NISTIR 5169

A National Testbed for Process Planning Research

Steven R. Ray
Allison Barnard Feeney

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

NIST

NISTIR 5169

A National Testbed for Process Planning Research

Steven R. Ray
Allison Barnard Feeney

U.S. DEPARTMENT OF COMMERCE
Ronald H. Brown
Secretary of Commerce

National Institute of Standards and Technology
Raymond G. Kammer
Acting Director

April 1993

Table of Contents

Abstract

The National Institute of Standards and Technology is in the process of establishing a testbed which will serve the research and information needs of the process planning community. This testbed is building up four primary services designed to facilitate the development of process planning technology: information services, workshops, a testing and integration laboratory, and a collaborative research program. Each of these services is described, along with their motivation and expected impact.

Keywords:

collaborative research program; information services; laboratory; process planning; process planning testbed; workshops

Introduction

This paper provides a description of the Process Planning Testbed at the National Institute of Standards and Technology. This document is intended for university, industrial and governmental process planning researchers who might benefit from the services and facilities offered, and for those who might be considering a collaboration with NIST in the area of manufacturing process planning. The project is sponsored by the Defense Advanced Research Projects Agency (DARPA) as part of a larger effort to consolidate and coordinate advanced manufacturing research [DARPA 1993].

The Process Planning Testbed Project began in December of 1991, with the long term objective of providing the following services to the process planning community:

- Information services
- Workshops
- Laboratory for testing and integration
- Collaborative research program

Each of these topics is discussed in more detail below.

The motivation for this project was to address a perceived lack of cohesion and communication among university, industrial, standardization and governmental personnel when tackling research and development problems in manufacturing process planning. Some of the negative results of this situation include redundant development projects and unnecessarily incompatible systems, both of which waste valuable research and development resources. The Process Planning Testbed Project seeks to reduce these problems by addressing each area in turn.

Technological solutions such as electronic networking and information repositories can ease many of the communication problems within the community. The establishment of consensus on an integrating infrastructure, on representations, and on communication protocols remains a critical challenge. For this, a series of workshops is ongoing. Finally, the migration of open architecture approaches to system integration are being encouraged by making a suite of tools available which enhance researcher productivity, once certain standard methodologies are adopted. These include EXPRESS (ISO Draft International Standard 10303-11) tools, as well as database code generators, sample part designs and process plans being defined at NIST.

Information services

Problem Description

Process planning is an interdisciplinary activity, and as such it lacks an easily identifiable supporting organization. There is no Process Planning Institute, or American Process Planning Association. This is symptomatic of the fact that process planning is often performed by personnel wearing several hats, be they machinists, designers or production engineers.

The result of this lack of a home is that it is quite difficult to remain current with all developments in the process planning arena, which increases the risk of duplicating research efforts and reduces the possibility of researchers learning from each other's experiences. The Testbed project has taken several measures to address this situation.

Email "Exploder"

One of the simplest steps to take was to provide a means of quickly and easily addressing the entire process planning academic research community, much as one might do at a conference. Since most academic researchers are connected to the Internet, this was easily accomplished by means of an electronic mail repeater, sometimes called an email exploder. (This approach is not as applicable to industrial researchers yet, but this is likely to change in the future). This approach involves an email address which, upon receiving an electronic mail transmission, sends it out to every address on a list maintained at an administration site. In this case, the address is `process-planning@cme.nist.gov`. At the time of publication of this document the list contained 89 names. Any incoming message is automatically routed to all the names on the list. A second address is also in place, in keeping with the conventions of Internet mailing lists, named `process-planning-request@cme.nist.gov`. It is used for administrative requests, such as being added to or removed from the list.

