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Systems Integration for Manufacturing Applications 1998 Annual Report

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Introduction

The Systems Integration for Manufacturing Applications (SIMA) Program is an intramural effort being undertaken at the National Institute of Standards and Technology (NIST) to support the application of information technologies to the manufacturing domain. Initiated in 1994, the Program works with industry to develop technology solutions enabling integration of the systems used in the engineering and manufacturing of various kinds of products. The plans for the Program were originally described in [1] and were updated in 1997 [2]. Program activities and project accomplishments for previous years have been documented in [3] and [4]. The purpose of this document is to report on two fiscal years of the Program's technical activities: 1997 and 1998 (FY97-FY98). The intended audience for this document includes private sector organizations and federal agencies collaborating with NIST, other agencies participating in the federal Computing, Information, and Communications (CIC)[1] effort, and the general public. This report is available via the SIMA web page (http://www.nist.gov/sima/) or by electronic mail request to the SIMA Program Office secretary (simasec@nist.gov).

This report is comprised of three major sections: the SIMA Overview, the Project Accomplishments, and the Appendices. The SIMA Overview section provides a high-level description of the Program's goals, technical efforts, results, and progress. The Project Accomplishments section provides individual descriptions for each of the projects funded by SIMA in FY97 and FY98. Each project description includes a summary of the project's technical accomplishments along with a list of the project's collaborators. The Appendices to the report include a description of the organization of the Program (Appendix A), tables summarizing all collaborators enumerated in each of the project descriptions (Appendix B), a list of publications completed by the projects (Appendix C), and a list of products available from the projects (Appendix D).

SIMA Overview

NIST's SIMA Program is the agency's coordinating focus for its CIC activities addressing the information interface needs of the U.S. manufacturing community. Specifically, the SIMA Program performs the following activities:

- develop standards for information exchange and interface protocols addressing interoperability problems in manufacturing systems.
- provide online access to NIST-resident capabilities supporting manufacturing technologies.
- develop collaboration technologies enabling industry researchers, practitioners, and NIST staff to remotely work together.

These efforts will allow manufacturing industries to make use of computer networks - be they local or wide-area, public or private - as a mechanism for communicating information among manufacturing activities. In the context of the SIMA Program the phrase "manufacturing activities" is broader than simply operations on the shop floor; it also includes activities such as the research conducted to devise new products and processes, the design of products and processes, the engineering analysis of prospective solutions, the planning of manufacturing operations, the scheduling of production operations, the engineering of production capabilities, and the myriad of other information-intensive activities required in industry today. All such activities are conducted using manufacturing software systems and these systems require information interfaces in order to communicate with each other. Those information interfaces may be realized as specifications for application programming interfaces, for data exchange protocols, or even as human-computer interfaces. The primary focus of the SIMA Program is the development and testing of information

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1. The federal government's initiative in High Performance Computing and Communications was subsumed by the overarching multi-agency Computing, Information, and Communications efforts in 1997.

interfaces that provide scientists, engineers, and manufacturing personnel with the capability to share information among different activities, among different application software components within manufacturing enterprises, and throughout the entire supply chain.

Background

The U.S. government initiated the High Performance Computing and Communication (HPCC) Program in 1991 with the High Performance Computing Act (Public Law 102-194). The government's effort was intended to accelerate the development of future generations of high performance computers and networks and the use of these resources in the government and throughout the U.S. economy. The four original components[2] of the HPCC Program were augmented in FY94 with a new component known as Information Infrastructure Technology and Applications (IITA) [5]. The IITA component supported research and development efforts that would enable integration of critical information systems and demonstrate feasible solutions to problems of national importance [6]. Twenty-first century manufacturing, i.e., advanced manufacturing processes and products, was one of the challenges to be addressed by IITA activities [7]. In recognition of the HPCC Program's continuing successes and broadening scope, the Program was renamed as Computing, Information, and Communications and the components of the Program were refocused into Program Component Areas (PCAs) [8]. These PCAs build on the foundations established in the previously identified component domains and continue to address the HPCC challenge problems. The PCAs are known as High End Computing and Computation, Large-Scale Networking, High Confidence Systems, Human-Centered Systems, and Human Resources, Education, and Training. The Human Centered Systems (HuCS) PCA, which evolved from the IITA component, performs research and development making the products of computing systems and communication networks more easily accessible and useable to a wide range of user communities. HuCS efforts focus on knowledge repositories, collaboratories, multi-modal system interactions, and virtual reality environments. Information interface issues are central to such research and development efforts, hence NIST's SIMA Program is part of the larger multi-agency HuCS PCA [9].

Major Technology Efforts

SIMA technology efforts stem from both the short- and long-term needs of U.S. manufacturers and their software suppliers. Industry needs evolve in response to technology and market realities, thereby resulting in corresponding changes in the SIMA Program's project portfolio over time. Twenty-five (25) projects comprised the SIMA Program in FY97 and FY98. These projects addressed a wide range of industry manufacturing domains: chemical products, electrical products, materials, mechanical products, and constructed facilities. In this section, the focus is on the technology areas addressed in the projects. As illustrated in Figure 1 the Program is organized into three technology areas: Interface Standards, Information Access, and Collaboration Mechanisms. Appendix A of this document provides organizational details of the Program. Each technology area is discussed in more detail below.

Interface Standards Efforts
The foundation for all efforts in the SIMA Program is the development, testing, and standardization of information specifications enabling communication among the multitude of software applications used in manufacturing industries. Even when software systems reside on the same computer, the present state of affairs is such that there is no guarantee that they can do anything more than send unintelligible data at one another. Still it stands to reason that, for example, the software used to design products should be able to provide design data to the software that is used to plan the manufacturing of the design. In reality engineers and other technical staff spend time recreating data in one software system that already exists in another, devising ad hoc data translation solutions, acquiring unique point-to-

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2. High Performance Computing Systems; National Research and Education Network; Advanced Software Technology and Algorithms; Basic Research and Human Resources.
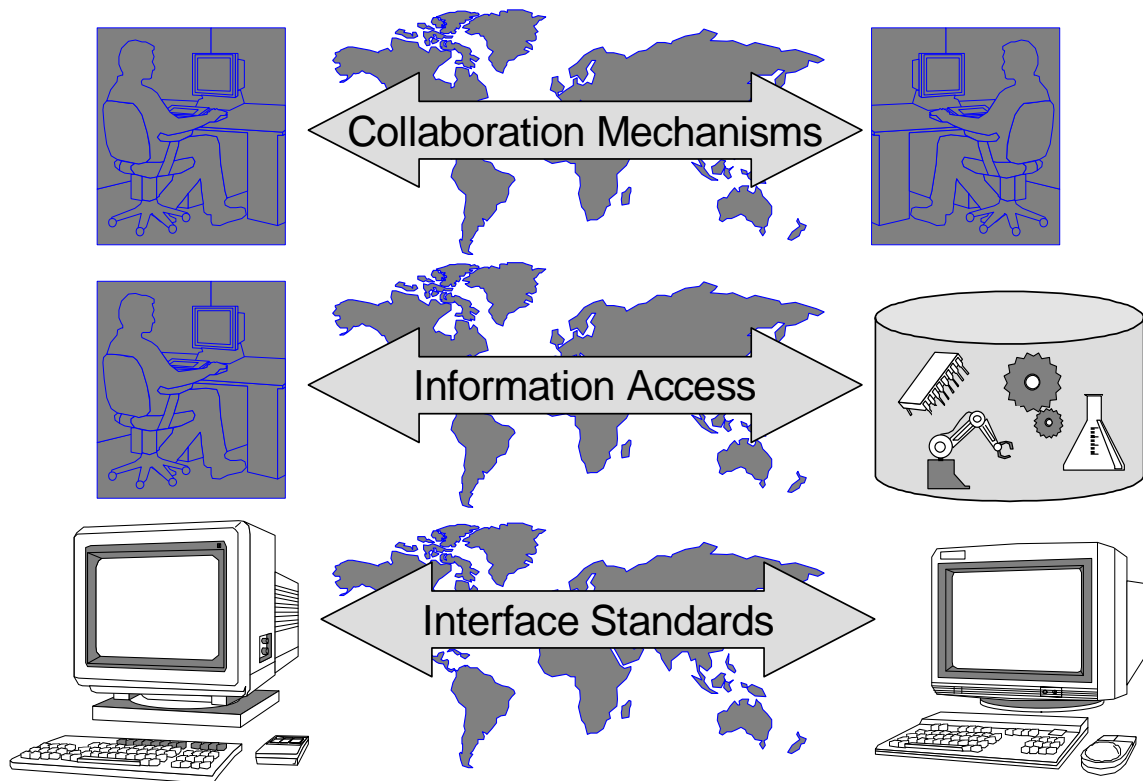
Figure 1. SIMA Technology Areas

point translation services, and identifying the errors that many of these work-arounds introduce. This *lack of interoperability* among software systems exists whether the systems are accessible to each other on the same intranet or on a wide-area network.

To address these interoperability issues, SIMA projects work in conjunction with industry collaborators to identify the requirements for the information that needs to be exchanged among engineering and manufacturing software applications. These requirements form the basis for the information models from which interface specifications are derived. With formal interfaces specifications in hand, prototype implementations of information exchange mechanisms can be developed to help validate the accuracy and utility of the specifications. These tests typically lead to pilot implementations in industry to further increase the robustness of the interoperability solution and to verify the business case for the solution (i.e., Is the prospective cost of the solution justified by the increase in efficiency? Is it less error-prone than existing methods?). With support from the manufacturing users and software developers, the interface specifications can be submitted to formal (or informal) standards developing organizations, e.g., the International Organization for Standardization (ISO) or the Object Management Group for further development and eventual standardization. These interoperability solutions have the effect of improving the degree of integration between particular software systems.

Given that the process for developing interface specifications is fundamental to many SIMA efforts, the Program has documented a methodology for their development. The methodology is called the Initial Manufacturing Exchange Specification (IMES) process [10] and the output from the process is known as an IMES. IMESs are information interfaces which can take the following forms:

- an interface specification between a human and a software application.
- an interface specification between two or more software applications.
- a reference information repository specification.

The third type of IMES refers to a specification for the contents of a repository (typically a database) that is used to provide information to many activities, but the contents of which are updated by only a single process (typically an administration process).

The IMES Process

An IMES is developed through an industry review and consensus process and is accepted by the manufacturing community as a definitive solution to a particular interoperability problem. The IMES process involves seven phases. The execution of these phases need not occur sequentially -- some may overlap while others may occur in parallel. Figure 2 illustrates the seven phases showing how results from each phase are used by the others. The individual phases are described as follows:

Phase 1: Identify/Define Industry Need
The initial activity of IMES development is identifying and documenting an industry need, manufacturing scenario, or problem statement to define the scope and manufacturing domain of the proposed project. This need could be identified in several ways. Industrial collaborators are to be involved in defining this need.

Phase 2: Analyze Requirements
This IMES development phase consists of analyzing the current situation within the manufacturing scenario to understand current capabilities, prior attempts at a solution, and specific needs that must be accommodated in the proposed IMES solution. A requirements specification is the primary desired output from this project phase. Such a specification will enable widespread industry review of the detailed requirements that a solution must satisfy in a form that is understandable by the majority of the target manufacturing community.

Phase 3: Design/Develop
This IMES development phase consists of the actual design, development, and documentation of the proposed IMES technical solution that satisfies the requirements specified in the previous phase. The solution may consist of a combination of deliverable types, including information model(s), interface protocol(s), or process model(s), as required by the problem to be solved. The primary output of this phase is the initial version of the strawman proposal for external review.

Phase 4: Validate
A validation phase is required to ensure the completeness, validity, and usability of the proposed IMES solution. Validation activities may take several forms, including: prototype implementations, detailed walk-through with domain experts, or a comparison with known references. A proposed solution with demonstrated prototype implementations and validation test results makes a much stronger case for standardization. The documented test results (obviously based upon the prototype implementation, test environment, test suites, or other validation tools) are considered the primary output of this phase.

Phase 5: Build Consensus
By definition, an IMES is developed from an industry consensus viewpoint. Whereas most IMES development phases require some collaboration or interaction with industrial counterparts, this phase of IMES development requires interaction with a large segment of the target manufacturing community. This interaction can be accomplished through technical workshops, user group meetings, correspondence, or site visits. IMES development projects should
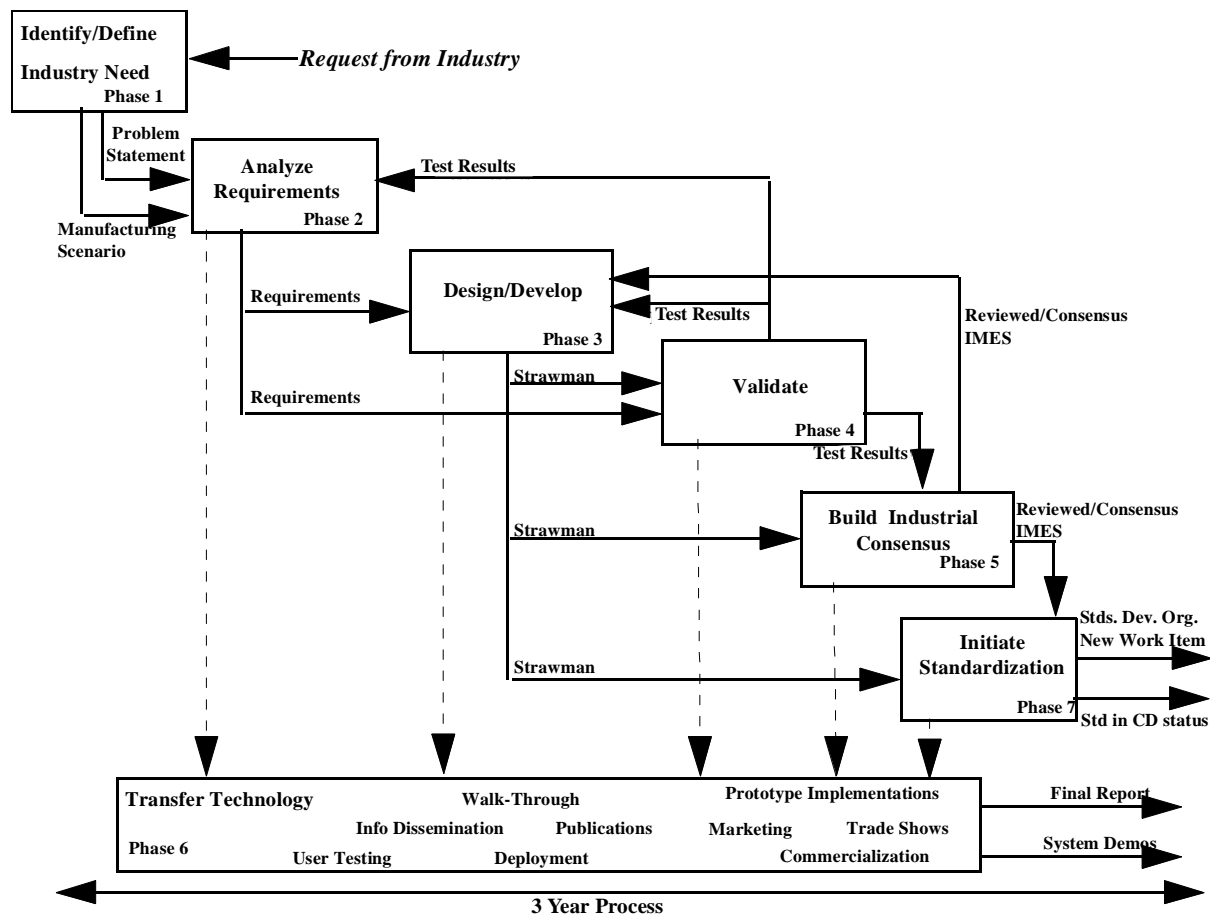
Figure 2. IMES Process Activities

endeavor to obtain and accommodate as much input and feedback from industry as possible in the proposed project solution. True consensus may never be reached. This project phase is deemed necessary, however, for positioning and delivering a quality-proposed strawman for standardization to an appropriate standards development organization. This phase is differentiated from the actual standardization process to allow and encourage other consensus-building activities without the potential constraints and procedures required by standards organizations. The primary deliverable of this phase is an updated Strawman IMES resulting from the consensus-building activities. In some cases, significant comments and suggestions may indicate the need for the project to iterate back to the IMES Design/ Develop Phase 3.

Phase 6: Transfer Technology
One of the primary missions of NIST is to provide technology transfer of NIST research results to industry. The SIMA Program supports this mission. IMES development efforts will include aspects of technology transfer to publicize, market, and transition project activities and results to industry or standards development organizations. Technology transfer should be an ongoing project activity. Various methods of technology transfer can be employed at the various stages of the IMES development effort to supply industry collaborators and the manufacturing community with current information. The primary deliverables for this phase consist of a final report and system demonstrations.

Phase 7: Initiate Standardization

Since an IMES is a proposed standard solution to a manufacturing integration need, IMES development efforts must include interaction with appropriate standards development organizations to initiate this standardization. These activities may include attending standards meetings, participating on various standards committees, or writing project correspondence with standards development organization conveners. The objective of this phase is to initiate the proposed standards work (either as a new work item or modifications to existing standards/work items) to a point where it will be self-sustaining within the standards development organization.

IMES Progress

Six of the SIMA projects have identified a total of seventeen IMES development efforts. Table 1 depicts the IMESs under development and their stage of completion in the IMES process as of the end of FY98. The majority of the IMESs are in the initial phases of development reflecting the projects' efforts in working with industry collaborators to define the scope of the problems that can be addressed through development of these information interface specifications.

Project Name	Identify Industry Need	Analyze Requirements	Develop Solution	Validate Solution	Build Consensus	Technology Transfer	Initiate Standardization
Design - Process Planning Integration (DPPI)	Conceptual CAD to Conceptual Process Planning Interface	❍	❍				
Information Exchange Protocols for Design	Design Knowledge Exchange	❍					
	Explicit Parametrization and Constraints for Geometric Product Models	●	●	●	❍		
	History-based Modeling	❍	❍				
	Solid Interchange Format	❍					
	Traditional CAD to Immersive CAD Interface	●	❍				
Operator Interfaces for Virtual and Distributed Manufacturing	Remote, Internet-based Operator Interfaces	❍					
Process Specification Language	Process Specification Language	●	●	●			

TABLE 1. IMESs by Project. The topic area for each IMES is listed in the Industry Need column. The ❍ symbol indicates on-going work in the corresponding IMES phase, the ● symbol indicates work in that phase is complete, and no symbol at all indicates that no work has occurred in the corresponding IMES phase.

Project Name	Identify Industry Need	Analyze Requirements	Develop Solution	Validate Solution	Build Consensus	Technology Transfer	Initiate Standardization
Production and Product Data Management Applications	Discrete Event Simulation for Production Systems Engineering	●					
	Job, Schedule, and Routing Data Exchange	○					
	Plant Layout to Simulation	●	○				
	Shop Floor Status	●	○				
	Workstation Level Process Plan	●	○				
Reference Model Architecture	Generic Control Node Shell Specification	●	○	○	○	○	
	Human Oversight Interface Specification	●	○	○			
	Message Suite Specifications	●	○	○	○	○	
	Plan Interface Specifications	●	○	○	○	○	

TABLE 1. IMESs by Project. The topic area for each IMES is listed in the Industry Need column. The ○ symbol indicates on-going work in the corresponding IMES phase, the ● symbol indicates work in that phase is complete, and no symbol at all indicates that no work has occurred in the corresponding IMES phase.

