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Testbed Requirements and Implementation Plan for the Rapid Response Manufacturing Intramural Project

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Executive Summary

One of the primary focus areas of the NIST Rapid Response Manufacturing (RRM) intramural project is to establish an RRM Testbed Laboratory. This RRM Testbed Laboratory will serve as a facility where collaborators can investigate interoperability between systems within the RRM engineering environment, experiment with the use of technology and standards as applied to RRM, perform exploratory system integration studies, and address information technology barriers to RRM. This testbed facility will be one of several facilities available for use by the National Center for Manufacturing Sciences (NCMS) RRM researchers. The purpose for this report is to identify the objectives and requirements of the NIST RRM Testbed and to document an Implementation Plan for establishing the testbed facility. The technical requirements of the RRM Testbed are grouped into the following four categories: Functional Aspects, Computer / Equipment / Support, Physical Facility, and Administrative / Operational Procedures. Several requirements are provided for each category. This report also addresses the Critical Success Factors to be considered during testbed requirements development and provides a detailed implementation schedule of required activities and durations.

Key Words: ATP, Implementation Plan, intramural, NCMS, RRM, Rapid Response Manufacturing, requirements, testbed

Introduction

The NIST Rapid Response Manufacturing (RRM) Project is sponsored as an intramural project through the NIST Advanced Technology Program (ATP) office[1] [1]. This ATP intramural project is managed and executed through the NIST Factory Automation Systems Division (FASD).

The principal objective of the RRM intramural project is to establish collaborations with the National Center for Manufacturing Sciences (NCMS) RRM consortium members and to leverage NIST skills and technologies to ensure the advancement of RRM capabilities. With this objective in mind, the RRM intramural project was initiated to build expertise and increase awareness of engineering and manufacturing technologies being applied to improve the process of rapid response manufacturing. The RRM consortium intends to enhance and adopt key technologies to enable use of advanced, highly-integrated systems for manufacturing.

One of the primary activities of the RRM intramural project is to establish an RRM Testbed Laboratory at NIST which emulates the system architecture proposed for the NCMS RRM integrated engineering environment. Development of this facility will draw upon experience

1. Advanced Technology Program, U.S. Department of Commerce, Technology Administration, National Institute of Standards and Technology, Administration Building, Room A430, Gaithersburg, MD 20899.

gained through the NIST Automated Manufacturing Research Facility (AMRF) research program [2], the National PDES Testbed [3], and related FASD research activities. The RRM Testbed Laboratory will be established to serve as a neutral arena for the comparison, integration, prototype development, and evaluation of software and hardware components designed for the RRM environment.

This NIST RRM Testbed will be used by both NCMS and NIST RRM researchers to test integration concepts, incorporate standards, validate and demonstrate results of research and development efforts, and ensure the success of the RRM effort. This testbed will also serve as a facility where collaborators can investigate interoperability between systems within the RRM engineering environment, experiment with the use of technology and standards as applied to RRM, perform exploratory system integration studies, and address information technology barriers to RRM.

The NIST RRM Testbed will be developed and operated in conjunction with other testbed facilities implemented by NCMS RRM member companies. The primary NCMS RRM testbed facility will be the “Central Site Facility” at Ford Motor Company. Satellite testbeds are also expected to be implemented at other NCMS RRM member companies. The requirements of the NIST RRM Testbed provided in this report recognize the need for well-defined interactions between each of these testbed facilities. These facilities will inherently have some overlap and duplication of capabilities due to the distributed nature of RRM Project activities and the need of each participant to address site-specific objectives.

The NIST RRM Testbed is envisioned as a unique satellite site which provides a neutral environment for development, evaluation, and demonstration of RRM applications. Another characteristic of the NIST facility includes visibility of project results and activities through frequent visits by industry, government, and academic manufacturing experts. Electronic access of the NIST RRM Testbed and information server capabilities will also be available.

The NIST RRM Testbed will be implemented in a phased approach to provide an initial capability as early as possible in the overall RRM program, with the ability to update testbed functionality as technologies and applications mature. The primary deliverable for this effort during the first year of the RRM intramural project is a demonstration of an operational initial implementation of the RRM Testbed Laboratory. This deliverable will be measured based upon the capability for NCMS RRM consortium members and NIST RRM staff to use the testbed facility, either on-site or remotely, for the research and development activities intended for the testbed.

Testbed Objectives

The initial phase of the NIST RRM Testbed will support the activities of the FASD RRM project team and the NCMS RRM Consortium technical teams. In future implementations, it is expected that the RRM Testbed will also support activities of other FASD projects relating to manufacturing automation research. Specifically, the NIST RRM Testbed seeks to satisfy the following objectives:

- Serve as a neutral arena for comparison, integration, and testing of software/hardware components for RRM engineering and manufacturing systems
- Serve as a conduit of information on issues and advancements in RRM-related technologies
- Provide capabilities to demonstrate and showcase RRM technology and results
- Provide facilities for the testing and integrating computer standards related to RRM
- Provide facilities in which to evaluate architecture design and interface specifications for the integrated engineering environment

and in future implementations:

- Serve as a mechanism for bringing internal FASD projects together to provide a division-wide resource for manufacturing automation research

Testbed Technical Requirements

This section discusses the technical requirements of the NIST RRM Testbed Laboratory. These requirements are grouped into the following categories:

A. Functional Aspects

B. Computer / Equipment / Support

C. Physical Facility

D. Administrative / Operational Procedures

Requirements for the NIST RRM Testbed were developed based upon input from both internal and external sources. Of primary importance is the information received through participation on the NCMS RRM consortium technical committees. The NCMS Direct Manufacturing, Reference Architecture, and Engineering Environment technical committees provided information on both the as-is and to-be computing and manufacturing environments within the consortium member companies. This information was obtained by the NCMS RRM participants through surveys of appropriate end-user customers.

Additional RRM Testbed requirements were formed based upon an analysis of existing FASD

testbed capabilities. Testbed facilities, including the National PDES Testbed, the Engineering Design Laboratory [4], and the Process Planning Testbed [5], were reviewed to determine available capabilities and functionality, and to assess typical customer expectations of a testbed operation. The RRM Testbed Laboratory will leverage available capabilities whenever possible and will strive for minimal overlap between existing testbeds. Information obtained during this review provided several lessons learned and substantial guidance for use during development and implementation of the RRM Testbed. Results of this FASD testbed review are provided in Appendix A.