Citation Database

In addition to enabling a healthy dialogue within the process planning research community, there was also a perceived need to provide assistance in directing researchers to the key publications in the field. This need was addressed by establishing a bibliographic citation database dedicated to process planning research and closely related activities, which was established in June of 1992. Unlike other library citation database systems, this system supports the addition of user comments and a score for every citation. Thus, not only does it encourage a bidirectional flow of information, it also provides the unique service of steering the user's search toward what are deemed by the research community to be the seminal works in the field. Clearly, libraries cannot provide such guidance – it must come from the researchers themselves. The database system captures this feedback. More details on the citation database can be found in [Feeney 1992], or by sending an email inquiry to `pptb@cme.nist.gov.`

Hardcopy Distribution Service

To complement the citation database, the possibility of providing a hardcopy distribution service is also being pursued at NIST. This would allow the database user, upon finding an interesting citation in the database, to simply request that the full text be sent to him or her, either by post or fax for example. If such a facility were established, then the population of the citation database would no longer be restricted to publicly available archival publications. Material such as presentation slides of interesting seminars could be added, since one would not have to use one's own library to retrieve the actual document. This service is not yet being offered, pending legal, copyright and NIST policy issue resolution.

Electronic Journal

To further enhance the sharing of research results, the possibility of establishing an Electronic Journal Of Process Planning Research is being explored. This journal would be established to meet three primary objectives:

- To provide an archival source of information focused on process planning.
- To exploit new electronic means of disseminating this information.
- To provide this information inexpensively, in response to the continuing escalation of subscription fees to the academic journals.

Such a publication is not without precedent. There are at least 10 peer-reviewed electronic journals in circulation today [Strangelove 1992]. This effort may be pursued as a joint venture with some private organization such as a consortium or association.

WAIS, Gopher, WWW

With the emergence of new technologies to support information access and transfer, several additional mechanisms are planned to support the distribution of information from the Process Planning Testbed. These include the WAIS (Wide Area Information Server) protocol and services, Gopher, and WWW (World Wide Web). Some of these technologies are beginning to see explosive growth, particularly within the information sciences community, but also in other disciplines. The Testbed project intends to pursue the incorporation of as many of these services as seems reasonable with the resource allocations available. A brief summary of these services is given below.

WAIS is a protocol which supports searching for arbitrary information in over 350 WAIS databases available on the Internet. WAIS is based upon a federated client-server model, and implementations exist for both servers and clients for most commonly used hardware platforms and operating systems. Gopher is similar in many respects, except that it favors a browsing type of interaction in contrast to the more focused searching supported by WAIS. Thus, if you know what you are looking for, but don't know where to find it, WAIS is more appropriate. If you are exploring to discover what information is available on the Internet, then Gopher is the more appropriate approach. WWW, as described in [Connolly 1992], is:

> "... a global hypertext project which defines a hypertext data format (HTML, the HyperText Markup Language), an addressing scheme that makes FTP, WAIS, Gopher, NNTP, and HTTP (their own protocol) objects addressable, and provides some client and server software."

To some extent, WAIS, Gopher and WWW are interoperable, in that they can exchange many of their file formats.

Workshops

Motivation

There were several motivations for organizing a series of workshops. One was to enhance the ability of academic researchers to use each other's results. Another was to enhance communication and cooperation among process planning researchers, industry, and relevant standardization and governmental organizations. Several steps were seen as necessary to achieve these goals. These included consensus on a functional definition for process planning, the definition of a unified infrastructure for process planning systems, and the establishment of positions on key issues within process planning. Secondary goals were the identification of similarities and differences in process planning architectures, recognition of the value of consensus of process planning architectures to future process planning research, and identification of consensus information models to support process planning.

The strategy adopted was to hold several meetings primarily involving the academic process planning community. A similarly structured meeting for the industrial community is planned for the spring of 1993. Then, both perspectives will be represented at a subsequent meeting, tentatively scheduled for late 1993 or early 1994. During this time, position papers will be developed to facilitate the exchange of ideas, needs, and perspectives of the various communities.

