evaluation	Massachusetts Institute of Technology, University of Colorado, University of Oregon, University of Wisconsin, Carnegie Mellon University, University of Utah, Rensselaer Polytechnic Institute
DLA/PDES for Apparel Industry	Clemson University, Fashion Institute of Technology, Georgia Institute of Technology, North Carolina State University, University of Southwestern Louisiana
Navy Mantech/Intelligent Module	University of California at Los Angeles, University of Southern California, Arizona State University, California Institute of Technology University of Arizona
Contract/System Integration AMRF and NIST/Manufacturing Systems Integration	Loughborough University

Table 1. Cooperative Research and Development Agreements in Effect During FY 1993

Research Partner	Project Title/Scope
American Heuristics Corp.	Computer Aided Process Planning and Cell Control
National Center for Manufacturing Science (NCMS)	Rapid Response Manufacturing Project/Work collaboratively to develop the key technologies that will enable US manufacturers to utilize RRM principles
Object Databases, Inc.	Advance the development and Application of Manufacturing Systems Using Object Oriented Databases
ModaCAD	Apparel Product Data Exchange Specification
Boeing Computer Services Company	Automated Manufacturing in the Aerospace Industry
General Motors Corporation (Technical Center)	Computer Integrated Manufacturing Based on the Manufacturing Automation Protocol
D. Appleton Company, Inc.	Data Dictionary Development
General Motors Corporation (Technical Center)	Development of Intelligent Monitoring and Debugging Tools for CIM
System Integration Specialists Company, Inc.	Manufacturing Messaging Specification Support Software

3. DESCRIPTION OF PROGRAMS AND PROJECTS

This chapter contains brief summaries of each of the Division's FY 93 projects, divided according to the five key technology areas cited earlier (Enterprise Integration, Product Data Exchange, FCIM Processes, Communications and Networking, and Database and Database Management).

3.1 Enterprise Integration

3.1.1 Manufacturing Systems Integration

Statement of Need: This project is responsive to the industry need for integration of manufacturing systems. It is estimated that, by 1994, systems integration spending will exceed information technology spending for hardware, software, communications and service for the U.S. government. Currently, the typical approach to systems integration is to customize each application. While the customized approach may meet the specific configuration need, the system is seldom applicable in a broader sense.

Objectives: To design a reference architecture for discrete machined parts which incorporates an integrated production planning and control environment; to establish a testbed for production management architectures which integrate process planning, production planning and shop floor control.

Implementation Mechanisms:

- o Demonstration of prototype system
- o Published papers and reports
- o Exchange of information with potential users through visits
- o Development of information models and interface specifications for use in Navy procurement specifications for planning and control systems

Prior Accomplishments/Deliverables: Papers on Production Management Information Model [RAY92-1], MSI Integration Architecture [SENE91-1], Control Entity Interface Specification for Controllers [SENE91-2], Control Entity Interface Specification [WALL 93-1].

FY93 Milestones:

- o Complete Software Integration (11/92). This milestone covers the final integration of the MSI and MCES software applications which conform to all interface specifications.

- o Demonstrate software during Automation Open House (12/92). Demonstrate a working prototype production cell which conforms to the MSI architecture specification. The demonstration includes the Emulated Production Cell software which will show emulated machines running a batch of parts.

o Publish NIST reports on Control Entity Interface Specifications (4/93) and MSI Production Management Information Models (5/93)

o Publish papers on Selected Aspects of the MSI Architecture (7/93), Lessons Learned from Implementing the CEI using MMS (6/93), A Production Management Information Model for Discrete Manufacturing (1/93)

3.1.2 Computer-aided Factory Engineering

Statement of Need: This project provides the focus for the development of new technologies, methods, tools, standards and collaborative efforts which are required to implement computer-aided tools for engineering manufacturing systems of the future.

Objectives: To investigate critical issue areas pertaining to engineering U.S. factories and to identify and develop solutions for computer-aided factory engineering. This project will accelerate the application of computer technology to the design and engineering of manufacturing systems for DoD weapons programs and US industry.

Implementation Mechanisms:

o Work with stakeholders (system developers, vendors and users) to identify critical technology-related issues and approaches to addressing the issues and implementing the new technologies

o Organize and sponsor workshops for the exchange of information and knowledge

o Published papers and reports; conference and workshop presentations and demonstrations

o Collaborative programs with industry (CRDAs)

o Development of requirements specifications for prototype CAFE environments, development of new engineering tools and incorporation of results through standards bodies

Prior Accomplishments/Deliverables: This project was initiated in FY92. Accomplishments prior to FY93 focused upon the development of a research approach and detailed research plans.

FY93 Milestones:

o Complete development of project plans (12/92)

o Prepare and deliver technical presentations on CAFE (Automation Open House, 12/92; local SME Chapter, 12/92; CAFE Workshop, 4/93; IFIP Conference, 9/93)

o Edit and publish proceedings of CAFE Workshop (7/93)

o Develop preliminary requirements specifications for a prototype CAFE environment (8/93)

o Report on CAFE environment requirements for use by researchers and system developers (9/93)

o Present construct tools demonstration (9/93)

3.1.3 Enterprise Integration Framework

Statement of Need: Enterprise integration is the coordination of people, processes, and information flow across a manufacturing enterprise. This project was established to provide the focus for building competitive US manufacturing environments for the twenty-first century by helping industry identify the technical barriers to EI and develop the needed technologies and standards to overcome the barriers.

