U.S. DEPARTMENT OF COMMERCE
National Institute of Standards and Technology

NISTIR 4421

National PDES Testbed Report Series

Development Plan

STEP Production Cell

NATIONAL PDES TESTBED

NIST

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Development Plan
STEP Production Cell

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DEPARTMENT OF COMMERCE • UNITED STATES OF AMERICA •

Preface

This document describes a plan to construct a prototype STEP-based manufacturing cell to demonstrate how parts are produced in a STEP environment. The manufacturing cell is an integral part of an overall project to establish 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 describes one of several technical project threads that have been established for the National PDES Testbed. Other threads address such areas as:

- development of testing systems to validate the proposed standard,
- specification and testing of application protocols,
- development of configuration management systems and services,
- establishment of a product data exchange network, and
- development of conformance testing systems.

The level of support provided for these technical threads and others will be determined by sponsor needs and a number of different priorities. As such, the development plan contained within this document outlines a reasonable schedule to accomplish the objectives of the thread. 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 project, current level of effort, and expected continued support.

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Executive Summary

The Standard for the Exchange of Product Model Data (STEP) is an emerging international standard addressing the problems of data exchange and representation for produced goods in a variety of manufacturing enterprises. As one aspect of NIST's mission, the agency has actively worked to assist US industry with the assimilation of standards, and in particular, standards that are used in Computer Integrated Manufacturing. NIST has established the National PDES Testbed specifically to address the development and testing of STEP, and to serve US industry in its use of the standard.

The STEP Production Cell is a machining system based on STEP data exchange. This system uses STEP data as the primary source for controlling manufacturing of small mechanical parts. The cell consists of subsystems typically found in a manufacturing environment: design, process planning, and equipment programming software systems, as well as machining and inspection hardware. The software subsystems employed in this system are commercially available products supplemented with the interfaces necessary to use STEP data.

The STEP Production Cell demonstrates how STEP is used in a typical, small batch manufacturing system. It also shows how commercial application software can be adapted to work with STEP. The system serves to validate STEP technology used for manufacturing. By participating in tests with other organizations performing related work, the system can be used to show how STEP supports manufacturing processes distributed over different sites.

This document describes the plan for developing the STEP Production Cell over the next four years. A system overview and key aspects of the technical approach are described. A high-level breakdown of tasks leading to completion of the system is given along with a schedule and list of deliverables. Staffing and equipment resources are discussed in the final section of the plan.

1 Goals and Objectives

The National PDES Testbed (NPT) will establish a STEP Production Cell (SPC) to demonstrate small batch manufacturing using STEP data[1]. The STEP Production Cell 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 dispersed over different sites.

The staff of the the Application Prototype Center (APC) within the NPT will develop the SPC. In building the STEP Production Cell, the APC draws upon NIST's experience in Computer Integrated Manufacturing, standards development, and standards testing.

This cell will not demonstrate futuristic or exotic manufacturing technologies. Rather, the objectives of the STEP Production Cell are:

- Combine basic STEP software tools, commercial databases, and commercial manufacturing applications into a prototype manufacturing system.
- Demonstrate the use of STEP in a small-scale manufacturing environment.
- Verify the performance of STEP in a real-world manufacturing environment.
- Demonstrate STEP-based manufacturing across different production sites.
- Disseminate STEP-based technologies - through reports describing architectures, requirements, designs, analyses, and prototype software - to US industry as a foundation for commercial developments.

The SPC effort is being closely coordinated with related work in PDES, Inc., advanced manufacturing projects in the DOD, interested system vendors, development of the international STEP standard, and other projects within the NPT. The Validation Testing System project provides validated STEP models. Access to current STEP documents and the means for distributing SPC information is provided by the Configuration Management Systems and Services project. Participation in multi-site tests is coordinated through the Product Data Exchange Network project.

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1. The acronym PDES means Product Data Exchange using STEP. The STEP acronym means Standard for the Exchange of Product Model Data. In this document, STEP refers to the proposed international standard and PDES refers to the US activity supporting the development of STEP.

2 System Overview

The STEP Production Cell consists of seven major subsystems (see Figure 1):

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

The manufacturing subsystems that people will see when using the SPC are the Design, Process Planning, Equipment Programming, Machining and Inspection Workstations. These are used to perform distinct functions when a part is produced. We refer to these subsystem as manufacturing applications. The manufacturing applications are distinguished from the Network Communications and Data Repository subystems because they perform functions which are specific to manufacturing, whereas the communication and repository systems do not.

The Network Communications subsystem ties the other six subsystems together. It is the medium through which the other subsystems pass data and control information to each other. The Network Communications subsystem provides a gateway for communicating with computers at remote sites as well.

The STEP Data Repository subsystem provides the storage mechanism for STEP data. The data respository can be more than one physical database. 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 [Van Maanen90].

The manufacturing applications need certain data to perform their intended functions. Figure 2 illustrates the functions these applications perform and the kind of data these applications require. The STEP specification must be able to represent the information the subsystems provide to one another. The SPC will demonstrate which STEP data is used to satisfy the information requirements of the manufacturing applications and how the application subsystems use the STEP data.

The Design, Process Planning, and Equipment Programming subsystems are used to prepare the information required to control the manufacture and inspection of a part. Collectively, these applications are called the manufacturing data preparation subsystems. STEP data is the primary form of data exchange between these subsystems.