Texas A&M Workshop

On August 5-6, 1991, a group of process planning researchers gathered at Texas A&M University for the first of these workshops. The workshop was co-sponsored by the National Institute of Standards and Technology (NIST) and Texas A&M University and co-chaired by Steven Ray of NIST, and Richard Wysk of Texas A&M. A brief summary of the workshop is provided in Appendix A. By the end of the meeting, the participants had agreed on a number of umbrella concepts and approaches to facilitate cooperation within the academic community.

NIST Workshop

On August 10-11, 1992, a second workshop was held, at NIST. This workshop built upon the results achieved at the first meeting. Topics of discussion centered around two themes: foundational issues, and architectural issues. Foundation topics included the identification of data requirements to support process planning (input and output), as well as a discussion of the relationships among process capabilities, manufacturing resources, and feature libraries. Architectural topics addressed the functional breakdown of the process planning activity, characterization of different levels of process planning, interaction of process planning with upstream and downstream manufacturing functions, enumeration of different planning domains within manufacturing, and key sources of information on process planning.

A number of action items resulted from this workshop, which helped encourage a mutually supporting sense of community among process planning researchers. These actions included the drafting of a white paper describing the components of process planning, the creation of a process planning repository as described in this paper, the collection and sharing of information on new publications in the field, and the generation of recommendations for community-wide adoption of various approaches to process planning research including specification languages, communication protocols, and representation models. These last recommendations in particular highlighted the problems currently impeding the sharing of results among researchers. Adoption of consensus positions on these problems should facilitate more interoperation of research planning systems and sharing of information among projects.

Laboratory for testing and integration

Goals

As part of the longer term objectives for the testbed, an open laboratory is being created. This laboratory is based upon an integrating framework as defined by the process planning and standardization communities, to allow the testing and experimentation of various combinations of planning systems. The need for an integrating framework arises because process planning systems in the future will likely be built from multiple subsystems, or modules, each of which handles an aspect of process planning. These modules could be expert systems, algorithmic systems or interactive systems. In order to integrate these various modules, a number of standard approaches are needed, in terms of data models, interfaces, protocols, and methodology.

The creation of the Process Planning Testbed will be modeled after the Engineering Design Testbed [Feeney 1991] in place at NIST. Standardized facilities will be available, such as databases supporting standard process planning support models, common interface protocols and platforms, and software development and validation tools (see Figure 1, and Appendix B for functional specifications). The intention is to encourage researchers from other institutions to bring their work to the Testbed in order to integrate it with other related systems, promote the awareness of developers to other work, and to encourage the adoption of existing and emerging standards in new systems. This is only possible in an open, non-competitive atmosphere, where financial gain is not an issue.

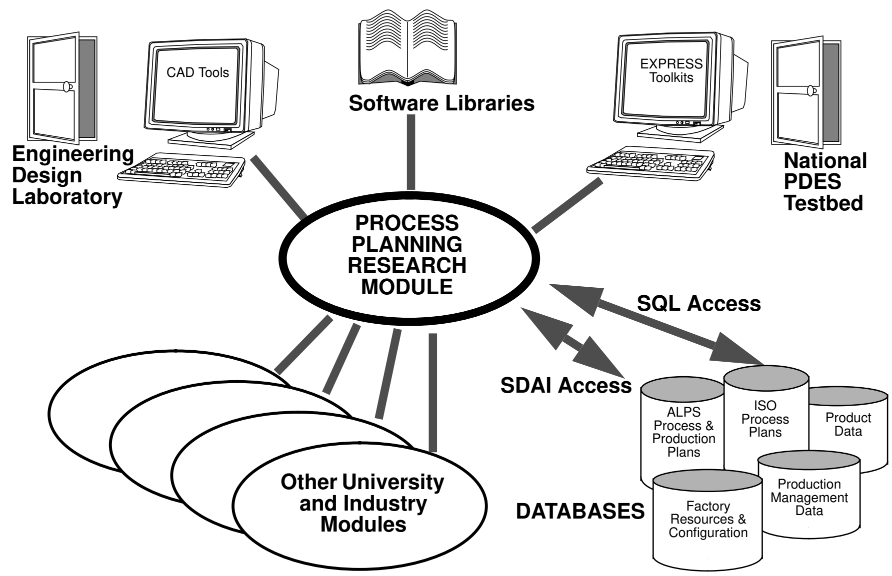

FIGURE 1. Conceptual Diagram of the Process Planning Testbed Laboratory

Process planning functions must ultimately be integrated with upstream (engineering) and downstream (production) functions in order to achieve full system integration. NIST will provide the process planning community with access to NIST's active research in other stages of manufacturing information technology development, [Bloom 1992, McLean 1990, Senehi 1992].

