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National PDES Testbed Report Series

National PDES Testbed Strategic Plan 1990

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NIST

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National PDES Testbed Strategic Plan 1990

Charles R. McLean

U.S. DEPARTMENT OF
COMMERCE
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PREFACE

This document presents a long range strategic plan for the National PDES Testbed at the National Institute of Standards and Technology (NIST). The Testbed was initiated in 1988 under the sponsorship of the U.S. Department of Defense Computer-aided Acquisition and Logistic Support (CALS) program. A major goal of the Testbed is to provide technical leadership in a national effort to implement a complete and useful specification for the exchange of product data. This specification must be designed to meet the needs of American industry and the CALS program.

The National PDES Testbed supports and actively participates in the international effort to develop the Standard for the Exchange of Product Model Data (STEP). The STEP development effort is led by the International Organization for Standardization (ISO) TC184/SC4.

This plan also outlines a number of supporting project threads that have been established for the National PDES Testbed. These threads address such areas as:

- initiation of the Testbed,
- development of configuration management systems and services,
- development of testing systems to validate the proposed standard,
- specification and testing of application protocols,
- construction of a prototype STEP-based manufacturing cell,
- establishment of a product data exchange network,
- development of conformance testing systems, and
- management and technical support activities.

The level of support provided for these threads and others will be determined by sponsor needs and a number of different priorities. As such, the plan contained within this document outlines a reasonable schedule to accomplish the objectives of the Testbed. Changes in priorities and levels of support may either accelerate or delay the proposed schedule. This plan will be updated periodically to reflect technical changes in the overall National PDES Testbed project, current level of effort, and expected continued support.

ACKNOWLEDGEMENTS

The author would like to recognize the contributions of NIST staff to the development of this strategic plan. First, I want to thank Cita Furlani for technical contributions to the "Evolution of Product Data Sharing" and editorial suggestions for the entire document. I would also like to recognize the technical contribution of Jim Fowler to the development of the "Challenges and Priorities" section.

The technical information and illustrations contained within Section 4, "Technical Plans" are based upon the technical thread plans listed in the "References" section. The development of the plans for the technical threads is largely a result of the National PDES Testbed Center Managers: Mary Mitchell, Jim Fowler, Sandy Ressler, and Simon Frechette. Susan Katz and Kevin Jurrens also made major contributions to the development of the technical plans. Sharon Kemmerer of the Information Systems Engineering Division at NIST authored the Conformance Testing System plan. Chuck Stark, the PDES, Inc. Liaison from the South Carolina Research Authority was primary author of the Application Protocol Specification and Validation plan. Project management charts and diagrams for the strategic plan and the development plans were prepared by Clarence Johnson.

I would also like to recognize the reviews, guidance, and editorial suggestions made by Howard Bloom and Merrill Hessel of NIST. The "Road Map for Product Data Sharing Technology" figure was provided from an internal document prepared by Howard Bloom for the U.S. Department of Commerce.

The staff of the Testbed project are grateful for the support and guidance provided by the CALS Program Office in the Office of the Assistance Secretary of Defense. I would particularly like to acknowledge the recommendations and suggestions offered, and patience displayed, by Mike McGrath, Bruce Lepisto, and Dan Sudnick during the course of the development of the strategic plan and detailed plans for the National PDES Testbed.

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EXECUTIVE SUMMARY

The ever-increasing role of computer systems in manufacturing and logistic support is leading to a greater and greater need for standards. Unfortunately, information cannot be easily and automatically passed between different computer systems running in the same organization, much less between different organizations. The basic problem is that application software, i.e. computer programs, use inconsistent proprietary data formats to store the information that they use. The problem is so severe that it is often the case that two programs, produced by the same software vendor to perform related functions, will not be able to use each other's data. Users of these software packages must either manually reenter data, pay additional costs to have special data translators built, or just not make full use of the capabilities that they have bought. These limitations radically diminish the effectiveness and economic benefits of expensive computer technology.

Product specification data is one major type of information which must be shared by different computer software applications and different organizations. This data is used by computers during all phases of a product's life cycle. It is used by product design, manufacturing engineering, production, and logistic support systems. Currently, no data standards exist which would allow all of these systems to share commonly needed information. This lack of standardization has had a major impact on productivity across American industry and within government manufacturing facilities. Given the extensive investment in information systems technology within the United States, the resolution of this problem could play a major role in improving national competitive capabilities.

In recent years, the importance of sharing product data among different systems and organizations has been recognized both nationally and internationally. Major technical activities have been initiated in the United States and abroad which support the development of standards for product data sharing. These activities share a common goal:

- the establishment of a complete, unambiguous, computer definition of the physical and functional characteristics of a product throughout it's life cycle.

The U.S. national activity that is working towards this goal is led by the IGES/PDES Organization (IPO). The proposed international standard, which the IPO supports, is called the "Standard for the Exchange of Product Model Data", or more informally, "STEP."

The international standards activity is led by the International Organization for Standardization (ISO). The ISO committee responsible for STEP development, i.e. TC184/SC4, expects to have a first draft international product data standard late in 1991. The draft STEP specification is divided up into a series of documents called "parts." Some of the major parts which have been identified within the STEP specification include: introductory--overview and fundamental principles (part 1), description methods--the EXPRESS modelling language (part 11), physical file--a method for implementing a file format for exchange and archiving (part 21), conformance testing (part 31), general product data model (part 41), shape representation (part 42), presentation (part 46), draughting (part 101), and application protocols (parts in the 200 series). The first version is expected to contain at least one application protocol (2-D drafting) which is based on physical file transfer for the exchange of information.

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

This document outlines the long range strategic plan for the National PDES Testbed project. The plan discusses major goals and objectives for the project. The goal of the Testbed is:

> *to provide technical leadership and a testing-based foundation for the rapid and complete development of the STEP specification.*

Major objectives of the Testbed include: the identification of computer software applications that will use STEP, the specification of technical requirements for these applications, the evaluation of the proposed STEP standard with respect to application requirements, the design and implementation of prototype STEP applications, the establishment of configuration management for STEP specifications and certain

supporting software, and improved communications/interactions between organizations which have a stake in the development of STEP.

The development of STEP is an effort which is very large in scope. The effort already involves many hundreds of technical experts around the world. Because of the complex technical nature of the problem, it will be a number of years before the full promise of STEP-based data sharing is achieved. How will STEP become a reality? To answer this question we must understand: a) how the technology is likely to evolve, and b) what institutions are involved in the evolutionary process. The stages of evolution for product data sharing which have been identified by the National PDES Testbed are:

I. Establishment of the technical foundation for STEP,
II. Validation and standardization of technical specifications,
III. Development of tools and prototype applications, and
IV. Commercialization of, and transition to, STEP-based systems.

Each stage of evolution is an essential step towards achieving the goal of product data sharing. Major institutions that are formally involved in the development of STEP include: the ISO standard subcommittee (TC184/SC4), the IGES/PDES Organization, the ANSI U.S. Technical Advisory Group, the PDES, Inc. industrial consortium, and the National PDES Testbed.

Some of the major challenges in the area of product data sharing technology which have been identified by the staff of the National PDES Testbed are: commercialization, conformance testing, data sharing, data representation, verification and validation, application development, and configuration management. Commercialization is the reduction of STEP technology to commercial products that are available "off the shelf." Conformance testing refers to the creation of a systems and an institutional framework that can be used to verify that commercial products comply with the STEP specification. The conformance testing system and institutional framework must be neutral, i.e. not favor specific commercial vendors. Data sharing means sharing information among different software applications on different computer systems within different organizations. Data representation refers to the creation of sound, neutral data structures for representing product information. Together the data sharing and data representation challenges must be met through a consensus-building process. Verification and validation is the testing-based evaluation of the proposed standard to ensure that it meets the needs of the user community. Application development is the implementation of practical STEP-based computer applications on the basis of application protocols. Configuration management refers to the control of the many

versions of documents and software that are created as a part of the STEP development process. Our approach to meeting these challenges is defined within the technical threads of the National PDES Testbed project.

This strategic plan describes a multi-year project to help accelerate the development of STEP. The overall objectives of this project will be accomplished through a number of technical threads. The project threads are the following:

- Testbed Initiation Activities - Establish the operational Testbed facility, coordinated efforts with outside organizations, perform initial technical studies, develop prototype systems, and perform preliminary testing of the draft STEP specifications.

- Configuration Management Systems and Services - Implement a configuration management system and estsblish a central repository for documents and software generated by various organizations involved in the STEP development process.

- Validation Testing System - Develop a system for testing and evaluating the application protocols which are defined as parts of the STEP specification.

- Application Protocol Specification and Validation - Specify and validate three application protocols that are essential to construction of a STEP-based manufacturing cell.

- STEP Production Cell - Construct a prototype manufacturing cell based upon three candidate applications protocols, i.e. Design, Process Planning, and NC programming, which demonstrates the feasibility of STEP for commercial system implementations.

- Product Data Exchange Network - Establish a network of government facilities, industrial sites, research and academic institutions that will conduct multi-site product data sharing tests, develop STEP-based software, review technical specifications, conduct training, and perform technology transfer activities.

• Conformance Testing System - Develop a system and an institutional framework which can be used to test commercial STEP products and certify that they comply with the standard.

• Management and Technical Support Activities - Perform a variety of management and technical activities which include: project planning, coordination with other organizations, administration of the Testbed, support of computer and communications systems, participation in outside technical programs and standards committee activities, training and technology transfer, creation of internal software quality assurance mechanisms, and establishment of an external project review process.

The Testbed Initiation Activities thread ended with the 1990 fiscal year. The activities of most of the other threads has only begun. Detailed plans have been developed for each of these threads and have been published in separate documents. These threads each have a set of major deliverables and key milestones. These threads represent timely issues that must be addressed during the march to implement STEP. As the Testbed develops, some of the present threads will end and new ones will be initiated.

The National PDES Testbed is an impartial, publicly-accessible facility where successive definitions of the STEP specification can be modeled, analyzed, prototyped, implemented, and tested. The Testbed facility is comprised of laboratories, computer hardware and software systems, and testing tools. The Testbed is used and staffed by leading experts on PDES issues from industry, academia, and government. The Testbed is currently staffed with the full-time equivalent of approximately 20 scientists, engineers, and support personnel.

In summary, this strategic plan describes how the National PDES Testbed will support the development of STEP. The Testbed staff recognize that they must be responsive to the needs of industry and other government agencies. Furthermore, if an international standard is to be achieved, it will undoubtedly require the consensus of many individuals and most surely some compromises. As such, this plan is intended to be a living document. It will be revised and reprinted on a periodic basis as sponsor needs and technical perspectives change.

SECTION 1. GOALS AND OBJECTIVES

Products manufactured today lead more complicated lives than those produced only a decade ago. The rapid advance of computer technology has played a major role in this change. Computers are now a part of each manufactured product's life cycle, from its inception to its eventual retirement. Computerized information systems are used to help design products, plan their manufacture, control the machinery that produces them, run tests to verify that they meet specifications, manage their deployment, and help support their operation and maintenance.

Typically, many different organizations and systems require access to computerized product data. This data tells everything that known about a product. It describes the product's functions and its design, e.g. components, shape, dimensions and tolerances, material composition. It also specifies the manufacturing processes that are used to make it. Other data is required which describes how the product is to be used or operated. There is also data which tells us how to maintain the product, i.e. keep it working up to specifications. Finally, there may be data on how to properly deactivate or dispose of the product.

The information systems which use this product data are essentially very large computer programs. They have been developed over many years by many different people. More systems are being developed every day. Because these systems have evolved independently from one other, they tend to use unique representations for storing product data. Unfortunately, each system is only able to use data that has been stored in the particular representation that it was programmed to understand. Getting several of these systems to work together is like trying to run an organization where everyone speaks a different foreign language.

Each time product information is passed from one system to the next, it must be translated or reformatted. Obviously, having to perform this extra step to share information is extremely inefficient. In fact, it can be very costly when many systems and products are involved.

The primary reason for using information systems technology in the first place is to reduce the costs that are associated with a product over its life cycle. Ironically, the incompatibility between these information systems is now having just the opposite effect, i.e. it is increasing costs. A solution must be found that will enable the sharing of product data between independently developed information systems.

PDES is that solution!

PDES, i.e. "Product Data Exchange using STEP", is the name given to the U.S. organizational activities in support of the development of a standard for product data sharing. The PDES activities will help establish a standard digital representation for product data. The specifications developed by the PDES activities have been submitted to the International Organization for Standardization (ISO) as a basis for an international standard for the exchange of product data. The evolving international standard for the representation of product data is called STEP, the Standard for the Exchange of Product Model Data. As the PDES and STEP efforts share common goals, they may be referred to jointly in this document, as PDES/STEP, or often just as STEP, the proposed ISO standard.

The many different organizations and individuals that are involved in the development of STEP share a common interest:

- the establishment of a complete, unambiguous, computer definition of the physical and functional characteristics of a product throughout it's life cycle.

As a standard method for digital product definition, STEP will permit communications among heterogeneous computer environments. It will be much easier to integrate systems which perform various product life cycle functions, e.g. design, manufacturing and logistics support. Automatic paperless updates of product documentation will also be possible. The principal technique for integrating these systems and exchanging data will be the shared database.

In the context of STEP, a product may range from a simple mechanical part, such as a bolt or a screw, to a complex set of systems, such as an aircraft, a ship, or an automobile. Ultimately, STEP should be able to represent the information which is needed to describe all types of products, e.g. mechanical, electrical, structural, etc.

STEP addresses many questions about a product: What does it look like? (geometric features); How is it constructed? (materials and assembly); For what function is it intended? (structural and functional properties); How can we tell a good product from a bad one? (tolerances and quality constraints); What are its components? (bill of materials).

The early development of the STEP specification is a major goal of virtually everyone who is involved in the development effort. The STEP specification is being produced as a series of documents called "parts" [ISO90-1]. The major parts of the specification are identified in [ISO90-2] and are outlined below:

- *Introductory*
  - Part 1 - Overview and Fundamental Principles: Introduction of STEP contents and description of Parts' structure,

- *Description Methods*
  - Part 11 - EXPRESS: Definition of the modelling language used for all resource information models,
  - Part 12 - Framework for Product Data Modelling: Integration and organization of concepts used in STEP,

- *Implementation Forms*
  - Part 21 - Physical File: Method for implementing a sequential file format for intersystem exchange and archiving,

- *Conformance Testing Methodologies*
  - Part 31 - Conformance Testing Methodology and Framework: General Concepts - introduction to this series of Parts and general concepts,
  - Part 32 - Requirements on Testing Laboratories and Clients for the Conformance Assessment Process,

- *Resource Information Models*
  - Part 41 - Miscellaneous resources: Identification, units, general functions and types,
  - Part 42 - Shape: Geometry, topology, shape types,
  - Part 43 - Shape interface: Shape representation interface,
  - Part 44 - PSCM (Product Structure and Configuration Management): Parts, versions, assemblies, lots,
  - Part 45 - Material: Material properties,
  - Part 46 - Presentation: Colours, symbols, libraries, line styles, patterns, text, views,
  - Part 47 - Tolerances: Three dimensional shape variation tolerances,
  - Part 48 - Features: Classification and representations of areas of shape regions,
  - Part 101 - Draughting: Annotation, dimension representation, sections, notes, drawing, sheet, views,
  - Part 102 - Ship Structures: Shape, material, identification, compartment, structural joints, openings,
  - Part 103 - Electrical Applications: Schematics, layered electrical product,
  - Part 104 - Finite Element Analysis: Finite element model,

Application Protocols
  - Part 201 - Draughting-related AP: Example application protocol.

As new needs are identified, existing parts may be revised or additional parts may be added to the specification. Eventually, there are likely to be many additional 200-series parts, as new application protocols are identified.