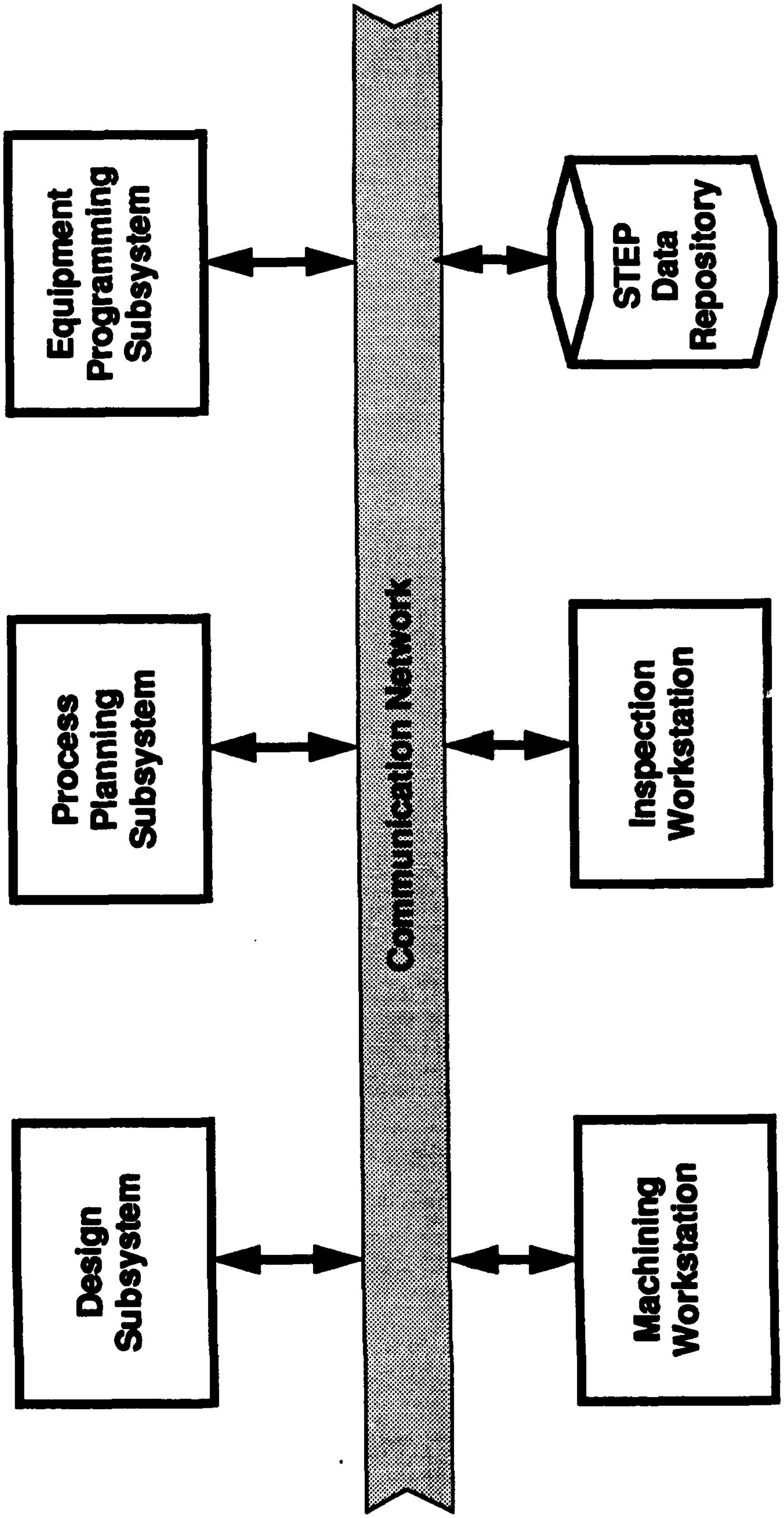

Figure 1: STEP Production Cell Subsystems

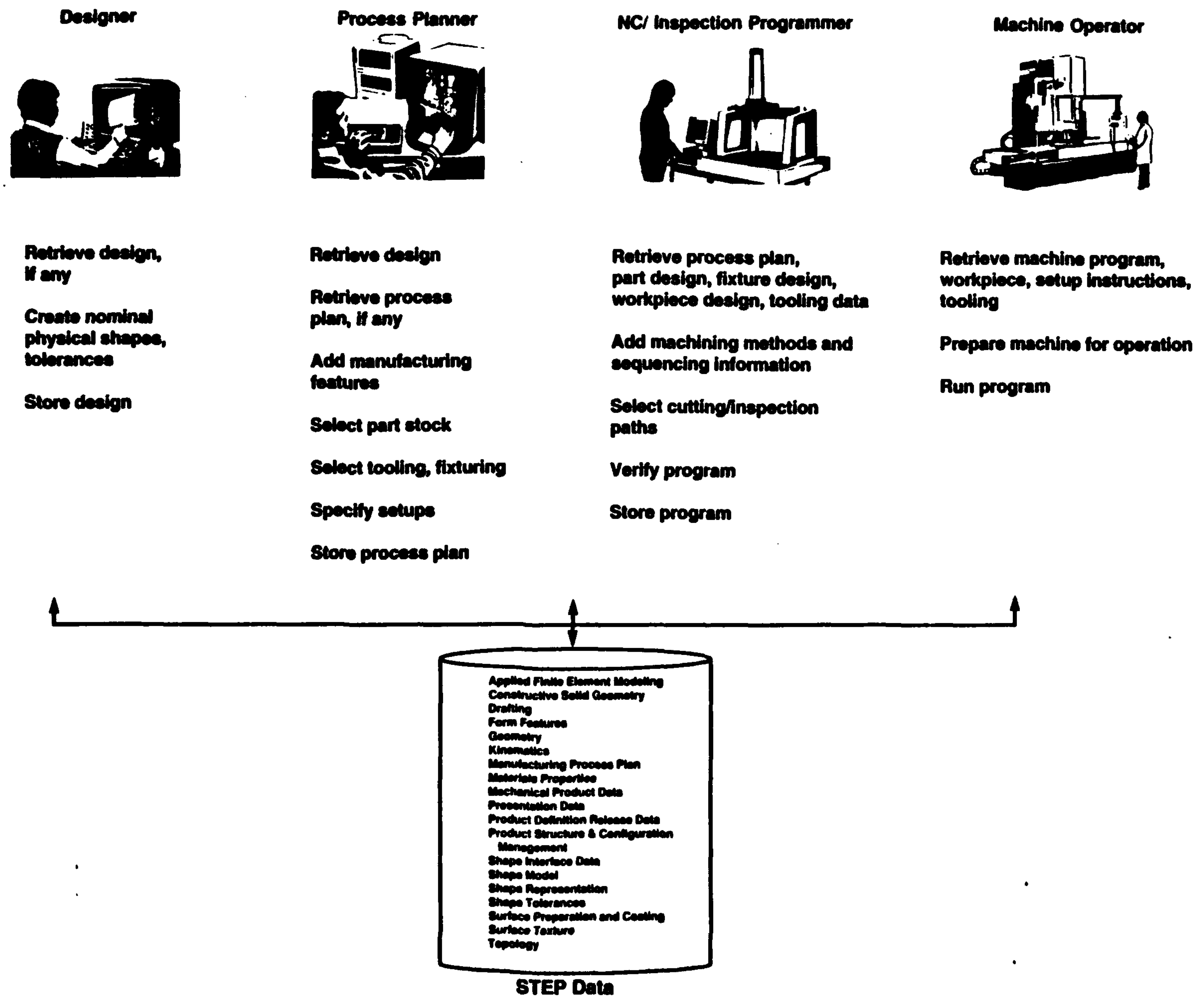

Figure 2: P- ·cesses and Information in the STEP Production Cell

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 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.