Standards Progress

Seven projects are contributing to the development or testing of information interfaces which are already in the formal standardization process (and hence are not considered IMESs). Specifications in these stages of development are typically those that have been in development for at least two years. Table 2 summarizes the twenty-two (22)

Project Name	Standard Designation	FY98 Status
Design - Process Planning Integration (DPPI)	ISO[a] 10303-213: Numerical control process plans for machined parts	Draft International Standard
Electronic Commerce for the Electronics Industry (ECEI)	IEC[b] 62016: Design automation reference model - Core conceptual model of the electronics domain (CCM)	Committee Draft
	Electronic Design Interchange Format	International Standard[c]
	IPC[d] 2510: Generic Computer Aided Manufacturing Descriptions for Printed Boards and Printed Board Assembly (GenCAM)	Industry Standard
	IEC 61360: Standard data element types with associated classification scheme for electric components	International Standard
	ISO/IEC 10303-210: Electronic assembly, interconnect, and packaging design	Draft International Standard
	IPC: Standard Recipe File Format[e]	Industry Standard
Enterprise Resource Planning Interfaces (ERP-I)	OMG[f]: Enterprise Resource Planning	Request for Information
Framework	ISO 10303-219: Exchange of dimensional inspection information	Preliminary Work Item
	OMG: Data Acquisition from Industrial Systems	Request for Proposals
	OMG: Manufacturing Execution Systems	Request for Information
	OMG: Product Data Management Enablers Specification	Adopted
	OMG: Release for Production	Request for Proposals
Standard for the Exchange of Product Model Data (STEP) Conformance and Interoperability Testing	ISO 10303-302: Abstract test suite: Associative draughting	Working Draft
	ISO 10303-303: Abstract test suite: Configuration controlled 3D designs of mechanical parts and assemblies	Working Draft

TABLE 2. Standards Efforts by Project

Project Name	Standard Designation	FY98 Status
STEP for the Process Plant Industries	ISO 10303-227: Plant spatial configuration	Draft International Standard
	ISO 10303-231: Process engineering data: Process design and process Specification of major equipment	Committee Draft
	ISO 10303-327: Abstract test suite: Plant spatial configuration	Pre-working Draft
	ISO 10303-331: Abstract test suite: Process engineering data: Process design and process Specification of major equipment	Pre-working Draft
Standards for Exchange of Instrument Data and NIST Chemical Reference Data	ASTM[g] E1947-98: Standard Specification for Analytical Data Interchange Protocol for Chromotographic Data	National Standard
	ASTM: Laboratory Equipment Communication Interface Specification	Draft Standard
	NCCLS[h] AUTO3-P: Communications with Automated Clinical Laboratory Systems, Instruments, Devices, and Information Systems	Draft Standard

TABLE 2. Standards Efforts by Project

a. The International Organization for Standardization (ISO) is a formal standards developing organization.

b. The International Electrotechnical Commission (IEC) is a formal standards developing organization.

c. This specification is continuing to develop under the auspices of the Electronic Industries Alliance, an industry trade association. Existing versions of the specification have been adopted as national standards by the American National Standards Institute and as international standards by the IEC.

d. The Institute for Interconnecting and Packaging Electronic Circuits (IPC) is an industry trade association.

e. This specification was developed under the auspices of the Surface Mount Equipment Manufacturer's Association (SMEMA). SMEMA has since merged with the IPC, where the specification continues to evolve.

f. The Object Management Group (OMG) is an industry trade association..

g. The American Society for Testing and Materials (ASTM) is a formal standards developing organization.

h. The National Committee for Clinical Laboratory Standards (NCCLS) is a formal standards developing organization.

standards to which the projects have been contributing.

As these standards become more fully deployed in industry it will become practical to assess the effects they are having on specific interoperability problems, and to assess the NIST contributions to those benefits. In the interim, the SIMA Program has already initiated efforts that will lay the foundation for future assessments. One recently completed effort is a study of the interoperability costs incurred by companies in the U.S. automotive supply chain [11]. That study identified annual costs of one billion dollars owing to problems in the exchange of technical data amongst the numerous engineering and manufacturing software applications used by those companies. The costs identified included expenditures for additional engineering labor to fix errors resulting from inaccurate data exchanges and time-to-market delay costs. The study indicated that these costs were likely to be representative of the interoperability costs experienced in other transportation manufacturing industries as well (e.g., aerospace). The information interfaces and interoperability solutions resulting from the SIMA Program are expected to play a significant role in reducing the interoperability costs that manufacturers are incurring.

Information Access Efforts

The Internet provides an information access capability that continues to evolve and grow with each passing month. Information resources are now available at the user's desktop with only a few keystrokes. With many thousands of information resources however, users are potentially overwhelmed, unable to find what is needed, and unable to use resources efficiently if found because of incompatabilities. Moreover, the veracity of information found on the Internet is frequently called into question. Yet the scientists and engineers responsible for creating new products and processes must have reliable, accurate, and timely access to technical data of known quality in order for their efforts to be successful.

The SIMA Program effort in providing Internet access to technical data is addressing such issues. This effort builds on NIST's well-respected Standard Reference Data Program (SRDP), which serves the U.S. technical community by collecting published technical data and determining their reliability. NIST's SRDP offers evaluated scientific data collections that together represent the world's largest collection of evaluated scientific data. These data collections are drawn from the more than 1,000,000 technical papers reporting research published each year in the fields of chemistry, physics, materials science, and engineering. The information in those papers includes numeric data used by U.S. scientists and engineers in their daily work of research, testing, and product/process development. The private sector does not offer the evaluated data services performed by NIST because preparation of reliable scientific databases is not a commercially viable activity. Reliable data requires evaluation, the assessment of data accuracy by expert scientists and engineers. With its strong technical staff, NIST sets the world benchmark for evaluation capability.

The SIMA Program adds value to NIST's existing SRDP effort by making these data collections available to any user with an Internet connection. This not only improves the penetration of these data in the technical community but also ensures that the data the users are depending on are the latest available. In addition, the evolving technical capabilities of internet browsers enable new mechanisms for interacting with these data collections. These include innovative search capabilities based on graphical input from users, interactive manipulation of data graphs, as well as outputs from the data collections that can be directly incorporated into the software on the user's local computer. Seven SIMA projects are involved in these SRDP efforts and have demonstrated considerable success as evidenced by the significant usage of their online data collections by industrial sites.

The SIMA Program also continues to explore related needs for online access to technical information as well as online access to technical capabilities. Other areas of active work include efforts to make interactive versions of widely used NIST reference books in statistics and mathematical functions available on the Internet. Another new effort is making NIST test services for manufacturing software available on the Internet. While the technical community is reaping immediate benefits from these types of capabilities, we expect that the continuing evolution of both Internet technologies and the information interfaces developed in the other parts of the SIMA program will together provide even greater information access benefits in the future.

Collaboration Mechanisms

> *"Research is conducted in virtual laboratories in which scientists and engineers can routinely perform their work without regard to physical location - interacting with colleagues, accessing instrumentation, sharing data and computational resources, and accessing information in digital libraries."*
> President's Information Technology Advisory Committee Interim Report To The President, August 1998

The concept of a collaboratory (collaboration + laboratory) is attributed to Dr. William Wulf, who explored the idea in a white paper (1989) while he was the assistant director of the National Science Foundation's Directorate for Computer and Information Science and Engineering. His vision is repeated in the above report to the President, which among other things, recommends transforming the way research is performed. A variety of technologies need to be more fully developed in order to realize this vision. While the interface standards and information access efforts of the SIMA Program will help to enable this vision, the efforts most relevant to that vision are those in the Program's

projects in collaboration mechanisms. Here, projects are developing the components of a collaboratory environment that will enable NIST researchers and their partners to share information, work together remotely, and in so doing improve the nature of computer-supported collaborations for manufacturing research.

NIST is working to deploy a cutting-edge manufacturing collaboratory as a neutral environment in which other industrial and government partners can cooperate and learn, and in which NIST can begin the active development work necessary to support the next generation of standards for using collaboration technology to support manufacturing. The manufacturing collaboratory provides an environment to test the applicability of human-centered design when applied to manufacturing requirements. Manufacturing partners benefit through early access to frontier collaboration technologies as well as to methodologies for evaluating the impact of these technologies. This exposure is likely to offer valuable insights into how to produce and introduce usable and useful systems for long-distance collaboration. In a broader sense, the manufacturing engineering community will benefit from the existence of a collaboratory testbed. In particular, the testbed will create a new forum for the exchange of technical information among academic, industry, government, and standards bodies. The ultimate goal of the effort will be to create a self-sustaining "critical mass" of expertise and experience with collaboratories, to be drawn upon by projects at NIST, manufacturing researchers, and practitioners.

Looking to the future we can expect that collaboration technologies will lead to new paradigms for the interactions that take place amongst users and amongst manufacturing software applications - indeed in all likelihood there will be new classes of software applications used in manufacturing in this context. The results will undoubtedly be new requirements for information interfaces addressing whole new interoperability problems. Hence the SIMA Program looks to the results of the efforts in collaboration mechanisms as a source of requirements for the other two focus areas of the Program.

SIMA Vision

The vision for the SIMA Program is that of product realization environments based on seamless communication of information among business enterprises, people, software systems, and hardware systems. It is our belief that the three major technology areas in the Program - interface standards, information access, and collaboration mechanisms - together cover most, if not all, of the significant technical challenges preventing a seamless environment for product realization. Decomposing those technology areas a bit further leads to a picture like that shown in Figure 3. Underlying the work of the Program is foundational knowledge of how to integrate systems, drawn from information theory, software engineering, systems engineering, and the like. This foundational knowledge manifests itself as methodologies for developing robust, extensible information-interface specifications and methodologies for testing implementations of those specifications. The importance of these testing methodologies can not be overstated, since the confidence in the implementation of the specification (and therefore its usefulness as an interoperability solution) is related directly to the confidence in the testing methods.

Based on this foundation of integration "know-how," we then have SIMA projects involved in the solution of particular interoperability problems; sometimes from the outset (as in the projects developing IMES's), and sometimes participating at later stages (as in the projects participating in standards development and deployment). The projects targeted at specific problem areas continue to add to the foundational knowledge for systems integration. Hence the short-term benefits of the Program manifest themselves as solutions to specific interoperability problems. But the lasting impact of the Program may well be the legacy of general methods and practices for development and testing of interoperability solutions.
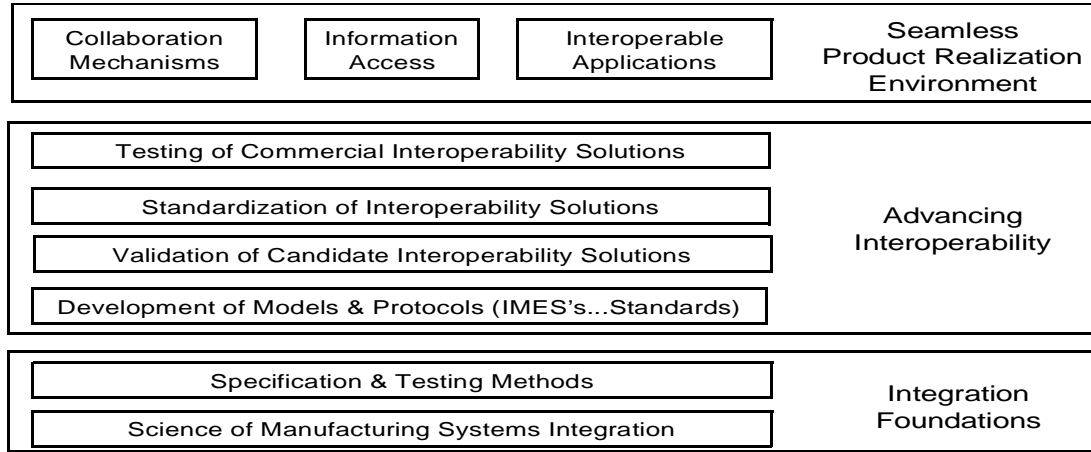
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│  ┌──────────────┐   ┌──────────────┐   ┌──────────────┐      Seamless         │
│  │ Collaboration│   │ Information  │   │ Interoperable│   Product Realization  │
│  │  Mechanisms  │   │   Access     │   │ Applications │      Environment       │
│  └──────────────┘   └──────────────┘   └──────────────┘                        │
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┌─────────────────────────────────────────────────────────────────────────────┐
│  ┌──────────────────────────────────────────────────────┐                     │
│  │   Testing of Commercial Interoperability Solutions    │                     │
│  └──────────────────────────────────────────────────────┘                     │
│  ┌──────────────────────────────────────────────────────┐      Advancing      │
│  │    Standardization of Interoperability Solutions      │   Interoperability  │
│  └──────────────────────────────────────────────────────┘                     │
│  ┌──────────────────────────────────────────────────────┐                     │
│  │  Validation of Candidate Interoperability Solutions   │                     │
│  └──────────────────────────────────────────────────────┘                     │
│  ┌──────────────────────────────────────────────────────┐                     │
│  │ Development of Models & Protocols (IMES's...Standards) │                     │
│  └──────────────────────────────────────────────────────┘                     │
└─────────────────────────────────────────────────────────────────────────────┘

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│  ┌──────────────────────────────────────────────────────┐                     │
│  │         Specification & Testing Methods               │      Integration    │
│  └──────────────────────────────────────────────────────┘      Foundations    │
│  ┌──────────────────────────────────────────────────────┐                     │
│  │   Science of Manufacturing Systems Integration        │                     │
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Figure 3. The SIMA Vision

Project Accomplishments

The following descriptions provide summaries of each SIMA Program technical project. Project summaries are organized by program environment element (see Appendix A for a description of the organization of projects). Each project summary provides a brief description of objectives, accomplishments, and collaborations. Detailed information on any project may be obtained by contacting the principal investigator listed for that project.

Interface Standards Project Summaries

### IS1: Application Protocol Development Environment (APDE)

Principal Investigator: Joshua Lubell
Telephone: (301) 975 - 3563
E-mail: joshua.lubell@nist.gov

The APDE project is working to accelerate the development of ISO 10303 (informally known as the STandard for the Exchange of Product model data, or "STEP") [12] by aiding application protocol (AP) developers in creating STEP specifications of higher quality at lower cost. The APDE project is meeting these objectives by providing an environment for authoring STEP specifications using the Standard Generalized Markup language (SGML) [13] as well as by providing web-based access to STEP specifications and software tools. STEP specifications submitted to ISO must meet specified criteria for document formatting and integration with existing STEP building block specifications. Application protocols (AP) usually require extensive rework before they are allowed to progress through the standards process. Current practices used for AP development require extraordinary labor expenditures on behalf of AP developers to create AP documents. While AP developers may use some software tools to help them accomplish their AP development tasks, the tools work independently, are not integrated, and have not been customized specifically for the purpose of AP development. By providing an SGML-based environment for STEP specification authoring, NIST is increasing the ability of AP developers to reuse relevant portions of existing specifications, to manage complex standards documents, and to improve the quality of the finished standard product.
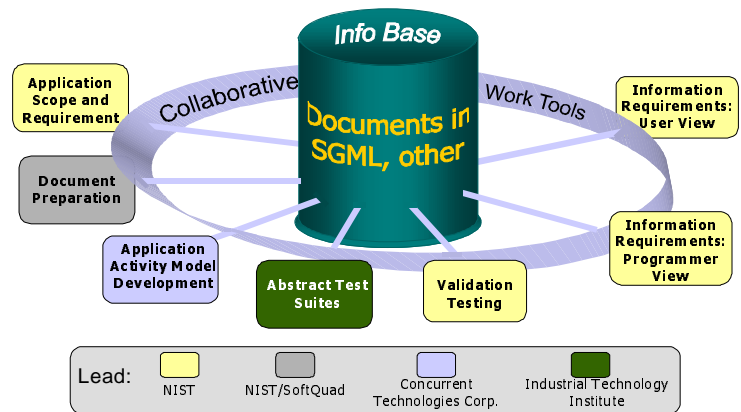
APDE components

Significant FY98/97 Accomplishments

- Supported the Draft International Standard publication of ISO/IEC 10303-210 [14] (Electronic Assembly, Interconnect, and Packaging Design), a 3600 page STEP application protocol utilizing the APDE SGML authoring environment.

- Provided an Internet-accessible, publicly available interface to software tools enabling the processing of STEP information models and data files.

- Developed and deployed a software tool enabling the conversion of SGML-tagged STEP specifications into Hypertext Markup Language (HTML) making them viewable by any Internet browser.

- Provided an Internet browser accessible resource enabling STEP AP developers to search for and view STEP specification building blocks ("units of functionality").

Collaborations

- Boeing, for development of ISO/IEC 10303-210.
- Concurrent Technologies Corporation, for joint development of AP software tools and methods.
- Delphi Delco, for development of ISO/IEC 10303-210.
- Industrial Technology Institute, for development of AP software tools.
- PDES Inc., for development of ISO/IEC 10303-210.
- PlantSTEP, for evaluation of APDE-developed methods and software.
- Rockwell Collins, for development of ISO/IEC 10303-210.
- SoftQuad, Inc., for customization of SGML editing tools for the STEP community.
- STEP Tools Inc., for use of their software tools in the development of the APDE.
- U.S. Army, for development of ISO/IEC 10303-210.
- University of Darmstadt, for development of SGML document type definitions.

IS2: Design - Process Planning Integration (DPPI)

Principal Investigator: Shaw Feng
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The objective of this project is to enable interoperability among the activities of conceptual design, detailed design, conceptual process planning, detailed process planning, and cost estimating. To achieve this, the project is working towards developing interfaces among the software applications used in those activities, reusing existing interface specifications where available, and validating prototype interoperability solutions.
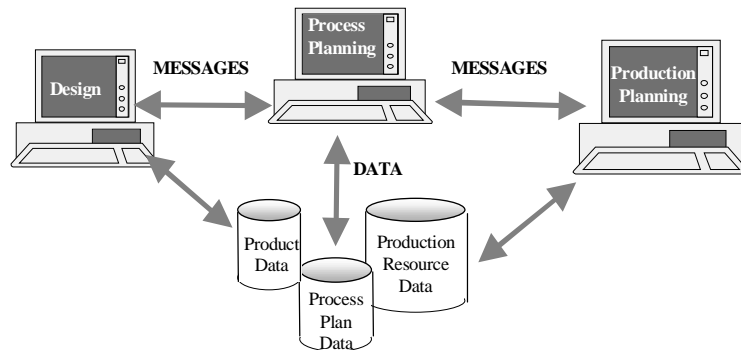
Interactions between engineering design and process planning systems

Significant FY98/97 Accomplishments

- Acquired commercially available, knowledge-based design systems, modeling systems, and process planning systems for use in assessing existing interoperability issues and potential solutions.

- Developed a design/manufacturing model of a gearbox and a conceptual design/process planning system for use in testing evolving interoperability solutions.

- Presented a project overview at the Artificial Intelligence and Manufacturing Research Workshop in Albuquerque, New Mexico, 1998.

- Published a report assessing the coverage of the STEP Application Protocol Process Planning for Numerical Controlled Machining (ISO 10303-213) [15].

- Assisted with the resolution of ballot comments for ISO 10303-213 and thereby enabled the promotion of the document to Final Draft International Standard status.

- Developed and demonstrated a prototype implementation of ISO 10303-213 using commercial process planning and numerical control software systems.

Collaborations

- CAMAX, for validation of numerical control (NC) programming application information requirements using their NC programming system, SmartCAM.

- CIMx, for validation of process planning application information requirements using their process planning system, CS/CAPP.

- CNC Software, Inc., for validation of NC programming application information requirements using their system, Mastercam.

- Institute for Advanced Manufacturing Sciences (IAMS), for work on a pilot implementation of ISO 10303-213.

- PDES Inc., for coordination of the ballot process on ISO 10303-213 and to participate in abstract test suite development.

- Technologies Enabling Agile Manufacturing (TEAM), for definition of requirements for integrated process planning.

- University of Maryland, for investigation of requirements for process specification languages.