Repository

Based upon feedback from the second workshop, the process planning community is calling for a single repository for contributed process planning systems from both the academic and commercial worlds, as well as sample part descriptions, process plans, factory models and supporting testbed documents. Given this mandate, we are establishing such a repository here at NIST, which would be accessible both physically and via the Internet*.

<u>Contributed systems</u>: The underlying motivation of the Testbed laboratory is to encourage researchers from other institutions to bring their work to the Testbed in order to integrate it with other related systems, promote the awareness of developers to other work, and to encourage the adoption of existing and emerging standards in new systems. Therefore, we expect a variety of process planning systems to be installed during the coming years, which will not only facilitate the integration of these systems, but also will give users a chance to assess the relative merits of various approaches to process planning.

The repository will also include database implementations and sample populations of:

- Product models (ISO 10303, also informally known as STEP) [ISO 1992]
- the ISO Process Plan model (ISO 10303, Part 49) [ISO 1992]
- the ALPS (A Language for Process Specification) model [Catron 1991, Ray 1992]

* Much of this information will be available for anonymous ftp downloading at ftp.cme.nist.gov.

- Factory Resource models (to be determined by TC184/SC4/WG3, WG8, or by the process planning community)

Product Models: Provision of sample part designs will be accomplished in cooperation with the DARPA-sponsored Engineering Design Laboratory [Feeney 1991] already in place at NIST.

Process Plans: ALPS was defined primarily to be a process plan representation after the creation of a plan, until its execution by an automated controller or a human machinist. The ISO Process Plan model is focused even more tightly, specifically supporting the output of a process planning system, but not directly supporting automated execution. Some work is underway at NIST on implementing database support for the emerging ISO process plan model. Thus, depending on the outcome of ongoing qualification efforts within ISO, both representation schemes will soon be available.

Factory Resource Models: One important information source for process planning is a complete and unambiguous characterization of a given manufacturing facility. This characterization would include at a minimum, capability models of the manufacturing resources. If production management concerns are to be taken into account during process planning, information about capacities and inventories must also be supported. The dynamic factory management information needed to run a factory is the focus of ISO TC184/SC4/WG8 (Industrial Manufacturing Management Data). The specification of the somewhat more static capability models for a factory have not yet been formally undertaken as a work item within the ISO community. Therefore, the Testbed may be forced to adopt an interim representation for this information, based upon input from the process planning community.

Tools

The laboratory will continue to grow in the number of tools it offers to collaborators. During the second year, efforts will focus on the provision of database access libraries, and sample populations of part designs, factory resource models, and process plans. These tools will be based upon an integrating framework as defined by the process planning and standardization communities, to allow the testing and experimentation of various combinations of planning systems. The need for an integrating framework arises because process planning systems in the future will likely be built from multiple subsystems, or modules, each of which handles an aspect of process planning. These modules could be expert systems, algorithmic systems or interactive systems. In order to integrate these various modules, a number of standard approaches are needed, in terms of data models, interfaces, protocols, and methodology.

EXPRESS tools: One important subset of these tools concerns the use of EXPRESS. The ISO document describing EXPRESS (ISO 10303-11, see [ISO 1992]) states that "it provides for specification of the objects belonging to a universe of discourse, the information units pertaining to those objects and the constraints on those objects." Most importantly, the EXPRESS language is computer interpretable, which allows the automatic generation of model-based applications, such as databases, access libraries, parsers, report generators, and data dictionaries. It is this aspect of the EXPRESS methodology which offers tremendous productivity improvement to researchers and developers in the manufacturing arena. To maximize the benefits offered by EXPRESS, the full suite of EXPRESS methodology tools will be available as part of the Process Planning Testbed Laboratory.