Within each high-level category (A, B, C, or D as listed above), the technical requirements are further grouped into lower-level sub-categories (identified below by **Bold-faced Topic Headings**). Each sub-category can have several technical requirements associated with it. For each technical requirement, a brief description is provided, as well as a description of the corresponding solution to this requirement as selected by the RRM Project Team. For certain requirements additional background is provided to explain the selection of a particular solution.

A. Functional Aspects

The Testbed Functional Aspects category consists of testbed requirements that determine how the testbed facility will be used and what types of applications will be supported by testbed resources. This category will include a definition of expected staff activities within the facility and specific types of software applications that must be available.

Intended Uses of Testbed Facility

Requirement A.1: The NIST RRM Testbed must provide a mechanism for direct interaction between FASD RRM and NCMS RRM project staff.

Solution A.1: This requirement will be satisfied through the following:

- Providing conference room facilities for joint meetings held at NIST
- Establishing network communication capabilities to the Internet network for electronic mail, file transfer, and remote logins
- Scheduling technical project reviews and demonstrations at the testbed facility

Requirement A.2: The NIST RRM Testbed must provide a mechanism for demonstrations of RRM system functionality.

Solution A.2: The layout of the testbed facility will be designed such that workstations, project posters, and other demonstration materials will be along the walls, with the center portion of the room available for the demonstration audience.

Testbed Technical Requirements

Requirement A.3: The NIST RRM Testbed must provide a mechanism for NCMS consortium technical teams to test and integrate RRM software components.

Solution A.3: RRM software components, including engineering applications and software development tools, will be installed in the NIST RRM Testbed. Documentation on the testbed facility and the software components will also be available. NCMS consortium technical teams will have full access to the software and other resources of the testbed facility to perform testing and integration of RRM software components.

Requirement A.4: The NIST RRM Testbed must provide a mechanism for NCMS consortium technical teams to implement and evaluate RRM-related computer standards.

Solution A.4: RRM software components and supporting documentation will be available in the NIST testbed. Software components that conform to specific standards can be installed, evaluated, and integrated within the context of RRM. NCMS consortium technical teams will have full access to the software and other resources of the testbed facility to implement and evaluate RRM-related computer standards. In addition, arrangements can be made for the NIST RRM Testbed to have access to the resources (e.g., software tools, facilities, personnel) of the NIST National PDES Testbed on an as-needed and as-available basis.

Requirement A.5: The NIST RRM Testbed must provide a mechanism for prototyping and evaluating RRM applications.

Solution A.5: RRM software components, including engineering applications and software development tools, will be installed in the NIST testbed. Documentation of the testbed facility and the software components will also be available. NCMS consortium technical teams, as well as FASD RRM staff, will have full access to the software and other resources of the testbed facility in order to prototype and evaluate RRM applications.

Background A.5: Actual prototyping and evaluation capabilities within the NIST RRM Testbed will be limited by hardware and software availability. These activities will be limited to strictly software prototyping and evaluation (e.g., computer simulation) for FY93. Funding is not available to procure desktop manufacturing equipment for the testbed facility during FY93. This equipment would be a valuable resource for prototyping and evaluation activities. Project staff will continue to pursue a desktop manufacturing capability for future use in the NIST RRM Testbed.

Requirement A.6: The NIST RRM Testbed must provide a mechanism to track and maintain configuration control between NIST and the NCMS RRM testbed facilities (both Central Site and satellite). Items potentially requiring configuration control include software, data, information models, documentation, and computer environments.

Solution A.6: Configuration control policies and procedures defined by the NCMS RRM consortium for interaction among NCMS testbed facilities will be instituted as appropriate by the NIST RRM Testbed. Efforts will be made to replicate the environment of the NCMS RRM Central Site as closely as possible, while still satisfying all objectives of the NIST RRM Testbed.

Requirement A.7: The NIST RRM Testbed must provide a suitable environment for meetings.

Solution A.7: Conference room equipment and furniture, such as a conference table, chairs, overhead projector, screen, whiteboard, etc., will be installed in the testbed facility. In addition, policies and procedures will be established for scheduling use of the facility.

Requirement A.8: The NIST RRM Testbed must provide a library and information resource capability for project researchers to obtain RRM-related information.

Solution A.8: Bookshelves will be installed to store RRM library information. Appropriate reference material from journals and textbooks will be selected and obtained to place in the library. Software documentation and product literature for all applications installed in the testbed will be kept within the facility. Electronic access to various bibliographic services, file transfer sites, and other information sources will be available through standard Internet network communications. Services of the NIST and NCMS Information Centers will also be available to RRM researchers.

Background A.8: Electronic access to various bibliographic services, file transfer sites, and other information sources will be fully pursued and documented during the second year of RRM Testbed operation. This capability is recognized as important, but sufficient resources will not be available during first-year testbed initiation activities to develop user-friendly access to these services. Another option that will be investigated is to establish NIST as an information server for RRM-related technical information.

Requirement A.9: The NIST RRM Testbed must provide a mechanism to help NIST RRM staff perform the R&D Program State-of-the-Art (SOTA) Assessments.

Solution A.9: The RRM Testbed library and information resources will be available to help RRM staff perform SOTA assessments. The software tools and applications within the testbed will also assist in this activity.

Background A.9: The RRM Testbed will not be the only mechanism used by RRM staff to perform the SOTA Assessments. Other facilities and resources (e.g., NIST Research Information Center, NCMS Manufacturing Information Resource Center, other NCMS RRM satellite testbeds) will be available and used during this research.

RRM Software Applications

Requirement A.10: The NIST RRM Testbed must support electronic access to the software applications selected by the NCMS RRM technical teams as being key components of the RRM Engineering Environment.

Solution A.10: NIST RRM staff will participate on the RRM Engineering Environment Committee to obtain NCMS requirements for available software applications. Without explicit guidance from NCMS, NIST will install only those applications deemed necessary by NIST RRM staff.

Requirement A.11: The NIST RRM Testbed must provide access to appropriate Engineering Applications and CAD/CAM systems selected to be within the RRM Engineering Environment.

Solution A.11: Appropriate Engineering Applications and CAD/CAM systems will be selected based on NIST RRM Project needs and interactions with the NCMS Engineering Environment Committee. These Engineering Applications and CAD/CAM systems will then be installed in the NIST RRM Testbed. Potential applications include the following:

- Parametric Technologies ProEngineer
- Unigraphics
- Spatial Technologies ACIS and Strata
- ICAD
- Aries Technology
- Cimplex
- Manufacturing Simulation Package
- Process Planning System
- NCMS Prototypes

Requirement A.12: The NIST RRM Testbed must provide access to appropriate Administrative and Management Software Tools selected to be within the RRM Engineering Environment.