In 1988, a government interagency task group was formed to focus on information sharing among interested federal agencies. The work of the task group was published in [Henghold89]. The objectives of the group were to: "prepare and consolidate government requirements for input into PDES development activities, and provide recommendations as to technical and other actions such as needed policy changes, regulatory changes or contractual vehicles/tools (e.g. data item descriptions, contract clauses, etc.) which the government should put in place to foster the development of the PDES specification." Some of the concerns about the current product data environment expressed in the Task Group report are:

- It is hard copy oriented.
- It is massively heterogeneous in terms of vendors and system age.
- Product knowledge is not well captured.
- Product cycles (from R&D to production) are very long and the handoff from one phase to the next phase often loses information.
- Technical data packages are often in error and incomplete.
- Incorporation of change/technology upgrades is slow.
- New efforts often just automate existing methods.
- Transfer of information to/from contractors is slow.
- Funding for "non-product" development such as PDES is limited and sometimes non-existent.
- Acquisition of improved producer technology, (e.g., new computers, CAD/CAM/CAE) is difficult, time consuming (avg. 3 to 5 years), and done in the face of ever shortening technology half lives.
- Industry concern with proprietary data rights is at odds with government desires.
- Legal reluctance to provide CAD/CAM data rather than part drawings.
- Data is replicated many places for different purposes (e.g., non-common/integrated databases).

As a result of needs and recommendations identified by the task group, the Computer-aided Acquisition and Logistic Support (CALS) Office in the U.S. Department of Defense

sponsored the creation of the National PDES Testbed to serve as a coordinator for PDES/STEP technical and standards efforts for government agencies.

The PDES activity is a major component of the U.S. Department of Defense (DOD) (CALS) program. CALS is tackling a related, but larger scale set of issues:

- Developing and testing standards for digital technical information;
- Sponsoring the development and demonstration of new technology for the integration of technical data and processes;
- Implementing CALS standards in weapon system contracts and encouraging Industry modernization and integration;
- Implementing CALS in DoD information system modernization programs.

Further background information on the objectives, strategy, information system environment, and management structure which has been defined for the CALS program can be found in [CALS89].

National PDES Testbed Goals

The National Institute of Standards and Technology (NIST) has established the National PDES Testbed at its Gaithersburg, MD site to support PDES/STEP development activities. Under the sponsorship of the DOD CALS program, the Testbed has assumed a critical role in the development of STEP. The goal of the Testbed is:

> *to provide technical leadership and a testing-based foundation for the rapid and complete development of the STEP specification.*

The staff of the NIST Testbed recognize that the establishment of a STEP standard is very much a consensus-building process. It can only be achieved with support from, and cooperation between: standards organizations, industry, government, and academia. Although the Testbed is just completing its initiation phase, it is already working closely with representatives from all of these different sectors.

The staff of the National PDES Testbed have defined objectives, developed detailed plans, and established a project organization which supports the accomplishment of its goals. Some of the major objectives of the Testbed are:

1) **Identify the types of computer applications which will use STEP and model their data,**

2) **Specify the technical requirements of these systems with respect to STEP,**

3) **Validate that the STEP specifications satisfy the technical requirements of those systems,**

4) **Design and implement prototype systems which support testing and provide a foundation for future development efforts,**

5) **Maintain control over the many versions of specifications, software tools, and test procedures/data generated by the standards and technical development activities,**

6) **Improve communication and interaction between the various programs and organizations which have a stake in the development of STEP.**

To meet these objectives, NIST has formed alliances with industrial research partners, other government agencies, and universities to work together to address the development of product data sharing capabilities. The National PDES Testbed is the physical realization of the progress that has been made towards STEP implementation. Over the next few years, these alliances will be greatly expanded with new partners as the cooperative efforts become more clearly scoped and defined. In addition, NIST has made a commitment to support the standards organizations, both by strong technical involvement in its committees, as well as leadership roles through chairmanships of both national and international standards activities.

The accomplishment of these objectives will go a long way towards putting STEP on a sound footing. Detailed plans have been developed to achieve these objectives. These plans are encapsulated in the "Technical Plans" section of this document.

SECTION 2. EVOLUTION OF PRODUCT DATA SHARING

When will "shrink wrapped" STEP-based applications software become available as off-the-shelf products in computer stores? System developers, vendors, and users would all like to know the answer to this question. Unfortunately, there are no easy answers. A great deal of work remains to be done before the vision of off-the-shelf, "plug compatible" STEP applications becomes a reality. This section describes how STEP will undoubtedly evolve and the major players that are involved in the process.

Technical Aspects of STEP

A sound technical specification for STEP must address many issues pertaining to the architectures of information systems and the management of product life cycle data. Many different technologies have been brought together to establish a technical foundation for STEP. Computer-aided design (CAD) and solid modeling systems have provided the initial framework for describing product data. Researchers in the fields of information modeling, relational and object-oriented data base management systems have provided software tools that have contributed to the development effort. Technical experts, who have either implemented or used pre-STEP applications software, have also made major contributions. Experts that are familiar with the data requirements of design, process engineering, machine programming, and product support systems have helped define the types of data that must be supported in a product data exchange specification.

What work must be done to fully implement STEP? What has already been accomplished? What remains to be done? The transformation of STEP from an abstract concept to a commercial reality, is very much an evolutionary process. STEP application areas range from simple mechanical parts, to complex electronics systems, to building and ship construction. Because of the broad range of product types and application technologies which must be covered, it is obvious that a complete STEP specification will not evolve overnight. Within the National PDES Testbed, we see STEP undergoing four stages of evolution:

Stage I. Establishment of the foundation for STEP - The creation of a specification for the standard representation of product data involves many complex issues. It is virtually impossible for one individual or even a small group of individuals to just sit down and write this kind of specification. The development of this specification requires both a strong technical and institutional foundation. The technical foundation for STEP is based upon a number of different information and manufacturing systems technologies and the experience of many technical experts. The institutional foundation is provided by voluntary technical activities, national and international standards

organizations, businesses and industrial consortiums, and government agencies. Because of the great need for consensus, all of these institutions must be in general agreement about the definition of STEP, if it is going to be an effective standard.

Stage II. Validation and standardization of technical specifications - Once an initial specification has been created, it must be validated, i.e. tested to determine that it meets the needs of the user community. Validation testing must take into account how the specification will be used. Technical experts need to define the requirements for the different kinds of software applications that will use STEP. They will need to build information models based on the proposed STEP standards. These information models must be tested to determine whether they will meet the needs of state-of-the-art software applications. Test criteria, test procedures, and test data must also be developed as part of the validation process. Only after satisfactory test results are achieved, can we be certain that the specification is workable and complete. The results and recommendations generated by validation testing must be fed back to the standards organizations for review and action. Standards committee members may then amend the specifications and vote intelligently on the approval of the specifications as standards.

Stage III. Development of tools and prototype applications - The development of commercial STEP-based software products can be accelerated by rapid prototyping. The developers of these prototype systems will learn a lot about using STEP technology that will help to accelerate the development of commercial products. The software tools that are developed may also be used in future products. If this work is done in the public domain, many companies can benefit from the results of this effort. Furthermore, early prototype applications can be used to validate the suitability of proposed standards. They can be used for interoperability testing, i.e. tests to determine whether or not different types of applications can work together. Prototype systems also may be needed to exercise conformance testing systems. In the absence of these prototype implementations, the first commercial products may be "guinea pigs" for the conformance testing process.

Stage IV. Commercialization of, and transition to, STEP-based systems - Ultimately, STEP-based systems must be developed and marketed commercially. These systems will not be developed overnight. It will take a number of years for industry to recognize all of the different specialty niches for these systems and develop stable products. Certainly this phenomenon can be seen in the personal computer market. Although the basic interface specifications for PCs were established in the early 1980's, new types of hardware and software products are still being defined today. It will undoubtedly take

a number of years after products become available, before they are put into widespread use within industry and government. Considerable advanced planning and investment of resources will be required to transition large government and industrial organizations to new STEP-based systems. It is likely that a great deal of existing product data may have to be translated into new STEP formats when those commercial systems become available.

Viewed in this light, it is easy to see that the first stage of STEP evolution is well underway, but the second stage has just barely started. Stages II, III, and IV of this process will have to be repeated for the different product technologies that STEP must cover, i.e. mechanical assemblies, sheet metal parts, structural systems, electronics components, etc.

How will we achieve our goals? There are many different opinions on how to develop product data sharing technology. Figure 1 illustrates a technical road map for developing product data sharing technology prepared for the U.S. Department of Commerce. The road map decomposes the problem into four major areas: Enterprise Integrated Framework, Product Data (PDES/STEP), Design, and Information Technology.

The ISO SC4 subcommittee will decide which parts will be included in the first draft STEP specification, scheduled to be completed late in 1991. The SC4 has resolved that the minimum set of parts which will be included in the Version 1.0 STEP specification are [ISO90-1]:

- Overview (Part 1)
- Express (Part 11)
- Physical File (Part 21)
- Conformance Testing (Part 31)
- Generic Product Data Model (Part 41)
- Shape Representation (Part 42)
- Presentation (Part 46)
- Drafting (Part 101)

and one or more application protocols. The subcommittee has made the statement that "additional parts may be considered for Version 1.0 but only if their inclusion will result in no slippage of the project schedule to have all parts necessary for a Version 1.0 capability ready for Committee Draft balloting by SC-4 in July 1991."

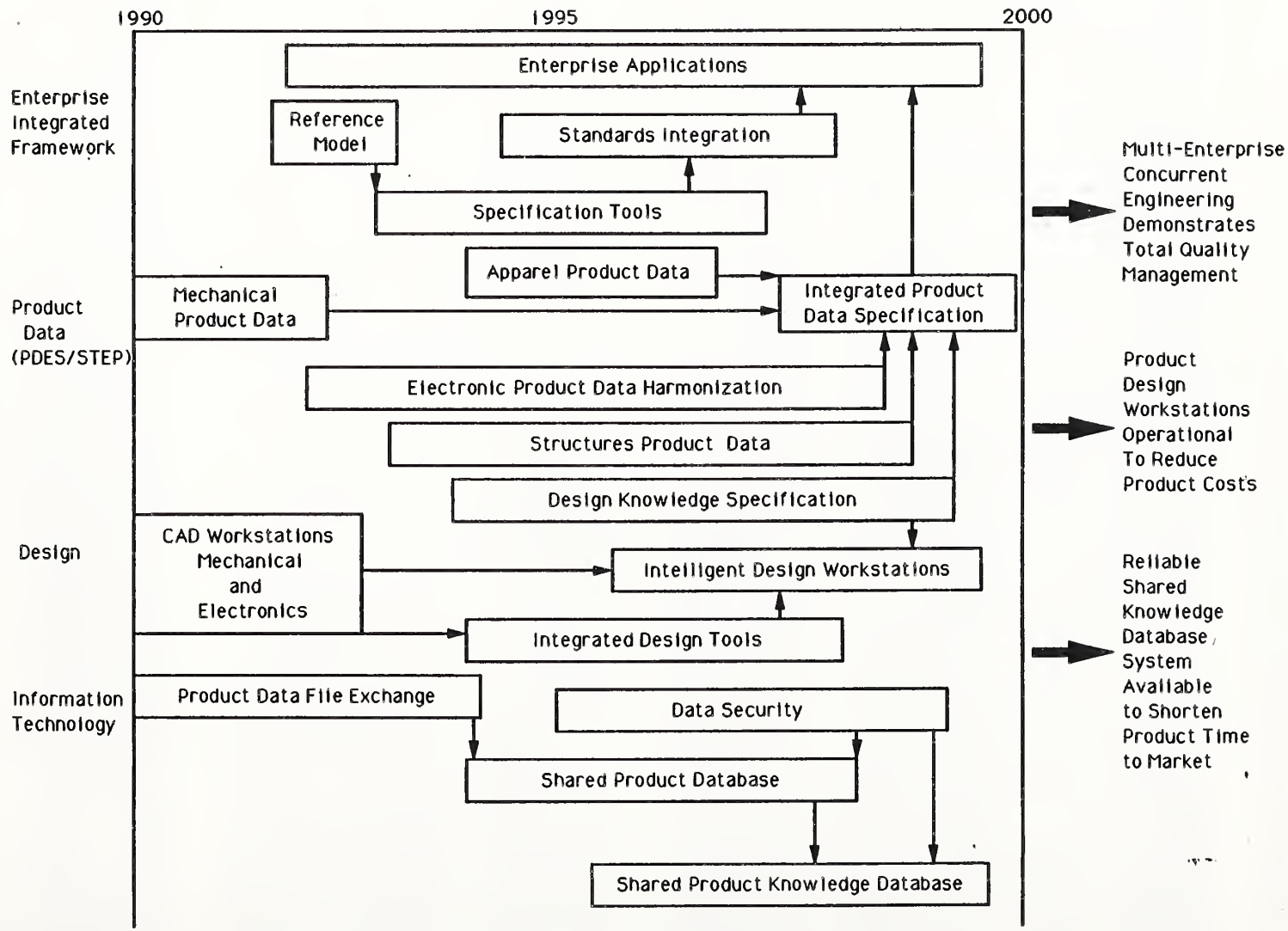

Figure 1. Road map for product data sharing technology

A coordinated technical plan is currently being assembled by the staff of PDES, Inc. and the National PDES Testbed from data provided by organizations involved in the development of STEP. This coordinated technical plan accounts for the stages of evolution described above. It also integrates the detailed information contained in the technical plans of each of the major organizations involved in STEP. It is expected that this coordinated technical plan will be completed in the draft stage, reviewed and refined by the various organizations, and publicly distributed in 1991.

Institutional Aspects of STEP

Who will be responsible for making STEP work? There are a number of organizations working at both the national and international levels to develop an exchange specification for product data. This section introduces some of the formal players, other than the National PDES Testbed (which is discussed in Section 5 of this document), in the development and implementation of STEP:

- IGES/PDES Organization
- ISO Committee TC184/SC4
- ANSI U.S. Technical Advisory Group
- PDES, Inc.

Representatives from American industry play key roles in each of the organizations described below. Ultimately, industry must define the requirements for STEP and assume the most critical role of implementing commercially viable STEP-based systems. After these systems are implemented, industry and government will have to coordinate efforts to jointly transition from existing information systems to those based upon STEP.

IGES/PDES Organization - The concept of PDES grew out of the Initial Graphics Exchange Specification (IGES) effort in 1985. The goal of IGES was to establish a standard that would permit computer-aided design (CAD) data to be exchanged between systems built by different manufacturers. IGES was first published in 1980 and was updated in 1983, 1986, 1988, and 1990 [IPO90-1]. When IGES data is passed between similar design systems, considerable human interpretation and manipulation of data may be required. IGES developers recognized that a more sophisticated standard would be required to support the integration of different types of product life cycle applications. IGES was designed primarily to support file exchanges between CAD systems, not as a mechanism for implementing shared data bases between dissimilar product life cycle applications. The IGES effort has not focused on the specification of a standardised information model for product data. The STEP efforts, on the other hand, are focusing

on developing a complete model of product information that is sufficiently rich to support advanced, state-of-the-art applications.

Voluntary technical activities in support of the development of PDES/STEP have been ongoing within the United States since 1985. The U.S. organization which is conducting these activities is the IGES/PDES Organization [IPO90-2]. It is chaired by a representative from the National Institute of Standards and Technology (NIST). These activities have grown out of the IGES effort. In 1985 a formal study was conducted, called the "PDES Initiation Effort" which established a framework and methodologies for subsequent PDES/STEP activities. Approximately 200 technical representatives from the United States and other countries meet four times a year for a week at a time to address PDES/STEP-related technical issues.