The architecture that binds these systems is evolving from ideas described in [Eggers89] and [Fowler89]. The SPC employs an architecture that can serve as a framework for any manufacturing applications using STEP. Such a generic architecture allows for mechanical design, electrical design and other specialized systems to co-exist in a STEP environment.

2.1 How The Cell Will Work

Several steps are required to produce a machined part. Producing a part using STEP data is different than producting a part using only engineering drawings. The SPC must address the differences to ensure the successful use of STEP. We will now describe a scenario for STEP-based manufacturing in the SPC. This scenario, and section 2.2, highlights those aspects of the manufacturing process that are unique to using STEP.

Select Test Part

A specification of the part to be machined must be supplied prior to manufacturing. Selected parts must be within the manufacturing capability of the SPC. Sources for test parts include other sites within the PDES Testbed Network, PDES, Inc. member companies, and the IGES/PDES organization. The test part data is provided in one or more forms: traditional engineering drawings; a STEP file representation of the part; or an Initial Graphics Exchange Specification (IGES) data representation of the part. Data may be supplied on magnetic media or electronically transmitted to NIST through a communications network.

Develop Design

Part design data includes much of the information that is fundamental to supporting the downstream manufacturing processes. This data is provided by the design subsystem as a STEP representation of the part. This data can include descriptions of geometry, the shape of the part, dimensions, tolerances, etc. Depending on how the test part data is delivered, the actual creation of this data may take place in several phases. If the part is delivered as an engineering drawing, a designer uses the design subsystem to replicate the part design in three-dimensional STEP format. If the part is delivered in IGES format, the IGES data will first be translated into STEP format before being processed further. If the

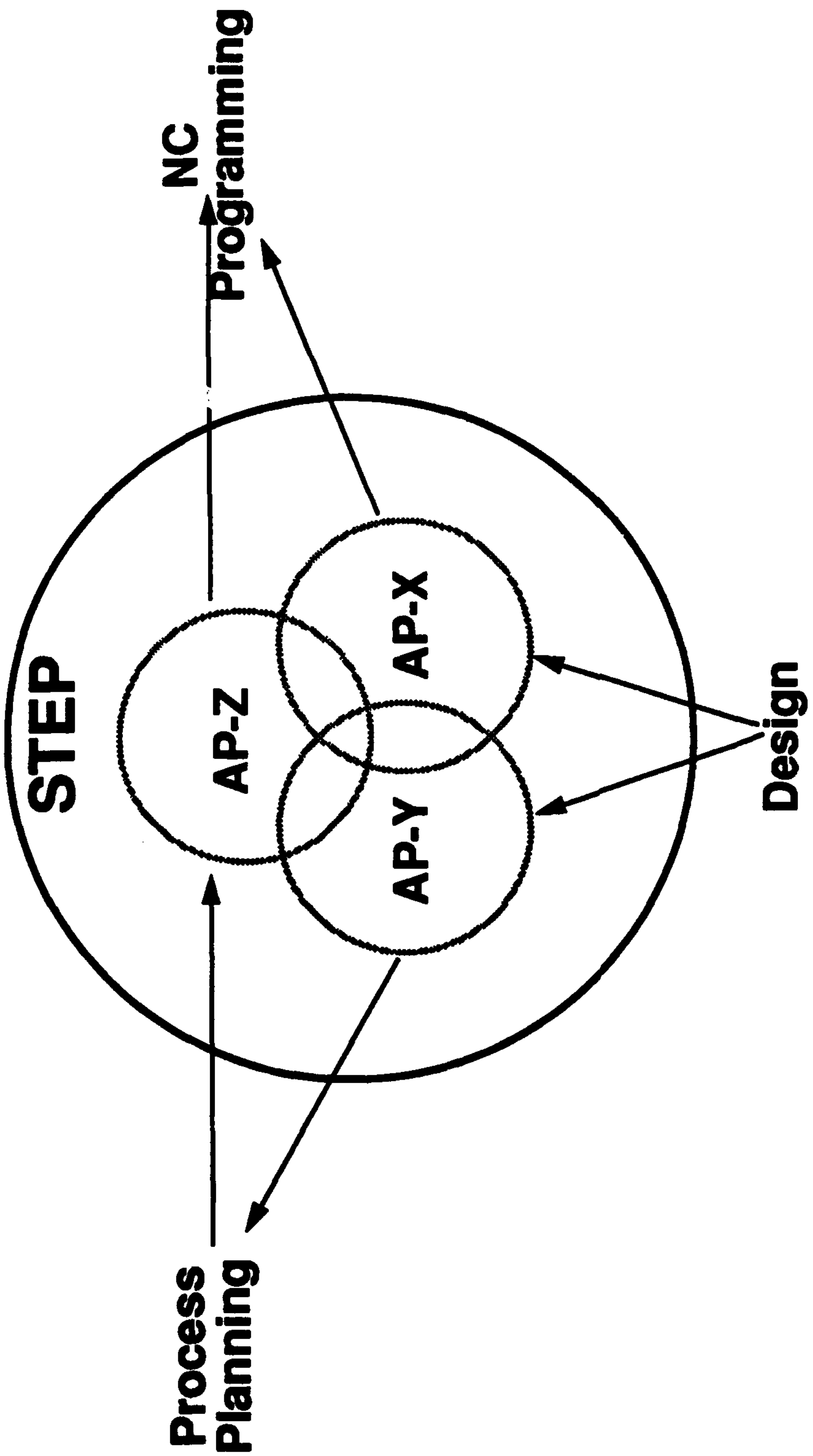

Figure 3: Application Protocols for the STEP Production Cell

test part data is available in STEP format this data will be checked to ensure that it fully meets the needs of the manufacturing data preparation applications. When STEP data is available but lacking certain design data information the designer supplements the existing data using the design subsystem. Once the STEP representation of the design of the part is complete it is saved in the STEP Data Repository.

Develop Process Plan

After retrieving the STEP design data from the STEP Data Repository, a process planner uses the process planning subsystem to develop operation sequences and select tools to manufacture the part. A process planner selects machine sequences and tools based not only on the STEP design data developed earlier but also on additional manufacturing data such as form features. The process planner adds this manufacturing data to the existing STEP representation of the part. The process planning system is used to produce a plan that is appropriate for the manufacturing resources available. The representation of a process plan is currently evolving into one of the many information models specified in STEP.Thus, the plan produced here will be another piece of the STEP data associated with the part. This plan will be saved to the STEP Data Repository along with the manufacturing data that was created here. In addition to the process plan, an inspection plan is generated as well. The inspection plan is analogous to the manufacturing plan, but is used to specify measurement sequences.