Database tools: Somewhat related to the EXPRESS tools, additional capabilities will be available to allow the user to access and browse supporting databases, both at the data (population) level, and at the schema (model) level. Some of these tools are themselves the products of EXPRESS-based productivity enhancement tools, while others are commercial products.

Physical versus Virtual Laboratory

In establishing a laboratory for collaboration in process planning research, attention has been paid to the fact that physical collocation is not a prerequisite for meaningful and productive cooperation. By taking advantage of the current information revolution and its technology, the laboratory will be built as an open, network-accessible facility. This work is very much in the spirit of a "collaboratory" as described in [NAS 1993].

Collaborative research program

In addition to the research facilitation services being put in place as part of this program, there will also be an ongoing research program in its own right. The nature of the research will initially address research issues closely related to the support of integration of process planning system with each other, and with other external manufacturing functions.

Representation Issues

One such area concerns the definition of appropriate and robust representation schemes to support process planning, including inputs, intermediate information constructs, and outputs. Some of this work is already the topic of formal standardization efforts, notably the product data standards known as STEP (Standard for the Exchange of Product Model Data, ISO 10303), and related efforts such as the ISO Process Plan Model, mentioned earlier. A far more challenging problem is the structuring of intermediate information which must be maintained to support the collaborative formulation of a process plan by multiple sub-modules. This intermediate information will require rich semantic support for constraints, partial goals and solutions, and incomplete or ill-defined knowledge.

Supporting Models

In addition to representing partial and completed process plans, there is also a need for consensus on a number of other supporting models and communication protocols. Examples include factory capability models, factory status models, system configuration models, and protocols to support intra-planner communications as well as communication with upstream (design) and downstream (production) functions. Attacking all of these areas is clearly a formidable task, so they will addressed at some realistic pace.

Future plans

After the start-up period, expected to last a total of three or four years, the Process Planning Testbed is expected to be in a "steady state" phase of operation. At that stage, there will be full support for on-line retrieval of process planning citations, a full-text delivery system, and a solid body of peer commentary on process planning literature available. The Electronic Journal Of Process Planning Research will be in production, providing an avenue for archival publications which addresses both the long lead times of traditional journals, as well as the rapidly increasing costs of journal subscriptions which is causing many libraries to cancel subscriptions to many periodicals. Much like an "Institute for Advanced Studies in Process Planning" there will be a regular presence of two or three guest researchers, who will be formulating and testing new ideas in process planning research, taking advantage of the infrastructure in place here to accelerate their own progress in realizing those ideas.

In the steady state mode of operation, new tools and techniques will be continually provided as the relevant technologies are brought to bear on process planning problems. At this point, the Process Planning Testbed should have established itself in the eyes of the worldwide process planning community as a fertile location for "recharging" oneself with ideas, and facilitating rapid prototyping of systems.

There are a number of additional roles which could be taken on by the Testbed. Some of these are listed below, and could be considered when the time is appropriate.

- The establishment of a funding tracking database. This could be modeled after some of the services provided by the National Science Foundation, which provides electronic access to information on all grants awarded by the NSF. The process planning testbed database would be targeted at tracking all process planning research grants, regardless of sponsor. This should help avoid duplication of efforts which waste valuable research dollars.
- The establishment of a validation testing service, as relevant process planning standards mature. It is widely accepted that a critical element of any new standardization process is the provision of testing and validation services. NIST has a great deal of experience with the techniques necessary to perform conformance testing, interoperability testing, and validation testing of standards [Breese 1991].

Disclaimer

Certain commercial equipment, instruments, or materials are identified in this paper. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the products identified are necessarily the best available for the purpose.