ISO Committee TC184/SC4 - In 1983 a unanimous agreement was reached within the International Organization for Standardization (ISO) on the need to create a single international standard which enables the capture of information to represent a computerized product model in a neutral form without loss of completeness and integrity, throughout the life cycle of the product [ISO90-2]. In December of the same year, the ISO initiated Technical Committee 184 on Industrial Automation Systems. Subcommittee 4 (SC4) was formed at that time to work in the area of representation and exchange of digital product data.

Twenty-five countries are involved in the work of SC4. Sixteen of these countries are participating members and nine are recognized as observers. The United States is a participating member, and as such has one vote on issues before SC4. The SC4 Secretariat is currently held by NIST.

Technical support for SC4 comes predominantly from its working groups. Twice a year, IGES/PDES Organization meetings are held concurrently with working group meetings. Many of the same technical participants from the U.S. and other countries are active in both organizations. Alternate quarterly meetings of the ISO Committee TC184/SC4 are held concurrently with the IGES/PDES Organization quarterly meetings.

In December 1988, the draft PDES Specification or Integrated Product Information Model (IPIM), developed through the voluntary activities of the IGES/PDES Organization, was submitted to SC4 as a draft proposal for an international standard. The international product data exchange standard is to be called "STEP" for "Standard for the Exchange of Product Model Data". In addition to the standard itself, a series of

companion documents are being developed to support implementation, testing and engineering use of the technology.

ANSI U.S. Technical Advisory Group - The American National Standards Institute (ANSI) is the recognized U.S. representative to ISO and provides the basis for U.S. participation in the international standards activities relating to PDES [Furlani90]. To ensure that the positions on standards that are presented to ISO are representative of U.S. interests, a mechanism has been established for the development and coordination of such positions. ANSI depends on the body which develops national standards in a particular standards area to determine the U.S. position in related international standardization activities. Such bodies are designated by ANSI as "USA Technical Advisory Groups" for specific ISO activities.

As a participating member in ISO Committee TC184/SC4, the ANSI U.S. Technical Advisory Group (U.S. TAG) selects the U.S. delegates to SC4 and advises the delegates on how they should vote on issues presented to SC4. The U.S. TAG usually meets at each IPO quarterly meeting. During the balloting on the first STEP Draft Proposal, it met more frequently to collect the ballot responses of the U.S. technical participants. It also prepared the final U.S. ballot response and submitted it to TC184/SC4.

The current U.S. TAG to TC184/SC4 was formed in 1984. Its membership is primarily comprised of technical experts from the IGES/PDES Organization. This type of representation ensures that the technical changes that the U.S. believes are necessary are reported to ISO for consideration.

PDES, Inc. - In April 1988, several major U.S. technology companies incorporated as PDES, Inc. with the specific goal of accelerating the development and implementation of PDES, i.e. Product Data Exchange using STEP [PDES90]. The South Carolina Research Authority (SCRA) was awarded the host contract to provide management support in August 1988. The technical participants provided by the PDES, Inc. member companies and SCRA's subcontractors are under the direction of the PDES, Inc. General Manager from SCRA. NIST is a government member and provides a testbed facility and technical team members to support the PDES, Inc. effort. PDES, Inc. efforts are being coordinated effectively with the IPO and the Government Interagency Users Group [Henghold89].

PDES, Inc. has a multi-phased plan for the acceleration of STEP development. Phases I and II of the plan are each defined to be eighteen months efforts. The Phase I focus was on testing and evaluating a subset of the November 1988 Integrated Product Information Model (IPIM) that was submitted by the IPO to the ISO. The emphasis of

the testing and evaluation effort has been placed on a data exchange implementation of mechanical parts and rigid assemblies. Phase II, which began in March 1990, is focusing on the identification of software implementation requirements, construction of prototypes, development of additional context-driven integrated models (CDIMs) for small mechanical parts, and broadening the program scope to include such areas as electronics, sheet metal and structures.

SECTION 3. CHALLENGES AND PRIORITIES

The STEP development community is faced with a number of technical challenges. Some of the highest priority challenges, which are introduced in this section, include:

- Commercialization
- Conformance Testing
- Data Sharing
- Data Representation
- Verification and Validation
- Application Development
- Configuration Management

All of these challenges must be eventually overcome before commercially-developed STEP-based systems become a reality within industry and government. After briefly outlining each of the challenges, this section briefly summarizes our approach to addressing these critical challenges.

Commercialization

One of the ultimate objectives of the PDES activities is the commercial development of STEP-based systems. Commercial system developers want to see:

- technical specifications that are sound and easy to implement,
- commercially fair standards that do not favor competitors, and
- a large potential market for their products.

How can we address the challenge of commercialization? To ensure that STEP is a success, a groundwork must be laid while the specifications are still under development. The problems and issues that will eventually be faced by system developers and users must be identified and addressed now. We must consider how future systems will work with STEP, as the specifications are being developed, not as an afterthought when they are already in place as standards.

Vendors of systems that will use STEP must be convinced that the standard is stable before they invest in development efforts. The standard must be shown to be complete and consistent. Mechanisms must be established which enable vendors to easily obtain the most current versions of the STEP specifications. Help should be freely available to assist vendors' understanding of the standard and how to implement to it. Finally, vendors need to know that there is a clearly defined market for systems that employ STEP.

Conformance Testing

Before commercially-developed systems are marketed, conformance testing procedures must be established which act as quality assurance mechanisms which protect both system developers and users. Conformance testing is the evaluation process or methodology that is used to certify that products adhere to standards or technical specifications. If independent conformance testing mechanisms are not established, customers will have to accept vendor assurances that their systems comply with STEP. Unscrupulous vendors may claim that their products adhere to the standard when in fact they do not. Some vendors may be incapable of determining whether or not their products faithfully comply with specifications. In either case, both industry and government may make costly investments in the procurement of incompatible or unsuitable products.

As a long term goal, the National PDES Testbed intends to develop conformance testing procedures which can be used by independent testing laboratories to verify that commercial applications conform to STEP specifications. The development of a solid STEP specification and sound conformance testing mechanisms will provide a strong foundation for product data sharing between different computer applications and organizations.

Data Sharing

Computer Integrated Manufacturing (CIM) is a term that elicits an image of computers improving manufacturing efficiency and increasing the productivity of the industry. Underlying this harmonious picture is the implication that the programs running on these computers can actually communicate with each other, that is, share data. Unfortunately, this is rarely the case today.

It is not the physical "hardware" connections between computers that is the major issue today. It is incompatible software. The root of the problem is proprietary data representations, i.e. vendor-specific data formats. More often than not, the vendors of computer applications store the data which is required and produced by their systems in their own proprietary format.

Consider product design data created on a CAD system. Once the design of the product has been completed on the CAD system, it is stored in a data file. Some of the information in that data file will represent the shape and size of the product. In an integrated information systems environment, the designer should be able to send that

data file over to the manufacturing planning system. The same data would then be used by the planning system to determine manufacturing processes for the product, based in part on its specified shape and size.

If the planning system can read the contents of the design data file, it can obtain the shape and size information it needs. It might be said that these two applications are integrated. But, it is a fact today that if two commercial products are integrated, it is likely that they were developed by and purchased from the same vendor. Furthermore, it is also likely that they were intentionally designed to work together from their inception. Often, it is the case today that applications offered by the same company are not even integrated.

STEP is intended to address the issue of product data sharing between different computer applications running on different computer systems within different organizations. STEP will provide a standard, neutral format for product data created by and shared between these different applications. Neutral means that the STEP data format will not favor one particular vendor.

A current example of a neutral data exchange format is IGES, the Initial Graphics Exchange Specification, Version 5.0 [IPO90-1]. IGES was originally intended to provide a means for exchanging engineering drawing data between CAD systems. As CAD and computer-aided manufacturing (CAM) systems became more sophisticated, the need for increased data sharing became more apparent--and thus the PDES effort was initiated. STEP goes beyond IGES both in information content and the sophistication of the information systems methodologies that are used.

One way that STEP extends IGES is by defining subsets of product data that is specifically required for particular usage contexts. By defining these STEP subsets, some of the serious problems faced by IGES can be avoided.

One of these problems is an outgrowth of the way vendors implement the software that is required to translate their data to and from the neutral IGES data file. Currently, a vendor's translator can create IGES data files which contain data that makes sense in the context of their system. When that same IGES data file is loaded into another vendor's system, an incomplete data translation often occurs. This loss of information can occur because the second vendor's translator has made a different set of assumptions about the data it is receiving.

STEP Application Protocols will address this issue by specifying in advance what data should be transferred in a particular context--alleviating the need for vendors to make problematic assumptions. These Application Protocols are essentially subsets of STEP which have been selected due to their general relevance to a particular data sharing scenario. Undoubtedly, there will be many STEP Application Protocols. Within the Testbed, our efforts will focus on three Application Protocols (see Section 4, Technical Plans). For further information on Application Protocols, see [Palmer90].

Data Representations

At the core of the data sharing problem, is data representation. STEP defines the information that describes products within different computer applications and across different enterprises. The use of computer software requires that the shared data representations be specified. Data representation scheme must identify the data elements involved, their format, their meaning, and their relation to each other. Data representations are formally defined within STEP specifications.

For example, in the geometry portion of the STEP specification, a simple data element may be called "point." The data representation for "point" might consist of three aspects: the point's X coordinate, its Y coordinate, and its Z coordinate. To complete the data representation, the type of numbers allowed for the point's X, Y, and Z coordinates must be explicitly stated. In this case they would be "real" numbers, i.e. not integers or whole numbers.

Having defined the data representation for "point", other, more complex, data elements can also be defined that make use of the "point" data element. Representations for data elements can become quite complex, making them difficult to define and understand.

The most important criterion for the data representations used in STEP is that they must be unambiguous. If the data representations specified by STEP are ambiguous then they can misinterpreted by applications, or interpreted differently by different applications. Ambiguous data representations lead to problems like wires being mistaken for conduits, or bolts being mistaken for machine screws.

The developers of STEP employ information modeling techniques to ensure that STEP is unambiguous. An information modeling language is actually used to define portions of the STEP specification. Unlike many standards which are written in English, portions of STEP are written in EXPRESS. EXPRESS is very much like a computer

programming language. Writing STEP in EXPRESS allows information modeling experts to use specialized computer software to check the integrity, validity, and efficiency of STEP. For further information on EXPRESS, see [ISO90-3].

Besides facilitating the development of the standard itself, these information modeling techniques will also help to speed the development of future software applications which are based on STEP.

Verification and Validation

Verification and validation are two ways in which commercialization can be expedited. Verification is the review of the system requirements to see that the right problem is being solved and the system design to see that it meets those requirements. Validation is the test and evaluation of the integrated system to determine compliance with the functional, performance and interface requirements that were verified. With respect to STEP, validation will require testing to confirm that the requirements for the product life cycle data have been met. One of the major goals of the validation testing efforts is to test the suitability of the proposed STEP standard for product life cycle information systems applications.

Validation testing, which is being performed jointly by PDES, Inc. and NIST National PDES Testbed staff, is aimed at evaluating the completeness and the integrity of the STEP specifications. Without validation testing, many deficiencies in the specifications might not be discovered until commercial applications are constructed. It is obvious that without this testing, developers might have had to bear the burden of excessive redevelopment costs and delays while the specifications are "fixed."

Application Development

The early development of prototype STEP applications is another way in which commercialization can be accelerated. Applications are the computer software products that will use STEP. What kind of applications are we talking about?

- Computer-Aided Design (CAD) systems
- Design analysis systems
- Manufacturing planning systems
- Resource allocation and scheduling systems
- Manufacturing equipment programming systems
- Quality assurance systems

These and other systems comprise the computer-based manufacturing environment that is found in today's modern factories and will be found in tomorrow's.

If STEP is to be successful, it must meet the needs of these applications and many others. Each application requires specific information about a product. Many of these systems have common data requirements, i.e they need to share data. A simple example of shared data is the name of the product and the identifiers of its component parts. Some product data requirements may be unique to a specific type of application. For example, the tolerances on a product's dimensions would be required by manufacturing planning systems, but this same data would be irrelevant to scheduling systems. Yet both systems would refer to the same names when identifying the product and its components.

Ensuring that STEP addresses the requirements for manufacturing applications is a significant challenge. Generally, there are no formal, publicly-available specifications of the information requirements for any of these systems. Functional requirements and design specifications must be developed for systems that will use STEP. These specifications should be defined concurrently with the evolving STEP specification. They will help to determine exactly how STEP will be used by future commercial systems.

Prototype systems should be developed that can be used to test the viability of the proposed standards. Different types of prototype applications can be tested with each other to ensure that STEP permits interoperability between various applications. If the prototypes are constructed in the public domain, they can later be used as foundations and building blocks for commercial implementations.

Configuration Management

The major reason for configuration management is the reduction of chaos and confusion that is associated with managing information. By keeping versions of information clearly identified and controlled, the configuration of a document or computer software can be managed. Configuration is the logical grouping and/or collection of elements into a coherent unit. This unit is typically a version of a software release or text document. If the configuration of an information unit is to be controlled, access and changes to the information must be controlled. Often "master" documents and approval mechanisms are established to ensure the quality and integrity of the information that is being managed. Configuration management could be an easy task for a simple collection of information--obviously STEP is not a simple collection of information.

The complexity of the configuration management problem is governed by the type of information involved and how it is to be controlled. In the case of simple configuration control systems, for example those that deal with software source code control, simple text files are usually just grouped together into a named or numbered unit and distributed as a single item. This is a simple process and many software products exist which perform just such a function. The complexity of the problem increases when the configuration involves more than just simple text files. Two examples of more complicated configuration control problems are the management of computer programs which run different computer systems and documents which include graphic images.

The development of STEP is very much a configuration management problem. It involves a number of different organizations, e.g. the International Organization for Standardization, IGES/PDES Organization, PDES, Inc., and the National PDES Testbed. All of these organizations have different interests in the technical aspects and the status the proposed standard. Each organization must be able to retrieve proper versions of the developing standard. Software tools are needed which can be used to merge electronic versions of text and produce a single unified document from each organization's contributions. This assembly process is one of the main functions of a good configuration management system. Reliable, controlled, and up-to-date access to an individual organization's data plus the capability to pull disparate pieces of information together is a major challenge that we face.

The National PDES Testbed is responsible for establishing a system for the maintenance of the many documents which are generated and modified by the different organizations. The Testbed must be concerned with and prepared to handle configuration management issues. The systems available at the Testbed must be capable of dealing with questions of what information will be maintained, who may or may not have access to the information, and when access to that information allowed or disallowed.

What is our approach?

Unfortunately, the resources which the National PDES Testbed can bring to bear on these challenges is limited. Priorities must be set. The Testbed will approach this problem by focusing different levels of resources on the challenges at different times. The project will also encourage participation and/or support from industry, other government agencies, and academia in accomplishing the objectives of the National PDES Testbed. Our current approach to this problem follows. Of course, a number of

different possible events and circumstances may cause these priorities to change with time.

Commercialization - This challenge will be met by through the construction of STEP-based commercial software applications and the implementation of STEP at industry and government sites. It is primarily the responsibility of industry and industrial consortiums to meet this challenge. The technical results of Testbed development efforts will provide a strong foundation for the future development of commercial software products. The conformance testing systems developed by the Testbed project will also help accelerate commercialization. The National PDES Testbed is currently working with PDES, Inc. and welcomes joint efforts through the NIST Industrial Research Associate Program.

Conformance Testing - Before significant progress can be made in the area of conformance testing, the proposed STEP standard must become more stable. Testbed staff are currently participating in the ISO activities which are addressing conformance. A study has been funded by the Testbed which will provide guidance on applying conformance testing experiences to STEP which have been derived from other information system areas. A detailed plan for the Conformance Testing System technical thread was developed this year. It is our intention to intensify activities in this area in the beginning of the 1992 fiscal year.