Objectives: This project, begun in FY92 and carried out in FY93 with limited carryover funding, has had as its objectives to 1) offer technical expertise to the Air Force's Technical Advisory Board for EI and 2) promote international collaboration in EI.

Implementation Mechanisms:

o Stimulate, through National and international standards bodies, the development of appropriate standards for EI
o Establish collaborative research with US industry as well as international organizations
o Published papers and reports

Prior Accomplishments/Deliverables: The activities in FY 92 included 1) participating in international activities, including conferences and workshops, aimed at identifying the technical barriers to EI as well as approaches to overcoming those barriers and 2) providing recommendations to the Air Force on strategies for carrying out EI research activities.

FY93 Milestones:

o Progress Report on EI Activities (4/93)

o Work with leaders in the US industry to identify barriers to the successful application of EI strategies

3.2 Product Data Exchange

3.2.1 IPO/ISO Management

Statement of Need: The successful development and implementation of the Standard for the Exchange of Product Model Data (STEP) is critical to the US industry's need for standards to enable the reliable and effective exchange of product data. This project, termed the IGES/PDES/STEP Administration Office, provides leadership in the international activities to develop STEP.

Objectives: To provide the chair role of technical coordination for activities of the IPO General Assembly; to provide the role of the Chair and Secretariat for the ISO TC 184/SC4; to provide administration of the US TAG to SC4.

Implementation Mechanisms:

The activities of the project are aimed at developing and implementing the standard, STEP and maintaining the existing national standard IGES.

Prior Accomplishments/Deliverables:

- o ANSI accredited the IPO as the US national standards body for product data in the US (6/92)
- o The IPO was incorporated as a not-for-profit organization. Its sponsoring body is the US Product Data Association (US PRO).
- o The National Initiative for Product Data Exchange (NIPDE) was initiated under IPO leadership (2/92)
- o The IPO Steering Committee established a policy for transition from IGES to STEP
- o A special team to accelerate the completion of the Initial Release of STEP was established (2/92)

FY93 Milestones:

- o Workshop to complete the technical work on the Initial Release Parts
- o Continue IPO leadership of the NIPDE
- o Expansion of US PRO/IPO activities in support of the strategic plan currently under development
- o Registration of all Initial Release Parts as DISs
- o Introduction of the Initial Release to US vendors and users; development of support for implementation, testing and education
- o Development of STEP capabilities beyond that of the Initial Release
- o Approval of the STEP Initial Release and IGES Version 5.2 as ANSI standards
- o Expansion of validation and testing programs for IGES and STEP
- o Transition of distribution of standards documentation to IPO/NCGA

3.2.2 STEP Requirements Management

Statement of Need: DoD, U.S. Industry and other Government agencies need a comprehensive process for managing STEP requirements. A collective understanding of requirements is required to enable identification opportunities for collaborative development and implementation projects and ensure that STEP meets the needs of the end-user community.

Objectives: The STEP Requirements Management project will define a formal process for specifying, analyzing, and tracking requirements for STEP, from both management and technical functions in industry and government. Procedures and techniques will be developed to collect requirements, infuse these requirements into the STEP development process and provide a basis for testing the STEP standard.

Implementation Mechanisms:

- o Delivery of published documents to the DoD CALS Office sponsor
- o Demonstration of a resulting system to sponsor and potential users
- o Presentation at program reviews, conferences and workshops

Prior Accomplishments/Deliverables: This project was initiated in FY 93.

FY93 Milestones:

- o STEP Planning Model for CALS (8/93)
- o Recommendations on Defining and Tracking DoD Requirements for STEP (8/93)
- o Demonstration of Requirements Management System (RMS) Mock-Up (7/93)
- o Procedures for the use of the STEP RMS (10/93)
- o RMS Deployment Plan (10/93)

3.2.3 Application Protocols for DoD and Industry

Statement of Need: There are many government and industrially sponsored STEP Application Protocol (AP) projects underway. No overall analysis has been conducted to identify commonality among DoD sponsored AP projects with national and international STEP efforts. With the diversity of topics which current STEP Application Protocol projects cover, a mechanism is needed to bring these projects into focus for deployment into mainstream DoD and industry operations.

Objectives: The FY93 objective of this project is to evaluate and specify the requirements needed to allow the DoD contractor base to deliver a STEP-based Technical Data Package and to enable DoD operations to receive and fully utilize the STEP product data provided. The National PDES Testbed will work closely with both industry and Government representatives.

Implementation Mechanisms:

- o Published papers and reports; conference and workshop presentations
- o Exchange of information with AP developers and key DoD Programs

Prior Accomplishments/Deliverables: The project was initiated in FY 93.

FY93 Milestones:

- o Workshop for DoD Program representatives (5/93)
- o Workshop for DoD technical representatives (7/93)
- o Consolidated DoD Application Protocol Requirements Report (9/93)
- o Development Plan for Technical Data Package STEP Capability (9/93)
- o Level 3 Production Engineering Technical Data Package Requirements (11/93)

3.2.4 Application Protocol Development Environment (ADPE)

Statement of Need: Current practices used by AP developers incur extraordinary labor expenditures and time to define the requisite components of an Application Protocol and to deliver the final documentation to the International Organization for Standardization. While AP developers may use some software tools to help accomplish the required tasks, the tools work independently, are not available in an integrated environment and have not been customized specifically for the purpose of AP development.

Objectives: The FY93 objectives of this project are to: analyze the AP development process to determine which tasks will most benefit from the application of software assistance; define the functional characteristics of a software environment suited to AP development; assess the usefulness of commercially available software components to the process of AP development; provide a prototype software environment suitable for evaluation by AP developments; and establish an electronic Application Protocol Information Base.