IS3: Electronic Commerce for the Electronics Industry (ECEI)

Principal Investigator: James St. Pierre
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The objective of this project is to contribute to the technical development of the neutral product data exchange specifications and the component information infrastructure for the electronics industry. Towards this goal, the project strives to resolve conflicts among competing and conflicting standardization efforts within the electronics industry. Project staff work with industry and other government laboratories to promote the transfer of technical information among the manufacturers of electronic parts and those who need parts for the design, manufacture, and repair of electronic systems. These efforts include research-based prototype development as well as specification development.
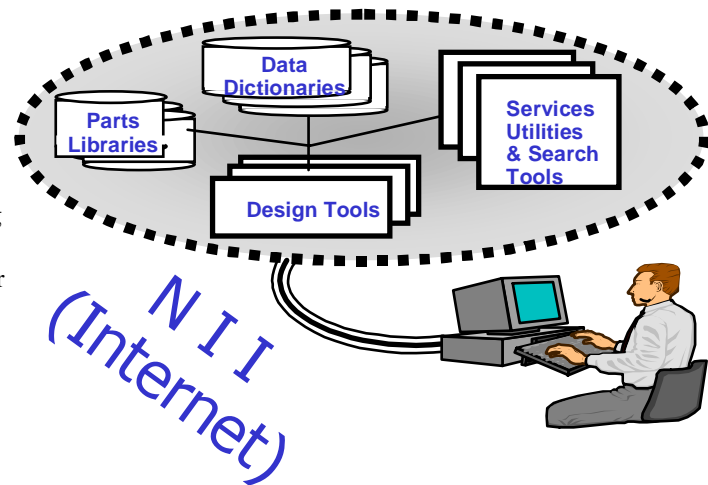
Engineering of electronic products via the internet

Some of the technical areas addressed by this project are: the fundamental terminology used to describe components, the organization of the component data and metadata, and the ability to access this data and incorporate it into the lifecycle of a design. Assisting in the development of standards in this domain is crucial in order for U.S. electronics manufacturers to take advantage of the global marketplace. Industry and standards groups in both Japan and Europe are working actively on ECEI-related projects. This project will work with these groups to minimize overlapping standards development and to ensure interoperability between U.S. ECEI data and that of other countries.

Significant FY98/97 Accomplishments

- Developed a prototype testing environment for implementations of the SEMATECH Computer Integrated Manufacturing (CIM) Framework. The environment can be viewed at http://megavolt.eeel.nist.gov/CIM.html.

- Developed a prototype dictionary translation tool enabling the conversion of electronic component information into the electronic component terminology format defined by the Silicon Integration Initiative. This capability was demonstrated at the Design Automation Conference in Anaheim, California, in June 1998.

- Provided key technical contributions to the development of the STEP Application Protocol for Electronic Assembly, Interconnect, and Packaging Design (ISO/IEC 10303-210) [14].

- Provided key technical contributions to the development of the "Standard Recipe File Format" under development by the Surface Mount Equipment Manufacturers Association and the Georgia Institute of Technology.

- Co-hosted a workshop on Electronic Commerce of Component Information (July 1998) with one result being a plan to initiate an international interoperability pilot test involving Europe and Japan.

- Conducted a joint Defense Advanced Research Projects Agency (DARPA)/NIST/Electronics Design Automation (EDA) Industry Council workshop on design reuse and intellectual property cores (January 1997).

Collaborations

- Electronic Industries Association, for resolution of issues on the Electronic Design Interchange Format (EDIF).
- Electronic Equipment and Component CALS (E-CALS), for development and deployment of electronic component information technologies.
- Component Information Representation European Project (CIREP), for evaluation of component dictionary tools.
- Georgia Institute of Technology, for use of their board assembly facility and development of software tools testing evolving interchange specifications.
- IGES Data Analysis, for development of electronic product information viewer specifications.
- National Electronics Manufacturing Initiative, for development of mechanisms enabling integration of electronics manufacturing equipment.
- Mitta Technology Group, for commercialization of the NIST-developed CIM Framework testing environment.
- Naval Research Laboratory, for analysis of standards issues in the Microwave & Millimeter-wave Advanced Computational Environment (MMACE) Program.
- PDES Inc., for development of ISO 10303-210.
- SEMATECH, for validation of the CIM Framework.
- Silicon Integration Initiative (formerly CAD Framework Initiative), for development of online electronic component databooks standards and software testing tools.
- Surface Mount Equipment Manufacturers Association (SMEMA), for development of interface specifications enabling control of printed circuit board manufacturing equipment.
- Texas Instruments, for development of electronic component dictionary tools.
- Viewlogic Systems Inc., for analysis of electronic component data requirements in electronic engineering and design software.
- Virtual Socket Interface Alliance, for development of software tools helping to resolve terminology issues in the electronics industry.

IS4: Enterprise Resource Planning Interfaces (ERP-I)

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Principal Investigator: Edward Barkmeyer
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The objective of this project is to investigate the need for standards among the software systems used in Supply Chain Management (SCM), Enterprise Resource Planning (ERP) and the other manufacturing software systems that may interface with those systems such as Product Data Management (PDM), Manufacturing Execution Systems (MES), and electronic commerce systems. The approach that the project will follow will be to identify the state-of-the-practice with respect to the enterprise activities making use of these systems, investigate the availability of evolving standards in these areas, identify a framework in which these multiple standards co-exist, identify gaps in the standards efforts, and identify NIST activities that can address those gaps.
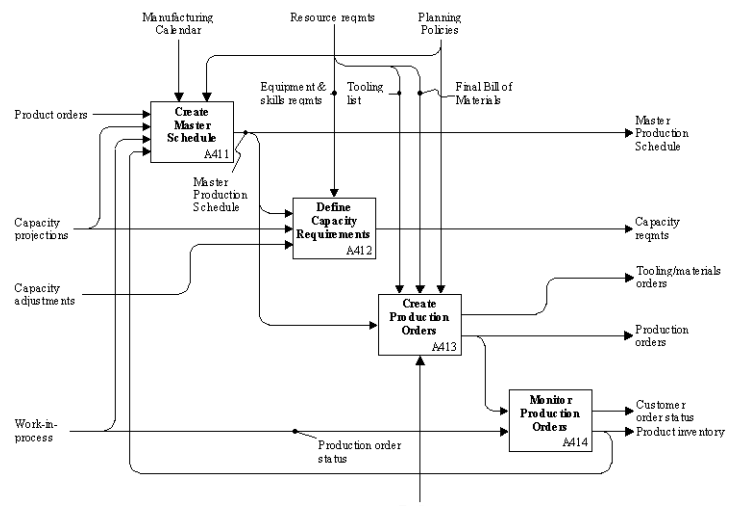
Development of production plan

Significant FY98/97 Accomplishments

- Developed a draft model of enterprise activities, the information resources employed in those activities, and the decision systems supporting those activities.

- Participated in the development of the Object Management Group's Manufacturing Domain Taskforce Release for Production Request for Proposals.

- Developed a state-of-the-art assessment of supply chain management practices.

Collaborations

- Advanced Manufacturing Research, for establishing a forum in which to uncover standards-related issues.

- Defense Advanced Research Projects Agency, for work with the Affordable Multi-Missle Manufacturing Program (AM3) on supply chain issues in missle manufacturing.

- Gartner Group, for identification of industry and market analysis information.

- Indian Institute of Management, for research in enterprise resource management.

- National Industrial Information Infrastructure Protocols (NIIIP) Program, for investigation of supply chain issues in missle manufacturing.

- Supply Chain Council, for modeling of intracompany and intercompany supply chains.

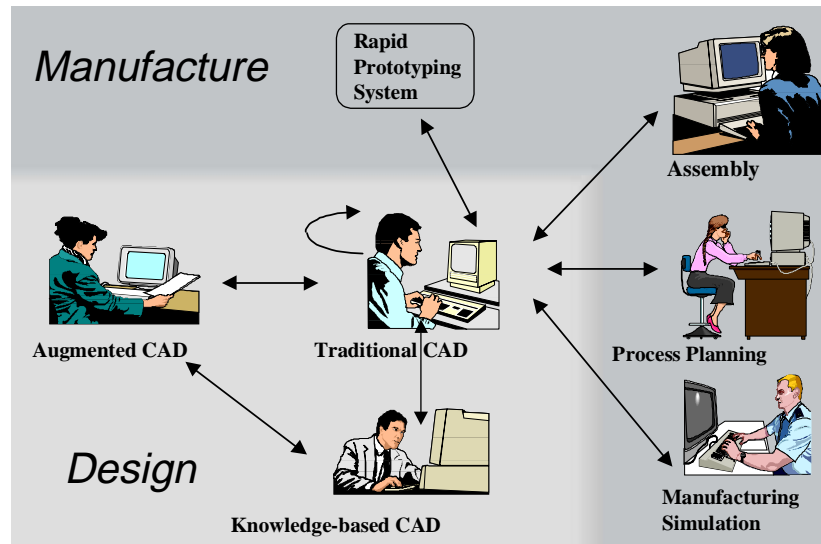## IS5: Information Exchange Protocols for Design

Principal Investigator: Ram Sriram
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The objective of this project is to develop appropriate standards and protocols for interoperability of design with other engineering tasks, such as process planning and production engineering. Specific objectives of the project are as follows:

- to enhance ISO 10303 (informally known as the STandard for the Exchange of Product model data, or "STEP") [12] for the capture and exchange of parametric, constraint-based and feature-based models such as are generated by all major modern computer-aided design (CAD) systems.

Interactions between design process and manufacturing

- to develop a more robust mechanism for the exchange of design data between CAD systems and rapid prototyping systems.

- to address integration issues of linking assembly-oriented tools (e.g., virtual assembly and design-for-assembly) to traditional CAD systems.

- to explore the development of engineering ontologies for communication of design knowledge information.

Significant FY98/97 Accomplishments

- Chaired meetings of the ISO TC184/SC4 Parametrics Working Group in Canada, the United Kingdom, California, Italy, Florida, and Germany as well as special workshops in Germany and Maryland.

- Published a study of proposals for standard computer-aided design system application programming interfaces as a precursor to standardizing such capabilities in STEP.

- Presented seminars on STEP Parametrics and related work at numerous company sites, universities, and conferences.

- Conducted an industry workshop on Measurements and Standards Issues in Rapid Prototyping in Oct. 1997 with partipation by numerous rapid prototyping system vendors and users; a white paper resulting from the workshop is being used to catalyze future efforts.

- Presented seminars on rapid prototyping measurement and standards issues at several conferences and industry events.

- Developed an initial data planning model for a solid interchange format for rapid prototyping systems based on existing and enhanced STEP models.

- Developed a preliminary function-assembly-behavior model which conceptually integrates function, form, and behavior models with assembly models.

- Developed an initial specification for the Open Assembly Design Environment (OpenADE) in the Unified Modeling Langage (UML).

- Conducted an industry workshop at NIST in November of 1997 to gather requirements for exhange of knowledge and design intent among engineering applications.

Collaborations

- Allied Signal, for development of ISO TC184/SC4 parametrics representations.

- Boeing, for investigation of knowledge-based system interchange issues.

- Black and Decker, for investigation of product development scenarios and as a source of data.

- Defense Advanced Research Projects Agency, for joint work in the Enabling Next Generation Design (ENGEN) project, the Rapid Design Exploration and Optimization (RaDEO) project, and the Solid Freeform Fabrication project.

- D.H. Brown Associates' Open CAD Architecture Interface project, for development of feature-based representation specifications.

- General Engineering and Systems Analysis Co., for investigation of tolerancing and design issues.

- George Washington University, for investigation of computer-assisted design (CAD) and virtual reality integration issues.

- International Business Machines Co., for investigation of tolerancing issues in assembly representations.

- Knowledge-based Organization, for investigation of knowledge-based system interchange issues.

- Knowlege Technologies Inc., for investigation of knowledge-based system interchange issues.

- National Center for Manufacturing Sciences, for work with the Rapid Prototyping Technology Advancement Program towards gathering industry requirements and development of an industry roadmap.

- Nihon Unisys, for development of ISO TC184/SC4 parametrics representations.

- Paccar Inc., for investigation of CAD and virtual reality integration issues.

- Rapid Prototyping Association of the Society of Manufacturing Engineers, to investigate industry requirements and potential standards development activities.

- Stanford University, for investigation of data representations suitable for the solid interchange format.

- Syracuse University, for investigation of tolerancing issues in assembly representations.

- Technosoft Inc., for investigation of knowledge-based system interchange issues.

- University of Maryland, for investigation of integration between knowledge-based design and traditional CAD.

- University of Michigan, for investigation of respresentations of materials in rapid prototyping interchange.

- University of Rochester, for investigation of tolerancing issues in assembly representations.

- Washington State University, for investigation of CAD and virtual reality integration issues.

- Wichita State University, for investigation of CAD and virtual reality integration issues.

- Xerox Corp., for investigation of tolerancing issues in assembly representations.

IS6: Internet Commerce for Manufacturing

Principal Investigator: Barbara Goldstein
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The objective of this project, initiated in 1998, is to work with industry to create an environment where small manufacturers of mechanical and electronic components may participate competitively in virtual enterprises for manufacturing printed circuit assemblies (PCAs). In particular, this project will identify and overcome some of the manufacturing information technology problems that exist at the intersection of manufacturing and electronic commerce systems. To accomplish this objective, the project will:

Architecting the Electronics Manufacturing Supply Chain

- Gather and document industry requirements and current practice through a series of scenario development/strategy workshops. This information will be used to develop or select an activity model to guide the project, and to publish a business case to document the economic motivation for migrating towards Internet commerce in the PCA industry.

- Identify and develop needed standards. A standards roadmap will be published to reflect the availability and status of standards for the exchange of both technical and business information. Team members will participate in the development and testing of those standards identified as critical to the migration towards Internet commerce, such as the Institute for Interconnecting and Packaging Electronic Circuit (IPC) Generic Computer Aided Manufacturing (GENCAM) format and the Surface Mount Equipment Manufacturers Association (SMEMA) Standard Recipe File Format (SRFF).

- Establish an Internet Commerce for Manufacturing testbed at NIST. A testbed will be established at NIST to validate the ability to use standards identified in the standards roadmap to address the industry needs identified in the business case and requirements document. Industry and academic partners will serve as demonstration nodes within the scenario.

- Transfer results to industry, academia and other agencies. The team will participate in a variety of in-house and conference demonstrations. The business case, standards roadmap, and proceedings from all workshops will be published and disseminated.

Significant FY98/97 Accomplishments

- Conducted multiple industry workshops to review the project's strategy, to develop scenarios, and to develop an architecture. An architecture advisory board was established with participation by several industry and academic experts.

- Released an initial version of a GENCAM conformance test module which is available for download from the IPC GENCAM website (http://www.gencam.org/software/ctm/ctmupload.html). The test module was demonstrated at several industry trade shows.

- Developed preliminary versions of an electronic-commerce scenario document for manufacturers and a standards roadmap.
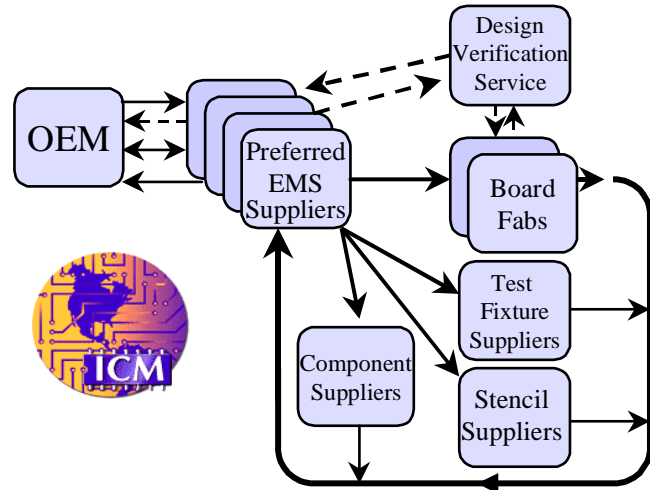
<u>Collaborations</u>

- Automata Design Inc., for implementation and testing of GENCAM and prototyping of web-based manufacturing services.
- CommerceNet, for work with the eCo system project in development of electronic commerce scenarios.
- Defense Advanced Research Projects Agency, for work with the Electronic CAD to CAM Exchange (ECCE) project.
- GenRad, for implementation and testing of GENCAM.
- Georgia Institute of Technology, as a testbed for for technologies and standards developed through this project.
- Hewlett Packard, for implementation and testing of GENCAM.
- Institute for Interconnecting and Packaging Electronics Circuits (IPC), for development and testing of GENCAM as a design transfer solution.
- National Electronics Manufacturing Initiative, for work with the Factory Information Systems working group to identify technology roadmaps.
- ORCAD, for implementation and testing of GENCAM.
- RosettaNet, for development of relevant standard interfaces and evaluation mechanisms.
- Solectron, for implementation and testing of GENCAM.
- State University of New York at Binghamton, for investigation into the electronics supply chain.
- Surface Mount Equipment Manufacturers Association, for development of the Standard Recipe File Format as a means for transferring information to board assembly equipment.
- Veo Systems, for development of electronic commerce infrastructure.

IS7: Framework

Principal Investigator: Neil Christopher
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E-mail: neil.christopher@nist.gov
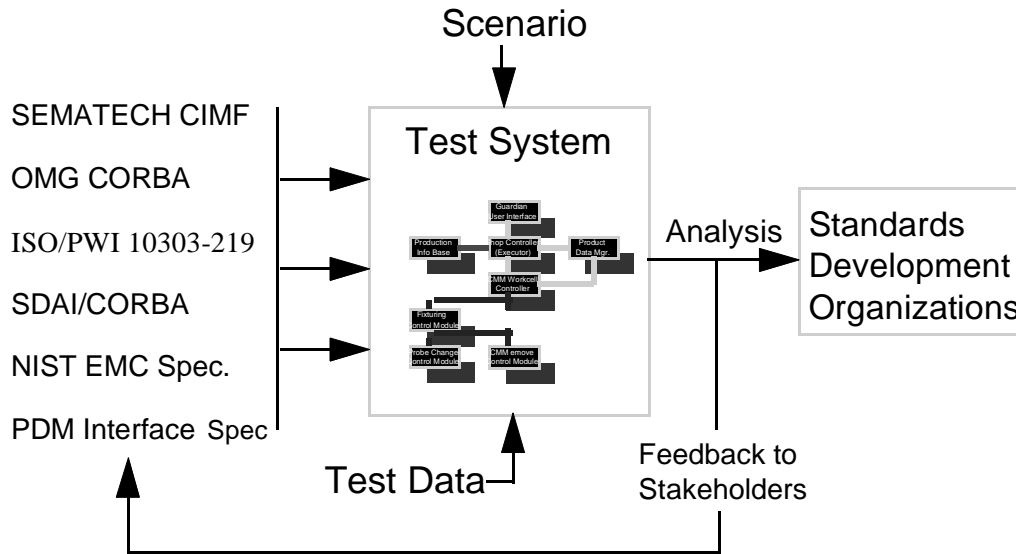
Framework Test System

The objective of this project is to accelerate the establishment and adoption of standards for distributed manufacturing systems through the implementation, testing, and analysis of emerging, open-industry specifications. In particular, this project addresses standards for the representation of information used or generated by manufacturing execution systems, enterprise resource planning systems, and shop floor control systems. The project addresses standards for the definition of interfaces to the software components that comprise these systems and the mechanisms for communication among components of these systems. The project also addresses standards for interfaces to systems that manage these types of information, such as product data managers and production information-bases. The project accomplishes its objective through validation testing of emerging, pre-standard, industry-specified, distributed manufacturing system technologies. The validation process consists of identifying specifications to test, analyzing the specifications, developing a test scenario, designing and implementing a test system and tools, feeding the results back to the industry sponsors, and feeding the results forward into the standards process. Pre-standard specifications to be evaluated must have an initial core of industry support, they must be generally non-proprietary, and they must contain elements that are suitable for standardization. These specifications are then implemented in NIST's laboratory environment and tested with production test data against a manufacturing scenario that operates physical and simulated manufacturing devices. The results of the implementation and testing form the basis for documented reviews of the specifications. These reviews address the internal consistency of each specification as well as the technical relationships among the specifications. These reviews are used as input to ongoing development within various consortia and they are used in the formal consensus building process within standards organizations.

Significant FY98/97 Accomplishments

- Provided key technical contributions to the Object Management Group Manufacturing Domain Taskforce (MfgDTF) Product Data Management (PDM) Enablers specification.

- Provided technical contributions to the evolving Object Management Group MfgDTF standardization efforts for manufacturing execution systems, enterprise resource planning, and release for production.

- Established a formal liaison between the Object Management Group MfgDTF and the International Organization for Standardization Subcommittee on Industrial Data (ISO TC184/SC4).

- Participated in the development of a new preliminary work item (PWI) for inspection information in the Standard for Exchange of Product model (STEP - ISO 10303).

- Conducted testing on the Honeywell Advanced Process Control framework implementation in NIST's National Advanced Manufacturing Testbed.