Data Sharing - Technical and standards activities are focused on resolving this challenge. Testbed staff are active members of these committees. Within the Testbed project, the STEP Production Cell and Product Data Exchange Network threads will both address the issue of product data sharing. The STEP Production Cell will provide an early public demonstration of product data sharing using STEP. Limited product data sharing capabilities already exist at the Testbed within a prototype system. Near-term prototyping efforts will focus on the establishment of the data repository and design system for the STEP Production Cell. The Product Data Exchange Network will initially be formed in 1991. The Testbed project will provide a headquarters and limited technical resources for the Network. As a general rule, each node or site in the Network must identify and provide its own system and staff resources.

Data Representation - The data representation challenge will be resolved through the establishment of sound information models and clear specifications. Consensus is the key to resolving the data representation issue. The Testbed will addressed this challenge through participation in appropriate technical and standards committees, the

development of tools as a part of the Validation Testing System thread, and through the Application Protocol Specification and Validation effort (described in Section 4).

Verification and Validation - The National PDES Testbed is currently addressing the verification and validation challenge in several ways: 1) Testbed staff have been actively participating in the PDES, Inc. CDIM testing program which shares common goals, 2) the Standards Testing Center is pursuing the Validation Testing System technical thread which will result in improved computerized tools for verification and validation, 3) an Application Protocol Specification and Validation technical thread has been defined which become more active in the 1991 fiscal year, and 4) NIST staff are actively involved in the evaluation activities of the IPO and the ISO committees.

Application Development - As a part of the STEP Production Cell project, the National PDES Testbed intends to develop three prototype STEP applications: design, process planning, and NC programming. These applications will be based upon candidate STEP Application Protocols validated by the Standards Testing Center. The Product Data Exchange Network encourages and supports the development of other STEP applications.

Configuration Management - The establishment of configuration management capabilities for the organizations involved in STEP is currently the highest priority. The Configuration Management Systems and Services project thread described in Section 4 of this document will be responsible for addressing this challenge. The project will provide an interim configuration management system for these organizations in 1990. A more fully-functional system will be made available in 1991. The 1991 system will be customized to meet the needs of the principal participating organizations. Each organization has the responsibility for identifying a person within the organization to serve as Configuration Manager. Each organization is responsible for establishing and maintaining its own internal configuration management procedures. Project staff will work with the designated Configuration Managers to ensure that the configuration management system meets the internal needs of each respective organization.

SECTION 4. TECHNICAL PLANS

The National PDES Testbed project is developing a number of "products and services" that will help to accelerate the implementation of STEP. The project staff are working closely with PDES, Inc. who shares the same objectives for STEP. The systems and services of the Testbed are continually being refined with the objective of achieving a "production" quality resource that can be used by NIST, PDES, Inc., industry and academia. NIST staff are working on improving the stability and efficiency of Testbed systems with the goal of streamlining the STEP testing process.

This section outlines the major technical threads of the National PDES Testbed. The technical threads are called:

- Testbed Initiation Activities
- Configuration Management Systems and Services
- Validation Testing System
- Application Protocol Specification and Validation
- STEP Production Cell
- Product Data Exchange Network
- Conformance Testing System
- Management and Technical Support Activities

Together these threads define the National PDES Testbed's coordinated plan to help accelerate the development of STEP.

How are the threads related?

To a large extent the threads are interdependent. A number of these threads will be accomplished through the joint efforts between the NIST National PDES Testbed and other outside organizations. The Gantt chart in Figure 2 describes the relative timing of the threads. Charts contained within the development plans for the technical threads decompose the threads into tasks. These charts describe both the functional and timing relationship between those tasks. The pie chart contained within Figure 3 describes the approximate percentage of funding currently devoted to each technical thread and other major budget categories. An annual statement of work will be prepared for the sponsors of the Testbed project which will specify the critical tasks and deliverables which must be completed during the coming the year.

Testbed Initiation Activities - This first thread provided a foundation for all of the other threads. The initiation activities established the National PDES Testbed as an operational facility at NIST. Results of the thread included: the establishment of the

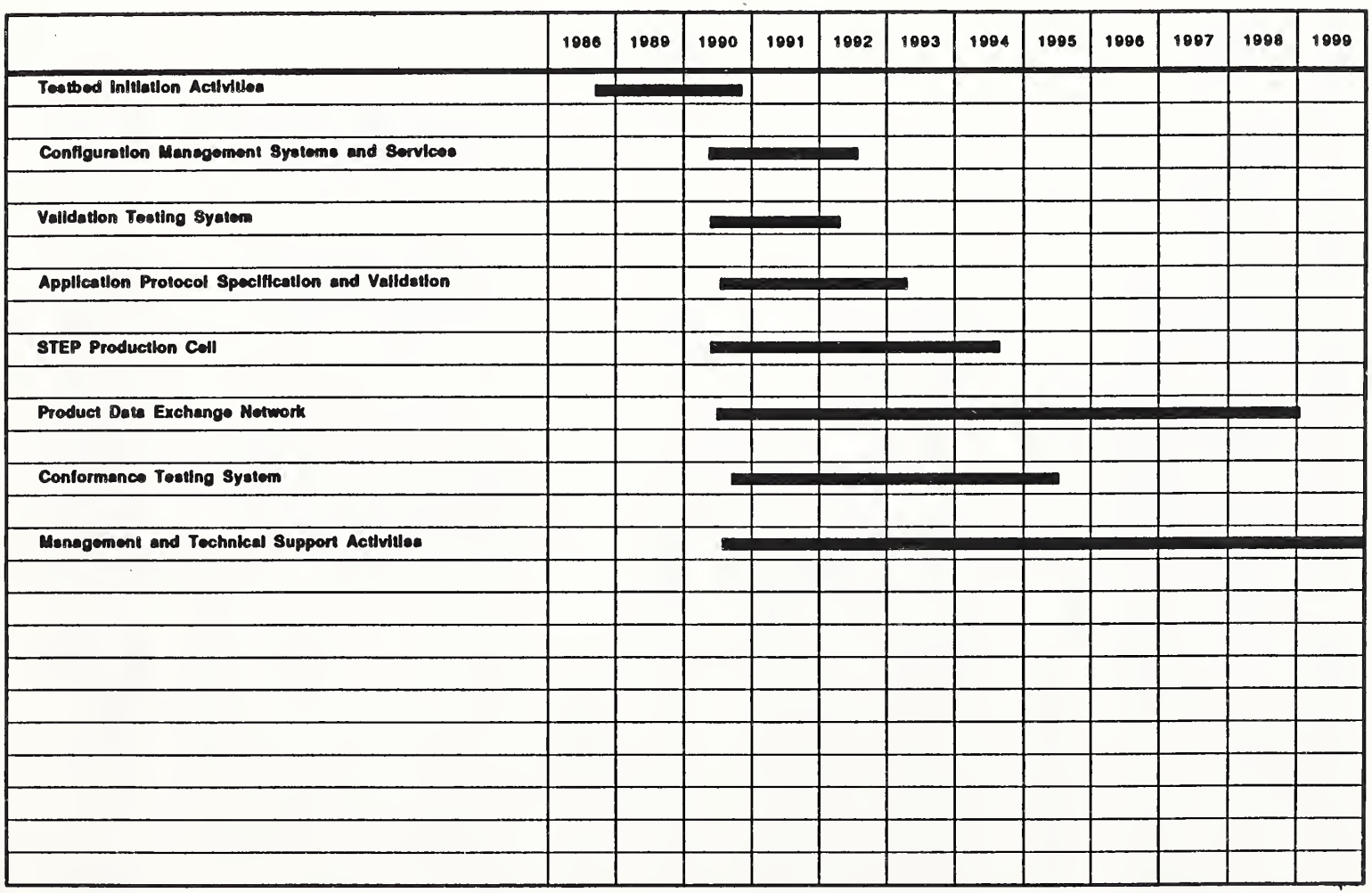

Figure 2. Project schedule for the technical threads of the National PDES Testbed

National PDES Testbed
Tentative Budget for FY91

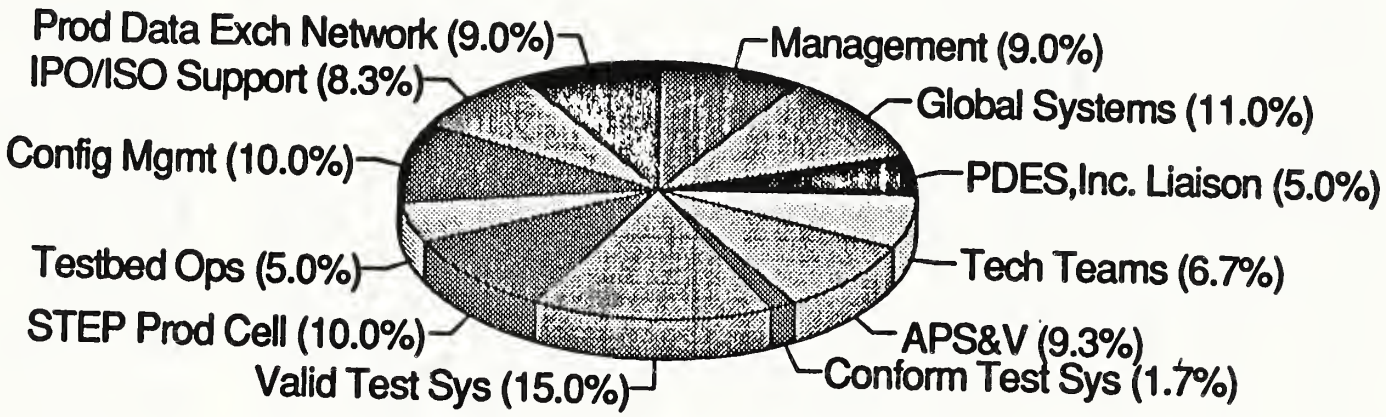

Figure 3. Approximate distribution of project funds among technical threads

project organization, joint working agreements with outside organizations, initial technical studies, installation of computer hardware and software, development of prototype testing and product data sharing systems, and initial testing of portions of the proposed STEP specification. The initiation activities established the foundation for the development of each of the other threads.

Configuration Management Systems and Services - A central repository and control point is needed for the specifications and software generated by the various organizations involved in the development of STEP. The ISO, IPO, and PDES, Inc. have all stated that there is an urgent need to establish configuration management capabilities. This technical thread will establish a "home" within the National PDES Testbed for storing and managing this information. Efficient, reliable access to this STEP information is required for the successful execution of all of the other technical threads.

Validation Testing System - This thread will extend and enhance the validation testing capabilities that were established during by the Testbed Initiation Activities thread. As the initial testing capabilities were developed jointly with PDES, Inc., it is expected that this continued effort will also be jointly conducted. The emphasis of this thread will be on the development of computer-assisted tools for evaluating proposed Application Protocol (AP) specifications which will become parts of STEP. As components of the Validation Testing System tools become operational, they will be used to validate the candidate AP specifications developed by the next thread.

Application Protocol Specification and Validation - The initial focus of this thread will be to specify and validate three candidate application protocols that will be needed to implement the STEP Production Cell: Design, Process Planning, and NC Programming. The specifications will be developed, to the maximum extent possible, using the ISO guidelines which are a part of the STEP specification. If draft specifications become available from outside sources for any of the three application protocols, the Testbed will use them as a basis for this effort. Once the candidate APs are defined, they will be evaluated using the Validation Testing System.

STEP Production Cell - This technical thread will demonstrate that STEP works and that it can be used to build commercial product data sharing applications. A STEP-based manufacturing cell will be constructed which is based upon both commercial software applications and prototype systems built for the NIST Automated Manufacturing Facility (AMRF). The cell will contain the following major subsystems: Design, Process Planning, Equipment Programming, Machining Workstation, Inspection Workstation, STEP Data Repository, and Network Communications. The software

constructed for the cell will support the candidate application protocols specified and validated in the previous thread. The cell will provide a basis for product data sharing production tests within the Product Data Exchange Network.

Product Data Exchange Network - Due to the depth and breadth of the product data sharing problem, no one organization has either the expertise or the resources to solve the entire problem. This thread will establish a network of sites which will tackle different aspects of the problem. The National PDES Testbed will serve as the headquarters for the network. The Network will provide: access to information about STEP, prototype software, test cases and data, and technical expertise. Network nodes may be established at government facilities, industrial sites, research and academic institutions. Different network sites will have different missions, functions, and capabilities. Some of the functions performed at Network sites may include: multi-site product data sharing tests, software development, review of technical specifications, training and technology transfer. It is expected that some Network sites will become regional centers of expertise in product data sharing technology. Some sites may become approved conformance testing centers which will test the compliance of commercial STEP-based applications with the standard. The Conformance Testing System thread will develop the methodologies and systems which will be used by these sites.

Conformance Testing System - Different developers of STEP-based systems may interpret the standard in different ways. These different interpretations could lead to the development of incompatible systems, thus defeating the purpose of the standard. The solution to this problem is conformance testing. Conformance tests can be used to determine whether or not a particular implementation of STEP does indeed comply with the standard. This thread will develop conformance testing methodologies and systems based upon the work of the ISO and the Validation Testing System thread. It is expected that the tools developed for validation will provide a foundation for developing conformance testing systems. These tools and methodologies used to establish an institutional framework for conformance testing. The framework will be implemented at approved conformance testing sites within the Product Data Exchange Network.

Management and Technical Support Activities - This thread includes a variety of ongoing management and technical activities. It will run for the life of the Testbed project. Some of the functions performed within this thread are: project management, reporting on the overall project and the technical threads, administration of the Testbed, support of Testbed computer hardware and software, coordination with other organizations, staff participation on standards and technical committees, team

participation within the PDES, Inc. program, software quality assurance, development of educational materials, training, and technology transfer.

A more detailed description of each thread follows. Each thread is outlined in this section in terms of its objectives, brief technical description, major deliverables, and key milestones. For further information on the threads, please consult the appropriate development or implementation plan listed in the references section of this document.

Testbed Initiation Activities

Objective:

Establish the National PDES Testbed site at NIST, initiate participation in external PDES/STEP activities, and perform initial investigations of issues pertaining to the development and implementation of STEP.

Description:

When the National PDES Testbed was established at NIST in 1988, many possible roles and functions were considered. At that time, only a small core staff was technically knowledgeable about product data sharing. The initiation phase focused on: 1) identification of management and technical staff, 2) development of initial plans, 3) education of staff on product data sharing technology and issues, 4) installation of testbed computer hardware and software systems, 5) development of initial testing and prototype STEP application software, 6) performance of preliminary studies, 7) initiation of involvement with other organizations which share common goals and objectives, and 8) initial testing in support of standards and technical committee activities. The initiation phase for the Testbed concluded with the end of the 1990 fiscal year.

Deliverables:

- Project plans - Documents include the strategic plan for the National PDES Testbed, development, and implementation plans for the technical threads.

- Initial testing system - Package includes software, technical documentation, and user manuals.

- Technical reports - A set of reports covering many different technical and management aspects pertaining to the solution of the product data sharing problem.

- End-of-phase report - Document provides summary of accomplishments, lessons learned, and deliverables for the phase.

Milestones:

- Standards and technical activities staffed with NIST personnel (6/88) - Testbed and other NIST staff assume key management and technical support roles in the IGES/PDES Organization (IPO), IPO Steering Committee, and the International Organization for Standardization (ISO).

- Initial working agreements established with other activities (6/89) - Joint working agreements and memorandums of understanding are negotiated with other organizations, e.g. PDES, Inc. and U.S. corporations, involved in the STEP effort.

- National PDES Testbed is staffed and operational (9/89) - Objectives and organization for the project are established. Basic testing and technical support operations are underway.

- Prototype testing and systems software developed (3/90) - An interim validation testing system to support near-term needs is assembled from commercial systems and prototype software developed at NIST and PDES, Inc. Testing systems are installed at NIST and PDES, Inc. Testbed sites.

