NISTIR 4584

The Technical Program of the Factory Automation Systems Division 1991

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May 1991

U.S. DEPARTMENT OF COMMERCE
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NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
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FACTORY AUTOMATION SYSTEMS DIVISION

1991 PROGRAM DESCRIPTIONS

INTRODUCTION:

The Factory Automation Systems Division is one of four technical divisions in the Manufacturing Engineering Laboratory, within the National Institute of Standards and Technology (NIST). The Manufacturing Engineering Laboratory supports the U.S. mechanical manufacturing industry through research and measurement services that are oriented toward a modern automated environment. The programs of the Laboratory are organized into five areas: Automated Manufacturing, Precision Engineering, Robotics, Manufacturing Data Interface Standards, and Support for Manufacturing Technology Transfer.

The work of the Factory Automation Systems Division contributes primarily to the interface standards and technology transfer areas. 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 logistic support system. Central to this effort is the development of an international "Standard for the Exchange of Product Model Data" (STEP). The U.S. national effort is called PDES, "Product Data Exchange using STEP." In April 1991, the National Critical Technologies Panel, appointed by the Director of the Office of Science and Technology, published a report on critical technologies. In the critical manufacturing process technology area called "systems management technologies," the report included a discussion of the importance of PDES.

MISSION AND FUNCTION:

The mission of the Factory Automation Systems Division 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 United States to remain competitive in world markets.

A major objective of the Division mission is to provide leadership in the development of national and international standards relating to information technology and manufacturing systems to meet U.S. industry needs for the twenty-first century. The work of the Division is based on the principle that this leadership must be founded on experience in implementing and testing new information technologies and engineering concepts. Such experience is used by Division staff to develop and promote appropriate standards and technologies (and the engineering disciplines needed to support them), particularly for manufacturing interface standards and product data exchange standards for automated manufacturing systems.

TECHNICAL PROGRAMS:

The scope of the Division's programs is the application of information technology to a multi-enterprise environment. More specifically, the Division staff apply their expertise in information technology and their knowledge of manufacturing to promote multi-enterprise concurrent engineering in the manufacturing of discrete parts. The work can be divided into four programs, as shown in Figure 1:

- Design Methods,
- Product Data Sharing,
- Systems Integration, and
- Life Cycle Applications.

The four Division programs are at different stages in their growth toward the size and strength intended for them to meet the goals of their missions. Currently, the Product Data Sharing Program is significantly larger than the other programs.

Typical outputs for the Division include: draft specifications for future standards, journal papers describing research results, prototype software systems that demonstrate proof-of-concept, test methodologies for supporting the implementation of standards, and testbeds for use by NIST, industry, and academia.

The funding distribution among the Division's technical programs is shown in Figure 2. Support from agencies outside of NIST represents about 76% of the total budget. The shaded areas in the diagram indicate the Commerce Department funding for each program.

DIVISION STAFF:

The Division is organized into four technical groups: Production Management Systems, Product Data Engineering, Integrated Systems, and Machine Intelligence. There are two projects managed from within the Division office: the IGES/PDES/STEP Administrative Office and the CALS/PDES Project Management Office. The Division organization chart is shown in Figure 3.

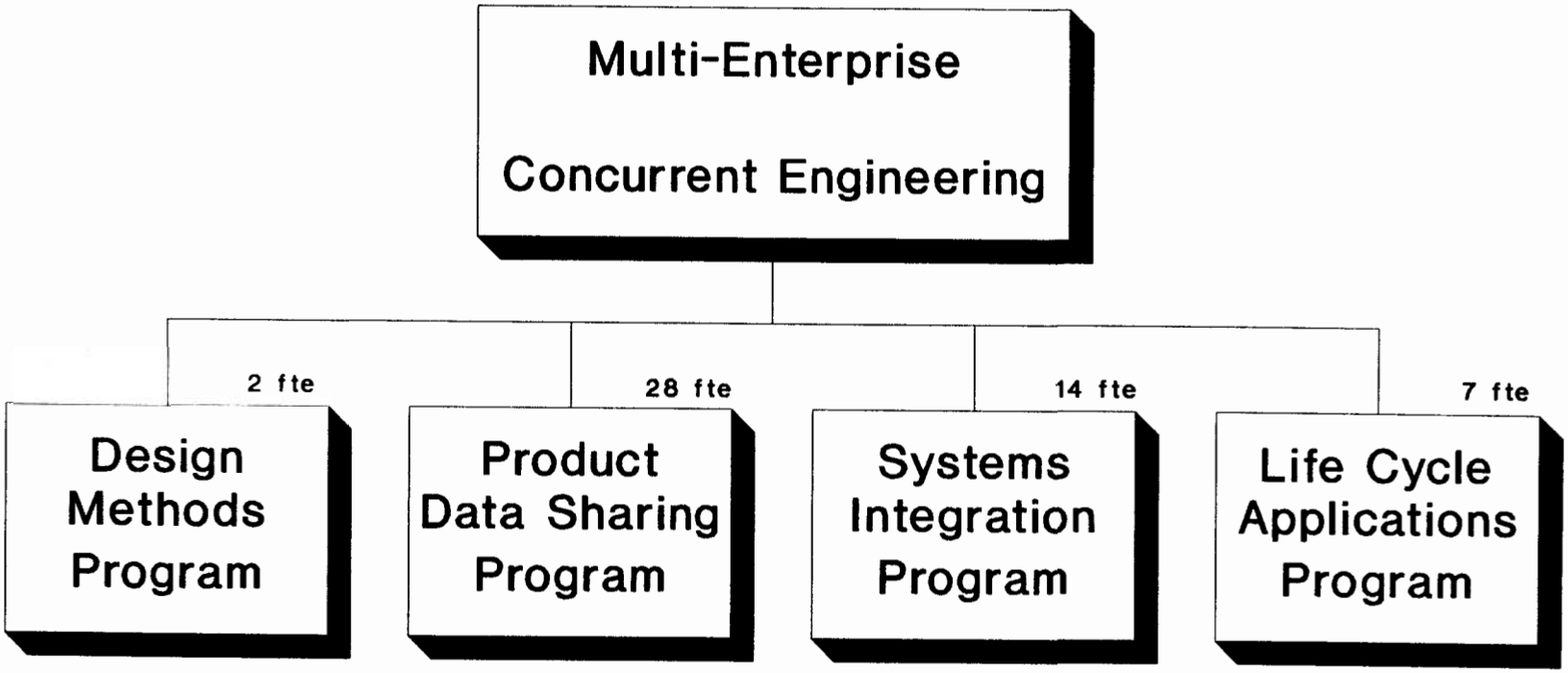
Permanent Staff:

Management	7
Professional	37
Technical Support	5
Secretarial Support	8
Total	57

Special Staff:

Summer Student	18
Guest Researcher	3
Research Associate	2
Total	23

MANUFACTURING DATA INTERFACE STANDARDS PROGRAM



The application of information technology to a multi-enterprise environment

Figure 1. **The four elements of the Factory Automation Systems Division's program reflect the theme "Multi-Enterprise Concurrent Engineering." At the top right of each box is the number of full time equivalent (fte) staff members.**