Solution A.12: Appropriate Administrative and Management Software Tools will be selected based on NIST RRM Project needs and interactions with the NCMS Engineering Environment Committee. These Administrative and Management Software Tools will then be installed in the NIST RRM Testbed. Potential software systems include the following:

- ProductTrack (Cimflex)
- Concurrent Engineering Data Management Tools
- Configuration Management Tools

- Sun and PC Productivity Software
  Emacs
  FrameMaker
  Wordperfect
- Timeline project management software

Requirement A.13: The NIST RRM Testbed must provide access to appropriate Software and Application Development Tools selected to be within the RRM Engineering Environment.

Solution A.13: Appropriate Software and Application Development Tools will be selected based on NIST RRM Project needs and interactions with the NCMS Engineering Environment Committee. These Software and Application Development Tools will then be installed in the NIST RRM Testbed. Potential software systems include the following:

- STEP Tools Inc. (or equivalent)
- National PDES Testbed tools
  Fed-X
  DataProbe
- Software Development Tools
  Compilers
  CASE tools
  Graphical User Interface (GUI) tools
- Data Modeling Tools
- System Modeling Tools
- Architecture Prototyping Tools
- Database Systems

B. Computer / Equipment / Support

This category documents the requirements of the RRM Testbed for computer equipment, manufacturing equipment, computer peripherals, and the computer support functions associated with operation and use of the facility.

Requirement B.1: The NIST RRM Testbed must provide computing platforms suitable for hosting the software applications selected for the RRM Engineering Environment.

Solution B.1: The NIST RRM project will obtain three Sun SPARC 2 computer systems and a compatible CD-ROM drive. One of these systems will act as a server for the other two systems (clients). The CD-ROM drive will be used for software installation, data retrieval,

and software demonstrations. Personal computers, (e.g., IBM PC compatibles and Macintoshes) will be obtained from existing FASD inventory on an as-needed basis.

Background B.1: The NIST RRM project staff will work with the NCMS Engineering Environment Committee to select computing platforms. This committee has already identified Sun workstations as the Unix operating system platform common to NCMS consortium members. Equipment funding allocations for the NIST RRM project are sufficient to obtain three Sun SPARC 2 workstations in FY93. Selection of additional computing platforms (aside from personal computer class machines) will be based on needs determined by the NCMS Engineering Environment Committee and NIST RRM project; procurement and installation of such platforms will be considered on a case-by-case basis.

Requirement B.2: The NIST RRM Testbed must provide computer storage facilities sufficient to support the installation and use of the software applications selected for the RRM Engineering Environment by both NIST and NCMS RRM staff.

Solution B.2: A 1.3 gigabyte (GB) hard disk storage mechanism will be obtained for the Sun SPARC 2 workstation acting as the NIST RRM Testbed computing server. Additional storage space will also be available (through networked filesystem sharing) from existing FASD servers.

Background B.2: FY93 funding is available for the procurement of the 1.3 GB disk. This disk will provide local storage capabilities for the RRM server and client operating systems, NIST RRM-specific project data directories, NCMS-specific data directories, and an initial set of application software selected for the RRM Engineering Environment. It is expected that the storage requirements of the RRM project will exceed the capacity of the 1.3 GB disk; arrangements for acquiring additional (local) storage on the RRM server will be made.

Requirement B.3: The NIST RRM Testbed must provide computer output devices suitable for printing information created in the software applications selected for the RRM Engineering Environment.

Solution B.3: The NIST RRM Testbed computing facility will have network access to all of the output facilities currently available to FASD. Output facilities available to FASD include several monochrome laser printers and a color laser printer. One printer (a monochrome laser printer) will be located within the NIST RRM Tesbed; another is located adjacent to the planned testbed facility; others are in the same building as the planned testbed facility. In addition, NIST's Computing and Applied Mathematics Laboratory can provide services for color output on various media.

Background B.3: Procurement of other output devices (e.g., plotter, color printer, etc.) may be considered in future testbed implementations, based upon available funding.

Requirement B.4: The NIST RRM Testbed must provide desktop manufacturing capabilities that support small-scale (i.e., proof-of-concept) machining of sample parts. This equipment would provide a valuable resource for demonstration and system prototyping activities. This desktop capability is not envisioned to replace actual production demonstrations at NCMS RRM member company testbed sites.

Solution B.4: Select, obtain, and install desktop manufacturing equipment which can be programmed using appropriate software applications selected for the RRM Engineering Environment.

Background B.4: Funding for the FASD RRM project in FY93 is insufficient to obtain desktop manufacturing equipment for the initial RRM Testbed implementation. When additional resources become available, NIST RRM staff will pursue the procurement of a desktop manufacturing capability.

Requirement B.5: The NIST RRM Testbed must ensure that computing facility users are supported in an efficient manner. Responses to requests for software/hardware problem resolutions, requests for software installations, and requests for system administration tasks should be initiated and completed without impacting the productivity of the RRM project.

Solution B.5: A system administrator will be tasked to the job of providing computer system support for the RRM Testbed facility. For FY93, the person filling this role will work 50% on the RRM Testbed. Support for the RRM Testbed will be this person's highest work priority. The RRM Testbed system administrator will establish user support techniques (e.g., an electronic mail address specifically for help requests) and problem logging/tracking methods. In addition, a Testbed Users Guide and other testbed documentation will be available within the testbed facility.

Requirement B.6: The NIST RRM Testbed must ensure that all computer platform software and data can be reliably recovered from alternate storage in events of hardware failures and user errors.

Solution B.6: The RRM Testbed system administrator will define a procedure describing what information must be "backed-up", how frequently different types of back-ups must be performed, and how back-up data will be verified. The procedure will prescribe the use of existing back-up mechanisms available in FASD (e.g., 8mm tape drives). The definition and execution of the procedure will be coordinated with the FASD Global System Support (GSS) staff to ensure that FASD back-ups and RRM back-ups do not interfere with each other.

Requirement B.7: The NIST RRM Testbed computing facilities must be available to authorized users in a well-defined manner and must support both direct and remote access.

Solution B.7: The NIST RRM Testbed system administrator will define a policy stating how authorization is granted for potential NIST RRM Testbed computing facility users and how access privileges are granted and maintained. Support for remote access to Testbed computers (i.e., remote login and telnet UNIX utilities) will be established through appropriate configuration of the Sun workstation operating systems and network. Physical access to the testbed facility is addressed in Requirements C.9 and D.1 of this requirements document.

Requirement B.8: The NIST RRM Testbed computing facility must be operational (at least for scheduled demonstrations of engineering/manufacturing applications) even when the NIST FASD computer servers are unavailable.