- Initial technical reports and system documentation prepared (5/90) - A number of technical reports are prepared which address technical aspects of PDES and STEP. Other reports define the architecture and usage of prototype testing systems.

- Strategic and development plans prepared (9/90) - High level plans are developed for the overall project and its component technical threads. Plans are submitted to sponsors and published for widespread distribution.

- Summary report produced (12/90) - An end-of-phase report is produced which summarizes the activities and accomplishments of the thread.

Configuration Management Systems and Services

Objective:

Provide configuration management systems and services for major PDES and STEP activities which can be used to control access and distribution of documents and software.

Description:

The process of developing an information processing standard involves the creation and management of thousands of documents and computer programs. Knowing which documents and computer programs are up to date, and which are obsolete, is critical to the development process. Configuration management provides the fundamental operational capability for tracking and maintaining versions of documents and software. Configuration Management Systems and Services will support the development of the Standard for the Exchange of Product model data, known as STEP, and will be undertaken in coordination with participating organizations [Ressler90].

The configuration management system addresses the configuration of both document and software (see Figure 4 for a high level functional view). The system must be capable of "mirroring" the processes and procedures of each organization. Given the number of organizations and complexity of issues which must be immediately served, an interim configuration management system will be constructed. The interim system will provide adequate functionality to create baseline documents and software releases. Conversion to the more functional and flexible long term system will be built into the design of the long term system.

The core of the configuration management system will be based upon a general set of common requirements. Customized interfaces will be constructed for the core system which account for each organization's internal processes and procedures. For example, see Figure 5 for an illustration of the internal ISO document flow process. Anyone should be able to read and obtain copies of the documents, however only authorized individuals may place new versions of these documents into the system. The security restrictions of each organization will be implemented, as feasible.

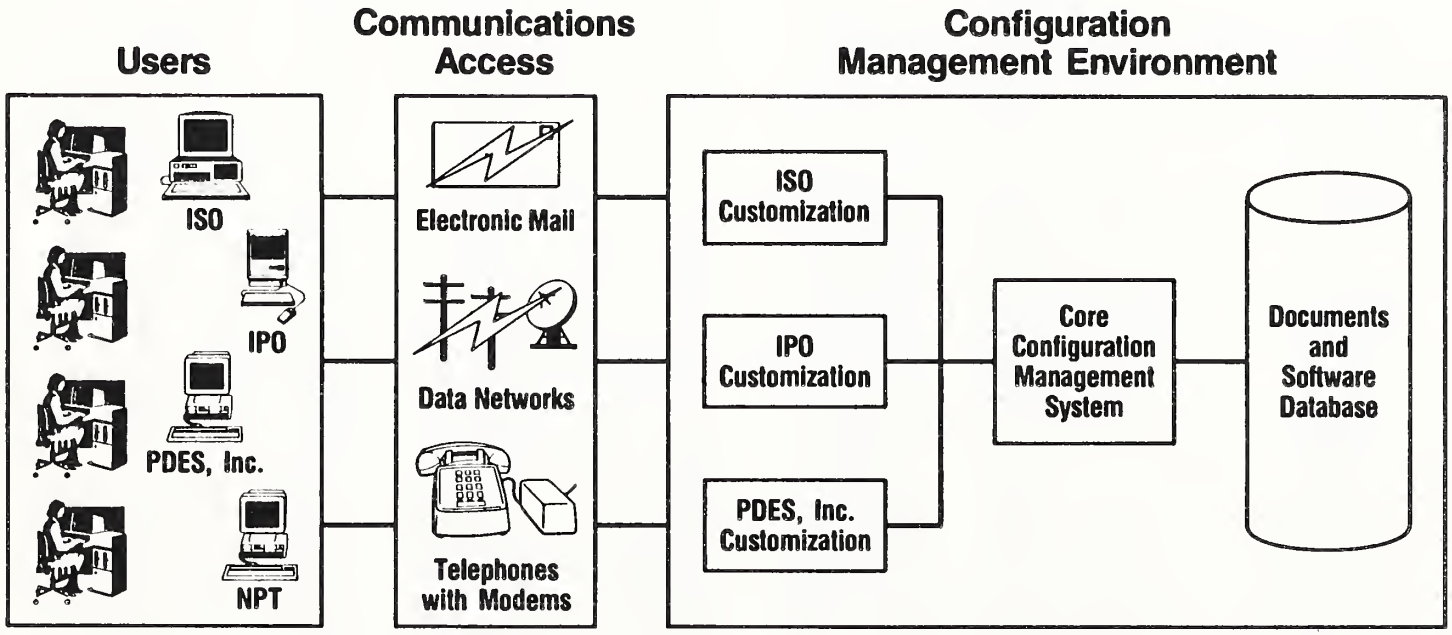

Figure 4. Functional view of the configuration management system

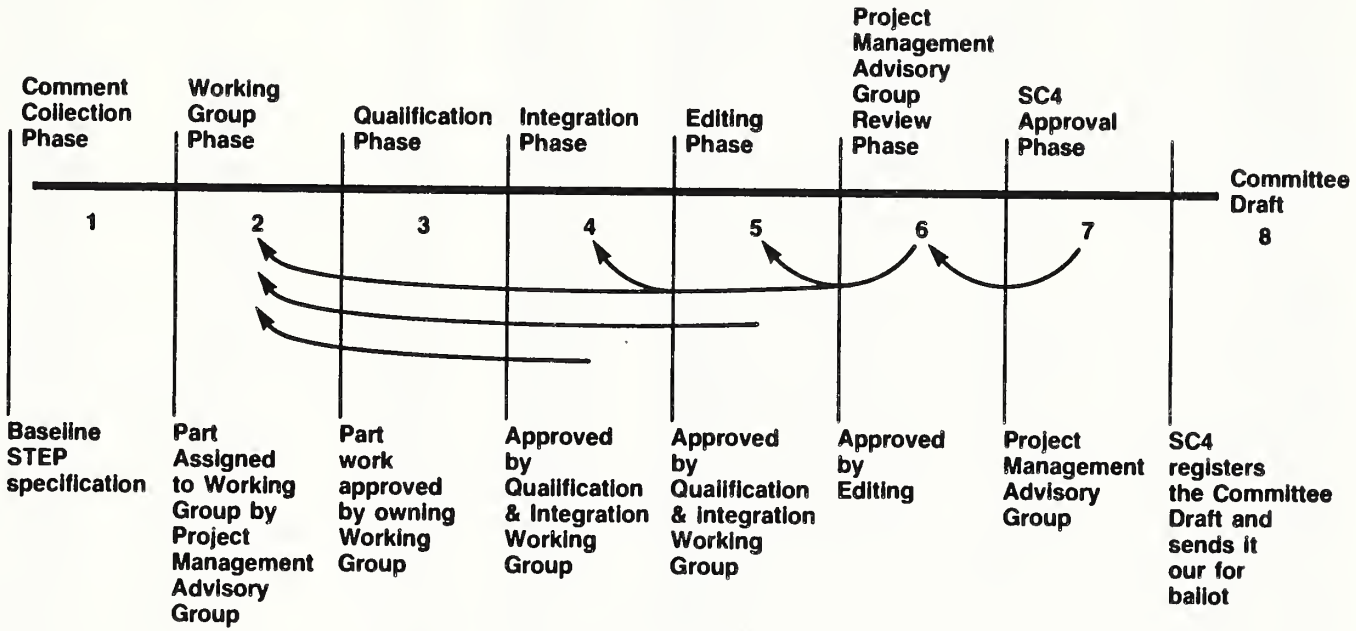

Figure 5. Document flow process for ISO STEP

As each system comes on-line, appropriate documentation and training will be provided to the users. In order for the systems to aid the development process, they must be viewed and implemented as practical, convenient tools, not impediments.

Deliverables:

- Development plan - A document which outlines the objectives, a brief overview, technical plans, and resource requirements for the technical thread.

- Interim configuration management system - A package which includes system software, technical documentation, and a user guide for the interim system.

- Customized configuration management system - A package which includes system software, technical documentation, and a user guide for the final system. The software is customized to meet the needs of the different organizations.

- Technical reports - A set of reports covering the requirements analysis, organizational processes, configured items, and system design for the configuration management system.

- End-of-phase report - Document provides summary of accomplishments, lessons learned, and deliverables for the phase.

Milestones:

- Development plan prepared for technical thread (9/90) - A plan for configuration management is written, submitted to sponsors, and published for widespread distribution.

- Interim configuration management system operational (10/90) - An interim configuration management system to support near-term needs is constructed. The system is designed to serve some of the immediate needs of ISO, IPO, and PDES, Inc.

• Configuration management requirements documented for principal organizations (12/90) - A detailed requirements analysis document is prepared on the processes and procedures of each organization whose documents and software are to be placed under configuration control.

• Configuration management system design established (1/91) - Based upon the detailed requirements of each organization, a design for the core configuration management system and the customized interfaces is produced.

• Customized configuration management packages operational (11/92) - Fully-functional system is operational and ready for the loading of documents and software.

• Technical system and user documentation prepared (1/92) - A number of documents are completed which describe technical aspects of the system and its use. These documents may be used to develop training materials.

• System demonstration for user organizations (1/92) - The operational system is demonstrated for representatives from the user organizations.

• Summary report produced (5/92) - An end-of-phase report is produced which summarizes the activities and accomplishments of the technical thread.

Validation Testing System

Objective:

Develop a "production" quality validation testing system for evaluating STEP application protocols. Provide testing tools to other Testbed sites.

Description:

Once an initial draft of the STEP specification has been created, it must be validated, i.e. tested to determine that it meets the needs of the user community. The results and recommendations generated by validation testing must be fed back to the standards organizations for review and action. Standards committee members may then amend the specifications, affected portions may be re-tested, and the specifications can be approved as standards.

The Validation Testing System (VTS) thread will establish techniques and provide systems which can be used evaluate and ensure the internal consistency and usability of the STEP specification [Mitchell90]. The VTS will be an integrated computing environment for evaluating the quality of the specification. In addition, the system will act as a repository for proof of the qualities that the STEP specification exhibits. This proof, in the form of test results and real-world test product data, will push the standardization process past the impasse of diverse technical opinion and encourage implementations of information systems which use STEP.

The Validation Testing System will be comprised of software which will: 1) automate the evaluation of the computable qualities, such as whether or not the syntax of the specification language was followed, and 2) assist validation teams with solving intuitive problems which are not feasible to automate. The names given to the major component modules of the validation testing system are:

- Model Scoping and Construction Tool
- Test Definition Tool
- Test Case Data Generation Tool
- Test Case Execution and Evaluation Tool

For an illustration of the major validation testing tools and their functions, see Figure 6.

The need for an automated validation testing system can be justified from our initial experiences in STEP validation. Through a joint effort with PDES, Inc., an industry consortium, a validation approach was defined in May 1989. The approach improved the measurability of results by linking the testing to application usability. Experience with this approach has demonstrated feasibility and clarified the necessary procedures. In addition, the need for software automation in the validation process has been unquestionably demonstrated. PDES, Inc. in their Phase I project invested approximately 30 man-years in validating portions of the STEP specification. Still, they were able to test only a small percentage of the STEP draft. The validation process needs full software automation to make more efficient use of the limited personnel resources available.

Deliverables:

- Development plan - A document which outlines the objectives, a brief overview, technical plans, and resource requirements for the technical thread.

- Validation Testing System - A package which includes system software, technical documentation, and a user guide for the validation testing system tool.

- Technical reports - A set of reports covering the requirements analysis, testing methodologies, and system design for the validation testing system.

- End-of-phase report - Document provides summary of accomplishments, lessons learned, and deliverables for the phase.

Milestones:

- Development plan prepared for technical thread (9/90) - A plan for validation testing is written, submitted to sponsors, and published for widespread distribution.

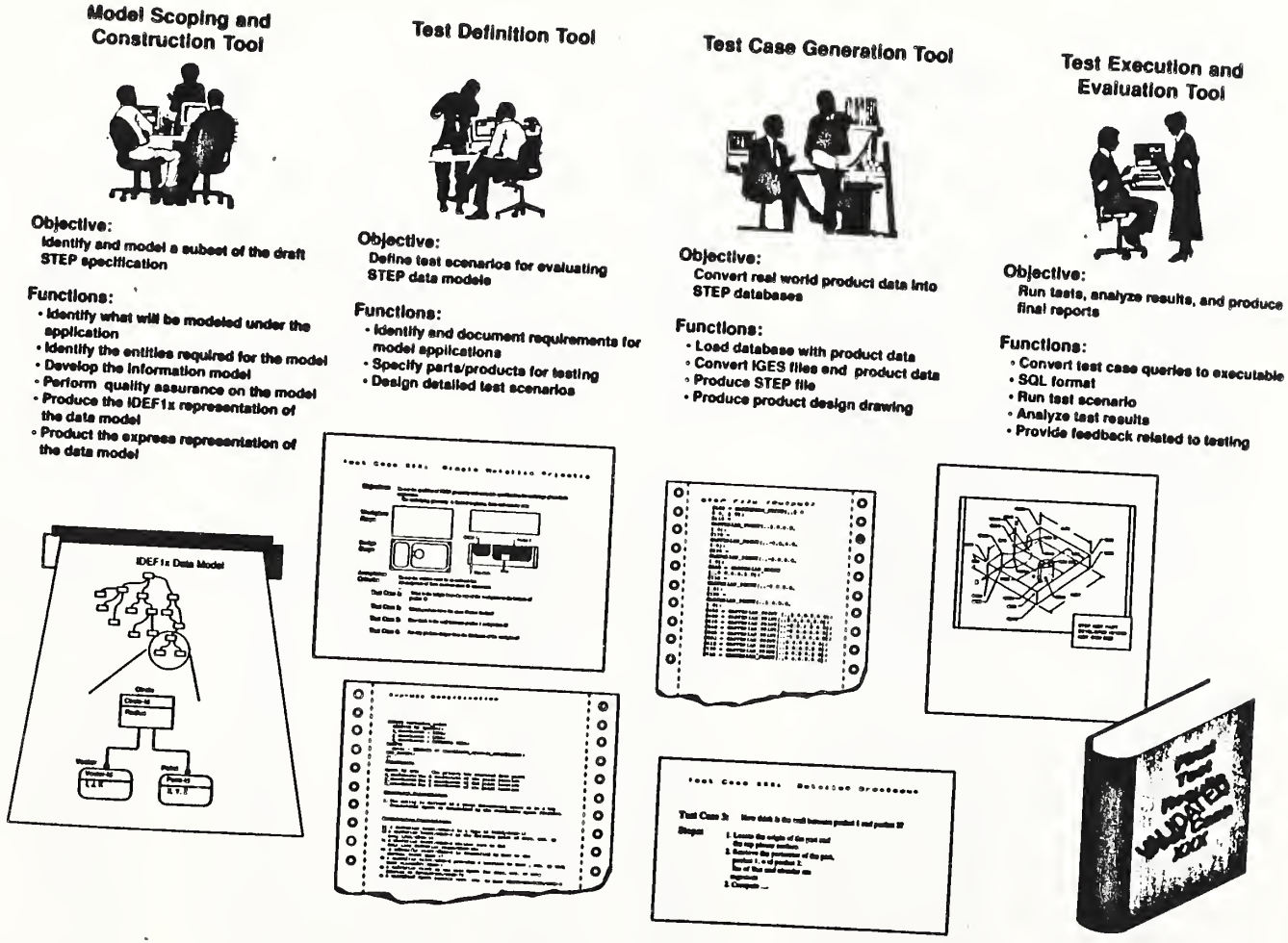

Figure 6. Major tools and functions of the Validation Testing System

• Validation testing methodology established (1/91) - A document is written which defines the basic methodology that will be used for validating STEP application protocols.