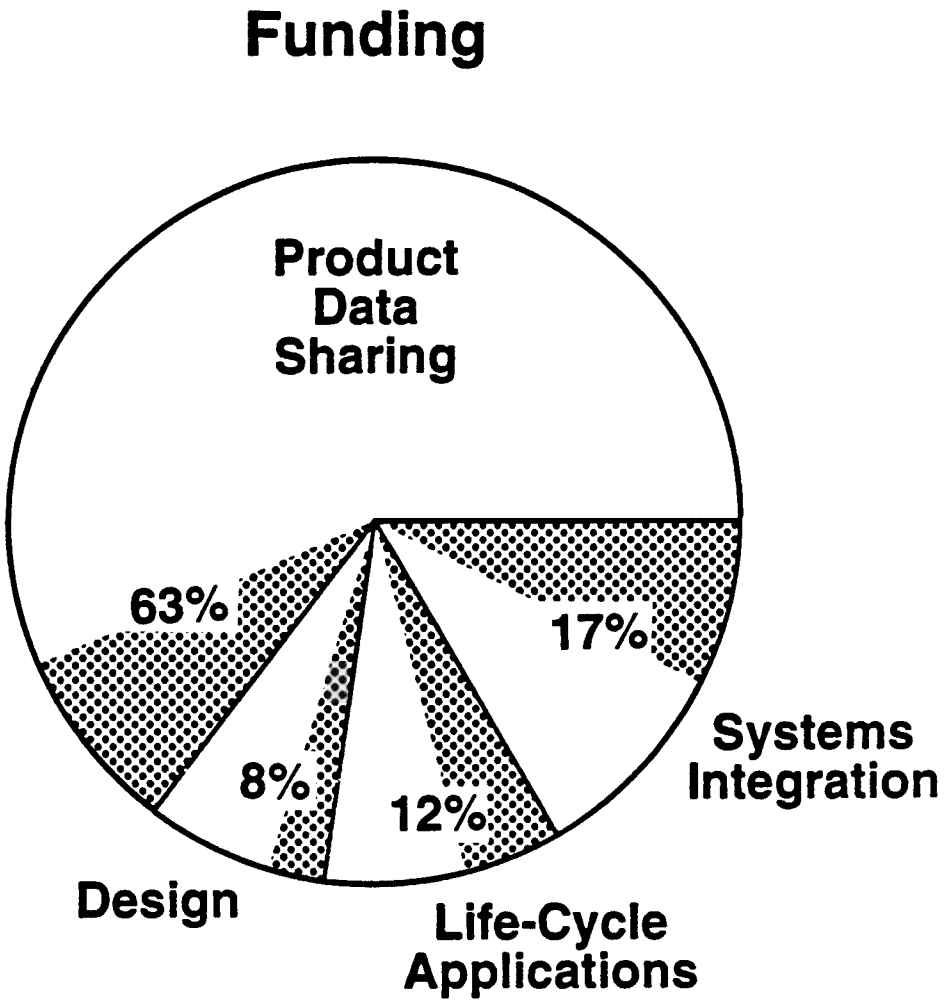


Figure 2. **Funding for the four programs of the Factory Automation Systems Division is a combination of NIST Congressional appropriations for Scientific and Technical Research and Services (STRS) and other-agency sponsored project funding.**

FACTORY AUTOMATION SYSTEMS DIVISION ORGANIZATION CHART

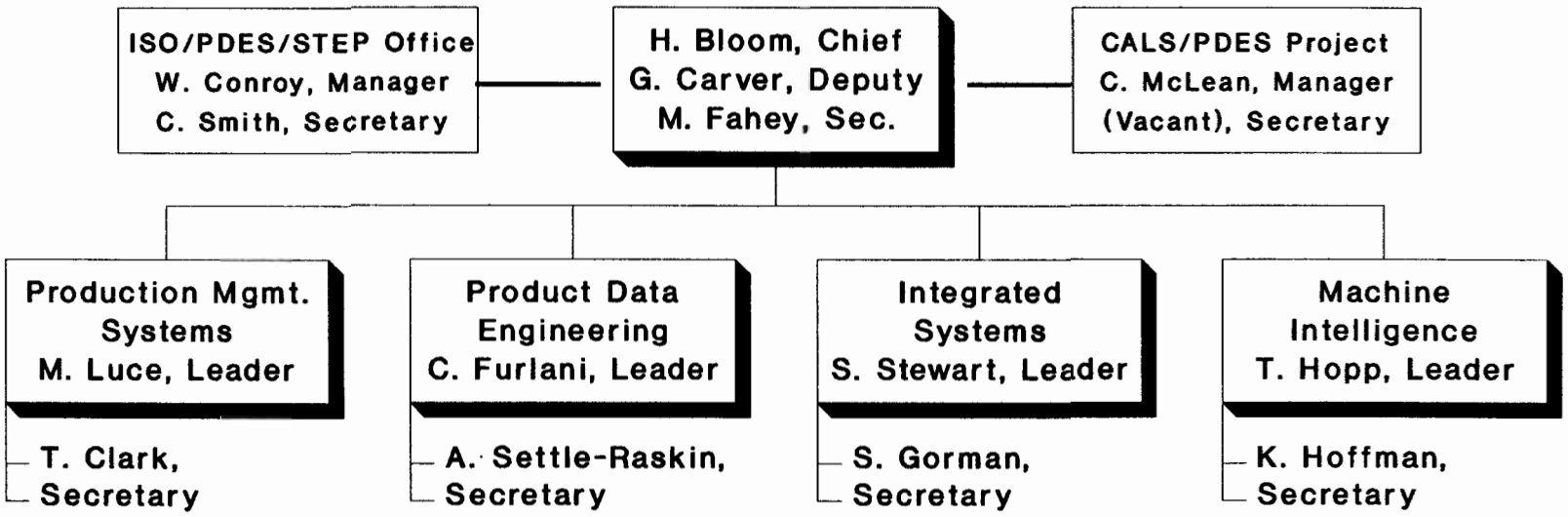


Figure 3. **The organization chart of the Factory Automation Systems Division shows the four technical groups and the two standards-related project offices.**

MAJOR CUSTOMERS:

The Division's customers include a variety of standards organizations, consortia, industrial enterprises, other government agencies, and universities. The Division cooperates with these organizations in mutually beneficial partnerships, and contributes to their work by developing testing methodologies, providing testbeds, developing integration and architecture concepts, and implementing feasibility demonstrations. As shown in the diagram in Figure 4, the Division fulfills the ideal role of NIST in providing the metrological and consensual basis for standards, technologies and products.

STANDARDS ORGANIZATIONS

Manufacturing and product-related standards have become internationally important in trade agreements. Recently, both government and industry have realized the importance of accelerating and participating in the development of standards because standards can 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, the chief customer of the Division has become the U.S. standards organizations. Division staff members serve in chair positions and on technical development committees, and they provide support for secretariats.