Implementation Mechanisms:

- o Published papers and reports; conference and workshop presentations; and demonstrations
- o Exchange of information with AP developers
- o Close coordination with PDES, Inc.

Prior Accomplishments/Deliverables:

- o Proof-of-Concept and prototype software systems
- o Numerous technical publications and workshops
- o Participation on PDES, Inc. technical teams

FY93 Milestones:

- o Release of enhanced version of Dataprobe (3/93)
- o AP EXPRESS Annotated Form Generation software (3/93)
- o Standardized General Markup Language (SGML) Data Type Descriptions (DTD) Structure for STEP Integrated Resources (4/93)
- o Functional Specification for APDE (4/93)
- o Survey of software available for use in AP development (6/93)
- o Architecture of the NPT APDE (8/93)
- o Application Protocol Information Base Implementation Report (10/93)
- o APDE Initial Operational Capability Demonstration (11/93)
- o APDE User's Guide (11/93)

3.2.5 STEP Implementation Prototypes

Statement of Need: An essential element in ensuring the successful implementation of STEP (Standard for the Exchange of Product Model Data) is the effective transfer of technology from the National PDES Testbed to industry and DoD user environments. Without effective technology transfer, the risk of an AP being stalled or not completed in a timely manner is significantly increased. At present, there is a limited pool of expertise in areas required for producing an AP. These areas include in-depth understanding of Integrated Resource model content, AP methods, and EXPRESS modeling practices. This project will help ensure the transfer of technology and know how which users need to apply STEP development techniques properly.

Objectives: The objective of this project is to provide NPT expertise and tools to DoD AP developers as a means of accelerating the delivery of DoD priority APs. The project provides technical

support and technology transfer of APDE products and results to AP projects for DoD user environments.

Implementation Mechanisms:

- o Published papers and reports
- o Work cooperatively with AP projects to define common objectives, particularly in identifying meaningful examples from AP projects that are relevant to DoD users
- o Ensure timely exchange of information and lessons learned by coordinating schedules to deliver support to users when it is most needed
- o Hold workshops to transfer NPT technology to AP developers
- o Develop training materials for use by AP developers

Prior Accomplishments/Deliverables: The project was initiated in FY93.

FY93 Milestones:

- o Report on AP Development Requirements for the APDE (Draft delivered 1/93)
- o Hold two Workshops (AIM, RMS) for PAS-C Project Teams
- o Set of training materials and user support for DoD AP project teams (TBD)
- o Hold two APDE user workshops for DoD AP projects and program teams (TBD)

3.2.6 Testing Methodologies and Tools

Statement of Need: In order to ensure the timely development of STEP, it is essential to remove barriers which impede the standards development process. One of the key barriers is the assessment of quality. In the past, the standards development process has not included quality assessment until late in development. Delays in schedule and unnecessary rework are caused by an "inspect quality in" approach.

Objectives: The objective of this project is to enhance the quality of the STEP specifications, provide quality management guidelines and processes for APs and resource models, and initiate feedback procedures early in the development cycle for APs.

Implementation Mechanisms:

- o Published papers and reports; presentations at workshops and conferences
- o Work cooperatively with AP projects to establish practical quality criteria and to develop precise guidance, based upon feedback from AP implementors on the usability of AP documents to provide benchmarks for AP projects to follow and consolidate into fewer documents

o Identify and propose refinements to the STEP development process for performing earlier review of quality

Prior Accomplishments/Deliverables: The project was initiated in FY 93.

o Related project Validation Testing System produced:
  - *Validating STEP Application Protocols at the National PDES Testbed*, NISTIR 4735 [MORR91]
  - Working Draft: *STEP Application Protocol Qualification Manual*, Version 0.7, ISO

FY93 Milestones:

o Publish proceedings of AP Validation Workshop (1/93)

o Report on STEP Quality System: Action Plan and Assessment of Practices (4/93)

o STEP Integrated Resource Qualification Manual (4/93)

o STEP AP Qualification Manual (6/93)

o Document: *Guidelines for the Documentation of Mapping Tables*, ISO TC184/SC4/WG4/N100 (3/93)

o Enhanced guidelines and extended criteria for fuzzy AP components (5/93)

o Proposed guidelines and quality criteria for AIC and AP test purposes (8/93)

o Consolidated STEP Part Qualification Manual (9/93)

o Report on AP Test Program (8/93)

o Evaluation of the Initial AP Validation System (10/93)

3.2.7 Interorganizational Assessment for STEP Adoption

Statement of Need: One of the primary purposes of STEP is to facilitate communication between different types of computers and different types of software. Achieving effective electronic communication between organizations, such as a prime contractor and its suppliers, presents enormous challenges. While many of the technical challenges are being addressed in research and standards organizations, little has been done to address barriers to STEP implementation which relate to organizational and people issues. This project is responsive to these latter issues.

Objectives: The objective of this project is to develop a prototype, user friendly, computer-based tool which will help assess an organization's state of readiness to use STEP based technologies across organizational boundaries. The project is

being carried out over a two-year period, by the Industrial Research Institute (ITI), under the guidance of NIST.

Implementation Mechanisms:

- o Work cooperatively with members of a Project Advisory Board to ensure the responsiveness and ease of use of the tool; encourage the Board members to aid in technology transfer to industry
- o Published papers and reports; presentations of results at workshops and conferences
- o Exchange of information with potential users through visits and demonstrations
- o Cooperative research with early users of STEP to help ensure organizational readiness
- o Delivery of a tool for easy use in assessing organizational readiness

Prior Accomplishments/Deliverables: The project was initiated late in FY92.