Develop Equipment Programs

The next task is to use the STEP data from the design and planning stages to create machine-specific code for machining and measurement. Code generation is a semi-automatic task that requires the use of NC and CMM programming software. Using STEP data retrieved from the Data Repository, equipment programmers generate control programs for each of the machines. These control programs are downloaded to the machine control computers over a communications link.

Manufacture Part

Once the equipment program has been downloaded to the machining workstation control computer, the actual production of the part can take place. A machine operator loads the metal stock onto the milling machine and initiates the control program to start the machining cycle. After machining, the part is moved to the inspection workstation.

Inspect Part

After a part is machined it is inspected to ensure that it has been produced as specified. The equipment operator loads the machined part onto the CMM. The operator initiates the inspection program that was previously downloaded to the CMM control computer. Measurement samples automatically obtained by the CMM are input to analysis software. The inspection subsystem analysis software derives part dimensions, shape, and surface tolerance data from the measurement samples. This analysis determines whether the manufactured part satisfies the design constraints.

2.2 Distinguishing Characteristics of the Cell

Data Requirements and Application Protocols

Each of the manufacturing data preparation applications discussed have their own data requirements. The data that these applications require to fulfill their functions must be formally specified. The STEP standard provides a mechanism for specifying the data needed by these applications. This mechanism is known as an Application Protocol [Palmer89]. STEP Application Protocols (APs) are being developed in parallel with the standard itself.

Choosing the set of APs used throughout the manufacturing process is a key element of successful STEP-based manufacturing. APs define the information exchanged between manufacturing applications. The AP used for producing turned parts on a lathe might be somewhat different from that used for producing complicated milled parts on a five-axis machining center. Figure 3 illustrates protocols relating information exchange in the SPC. This figure shows three APs - each specifies a subset of STEP data shared between two of the manufacturing data preparation applications. The APs in the figure are labeled as AP-X, Y, and Z highlighting the fact that the formal definition of these APs has yet to take place.

The ISO has identified numerous APs that are candidates for standardization along with STEP. Most of these candidate APs exist only as a name; i.e. they are not completely defined. Some of the proposed APs may satisfy information requirements of the SPC. In that case they will be used, subject to the limitations of the SPC environment and resources. Other APs may be developed in coordination with the STC.

APs specify the nature of the information exchanged between subsystems, the meaning of that information, and the restrictions on that information. Considering that these protocols are essential to successful product data exchange, it is imperative that the protocols themselves be well formulated. Validation of STEP and certain APs is performed under the Validation Testing System project in coordination with PDES, Inc. The SPC will only use validated models to fulfill the data requirements between its application subsystems.

Implementing STEP-based Applications

The specification for STEP is changing and will continue to change into the foreseeable future. Yet even as the specification is changing, we must press on with the development of STEP-based applications. *How can we protect the investment made in software developed for a particular version of STEP?* By providing a layer of insulation between the applications and the STEP data itself. The interface between the applications and the STEP data can not entirely negate the effects of a changing specification. But it does lessen the problem to some degree.

Such an interface is part of the work in the development of the STEP Data Repository subsystem. By combining commercial applications with the interface software we have gone halfway towards making the applications STEP-based. The remaining challenge is to ensure that the applications can support the data relationships that STEP prescribes.

A changing specification also impacts the mechanisms for storing data according to the specification. Our approach is to automatically derive the STEP data representations from the specification of the data itself. This is known as a schema-independent approach. The software that generates actual data representations is independent of the specification of that data (the schema). Wherever possible, we use schema-independent software, thus making the software useful for any version of the specification.

2.3 What The Cell Is Expected To Show

The SPC will show how STEP data can successfully drive current manufacturing applications. The SPC will also provide a mechanism for assessing the performance of STEP in a typical small batch manufacturing environment. The SPC will not use a large part of the STEP standard. Its coverage will likely include data from the geometry, topology, shape, features, tolerances, and product structure areas. The SPC may uncover problems in STEP or APs even with this relatively small coverage of the standard. Resolving such problems with the appropriate standards committees before they become the *status quo* is an activity that benefits all implementers and users of the standard.

The SPC will also show how commercial applications can be adapted to work with STEP APs. Commercial application implementers have no experience in supporting or conforming to APs. By supporting and using APs in the SPC we can provide much-needed insight regarding the considerations that APs require.

Aside from showing STEP-based manufacturing by itself, the SPC can demonstrate interoperability between sites using STEP. By cooperating with other sites in the Product Data Exchange Network, we can exchange STEP data between sites. We envision taking part data created at one site, manufacturing it at another and inspecting the finished part at a third. This, after all, is the promise of STEP, and we must work now to show that promise can be fulfilled.

3 Technical Plan

The STEP Production Cell development plan is based on NIST's past experience with the Automated Manufacturing Research Facility [Simpson82] and associated projects. The planning described here takes the SPC into fiscal year 1994. The development effort employs a team of manufacturing application specialists and computer scientists. This staff will be knowledgeable in the areas relevant to manufacturing and STEP. The building blocks of the STEP Production Cell are readily available commercial products supplemented with interfaces that work with STEP models and data.

Deliverables

The primary deliverable of the SPC project is a working manufacturing system at the NIST site. The plan also provides for delivery of an extensive collection of documents. Analyses of requirements, detailed subsystem design specifications, subsystem implementation descriptions, and test reports make up the bulk of the material available for public dissemination. Certain software modules - in particular, those that do not incorporate or specifically interface to proprietary commercial packages - may also be made available through the NPT Information Services Center.

Relationships with Key Organizations

The SPC cannot be developed in a void. The successful development of the SPC hinges on interaction with the developers and users of STEP. The SPC project is coordinated with other projects in the National PDES Testbed and with external efforts as well. The main contact points outside the Testbed are the ISO, the IGES/PDES Organization, other STEP prototype implementers, and PDES, Inc. Work descrtibed in Task 5.1 is being coordinated with current work in PDES, Inc. Similarly, the APs used for Task 5.2 will be based on, if not entirely the same as, protocols that PDES, Inc. is developing for the ISO. The SPC intends to pursue an agreement with another STEP-based production facility in order to participate in joint demonstrations. Such joint demonstrations will show that STEP data created at one site can drive the manufacturing process at another (see Tasks 2,3,4, and 13). Through these associations the STEP Production Cell will ensure its use of STEP is both current and realistic.