- Completed testing of the capability of software based on Common Object Request Broker Architecture (CORBA) implementations to satisfy real-time control requirements.

- Publicly released the Manufacturer's CORBA Interface Testing Toolkit (MCITT) software.

Collaborations

- Advanced Micro Devices, for validation of the Advanced Process Control framework.

- Honeywell, for validation of the Advanced Process Control framework.

- Intelligent Automation Inc., for investigation of agent-based systems.

- Industrial Technology Institute, for development of CORBA-based interfaces.

- National Center for Manufacturing Sciences (NCMS), for development of product data management system interfaces.

- NIIIP (National Industrial Information Infrastructure Protocols), for analysis of manufacturing integration architectural approaches.

- SEMATECH, for investigation of integration methodologies and the computer-integrated manufacturing framework (CIMF).

- Software Engineering Institute, for investigation of real-time software issues.

- Technologies Enabling Agile Manufacturing (TEAM), for analysis of integration solutions.

- University of Cincinnati, for investigation of integration methodologies.

IS8: Operator Interfaces for Virtual and Distributed Manufacturing

Principal Investigator: Ernie Kent
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The objective of this project is to address human interface issues for development, planning, management, monitoring, and control of remote, distributed, or simulated manufacturing systems and their component activities. One approach being pursued addresses these issues in a laboratory setting using the Immersadesk virtual reality interface and other real-time graphics interfaces. A parallel approach has focused on the development of real-time, interactive, Internet-based, multi-user interfaces into manufacturing databases to support cooperative, remote access. A multi-user, real-time, interactive, shared-environment has been established that can be reached from anywhere on the Internet with PC-based equipment and standard phone lines. The general problem is to collect and present the relevant information, at the appropriate level of detail, and in the most efficient possible format, to a wide variety of remote users, operators, consultants, and decision-makers, and to allow them to singly or interactively view simulations, manipulate remote databases, examine remote situations, and cooperatively control remote environments.
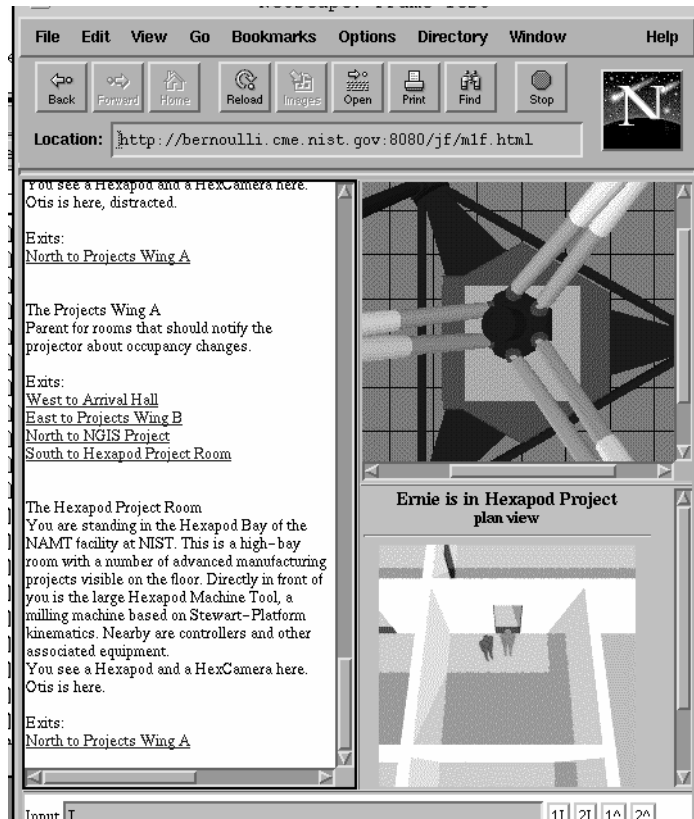
Prototype Web Interface for Hexapod Machine Tool

Significant FY98/97 Accomplishments

- Completed development of system for interfacing multiple, simultaneous, remote users to one another, to local operators, and to controlled systems using coordinated graphics and bidirectional, text-based interactions over the Internet. Demonstrated systems's functionality in the context of simulated control of an octahedral hexapod milling machine tool ("the hexapod").

- Demonstrated immersive display capabilities for hexapod workspace visualization and for observing calibration errors in laser range data.

Collaborations

- Clearwater Technical Services, for development of web-projector technology.

- Deneb Robotics, for technology transfer of Immersadesk interface software into their products.

- University of Illinois, to enhance Immersadesk capabilities.

IS9: Process Specification Language

Principal Investigator: Craig Schlenoff
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The objective of this project is to develop a process representation that is common to all manufacturing applications, generic enough to be decoupled from any given application, and robust enough to be able to represent process information for any given application. This representation, the Process Specification Language (PSL), will facilitate the automated exchange of process information

Process Planning   Scheduling   Machining

PSL-enabled information exchange

among the many process-related applications found in the manufacturing environment. In the last decade, there has been an increase in the number and types of software applications that attempt to capture the essence of process. These range from tools that simply portray processes graphically to tools that enable simulation, analysis, and/or control of processes. As more of these automated applications are implemented and integrated, there must be a robust, standard, formal method for representing processes to allow for the exchange of process information. Key challenges in defining this neutral process representation include defining a common understanding of the meanings of terms (the semantics) describing process and developing multiple syntactic interpretations of these semantic descriptions to enable a mapping to various legacy applications. Several related efforts are underway to address these needs, including the Process Interchange Format (PIF) project, a DARPA-funded, informal consortium focusing on business processes. NIST is welcomed into this community as an organization that can coordinate efforts and offer expertise in manufacturing processes, in data exchange standards, and in standards development. This project is designed specifically to promote outreach and consensus through activities such as electronic discussion lists, active industry review and feedback, and on-line project status over the Internet. Already completed under this project are an in-depth identification of requirements for specifying process, an analysis of existing process representations, definition of an initial core PSL, and identification and support of a community of researchers from academia and industry.

Significant FY98/97 Accomplishments

- Completed development of an initial, limited version of the Process Specification Language (PSL), which is available on the project web page (see http://ww.nist.gov/psl/).

- Conducted a "Process Information Technology" workshop in March 1998, bringing together researchers in the process specification field for the purposes of collectively addressing research issues in the field of process specification. One significant result of the workshop was to solidify the involvement of software vendors in pilot implementations of the PSL.

- Exploited the power of the Internet as the means to involve geographically dispersed reserachers in online discussion and analysis of process representations, resulting in the identification of the means to address the project's process representation requirements.

- Convened a two-day PSL roundtable meeting in April 1997, for experts from industry and academia to discuss issues central to the development of the initial version of the PSL.
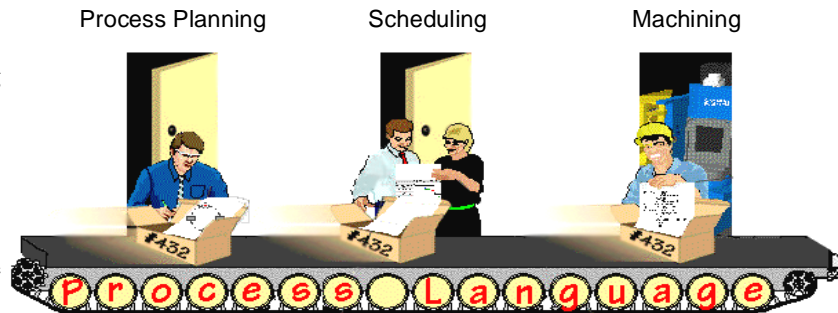
<u>Collaborations</u>

- Boeing Helicopter, for work with the Natural Language Processing group to develop a PSL encoding.
- Defense Advanced Research Projects Agency, for work with the DARPA-sponsored Process Interchange Format group.
- George Washington University, for investigation of process representation requirements, semantics, and scenarios.
- Knowledge Based Systems Inc., for work on the development of manufacturing semantics and pilot implementations.
- Raytheon Electronic Systems, for validation of the PSL requirements and manufacturing scenario development.
- STEP Tools Inc., for work on syntactic representations of the PSL as well as mappings to other languages.
- University of Edinburgh, for work with the Artificial Intelligence Application Institute on the development of manufacturing scenarios.
- University of Maryland, for work with the Institute for Systems Research on language development issues and the integration of formal ontologies.
- University of Toronto, for work with the Enterprise Integration Laboratory on the development of core language semantics.

IS10: Production and Product Data Management Applications

Principal Investigator: Charles McLean
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This project is addressing integration problems associated with product data management, production engineering, scheduling, and simulation systems. The project is developing process models, information models, interface specifications, databases, and extensions to commercial production software that resolve or facilitate system integration. After assessing industry needs, this project has selected and installed software applications that are used to engineer a production system, perform production scheduling, and simulate production. Prototype, integrated systems are being constructed from commercial products and

Simulated production facility

industry-provided data. The principal elements of the technical approach are:

- identify and address critical industrial needs.

- develop solutions to integration problems for production software.

- construct prototype solutions using commercial products.

- validate results through industrial testing of system implementations.

- specify and promote needed industry standards.

- facilitate rapid commercialization of new technology.

Significant FY98/97 Accomplishments

- Developed a reactive scheduling testbed for validation of scheduling and shop floor data collection interfaces. The testbed incorporates numerous commercial software applications and employs interfaces for components developed in the Unified Modeling Language and communication among components is implemented using the Common Object Request Broker Architecture.

- Developed a supply chain simulation testbed modeling a two-level supply chain for the manufacture and distribution of personal computers. The simulation incorporates aspects of production planning, bill-of-material explosion, and master production scheduling.

- Developed a demonstration interface between assembly planning systems and a simulation of a miter saw production line.

- Provided key technical contributions to the development of the Object Management Group's Manufacturing Domain Taskforce specification for product data management interfaces.

- Submitted the SIMA Architecture Activity Models [16] to the Object Management Group's Manufacturing Domain Taskforce where it was accepted as the base roadmap document for interface standards development.

Collaborations

- AMP, Inc., for integration of scheduling and shop floor data collection.

- Arizona State University, for development of a production systems engineering decision model.

- AutoSimulation Inc., for integration of scheduling and simulation applications with upstream and downstream applications.

- B. F. Goodrich Corp., for integration of scheduling and simulation applications with shop floor data collection and supply chain models.

- Black and Decker, to provide test parts and manufacturing data.

- Deneb Robotics, for integration of simulation applications with upstream and downstream applications.

- DLoG REMEX Inc., for integration of shop floor data collection software with upstream and downstream applications.

- Eindhoven University of Technology, for development of information models for interfaces to scheduling systems.

- Institut Francais de Mecanique Avancee, for development of infrastructure for distributed simulations.

- Intelligent Manufacturing Systems MISSION Project, for work with this international consortium on development of neutral interfaces for simulation software.

- Michigan Technological University, for development of interfaces between assembly process specification and simulation.

- Musahi University, for development of object-oriented simulation modeling and business process models for supply chain management.

- National Center for Manufacturing Sciences, for work with the Rapid Response Manufacturing (RRM) consortium on definition of product data management and manufacturing application interfaces.

- Ohio University, for engineering tool integration, simulation, and other system interfaces.

- Orca Computers Inc., for integration of simulation applications with upstream and downstream applications.

- Pennsylvania State University, for development of a routing specification interface for both scheduling and simulation.

- Politechno di Milano, for development of generic simulation objects for discrete event simulations.

- Pritsker Corporation, for integration of scheduling and simulation applications with upstream and downstream applications.

- SEMATECH, for definition of product data management and manufacturing application interfaces.

- Systems Modeling Corp., for integration of scheduling and simulation applications with upstream and downstream applications.

- University of Illinois, for development of interfaces for production systems engineering applications.

- University of Maryland, for development of information requirements and models for performance metrics for manufacturing system design.

- Universite de Nancy, for development of interfaces among scheduling, simulation, and shop floor data collection.

- Virginia Polytechnic Institute, for development of interfaces for production systems engineering applications.

- Wonderware Inc., for integrayion of shop floor data collection applications with upstream and downstream applications.

IS11: Reference Model Architecture

Principal Investigator: Harry Scott
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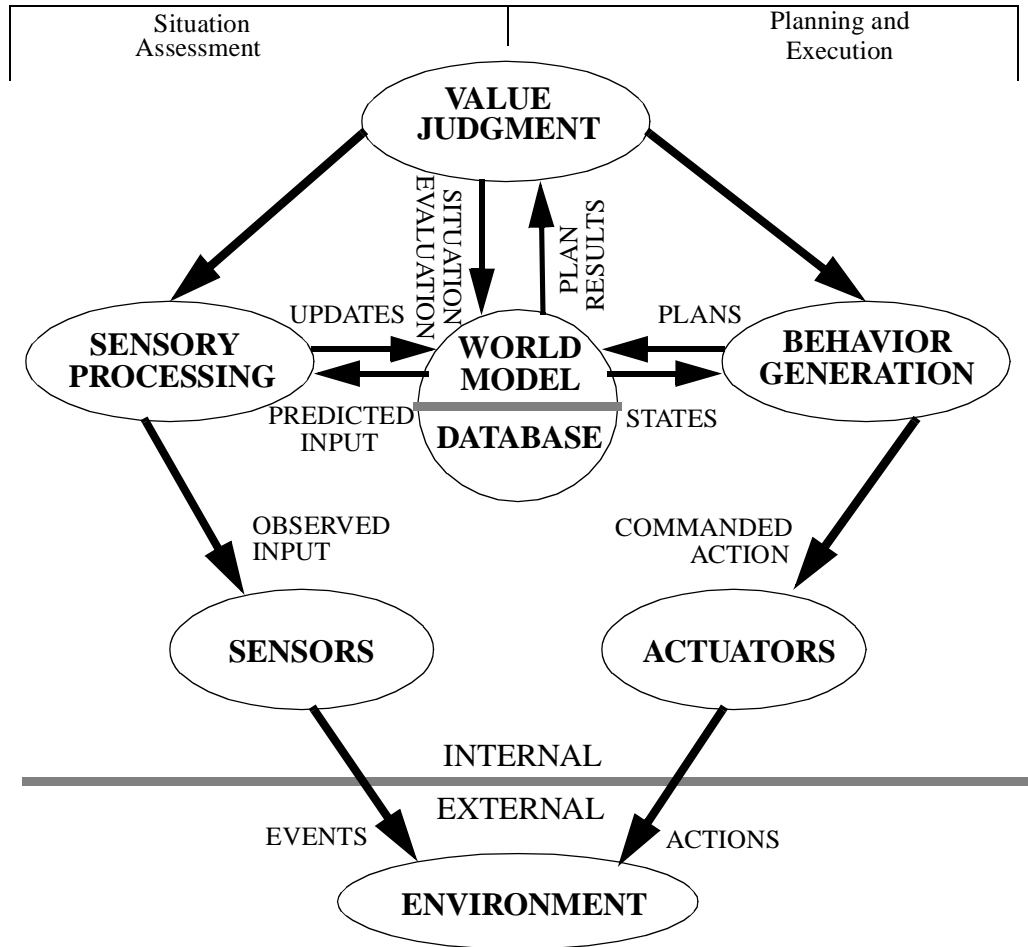
Abstract model of the architecture

The objectives of this project are to develop a detailed reference model architecture for intelligent control of manufacturing processes, and to demonstrate, validate, and evaluate the NIST Reference Model Architecture through analysis and performance measurements of a simulated and prototype implementation. The approach includes leveraging the work of other programs, such as the NIST Enhanced Machine Controller, in developing interface specifications among the architectural components, and working with industry in developing tools to support development of Reference Model Architecture-based system implementations. The goals of this work are to provide U.S. industry with state-of-the-art manufacturing architectures and models, foster the development and implementation of advanced manufacturing systems, and anticipate and address the needs of the U.S. manufacturing industry for the next generation of advanced systems and standards.

Significant FY98/97 Accomplishments

- Completed implementation of the core functionality required for the generic control shell. Numerous improvements have been incorporated in this portion of the architecture implementation including modularization of the code structure to facilitate integration with other modules, performance measurement capabilities, and additional interfaces for planning and execution.

- Developed a testbed implementation for a coordinate measuring machine inspection workstation in which motion control and machine vision are integrated and in which features extracted from an image captured by the vision system are used to compute the actual location and orientation of the part.

- Demonstrated feature-based, inspection highlighting multi-level planning, generation of plans from feature representations, generation of coordinate measuring machine and machine tool control programs, and modularization of the architecture.

- Completed an initial version of a finite-state-machine package for the Open Modular Architecture Controller (OMAC) interface testbed.

- Hosted a meeting of the OMAC workgroup, including participation from General Motors and Boeing, in November 1997 that led to the finalization of the OMAC interface specifications.

- Participated in the formation of the Open Modular Architecture Controller Users Group in February 1997. Members include end users, integrators, and technology providers.

Collaborations

- Advanced Technology and Research Corp., for development of real-time control system software and supporting tools.

- Catholic University, for development of inspection-related software.

- Department of Energy, for work with the Technologies Enabling Agile Manufacturing (TEAM) Consortium on the development of message interfaces as part of the Intelligent Closed Loop Processing effort and for development of an enhanced machine controller (EMC).

- Enhanced Machine Controller Consortium, for development of software and hardware environments enabling implementation of Reference Model Architecture concepts.

- Drexel University, for development of experimental planning and learning components.

- National Center for Manufacturing Sciences (NCMS), for development of the Next Generation Inspection System control system.

- Open Modular Architecture Controller (OMAC) Users Group, for development of interface specifications for machine controllers.

- Real-time Innovations Inc., for investigation of control system design tools and technology transfer of architecture concepts.

- University of Illinois, for development of real-time scheduling capabilities in discrete-event systems.

- University of Maryland, for investigation of computational intelligence methodologies for learning systems and development of planner/learning functions.

IS12: STEP Conformance and Interoperability Testing

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This project is providing the means by which vendors' software products will be measured for conformance to the ISO 10303 (informally known as the STandard for the Exchange of Product model data, or "STEP") [12], and is promoting industry consensus on STEP implementation by identifying requirements for interoperable systems through participation in industry pilots. The project continues development of software tools for vendors to use during their product development process. With these tools, vendors gain confidence that their products can pass testing, can improve the quality of their products and reduce the costs of software testing, and gain in the expanded market that user confidence in testing brings. In

Conformance testing process

addition, the project is participating in the formation of an industry-led certification authority for STEP implementations and is helping to ensure that U.S. certification procedures are compatible with foreign certification practices. Finally, through participation in industry pilots of STEP implementation, the project is helping to identify the data-exchange metrics, practices, and guidelines that will lead to improved interoperability between STEP implementations.
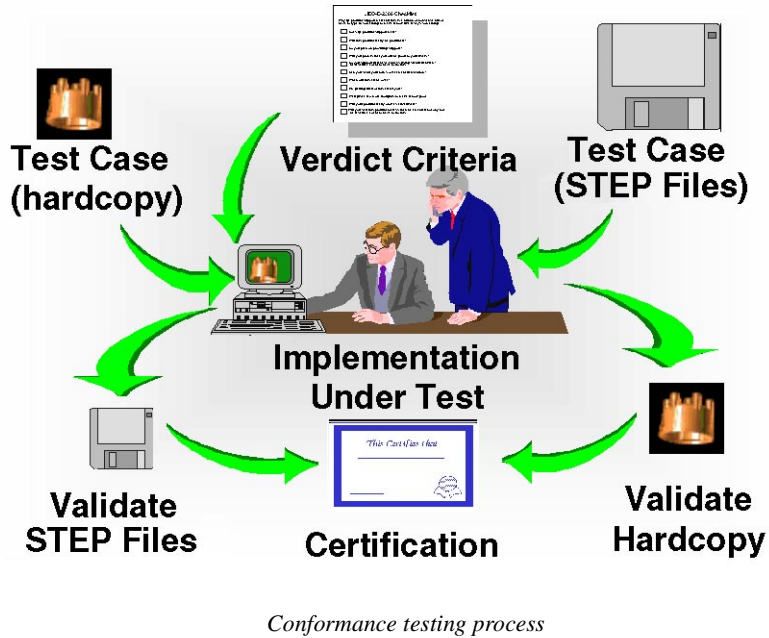
Significant FY98/97 Accomplishments

- Completed a revised release of the Expresso software toolkit[1] which is used for validating STEP information models and the data corresponding to those models.