FY93 Milestones:

- o Report on Task 1, Identification of Tool Requirements (1/93)

- o Two additional reports, including the delivery of the final tool, are scheduled for FY94

3.2.8 AP for Inspection Planning

Statement of Need: The STEP Part 47 (Shape Tolerance Model) is required by many STEP APs currently under development. The new EXPRESS-G of the Model, currently under development, requires additional work prior to the standard's being submitted for qualification, integration, editing and CD balloting. The project will enable Part 47 to move forward and will advance the development of the Inspection Planning AP status from AAM developed to ARM developed.

Objectives: The objective of this project is to develop an Application Protocol for the inspection planning process.

Implementation Mechanisms:

- o Present results of the work to developers of Part 47, which will be drawn upon by developers of APs
- o Collaborate with the ESPRIT/VIMP (Visual Inspection of Mechanical Parts) project

Prior Accomplishments/Deliverables:

- o Paper identifying the various national and international standards related to tolerancing [FENG92]

FY93 Milestones:

- o Shape Tolerance Model in EXPRESS-G (12/92)

- o Shape Tolerance Model in EXPRESS (3/93)
- o Draft Planning Data Model in IDEF1x or EXPRESS-G (3/93)
- o Prepare a new version of draft Part 47 (6/93)
- o Draft ARM for Inspection Planning in IDEF1x or EXPRESS
- o Two papers on the results of the research (9/93)

3.2.9 PDES for Apparel

Statement of Need: The apparel industry is in transition from a labor-intensive, manually operated technology base to a more competitive computer technology base. Such a transition is essential if U.S. companies are to recapture market shares lost to foreign competition. Apparel companies are using an increasingly number of computer systems in all phases of design,*p216) analysis, manufacture, and suppor of their products. This increasing role of computer systems in manufacturing, logistic support and system integration is leading to a greater need for standards. The long range goal of this research is to develop a comprehensive specification for sharing apparel product data throughout the entire product life cycle.

Objectives: The objective of this project is to improve the productivity, quality control, and competitiveness of the US apparel industry by helping develop methods for product data exchange appropriate to the industry.

Implementation Mechanisms:

- o Work with the staff of the Georgia Institute of Technology in framing their Apparel Manufacturing Architecture as a strawman for the enterprise framework
- o Collaborate with industry leaders and key associations in developing a national strategy for meeting the data exchange needs of the US apparel industry
- o Published papers and reports; presentations at workshops and conferences

Prior Accomplishments/Deliverables:

- o Report on an Apparel Pattern Information Model to demonstrate the feasibility of extending STEP to include the exchange of apparel pattern data [LEE92]
- o Report on a prototype system for translating apparel pattern data between different file storage formats [MONC91]
- o Report on a suggested strategy for addressing the national needs for apparel product data exchange [MONC92]

FY93 Milestones:

- o Report on survey of US industry needs in the area of made-to-measure technology (4/93)
- o Report on the information model of made-to-measure pattern making (9/93)
- o Present APDES poster for the NIST Automation Open House (12/92)
- o Present paper at the Apparel Research Planning Meeting (10/92)
- o Present paper or poster at the Apparel Academic Research conference (2/93)
- o Present IDEF training courses
- o Three NISTIRs on Scoping, Glossary and Prototype AP (11/92)

3.2.10 Support for Release of STEP Parts

Statement of Need: The initial release effort within TC184/SC4 involved the coordination of technical changes to twelve parts of ISO 10303, informally referred to as STEP. This effort was designed to produce a high quality Draft International Standard in minimum time. The effort attempted to produce a series of compatible documents. This proved to be a very difficult task, requiring the support of automated tools and centralized change control and coordination. The responsibility for some of the components of these parts was assumed by NIST to improve materially the condition of the STEP parts for registration as draft international standards and, eventually, as international standards.

Objectives: The objectives of this project are to:
1) ensure that the data specification method used for stating exchange requirements, EXPRESS, is syntactically correct;
2) review the parts required content and format in compliance with ISO directives and report deviations;
3) generate the computer-interpretable components from the master source documents (unique abbreviated names, EXPRESS extractions, etc.); and
4) coordinate the quality reviews to ensure technical consistency.

Implementation Mechanisms:

- o Document procedures used for the STEP initial release
- o Work with ISO ballot response teams to ensure that comments from the international balloting process are addressed
- o Coordinate part qualification workshops on parts being readied for DIS (Draft International Standard) balloting.

o Use available STEP-based tools to generate computer-interpretable components and check EXPRESS syntax, and improve consistency.

Prior Accomplishments/Deliverables:

1. Workshops (6) in 2/92 through 10/92 performed quality inspections on parts in the initial release of ISO 10303 for consistency, clarity, & correctness.
2. Ballot resolution workshop provided facilities, ballot resolution coordination, and technical support to 38 international technical experts. Resolved 2000+ comments across 10 parts, maintaining coordination of changes across interdependent documents.
3. Software delivered that generated unique short names for all information concepts in the initial release. Database registry established.
4. Test reports generated (7/92, 8/92, 10/92) to identify EXPRESS syntax errors in all parts. 7 STEP centers participated. Consolidated results and resolved discrepancies.
5. Maintained configuration control of WD & CD parts, ballot comments, and ballot resolutions.