Adapting Commercially Available Applications

The SPC will make use of commercial software which meets the SPC's functional requirements and adapt these systems to work with STEP data (see Tasks 5.2, 5.3, and 5.4). Adapting existing software in this way will ultimately benefit both the software users and vendors: it shows both groups what has to be done to become "STEP-driven." It will thereby provide a framework for in-house and commercial implementations.

A Working System

While the SPC is undergoing development, there will be opportunities for demonstrations of the evolving system. Subsytem integration tests (see Task 7) will be the appropriate time for such demonstrations. Upon completion, periodic public demonstrations of the SPC can take place (see Task 13). A final report will be made available at this time for public dissemination. After the implementation phase of the SPC is complete, we will consider other applications of the system and extensions to its capabilities. The SPC could be extended by adding or substituting other machine tools, or by providing support for new APs. These are but a few examples of how the architecture of the SPC could be applied in the future.

The following sections outline the major tasks necessary for development of the STEP Production Cell. Figure 4 illustrates the timeline for these tasks. Figure 5 illustrates the Work Breakdown Structure (WBS) for the SPC. The WBS shows some of the subtasks that are not detailed in this document. Table 1 follows the task descriptions and summarizes the deliverables for the project.

SPC 1 Develop Conceptual Architecture For STEP Production Cell

Produce a conceptual architecture document which identifies the major subsystems and describes how the subsystems work together. The architecture provides an overview of the functions, operations, inputs, outputs, and database interface for each major subsystem. The document also addresses areas of overlap with validation testing and PDES, Inc. development/testing.

SPC 2 Establish Working Agreement With External PDES Facility

Select an external STEP-based production facility and establish a cooperative testing agreement with this facility. The agreement will specify the intent for interoperability testing between the SPC and the external facility. The agreement will also be used as the means for coordinating schedules and activities for the two sites.

SPC 3 Analyze Current/Planned Part Manufacturing Capabilities Of External Facility

Develop and document an analysis of the current/future capabilities of a manufacturing cell at an external facility. The analysis determines the extent of interoperability between the SPC and the external facility.

SPC 4 Specify Manufacturing Capabilities For Testbed

Determine the families of parts that can be specified and manufactured at the SPC and the external facility. This determination is based on the analysis from Task 3 along with knowledge of the manufacturing capabilities available at NIST. Produce a report specifying the scope and domain of STEP parts production intended within the SPC. The information specified here will be incorporated into future versions of the SPC Development Plan.

SPC 5 Develop Major Subsystems

This task addresses the specification and implementation of the major subsystems. It is broken out below into a subtask for each subsystem.

SPC 5.1 Develop STEP Data Repository/Interface Subsystem

Develop the primary storage mechanism for STEP data and a generic interface to this data. Produce a requirements document addressing the storage of STEP data and shared access to the data from manufacturing applications. Evaluate different data storage mechanisms, e.g. exchange files, databases, and memory-resident data structures. Specify a uniform data access interface useful for any representation of STEP data. Produce a detailed design document for a STEP data repository and interface. Adapt a commercial database system for use as the STEP data repository. Coordinate specification and development of this subsystem with related PDES, Inc. efforts.

SPC 5.2 Develop Design Subsystem

Develop a design subsystem compliant with STEP design data. Select APs according to the information requirements of downstream manufacturing subsystems. Produce a requirements document addressing STEP data compliance and integration with the STEP data repository. Produce a detailed design document addressing subsystem implementation. Adapt a commercially available geometric modeling system for use as the design subsystem. Implement user and data interfaces. Perform stand-alone tests of subsystem. Perform application tests with STEP data repository. Provide usage and implementation documentation.

SPC 5.3 Develop Process Planning Subsystem

Develop a process planning subsystem compliant with STEP design and manufacturing data. Select an AP according to the information requirements of the NC programming subsystem. Produce a requirements document addressing STEP data compliance and integration with the STEP data repository. Produce a detailed design document addressing subsystem implementation. Adapt a commercially available software system for use as the process planning subsystem. Implement user and data interfaces. Perform stand-alone tests of subsystem. Perform application tests with design subsystem. Provide usage and implementation documentation.

SPC 5.4 Develop NC Programming Subsystem

Develop an NC subsystem compliant with STEP design and process planning data. Produce a requirements document addressing STEP data compliance and integration with the STEP data repository. Produce a detailed design document addressing subsystem implementation. Adapt a commercially available software system for use as the NC programming subsystem. Implement user and data interfaces. Perform stand-alone tests of subsystem. Perform application tests with process planning and design subsystems. Provide usage and implementation documentation.

SPC 5.5 Develop Machining Center Subsystem

Develop a machining subsystem for part production. Produce a requirements document addressing integration with the NC programming subsystem, machine control, and operational characteristics. Produce a detailed design document addressing subsystem implementation. Adapt existing NIST manufacturing and control equipment for use as the machining center subsystem. Perform application tests with NC programming subsystem. Provide usage and implementation documentation.

SPC 5.6 Develop Part Inspection Subsystem

Develop a part inspection subsystem capable of verifying machined part correctness. Produce a requirements document addressing inspection programming requirements, inspection operation, and inspection results analysis. Produce a detailed design document addressing subsystem implementation. Adapt existing NIST inspection and control equipment. Implement data interfaces and inspection analysis software. Perform stand-alone testing. Provide usage and implementation documentation.

SPC 6 Develop Integration Tests For SPC Subsystems

Specify a series of subsystem integration tests ensuring that the SPC subsystems work together. Produce a document addressing hardware and software interface testing particularly focusing on successful fulfillment of information requirements. Note that the test specification document is a "living" document, evolving with the implementation of the SPC.

SPC 7 Perform Integration Testing

Actively perform integration testing according to the tests specified in SPC6. Tests are executed according to the phased development of the SPC. Produce integration test results reports.

SPC 8 Obtain Test Part Data

Identify potential sources for test parts. Solicit test part data from identified sources. Select test part data according to the application protocols supported in the SPC.

SPC 9 **Develop Acceptance Criteria For Test Part Production**

Produce a document specifying acceptance criteria for parts produced in the SPC. Establish criteria for pass/fail determination by the inspection subsystem. Relate acceptance criteria to subsystem performace characteristics.

SPC 10 **Perform Test Part Production**

Use all subsystems of the SPC in a full production test of the entire system's capabilities. Ensure that the entire system is operational and functions as intended. This is the final test before regular operational usage. Produce a document assessing the entire system's performance and operational readiness.

SPC 11 **Evaluate Test Part Production Performance**

Examine the system performance assessment produced in SPC10 and integration test results from SPC9. Compare test part production vs. the acceptance criteria for the purpose of improving or correcting system performance. Generate a list of issues and recommendations indicating suggesting areas within the system that would benefit from further enhancement.