Solution B.8: The NIST RRM Testbed computing facility will be configured by the system administrator to provide this functionality. The system administrator will consider the implementations/designs of FASD network routing, Network Information Service (NIS), local user access account information, and typical demonstration needs in defining the appropriate configuration.

Requirement B.9: The NIST RRM Testbed computing facility should minimize duplication of system configurations between FASD computing servers and RRM computing servers.

Solution B.9: The NIST RRM Testbed computing facility will be configured by the system administrator to address this constraint to the extent feasible. The configuration provided by the system administrator will be a compromise which seeks to minimize redundancy (e.g., by using shared filesystems from FASD computing servers for appropriate software), while still maintaining the capabilities identified in Requirement B.8.

Requirement B.10: The NIST RRM Testbed computing facility configuration should ensure that the functionality of FASD RRM staff login environments on FASD Sun workstations is preserved on RRM Testbed Sun workstations.

Solution B.10: The NIST RRM Testbed computing facility will be configured by the system administrator to address this requirement by ensuring that the directory structure used on the RRM Testbed Sun server is compatible with that of the FASD Sun servers.

Requirement B.11: The NIST RRM Testbed computing facility must provide system access security equal to or greater than that provided for FASD computing facilities.

Solution B.11: The NIST RRM Testbed computing facility will be configured by the system administrator to prevent unauthorized access to systems, software, and data by users through the use of password protections and group privileges. In addition, the system administrator will coordinate with FASD GSS staff to ensure that passwords are sufficiently robust, that

system privileges are protected, and that NIST and FASD computer security procedures are followed.

C. Physical Facility

The Physical Facility requirements category consists of furniture and office equipment requirements, room modification requirements, and laboratory layout requirements. The room must be furnished with suitable furniture and office equipment so that the facility will be comfortable and efficient for working at the computer workstations, storing work materials, jointly working with small groups, and conducting meetings.

Furniture, Office, and Other Equipment

Requirement C.1: The NIST RRM Testbed must contain facilities for 3 computer workstations for immediate use and allow for the future addition of up to 2 more workstations.

Solution C.1: The following furniture and office equipment will be obtained: 3 ergonomic workstation desks with keyboard shelf, desk drawers, and overhead storage. Allocate space in the laboratory layout for the future addition of 2 more workstations similar to those above.

Requirement C.2: The NIST RRM Testbed must provide facilities for up to 9 people to perform project work (with the exception of meetings).

Solution C.2: The following furniture and office equipment will be obtained:

- 9 ergonomic chairs
- Work tables (as space allows)

Requirement C.3: The NIST RRM Testbed must provide facilities for conference-room style meetings for up to 15 people. The conference room table, chairs, and other equipment must be somewhat portable to enable modifying the room layout and to allow use of the center portion of the room for demonstrations when necessary.

Solution C.3: The following furniture and office equipment will be obtained:

- Fold-up conference table
- 15 stackable chairs
- Overhead projector in roll-around cart
- Combination white board / chalk board / projection screen
- Computer image display device
- TV/VCR in lockable cabinet

Requirement C.4: The NIST RRM Testbed must provide facilities for storing reference materials and project files.

Solution C.4: The following furniture and office equipment will be obtained:

- Book shelves
- File cabinets

Requirement C.5: The NIST RRM Testbed must provide for the future addition of desktop manufacturing equipment (e.g., machining center).

Solution C.5: Space in the laboratory layout will be allocated for the future addition of desktop manufacturing equipment. Specific computing and networking requirements will be addressed when the equipment can be procured.

Room Modifications

Requirement C.6: The NIST RRM Testbed must have suitable lighting to provide comfortable working conditions for operating computer workstations without glare, conducting meetings at the conference table, and taking notes during slide presentations.

Solution C.6: Track lighting with dimmers will be installed. The lighting will have the ability to be controlled for separate sections of the room. Portable desk lamps (2) will be obtained to provide further flexibility and sufficient lighting for people working in the testbed.

Requirement C.7: The NIST RRM Testbed should provide reasonable telephone access for users of the facility.

Solution C.7: Two telephones will be available, each with a separate line. One of the telephones will be a speakerphone to enable conference calls.

Requirement C.8: The NIST RRM Testbed should provide a modem capability for users of the testbed to access electronic information sources (e.g., NCMS RRM Bulletin Board System).

Solution C.8: An analog telephone line will be installed within the testbed to enable use of computer modems. The NIST modem pool will be used for all modem connections and instructions for accessing this capability will be available for users of the testbed.

Requirement C.9: The NIST RRM Testbed must provide physical access to the facility for NIST staff as well as to NCMS personnel on an as-needed basis, while still providing a level of security to safeguard the equipment and facilities.

Solution C.9: An electronic Cypher lock will be installed with a combination that can be given to people who need access to the testbed. This combination will be changed on a periodic basis. Additionally, a key lock will be provided that can be used in place of the Cypher lock for back-up purposes. The key will be available to the NIST RRM team.

Requirement C.10: The RRM Testbed must provide a storage area for the conference table and stackable chairs to allow additional floor space during demonstrations.

Solution C.10: A portion of the room will be set aside for use as a storage area as needed. Movable partitions or a curtain suspended from portable stands will be evaluated to enclose storage areas within the facility.

Laboratory Layout

Requirement C.11: The laboratory layout should enable all of the furniture and office equipment to fit comfortably during the laboratory's normal activities. Furthermore, space must be allocated for future additions as required.

Solution C.11: A proposed layout for the RRM Testbed Laboratory is illustrated in Figure 1.