National

AAMA (American Apparel Manufacturers Association) CIM Standards Committee

ANSI (American National Standards Institute)

- B89: Dimensional Metrology
  - B89.3.2: Dimensional Measurement Practice
  - B89.4.10: Coordinate Measurement Machine Software
- Electronic Product Data Harmonization Organization
- IAPP (Industrial Automation Planning Panel)

- X3: Information Processing Systems
  - X3T.2: Data Interchange
  - X3H2.1: Remote Database Access
  - X3J16: Programming Language C++
- Y14: Standards for Drawings and Drafting Practices
  - Y14.5.1: Mathematics of Dimensions and Tolerances
  - Y14.26: Computer-Aided Preparation of Product Definition Data

IGES/PDES Organization: Product Data Standards and Technology

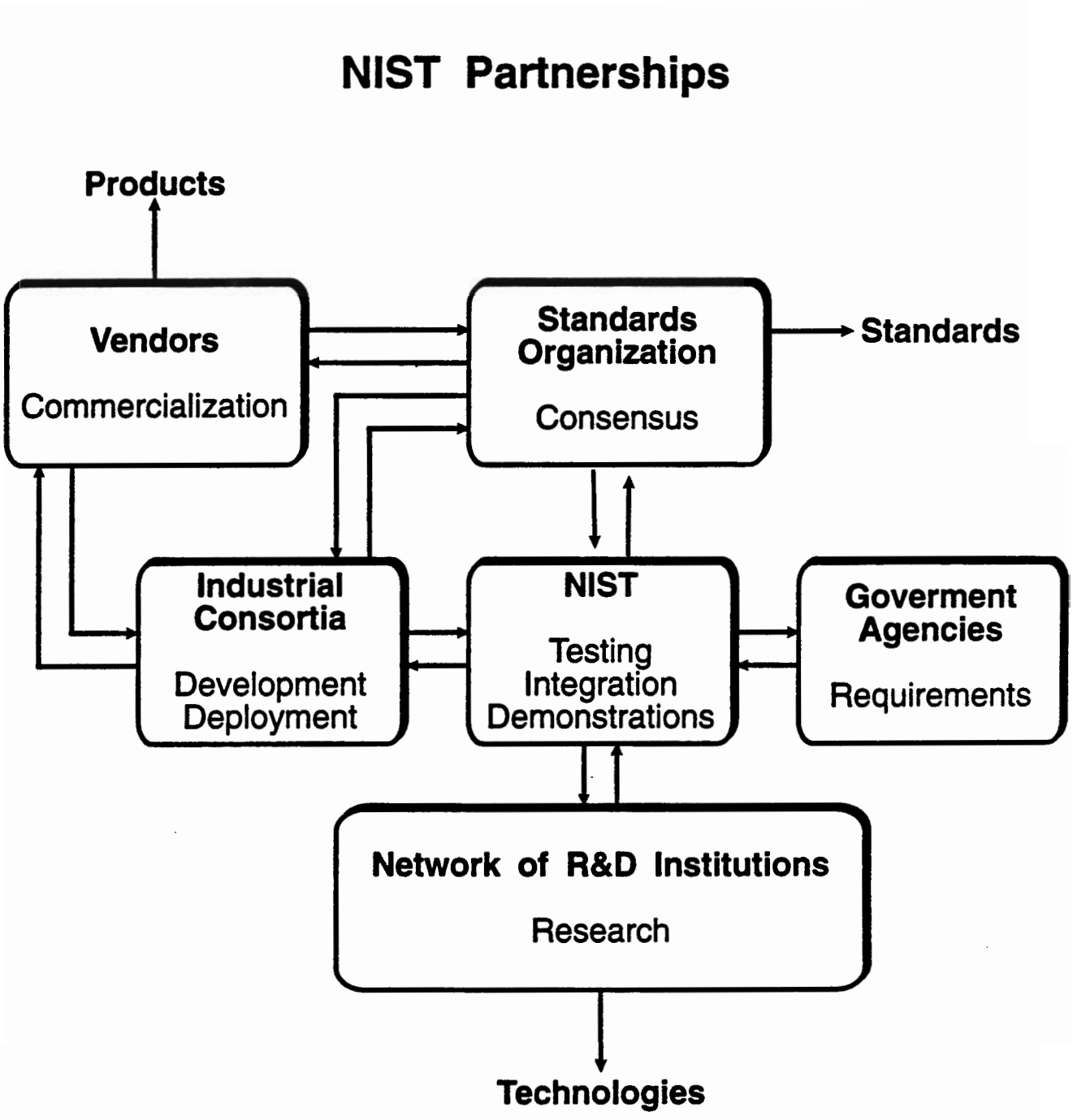


Figure 4. **The Factory Automation Systems Division, (1) in a partnership with standards organizations, industry, other government agencies, and research and development institutions, (2) provides testing methodologies, integration technologies, and feasibility demonstrations (3) in support of the development of standards, technologies, and products.**

International

ISO (International Organization for Standardization)
- TC10: Technical Drawings
  - TC10/SC1: General Principles
- TC184: Industrial Automation Systems and Integration
  - TC184/SC4: Manufacturing Data and Languages (Includes STEP)
  - TC184/SC5: Architecture and Communications
    - TC184/SC5/WG1: Reference Models
    - U.S. Technical Advisory Group to TC184/SC4

ISO/IEC (International Organization for Standardization/International Electrotechnical Commission) Joint Technical Committee 1
- JTC1/SC22/WG11: Language Binding Techniques

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 pre-competitive 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.

Name	Program/Project
PDES, Inc.	National PDES Testbed
AAMA	PDES for Apparel Industry
Powdered Metals Consortium	Metal Powder Processing
CAM-I	Systems Integration

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.

Name	Program/Project
Boeing	Manufacturing Systems Integration
GM/EDS	IGES/PDES/STEP Administration Office
IBM	National PDES Testbed

INDUSTRY (Producers of CIM Technology)

The Division has become a mechanism for demonstrating new technologies that are available from CIM vendors. In addition, the prototype systems developed through the Division's testbeds are made available to vendors for future development of actual products.

Name	Activity
Control Data	Information modeling system software donation
D. Appleton Co.	Information modeling system software donation
Datamatic	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
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
Versant	Object-oriented database management system and software donation (expected)

OTHER GOVERNMENT AGENCIES

Most of the Division's funding is derived from technical and standards-related projects that are supported by other government agencies. NIST has a unique role in the standards arena that will continue to attract other government agencies as customers.

Sponsor	Project
Air Force/Mantech	Enterprise Integration Framework
Army/Rock Island Arsenal	Tool Management Specification
DARPA/ISTO	Manufacturing Research Testbed
DoD/CALS	National PDES Testbed
DoD/DLA	PDES for Apparel Industry
Navy/Mantech	Design Research, Inspection Workstation Research, Manufacturing Systems Integration, System Visualization, Vertical Workstation

UNIVERSITIES

The Division is developing a new role in its relationship with university researchers. Through the sponsorship of other government agencies such as DARPA and 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.

Sponsor/Project	University
DARPA/Manufacturing Research Testbed	Carnegie Mellon University, Cornell University, Purdue University, Rensselaer Polytechnic Institute, Stanford University, University of Utah
DLA/PDES for Apparel Industry	Clemson University, Fashion Institute of Technology, Georgia Institute of Technology, North Carolina State University, University of Southwestern Louisiana
Division Grant/Product Data Sharing	Catholic University
Division Grant/Inspection Software Performance	George Washington University
Division Grant/Simulation of Rock Island Arsenal Flexcell Performance	University of Illinois
Division Grant/Systems Integration	University of Florida

DESIGN METHODS PROGRAM

MISSION AND FUNCTION:

The mission of the Design Methods Program is to develop, through the use of computer-shared databases and knowledge, the ability to include information about all stages of a product's life cycle in the design process. A major objective is the development of the means to incorporate product knowledge (such as knowledge about the product's manufacture, maintenance and disposal) into the design system database, as well as the integration of appropriate computer representations of a product.

Design research is performed in the Engineering Design Laboratory. The laboratory is an integrated design and analysis environment for modeling the technical information needed to design and build complex mechanical systems. The Laboratory makes use of university-developed research tools and commercially available design and analysis tools. Both the development of the product models and the issues raised in integrating a diverse set of computer-based tools will help to identify interface problems, to evaluate the usefulness of STEP in the design process, and to contribute to standards development.