- Completed testing trials for a revised version of the STEP conformance testing tools with the participation of four major computer-aided design system vendors.

- Provided significant contributions to STEP testing standards, including abstract test suites as well as a technical corrigendum for ISO 10303-203 [17] (Configuration controlled 3-dimensional design).

- Participated in the formation of a U.S. certification control board for vendor implementations of STEP. The board includes representatives from the STEP user community and from the STEP implementer community as well as representation of a commercial test laboratory that will be conducting the actual certification tests.

- Developed evaluation metrics for data exchange trials conducted under the auspices of the AutoSTEP implementation pilot project and performed analyses of exchange results to isolate sources of errors.

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1. For more information about Expresso see Program Products Newly Available in FY97-98 (p. 84).

Collaborations

- Automotive Industry Action Group, for work on the evaluation of STEP capabilities in production environments.
- Boeing, for development of conformance testing and vendor certification requirements.
- Industrial Technology Institute, for development of STEP test systems and test methods.
- National Industrial Information Infrastructure Protocols, for investigation of protocols facilitating the establishment of virtual enterprises.
- PDES Inc., for validation of conformance testing tools through pilot implementation projects and for investigation of solutions to STEP interoperability issues.
- U.S. Army Tank Automotive Command, for investigation of STEP implementations for the defense supply chain.
- Wayne State University, for investigation of business issues related to STEP adoption.

IS13: STEP for the Process Plant Industries

Principal Investigator: Mark Palmer
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This project is working with industry to develop, test, and demonstrate the ISO 10303 (informally known as the STandard for the Exchange of Product model data, or "STEP") [12] application protocols (APs) needed for exchanging and sharing information during the design, construction, operations, and maintenance of process plants. The objectives of this project are:

Process plant model

- analyze the information exchange problems and needs of the process plant industries.

- define a strategy for the collaborative development of the STEP application protocols (APs) that meet the industries' requirements.

- work with industry to develop and validate the highest priority APs.

- demonstrate prototypes and support the industrial implementation of these APs as international standards.
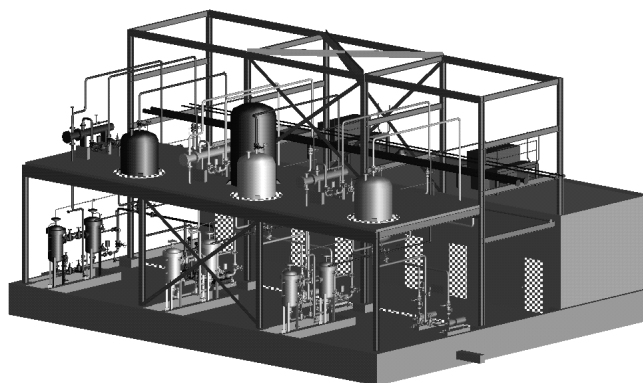
Significant FY98/97 Accomplishments

- Completed the draft international standard version of the Plant Spatial Configuration application protocol specification (ISO 10303-227) [18].

- Completed the committe draft version of the Process Engineering Data application protocol specification (ISO 10303-231) [19].

- Provided significant technical contributions to the review of the committe draft ballot on the Functional Data and Schematic Representation for Process Plant application protocol specification (ISO 10303-221) [20].

- Completed an initial version of the Process Industry Executive for achieving Business Advantage using Standards for data Exchange (PIEBASE) Industry Activity Model; the model has since been adopted by mutiple ISO standards development projects.

- Established an implementers forum enabling users and developers of ISO 10303-227 to resolve ambiguities in the specifications in the context of industry trial implementations.

Collaborations

- Bechtel, for development, testing, and deployment of ISO 10303-227 as well as on PIEBASE efforts.

- Black & Veatch, for development of ISO 10303-227 and on an industry roadmap for information exchange standards for the process and construction industries.

- DuPont, for development, testing, and deployment of ISO 10303-227 and ISO 10303-231 as well as on PIEBASE efforts.

- Merck, for development, testing, and deployment of ISO 10303-227 as well as on PIEBASE efforts.

- PIEBASE, for development of an industry roadmap for information exchange standards for the process and construction industries as well as the development of a common industry activity model.

- PlantSTEP Inc., for development of ISO 10303-227 and on development of test suites for that standard.

- POSC (Petrotechnical Open Software Corporation), to identify industry requirements for standards to support data sharing over the lifecycle of process plants.

- Process Data eXchange Institute of AIChE (pdXi), for development of ISO 10303-231 and on development of test suites for that standard.

IS14: Virtual Environments and Visualization for Manufacturing

Principal Investigator: Sandy Ressler
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The objective of this project is to create new visualization environments that improve the usability of the data available from advanced manufacturing software. By creating prototypes of various virtual manufacturing worlds we will provide human interface guidelines to improve the effectiveness of those worlds. Existing proprietary software tools are being used as mechanisms to create portable, interoperable environments using non-proprietary standard representations such as the Virtual Reality Modeling Language (VRML) (ISO 14772). Finally, the introduction of virtual humans into the factory floor will revitalize the practice of ergonomic and human motion-time studies, a necessary factor in the design of production spaces.
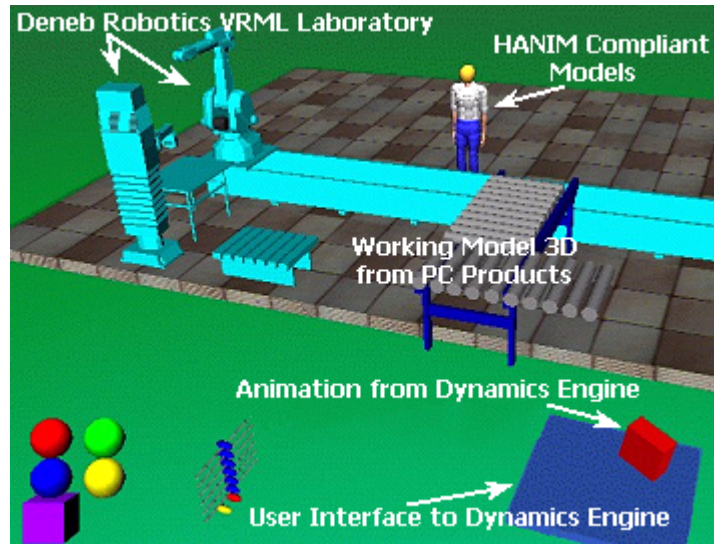
Simulation model of product assembly line

Significant FY98/97 Accomplishments

- Developed VRML translators enabling integration of multiple software vendors' virtual environment/simulation systems into a single virtual world. Knowledge Revolution has incorporated the NIST-developed translation capabilites into their commercial "Working Model 3D" product.

- Provided Internet access to a collection of children's anthropometric data originally developed by the Consumer Product Safety Commission in the 1970's. Through collaboration with Transom Technologies, this data has been incorporated into Transom's commercial "Jack" human ergonomic modeling product.

- Organized and conducted a workshop on Systems Anthropometry in conjunction with the Consumer Product Safety Commission in April 1997.

Collaborations

- Black and Decker, for provision of manufacturing data and scenarios.

- Consumer Product Safety Commission, for investigation of human anthropometry issues.

- Deneb Robotics, for investigation of the use of VRML in conjunction with their software.

- Knowledge Revolution, for investigation of the use of VRML in conjunction with their software.

- Transom Technologies, for investigation of human modeling issues.

- University of Pennsylania, for investigation of human modeling issues.

Information Access Project Summaries

IA1: Analysis Tools for Assessment and Optimization of Process and Product Design

Principal Investigator: James Filliben
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The objective of this project is to develop an integrated computer environment that provides a design/manufacturing engineer immediate on-line access to those statistical analysis tools necessary for characterizing, modeling, monitoring, and optimizing a process or product. This is achieved by creating an engineering-friendly, integrated system with the following capabilities:

Web interface to handbook

- ready access to an on-line "statistics for engineering" handbook with state-of-the-art discussion/exposition of statistical solutions for everyday engineering problems.

- an on-line translator that maps engineering problems into appropriate statistical counterparts.

- an on-line solver that identifies via its structure what the optimal statistical methodology is for a given engineering problem.

- an on-line environment that has seamless and simultaneous access to both the engineer's data and to an appropriate analysis engine so as to automatically and immediately apply the correct methodology to the engineer's data.

- an on-line interpreter that translates the output of the statistical methodology tools into conclusions that are significant and meaningful to the engineer.

Significant FY98/97 Accomplishments

- Augmented Dataplot statistical software engine for easier access from Windows and Windows NT platforms.

- Developed draft version of revised Dataplot statistical software reference manual. Tested options for transforming the manual into an Internet-accessible version.

- Implemented a prototype version of an on-line "graphics gallery" providing a resource for common graphical data analysis techniques referred to and recommended during handbook usage.

- Implemented an initial on-line resource consisting of frequently-asked-questions on Dataplot usage.

- Implemented an initial version of an on-line glossary to reduce terminology ambiguities that may arise between statistical and engineering disciplines.

- Developed and evaluated alternatives in the handbook organization, structure, and visual design.

- Implemented prototype versions of parts of selected chapters to identify issues of dynamics and navigation.

- Developed a compact navigation bar and uniform layout to apply to all handbook pages.

- Converted prototype handbook text, equation, and graphics input from multiple platform sources. Evaluated different text to hypertext markup language (HTML) processing systems. Started investigation to allow direct HTML entry via HTML template to obviate conversion problems and increase flexibility and uniformity of page appearance.

Collaborations

- Advanced Micro Devices, to co-author the Engineering Statistics Handbook.

- Arizona State University, to co-author the Engineering Statistics Handbook.

- Motorola, to co-author the Engineering Statistics Handbook.

- SEMATECH, to co-author the Engineering Statistics Handbook.

- University of Texas, to co-author the Engineering Statistics Handbook.

IA2: Web-based Testing Service for Coordinate Measuring Machine (CMM) Software

Principal Investigator: Neil Christopher
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Initiated in 1998, this project is working to provide a web-accessible testing service for coordinate measuring machine (CMM) software. The web-based service will be implemented using NIST's existing Special Test Service, which is currently providing industry with assessment of the accuracy of the geometric algorithms embedded in CMMs. CMMs are used in the discrete parts industry to determine whether manufactured parts meet tolerance specifications. The web-based calibration service will give CMM users the capability of performing CMM software validation tests readily in house

CMM software testing process

while still acquiring official results from NIST. The dimensional metrology community, users, vendors, and manufacturers of CMMs need formal mechanisms for testing and evaluating the performance of data analysis software embedded in CMMs. This service will help industry reduce inspection costs, improve procurement methods, and decrease measurement uncertainties, while providing traceability of measured results to national standards.

Significant FY98/97 Accomplishments

- Documented initial requirements for web-based testing-service capabilities, documented design specifications, and specified user interface characteristics.

- Developed initial testing-service database, demonstrating an interface to an underlying commercial database management system and an interface to a commercial mathematical analysis software application.

Collaborations

- Computer Data Systems Inc., for implementation of the web interface to the existing special test service.

Standard Reference Data Delivery and Use Projects

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Critical decisions in manufacturing and engineering depend on reliable data. The NIST Standard Reference Data Program (SRDP) provides numeric data, critically evaluated in data centers throughout the NIST laboratories. The thrust of this group of SIMA projects is to make that data more readily available to engineers and scientists in U.S. industry. The breadth of the NIST data program and the diverse expectations of the industrial community require that NIST provide tools to help users find the data they need. Project participants are creating ways to reuse existing structures and algorithms and generating new algorithms where necessary to deliver existing and future NIST data so

Data plot from the NIST ionization cross section database

that the data are both accessible on-line to individuals and freely exchangeable among instruments. SIMA efforts are taking place in three NIST laboratories, the Chemical Science and Technology Laboratory, the Materials Science and Engineering Laboratory, and the Physics Laboratory. These SIMA efforts are coordinated and jointly supported by SRDP. Recently released or revised on-line sources of standard reference data (SRD) information are detailed in Appendix D, "Program Products Newly Available in FY97-98" on page 84.

IA3: Computerized Access to Full Structural Crystallographic Data

Principal Investigator: Vicky Lynn Karen
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Initiated in 1998, this project is working to make the inorganic crystal structure database readily accessible via the Internet using a modern database management system and to offer additional functionality through the development of software tools for the calculation and standardization of derived data items as well as modules for intelligent access of scientific data.

Significant FY98/97 Accomplishments

- Created initial relational database structure from existing inorganic crystal structure data files.
- Completed preliminary design for a graphical user interface based on the periodic table of the elements.

Collaborations

- Fachinformationszentrum Karlsruhe Gesellschaft für wissenshaftlich-technische Information mbH (FIZ Karlsruhe), for development of the inorganic crystal structure database.
- Max-Planck Gesellschaft zur Förderung der Wissenschaften e.V., (the Max Planck Society for the Advancement of the Sciences) for development of the inorganic crystal structure database.

IA4: Green's Function Library for Advanced Materials Applications with Web Access

Principal Investigator: Vinod Tewary
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The objective of this project is to develop an Internet-accessible tool for using Green's function and boundary element methods in analysis of components made with advanced materials. With the Green's functions approach, problems in stress analysis, ultrasonics, and acoustics involving anisotropic materials can be analyzed more efficiently than with conventional approaches.

Significant FY98/97 Accomplishments

- Completed a Green's Function Library capability to calculate and visually display farfield ultrasonic data for scattering of ultrasonic waves from buried flaws in linear, isotropic, and elastic structures.
- Completed a Green's Function Library capability to calculate and display results for intact and damaged composite material models.

Collaborations

- Colorado School of Mines, for development of the library and the user interface to the library.
- Iowa State university, for development of the library in the context of specialized applications.

IA5: Integration of NIST Standard Reference Data into Information Networks

Principal Investigator: Edward Saloman
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The objective of this project is to make physical reference data available via the Internet (http://physics.nist.gov/data) and in so doing demonstrate a prototypical framework for making the full range of scientific and engineering information available to application systems.

Significant FY98/97 Accomplishments

- Released the NIST standard reference database for photon cross sections for use via the Internet. This database can be used to determine photon cross sections for scattering, photoelectric absorption, and pair production as well as total attenuation coefficients in any element, compound or mixture. The database provides both graphic and tabular results as well as providing users with the capability to upload a set of energies for which tabular results will be calculated. These data are used in many scientific and engineering applications as well as in medical applications.
- Revised and upgraded both the database of fundamental physical constants and the bibliographic database of fundamental physical constants. The latter database has provided citations for important theoretical and experimental publications relevant to the fundamental physical constants and related precision measurements since the mid 1980s. For both databases, new user interfaces were developed, new references were added, and the capability to "cut and paste" materials from the database was added.
- Released the database of electron-impact ionization cross sections for use via the Internet. The database provides the analytic formula and a means of calculating cross sections at given energies with results presented in both tabular and graphical forms. These data are used in the modeling of plasmas used in semiconductor processing, design of flourescent lamps, and in modeling radiation effects on materials.

Collaborations
- Harvard-Smithsonian Center for Astrophysics, for development of the atomic spectroscopy database.
- University of Melbourne, for development of the X-ray form factor, attenuation, and scattering database.
- University of New Brunswick, for development of a database of ground state energy levels for certain small molecules.

IA6: NIST Ceramics WebBook

Principal Investigator: Ed Begley
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The objective of this project is to make NIST ceramics-related reference databases, topical data sets, data guides and advisories, tools, and references to other resources related to advanced ceramics materials accessible via the Internet (http://www.ceramics.nist.gov/webbook/webbook.htm).

Significant FY98/97 Accomplishments
- Released the structural ceramics database for use via the Internet. Structural ceramics are used in designs of high efficiency, high temperature heat exchangers, corrosion resistant components, and electronic packaging. The database contains high temperature mechanical, thermal, and corrosion materials property data for a wide variety of boride, carbide, nitride, oxide, and oxynitride materials.
- Released the high temperature superconducting materials database for use via the internet. High temperature superconductivity remains a field of great interest to scientists and engineers. This database provides physical and materials characteristics for oxide superconductors.

IA7: Online Access to NIST Chemical Reference Data

Principal Investigator: Gary Mallard
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The objective of this project is to make NIST chemical reference data available via the Internet (http://webbook.nist.gov/chemistry/) and to develop the tools and mechanisms necessary to make all NIST chemical data uniformly accessible.

Significant FY98/97 Accomplishments
- Released three new versions of the NIST Chemistry WebBook in the last two years.
- Augmented capabilities for searching by chemical substructures by enabling input of industry standard file formats as well as by specification of structures through an interactive drawing applet.
- Provided new data types, including Henry's Law constants (solubility of gas in water), fundamental infrared frequencies, and high accuracy fluid properties.
- Enhanced tools for acquiring Chemical Abstract Service registry numbers from files for more rapid processing.
- Improved equation handling capabilities as well as the graphical display of equations. Developed browser-independent and operating system-independent mechanisms for display of Greek and scientific characters.

Collaborations

- Dow Chemical, for development of prediction techniques.
- Long Island University, for evaluation of data for hydrogenation reactions.
- Monsanto Chemical Company, for evaluation of data for phosphorous compounds.
- Pacific Northwest Laboratory, for development of prediction techniques.
- University of Canterbury, for evaluation of ion cluster data.
- University of Maryland, for evaluation of data for chemical thermodynamics.
- University of Tennessee, for evaluation of data for ion thermochemistry.

IA8: Standards for Exchange of Instrument Data and NIST Chemical Reference Data

Principal Investigator: Gary Kramer
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The objective of this project is to develop information models supporting data exchange standards in analytical chemistry for instrument-to-instrument, instrument-to-application, and application-to-application interchanges and to evaluate current industry standards for NIST reference data interchange.

Significant FY98/97 Accomplishments

- Extended the device capability dataset for laboratory instruments with the notion of system-level capabilities. Initiated prototype implementation for these instrument interfaces using a spectrophotometer as the basis for validation.
- Presented project results at several significant events, including a keynote address on laboratory automation at Eastman Chemical's Annual Analytical Technology Forum and award-winning poster presentations at the LabAutomation 1998 Conference in San Diego, CA.
- Advanced several specifications further in the ASTM standardization process, including the Laboratory Equipment Communication Interface Specification and the Analytical Data Interchange Standard.

Collaborations

- Fachhochschule Wiesbaden, for development of instrument control interface models.
- Hypertek Inc., for development of software for control of laboratory instruments.
- Information Management Resources, for development of databases supporting data sharing among instruments.
- Los Alamos National Laboratory, for implementation and validation of instrument control interface specifications.

IA9: Web-Based Bioinformatics Databases

Principal Investigator: Michael Gilson
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Principal Investigator: Gary Gilliland
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The objective of this project is to provide access to two databases of importance to biotechnology and that contain evaluated data on the properties, structures, and interactions of biological macromolecules. One database focuses on data characterizing the recognition by one molecule of a suitable reaction site on another; this database will also feature an online contribution facility. The second database is the Protein Data Bank, an international archive. This second database will also will be coupled with internet-accessible data evaluation software.

Significant FY98/97 Accomplishments

- Formed the Research Collaboratory for Structural Bioinformatics (RCSB) as a non-profit consortium dedicated to improving the understanding of biological systems through knowledge of 3-dimensional biological macromolecular structures. Other members are Rutgers University and the University of California.

- Developed comprehensive plans for the scope, implementation, and management of the molecular recognition database were developed in conjunction with bioinformatics groups at Rutgers University and the University of California.

- Completed work to adapt the software programs MAXIT and mmCIF Input Tool to allow their use in the evaluation and conversion of protein data structures.

- Completed the evaluation and conversion of all structures in one family of proteins and initiated work on the evaluation and conversion of proteases, immunoglobins, and hemoglobins; together these represent a significant fraction of the Protein Data Bank.

- Hosted a workshop on molecular recognition issues, August 1997. The workshop helped to establish a preliminary data model, the scope of data to be included in the molecular recognition database, preliminary guidelines for the user interface to the database, and future collaborative work. Participants included representatives from pharmaceutical companies, academic institutions, and other government agencies.

Collaborations

- DuPont Merck Pharmaceutical Company, for development of the molecular recognition database.