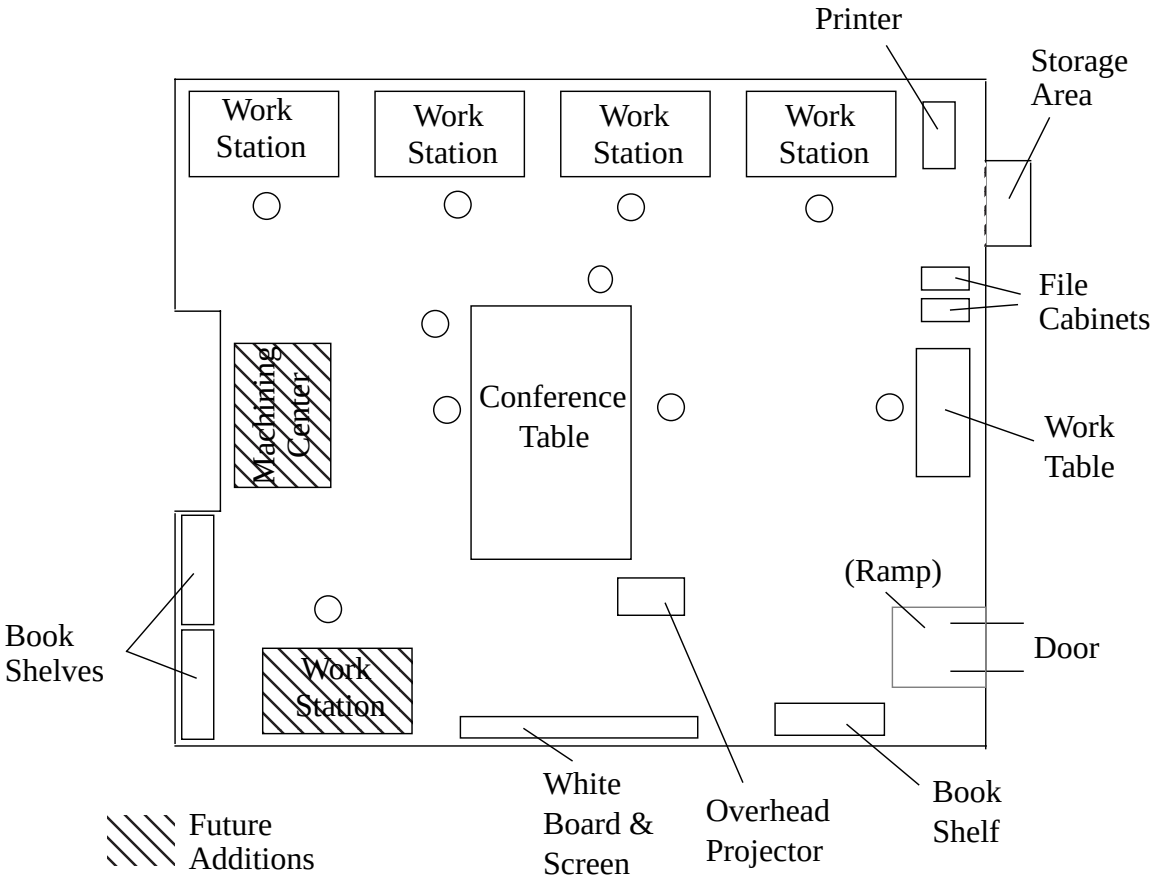

Figure 1: Proposed NIST RRM Testbed Layout
NIST Building 220, Room B107

D. Administrative / Operational Procedures

The Administrative and Operational Procedures category consists of operating procedures for use and control of the testbed for both internal and external users. Additional requirements identifying support documentation on both hardware and software systems installed within the testbed, training needs for testbed users, and requirements to meet demonstration needs are also included in this category. These requirements, along with the proposed solutions, will provide administrative control over the testbed.

Testbed Policies

Requirement D.1: The RRM Testbed must institute a policy for controlling physical access to the facility.

Solution D.1: As described in Requirement C.9, an electronic Cypher lock and a backup key lock will be used to control physical access to the facility. The Cypher lock combination will be provided to FASD RRM staff and to NCMS RRM consortium members on an as-needed basis. The combination to this lock will be changed every six (6) months. Keys to the room will be available from the FASD RRM staff and the FASD division office.

Requirement D.2: The RRM Testbed must provide a method for scheduling facility use by RRM project staff and other users.

Solution D.2: The Sun Calendar Manager utility will be used for scheduling of the testbed. This capability will be implemented by the testbed system administrator. Printed schedules will also be posted on the RRM Testbed door.

Requirement D.3: Priorities must be defined for use of the RRM Testbed facility by NCMS consortium technical committees, FASD RRM staff, and others.

Solution D.3: Priorities for use of the RRM Testbed are as follows:

- Scheduled demonstrations
- FASD RRM staff work
- NCMS technical committee work
- Other FASD activities

This information will be documented in a policy memorandum to both internal and external users by the NIST RRM Project Manager.

Requirement D.4: Software needs and cost justifications must be assessed prior to installation of Engineering Application software and Application Development Tools in the RRM Testbed. These assessments are necessary to ensure sufficient use of the software to justify corresponding expenses (e.g., installation costs, disk storage, software maintenance fees).

Solution D.4: The RRM staff will evaluate the intended use and associated costs of each Engineering Application package and Application Development Tool to be installed in the RRM Testbed. A determination as to whether the software will be installed (and maintained) will be made based upon the results of this evaluation.

Requirement D.5: Information describing software and hardware installation, updates, and maintenance must be maintained for all server and personal computer class computer systems

located in the RRM Testbed facility.

Solution D.5: The RRM system administrator will create computing systems log books for all server and personal computer class computer systems located in the testbed. The administrator will use existing FASD GSS requirements for log books as a baseline. Log books will be kept within the testbed facility and in proximity to the corresponding computers.

Requirement D.6: A computer administration policy for data back-ups, software installation structure, and other user support activities must be developed in conjunction with existing FASD computer support policies.

Solution D.6: The RRM system administrator will confer with FASD GSS staff regarding existing computer administration and support policies, define appropriate modifications of these policies (if any), and document the computer administration and support policies used by the NIST RRM Testbed. All NIST RRM Testbed computer administration policies will be coordinated with FASD GSS staff.

Testbed Documentation

Requirement D.7: The operating procedures, user orientation, usage instructions, and other reference information for the RRM facility must be documented in a Testbed Users Guide.

Solution D.7: FASD RRM staff will develop the detailed contents of a Testbed Users Guide and make the guide available to internal and external users.

Requirement D.8: The RRM Testbed must maintain the vendor-supplied documentation and operating procedures for all equipment and software installed in the testbed. In addition, the RRM Testbed must maintain available documentation for software developed in-house by the NIST RRM Intramural Project and NCMS RRM consortium. This documentation will assist internal and external users with the operation of the facility and use of software applications.

Solution D.8: FASD RRM staff will collect and maintain a library of manuals supplied by software and hardware vendors. Available software documentation for NIST and NCMS RRM-developed software will also be maintained. Storage areas for this documentation will be made available within the testbed facility.

Requirement D.9: The RRM Testbed must make available technical books, journals, and standards documents relating to RRM technology for study by testbed users.

Solution D.9: FASD RRM staff will identify and acquire an appropriate set of books, journals, and standards documents related to RRM technology to form an RRM library. This library will be maintained within the testbed facility. Additional standards information will be

available through the NIST Research Information Center, NCMS Manufacturing Information Resource Center, and NIST Standards Library.