TECHNICAL THEMES:

- ❑ Formal methodologies for design
- ❑ Computer representation of in-progress designs, especially feature-based representations
- ❑ Design-oriented analysis and simulation tools
- ❑ Quality and cost models for design
- ❑ Common definition and methods for encoding and disseminating design knowledge
- ❑ Theory of tolerances
- ❑ Interfaces for integrating design tools
- ❑ Architecture for design-tool functionality

CURRENT STATUS:

The design program is currently very small but it is expected to grow in future years. At this time it is comprised of only two projects that cannot address all the important technical themes within the scope of the design program. New projects are being sought and are anticipated.

REPRESENTATIVE RECENT ACCOMPLISHMENTS:

The DARPA Manufacturing Research Testbed was expanded and a Design Research Laboratory was established to support the Design Methods Program.

- Installed and evaluated in the Engineering Design Laboratory university-developed and commercial software tools for solid modeling, kinematic behavior of objects modeling, and design modeling.

- Published a description of the capabilities of the Engineering Design Research Laboratory.
- Identified, developed models and performed analysis of two design test cases for developing product models--the DARPA/USMC diesel engine and the NIST molecular measuring machine.

REPRESENTATIVE PLANNED ACCOMPLISHMENTS:

Develop and install mechanisms for remote execution of design tools over the Internet and for access to repositories of product data models in standard formats.

Establish a network with DARPA-funded university design/analysis research projects for the exchange of design, STEP, and analysis files.

Demonstrate tools for using design knowledge to assess product performance by developing interfaces between a conceptual design tool and analysis tools.

Develop and document a model of the vibration isolation system of the NIST molecular measuring machine.

MAJOR PROJECTS (Sponsor):

Manufacturing Research Testbed (DARPA/ISTO)

Evaluate software tools for integrating design and analysis; provide consultation to DARPA on sponsored research programs; facilitate the transfer of DARPA-sponsored research results to industry.

Design Research (Navy/Mantech)

Demonstrate, using the Molecular Measuring Machine design effort, the modeling of design intent or design knowledge for access and use throughout the life cycle of a product.

STAFF: Professional 2

FACILITIES: Engineering Design Laboratory

IMPACT:

Including information about all stages of a product's life cycle in the design process expands the designer's role and improves efficiency in product development.

Results of the evaluation of research design and analysis tools for integration of the design, analysis, and manufacturing stages of a product's life cycle will be used: (1) by DARPA to set

programmatic goals for future work, and (2) by the PDES/STEP community to determine the design information required in the standard to support analysis, such as structural and thermal stress analysis.

LONG-TERM GOAL:

The long-term goal of the Design Program is an intelligent design workstation that demonstrates concurrent design processes using an integrated set of software tools, models, and knowledge databases.

PRODUCT DATA SHARING PROGRAM

MISSION AND FUNCTION:

The mission of the Product Data Sharing Program is to provide technical leadership and a testing-based foundation for the rapid and complete development of the STEP specification. STEP is being developed as a neutral method and mechanism that can be used to represent completely product data throughout the life cycle of a product. The completeness of this representation makes it suitable not only for neutral file exchange, but also for implementing and sharing databases and for archiving. The Product Data Sharing Program focuses on the development of STEP, methods for testing the standard, and methods for implementing it in a shared-database environment. In addition, to help promote the achievement of STEP-based commercial systems, NIST is assisting in establishment of a long-range STEP development and deployment plan and a national testing network.

TECHNICAL THEMES:

- ❑ Advanced information modeling languages and tools to support information standards development
- ❑ Architectures to support product data sharing
- ❑ Advanced database technology to support product data sharing (e.g. extensions to data dictionaries and object-oriented methods)
- ❑ Capability to describe unambiguously the characteristics of manufactured products
- ❑ Harmonization among product and application standards
- ❑ Architectures to support product knowledgebase capability
- ❑ Formal methodologies to develop application protocols
- ❑ Verification and validation testing methods for STEP
- ❑ Conformance testing methods for STEP
- ❑ Software tools for using STEP
- ❑ Extensions to STEP to support product knowledge

CURRENT STATUS:

The Product Data Sharing Program is the largest program in the Division. At present, it is funded primarily by the Department of Defense. Additional support from the Department of Commerce is anticipated, in accord with a Memorandum of Understanding between the Departments.

REPRESENTATIVE RECENT ACCOMPLISHMENTS:

Identified baseline contents for STEP Version 1 draft specification, specified development and testing methodologies, and established initial set of software tools to support the STEP effort.

- Established National PDES Testbed facility and initiated implementation of the validation and testing system, the STEP-based production cell, and the configuration management system and services as functional components of the Testbed.

- Conducted Testbed training for users from industry and published technical plans for Testbed technical threads.
- Established STEP On-Line Information Service facility, published user's guide and conducted training for users, developed document tracking system for the IGES/PDES Organization, and published a prototype CD-ROM containing browseable and searchable information about product data standards.
- Contributed to the development and publication of STEP model qualification guidelines, the STEP unification meta-model, STEP integration methods, and the expandable core for STEP.
- Helped establish a product data exchange standards activity within the American Apparel Manufacturer's Association, developed a specification for a neutral-file definition for two-dimensional apparel patterns, and implemented translators between two popular apparel pattern formats and our neutral file definition.
- Established a new IGES/PDES/STEP Administrative Office to support national and international product data standards activities, and developed goals, tasks, resource allocations, and established operations for the Administrative Office.

REPRESENTATIVE PLANNED ACCOMPLISHMENTS:

Develop and publish PDES/STEP strategic and technical plans for application protocol specification, validation, conformance testing, and technical support activities.

Provide support for completion of the Version 1 STEP specification, including leadership, editing, validation testing, methodology, model-quality management, and configuration management.

Publish (1) the results of a study of the relationship between the Information Resource Dictionary System (IRDS) and the STEP Unification Meta-Model (SUMM), (2) the design and specifications of the National PDES Testbed Configuration Management System, (3) the requirements for information model quality management, and (4) a new CD-ROM containing the 1991 draft STEP Version 1.0, including updated supporting documentation.

Establish the Product Data Exchange Network of testbeds and test nodes to support STEP implementations at various government, industry, and university sites.

Demonstrate exchange of apparel product data between dissimllar pattern design systems.

Define goals, tasks, and resources necessary to support the activities in the memorandum of understanding between the Departments of Defense and Commerce on PDES/STEP and in the new IGES/PDES Organization role as an accredited product data standards developer.

Complete editing of assigned IGES/PDES/STEP documents being issued for ballot and distribute part documents for STEP Version 1 ballot as draft international standard.

MAJOR PROJECTS (Sponsor):

National PDES Testbed (DoD/CALS)

Provide technical leadership for the development of the STEP standard by establishing (1) a testing program for validating the draft STEP specifications, (2) an application prototype center for evaluating and demonstrating the use of STEP in an industrial environment, (3) a configuration control system for managing and making available STEP documents and software, and (4) a national product data exchange network in cooperation with the CALS Test Network.

PDES for Apparel Industry (DoD/DLA)

Assist DoD to improve productivity, quality control, and competitiveness of the U.S. apparel industry by helping to develop methods for product data exchange appropriate to the industry.

Product Data Engineering (STRS[1])

Participate in the development and testing of a product data model that can serve as an international standard for product data sharing, including research into neutral representations and quality management of such models. Study new techniques for representation of standards documents and activities through the use of such technologies as hypertext.

Testing Object Oriented Databases (DARPA)

Assess trends and requirements for object technology in engineering and manufacturing environments.

IGES/PDES/STEP Administration Office (STRS)

Support the development of STEP by chairing and operating the U.S. Secretariat for ISO Technical Committee 184, Subcommittee 4 and chairing the IGES/PDES Organization.