• Requirements analyses completed for tools (7/91) - A set of detailed requirements analysis documents are prepared which identify the functions and data that the testing tools must support.

• Design specifications completed for tools (9/91) - Based upon the detailed requirements analyses, a design document is produced for each tool.

• Test Case Data Generation Tool operational (10/91) - The testing tool is operational and ready for use in stand-alone mode.

• Model Scoping and Construction Tool operational (12/91) - The testing tool is operational and ready for use in stand-alone mode.

• Test Definition Tool operational (12/91) - The testing tool is operational and ready for use in stand-alone mode.

• Test Case Execution and Evaluation Tool operational (12/91) - The testing tool is operational and ready for use in stand-alone mode.

• Integrated validation testing system operational (1/92) - All of the testing tools are operational and ready for use in integrated mode.

• Technical system and user documentation prepared (1/92) - User guides and documentation on system internals are available. This information may be used to develop training materials.

• Testing system demonstrated for other testbed sites (2/92) - The integrated validation testing system is demonstrated for representatives from other testbed sites.

• Summary report produced (4/92) - An end-of-phase report is produced which summarizes the activities and accomplishments of the thread.

Application Protocol Specification and Validation

Objective:

Develop and validate the application protocols that are needed to support the development of the STEP-based production cell. Develop and validate additional application protocols in cooperation other activities wherever possible.

Description:

The Application Protocol Specification and Validation (APSV) thread [Stark90] will develop Application Protocols (APs) which will be used in the construction of the STEP Production Cell [Fowler90]. Where possible, the APs will adhere to the guidelines for technical content and format as defined by the Application Protocol methods group and standards committees with the ISO. The APSV team will pool resources, wherever possible, with outside organizations involved in STEP AP development.

What is an application protocol? It will consist of: 1) Scope - a clear definition of what it applies to and what it functionally includes, 2) Application Reference Model - a definition of the information requirements in terms familiar to an expert in the relevant application area, 3) Application Interpreted Model - a specification of the standardized STEP data that matches the requirements of the Application Reference Model, 4) Validation Tests - a full set of tests which are used to determine whether or not the AP achieves the requirements defined in the Application Reference and Interpreted Models, and 5) Documentation - a description of how the information is to be used for the exchange of product data. For further information on Application Protocols, see [Palmer90].

The APSV technical thread will focus on specifying three candidate application protocols: Design, Process Planning, and NC Programming. If satisfactory specifications are available from outside sources, they will be used. These specifications will be reviewed and edited so that they conform as closely as possible to evolving ISO format specifications. The draft specification documents for the candidate application protocols will then be validated using tools developed by the Validation Testing System

thread. The draft specifications and testing results will be submitted to the appropriate technical and standards committees for further action.

Deliverables:

- Development plan - A document which outlines the objectives, a brief overview, technical plans, and resource requirements for the technical thread.

- Candidate application protocols specifications - A set of documents which contain draft specifications for candidate application protocols for: Design, Process Planning, and NC programming. The documents adhere as closely as possible to ISO-specified formats.

- Validation test results - Reports of the validation testing performed on the candidate application protocols. The reports describe the tests conducted, the test cases and data used, the results that were obtained, and the conclusions derived from these results.

- End-of-phase report - Document provides summary of accomplishments, lessons learned, and deliverables for the phase.

Milestones:

- Development plan prepared for technical thread (9/90) - A plan for application protocol specification and validation is written, submitted to sponsors, and published for widespread distribution.

- Requirements analyses completed for application protocols (12/90) - The unique and common requirements for the three application protocols are specified in a requirements analysis document.

- Application protocol specification format established (1/91) - A format is established for specifying candidate application protocols. The format will adhere as closely as possible to ISO STEP guidelines. The format will be revised periodically as ISO STEP guidelines are finalized.

• Candidate application protocols specified (11/91) - Specification documents are completed for the Design, Process Planning, and NC programming application protocols.

• Candidate application protocols validated (7/92) - Validation testing is completed for the Design, Process Planning, and NC programming application protocols.

• Supporting documentation and test results prepared (12/92) - Revised specifications for the candidate application protocols and report of test results are produced in a technical report.

• Summary report produced (3/93) - An end-of-phase report is produced which summarizes the activities and accomplishments of the thread.

STEP Production Cell

Objective:

Develop an integrated, automated manufacturing environment within the NIST AMRF whose product specification data representation is based upon validated STEP data models.

Description:

The STEP Production Cell (SPC) will demonstrate small batch manufacturing using STEP data [Fowler90]. It will help verify that the STEP standard is workable through production level testing. STEP is intended to facilitate the sharing of product data between manufacturing systems. This is true whether the manufacturing systems are located at the same site or geographically dispersed. With help from test sites having similar capabilities to the SPC, the SPC will be able to test and demonstrate how STEP supports production operations occurring at different sites.

This cell will not demonstrate futuristic or exotic manufacturing technologies. Rather, the STEP Production Cell will: 1) integrate basic STEP software tools, commercial databases, and commercial manufacturing applications into a prototype manufacturing system, 2) demonstrate the use of STEP in a small-scale manufacturing environment, 3) verify the performance of STEP in a real-world manufacturing environment, 4) demonstrate STEP-based manufacturing across different production sites.

The STEP Production Cell consists of seven major subsystems:

- Design
- Process Planning
- Equipment Programming
- Machining Workstation
- Inspection Workstation
- STEP Data Repository
- Network Communications

The manufacturing data preparation subsystems (i.e. Design, Process Planning, and Equipment Programming) are used to generate the information that is required to control the manufacture and inspection of a part. STEP data is the primary information shared by these subsystems.

The principal component of the Machining Workstation is a 3-axis vertical milling machine. This computer-driven machine tool can produce simple, prismatic parts. The computer programs that control this machine tool are derived from the STEP data provided by the manufacturing data preparation subsystems.

The STEP Data Repository subsystem provides the storage mechanism for STEP data. The repository provides a generic software interface to the data representations. The generic interface allows the application subsystems to store and retrieve the desired STEP data without regard to the details of its representation. The Network Communications subsystem ties the other six subsystems together.

The principal component of the Inspection Workstation is a coordinate measuring machine (CMM). It provides the facility for determining whether machined parts are produced as specified. This computer-driven machine measures the size of critical features of parts. Based on measurements from the CMM, analysis software determines whether dimensions of the machined part fall within designed tolerances. As with the milling machine, the computer programs that control the measurement process are derived from the STEP data provided by the manufacturing data preparation subsystems.

For an illustration of some of the major processes and information contained within the STEP Production Cell, see Figure 7.

Deliverables:

- Development plan - A document which outlines the objectives, a brief overview, technical plans, and resource requirements for the technical thread.

- STEP Production Cell Systems - A package which includes system software, technical documentation, test data, and user guides for the major

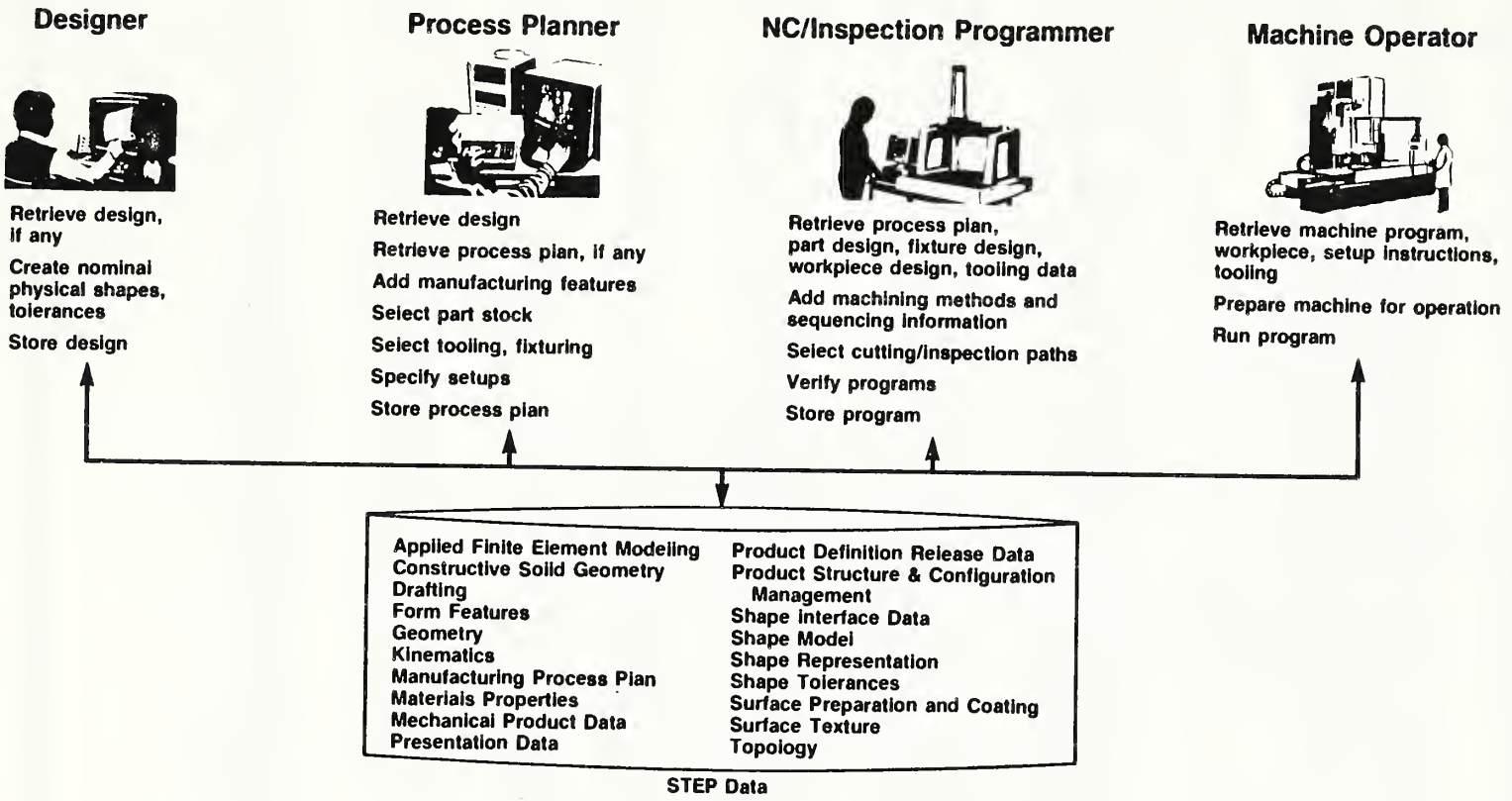

Figure 7. Major processes and information for the STEP Production Cell

subsystems of the STEP Production Cell: Design, Process Planning, NC Programming, and the Data Repository.

• Technical reports - A set of reports covering the requirements analysis, and subsystem designs for the STEP Production Cell.

• End-of-phase report - Document provides summary of accomplishments, lessons learned, and deliverables for the phase.

Milestones:

• Development plan prepared for technical thread (9/90) - A plan for the STEP Production Cell is written, submitted to sponsors, and published for widespread distribution.

• STEP application requirements specified (10/91) - A set of detailed requirements analysis documents are prepared which identify the functions and data that must be supported by the STEP applications, i.e. Design, Process Planning, and NC Programming.

• STEP application system designs specified (12/91) - Based upon the detailed requirements analyses, a design document is produced for each STEP application and the data repository.

• Data repository operational (1/93) - The data repository is operational and ready for use by STEP applications.

• Design application operational (1/93) - The STEP Design application software is operational and ready for use in stand-alone mode.

• Process planning application operational (4/93) - The STEP Process Planning application software is operational and ready for use in stand-alone mode.

• NC programming application operational (4/93) - The STEP NC Programming application software is operational and ready for use in stand-alone mode.

• Cell applications integrated (5/93) - All of the application software in the cell is operational and ready for use in integrated mode.

• STEP production cell demonstrated (12/93) - The STEP Production Cell is demonstrated for sponsors, selected technical and standards committee members, and management representatives from Product Data Exchange Network sites.

• Public domain cell software and documentation set prepared (3/94) - The SPC software package and technical documentation on the cell is ready for distribution.

• Summary report produced (6/94) - An end-of-phase report is produced which summarizes the activities and accomplishments of the thread.

Product Data Exchange Network

Objective:

Establish a network of organizations and individuals which supports the specification, validation, prototyping, commercial development, and transitioning to STEP.

Description:

The Product Data Exchange Network (PDEN) will help accelerate the development, testing, and validation of STEP and ensure that STEP will function as intended in actual manufacturing environments [Frechette90]. It will consist of manufacturing facilities and research centers from industry, academia, and government linked electronically via computer networks. Figure 8 illustrates possible network sites. The National PDES Testbed at NIST will serve as headquarters for the Product Data Exchange Network. As the PDEN and the Computer-aided Acquisition and Logistic Support (CALS) Test Network sponsored by the U.S. Department of Defense have similar objectives, the activities and results of these two programs will enhance and complement each other.

STEP will provide the framework for product specification data bases which support design, engineering, manufacturing, deployment, maintenance, support and recovery activities at both government and commercial facilities. The ultimate goal of the Product Data Exchange Network is to accelerate the transition of these facilities to STEP-based information systems. The Network will have achieved its primary objective when the commercial or government Testbed sites are capable of STEP-based production operations.

The Product Data Exchange Network will help distribute STEP development, testing, and validation activities across a broad spectrum of manufacturing enterprises. An objective is to have representatives from each of the various manufacturing domains participate in this program in order to provide technical expertise not available at NIST. Possible manufacturing domains include: aerospace, shipbuilding, apparel, sheet metal product, electrical product, mechanical products. Organizations which participate as PDEN members will realize the far-reaching potential

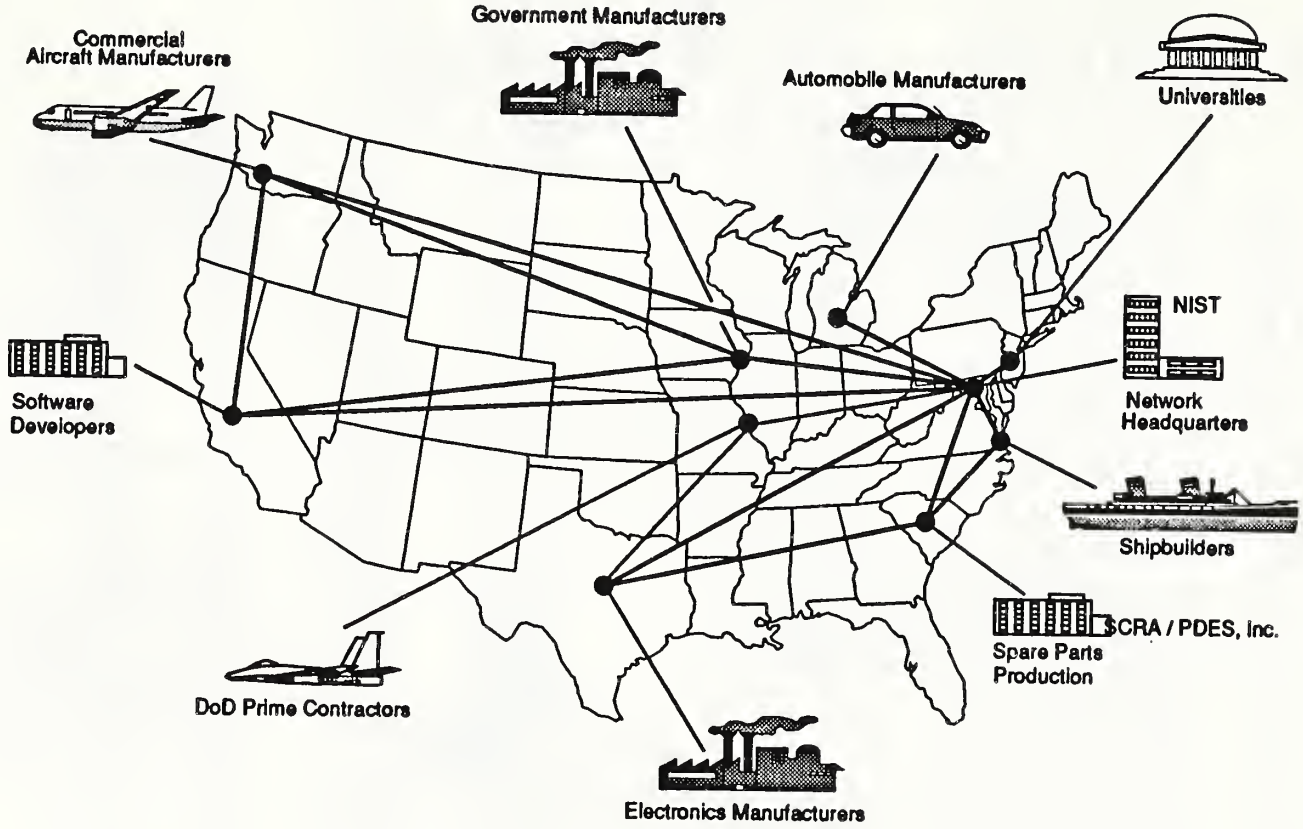

Figure 8. Possible Product Data Exchange Network sites

of an accepted STEP standard and will maintain a competitive edge through knowledge and application of this technology.