- Robert Wood Johnson Medical School, for development of the molecular recognition database.

- Rutgers University, for development of the molecular recognition database.

- University of California, for work with the San Diego Supercomputer Center on development of the molecular recognition database.

- University of Pittsburgh, for investigation of molecular recognition involving small organic molecules.

Collaboration Mechanisms Project Summaries

CM1: NIST Manufacturing Collaboratory

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Principal Investigator: Amy Knutilla
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The objective of this project is to enable individuals and groups of manufacturing researchers to gain access to, as well as contribute to, the collective knowledge regarding advanced manufacturing research and standards in a coherent, unencumbered fashion. The project will work to address manufacturing domain-specific issues for collaboratories and collaboratory technologies. A testbed for research in collaboratory technology for manufacturing will be developed. The testbed will provide an environment to test the applicability of human-centered design when applied to manufacturing requirements. In the longer term there is the expectation that deployment of collaboration technologies in the manufacturing environment will lead to new business processes and these in turn will lead to the identification of new manufacturing software integration requirements.
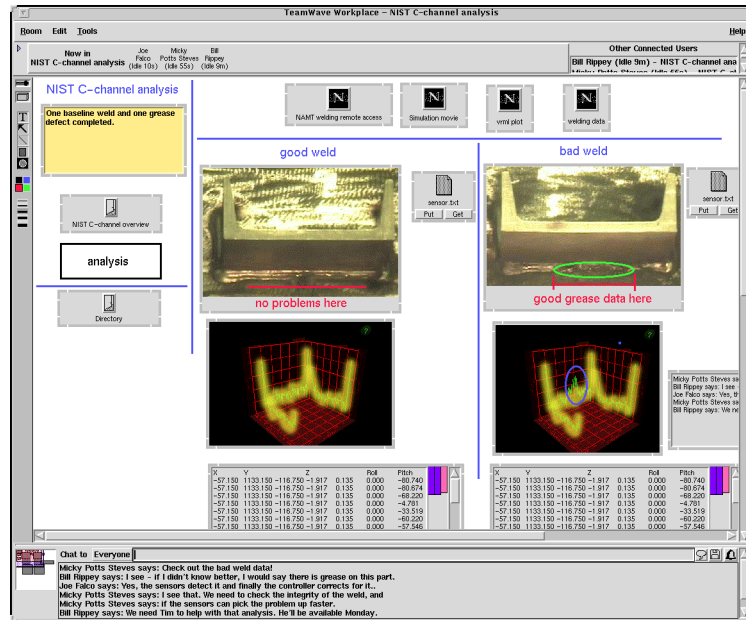
Remote welding collaboration demonstration

Significant FY98/97 Accomplishments

- Identified and analyzed initial user requirements for systems and tools to be included in the initial collaborative environment. Selected commercial off-the-shelf tools and customized them according to user needs.

- Deployed a pilot collaboratory for robotic arc welding researchers developing standards for automated robotic gas-metal arc welding. The pilot environment enables synchronous and asynchronous collaborations, exchange of mutiple diverse data formats, and remote collaborations. Participating researchers are located on the NIST Gaithersburg (Maryland) campus and the NIST Boulder (Colorado) campus as well as at industrial sites in Illinois, Michigan, and Ohio.

- Initiated investigations into how to assess the effectiveness of collaborations in the robotic arc welding pilot.

Collaborations

- General Motors Corporation, for investigation of robotic arc welding collaboratory capabilities for troubleshooting problems on the shop floor.

- Sun Microsystems, for implementation and analysis of the pilot collaboratory.

- TeamWave Software, Ltd., for implementation and assessment of collaboration systems.

- University of Michigan, for development, piloting, and analysis of collaboratories in the manufacturing domain.

CM2: Virtual National Advanced Manufacturing Testbed (VNAMT)

Principal Investigator: Keith Stouffer
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Initiated in 1998, this project is working to provide an Internet-accessible version of NIST's National Advanced Manufacturing Testbed (NAMT) bringing the capabilities of the NAMT and results stemming from NAMT projects to interested researchers and collaborators. The multimedia VNAMT environment will provide access to live and stored video, control of cameras in NAMT project laboratories, interactive manipulation of virtual reality models of equipment, and relevant project information.
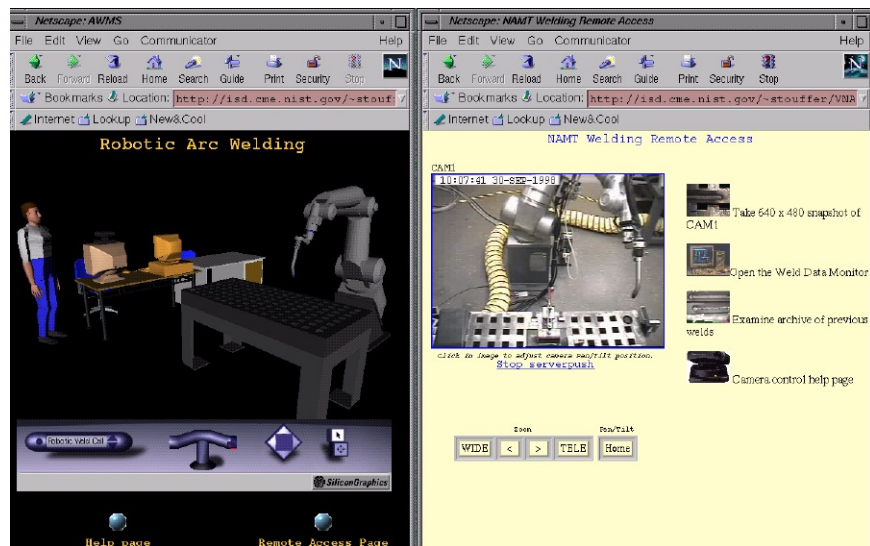
Robotic welding demonstration

Significant FY98/97 Accomplishments

- Developed a prototype VNAMT environment illustrating capabilities to provide live video from welding experiments, client control of cameras, controller interfaces, and interactive models of NIST's octahedral hexapod machine tool.

Supported Projects

- Nanomanufacturing of Atom-Based Dimensional Standards
  http://www.mel.nist.gov/namt/projects/nano/nano1.htm

- Characterization, Remote Access, and Simulation of Hexapod Machines
  http://www.mel.nist.gov/namt/projects/hexapod/hex1.htm

- Interface Standards and Internet Technologies for Robotic Arc Welding
  http://www.mel.nist.gov/namt/projects/weld/weld1.htm

Conclusion

The premise of the SIMA Program is that the multitude of software systems used in manufacturing activities do not interoperate as well as required. The SIMA Program's project leaders work with their industrial partners to identify information needs among manufacturing enterprise activities, the contexts for those needs, in order to identify the information representation issues between the software systems used in those activities, and to define mechanisms appropriate to resolving those issues. By maintaining a neutral perspective in the testing of information interfaces for engineering and manufacturing, the Program ensures that validated solutions addressing the common requirements of both users and software providers can be adopted.

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Appendix A: Program Organization

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                    │   NIST HPCC Initiative    │
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   Information Technology         │    SIMA      │
│  Metrology, Testing, and│       │   Program    │
     Applications                 └──────────────┘
└ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ┘               │
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Interface Standards Projects	Collaboration Mechanisms Projects	Information Access Projects
1. Application Protocol Development Environment (APDE) 2. Design - Process Planning Integration (DPPI) 3. Electronic Commerce for the Electronics Industry (ECEI) 4. Enterprise Resource Planning Interfaces (ERP-I) 5. Information Exchange Protocols for Design 6. Internet Commerce for Manufacturing 7. Framework 8. Operator Interfaces for Virtual and Distributed Manufacturing 9. Process Specification Language 10. Production and Product Data Management Applications 11. Reference Model Architecture 12. STEP Conformance and Interoperability Testing 13. STEP for the Process Plant Industries 14. Virtual Environments and Visualization for Manufacturing	1. NIST Manufacturing Collaboratory 2. Virtual National Advanced Manufacturing Testbed (VNAMT)	1. Analysis Tools for Assessment and Optimization of Process and Product Design 2. Web-based Testing Service for Coordinate Measuring Machine (CMM) Software Standard Reference Data Delivery & Use 3. Computerized Access to Full Structural Crystallographic Data 4. Green's Function Library for Advanced Materials Applications with Web Access 5. Integration of NIST Standard Reference Data into Information Networks 6. NIST Ceramics WebBook 7. Online Access to NIST Chemical Reference Data 8. Standards for Exchange of Instrument Data and NIST Chemical Reference Data 9. Web-Based Bioinformatics Databases

Figure 4. Organization of NIST's CIC Efforts
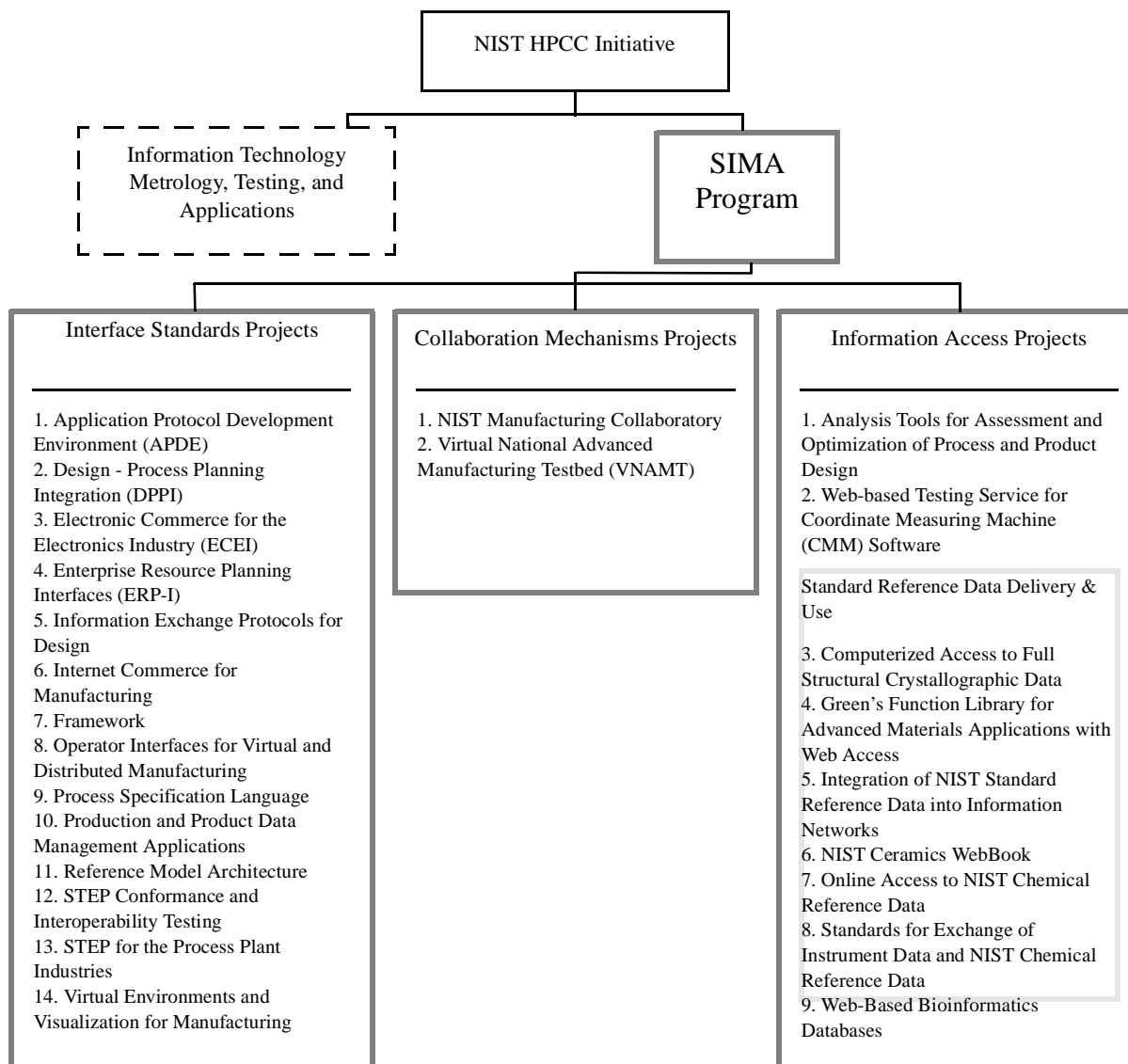
The SIMA Program was one of two CIC initiative efforts underway at NIST in FY97-98 (see Figure 4). The SIMA Program is directed by a manager in the Manufacturing Systems Integration Division (MSID) of NIST's Manufacturing Engineering Laboratory (MEL). Individual SIMA projects are led by NIST research staff. The projects are organized into the technology areas briefly described below.

Program Technology Areas

To align the resources of the program with the needs defined by industry, the SIMA Program organizes projects into one of three program areas: (1) Interface Standards, (2) Information Access, and (3) Collaboration Mechanisms. Activities within each area satisfy a unique NIST role in support of CIC goals and address the major technology and standards issues outlined in the IITA program report [6]. The focus of these technology areas are as follows.

Interface Standards (IS)
These SIMA projects continue work leading to the definition and creation of standards facilitating the exchange of manufacturing data within and across all levels of the product realization process. Objectives include the establishment of:

- rigorous methods for defining and testing interoperability solutions.

- standards specifying information to be exchanged as well as the interface mechanisms necessary to do so.

- tests validating potential standards solutions and implementations.

Information Access (IA)
SIMA-supported efforts in this area are providing greatly broadened access to large amounts of authoritative scientific engineering data in NIST databases by initiating effective Internet access to those databases through user-friendly interfaces and sophisticated search techniques.

Collaboration Mechanisms (CM)
By supporting the establishment and evolution of computer-supported collaboration mechanisms for NIST researchers to work with each other and with external partners, the SIMA program aims to:

- improve the effectiveness of the researchers' work.

- evaluate and, where benefical, adapt and refine collaborative technologies.

- identify and address interaction issues resulting from remote collaborations.

Participating NIST Organizational Units

All of NIST's intramural, technical organizational units participate in the SIMA Program. The following descriptions briefly summarize the mission of each participating NIST organization[1].

Building and Fire Research Laboratory (BFRL)
BFRL works to enhance the competitiveness of U.S. industry and public safety through performance prediction and measurement technologies and technical advances that improve the lifecycle quality of constructed facilities.

Chemical Science and Technology Laboratory (CSTL)
As the Nation's Reference Laboratory, CSTL performs cutting edge research in measurement science. The Laboratory develops and maintains measurement methods, standards, and reference data; and develops models for chemical, biochemical, and physical properties and processes.

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1. More information about NIST Laboratories can be found at http://www.nist.gov/labs2.html.

Information Technology Laboratory (ITL)

ITL develops, demonstrates, and supplies high quality information technology, metrology, and standards that enable U.S. industry to develop usable, reliable, interoperable products. In doing so, the ITL serves as a neutral agent to accelerate acceptance and use of information technology that will promote economic competitiveness and the public good. ITL provides leadership and collaborative research to NIST programs in the areas of mathematics, statistics, and information technology use and services to enable NIST to maintain its status as a world class institution.

Electronic and Electrical Engineering Laboratory (EEEL)

EEEL promotes U.S. economic growth through improved international competitiveness, by providing measurement capability of high economic impact focused primarily on the critical needs of the U.S. electronics and electrical-equipment industries.

Manufacturing Engineering Laboratory (MEL)

MEL works to improve the competitiveness of U.S. manufacturing by working with industry to develop and apply infrastructural technology, measurements, and standards for manufacturing.

Material Science and Engineering Laboratory (MSEL)

MSEL works to stimulate the more effective production and use of materials by working with materials suppliers and users to assure the development and implementation of the measurements and standards infrastructure for materials.

Physics Laboratory (PL)

PL supports U.S. industry by providing measurement services and research for electronic, optical, and radiation technology.

Technology Services (TS)

TS provides a wide variety of services and programs to help U.S. industry improve its international competitiveness. TS supplies NIST reference materials, data, and calibrations to help industry maintain production quality control. TS also provides information and assistance concerning national and international voluntary and regulatory product standards and certification systems.

Appendix B: Collaborators

Consortia, National Programs, Professional and Trade Associations			
Name	Location	Description	Collaborating Project(s)
Automotive Industry Action Group (AIAG)	Southfield, MI	An automotive trade association addressing industry issues in supply, manufacturing, engineering, quality, and finance. The association has over 1000 member companies and includes Chrysler, Ford, and General Motors.	STEP Conformance and Interoperability Testing (p. 33)
CAD Framework Initiative, Inc.	Austin, TX	An international, not-for-profit consortium whose mission is to facilitate and promote the adoption of open electronic design automation technologies that improve designer productivity. CFI's membership includes over 40 companies comprised of electronic design automation designers and suppliers of high performance semi-custom silicon in North America, Europe, and Asia.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)
CommerceNet	Palo Alto, CA	An international, not-for-profit organization meeting the evolving needs of companies doing electronic commerce.	Internet Commerce for Manufacturing (p. 22)
Component Information Representation European Project (CIREP)	Orsay, France	An effort funded by ESPRIT to build a complete information system for the electronic exchange of standardized libraries of Component Information Representations (CIR).	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)
Electronics Industries Association (EIA)	Arlington, VA	A trade association representing the U.S. high technology community. EIA has created a host of activities to enhance the competitiveness of the American producer including such valuable services as technical standards development, market analysis, government relations, trade shows and seminar programs.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)
Enhanced Machine Controller (EMC) Consortium	Gaithersburg, MD	Provides initial open-architecture control system and development environment hardware and software configuration, base controller template, Java-based operator tools and communications mechanism for Joint Architecture project implementation testbeds	Reference Model Architecture (p. 31)
Institute for Interconnecting and Packaging Electronics Curcuits (IPC)	Northbrook, IL	Trade association for companies in the electronic interconnection industry.	Internet Commerce for Manufacturing (p. 22)

Consortia, National Programs, Professional and Trade Associations			
Name	Location	Description	Collaborating Project(s)
Institute of Advanced Manufacturing Sciences (IAMS)	Cincinnati, OH	Not-for-profit organization for manufacturers, offering solution-focused implementation of change in manufacturing operations.	Design - Process Planning Integration (DPPI) (p. 16) Information Exchange Protocols for Design (p. 20)
Intelligent Manufacturing Systems (IMS) MISSION Project	Tokyo, Japan	The primary objective of MISSION is a bridge from today's tools and regionally-oriented factory design processes into those needed for extended enterprises and/or virtual enterprise networks.	Production and Product Data Management Applications (p. 29)
Knowledge-based Organization	n/a	A loosely based conglomerate of companies dedicated to incorporating knowledged-based systems into their businesses.	Information Exchange Protocols for Design (p. 20)
National Electronics Manufacturing Initiative	Herndon, VA	Consortium dedicated to facilitating long-term North American leadership in volume electronics manufacturing.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)
National Industrial Information Infrastructure Protocols (NIIIP)	Stamford, CT	The NIIIP consortium's objective is to develop open industry software protocols that will make it possible for manufacturers and their suppliers to interoperate effectively as if they were part of the same enterprise. The consortium includes IBM, Digital Equipment Corporation, Enterprise Integration Technologies, General Dynamics, Lockheed Aeronautical Systems, Magnavox, Texas Instruments, and other participants.	Enterprise Resource Planning Interfaces (ERP-I) (p. 19) Framework (p. 24) STEP Conformance and Interoperability Testing (p. 33)
Next Generation Inspection System Program	Ann Arbor, MI	NGIS is a program of the National Center for Manufacturing Sciences, Production Equipment and Systems Special Interest Group. The objective is to develop next-generation inspection capabilities on coordinate measuring machines and machine tools.	Reference Model Architecture (p. 31)
Open Modular Architecture Control (OMAC)	Oak Ridge, TN	OMAC seeks to develop an Open Architecture, Application Programming Interface (API) for machine controllers	Reference Model Architecture (p. 31)