STAFF:

Professional	20
Technical Support	3
Clerical Support	3
Guest Researcher	2

FACILITIES: Validation Testbed Computer Facility
STEP Information Service Facility
Apparel Design Research System

[1] NIST Congressional appropriations for Scientific and Technical Research and Services.

IMPACT:

The development of STEP involves hundreds of technical experts around the world; it is one of the largest and most complex standards efforts ever. Major institutions that are involved formally in the development of STEP include: the ISO Subcommittee (TC184/SC4), the IGES/PDES Organization, the ANSI U.S. Technical Advisory Group to TC184/SC4, the PDES, Inc. industrial consortium, and NIST. Some of the major challenges in the area of product data sharing technology are shared database technology, product data modeling, data representation, verification and validation methods, application development and testing methods, configuration management, commercialization, and conformance testing. NIST is involved in all aspects of the development of STEP, primarily as the leader in the development and implementation of testing procedures. The development of STEP fits into NIST's mission to develop standards for information technology and to develop tests to ensure that computer software and data conform to the standards. STEP must be based upon an accurate representation of data that is exchanged or shared during the various stages of a product's life cycle.

The NIST National PDES Testbed supports the goals of the IPO and ISO to establish an international standard that will support product data sharing. The National PDES Testbed was established at NIST in 1988 under U.S. Department of Defense Computer-aided Acquisition and Logistic Support (CALS) program funding. Standards which support product data sharing are recognized as a major building block in the CALS program. Under CALS sponsorship, the National PDES Testbed is supporting the development of product sharing technologies not only for the Department of Defense, but also for other agencies within the U.S. government and American industry. The staff of the National PDES Testbed are not only involved with the ISO and IPO, but also actively participate in the program of PDES, Inc. NIST is a government associate in the PDES, Inc. industrial consortium.

A November 1990 Memorandum of Understanding (MOU) between the Department of Defense, Production and Logistics, and the Department of Commerce, Technology Administration, identifies PDES and STEP as integral to the common goal of accelerating the development and deployment of "technology that will result in higher quality, shorter time to production, and lower costs for both weapon systems and commercial products." Under the MOU action plan, the Department of Commerce is supporting CALS/PDES standards through research and development of relevant technologies, standards organization activities, technology transfer, information dissemination, and management and coordination of the National PDES Testbed.

LONG-TERM GOAL:

The long term goal for the Product Data Sharing Program is a product data standard that defines all the data needed to cover the entire life cycle of a complex product such as a motorized vehicle. The standard will specify the application protocols against which life cycle applications can be tested. In addition, the standard will specify the shared database or knowledgebase environment for implementing product data specifications.

SYSTEMS INTEGRATION PROGRAM

MISSION AND FUNCTION:

The Systems Integration Program provides a common reference framework, modeling methodology and associated software tools to enable industry to establish a cost-effective strategy for automating enterprise infrastructures. The framework will enable the integration of such functions as business operations, process control, information management, and communication services. The Systems Integration Program addresses inter- and intra-enterprise operations. International consensus on the framework will be the model for development and implementation of international standards and for integration of many types of applications and industries. Supporting this enterprise framework are computer and networking systems to support the design, implementation, operation and evolution of distributed information systems. The concept is to create modular information technology components that can be easily integrated on an information platform.

TECHNOLOGY THEMES:

- ❑ Common reference framework for enterprise integration
- ❑ Generic specifications for different views of an enterprise
- ❑ Modeling methodologies to support an enterprise integration framework
- ❑ Software tools for implementing enterprise models
- ❑ Standards for enterprise integration framework
- ❑ Harmonization with existing standards in open systems architectures (OSA), open distributed processing (ODP), and distributed information systems (i.e., Information Resource Dictionary System (IRDS), Remote Data Access (RDA), and Structured Query Language (SQL))
- ❑ Conformance-testing methods for framework standards
- ❑ Methodologies for data security

CURRENT STATUS:

The present focus of the Systems Integration Program is the objective of the Manufacturing Systems Integration Project: integration and interface manufacturing standards. In the future, enterprise integration framework research and development will occupy a larger component of the program. As a result, the accomplishments will relate better to the technology issues in the program.

REPRESENTATIVE RECENT ACCOMPLISHMENTS:

Designed an open system architecture for integrating manufacturing engineering and production engineering software applications, and demonstrated initial working prototype of an integrated testbed utilizing real and emulated manufacturing equipment, including the production of mechanical parts.

- Documented specifications for an open system architecture and a draft of system interface requirements.
- Implemented a basic factory resource model for AMRF resources and implemented a generic factory controller to utilize ALPS (A Language for Process Specification) process plans for scheduling tasks on the vertical workstation.
- Demonstrated working prototype of the integrated desktop testbed.
- Developed a concept document that defines a control architecture that facilitates the integration of manufacturing engineering, production planning, and shop floor control to test standards to support integration.
- Organized the Enterprise Integration Framework Working Group and held first three meetings.

REPRESENTATIVE PLANNED ACCOMPLISHMENTS:

Design and document a production control architecture that can be used to test different types of factory control configurations.

Evaluate and incorporate into the Manufacturing Systems Integration Project testbed enterprise framework tools and evolving standards for communications, STEP, and database access.

Publish a description of the manufacturing systems integration factory configuration management system and the shop-to-workcell control interfaces for existing and emulated workstations.

Participate and assist in organizing meetings and a series of workshops with the European Community Esprit Program to study areas of mutual concern in computer integrated manufacturing and enterprise integration.

MAJOR PROJECTS (Sponsor):

Manufacturing Systems Integration (MSI) (Navy/Mantech)

Develop a "desktop testbed" environment to test and demonstrate integration and interface-standards concepts. Study emerging manufacturing standards and database requirements.

Enterprise Integration (AF/Mantech)

Champion the establishment of an organized information systems structure and set of guidelines, including definitions and standards that will support the integration of enterprise information systems. Apply information modeling methodology to enterprise integration. Work to overcome the barriers to harmonization of product data for mechanical and electrical products.

Manufacturing Engineering Systems (STRS)

Study data and interface requirements for commercial manufacturing engineering software systems to support the development of standards for software systems integration. Study emerging standards and database requirements that support integration of product data across commercial systems. The emphasis is on manufacturing functions, such as

- Documented specifications for an open system architecture and a draft of system interface requirements.
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process planning, engineering design, tool management and off-line programming, for small mechanical parts.

Access to Manufacturing Information (STRS)

Perform research and develop standards in distributed data access. Develop and test prototype reliable distributed data services in a heterogeneous computer environment.

STAFF:	Professional	9
	Technical support	2
	Clerical Support	2
	Guest Researcher	1

FACILITIES: AMRF Vertical Workstation and control rooms
Division computer systems and networks

IMPACT:

"Enterprise integration framework" is a term that is used to refer to the overall approach to the integration of all activities of an enterprise. Just as STEP implies a standard means of representing information about a product as well as the infrastructure necessary to access and contribute to that information in a heterogeneous computer environment, enterprise integration framework includes the structure, methodologies, and standards to accomplish the integration of all activities of an enterprise. One important key is the sharing of all kinds of information. In a sense, enterprise integration framework allows for a concurrent approach not only to engineering, but also to accounting, marketing, management, inventory control, payroll, and other activities that are vital to the functioning of an enterprise. It is an approach that can both guide the integration of an enterprise's activities and provide the standardized organization and arrangement for the integration to occur. Just as multi-enterprise concurrent engineering is the next step in the evolution of manufacturing, the enterprise integration framework is the next step in the evolution of engineering standards.