Several of the network sites will serve as model facilities for developing STEP-based manufacturing systems. Various Product Data Exchange Network sites will perform STEP validation activities based upon specific capabilities available at that site. These activities may include testing or developing STEP-based software applications, developing transition plans to implement STEP in manufacturing environments, or producing actual products using STEP. Figure 9 illustrates some of the activities which may occur at Network sites.

National PDES Testbed will support the sites by providing: a headquarters for the Network, program management and orientation, coordination of testing between network sites, and distribution of a Product Data Exchange Network site kit. The PDEN site kit will consist of STEP software tools and background information. The site kit is intended to provide each site with a start-up point.

Deliverables:

- Development plan - A document which outlines the objectives, a brief overview, technical plans, and resource requirements for the technical thread.

- Network site kit - A package which includes system software, technical documentation, and a user guide for the Product Data Exchange Network sites.

- Technical reports - A set of reports covering various aspects of the Product Data Exchange Network.

- End-of-phase report - Document provides summary of accomplishments, lessons learned, and deliverables for the phase.

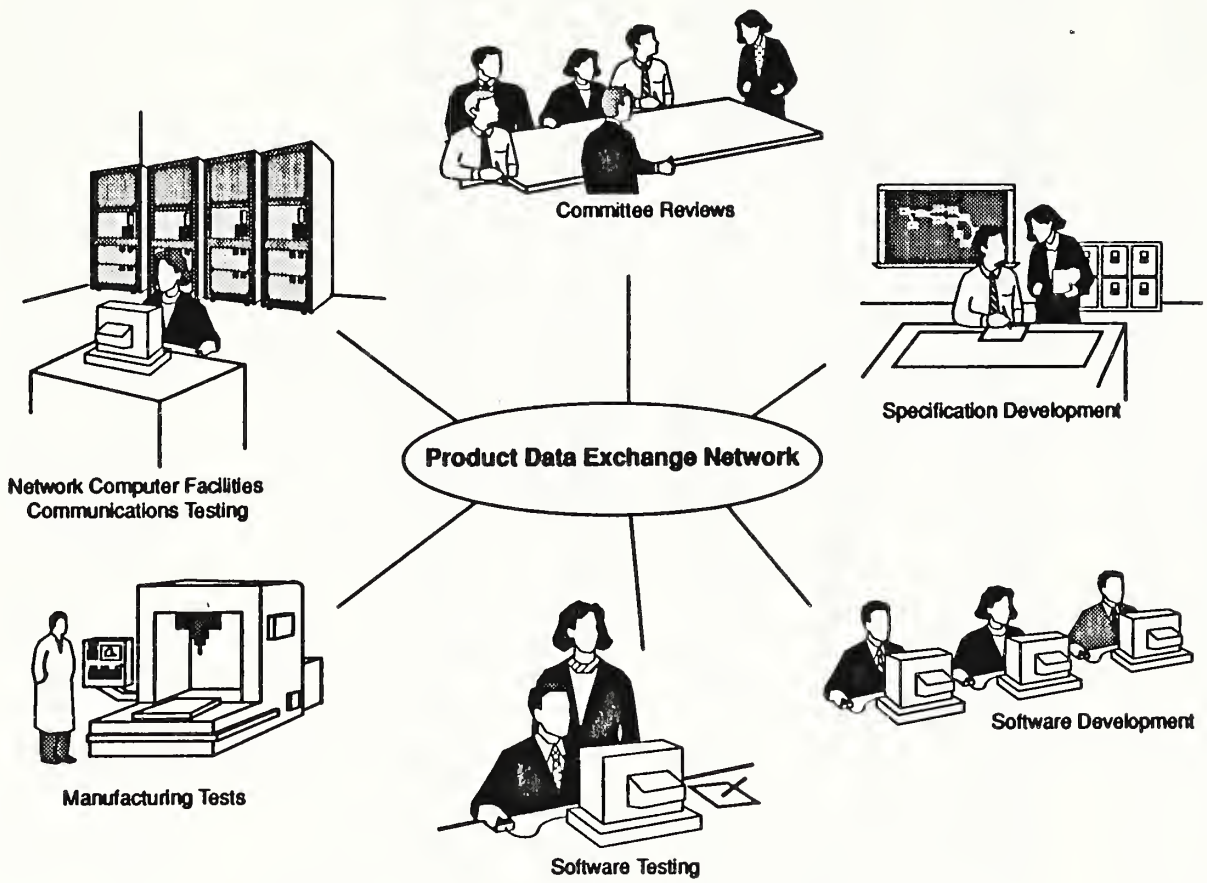

Figure 9. Possible activities at Product Data Exchange Network sites

Milestones:

- Development plan prepared for technical thread (9/90) - A plan for Product Data Exchange Network is written, submitted to sponsors, and published for widespread distribution.

- Initial Network sites established (10/91) - A core set of Network sites are identified and the Product Data Exchange Network is activated.

- Training and technology transfer initiated (1/92) - An information and training package is made available to Network sites that have been identified as regional centers of expertise. Training and technology transfer program begins at those sites.

- Product data sharing test plans developed (6/92) - An initial set of test plan documents are developed which define multi-site product data sharing tests.

- Multi-site tests conducted (6/93) - On the basis of the product data sharing test plans, the first multi-site tests are conducted.

- First STEP-based production operations at a Testbed site (1/94) - Manufacturing operations based upon STEP data is demonstrated for Network site technical staff.

- First summary report produced (12/93) - A summary report is produced which summarizes the activities and accomplishments of the thread to date.

Conformance Testing System

Objective:

Develop conformance testing techniques, procedures and systems which can be used to verify that STEP implementations comply with accepted standards.

Description:

Conformance testing is the testing of a candidate product for the existence of characteristics required by the standard itself. It helps assure product conformity in implementations, clarify the standard itself for implementation, provide a feedback loop to the standards-making bodies for improvements to the standard, and encourage commercial development by providing a baseline for commonality in all products. The implementation of a conformance testing system and an independent testing program increases the probability that different STEP implementations will be able to interoperate. Figure 10 illustrates the conformance testing program model.

In the conformance testing process, the Client is the organization or individual that is seeking certification that a product complies with the standard. With the successful completion of conformance testing on a Client's STEP application, the Client can obtain a certificate--possibly buying power to bid on a government contract or show a potential government user that the Client's product has been tested under a controlled environment by an unbiased testing laboratory. This formal process improves the competitive edge for the Client against those implementors who have not gone through the same process. Figure 11 illustrates the process a typical client might go through in obtaining certification for a product.

The Conformance Testing System thread will: 1) construct a conformance testing system, 2) develop test procedures and data that adhere to STEP specifications, 3) specify the process which will be used for certifying compliance with the standard, 4) define the procedure which will be used to approve and review the operations of conformance testing sites, and 5) establish a conformance testing program at selected sites within the

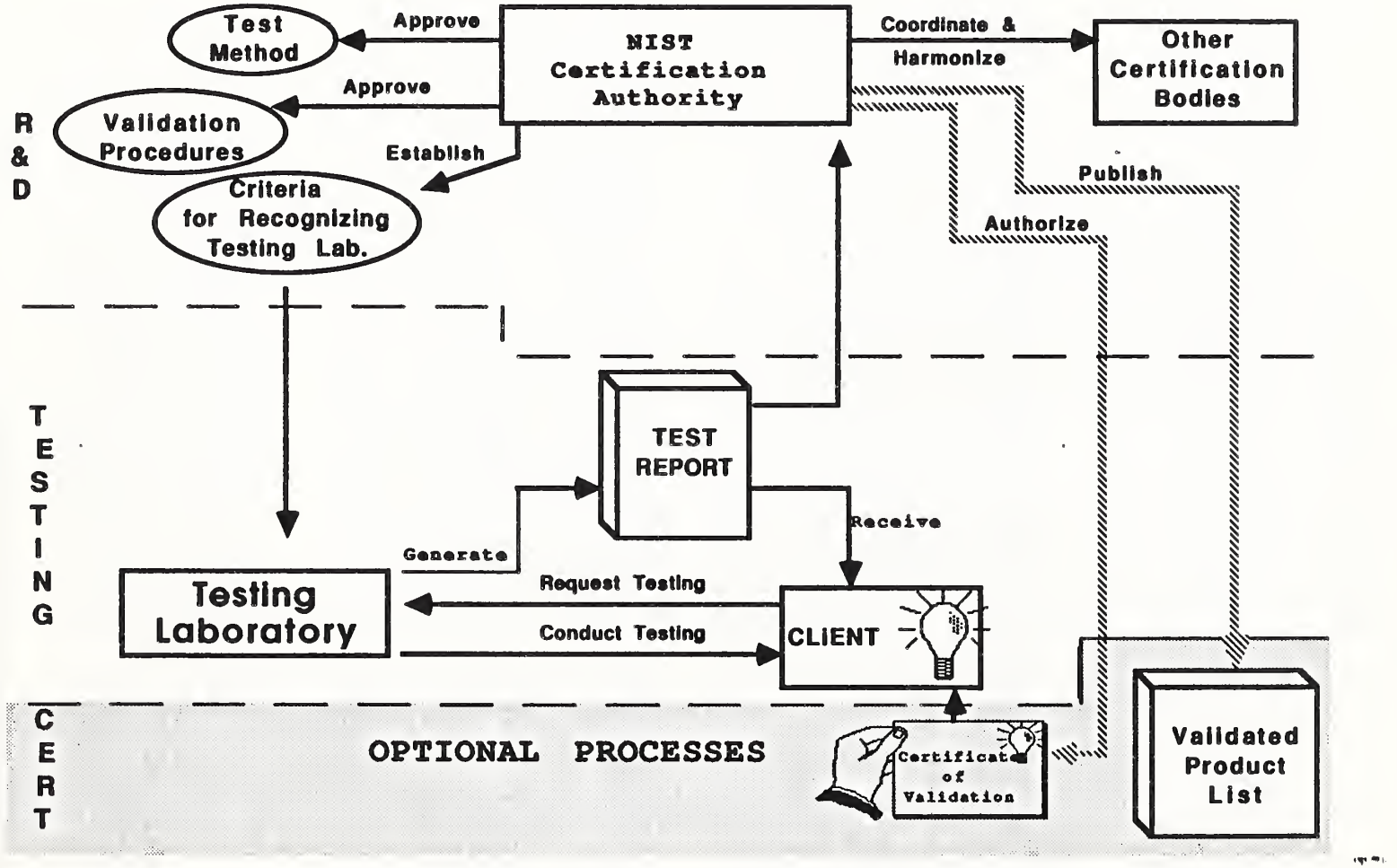

Figure 10. The conformance testing process model

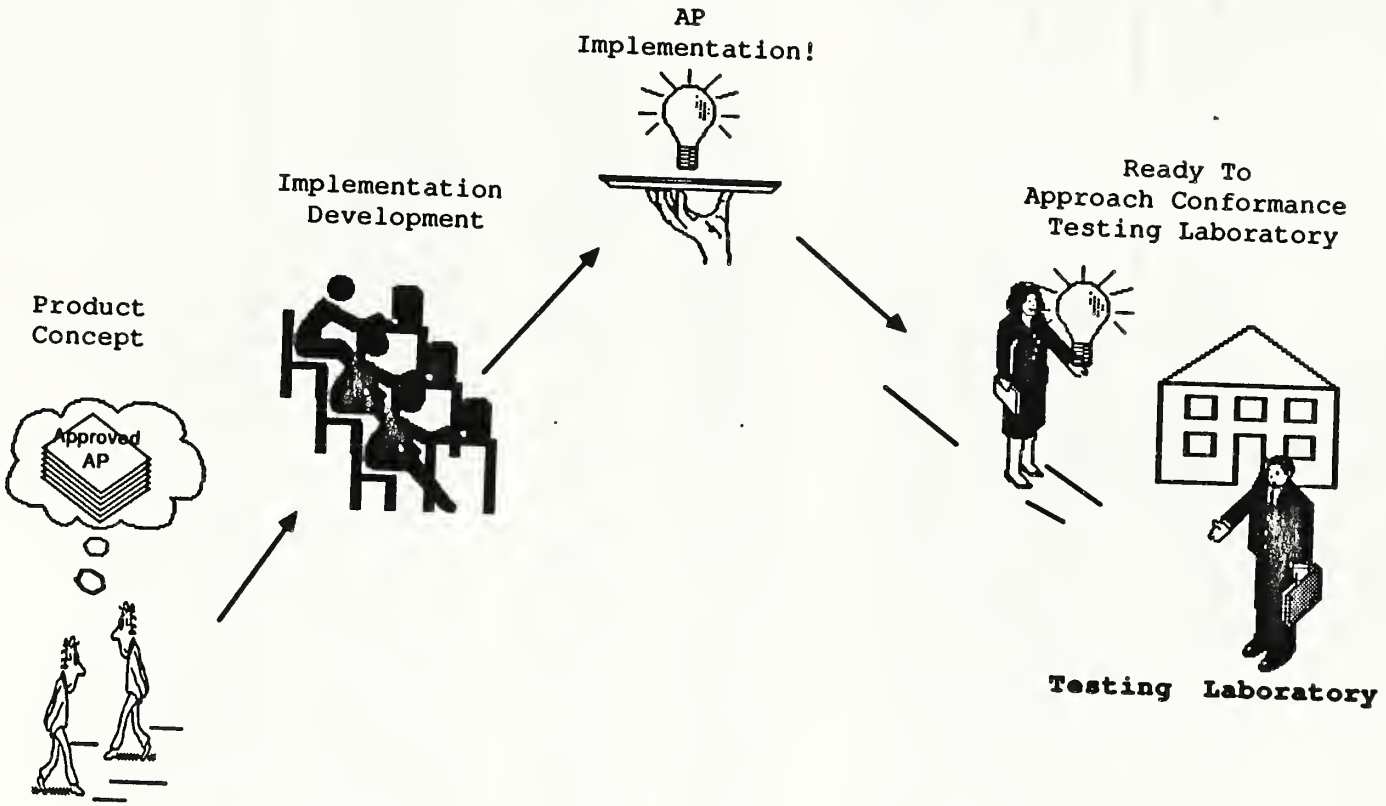

Figure 11. Process a client goes through in obtaining conformance certification

Product Data Exchange Network [Kemmerer90]. It may not be feasible to use sites other than the National PDES Testbed for conformance testing. If this is indeed the case, the plans for this thread will be revised accordingly.