Acknowledgment

This work was funded by the Defense Advanced Research Projects Agency (DARPA) under ARPA Order Number 8609.

References

Bloom 1992 H.M. Bloom & L.W. Masters, "The Technical Program of the Factory Automation Systems Division 1992, NIST Interagency Report 4856, 1992.

Breese 1991 J.N. Breese, M. McLay, G. Silvernale, "The Validation Testing Laboratory User's Guide," NIST Interagency Report 4683, 1991.

Catron 1991 — B.A. Catron, & S.R. Ray, "ALPS: A Language for Process Specification," *International Journal of Computer Integrated Manufacturing*, 4, 2, 1991.

Connolly 1992 — D. Connolly, "Re: MIME and WWW?" *Usenet newsgroup comp.infosystems.wais*, message from connolly@convex.com of 17 Nov, 1992, 01:37:51 GMT.

DARPA 1993 — DARPA Manufacturing Automation and Design Engineering (MADE) Program, Broad Agency Announcement BAA #93-xx, Commerce Business Daily, March xx, 1993.

Feeney 1991 — A. Barnard Feeney, "Engineering Design Laboratory Guide," NIST Interagency Report 4519, 1991.

Feeney 1992 — A. Barnard Feeney, "User's Guide to the On-Line Bibliographic Reference System for the NIST Process Planning Testbed," NIST Interagency Report 4891, 1992.

ISO 1992 — ISO 10303-n, Product Data Representation and Exchange, ISO TC184/SC4 Secretariat, Gaithersburg, MD. (Available from the IGES/PDES/STEP Administration Office, National Institute of Standards and Technology, Building 220, Room A127, Gaithersburg, MD 20899.)

McLean 1990 — C. McLean, "National PDES Testbed Strategic Plan 1990," NIST Interagency Report 4438, 1990.

NAS 1993 — National Academy of Sciences, "Toward National Collaboratories: Establishing User-Developer Partnerships," National Academy Press, Washington, D.C., 1993 (in press).

Ray 1992 — S.R. Ray, "Using the ALPS Process Plan Model," Proceedings of the ASME Manufacturing International Conference, Dallas, Texas, March 1992.

Strangelove 1992 — M. Strangelove, "Directory of Electronic Journals and Newsletters," send the following commands as an e-mail message to `listserv@acadvm1.uottawa.ca`

```
GET EJOURNL1 DIRECTRY
GET EJOURNL2 DIRECTRY
```

Appendix A

Summary of the Workshop on Process Planning Concepts, Representations and Architectures

On August 5-6, 1991, a group of process planning researchers gathered at Texas A&M University to discuss a number of issues related to process planning. The workshop was co-sponsored by the National Institute of Standards and Technology (NIST) and Texas A&M University and co-chaired by Steven Ray of NIST, and Richard Wysk of Texas A&M. There were several motivations for this meeting. One was a desire to enhance the ability of academic researchers to use each other's results. Another was to enhance communication between process planning researchers and relevant standardization committees.

Goals

A number of specific goals for the meeting were identified early on. These included a functional definition for process planning, the definition of a unified infrastructure for process planning systems, and the establishment of positions on key issues within process planning. Secondary goals were the identification of similarities and differences in process planning architectures, recognition of the value of consensus of process planning architectures to future process planning research, identification of consensus information models to support process planning.

Definition of Process Planning

The group defined process planning as: *"Creating work instructions to realize a product or goal that meets customer requirements. A work instruction is the specification of an activity and the resources to perform the activity."* Process planning as viewed by this group is primarily in the domain of discrete manufacturing activities.