The Manufacturing Systems Integration Project provides a critically needed foundation for future facilities that can effectively utilize current standards, yet can grow easily to support future data exchange and communication standards. A number of major manufacturing companies have already requested information on various parts of the manufacturing systems integration desktop testbed.

LONG-TERM GOAL:

The long term goal for the Systems Integration Program is an international standard for an enterprise integration framework that can be used for applications such as enterprise modeling, information systems integration, enterprise application interoperability, and enterprise networking.

LIFE CYCLE APPLICATIONS PROGRAM

MISSION AND FUNCTION:

The mission of the Life Cycle Applications Program is the implementation of prototype applications of different processes in different manufacturing industries to test proposed standards, concepts and frameworks for shared database and "knowledge-base" technology. The applications are implemented in both laboratory and more realistic manufacturing environments. The results of such applications lead to further understanding and improvements in manufacturing-related standards and information technology methods. Through the development of applications, NIST collaborates with U.S. industry as well as other government agencies to transfer and implement technology.

TECHNOLOGY THEMES:

- ❑ Methodologies for capturing and representing product and process knowledge
- ❑ Methodologies for representing process performance capabilities
- ❑ Product data-driven processing
- ❑ Methodologies for evaluating the performance of data interface standards implementations
- ❑ Testing procedures to ensure that information and interface standards work in a multi-enterprise concurrent engineering environment
- ❑ Testing procedures to ensure that software applications have the functionality to support a concurrent engineering approach.

CURRENT STATUS:

The scope and variety of projects in the Life Cycle Applications Program will be increased as opportunities to apply the Division's research and development results become available.

REPRESENTATIVE RECENT ACCOMPLISHMENTS:

Designed and implemented life cycle systems relating to tool management, postal tray handling and management, and gas atomization metal powder processing, characterizing them in terms of product data interfaces, performance characteristics usable for concurrent engineering, and integration interfaces.

- Demonstrated initial prototype algorithm testing systems for coordinate measuring machine software performance.
- Documented requirements for an automated tool management system for flexible machining cells at the U.S. Army Rock Island Arsenal and for U.S. Postal Service automated tray and operations management system.
- Completed development of a monitoring and control system for the production of metal powders and demonstrated the control of a learning system that uses neural nets.

REPRESENTATIVE PLANNED ACCOMPLISHMENTS:

Publish draft standards for the assessment of coordinate measuring machine software and for the mathematics of tolerances.

Complete implementation of algorithm testing system for coordinate measuring machines.

Establish engineering principles for using manufacturing process models to design the inspection process.

Devise and implement intelligent control strategies to achieve desired particle size distributions in a metal powder process.

Complete and document an open systems architecture for tool management system at Rock Island Arsenal.

MAJOR PROJECTS (Sponsor):

Inspection Systems Research (Navy/Mantech)

Conduct research on establishing mathematical models for the definition and evaluation of tolerances. Test the validity of STEP, particularly the tolerance model. Develop standards for the mathematics of tolerances and for measurement methods.

Inspection Software Performance (STRS)

Develop methods to evaluate the performance of software used in inspection systems.

Vertical Workstation (Navy/Mantech)

Install, evaluate and demonstrate commercial software systems that support production planning and control.

Tool Management Specification (Army/Rock Island Arsenal)

Establish the requirements for tool management at the Rock Island Arsenal automated manufacturing facility. Develop an open architecture and promote standard interfaces for tool management systems.

System Visualization (Navy/Mantech)

Investigate ways of utilizing state-of-the-art visualization technology to demonstrate the internal operations of software systems.

Metal Powder Processing (STRS/Materials Science and Engineering Laboratory)

Develop a controller for the Supersonic inert Gas Metal Atomization (SiGMA) process capable of regulating the production of metal powders and of using acquired knowledge to increase the efficiency of the process.

STAFF:	Professional	6
	Clerical Support	1

FACILITIES: AMRF Inspection Workstation
AMRF Vertical Workstation
Inspection Software Performance Facility
Supersonic inert Gas Metal Atomization (SiGMA) Facility

IMPACT:

Applications of standards, concepts and frameworks are a reliable means for the testing and evaluation needed to move standards and technology quickly into U.S. industry. By applying information technology to working systems, experience and credibility is gained that accelerates the process of dissemination and utilization of standards and supporting technology to improve U.S. competitiveness. Applications also reflect the broader mission of the Factory Automation Systems Division to apply information technology to a multi-enterprise concurrent engineering environment. Applications increase the opportunities for NIST staff to work with industry on specific processes, products and manufacturing systems.

LONG-TERM GOAL:

The long-term goal of the Life Cycle Applications Program is a set of manufacturing standards for a variety of industries that work in a multi-enterprise concurrent engineering environment. This is accomplished through the development of a complete set of applications that can access and process product data for building a complex product such as a motorized vehicle. These applications must have the functionality to process those requirements addressed by concurrent engineering methodology.

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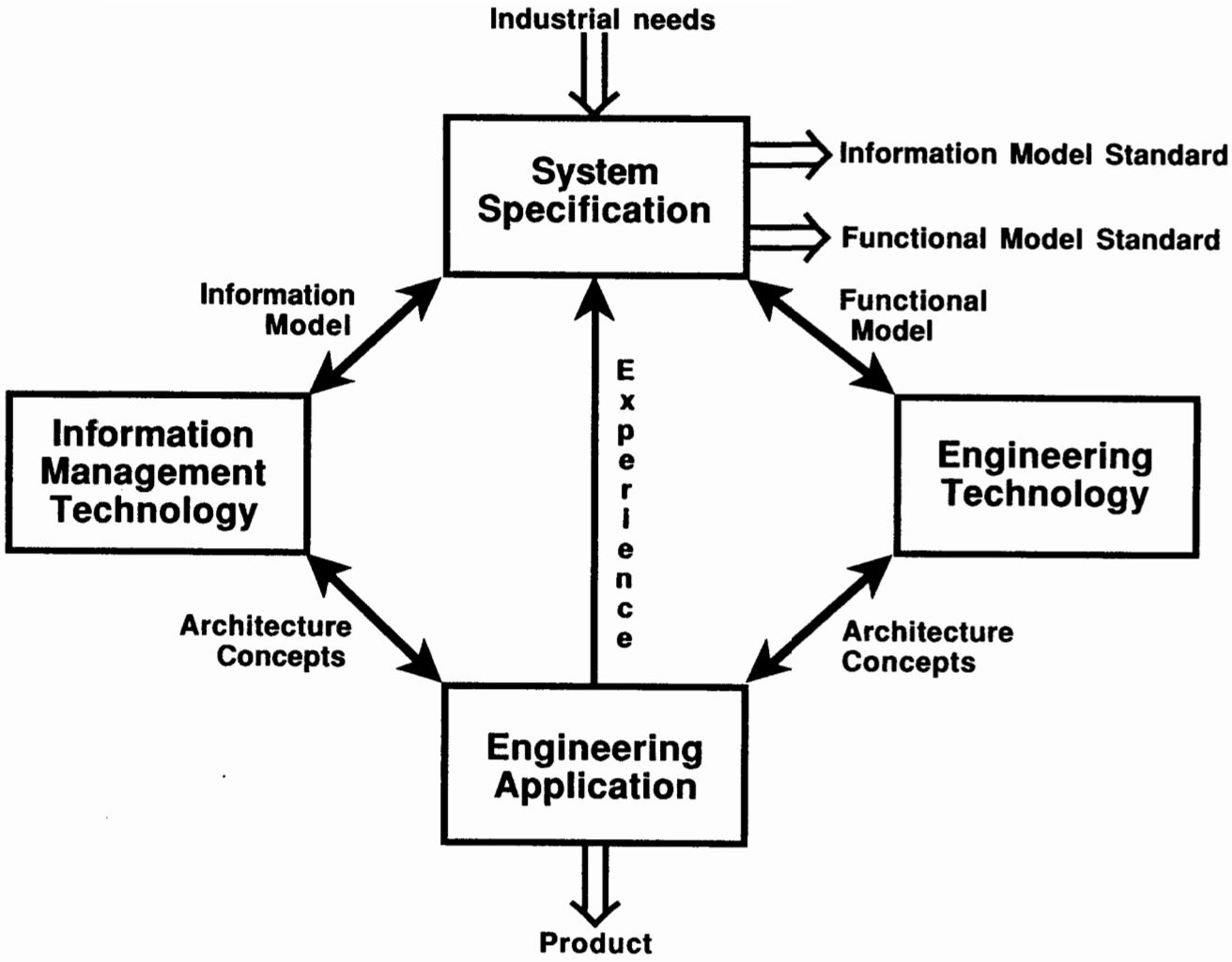