The initial focus of this effort will be based upon a single application protocol (AP) within the STEP specification. The abstract test suite which is contained within the AP will be used to develop an executable test suite. The validation testing system capabilities will be used as a foundation for the construction of the AP conformance testing system. The CTS thread will also define the conformance assessment process which is carried out by a approved testing laboratory for a specific Client. A conformance testing service will be established which can be used by implementors, government agencies, and academia to ensure that commercially-developed systems conform to the requirements of the appropriate STEP application protocol(s).

Deliverables:

- Development plan - A document which outlines the objectives, a brief overview, technical plans, and resource requirements for the technical thread.

- Conformance Testing System - A package which includes system software, technical documentation, and a user guide for conformance testing.

- Technical reports - A set of reports covering the requirements analysis, description of testing methodologies, system design for the conformance testing, proposed institutional framework for conformance testing service, and testing site approval process.

- End-of-phase report - Document provides summary of accomplishments, lessons learned, and deliverables for the phase.

Milestones:

- Development plan prepared for technical thread (10/90) - A plan for conformance testing is written, submitted to sponsors, and published for widespread distribution.

- Conformance testing methodology specified (7/91) - A report is prepared which specifies the methodology which will be used to conduct conformance testing.

- Conformance testing system requirements defined (4/92) - A set of detailed requirements analysis documents are prepared which identify the functions and data that the conformance testing system must support.

- Conformance testing system design specified (12/92) - Based upon the detailed requirements analyses, a design document is produced for the conformance testing system.

- Institutional framework established (9/93) - The framework for approving conformance testing sites is specified and initial testing sites are identified.

- Conformance testing system operational (12/94) - The testing system is operational and ready for distribution to approved conformance testing sites.

- Technical system and user documentation prepared (12/94) - User guides and documentation on system internals are available. This information may be used to develop training materials for test sites.

- Conformance testing system demonstrated (3/95) - The conformance testing system is demonstrated for representatives from standards organizations, technical committees, and initial testing sites.

- Summary report produced (6/95) - An end-of-phase report is produced which summarizes the activities and accomplishments of the thread.

Management and Technical Support Activities

Objective:

Establish a program for managing, coordinating and supporting Testbed involvement in the development of product data sharing standards.

Description:

The National PDES Testbed is just one small, but critical, component of a large international effort to develop product data sharing capabilities. As such, the Testbed must develop plans for project efforts and track their execution. Testbed efforts must be coordinated with those of many other organizations. The Management and Technical Support Activities (MTS) thread will provide a broad umbrella under which a wide variety of activities will take place [McLean90]. The thread will run for the duration of the Testbed project.

Some of the activities included in this thread are: 1) development and maintenance of strategic plans, 2) development of coordinated master plans with other organizations, 3) establishment of project work statements, budgets, and policies, 4) development of software quality assurance plans and software management, 5) participation in standards and technical development activities of other organizations, 6) administration of the Testbed as a user facility, 7) maintenance of the Testbed PDES Hotline, 8) support of global Testbed facilities, i.e. computer hardware, software, and communications systems, 8) development of training materials and programs, 9) performance of various information support, technology transfer, and public relations functions, and 10) establishment of internal and external review boards for the Testbed project.

Deliverables:

- Strategic, development and implementation plans - Documents which outline the objectives, a brief overview, technical plans, and resource requirements for the overall project and each technical thread.

- Technical reports - A set of reports covering Testbed administration, system configuration, policies and procedures, general technical

information, project status, participation in standards and technical activities, training materials, etc.

• Public Demonstrations - Various demonstrations of Testbed capabilities and results.

• Project reviews - Various reviews with sponsors, outside organizations, and advisory boards.

Milestones:

Testbed PDES Hotline operational (6/90) - The PDES Hotline became operational on a daily basis to answer questions and resolve problems for users of the Testbed software at remote locations across the nation.

Testbed strategic plan completed (9/90) - A plan is completed which outlines the plans for the National PDES Testbed, i.e. this document.

Revised agreements negotiated with other organizations (11/90) - New memorandums of understanding and working agreement are negotiated with other organizations, e.g. PDES, Inc. and the IGES/PDES Organization.

Software quality assurance plan prepared (1/91) - A plan is developed which establishes life cycle requirements for project software. The plan specifies document formats, review procedures, and testing requirements for different classes of software.

Coordinated plan for product data sharing (3/91) - A first draft of a coordinated technical plan is produced for organizations involved in the product data sharing development effort.

Testbed Advisory Board established (6/91) - An external review board is established with outside managers and technical experts to review Testbed operations.

Testbed operations demonstration (10/91) - As part of the annual Automation Open House, the operations of the National PDES Testbed are demonstrated to the public. At least one public demonstration will be planned annually.

Project status reports prepared - Interim project status reports are prepared on a quarterly basis.

SECTION 5. STRUCTURE OF THE NATIONAL PDES TESTBED

The National PDES Testbed is an impartial, publicly accessible facility where successive definitions of the STEP specifications can be modeled, analyzed, implemented, and tested. The Testbed facility is comprised of laboratories, computer hardware and software systems, and testing tools. The Testbed is used and staffed by leading experts on PDES issues from industry, academia, and government. The organizational components of the National PDES Testbed are:

- Standards Testing Center
- Application Prototype Center
- Information Services Center
- Program Coordination Office

Their work is described below.

Standards Testing Center - It has established a rigorous testing program for evaluating the draft STEP specifications. The Standards Testing Center (STC) performs the following functions:

- constructs computerized representations of the information models that have been derived from the product representation schemes defined in the draft STEP specifications,

- evaluates the correctness and completeness of STEP information models using established analytical techniques which are accepted by industry professionals,

- defines the databases that correspond to the information model, generates test product specification data, and populates the databases with that data,

- develops comprehensive test criteria and test cases with support from industry experts which test the STEP databases with transaction scenarios that reflect "real world" requirements and operating conditions,

- reviews test results, documents deficiencies, and recommends changes to the draft STEP specifications to relevant standards committees, PDES, Inc., and project sponsors.

In the long term, as commercial systems are constructed using STEP standards, the Standards Testing Center will develop unbiased conformance tests. The conformance

tests will be assembled as packages which include test criteria, procedures, and sample data.

The testing packages will be made available to authorized independent testing laboratories. The laboratories will conduct conformance tests on commercially-developed products. Upon the receipt of a report of the successful completion of testing, the National PDES Testbed will certify that the tested system complies with the standard.

Application Prototype Center - This center's activities are centered around the development of prototype STEP applications. The Application Prototype Center (APC) is responsible for identifying the technical requirements, with respect to STEP, of application systems. It also develops generic architecture and design specification for these systems.

The Application Prototype Center will construct libraries of software tools which can be used to implement STEP-based systems. Some examples of prototype systems that may be installed or implemented include:

- 2-D drafting
- part design and modeling
- process planning
- part programming for numerically controlled (NC) machine tools
- machining systems
- measurement and inspection systems
- data dictionary systems
- data administration systems
- application databases

Of course, this list is not exhaustive. It is indicative of the expertise that is available at NIST. This expertise was gained in the development of the NIST Automated Manufacturing Research Facility (AMRF).

The prototype systems that are implemented will serve many purposes. They will be used to:

- support the development and evaluation of validation and conformance testing systems,

- test the interoperability of STEP applications,
- identify critical STEP application area issues, and
- demonstrate the feasibility of STEP-based applications.

The prototype applications may be either acquired from outside sources or constructed internally from "scratch." Existing commercial or research systems may be modified to support STEP. They may have "shells" or translators built which make them STEP-compatible. Whenever possible, the STEP prototypes developed by industry or other research institutions will be used.

The successful implementation and demonstration of these systems in a STEP environment will provide a foundation for competitive commercial systems development. The source code, i.e. the computer programs developed for these prototypes, will be made available in the public domain. The computer programs may provide baseline software that commercial developers and other researchers can use to "bootstrap" their own efforts. The prototyping efforts will extend the envelope of the types of systems for which STEP applicability has been demonstrated.

Information Services Center - The ISC will manage selected version-controlled STEP information in a computerized configuration management system. The creation of many versions of each document is inherent to the standards process. All versions of STEP information, e.g. draft specifications documents and testing software, will be readily retrievable. Access to this information will be controlled, so that only properly authorized personnel can view or modify working documents. Many different kinds of information will need to be configuration controlled:

- draft working specifications and approved standards,
- information models and data definitions,
- technical papers and other publications,
- public domain software,
- proprietary software,
- sample test data, scenarios, databases, and procedures.

Although some of the STEP source materials will be provided in a form that is ready for distribution, others will not. Installed editting and desktop publishing tools will facilitate the complex standards document review process. These tools should support the sharing and cooperative markup of documents by authors and reviewers located at

remote sites, i.e. not physically present at NIST. Finally, this Testbed activity will maintain mailing lists and choose distribution mechanisms that are best suited for the material that is being circulated. Wherever appropriate, the archiving, indexing, and distribution facilities of the National Technical Information Service (NTIS) will be utilized.

Program Coordination Office - This "center" will provide the technical, administrative and management support necessary to help coordinate various aspects of the PDES activities within and outside of NIST. Activities that might have an impact on the PDES program will also be monitored, including:

- international standardizations efforts,
- related national standards programs, and
- independent research and development work.

The Program Coordination Office (PCO) will ensure, to the maximum extent possible, that NIST staff are represented on appropriate standards committees, technical task groups, review panels, and interagency management policy boards. The PCO will identify positions in these organizations that need to be filled and select appropriate NIST representatives. Through these representatives, it will track NIST participation and ensure that promised support commitments are fulfilled.

The PCO will also establish a Product Data Exchange Network as an extension of the CALS Test Network. As headquarters for the Product Data Exchange Network, PCO staff will coordinate the definition and execution of multi-site product data sharing exercises and public demonstrations of STEP technology.

Workshops, conferences, and training programs are needed which will educate and involve industry and government in PDES. The PCO will organize these activities and establish partnerships with both industry and other government agencies.

The PCO will also prepare periodic progress reports for sponsors which provide updates on the coordination efforts and other center's activities within the Testbed. The progress reports will be produced as NIST technical reports and will be made available for widespread distribution.

Testbed Facilities and Resources - The National PDES Testbed is comprised of laboratories, computer hardware, software, communication equipment, and technical staff who are educated in product data sharing technology. The staff include not only

NIST staff, but also representatives from industry and academia. Many of the computer systems and software packages used within the Testbed are loaned or donated by industry. Some of the major components of the Testbed are summarized below.

The focal point of the National PDES Testbed is currently the Validation Testing Laboratory. It houses the computer systems which are being used by PDES, Inc. and Testbed staff to evaluate portions of the STEP specification. As Testbed activities intensify, other laboratories are planned.

The computer facilities of the Testbed include two mainframe computer systems, more than 30 engineering workstations and personal computers, tape drives, printers, and plotters. Testbed users may access these systems locally, via telephone modems, or over publicly-accessible computer communications networks. Other supporting hardware available to the National PDES Testbed includes the shop floor equipment of the Automated Manufacturing Research Facility (AMRF). The AMRF shop floor contains machine tools, coordinate measuring machines, material handling systems, robots, and other supporting production systems.

A number of different types of software packages are installed on these computers systems. Some of the software packages include: information modeling systems, data base management systems, computer-aided design systems, graphics tools, program development systems, word processors, and desktop publishing systems. Other software includes prototype testing tools, process planning, and NC programming systems.

The Testbed is currently staffed by the full-time equivalent of approximately 22 managers, scientists, engineers, technicians, and support personnel. The actual number of staff working on the Testbed is considerably larger. Some staff work part-time on this project, thus the number of different members of the staff working on the project is considerably higher. The total staff is augmented with Industrial Research Associates, students and visiting researchers from academia, and staff working under contract.

Taken together, the facilities and staff expertise found within the National PDES Testbed are a unique resource. It is expected that the National PDES Testbed will make major contributions to the development of product data sharing standards and technology.

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SECTION 7. GLOSSARY

AMRF

The Automated Manufacturing Research Facility at the National Institute of Standards and Technology.

ANSI

American National Standards Institute.

APC

The Application Prototype Center of the National PDES Testbed.

Application Protocol (AP)

Part of the STEP specification which deals with how a particular type of application will use STEP. An Application Protocol will specify which STEP resources, i.e. data entities, are relevant to the application and how they are used by an applications. The Application Protocol will also establish test criteria and test cases.

CALS

The Department of Defense Computer-aided Acquisition and Logistic Support program.

CDIM

Context Driven Integrated Model, a term used by PDES, Inc. which refers to an integrated information model which provides data requirements for a specific application context.

Certification of Conformance

Third party approval that a product (eg., a CAD/CAM software package) meets the requirements of a specific standard or technical specification as determined through use of specified test methods.

Conformance Testing

The testing of a candidate product to determine if it meets the requirements of the standard.

EXPRESS

A specification language for capturing structural and semantic aspects of the STEP information model.

Fiscal Year

The budgetary cycle of the U.S. Government which runs from 1 October through 30 September of the following year.

IGES

Initial Graphics Exchange Specification.

IGES/PDES Organization

The U.S. voluntary technical effort which promotes and facilitates the development of IGES and STEP by working with other standards making bodies, for the purpose of developing related specifications into formal standards.

ISC

The Information Services Center of the National PDES Testbed.

IPO

IGES/PDES Organization.

ISO

International Organization for Standardization.

Life Cycle

The distinct phases in the life of every system or product: requirements analysis, design specification, implementation or production, deployment and maintenance.

NIST

National Institute of Standards and Technology, formerly the National Bureau of Standards (NBS).

PCO

The Program Coordination Office of the National PDES Testbed.

PDES

PDES is the name given to the United States development activity in support of the international standard known as STEP (Standard for the Exchange of Product Model data). Previously PDES and STEP were both used to refer to the developing standard that will enable the interchange of product information throughout a product's life cycle--through design, development, manufacturing

and service. Recently in a March 1990 IPO Steering Committee Meeting, the more explicit definition of PDES was made by altering the meaning of the acronym from its earlier meaning of "Product Data Exchange Specification".

PDES, Inc.

A consortium of companies and government organizations which was formed in 1988 with the specific goal of accelerating the implementation of PDES. The program is managed by the South Carolina Research authority and actively seeks new member companies. NIST is a government associate of PDES, Inc.

SCRA

South Carolina Research Authority.

SQL

The Structured Query Language is the ANSI standard data definition and access for relational databases.

STC

The Standards Testing Center of the National PDES Testbed.

STEP

The informal name which is used to refer to the ISO Standard for the Exchange of Product Model Data.

Testbed

A test environment containing the hardware, instrumentation tools, simulators, and other support software necessary for testing a system or system components.

Validation Testing

The testing process which is directed at evaluating whether the proposed STEP specification is suitable for its intended purpose.

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This document presents a long range strategic plan for the National PDES Testbed project at the National Institute of Standards and Technology (NIST). The Testbed was initiated in 1988 under the sponsorship of the U.S. Department of Defense Computer-aided Aquisition and Logistic Support (CALS) program. A major goal of the Testbed is to provide technical leadership in a national effort to implement a complete and useful specification for the exchange of Product Model Data (STEP). The STEP efforts is led by the International Organization for Standardization (ISO) TC184/SC4.

This plan also outlines a number of supporting project threads that have been established for the Testbed: initiation of the Testbed, development of configuration management systems and services, development of testing systems to validate the proposed standard, specification and testing of application protocols, construction of a prototype STEP-based manufacturing cell, establishment of a product data exchange network, development of conformance testing systems, and management/technical support activities.

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

CALS, National PDES Testbed, PDES, product data exchange, product data sharing, Standard for the Exchange of Product Model Data, STEP

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