FY93 Milestones

o Document: Procedures for the Initial Release of STEP [2/93].

o ISO/DIS 10303, parts 41-44, 101, & 203 delivered 3/93-4/93 for registration. Final editing of Parts 41-44 performed and coordinated changes on remaining DIS parts to manage interdependencies.

o Test reports (1/93, 3/92): All initial release EXPRESS syntactically error free. Coordinated with initial release Part Editors to reach agreement on technical changes to correct errors.

o Reports providing unique short names to editors (1/93). Ensured correctness of digital document sources.

o Standardized document style library delivered to ISO 10303 Part Editors (1/93, 3/93).

o Support preparation of ISO/DIS 10303, parts 46 & 201 (6/93).

o Support resolution of DIS comments on ISO 10303 parts 11 & 31. Ballot closes 5/93; process comments (7/93).

o Support preparation of either ISO/IS 10303 parts 11 & 31 or new CD (10/93).

3.3 FCIM Processes

3.3.1 Rapid Response Manufacturing

Statement of Need: This project is in response to the national need to develop and adopt key technologies that will help US manufacturers outperform foreign competitors through the use of advanced, highly integrated systems for manufacturing. The project, supported through the NIST Advanced Technology Program (ATP), was formed to establish a collaborative relationship with the National Center for Manufacturing Sciences (NCMS) Rapid Response Manufacturing (RRM). By increasing the knowledge and skills of both NIST personnel and NCMS RRM consortium members, the research will stimulate technology development, collaboration and technology transfer needed to respond to the needs of the US industry.

Objectives: The principle objective of the project is to establish collaborative research efforts in response to the need for skills and technologies for ensuring the advancement of RRM capabilities throughout US industry.

Implementation Mechanisms:

- o Establish collaborative efforts with the NCMS RRM consortium members
- o Demonstrate, through the development of an RRM Testbed, the opportunities for US industry to draw upon advanced, highly integrated systems for manufacturing
- o Provide, through the Testbed, a mechanism for integrating system functionality of each software module identified for RRM, testing initial releases of the software components, and providing an environment for both NIST and NCMS RRM participants to interact and exchange technology
- o Published papers and reports; presentations at workshops and conferences

Prior Accomplishments/Deliverables: The project was initiated in FY92.

FY93 Milestones:

- o Establish a Cooperative Research and Development Agreement (CRDA) with NCMS
- o Organize and hold workshop between NIST and NCMS RRM to address technology barriers; publish proceedings
- o Develop a RRM Testbed Laboratory Implementation Plan
- o Draft papers on State-of-the-Art and State-of-the-Practice Manufacturing Systems to support RRM.

3.3.2 Process Planning Testbed

Statement of Need: This project is in response to the US industry need for an advanced, state-of-the-art laboratory facility to conduct research on process planning. The Process Planning Testbed (PPT) will contain a suite of contributed process planning systems, allowing researchers to test interoperability and the relative merits of various approaches to process planning.

Objectives: The long-term objective of the PPT project is to provide information services, workshops, a laboratory for testing and integration, and a collaborative research program for the process planning community.

Implementation Mechanisms:

- o Collaborative relationships with leaders in the process planning community
- o Hosting guest workers to carry out process planning research and to carry the results of PPT activities back to their laboratories and manufacturing facilities
- o Organizing and hosting workshops
- o Published papers and reports; presentations at workshops and conferences
- o Publication of the first electronic process planning journal
- o Establishment and maintenance of a mailing list/newsgroup communication network

Prior Accomplishments/Deliverables:

- o Paper on ALPS, a process specification language [RAY92-2]
- o An on-line bibliographic service connected to Internet including three reports on user documentation:
  - "Selection of an On-Line Bibliographic Reference System for the NIST PPT," A. Barnard Feeney
  - "User's Guide to the On-Line Bibliographic Reference System for the NIST PPT," A. Barnard Feeney
  - "PPTB IRX Administrator's Manual," C. Wenger
- o An electronic mailing list (process-planning@cme.nist.gov)

FY93 Milestones:

- o Organize and hold a workshop on process planning(8/93); publish proceedings (9/93)
- o Establish a process planning repository for sample data, systems, and libraries (1/93)
- o Publish the first issue of the process planning journal (9/93)

3.3.3 Manufacturing Design Research Testbed

Statement of Need: This project is in response to the U.S. industry need for advances in manufacturing design. The design stage of the manufacturing process is particularly crucial because, by the time

of its completion, a large portion of a product's life cycle cost is accounted for. Thus it is essential that designers have all important data information available to them both when it is needed and in a format in which it is needed. The goal of the testbed is to provide an environment for studying the design process, understanding how design information can be represented and determining how to make design information available to necessary systems throughout a product's life cycle.

Objectives: The objective of this project is to evaluate software tools for integrating design and analysis. A prototype of machine interpretable representation of design knowledge stored in handbooks, textbooks and journals will be developed.

Implementation Mechanisms:

- o Published papers and reports; presentations at workshops and conferences
- o Collaborative work with participants in the ARPA MADE (Manufacturing Automation and Design Engineering) Program, industrial design engineers, engineering societies and others who are interested in advancing knowledge in manufacturing design
- o Exchange of information with potential users and contributors through visits, demonstrations, etc.

Prior Accomplishments/Deliverables: By the end of FY92, a variety of tools had been acquired and installed into the laboratory [FEEN91].