Requirement D.10: A mechanism must be established to manage the testbed documentation, specifically regarding methods for determining and tracking the contents of the RRM Testbed library information and vendor documentation.

Solution D.10: FASD RRM staff will establish and maintain an on-line electronic index of available testbed documentation. This electronic index will contain bibliographic references (e.g., title, author, publication date) for all library information and vendor documentation stored within the testbed. Documentation key words and brief abstracts will be included to allow searching of the electronic index to locate specific information. Entries will also be made for references to appropriate on-line information sources, such as for user computing assistance or software/equipment operating procedures. When appropriate, entries will be made for the title and location of related references, operating procedures, and other pertinent information that are not directly available through the NIST RRM Testbed.

Requirement D.11: A mechanism must be established for temporarily removing documentation from the facility.

Solution D.11: FASD RRM staff will implement a document sign-out sheet located next to the RRM library. RRM staff will be required to record the document title, current date, and intended destination when removing documents from the testbed. Upon return, documents will again be signed back in to the facility.

Requirement D.12: Presentation materials describing the RRM Testbed facility must be available for use by FASD management and technical staff.

Solution D.12: FASD RRM staff will create testbed presentation materials that can be used to describe and promote the functionality of the testbed. The materials will be developed when the facility becomes operational.

Training Needs for Testbed Users

Requirement D.13: The RRM Testbed must provide a training facility capability to train internal and external users on the operation of commercial software systems installed within the testbed.

Solution D.13: The testbed layout will be designed such that adequate space and resources are available to conduct training classes on software applications. These resources will include:

- Computer workstations
- Overhead projection equipment

- Computer image display device
- Classroom-style seating arrangements

Requirement D.14: The RRM Testbed must provide computing resources to course instructors contracted to perform training.

Solution D.14: The RRM system administrator will identify and install adequate computing resources to allow training classes on software applications used by the RRM project. The following resources will be available for training purposes:

- Computer support for software installation
- Sufficient disk space for training needs
- Computer workstations and other testbed equipment

All RRM project training will be provided by organizations external to the FASD staff. This training will be identified and coordinated on an as-needed basis by NIST and NCMS RRM staff. All training will also be approved by FASD management to justify the allocation of FASD project resources.

Demonstration Needs

Requirement D.15: The testbed must provide adequate resources to perform various types of demonstrations to NIST visitors and other personnel interested in RRM technology.

Solution D.15: Demonstration content will be dependent on the software and hardware available in the testbed and the target audience. RRM staff will develop appropriate demonstrations based on these factors. Standard demonstrations will be developed that illustrate the basic functionality of the testbed. Sufficient demonstration abilities among RRM project staff will be developed to enable any staff member to execute demonstrations.

Requirement D.16: A mechanism must be established to schedule upcoming demonstrations. This mechanism will be used to identify when demonstration audiences can be combined, to ensure that demonstration materials are developed when needed, to distribute staff work assignments relating to demonstrations, and to ensure that RRM staff do not become overburdened with demonstration activities.

Solution D.16: The Sun Calendar Manager utility established for scheduling use of the facility will also be used to schedule demonstration activities. The FASD RRM Project Manager will use this information to distribute specific demonstration responsibilities.

Requirement D.17: The RRM Testbed must contain display posters for project information and demonstration purposes.

Solution D.17: FASD RRM staff will produce RRM Posters to display inside the testbed and in the adjacent hallway. High-level project posters will be displayed on the facility walls at all times so that brief overviews of the facility can be provided on short notice. Detailed project information for demonstration purposes will be developed based upon the specific target audience.

Requirement D.18: Software intended for use in RRM Testbed demonstrations must be tested and validated prior to demonstrations to verify system functionality. The level of this validation will be dependent on the target audience and the specific software application.

Solution D.18: RRM project staff will ensure that software systems are tested and exercised prior to demonstrations to verify system functionality.

Testbed Critical Success Factors

The FASD RRM Intramural Project Team has identified several items as being "Critical Success Factors" for the implementation of the NIST RRM Testbed. These Critical Success Factors are the considerations that RRM project staff felt must be evaluated to determine the success of the testbed implementation. A failure to satisfy the objectives of these Critical Success Factors may lead to a less-than-optimal RRM Testbed.

Identification of a project's Critical Success Factors is accomplished through a brainstorming process which obtains information from several different viewpoints. This technique is primarily used in the initial stages of a project as a team-building exercise and to focus a project team on a common set of goals. This activity typically results in a list of objectives and work items to be considered when planning and executing a given task. These results can be reviewed as the work item progresses to assess the success of the project.

The objective statement used for the FASD RRM brainstorming process was to identify the Critical Success Factors for the following project activity:

> Implement a showcase demonstration facility for use by all FASD projects with the capability to emulate the entire mechanical part production process from design through part machining.

The resulting Critical Success Factors identified by the FASD RRM Project Team are provided below, as well as a discussion stating how these factors are addressed in this Testbed Requirements and Implementation Plan document.

1. Must be a practical implementation based on the available resources

   This plan was developed by a team effort of NIST RRM Project staff. Funding, staff, and

Testbed Critical Success Factors

other resource availability were considered during development of testbed implementation plans.

2. Must demonstrate an operational facility for RRM technology

   As defined in the Critical Success Factor brainstorming objective statement, an operational facility would emulate the entire mechanical part production process from design through part machining. The content of the testbed demonstration, however, will be dependent upon the available hardware and software capabilities and the specific target audience. The initial implementation of the RRM Testbed will rely on software simulation for the part machining process. The planned desktop manufacturing equipment for proof-of-concept part production will be obtained and demonstrated during future additions to the testbed.

3. Must have some demonstration capability available in first year

   Demonstrations are planned for the first year of the NIST RRM Project (e.g., AMRF Automation Open House, RRM Project reviews). As outlined in this report, the testbed will contain Sun workstations, engineering applications, application development tools, and other software packages for use during demonstrations. The content of the demonstration will be dependent upon existing hardware and software capabilities and the specific audience.

4. Need existence of Cooperative Research and Development Agreements (CRDA) or teaming arrangements to bring in additional hardware, software, methods, etc.

   A CRDA is currently being pursued with NCMS. Under this CRDA, NCMS is supplying the NIST RRM Project with software applications available from member company software vendors. Other CRDAs will be pursued as appropriate to achieve RRM Project objectives.

5. Need support from NIST upper management (for funding, recognition, etc.)

   The NIST RRM Project has been reviewed by FASD management. In addition, management personnel have participated in the RRM R&D Program research needs assessment activity.