Figure 5. A diagrammatic representation of the Engineering Research Paradigm shows how models, concepts and applications experience connect the four paradigm elements. The double-lined arrows represent inputs to and outputs from the system (e.g., needs, standards and products).

Information Management Technology

- ❑ Information modeling
- ❑ Data dictionaries
- ❑ Distributed database systems
- ❑ Persistent object data systems
- ❑ Product knowledge representations
- ❑ Communication networks
- ❑ Hypertext
- ❑ Configuration management

Engineering Technology

- ❑ Design theory, methodology and tools
- ❑ Geometric modeling
- ❑ Process and materials modeling
- ❑ Product-feature driven manufacturing processes
- ❑ Factory control and scheduling
- ❑ Manufacturing engineering software systems
- ❑ Enterprise integration modeling
- ❑ Manufacturing systems integration

Engineering Application

- ❑ Automated Manufacturing Research Facility
- ❑ Product Data Exchange using STEP (PDES)
- ❑ National PDES Testbed
- ❑ Design Research Testbed

The manufacturing engineering output that best reflects the mission and function of the Division is a shared database used for a multi-enterprise concurrent engineering environment. Research and development activities in the Division are chosen using the criterion that the result of such activities leads to the implementation of technologies and standards for supporting this database system. Such a shared database should contain an unambiguous description of the characteristics of each manufactured product and the rules and practices needed for efficient production of quality products. The application of the elements of the Paradigm to concurrent engineering is shown in Figure 6.

ENGINEERING STANDARDS, DISCIPLINES, AND TECHNOLOGY DEVELOPMENT:

The engineering standards, disciplines and technologies that have evolved to meet the challenges of manufacturing in the twenty-first century are schematically shown in Figure 7. The following discussion relates the work of the Division to the goals of enterprise integration, product data engineering, and concurrent engineering practices.

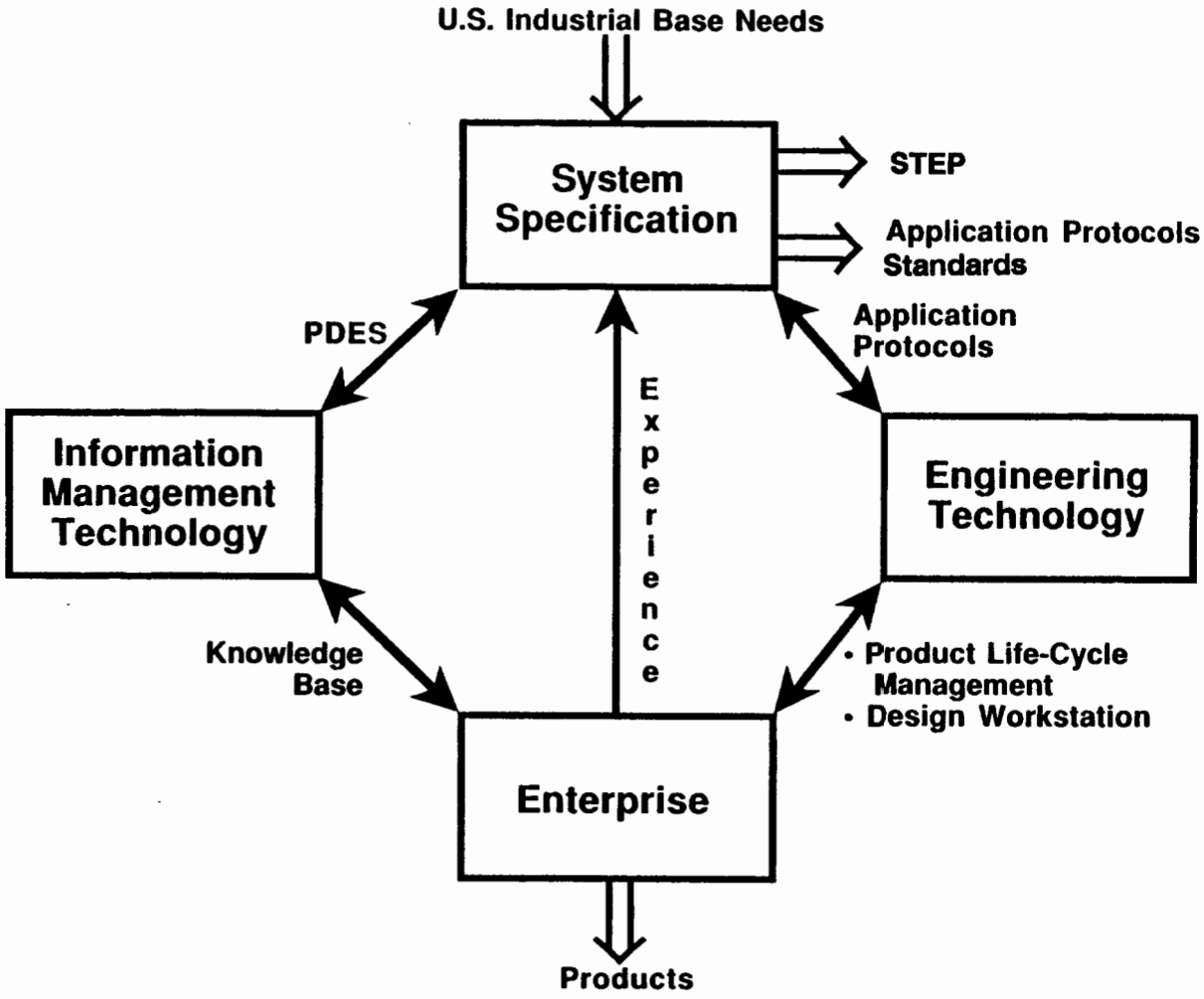

Figure 6. When the paradigm is applied to concurrent engineering, the engineering application is a manufacturing enterprise.