SPC 12 **System Revisions**

Perform corrections and/or enhancements to the system in response to the recommendations for such from SPC11.

SPC 13 **Demonstrate Production Cell**

This is a milestone indicating that the SPC is ready and operational. From this point on it can be used for regular demonstrations and exchange tests.

SPC 14 **Produce Final Report**

Provide a summary of the development, implementation, and operation of the SPC. Describe problems encountered, solutions, and technical issues that remain unresolved.

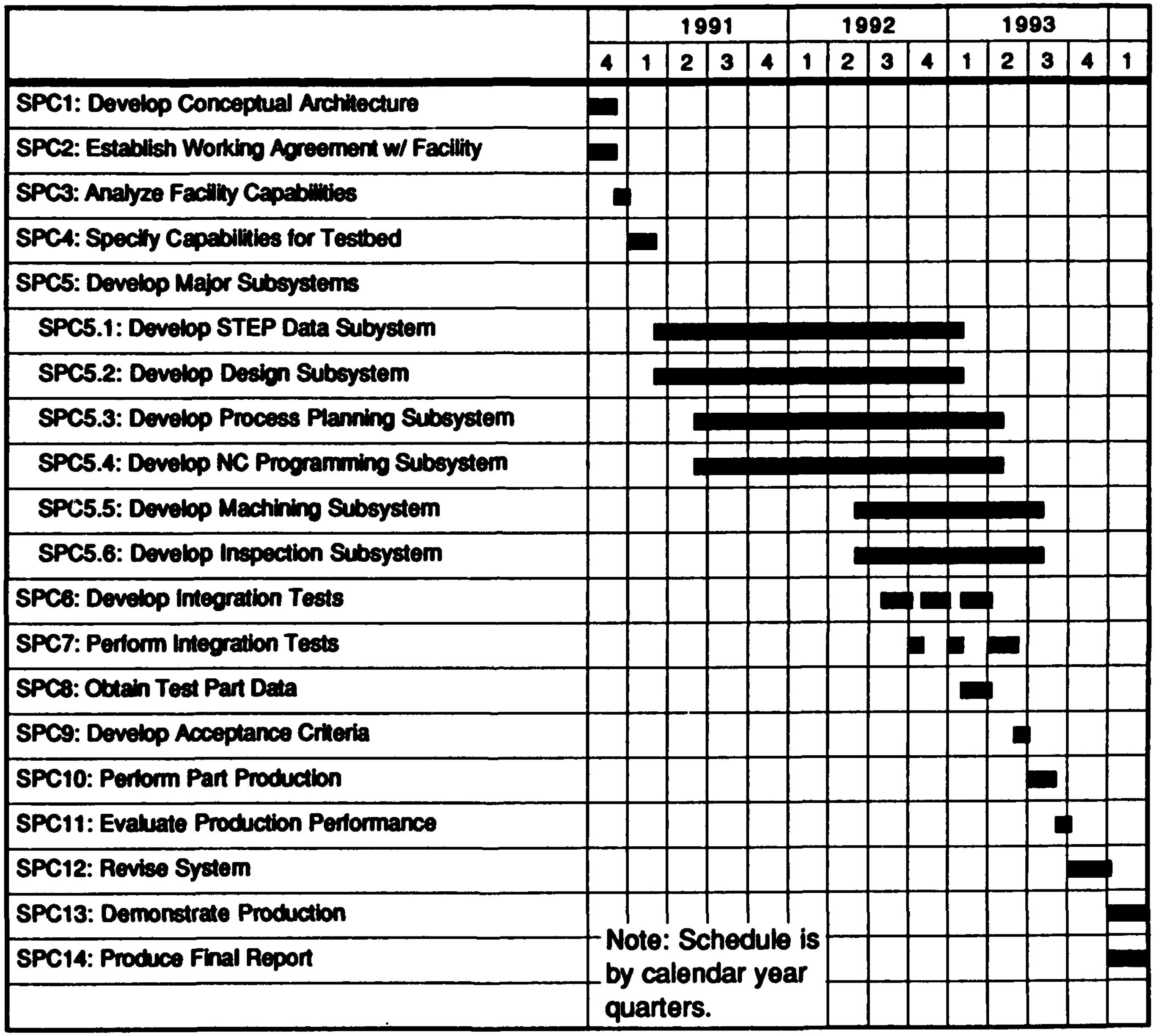

Figure 4: SPC Schedule

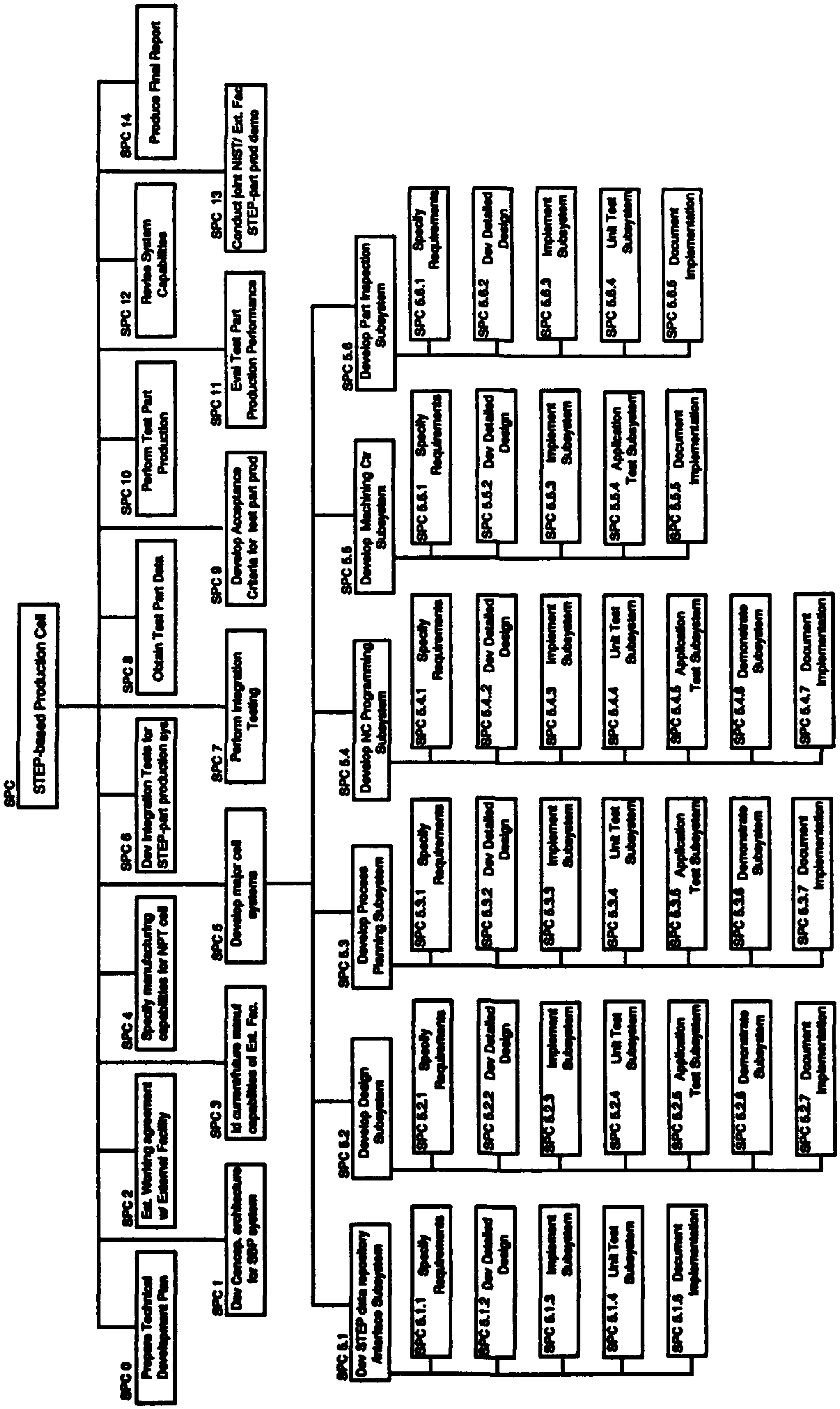

Figure 5: Work Breakdown Structure

DELIVERABLES: STEP-BASED PRODUCTION CELL

TASK	START	STOP	DELIVERABLE	SUPPLIER	CUSTOMER
0. Prepare Tech. Dev. Plan	6/90	8/90	Tech. Dev. Plan	APC	RAMP/CALS/NTIS
1. Dev. SPC Concept. Arch.	10/90	11/90	Conceptual Arch Doc	APC	RAMP/CALS/NTIS
2. Est. Agreement w/ Ext. Facility	10/90	11/90	Memo of Understanding	APC/Facility	CALS
3. Analyze Facility Mfg. Capabilities	12/90	12/90	Facility Mfg Cap Analysis	Facility	NIST
4. Spec. NPT Mfg. Capabilities	1/91	2/91	Testbed Mfg Specification	APC	Facility/CALS/NTIS
5.1 Dev. STEP Data Rep./Interface	3/91	1/93	Data Rep. Interface Specs Data Rep. Req's Analysis Data Rep. Sys. Design Data Rep. Sys. Imp.	APC	CALS/NTIS
5.2 Dev. Design Subsystem	3/91	1/93	Design Sys. Req's Analysis Design Sys. Design Design Sys. Imp.	APC	CALS/NTIS
5.3 Dev. Process Planning Subsystem	6/91	4/93	Proc. Plan'g Req's Analysis Proc. Plan'g Sys. Design Proc. Plan'g Sys. Imp.	APC	CALS/NTIS
5.4 Dev. NC Pgm'g Subsystem	8/91	4/93	NC Pgm'g Sys. Req's Analysis NC Pgm'g Sys. Design NC Pgm'g Sys. Imp.	APC	CALS/NTIS
5.5 Dev. Mach'g Center Subsystem	6/92	7/93	Mach'g Sys. Req's Analysis Mach'g Sys. Design Mach'g Sys. Imp.	APC	CALS/NTIS
5.6 Dev. Insp. Center Subsystem	8/92	7/93	Insp. Sys. Req's Analysis Insp. Sys. Design Insp. Sys. Imp.	APC	CALS/NTIS

Table 1: SPC Deliverables

TASK	START	STOP	DELIVERABLE	SUPPLIER	CUSTOMER
6. Dev. Integration Tests	8/92	3/93	Integration Test Spec's	APC	CALS/NTIS
7. Perform Integration Testing	10/92	5/93	Integration Test Results	APC	CALS/NTIS
8. Obtain Test Part Data	2/93	3/93	Test Part Data Sets	APC/Facility	CALS/Facility/APC
9. Dev. Production Accept. Criteria	6/93	6/93	Test Accept. Guidelines	APC	CALS/Facility
10. Perf. Test Part Prod.	8/93	9/93	Assess. Sys. Perf.	APC	CALS/NTIS
11. Eval. Test Part Prod. Perf.	9/93	9/93	Sys. Rev. Recmnd'tns	APC/Facility	CALS