FY93 Milestones:

- o Complete MADE Phase 1 meeting work (11/92)
- o On-line libraries of MADE developed ontologies and knowledge bases (1/93)
- o NISTIR and journal publication on design knowledge taxonomy; literature review (2/93); language modeling and taxonomy developed (5/93); Paper (9/93)
- o Prototype computer interpretable design knowledge representations demonstrated (8/93)
- o NISTIR and journal paper on literature review of fuzzy logic (4/93) and example and experiment (7/93)
- o NISTIR on an Engineering Design Laboratory (6/93)

3.3.4 CMS Software Performance

Statement of Need: Coordinate measurement systems (CMS) are used throughout the DoD and industry. However, may facilities are

unable to use in-place systems because of software problems. The industry needs methods by which the performance of software used in inspection systems can be evaluated. The NIST Algorithm Testing System (ATS) provides a mechanism and the reference algorithms for evaluating CMS software and provides an environment for conducting experiments to characterize algorithms.

Objectives: The objectives of this project are to enhance the capabilities of the NIST ATS and to make the system available to the coordinate measurement community.

Implementation Mechanisms:

- o Through leadership in ASME and ISO Committee activities (Y14.5.1, B89.4.10, B89.3.2 and ISO/TC10/SC 1), ensure the incorporation of research results into ongoing standards development activities
- o Published reports and papers; presentations at workshops and conferences
- o Exchange of information with potential users through visits

Prior Accomplishments/Deliverables:

- o Report on current geometric tolerancing theories and CMS inspection data analysis algorithms [FENG91]
- o Report on the implementation of ATS, a software package for testing geometric fitting software for CMMs [ALGE92]

FY93 Milestones:

- o Report on ATS algorithms (12/92)
- o Demonstration at NIST AMRF Open House (12/92)
- o Conference Paper on tolerance theory (4/93)
- o Report on theory of algorithm testing (6/93)
- o Journal paper on requirements for experimental design (9/93)

3.3.5 Reverse Engineering Production Cell

Statement of Need: The Naval Air Depot North Island, San Diego (NADEP NI) is responsible for the repair and maintenance of F/A-18 and various other naval aircraft. Repair and replacement of corrosion-damaged sandwich panel constructions is frequently required. Partial or complete replacement means that replacement sections must be manufactured, with strict tolerances, from stock core blanks. A cost-effective means of carving the replacement sections is needed. The final tasks of the project will be completed in FY94.

Objectives: The objective of this project is to design and implement a Reverse Engineering Production System at the NADEP NI facility. In order to build upon existing technology and carry the state-of-the-art to the next step, the workcell is based upon the integration of commercially available systems.

Implementation Mechanisms:

- o The Reverse Engineering Production System, will be designed and implemented at NADEP NI through cooperative research with NADEP NI.
- o Published papers and reports, as well as presentations at workshops and conferences, will help extend the results to other potential users.
- o Define system design specifications for optical measurement system (OMS).

Prior Accomplishments:

- o Documented project plan
- o Completed cell design
- o Issued contract for OMS

FY93 Milestones:

- o Issue and manage contract for optical measurement system; participate in acceptance testing
- o Identify training courses for NADEP NI staff
- o Perform final systems integration verification (9/93)

3.3.6 Metal Powder Processing

Statement of Need: This research addresses the needs to 1) understand the formation of metal powder as a result of supersonic inert-gas atomization and 2) develop a control system capable of regulating the size distribution of the produced particles. The investigation involves the development of specific processing hardware, the on-line measurement of the size distribution of the produced metal particles, modelling of the gas-metal interaction and atomizer gas dynamics, and the development of a particle size distribution feedback control system.

Objectives: The objective of the project is to demonstrate a methodology to achieve feedback control of the size distribution of metal powder particles produced by supersonic inert-gas atomization.

Implementation Mechanisms:

- o Published reports and papers; presentations at workshops and conferences
- o Collaborative research with key industry representatives through a consortium addressing supersonic inert-gas metal atomization
- o Hosting of guest workers from industry

Prior Accomplishments/Deliverables:

- o Developed a controller for the metal atomization process capable of regulating the production of metal powders and of using acquired knowledge to increase the efficiency of the process [OSEL91]
- o Paper on the use of neural networks as presented in the Collective Learning Systems Theory [OSEL89]

FY93 Milestones:

- o Complete on-line particle size distribution measurement instrument (3/93)
- o Complete experiments to correlate the various process parameters with the size distribution of the produced powder particles (9/93)
- o Integrate all hardware and software systems and process knowledge to control the size distribution of the produced metal particles (9/93)

3.3.7 Enhanced Machine Controller

Statement of Need: The use of proprietary hardware platforms, operating systems, communication protocols, and data formats by CNC manufacturers has resulted in a myriad of problems for CNC users. Problems include 1) the need to assimilate a multitude of programming languages, 2) varying user interfaces and implementations of "standard" control languages, 3) difficulty of connecting controllers to a LAN (Local Area Network), 4) limited or no access to low-level control functions, 5) expensive software customization, 6) limited sources of spare parts, and 7) limited controller capabilities offered by OEM. There is a need for new technologies and standards if the US machine tool industry is to be able to compete in the global marketplace. This project is responding to that need, in conjunction with the Air Force Next Generation Controller (NGC) Program. It is being carried out jointly between the Robot Systems Division and the Factory Automation Systems Division of MEL.

Objectives: The objectives of this project are to 1) implement and demonstrate an open architecture machine controller in a machining center testbed, 2) utilize the testbed to integrate/develop third-party vendor controller components, 3) stimulate the development of third-party commercial sources for controller components and enhancements and 4) produce specifications which can be used for procurement purposes.