6. Need Implementation Plan documented

   A later section of this report documents the testbed implementation schedule.

7. System and facility must satisfy well-defined needs

   This report documents the testbed requirements and intended uses of the facility.

8. Need facility that is actually used (active & regular use)

   Actual use of the facility will be dependent upon functionality and location. Testbed functionality has been addressed in this report through survey results of intended testbed customers. Software and hardware components required by NIST and NCMS RRM researchers will be available in the testbed facility. Location of the physical facility has been selected for accessibility to FASD staff and computer support personnel.

Testbed Critical Success Factors

9. Need facility resources, usage instructions, procedures, policies, etc. documented for both internal and external use

   These requirements are addressed in Section D.

10. Must form cohesive RRM team to perform demonstrations (backups available, no reliance on a single person)

    This requirement is addressed in Requirement D.15.

11. Demonstration responsibility must be shared by other FASD projects

    This issue is addressed through a planned phased implementation of the RRM Testbed. Activities of other FASD projects will be incorporated into the RRM Testbed during future implementations. Testbed demonstration responsibilities will be addressed at that time.

12. Need buy-in from FASD staff (including other testbed efforts)

    Existing FASD testbed efforts were reviewed prior to development of this requirements document. These reviews provided the opportunity to discuss collaboration, lessons learned, and suggested ideas for the RRM Testbed implementation. In addition, a cross-section of FASD staff participated in the RRM R&D Program research needs assessment survey to provide direction to RRM and to discuss potential collaboration. Results of this survey were distributed to all FASD staff.

13. Need to define FASD research focus prior to finalizing testbed facility

    This activity is currently in progress through the FASD and NCMS R&D Program research needs assessment. FASD management is also developing a long-term strategic plan to refine the division research focus.

14. Need independent review of the state of the facility and the demonstrations to make improvements based on feedback

    This feedback will result from reviews by the Manufacturing Engineering Laboratory Assessment Panel and by AMRF management prior to the AMRF Automation Open House. In addition, NCMS RRM member companies will provide feedback based on use of the facility.

15. Must leverage other project results

    The RRM Testbed will use available software applications from other FASD projects as appropriate (e.g., National PDES Testbed software tools, CAD/CAM systems). The review of other FASD testbed efforts also provided several recommendations and lessons learned for use by the RRM Project. Specific ideas from FASD staff concerning testbed location, policies, documentation, system administration, and electronic information access were included in the testbed requirements defined in this report.

Implementation Schedule

References

[1] K.K. Jurrens and M.E. Luce, Project Plan for the Rapid Response Manufacturing (RRM) Intramural Project, Draft NISTIR, March 1993.

[2] J. Simpson, R. Hocken, and J. Albus, The Automated Manufacturing Research Facility of the National Bureau of Standards, Journal of Manufacturing Systems, Vol. 1, April 1982.

[3] C.M. Furlani, The National PDES Testbed -- An Overview, Proceedings of the UPCADM Conference, July 1989.

[4] A.B. Feeney, Engineering Design Laboratory Guide, NISTIR 4519, February 1991.

[5] S.R. Ray and A.B. Feeney, A National Testbed for Process Planning Research, Draft NISTIR, March 1993.

Appendix A: Review of Existing FASD Testbeds

The NIST RRM Intramural Project Team reviewed three previously created FASD testbeds: the Process Planning Testbed (PPTB), the National PDES Testbed (NPT), and the Engineering Design Laboratory (EDL). This review was done to apply the lessons learned from creating and maintaining these previous testbeds to the planning and development of the NIST RRM Testbed. The notes from these reviews were recorded in somewhat of a raw and unedited form to be used as data during the development of this Testbed Requirements document. These notes were compiled by NIST RRM Project staff members Y. Tina Lee and Howard T. Moncarz and are provided in this Appendix. For each testbed review, the notes are organized according to the following structure:[1]

OBJECTIVE

- Objective
- Users (internal / external)

FACILITIES

- Hardware and software
- Communication equipment
- Size (current / future)

STAFF RESOURCES

- Number of staff
- Type of staff / technical knowledge required

TIME TO SET UP

- Design Testbed
- Buy equipment
- Loan equipment
- Install / integrate systems

ADMINISTRATION AND MANAGEMENT

- Types of support
- Levels of support / training
- Mechanism to provide service to external users
- Maintenance

1. If no information was provided for a particular section, that section is not shown in this Appendix.

FUTURE PLANS

- Interests in leveraging other internal projects

OVERALL EXPERIENCE

- Lessons learned
- Problems encountered

RESOURCES AVAILABLE TO OTHER TESTBEDS

ADDITIONAL COMMENTS

PROCESS PLANNING TESTBED (PPTB)

OBJECTIVE

To facilitate process planning research by making the following available to the process planning research community:

- Published information (citation database system)
- Communication with peers (email list, workshops)
- Software tools (EXPRESS, database system, remote execution of software at NIST)
- Sample data (parts, plans, factory models)

User Profile:

- This past year: university professors and graduate students
- Next year: industry expected to use the testbed

FACILITIES

- Hardware: used existing computers, no plan to buy hardware
- Software: software from EDL and NPT projects, object-oriented database (Gbase/Matisse), citation database - user support needs are very low
- Size: (virtual testbed only - no facility necessary)

STAFF RESOURCES

• 1 senior-level staff	60%	project manager, process planning, writing
• 1 intermediate-level staff	75%	process planning, writing
• 1 intermediate-level staff	25%	lead programming, design
• 1 junior-level staff	25%	programming support
• University staff/students		

TIME TO SET UP

- Not applicable—not a physical laboratory, just a virtual testbed

ADMINISTRATION AND MANAGEMENT

- Support: anticipate integration support for research modules
- Training: only through documentation for now
- Mechanisms: Internet, ServiceMail

FUTURE PLANS

In-house research program—address fundamental issues first, such as data representation

Make use of leveraging through various internal NIST projects:

- Persistent Object Base (POB) project (object oriented database support)
- Engineering Design Laboratory (part libraries, design tools)
- National PDES Testbed (EXPRESS, STEP methodologies)
- Manufacturing Systems Integration (MSI) project (Gbase/Matisse and support tools, process plan editor)

Make use of leveraging through various external projects:

- IPPI (Intelligent Process Planning Initiative)
- IMS/SILMA (Intelligent Manufacturing Systems - NIST Robot Systems Division and industry representatives)
- RapidCIM (Rapid Development of Control Architecture - project sponsored through the Defense Advanced Research Projects Agency (DARPA))
- IMAR (Institute for Manufacturing and Automation Research) projects
- Advanced Technology Program (ATP) Rapid Response Manufacturing (RRM) Project
- U.S. Department of Energy Agile Manufacturing Project

OVERALL EXPERIENCE

Lessons learned:

- Leverage project funding with:
  - Focused university grants (recommend using university grants for definable tasks)
  - Commercial software (recommend using only supported tools)
- Do not accept donated software if it is not needed by the project (due to maintenance costs).
- Develop and use a clear project plan and schedule (make sure tasks are understood and work is proceeding properly)
- A physical facility is not necessary if there is easy access over the network.