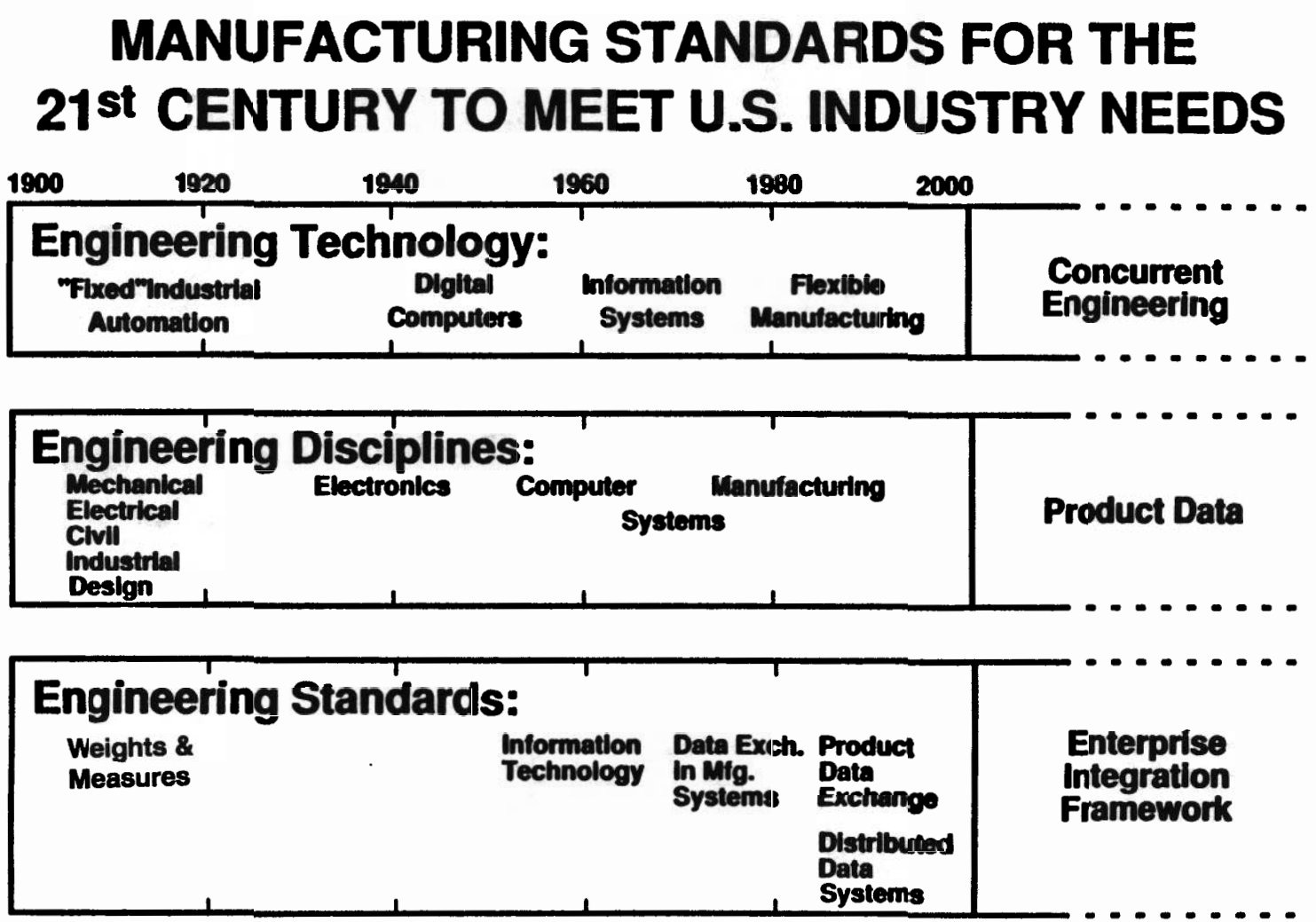

Figure 7. The evolution of engineering standards, disciplines, and technology is leading to an enterprise integration framework as a standard, product data engineering as a discipline, and concurrent engineering as a technology.

In the area of engineering standards development, the Division is building upon:

- Existing and emerging information technology standards (first introduced in the 1960's),
- Manufacturing data exchange standards (introduced in the 1970's and 1980's through such programs as the Automated Manufacturing Research Facility at NIST,
- Product data exchange standards, and
- Distributed data systems standards (introduced in the late 1980's).

The merger of these standards will lead to the development of an Enterprise Integration Framework (EIF) that will help U.S. industry to better communicate among its internal and external organizational units. EIF is an organized information systems structure and a set of definitions which supports the integration of enterprise information systems.

In the area of the engineering discipline required to support the standards and technology development, the Division has incorporated:

- Classic engineering disciplines (such as mechanical, electrical, civil, industrial and design) that have existed since the early 1900's,
- Electronics (introduced in the 1940's),
- Computer science (introduced in the 1960's), systems engineering (emerging in the 1970's), and
- Manufacturing engineering (introduced in the 1980's)

in an effort to promote a new engineering discipline to meet the needs of the twenty-first century. This new discipline, Product Data Engineering (PDE), is an information management technology approach to the application of standardized product data to all aspects of an enterprise's mode of business.

In the area of the engineering technology research and development, the Division builds upon:

- The original "fixed industrial automation" (introduced in the early 1900's),
- Digital computer technology (from the 1940's),
- Information systems (from the 1960's), and
- The flexible manufacturing systems (of the 1980's)

to develop new approaches to the application of concurrent engineering to meet U.S. industrial needs. Concurrent engineering is a systematic approach to the integrated, simultaneous design of products and their related processes, including manufacture and support. The research involves defining and implementing the information technology requirements for such manufacturing processes as product design, process planning, equipment control (e.g., machine tools, coordinate measurement machines), and logistics support (e.g., maintenance and repair). This research will lead to an better understanding of the database requirements to support the product life cycle through the development of a product data sharing technology and an enterprise integrated framework.

INDEX

NIST-114A
(REV. 3-90)

U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

BIBLIOGRAPHIC DATA SHEET

1. PUBLICATION OR REPORT NUMBER
NISTIR 4584

2. PERFORMING ORGANIZATION REPORT NUMBER

3. PUBLICATION DATE
May 1991

4. TITLE AND SUBTITLE

Technical Program of the Factory Automation Systems Division 1991

5. AUTHOR(S)

Howard M. Bloom; Gary P. Carver

6. PERFORMING ORGANIZATION (IF JOINT OR OTHER THAN NIST, SEE INSTRUCTIONS)

U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
GAITHERSBURG, MD 20899

7. CONTRACT/GRANT NUMBER

8. TYPE OF REPORT AND PERIOD COVERED

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (STREET, CITY, STATE, ZIP)

10. SUPPLEMENTARY NOTES

11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

The Factory Automation Systems Division (FASD) provides a focus for national research and standards efforts related to information systems for manufacturing. In carrying out its mission, the FASD contributes to the strength of manufacturing in the United States and to the ability of the United States to remain competitive in world markets. A major objective of the FASD is to provide leadership in the development of national and international standards relating to information technology and manufacturing systems to meet U.S. industry needs for the twenty-first century. The work of the FASD is based on the principle that this leadership must be founded on experience in implementing and testing new information technologies and engineering concepts. Such experience is used by Division staff to develop and promote appropriate standards and technologies (and the engineering disciplines needed to support them), particularly for manufacturing interface standards and product data exchange standards for automated manufacturing systems.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

Automated manufacturing, concurrent engineering, information systems, information technology, manufacturing, manufacturing standards, manufacturing systems, PDES, product data sharing, system integration

13. AVAILABILITY

XX	UNLIMITED
	FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NATIONAL TECHNICAL INFORMATION SERVICE (NTIS).
	ORDER FROM SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, DC 20402.
X	ORDER FROM NATIONAL TECHNICAL INFORMATION SERVICE (NTIS), SPRINGFIELD, VA 22161.

14. NUMBER OF PRINTED PAGES
33

15. PRICE
A03

ELECTRONIC FORM