12. Revise Sys. Software	10/93	12/93	Revised System Software	APC	CALS/NTIS
13. Demo. Part Prod.	12/93		Public Demo	APC/Facility	CALS
14. Produce Final Report	1/94	3/94	SPC Dev./Imp. Report	APC	CALS/NTIS

Table 1: SPC Deliverables (cont'd)

4 Resources

4.1 Personnel

This section describes the personnel roles within the NPT used for development of the STEP Production Cell. The primary staff required for this project includes technical management, manufacturing application specialists, and software specialists. In addition to the primary personnel, the project will require coordination with or support from:

- NPT Standards Testing Center
- NPT Information Services Center
- NPT Program Coordination Office
- NIST computer systems administration personnel
- NIST manufacturing shop personnel
- NIST/PDES, Inc. liaison personnel
- PDES, Inc. personnel

and secretarial staff.

The project staff required to develop the SPC is described in the following paragraphs. All members of the project staff will be responsible for producing technical documentation according to NPT and NIST guidelines. Project staff will also contribute to implementation planning.

Project Manager

Responsible for the overall structure and planning for the SPC. Performs SPC planning, SPC information dissemination, and SPC resource acquisition. Coordinates SPC activities and goals with those of both other Testbed centers, other applicable NIST projects, and external organizations. Initiates, supervises, participates in, and reviews prototype systems design, development, testing, and documentation. Assigns tasks to project staff. Tracks SPC deliverables and reports regularly to Testbed Manager. Knowledge of techniques for product modeling and manufacture. Experience in development and usage of product modeling and manufacturing systems. Experience in software engineering practice and software architecture design.

Data Interface Developer

Responsible for designing and implementing schema-independent STEP data interface. Researches applicable techniques and investigates alternative strategies for developing software that automatically generates function-specific software from information modeling languages. Has extensive knowledge of Computer Science theory and practice, particularly compiler design and object-oriented design. Knowledge of information and product modeling techniques. Experience in multiple, contemporary programming techniques and environments. Experience in developing and integrating large software systems.