Consortia, National Programs, Professional and Trade Associations			
Name	Location	Description	Collaborating Project(s)
PDES, Inc.	Charleston, SC	The PDES, Inc. consortium's objective is to accelerate the development and implementation of STEP. The consortium includes the South Carolina Research Authority, Boeing, Ford, General Motors, Hughes, Lockheed Martin, Northrop Grumman, and other participants.	Application Protocol Development Environment (APDE) (p. 14) Design - Process Planning Integration (DPPI) (p. 16) Electronic Commerce for the Electronics Industry (ECEI) (p. 17) STEP Conformance and Interoperability Testing (p. 33)
PIEBASE (Process Industry Executive for achieving Business Advantage using Standards for data Exchange)	London, UK	PIEBASE is a global umbrella that coordinates development and implementation of data exchange and data-sharing standards for the process plant industry consortia and member companies.	STEP for the Process Plant Industries (p. 35)
PlantSTEP, Inc.	Wilmington, DE	PlantSTEP, Inc. is a consortium working to support the development of information exchange standards to advance the capabilities of process plant and construction industries. Members include DuPont, Merck, Black & Veach, Bechtel, Intergraph, Computervision, and CAD Centre.	Application Protocol Development Environment (APDE) (p. 14) STEP for the Process Plant Industries (p. 35)
POSC (Petrotechnical Open Software Corporation)	Houston, TX	A not-for-profit corporation dedicated to facilitating integrated business processes and computing technology for the exploration and production segment of the international petroleum industry.	STEP for the Process Plant Industries (p. 35)
Process Data eXchange Institute of AIChE (pdXi)	New York, NY	pdXi is an industry trade group working to develop and maintain open approaches to electronic data exchange and management of process engineering data. Members include DuPont, Exxon, and Simulation Sciences, Union Carbide, and others.	STEP for the Process Plant Industries (p. 35)
Process Interchange Format Group	Manoa, HI	Informal industry and academic consortium.	Process Specification Language (p. 27)
Rapid Prototyping Association of the Society of Manufacturing Engineers	Dearborn, MI	Association seeking to communicate the vision and direction of rapid prototyping technology to users.	Information Exchange Protocols for Design (p. 20)

Consortia, National Programs, Professional and Trade Associations			
Name	Location	Description	Collaborating Project(s)
Rapid Response Manufacturing	Ann Arbor, MI	The RRM consortium's objective is to increase first product quality while decreasing design to manufacturing cycle time. The RRM consortium includes the National Center for Manufacturing Sciences (NCMS), General Motors, Ford Motor, Texas Instruments, United Technologies, Lockheed Martin Energy Systems, and other participants.	Information Exchange Protocols for Design (p. 20) Framework (p. 24) Production and Product Data Management Applications (p. 29)
Research Collaboratory for Structural Bioinformatics (RCSB)	Piscat-away, NJ	A non-profit consortium dedicated to improving our understanding of the function of biological systems through an understanding of 3-dimensional biological macromolecular structure.	Web-Based Bio-informatics Databases (p. 43)
RosettaNet	Los Angeles, CA	Consortium dedicated to development of industry-wide electronic business operability standards.	Internet Commerce for Manufacturing (p. 22)
SEMATECH	Austin, TX	The SEMATECH consortium's objective is to sponsor and conduct research aimed at assuring leadership in semiconductor manufacturing technology for the U.S. semiconductor industry. The consortium includes Advanced Micro Devices, Digital Equipment Corporation, Hewlett-Packard, Intel, IBM, Lucent Technologies, Motorola, National Semiconductor Corporation, Rockwell International, and Texas Instruments.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17) Framework (p. 24) Production and Product Data Management Applications (p. 29) Analysis Tools for Assessment and Optimization of Process and Product Design (p. 37)
Silicon Integration Initiative	Austin, TX	Organization of industry-leading silicon systems and tool companies focused on improving productivity and reducing cost in creating and producing integrated silicon systems.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)
Software Engineering Institute (SEI)	Pittsburgh, PA	Department of Defense-funded R&D center tasked to provide leadership in advancing the state of the practice of software engineering to improve the quality of systems that depend on software.	Framework (p. 24)

Consortia, National Programs, Professional and Trade Associations			
Name	Location	Description	Collaborating Project(s)
Surface Mount Equipment Manufacturers Association (SMEMA)	Highland Park, IL	A non-profit organization of companies manufacturing equipment or producing software for surface mount board production.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17) Internet Commerce for Manufacturing (p. 22)
Supply Chain Council	Pittsburgh, PA	A cross-industry consortium formed to establish a framework to enable manufacturers and their supply-chain vendors to build a stronger supply chain and reap the competitive rewards of improved supply-chain management.	Enterprise Resource Planning Interfaces (ERP-I) (p. 19)
Technologies Enabling Agile Manufacturing (TEAM)	Oak Ridge, TN	The TEAM consortium's objective is to enhance national industrial competitiveness by advancing and deploying manufacturing technologies that promote agility. The consortium includes American firms and consortia representing many industrial sectors including aerospace, automotive, consumer electronics, and software along with multiple federal agencies and facilities.	Design - Process Planning Integration (DPPI) (p. 16) Information Exchange Protocols for Design (p. 20) Framework (p. 24) Reference Model Architecture (p. 31)
VSI Alliance	Los Gatos, CA	The VSI Alliance is chartered to define, develop, authorize, test, and promote open standard specifications relating to data formats, test methodologies, and interfaces. These standards are to facilitate the mix and match and the reuse of blocks of electronic circuit functions from different sources in the design and development of system-level ICs.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)

Individual Companies			
Name	Location	Description	Collaborating Project(s)
Advanced Manufacturing Research	Boston, MA	Industry and market analysis firm specializing in enterprise applications and related trends and technologies.	Enterprise Resource Planning Interfaces (ERP-I) (p. 19)
Advanced Micro Devices, Inc.	Austin, TX	Supplier of integrated circuits for the computer and communications markets.	Framework (p. 24) Analysis Tools for Assessment and Optimization of Process and Product Design (p. 37)
Advanced Technology and Research Corporation	Burtonsville, MD	Consultants specializing in research and development of intelligent control systems, automation, robotics, simulation, engineering analysis, and computer science.	Reference Model Architecture (p. 31)
AlliedSignal Kansas City Plant	Kansas City, MO	Manufacturer of electrical, mechanical, and engineered materials for weapons production.	Information Exchange Protocols for Design (p. 20)
AMP, Inc.	Harrisburg, PA	Manufacturer of electronic connectors.	Production and Product Data Management Applications (p. 29)
Automata Design, Inc.	Herndon, VA	Vendor of software simulating circuit board design and production processes.	Internet Commerce for Manufacturing (p. 22)
AutoSimulation, Inc.	Bountiful, UT	Vendor of simulation and scheduling software.	Production and Product Data Management Applications (p. 29)
Bechtel	San Francisco, CA	Provider of services to develop, engineer, construct, and manage capital projects and facilities worldwide.	STEP for the Process Plant Industries (p. 35)
B.F. Goodrich Corporation	Cleveland, OH	Aerospace and performance products manufacturer.	Production and Product Data Management Applications (p. 29)

Individual Companies			
Name	Location	Description	Collaborating Project(s)
Black and Decker	Towson, MD	Manufacturer of portable power tools and household appliances.	Information Exchange Protocols for Design (p. 20) Production and Product Data Management Applications (p. 29) Virtual Environments and Visualization for Manufacturing (p. 36)
Black & Veatch	Kansas City, MO	An engineering construction company.	STEP for the Process Plant Industries (p. 35)
Boeing	Seattle, WA	Aerospace manufacturer.	Application Protocol Development Environment (APDE) (p. 14) Information Exchange Protocols for Design (p. 20)
Boeing Commercial Airplane Group	Seattle, WA	Manufacturer of commercial aircraft.	STEP Conformance and Interoperability Testing (p. 33)
Boeing Helicopters	Philadelphia, PA	Manufacturer of rotary-wing aircraft.	Process Specification Language (p. 27)
CAMAX	Eugene, OR	Vendor of computer-aided manufacturing software.	Design - Process Planning Integration (DPPI) (p. 16)
Caterpillar	Peoria, IL	Manufacturer of heavy earth-moving equipment.	Information Exchange Protocols for Design (p. 20)
CIMx	Cincinnati, OH	Vendor of software systems for discrete manufacturing applications.	Design - Process Planning Integration (DPPI) (p. 16)

Individual Companies			
Name	Location	Description	Collaborating Project(s)
Clearwater Technical Services	Yungaburra, Australia	A consulting firm specializing in custom software development and network support.	Operator Interfaces for Virtual and Distributed Manufacturing (p. 26)
CNC Software, Inc.	Tolland, CT	Vendor of software tools for the CAD/CAM manufacturing markets.	Design - Process Planning Integration (DPPI) (p. 16)
Computer Data Systems, Inc.	Rockville, MD	Provides data processing and professional computer services and products.	Web-based Testing Service for Coordinate Measuring Machine (CMM) Software (p. 39)
Concurrent Technologies Corporation	Johnstown, PA	A non-profit company chartered to take technology from research labs to the commercial workplace.	Application Protocol Development Environment (APDE) (p. 14)
Delphi Delco	Indianapolis, IN	Electronics manufacturer.	Application Protocol Development Environment (APDE) (p. 14)
Deneb Robotics	Auburn Hills, MI	Vendor of 3D graphics-based factory simulation, telerobotic, and virtual reality software.	Operator Interfaces for Virtual and Distributed Manufacturing (p. 26) Production and Product Data Management Applications (p. 29) Virtual Environments and Visualization for Manufacturing (p. 36)
D.H. Brown Associates (DHBA)	Port Chester, NY	DHBA is a research analysis firm specializing in analysis of technologies to support computer environments for engineering, manufacturing, design, and open systems.	Information Exchange Protocols for Design (p. 20)

Individual Companies			
Name	Location	Description	Collaborating Project(s)
DLOG Corporation	Chicago, IL	Vendor of shop floor data collection software.	Production and Product Data Management Applications (p. 29)
Dow Chemical Company	Midland, MI	The Dow Chemical Company provides chemicals, plastics, energy, agricultural products, consumer goods and environmental services.	Online Access to NIST Chemical Reference Data (p. 42)
Dupont	Wilmington, DE	An energy and chemistry-based company.	STEP for the Process Plant Industries (p. 35)
Dupont-Merck Pharmaceutical Co.	Wilmington, DE	A company focusing on research, development and delivery of pharmaceuticals to treat currently unmet medical needs	Web-Based Bioinformatics Databases (p. 43)
Fachinformationszentrum Karlsruhe Gesellschaft für wissenschaftlich-technische Information mbH	Karlsruhe, Germany	A non-profit organization set up to provide information and information services for academic and industrial research & development, as well as for business and administration.	Computerized Access to Full Structural Crystallographic Data (p. 40)
Gartner Group	Stamford, CT	Research and consulting firm specializing in the information technology arena.	Enterprise Resource Planning Interfaces (ERP-I) (p. 19)
General Engineering and Systems Analysis Co. (GESAC)	Boonsboro, MD	Engineering consulting firm and manufacturer of crash test dummies.	Information Exchange Protocols for Design (p. 20)
General Motors Corporation	Detroit, MI	Large industrial corporation and vehicle manufacturer.	NIST Manufacturing Collaboratory (p. 45)
GenRad, Inc.	Westford, MA	Supplies electronics OEMs and their customers with hardware, software, inspection systems and services to optimize design, manufacturing and aftermarket service productivity.	Internet Commerce for Manufacturing (p. 22)
Hewlett-Packard	Palo Alto, CA	Producer of Computers and test and measurement equipment.	Internet Commerce for Manufacturing (p. 22)
Honeywell	Minneapolis, MN	Supplier of automation and control systems, components, software, products and services for homes, industry, and aerospace.	Framework (p. 24)

Individual Companies			
Name	Location	Description	Collaborating Project(s)
Hypertek, Inc.	Gaithers-burg, MD	Independent computer consultant.	Standards for Exchange of Instrument Data and NIST Chemical Reference Data (p. 43)
IBM	White Plains, NY	Large information technology corporation.	Information Exchange Protocols for Design (p. 20)
Information Management Resources, Inc.	Gaithers-burg, MD	An independent computer consulting firm specializing in database and client/server applications.	Standards for Exchange of Instrument Data and NIST Chemical Reference Data (p. 43)
InterData Access, Inc. (formerly IGES Data Analysis)	Westches-ter, IL	Consulting firm specializing in the sharing, access and exchange of electronic product data used throughout the design and manufacturing process chain.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)
Intelligent Automation, Inc.	Rockville, MD	R&D and consulting firm specializing in Artificial Intelligence applications.	Framework (p. 24)
Knowledge Based Systems, Inc.	College Station, TX	Vendor of software products for process modeling and analysis.	Process Specification Language (p. 27)
Knowledge Revolution	San Mateo, CA	Producer of functional motion simulation software for engineering, visualization, and education.	Virtual Environments and Visualization for Manufacturing (p. 36)
Knowledge Technologies International, Inc.	Burling-ton, MA	An independent organization handling development, marketing, sales and consulting services related to providing Knowledge-Based solutions to global manufacturing businesses.	Information Exchange Protocols for Design (p. 20)
Merck & Co., Inc.	Somersett, NJ	A research-driven pharmaceutical products and services company.	STEP for the Process Plant Industries (p. 35)

Individual Companies			
Name	Location	Description	Collaborating Project(s)
Michigan Manufacturing Technology Center (MMTC) (formerly the Industrial Technology Institute)	Ann Arbor, MI	Not-for-profit organization that provides training and assistance to help companies meet customer requirements and industry standards, increase profits, improve quality, and lower costs.	Application Protocol Development Environment (APDE) (p. 14) Framework (p. 24) STEP Conformance and Interoperability Testing (p. 33)
Mitta Technology Group	Sunnyvale, CA	A provider of integration and consulting services for Factory Automation (FA) in the semiconductor and related high-technology industries.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)
Monsanto Chemical Company	Bridgeport, NJ	(Formerly) a manufacturer of a wide range of chemical products.	Online Access to NIST Chemical Reference Data (p. 42)
Motorola	Schaumburg, IL	Manufacturer of integrated circuits and wide variety of semiconductor-based consumer products.	Analysis Tools for Assessment and Optimization of Process and Product Design (p. 37)
Nihon Unisys	Tokyo, Japan	Developer and integrator of information technology systems.	Information Exchange Protocols for Design (p. 20)
OrcaComputers, Inc.	Fairfax, VA	Vendor of object-oriented simulation software.	Production and Product Data Management Applications (p. 29)
OrCAD, Inc	Beaverton OR	Producer of electronic design automation software products for the design of printed circuit boards, field-programmable gate arrays and complex programmable logic devices.	Internet Commerce for Manufacturing (p. 22)
PACCAR, Inc.	Bellevue, WA	Manufacturer of on and off-road trucks.	Information Exchange Protocols for Design (p. 20)
Pritsker Corporation	West Lafayette, IN	Vendor of simulation and scheduling software.	Production and Product Data Management Applications (p. 29)

Individual Companies			
Name	Location	Description	Collaborating Project(s)
Raytheon Electronic Systems	Tewks-bury, MA	Defense electronics firm.	Process Specification Language (p. 27)
Real Time Innovations, Inc.	Sunnyvale, CA	Vendor of real-time software development tools.	Reference Model Architecture (p. 31)
Rockwell Collins	Cedar Rapids, IA	Manufacturer of communications and navigational electronics and avionics.	Application Protocol Development Environment (APDE) (p. 14)
SoftQuad, Inc.	Toronto, Canada	Vendor of Standard Generalized Markup Language (SGML) software tools.	Application Protocol Development Environment (APDE) (p. 14)
Solectron Corp.	Milpitas, CA	Provides integrated solutions for the entire product cycle from pre-production planning and design, to manufacturing, distribution and end-of-life product service and support for electronics OEMs.	Internet Commerce for Manufacturing (p. 22)
STEP Tools Inc.	Troy, NY	Vendor of software tools that support the STEP (ISO 10303) standard for data exchange and information modeling.	Application Protocol Development Environment (APDE) (p. 14) Process Specification Language (p. 27)
Sun Microsystems Laboratories (SunLabs)	Palo Alto, CA	Develops, demonstrates, and introduces new advanced technology and technical methodologies for Sun Microsystems, Inc. and its subsidiary corporations. Maintains an awareness of, and contact with, outside technical activities in academia, government, and industry.	NIST Manufacturing Collaboratory (p. 45)
Systems Modeling Corporation	Pittsburgh, PA	Vendor of scheduling and simulation software.	Production and Product Data Management Applications (p. 29)
TeamWave Software Ltd.	Calgary, Alberta, Canada	Vendor of software products that support distributed collaborations.	NIST Manufacturing Collaboratory (p. 45)

Individual Companies			
Name	Location	Description	Collaborating Project(s)
Texas Instruments	Dallas, TX	Electronics manufacturer.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17) Information Exchange Protocols for Design (p. 20)
TechnoSoft, Inc.	Cincinnati, OH	Software vendor.	Information Exchange Protocols for Design (p. 20)
Transom Technologies	Ann Arbor, MI	A provider of human modeling and simulation software.	Virtual Environments and Visualization for Manufacturing (p. 36)
Veo Systems, Inc.	Mountain View, CA	A supplier of products and services to enable open commerce networks.	Internet Commerce for Manufacturing (p. 22)
Viewlogic Systems Incorporated	Marlborough, MA	Vendor of electronic product design and engineering software.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)
Wonderware, Inc.	Irving, CA	Vendor of shop floor data collection software.	Production and Product Data Management Applications (p. 29)
Xerox Corporation	Stamford, CT	Large document and document technology company.	Information Exchange Protocols for Design (p. 20)

Government Agencies			
Name	Location	Description	Collaborating Project(s)
Consumer Product Safety Commission	Washington, DC	An independent federal regulatory agency charged to "protect the public against unreasonable risks of injuries and deaths associated with consumer products."	Virtual Environments and Visualization for Manufacturing (p. 36)
Defense Advanced Research Projects Agency (DARPA)	Arlington, VA	This Defense Department agency's primary mission is to develop imaginative, innovative and often high risk research ideas offering a significant technological impact that will go well beyond the normal evolutionary developmental approaches; and, to pursue these ideas from the demonstration of technical feasibility through the development of prototype systems.	Enterprise Resource Planning Interfaces (ERP-I) (p. 19) Information Exchange Protocols for Design (p. 20) Internet Commerce for Manufacturing (p. 22)
Los Alamos National Laboratory	Los Alamos, NM	The Laboratory's central mission is reducing the danger of nuclear weapons and nuclear materials worldwide. Its statutory responsibility is the stewardship and management of the nuclear stockpile. Work for this project involves development of a Laboratory Equipment Control Interface (LECI) specification.	Standards for Exchange of Instrument Data and NIST Chemical Reference Data (p. 43)
Max-Planck Gesellschaft zur Förderung der Wissenschaften e.V.	Munich, Germany	Max Planck Institutes carry on basic research in service to the general public in the areas of natural science, social science, and the arts and humanities. In particular, the Max Planck Society takes up new and promising directions in research that universities are unable to accommodate sufficiently, if at all.	Computerized Access to Full Structural Crystallographic Data (p. 40)
Naval Research Laboratory	Washington, DC	As the Navy's corporate laboratory, NRL conducts a broadly-based multidisciplinary program of scientific research and advanced technological development directed toward maritime applications of new and improved materials, techniques, equipment, system, and ocean, atmospheric, and space sciences and related technologies.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)
Pacific Northwest National Laboratory	Richland, WA	The Pacific Northwest National Laboratory's core mission is to deliver environmental science and technology.	Online Access to NIST Chemical Reference Data (p. 42)

Government Agencies			
Name	Location	Description	Collaborating Project(s)
TACOM	Warren, MI	Mission is to research, develop, field and support mobility, armament, munitions, and chemical systems and materiels through their total life cycle.	STEP Conformance and Interoperability Testing (p. 33)
US Army, Tobyhanna Army Depot	Tobyhanna, PA	Communications and electronic equipment repair, overhaul, and fabrication facility.	Application Protocol Development Environment (APDE) (p. 14)