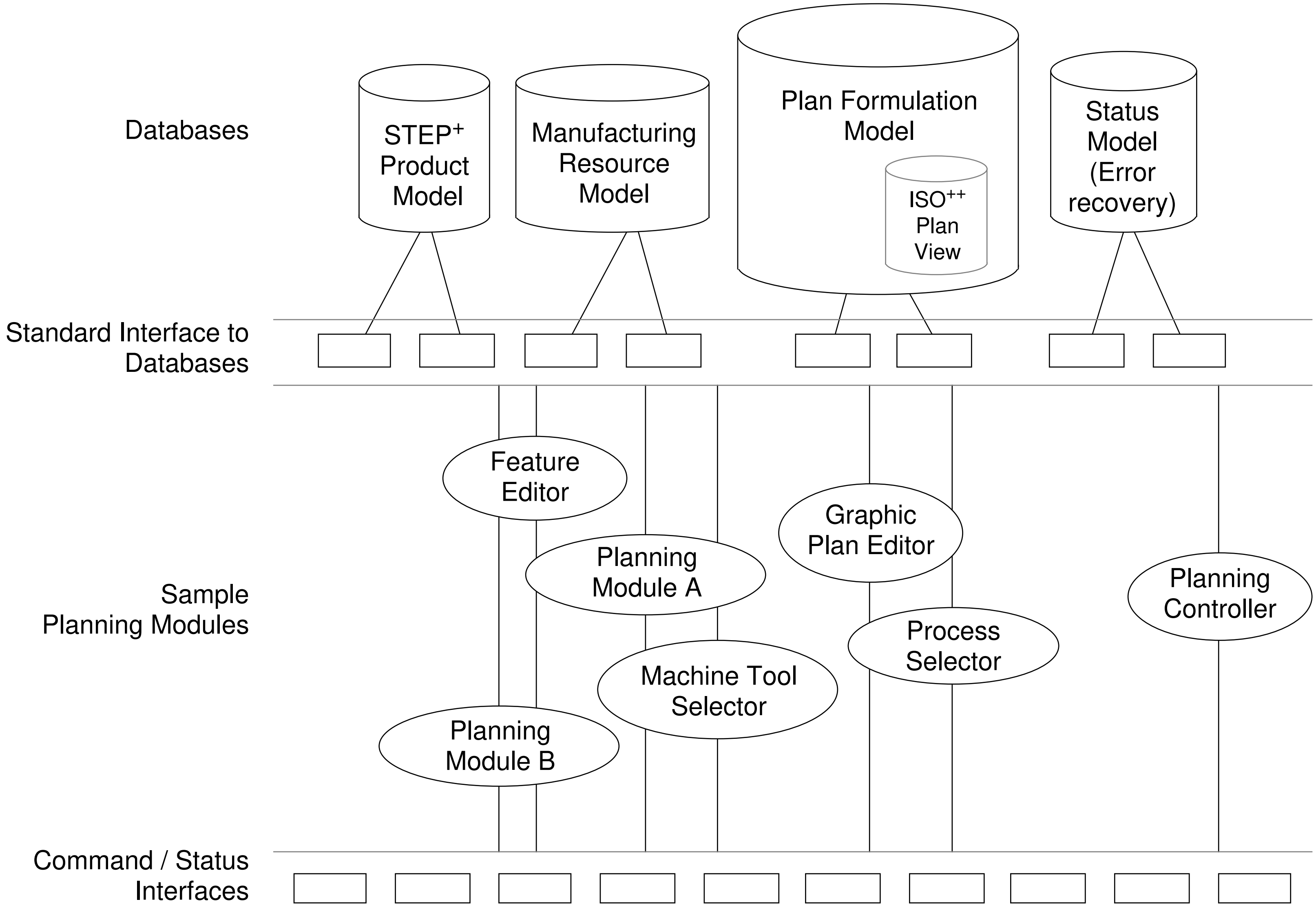

Figure 1. This is the infrastructure adopted by the attendees of the Workshop on Process Planning Concepts, Representations and Architectures, as an integrating framework for process planning research.