Implementation Mechanisms:

- o Collaborative agreements with industry, including industrial partners and production test sites

o Published papers and reports; presentations at workshops and conferences
o Demonstration of operational lab and shop controllers

Prior Accomplishments/Deliverables:
o Established controller testbed for NGC validation
o Demonstrated capability of supporting different operator displays (AB8200, GE2000, Fanuc M10)

FY93 Milestones:
o Develop SOSAS (Spec for Open Systems Architecture Standard) compliant interface specifications for controller enhancements

o Integrate and demonstrate enhancements into EMC

o Establish agreements with industrial partners and production test site

o Contract to install "beta" version of controller at production test site

3.4 Communications and Networking

3.4.1 MAP/TOP Laboratory

Statement of Need: Factories which are built today consist of hardware and software systems (machine tools, robots, material handling systems, material resource planning, schedulers, controllers, etc.) which are connected by a network. Factory systems rely on these networks for communication with each other, and with databases holding crucial information such as NC code, production plans, schedules and orders. Thus the performance of the networks is crucial. But network maintenance and trouble shooting is expensive. Tools are needed for monitoring the factory network, maintaining the health of the network, and providing assistance in the diagnosis of network problems. Such tools should be designed to assist network experts in the maintenance of the factory network and diagnosis of network problems, but should also permit trained factory personnel to diagnose and solve common network problems in emergency situations. The project is intended to be carried out over a period of four years and is now in the second year. Completion in FY95 is planned.

Objectives: The objective of this project is to develop a software tool, the Intelligent CIM Monitoring and Troubleshooting Tool (Intellimon), which can be used by an operator at a centralized location to track the data exchange between CIM applications, provide the operator with suggestions for maintaining a healthy networking environment and diagnose problems within the networking environment.

Implementation Mechanisms:

- o Cooperative Agreement with the General Motors Technical Center, where part of the research will be carried out
- o Collaborative research with industry in the NIST MAP Laboratory
- o Published papers and reports; presentations at workshops and conferences
- o Exchange of information with potential users through visits
- o Delivery of the Intellimon software tool in a format of benefit to industry

Prior Accomplishments/Deliverables:

- o MAP Laboratory is available at NIST; the laboratory contains computing equipment and associated communication systems representative of those found in state-of-the-art manufacturing facilities
- o In 1990, the Manufacturing Messaging Specification (MMS; ISO 9506:1990), an OSI standard for inter-controller communications, was produced

FY93 Milestones:

- o Install the Network Interface Unit (NIU) board and communications software
- o Install database for use by the Intellimon system; install C and C++ compiler
- o Demonstrate and prepare user documentation for the Intellimon Tool

3.4.2 Automated Processing System

Statement of Need: The United States Postal Service (USPS) currently has no standard for communications with Mail Processing Equipment (MPE), although there are two information systems which currently communicate with MPE controllers and two more in the planning stages. MPE controllers are not significantly unlike manufacturing equipment controllers and can thus benefit from existing manufacturing standards.

Objectives: The objective of this project is to provide the USPS with a standard massaging protocol for all communication with mail processing equipment controllers, using international standards, to ensure interoperability of postal automation systems into the 21st century

Implementation Mechanisms:

- o Delivery to the USPS of a set of specifications which detail the explicit communications requirements for each of six classes of postal equipment. These specifications extend the

generic standard, Postal Equipment Message Specification (PEMS), proposed in FY92.
o Promulgate the PEMS as a national or international standard, in order to obtain maximum vendor participation and acceptance and to ensure it long-term viability

Prior Accomplishments/Deliverables:
o Report on a requirements document that specifies the communication protocols needed to integrate the automation equipment (e.g., letter sorters) in the centers

FY93 Milestones:
o Reach agreement on modified scope of work due to changing staff (4/93)
o Provide continuing guidance to the USPS on integration of automation systems
o Complete revised draft of the PEMS (Postal Equipment Messaging Specification)
o Document General PEMS Implementation specification
o Complete prototype of MPE emulator and demonstration (7/93)

3.5 Database and Database Management

3.5.1 Persistent Object Bases for Manufacturing

Statement of Need: The development of new technology is proceeding at a pace faster than industry is able to absorb and faster than applicable information standards can be developed. The POB evaluation project is attempting to head off the divergence of new technology from the standards which are designed to support that technology, and from industrial implementations.

Traditionally the lag time between technology development and standards has been viewed as a necessary evil. Conventional wisdom said that standards should only be formed for a mature technology. However, more recently due to the rapid pace of development of new technology this lag time in standards development has become unacceptable. By the time a standard is created the technology that is being standardized is often out-dated. By developing the standards in light of emerging technology it is anticipated that the resulting standard will be suitable for the up-coming generation computing systems.

Furthermore, data management technology for engineering and manufacturing has lagged far behind its counterpart for business applications. Recent advances in the technology have resulted in systems which are more suitable for these types of applications. At the same time the product data standard STEP is emerging. The POB project serves to validate the applicability of the new data management technology for future information systems which use the emerging standard STEP.

Objectives: To facilitate the transition of POB technology into industrial implementation. Two aspects of this process, which brings technology from research to implementation, are targeted for improvements: 1) the focus and quality of research and 2) the transfer of the technology into standards activities and user communities. POB research needs to be focused on the application areas which it will support -- specifically manufacturing and engineering. As POB technology is emerging, plans to develop standards related to the technology and to incorporate it into future projects need to begin.