Academic Institutions			
Name	Location	Department	Collaborating Project(s)
Arizona State University	Tempe, AZ	Department of Industrial & Manufacturing Systems Engineering	Production and Product Data Management Applications (p. 29) Analysis Tools for Assessment and Optimization of Process and Product Design (p. 37)
Catholic University	Washington, DC	Department of Mechanical Engineering	Reference Model Architecture (p. 31)
Colorado School of Mines	Golden, CO	Division of Engineering	Green's Function Library for Advanced Materials Applications with Web Access (p. 41)
Drexel University	Philadelphia, PA	Department of Electrical and Computer Engineering	Reference Model Architecture (p. 31)
Eindhoven University of Technology	Eindhoven, The Netherlands	Department of Technology Management	Production and Product Data Management Applications (p. 29)

Academic Institutions			
Name	Location	Department	Collaborating Project(s)
Fachhochschule Wiesbaden	Weis-baden, Germany	Computer Science Department	Standards for Exchange of Instrument Data and NIST Chemical Reference Data (p. 43)
George Washington University	Washing-ton, DC	Department of Engineering Management	Information Exchange Protocols for Design (p. 20) Process Specification Language (p. 27)
Georgia Institute of Technology (Georgia Tech)	Atlanta, Georgia	Manufacturing Research Center	Electronic Commerce for the Electronics Industry (ECEI) (p. 17) Internet Commerce for Manufacturing (p. 22)
Harvard University	Cam-bridge, MA	Harvard Smithsonian Center for Astrophysics	Integration of NIST Standard Reference Data into Information Networks (p. 41)
Indian Institute of Management Bangalore	Bangalore, India	Specializes in the field of management education for the highly competitive and varied businesses of the future.	Enterprise Resource Planning Interfaces (ERP-I) (p. 19)
Institut Français de Mécanique Avancée	Aubiere, France	Advanced Production Systems	Production and Product Data Management Applications (p. 29)
Iowa State University	Ames, Iowa	Department of Aerospace Engineering and Engineering Mechanics	Green's Function Library for Advanced Materials Applications with Web Access (p. 41)
Long Island University	Brooklyn, NY	Department of Chemistry	Online Access to NIST Chemical Reference Data (p. 42)

Academic Institutions			
Name	Location	Department	Collaborating Project(s)
Michigan Technological University	Houghton, MI	Department of Mechanical Engineering	Production and Product Data Management Applications (p. 29)
Musashi University	Tokyo, Japan	Department of Management	Production and Product Data Management Applications (p. 29)
Ohio University	Athens, OH	Department of Industrial and Systems Engineering	Production and Product Data Management Applications (p. 29)
Pennsylvania State University	State College, PA	Industrial and Manufacturing Engineering Department	Production and Product Data Management Applications (p. 29)
Politechno di Milano	Milano, Italy	Diportimento di Economia e Produzione	Production and Product Data Management Applications (p. 29)
Robert Wood Johnson Medical School	New Brunswick, NJ	Department of Pharmacology	Web-Based Bioinformatics Databases (p. 43)
Rutgers University	New Brunswick, NJ	Department of Chemistry	Web-Based Bioinformatics Databases (p. 43)
Stanford University	Palo Alto, CA	Computer Science Department	Information Exchange Protocols for Design (p. 20)
State University of New York	Binghamton, NY	Department of Systems, Sciences, and Industrial Engineering	Internet Commerce for Manufacturing (p. 22)
Syracuse University	Syracuse, NY	Department of Mechanical, Aerospace, and Manufacturing Engineering	Information Exchange Protocols for Design (p. 20)

Academic Institutions			
Name	Location	Department	Collaborating Project(s)
Université de Nancy	Nancy, France	École Supérieure d'Informatique et Applications de Lorraine	Production and Product Data Management Applications (p. 29)
University of Canterbury	Christchurch, NZ	Department of Chemistry	Online Access to NIST Chemical Reference Data (p. 42)
University of California	San Diego, CA	San Diego Supercomputer Center	Web-Based Bioinformatics Databases (p. 43)
University of Cincinnati	Cincinnati, OH	Department of Electrical and Computer Engineering and Computer Science	Framework (p. 24)
University of Darmstadt	Darmstadt, Germany	Industrial Applications Department	Application Protocol Development Environment (APDE) (p. 14)
University of Edinburgh	Edinburgh, UK	Artificial Intelligence Application Institute	Process Specification Language (p. 27)
University of Illinois	Chicago, IL	Department of Computer Science	Operator Interfaces for Virtual and Distributed Manufacturing (p. 26)
University of Illinois	Chicago, IL	Department of Mechanical Engineering	Production and Product Data Management Applications (p. 29) Virtual Environments and Visualization for Manufacturing (p. 36)
University of Illinois at Urbana-Champaign	Urbana, IL	Department of General Engineering	Reference Model Architecture (p. 31)

Academic Institutions			
Name	Location	Department	Collaborating Project(s)
University of Maryland	College Park, MD	Department of Computer Science	Information Exchange Protocols for Design (p. 20) Process Specification Language (p. 27) Production and Product Data Management Applications (p. 29)
University of Maryland	College Park, MD	Department of Electrical Engineering	Reference Model Architecture (p. 31)
University of Maryland	College Park, MD	Department of Mechanical Engineering	Process Specification Language (p. 27) Design - Process Planning Integration (DPPI) (p. 16)
University of Maryland - Baltimore County	Catonsville, MD	Department of Chemistry	Online Access to NIST Chemical Reference Data (p. 42)
University of Melbourne	Parkville, Victoria, Australia	School of Physics	Integration of NIST Standard Reference Data into Information Networks (p. 41)
University of Michigan	Ann Arbor, MI	School of Information Collaboratory for Research in Electronic Work (CREW)	NIST Manufacturing Collaboratory (p. 45)
University of Michigan	Ann Arbor, MI	Electrical Engineering and Computer Science Department	Information Exchange Protocols for Design (p. 20)
University of New Brunswick	Saint John, NB, Canada	Department of Physical Sciences	Integration of NIST Standard Reference Data into Information Networks (p. 41)

Academic Institutions			
Name	Location	Department	Collaborating Project(s)
University of Pennsylvania	Philadelphia, PA	Center for Human Modeling and Simulation	Virtual Environments and Visualization for Manufacturing (p. 36)
University of Pittsburgh	Pittsburgh, PA	Department of Chemistry	Web-Based Bioinformatics Databases (p. 43)
University of Rochester	Rochester, NY	Department of Mathematics	Information Exchange Protocols for Design (p. 20)
University of Tennessee	Knoxville, TN	Department of Chemistry	Online Access to NIST Chemical Reference Data (p. 42)
University of Texas	Arlington, TX	Department of Industrial & Manufacturing Systems Engineering	Analysis Tools for Assessment and Optimization of Process and Product Design (p. 37)
University of Toronto	Toronto, Canada	Enterprise Integration Laboratory	Process Specification Language (p. 27)
Virginia Polytechnic University	Blacksburg, VA	Department of Industrial and Systems Engineering	Production and Product Data Management Applications (p. 29)
Washington State University	Pullman, WA	School of Mechanical and Materials Engineering	Information Exchange Protocols for Design (p. 20)
Wayne State University	Detroit, MI	Industrial and Manufacturing Engineering Department	STEP Conformance and Interoperability Testing (p. 33)

Standards Committees			
Committee	Organization	Description	Collaborating Project(s)
ASTM/SC E49.08	American Society for Testing and Materials	Analytical Data Interchange Protocols.	Standards for Exchange of Instrument Data and NIST Chemical Reference Data (p. 43)
ASTM/SC E49.52	American Society for Testing and Materials	Computerization of Analytical Sciences Data.	Standards for Exchange of Instrument Data and NIST Chemical Reference Data (p. 43)
DATC/ECCI	Institute of Electrical and Electronics Engineers (IEEE)	Professional society for advancing the theory and practice of electrical, electronics and computer engineering and computer science.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)
IEC/TC3/SC3D	International Electrotechnical Commission (IEC)	The role of IEC/TC3/SC3D is to prepare standards regarding methods and rules associated with the handling of information in computer-sensible form. This includes definition of data element types and data sets for use in information models and technical documentation, and for exchange of technical information.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)
IEC/TC93/WG1	International Electrotechnical Commission (IEC)	The role of IEC/TC93/WG1 is to propose to TC 93 an overall strategy and practical working approach for the harmonization and interoperability of electrotechnical data description standards.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)
IEC/TC93/WG2	International Electrotechnical Commission (IEC)	The role of IEC/TC93/WG2 is to review the technical quality of hardware description language (HDL)-related draft standards developed by working groups of other standards group, the harmonization of HDL-related work done in other standards groups, and to make recommendations to allied standards groups such as the IEEE and EIAJ for development of new standards.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)
IEC/TC93/WG3	International Electrotechnical Commission (IEC)	The role of IEC/TC93/WG3 is to develop an IEC Standard based on the EDIF Standard from the EIA (Electronic Industries Association) in the U.S. The coverage of this standard includes an exchange format for describing the connectivity of components in electronic and electrotechnical netlists and PC boards.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)

Standards Committees			
Committee	Organization	Description	Collaborating Project(s)
IEC/TC93/WG5	International Electrotechnical Commission (IEC)	The role of IEC/TC93/WG5 is to investigate test, validation, conformance and qualification methodologies for international standards for electrical and electronic product data exchange.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)
Area Committee: Automation	National Committee for Clinical Laboratory Standards	Subcommittee: System Status and Error and Exception Handling.	Standards for Exchange of Instrument Data and NIST Chemical Reference Data (p. 43)
Area Committee: Automation	National Committee for Clinical Laboratory Standards	Subcommittee: Communications with Automated Systems.	Standards for Exchange of Instrument Data and NIST Chemical Reference Data (p. 43)
TC29/WG34	International Organization for Standardization (ISO)	Technical Committee: Small Tools. Working Group: Carbide Cutting Tools.	Information Exchange Protocols for Design (p. 20)
TC184/SC4	International Organization for Standardization (ISO)	Technical Committee: Industrial Automation Systems and Integration. Subcommittee: Industrial Data. SC4 develops standards that provide capabilities to describe and manage product data throughout the life of the product.	Application Protocol Development Environment (APDE) (p. 14)
TC184/SC4/ Quality Committee	International Organization for Standardization (ISO)	Responsible for developing STEP methods and assessing the compliance of draft STEP parts with prescribed methods.	STEP Conformance and Interoperability Testing (p. 33)
TC184/SC4/ WG3/ Ad Hoc Committee on Parametrics	International Organization for Standardization (ISO)	The role of the Parametrics Committee is to determine the need for parametric representations in STEP and related standards, and propose how techniques and models may be changed to meet those needs.	Information Exchange Protocols for Design (p. 20) Reference Model Architecture (p. 31)
TC184/SC4/ WG3/T7	International Organization for Standardization (ISO)	Technical Committee: Industrial Automation Systems and Integration. Subcommittee: Industrial Data. Working Group: Product Modeling. Team: Mechanical Product Definition.	STEP Conformance and Interoperability Testing (p. 33) Reference Model Architecture (p. 31)

Standards Committees			
Committee	Organization	Description	Collaborating Project(s)
TC184/SC4/ WG3/T11	International Organization for Standardization (ISO)	Technical Committee: Industrial Automation Systems and Integration. Subcommittee: Industrial Data. Working Group: Product Modeling. Team: Manufacturing Technology.	STEP Conformance and Interoperability Testing (p. 33) Reference Model Architecture (p. 31)
TC184/SC4/ WG3/T20	International Organization for Standardization (ISO)	Technical Committee: Industrial Automation Systems and Integration. Subcommittee: Industrial Data. Working Group: Product Modeling. Team: Process Plant Industries.	STEP for the Process Plant Industries (p. 35)
TC184/SC4/ WG8	International Organization for Standardization (ISO)	Technical Committee: Industrial Automation Systems and Integration. Subcommittee: Industrial Data. Working Group: Industrial Manufacturing Management Data.	Enterprise Resource Planning Interfaces (ERP-I) (p. 19)
TC184/SC4/ WG11	International Organization for Standardization (ISO)	Technical Committee: Industrial Automation Systems and Integration. Subcommittee: Industrial Data. Working Group: EXPRESS Language, Conformance, Testing, and Implementation Specifications.	STEP Conformance and Interoperability Testing (p. 33)
TC184/SC4/ JWG9	International Organization for Standardization (ISO)	Technical Committee: Industrial Automation Systems and Integration. Subcommittee: Industrial Data. Joint (with IEC/TC-3) Working Group: Electrical Application.	Electronic Commerce for the Electronics Industry (ECEI) (p. 17)
TC213	International Organization for Standardization (ISO)	Dimensional and Geometrical Product Specifications and Verification.	Information Exchange Protocols for Design (p. 20)
STEP Steering Committee	International Society for Measurement and Control (ISA)	Develops the ISA STEP implementation plan and promotes the value of participation in the development of STEP APs.	STEP for the Process Plant Industries (p. 35)

Standards Committees			
Committee	Organization	Description	Collaborating Project(s)
Manufacturing Domain task Force	Object Management Group	Consortium dedicated to the development of technology and standards for distributed object systems.	Enterprise Resource Planning Interfaces (ERP-I) (p. 19) Production and Product Data Management Applications (p. 29)
OAG Integration Specification	Open Applications Group (OAG)	A nonprofit consortium of enterprise application software developers, formed in February 1995 to create common standards for the integration of enterprise business applications. Member companies are building specifications to standardize integration between enterprise business applications.	Enterprise Resource Planning Interfaces (ERP-I) (p. 19)

Appendix C: FY97-98 Project Publications

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Appendix D: Program Products Newly Available in FY97-98

Software/Services

EXPRESS Web Server

The EXPRESS Web Server is a World Wide Web interface for standards developers creating specifications for STEP, the STandard for the Exchange of Product model data (officially ISO 10303). The Server enables users to run applications needed to build and populate EXPRESS specifications using a Web browser and without having to install and configure the applications locally. The Server also allows users to share EXPRESS specifications and data sets with one another, providing standards development teams with an infrastructure for collaboration.
Available: http://pitch.nist.gov/cgi-bin/sauder/express-server/server.cgi

Manufacturer's CORBA Interface Testing Toolkit (MCITT)

The Common Object Request Broker Architecture (CORBA) supports the construction of distributed systems containing many components. These components can interact in complex ways, not necessarily conforming to a strict client-server model. This generality is necessary to enable many real-world systems to be built on a distributed architecture. However, it is also the reason why testing these systems is so difficult. Because each component can have complex dependencies on any number of other components, it is often impossible to test them in isolation. MCITT mitigates this problem by minimizing the amount of effort needed to produce simple emulations -- test servers -- that can be used to replace actual servers in a testing scenario. Once the behaviors important for a given scenario are specified, MCITT will automatically generate CORBA boilerplate code, memory management, and stubs for unused operations.
Available: http://www.mel.nist.gov/msidstaff/flater/mcitt/

NIST Expresso version 1.5.1 (updated Beta-test version)

NIST Expresso is a language environment for the ISO EXPRESS language (ISO10303-11) providing tools to aid in the development and validation of EXPRESS information models and representative data sets. NIST Expresso is available as an executable that runs under Microsoft Windows 95 and NT operating systems. The downloadable PC executable allows the user to specify and incrementally modify his own EXPRESS information model for analysis and validation. It may also be used to build representative data sets for the subject schema.
Available: ftp://ftp.nist.gov/pub/mel/denno/beta/expresso1-5-1.exe

STEP Conformance Testing System

The STEP conformance testing systems, or NITS (NIST-ITI Test System) is a WWW-based resource designed to support the testing needs of software application developers who are implementing STEP standards. Developers, and users as well, can access NITS and interactively execute tests on their implementations in order to ascertain the degree to which these implementations conform to a specific standard. Currently, NITS specifically provides for testing of implementations of the STEP standard for configuration controlled design (ISO SC4 203). NITS provides reference test case data and integrates independent test tools such as generators, analyzers, and recorders into a repeatable and traceable process. NITS also provides users a common interface for administrative support in collecting, organizing, and reviewing test results.
Available: http://frigg.erim.org:8080/nits

Standard Reference Databases[2]

XCOM: Photon Cross Sections Database, Berger, M., Hubbell, J.
A web database that can be used to calculate photon cross sections for scattering, photoelectric absorption and pair production, as well as total attenuation coefficients, for any element, compound or mixture ($Z \leq 100$), at energies from 1 keV to 100 GeV.
Available: http://physics.nist.gov/PhysRefData/Xcom/Text/XCOM.html

X-Ray Form Factor, Attenuation and Scattering Tabulation, Chantler, C.
The primary interactions of x-rays with isolated atoms from $Z = 1$ (hydrogen) to $Z = 92$ (uranium) are described and computed within a self-consistent Dirac-Hartree-Fock framework. This has general application across the range of energy from 1 eV-10 eV to 400 keV-1000 keV, with limitations as the low- and high-energy extremes are approached. Tabulations are provided for the f_1 and f_2 components of the form factors, together with the photoelectric attenuation coefficient for the atom, μ, and the value for the K-shell, μ_K, as functions of energy and wavelength. Also provided are estimated correction factors as described in the text, conversion factors, and a simple estimate for the sum of the scattering contributions (from an isolated atom).
Available: http://physics.nist.gov/PhysRefData/FFast/Text/cover.html

Fundamental Physical Constants Database, Cohen, E., Taylor, B.
This site addresses three topics: fundamental physical constants, the International System of Units (SI), which is the modern metric system, and expressing the uncertainty of measurement results. Both essential information and background information are given for each topic.
Available: http://physics.nist.gov/cuu/Constants/index.html

Electron-Impact Ionization Cross Section Database, Kim, Y., Rudd, M.
This is a database primarily of total ionization cross sections of molecules by electron impact. The database also includes cross sections for a small number of atoms and energy distributions of ejected electrons for H, He, and H_2. The cross sections were calculated using the Binary-Encounter-Bethe (BEB) model, which combines the Mott cross section with the high-incident energy behavior of the Bethe cross section. Selected experimental data are included.
Available: http://physics.nist.gov/PhysRefData/Ionization/Xsection.html

NIST Chemistry WebBook, Mallard, W., Linstrom, P.
The WebBook provided access to the full array of data compiled and distributed by NIST under the Standard Reference Data Program, including thermochemical data for over 5000 organic and small inorganic compounds, reaction thermochemistry data for over 8000 reactions, infrared spectra for over 5000 compounds, and thermophysical property data for 16 fluids.
Available: http://webbook.nist.gov/

Ground Levels and Ionization Energies for the Neutral Atoms, Martin, W., Musgrove, A.
The ionization energies in the table are based on a recent survey of the literature. A reference to one or another data compilation is given for a number of elements; the cited compilation gives the reference(s) for the original ionization-energy data. The uncertainties are mainly in the range from less than one to several units in the last decimal place, but a few of the values may be in error by 20 or more units in the final place; i.e., the error of some of the two place values could be greater than 0.2 eV. Estimated uncertainties of the ionization energies are usually given in the references. Although no more than four decimal places are given, the accuracies of some of the better known values would, in eV units, be limited only by the uncertainty in the conversion factor, $1.239\ 842\ 44(37) \times 10^{-4}$ eV/cm^{-1}.
Available: http://physics.nist.gov/PhysRefData/IonEnergy/ionEnergy.html

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2. More information on Standard Reference Data products can be found at http://www.nist.gov/srd/.

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Radionuclide Half-Life Measurements Made at NIST, Unterweger, M., Hoppes, D., Schima, F.
The half lives of many radionuclides have been measured in the Radioactivity Group of NIST over the last three decades. The results of these measurements for many long-lived radionuclides, such as ^{60}Co, ^{137}Cs, ^{85}Kr, ^{22}Na, ^{133}Ba, ^{207}Bi, ^{152}Eu, ^{154}Eu, ^{155}Eu, and ^{125}Sb have been recently revised. The results for the half lives of the many radionuclides measured over the last three decades are tabulated. The table is the revised listing of the half lives determined at NIST since 1967 and supersedes the table presented in NBS Special Publication 626 [D.D. Hoppes and F.J. Schima, ed. (1982), p. 85]. The half lives of radionuclides not previously reported are noted as well as those which have been significantly revised. The revised values for the half lives of various "short-lived" radionuclides arise from improved impurity analysis, incorporation of additional data from new sources, and reevaluation of old data.
Available: http://physics.nist.gov/PhysRefData/Halflife/halflife.html