Resolutions

After 1 1/2 days of discussion, the following positions evolved:

1. To adopt the infrastructure as shown in Figure 1*.
2. To adopt the ISO TC184/SC4/WG3/P11 Process Plan Model, with extensions, for plan representation.
3. To endorse the use of the ISO Process Plan Model as a formalized view of a larger, “complete” plan formulation model which has an as yet undefined structure.
4. To adopt the STEP Model (ISO 10303), with possible extensions, for product definition input.
5. To create a forum for the exchange of process planning research information, by means of:
   a) An electronic newsgroup, or mailing list, for open discussion.
   b) An electronic annotated bibliographic service.
   c) A process planning library service.
   d) An annual workshop to assess needs and progress.
6. To call for a manufacturing resource model which will enable collaborative research in process planning.
7. We see the following list of activities as candidate process planning modules within our adopted infrastructure.
   strategic planning
   execution planning
   process selection
   resource selection
   process design
   design feedback
   error recovery
   process ordering
   process deconfliction
   process optimization
   product interpretation
   process grouping
   equipment programming
   operation instruction authoring
   parameter specification
   tooling design
   fixture design
   inspection design
   setup requirements
   intermediate product descriptions
   stock selection
8. We anticipate the plan formulation model is likely to contain the following:
   geometric relationships
   physical relationships
   situation relationships

* The superscripts in the figure, specifically STEP+ and ISO++ are intended to mean the respective models, with extensions as deemed necessary.

plan fragments
temporal relationships
metrics
* efficiency
* fidelity
planning assumptions
planning premise
functional constraints
manufacturing strategy
materials planning strategy
planning status

... to serve as a scratch pad and as an interface to other CIM activities.

The workshop was intended to create a group identity for the process planning research community. Since there is no identifiable forum dedicated to process planning research issues, the intent was to provide a mechanism to encourage the timely and free interchange of ideas and results. Other research issues requiring attention were identified in the areas of supporting technologies, standards, representation, storage and access, and implementation. It was felt by the group that there is no identifiable source currently taking responsibility for funding process planning research. The pronounced lack of funding inhibits significant progress.

Appendix B

Functional Requirements for the Process Planning Testbed Laboratory

Below is a listing of the functional capabilities projected for the Process Planning Testbed Laboratory during Fiscal Year 1993.

Support Tools and Technologies

Computer systems
- Sun* Workstations

Operating systems
- Unix™ (SunOS 4.x)

Database management systems
- Matisse† 2.x
- EXPRESS‡-to-Matisse schema generator
- SDAI**-Matisse library generator
- Matisse schema browser
- Matisse ad hoc population browser

Computer languages
- C, C++, Lucid Common Lisp
- Compilers, linking capabilities
- Development environments (to be researched)

Application Systems

ALPS applications
- Graphical Editor
- Plan traversal algorithm
- File-to-database translator

---

* Sun Microsystems, Inc.

† Sold by Object Databases, Inc.

‡ As defined in ISO 10303-11.

** Standard Data Access Interface (ISO 10303-22)

- Database-to-file generator
- ALPS plan copy capability
- ISO plan file-to-ALPS file translator
- ALPS file-to-ISO plan file translator

ISO plan applications
- ISO plan file-to-ALPS file translator
- ALPS file-to-ISO plan file translator

Factory resource model applications
- Resource schema definition
- Matisse implementation of resource schema
- Physical file and/or report generation facility

Repository

- Part designs (files)
- Supporting process plans for these parts, plus others (files in ALPS and Matisse)
- Resource model populations in Matisse

Electronic Library Services

- FTP (file transfer protocol) capabilities
- Serial line access for telephone dial-in, to support file downloads via Kermit and X-modem
- Mail service, for automated distribution of files upon request via electronic mail (email)
- MIME protocol, a multi-medial extension to electronic mail
- LISTSERV service, to support automatic maintenance of email mailing lists and discussion groups, or equivalent.
- WAIS (Wide Area Information Service) utilities for indexing and accessing WAIS databases
- Gopher services, providing browsing capabilities for Gopher systems
- WWW (World wide web) services (to be looked into)
- Remote interactive services, including:
  IRX database of process planning citations
  TTY-oriented contributed process planning software (Unix only)
  X-11 based remote operation of selected software applications, as determined throughout the year.