Implementation Mechanisms:

- o Published reports and papers; attendance and presentations at workshops and conferences.
- o Development and demonstration of prototype systems.
- o Distribution of software, examples, and other information related to product data standards development.
- o Collaboration with POB researchers and with developers of other standards related to STEP.

Prior Accomplishments/Deliverables:

- o Organized a public lecture series on object technology
- o Participated in working and discussion groups between different research areas and standards activities
- o Reported to sponsors on technology and standards related to POB systems; participated in review of proposals for research into areas related to data management technology for engineering and manufacturing
- o Wrote chapter for the _Encyclopedia of Software Engineering_ on the use of data management systems in engineering and manufacturing

FY93 Milestones:

- o Participation in ARPA proposal review (4/93).

- o Demonstration of prototype incorporating the ARPA-funded research POB system from TI (Open OODB) into the NIST STEP software (6/93).

- o Availability of Express server announced (7/93).

- o Distribution of NIST software and STEP example package to POB research community. This software implements the STEP Standard Data Access Interface (SDAI) based on the Open OODB (9/93).

- o Document describing experiences in prototyping the SDAI using Open OODB for submission for publication (9/93).

- o Participation in research and standards communities. Attendance at ARPA workshops, ISO/STEP meetings, and meetings related to standards harmonization (as appropriate).

Bibliography

[ALGE92] Algeo, M.B., Hopp, T.H., "Form Error Models of the NIST Algorithm Testing System," NISTIR 4740, January 1992.

[AM92] Agile Manufacturing Forum, "21st Century Manufacturing Enterprise Strategy - An Industry-Led View," Published by the Iacocca Institute, Bethlehem Penn., November 1991.

[AMI92] Advance Manufacturing Initiative Industrial Working Group, "Crafting a Common Manufacturing R&D Agenda," Letter to the Honorable Robert M. White, Under Secretary for Technology, U.S. Department of Commerce, August 5, 1992.

[CARV91] Carver, G.P., Bloom, H.M., "Concurrent Engineering Through Product Data Standards," NISTIR 4573, May 1991.

[DCTP91] The Department of Defense, "Critical Technologies Plan for the Committees on Armed Services, United States Congress," Report AD-A234 900, 1 May 1991.

[FEEN91] Feeney, A.B., "Engineering Design Laboratory Guide," NISTIR 4519, February 1991.

[FENG91] Feng, S.C., and Hopp, T.H., "A Review of Current Geometric Tolerancing Theories and CMM Inspection Data Analysis Algorithm," NISTIR 4509, February 1991.

[FENG92] Feng, "Comparison of ISO 10303 Part 47 Draft with ANSI and ISO Tolerancing Standards for Harmonization and Completion of Part 47," NISTIR 4744, January 1992.

[JACK92] Jackson, R.H.F., Leondes, C.T., editors, Three Pillars of Manufacturing, *Control and Dynamic Systems, Vol. 45: Manufacturing and Automation Systems: Techniques and Technologies,* Academic Press, Inc., 1992.

[LEE92] Lee, Y.T., "Apparel Product Data Exchange Standard," published in the Proceedings of the Third Annual Academic Apparel Research Conference, Atlanta, GA, February 17, 1992.

[MONC91] Moncarz, H.T. and Lee, Y.T., "Apparel STEP Translator," NISTIR 4612, June 1991.

[MONC92] Moncarz, H.T., "Information Technology Vision for the U.S. Fiber/Textile/Apparel Industry," NISTIR 4986, November 1992.

[MORR91] Morris, K.C., Mitchell, M.J., and Sauder, D.A, "Validating STEP Application Models at the National PDES Testbed," NISTIR 4735, December 1991.

[NCTP91] "Report of the National Critical Technologies Panel," National Critical Technologies Panel, W.D. Philips, Office of Science and Technology Policy, Chair (1991). (Available from The National Critical Technologies Panel, 1101 Wilson Boulevard, Suite 1500, Arlington, VA 22209.)

[OSEL89] Osella, S.A., "Collective Learning Systems: A Model for Automatic Control," Proceedings of the 4th International Symposia for Intelligent Control, October 1989.

[OSEL91] Osella, S.A., Ridder, S.D., Biancaniello, F.S., Espina, P.I., "The Intelligent Control of an Inert-Gas Atomization Process," published in the *Journal of the Minerals Metals & Materials Society (JOM)*, January 1991, Vol. 43, No. 1, pp. 18-21.

[OTA92] U.S. Congress, Office of Technology Assessment, Global Standards: Building Blocks for the Future, TCT-512 (Washington, DC: U.S. Government Printing Office, March 1992.).

[RAY92-1] Ray, S.R., Wallace, S., "A Production Management Information Model for Discrete Manufacturing," for publication in Production Planning and Control, 1992.

[RAY92-2] Ray, S.R., "Using the ALPS Process Plan Model," published in the Proceedings of the Manufacturing International Conference, March 29-April 1, 1992, Dallas, TX.

[SENE91-1] Senehi, M.K., Wallace, S., Wallace, E., Ray, S., and Barkmeyer, E., "Manufacturing Systems Integration Control Entity Interface Document," NISTIR 4626, June 1991.

[SENE91-2] Senehi, M.K., Barkmeyer, E., Ray, S., and Wallace, E., "Manufacturing Systems Integration Initial Architecture Document," NISTIR 4682, September 1991.

[WALL 93-1] Wallace, S.E., Senehi, M.K., Barkmeyer, E., Ray, S. and Wallace, E., "Manufacturing Systems Integration Control Entity Interface Specification," will officially be published in 1993.