Data Representation Developer

Responsible for the design and implementation of schema-driven software data management structures and databases. Researches applicable techniques and investigates alternative strategies for developing software that automatically generates both persistent and non-persistent data representations. Has extensive knowledge of Computer Science theory and practice, particularly database design and object-oriented design. Has knowledge of information modeling techniques. Experience in multiple, contemporary programming techniques and environments. Experience in developing and integrating large software systems.

Design Application Developer

Responsible for design and implementation of prototype STEP-based product design application software. Incorporates schema-independent software tools, schema-driven data management software mechanisms, and commercially available software components into a design specific software system. Has extensive knowledge of product modeling issues and representations in general and as they apply to design in a PDES environment. Experience in formulating practical software solutions to application-specific conceptual problems. Experience in multiple, contemporary programming techniques and environments. Experience in developing and integrating large software systems.

Process Planning Application Developer

Responsible for the design and implementation of prototype STEP-based process planning software. Incorporates schema-independent software tools, schema-driven data management software mechanisms, and commercially available software components into a process planning specific software system. Has extensive knowledge of process planning issues and product representations in general and as tney apply to process planning in a PDES environment. Experience in formulating practical software solutions to application-specific conceptual problems. Experience in multiple, contemporary programming techniques and environments. Experience in developing and integrating large software systems.

NC Programming System Developer

Responsible for the design and implementation of s prototype STEP-based NC programming application software. Incorporates schema-independent software tools, schema- driven data management software mechanisms, and commercially available software components into a NC programming specific software system. Has extensive knowledge of NC programming issues and product model representations in general and as they apply to NC programming in a PDES environment. Experience in formulating practical software solutions to application-specific conceptual problems. Experience in multiple, contemporary programming techniques and environments. Experience in developing and integrating large software systems.

Inspection System Developer

Responsible for the design and implementation of an inspection system that serves to verify the correctness of parts produced in the SPC. Integrates existing inspection hardware equipment, inspection programming software, inspection analysis software, and STEP software tools as necessary. Has extensive knowledge of part inspection issues and product model representations in general and as they apply to manufacturing in a PDES environment. Experience in formulating practical solutions to application-specific conceptual problems. Experience in contemporary inspection techniques. Experience in developing and integrating complex systems.

Senior Software Engineer

Responsible for overall integration of software systems. This includes the task of ensuring that current versions of PDES software tools are employed appropriately, that applications and data interfaces are integrated appropriately, and that major systems are integrated both at the conceptual and implementation levels. Ensures effective use of configuration control systems and software development methodologies. Has extensive knowledge of Software Engineering principles and practice, Computer Science theory and practice, and systems integration techniques. Experience in multiple, contemporary programming techniques and environments

Computer Programmer

Responsible for developing small software modules and programming assistance tasks. Provides support for software tools and systems over their life-cycle. Provides maintenance and fixes in response to user needs. Addresses portability issues. Performs upgrades and modifications to software as directed. Supports software users by providing usage guidance and by keeping documentation synchronized with software revisions. Has knowledge of contemporary programming techniques and environments. Experience in software development and maintenance. Ability to quickly learn other software developer's design and implementation.

Equipment Technician

Responsible for configuring machine controller software and hardware interfaces for machining and inspection system. Assists with operation of shop floor equipment. Responsible for routine equipment maintenance. Assists in integration testing and production demonstrations. Understands use and interpretation of inspection analysis software. Has knowledge of equipment-specific software and hardware.

4.2 Equipment

This section describes the equipment required for development of the STEP Production Cell.

Computer Hardware

- 9 Unix Workstations with bit-mapped screen display devices
- 6 Personal Computers
- Local, Wide-Area, and Inter-Site Networks
- Laser Printers

Manufacturing Equipment

- 3-axis Milling Machine with accompanying control computers and interfaces
- Coordinate Measuring Machine with accompanying control computers and interfaces

4.3 Computer Software

- Database(s)
- Geometric Modeling Library
- Graphics Packages
- User Interface Toolkits
- Embeddable Process Planning
- Embeddable NC Programming
- Inspection Programming

5 Glossary

The following is a list of the terms used in this document and their definitions.

AP(s)

Application Protocol(s); used in this document to mean a specification of a subset of STEP data, context of this data, and usage of this data for the purposes of meaningful exchange between particular applications.

APC

Application Prototype Center; one of the four organizational elements under the umbrella of the National PDES Testbed.

CMM

Coordinate Measuring Machine; a computer driven machine which can be directed to take measurements on a part.

IGES

Initial Graphics Exchange Specification; an existing standard used largely for exchanging the computer representations of engineering drawings between Computer Aided Design systems.

IPO

IGES/PDES Organization; the voluntary organization in the US devoted to development of the IGES and STEP.

ISC

Information Services Center; one of the four organizational elements under the umbrella of the National PDES Testbed.

ISO

International Organization for Standardization; the international voluntary organization devoted to the development and setting of standards - STEP is just one of the many standards this organization is responsible for.

NC

Numerical Control; a historical term now generally used to mean the programs or means of controlling manufacturing equipment via computer.

NIST-IR

National Institute of Standards and Technology Internal Report; means a publicly available report describing work performed at NIST.

NPT

National PDES Testbed; the NIST facility devoted to development, testing, and dissemination of STEP.

NTIS

National Technical Information Service; an agency of the US government which provides the mechanism for distribution of other agency's technical reports, data, etc.

PCO

Program Coordination Office; one of the four organizational elements under the umbrella of the National PDES Testbed.

PDES

Product Data Exchange using STEP; it is a verb referring to the exchange of STEP data.

PDES, Inc.

An expanding consortium of companies formed in 1988 for the purpose of accelerating the development and use of STEP.

STC

Standards Testing Center; one of the four organizational elements under the umbrella of the National PDES Testbed.

STEP

Standard for the Exchange of Product Model Data; it is the proposed international standard.

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The Standard for The Exchange of Product model data (STEP) is an emerging international standard addressing the problems of data exchange for a variety of manufacturing enterprises. NIST has established the National PDES Testbed specifically to address the development and testing of STEP, and to serve US industry in their use of the standard. The STEP Production Cell is a machining system based on STEP data exchange. This system uses STEP data as the primary source for controlling part manufacturing. The STEP Production Cell demonstrates how STEP is used in a typical, small batch manufacturing system. The system serves to validate STEP technology in a manufacturing scenario. The plan for developing the STEP Production Cell over the next four years is described in this document.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)
STEP; PDES; Computer Integrated Manufacturing; data exchange standards; product modeling; standards validation; National PDES Testbed

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