RESOURCES AVAILABLE TO OTHER TESTBEDS

- Gbase/Matisse object-oriented database and supporting tools
- Citation database system from National Library of Medicine
  - Includes documentation: three documents are available
  - This is an inverted index system - uses Boolean operators to find papers

ADDITIONAL COMMENTS

- Software tools based on specific standards can be provided to promote the use of those standards.

- Needs for process planning:
  - Conceptual modeling tools that would feed directly into information modeling languages (e.g., IDEF1X, EXPRESS)
  - Suites of tools for relational and object-oriented databases that any project can use
  - Literature support
- Example of university needs: sample data sets for real parts
- This past year (1st year), the information requirements for the testbed and the citation system were established. During the current year, project staff will start setting up testbed.
- Staff first need to do some background work to study representations, architecture, etc. before going on to do research.
- Co-laboratory for collaborative work among laboratories

NATIONAL PDES TESTBED (NPT)

OBJECTIVE

To provide technical leadership and a testing-based foundation for the rapid and complete development of the STEP specification. The National PDES Testbed began as a physical site, which primarily NIST and PDES, Inc. staff would use. Over time, fewer people are using the physical site, while more are using it remotely. This testbed is evolving into a virtual testbed, available over the network.

FACILITIES

- Physical capacity for 10-15 people. Rarely more than 6 people working in the facility at a time.
- The testbed was used heavily by outside users. Currently, there are over 100 external user accounts.
- Capacity is currently under-utilized - about 1 to 2 users per week through remote login, possibly due to unstable tools and environment.
- Electronic CYPHER lock used for physical access.

TIME TO SET UP

The facility evolved in phases due to changing needs.

ADMINISTRATION AND MANAGEMENT

- Administrative help is very useful. All testbed activities need to be coordinated.
- An on-line calendar is helpful. Schedule should be maintained by one person to avoid schedule conflicts.
- A User's Guide for the testbed needs to contain a list of software within the testbed.

OVERALL EXPERIENCE

Problems:

- Initially, critical software required by all testbed workstations was on separate testbed systems. If one workstation went down, it would crash the entire system.
- The biggest dependency that the testbed has on FASD systems is the X-Windows environment. If X-Windows is updated to a new version, it is possible to shut down the testbed operation.
- Internal NIST people tend not to use the testbed facility because of its inconvenient location.
- Internal NIST users tend not to check the facility calendar and run into schedule conflicts. It is a distraction to a meeting if workers are in testbed while the meeting is going on; conversely, a meeting is distracting to other workers in the testbed.

- Testbed has multiple different computer platforms due to donations. This situation tends to cause configuration and support problems.
- The system was initially overloaded due to heavy use by outside users. Currently, there are over 100 user accounts.
- Users connected to the network are running different environments. This makes it difficult to resolve problems over the telephone because of the different environments.
- It is difficult to keep track of documentation—it is often borrowed and not returned.

Recommendations:

- Need to define role, interfaces, and services of testbed.
- Use a generic environment for testbed users to simplify support issues.
- A key variable for testbed success (in terms of being used) is reliability. To ensure reliability:
  - Isolate the testbed—there should be no dependence on outside systems, or the FASD network.
  - Testbed should have its own file server, connected to all testbed workstations. Do not use the file server for any other type of computational tasks.
  - Provide a backup to the file server (if funding allows).
  - Install a separate ethernet network for the testbed.
  - Each workstation should have its own local disk (swap device).
  - Do not strive for non-redundant software because disk space is cheap. Keep control of the software within the testbed.
  - Need to clearly know where the lines are drawn regarding software dependencies.
  - Need version control of software. “Functional” and “reliable” are more important than “up-to-date.” To test a new version of system software for use in the testbed—e.g. a new release of X-Windows that is put on the FASD network: mount that version of the software in place of the version currently being used in the testbed. If the software on a specific workstation still executes properly, migrate the new version from FASD to the testbed file server. Back-up copies of the previous version should be saved, just in case.
- Use only one UNIX architecture. (Connecting Personal Computers and Macintosh machines to this architecture is not a problem.)
- Testbed administration recommendations:
  - Employ a system administrator to set up the facility and document the configuration. Afterwards, minimal support is required.
  - A hand-written log book should be used for file server installation and maintenance.
  - Need to have a security system for outside users.
- Hardware and facility recommendations:

  - Cover all systems with one Uninterruptable Power Supply (UPS). This is much simpler and more cost effective than using multiple UPS devices.
  - Only need one CD-ROM drive—they are easy to move around between workstations.
  - Recommend not to use 24 bit-plane monitors due to incompatibilities for some software packages.
  - Use a folding conference table and stackable chairs for more flexibility
  - Let modem users use the NIST modem pool service. Don't provide that service separately.
  - Need to address system backups. Use the 8 mm backup tape capability—5 gigabytes on a single tape, relatively inexpensive
  - LAN bridges can be used to provide reliability and isolation.
- Software support recommendations:
  - Stick to released, supported software.
  - The level of system support required is based on the time you are willing to wait to have software installed and tested, once you request that service.
  - Knowledge of the software and how it will be used can have a large impact on how the software is installed.
- Make testbed rewarding to use, so that internal staff will use it over the long term
- Room B107 of Building 220 would be a good location for a testbed because an 18 KVA UPS (only 30% used) is located next door in room A108. This is a potential cost savings.

ADDITIONAL COMMENTS

Two ways to have outside users log in:

- Use FASD Yellow Pages to verify user accounts and passwords (easiest method)
- Establish own Yellow Pages
  - Cannot log into FASD, only testbed
  - Lot of work for system administrator to set up
  - Software within the testbed domain is better protected, but it is not cheap to do it this way.

ENGINEERING DESIGN LABORATORY (EDL)

OBJECTIVE

- For integration and architecture development
- Evaluate DARPA (Defense Advanced Research Projects Agency) funded research software plus relevant commercial software

Users:

- Testbed is intended for internal (NIST) use only, not for outside people (with some exceptions)
- Primary users are from NIST, with a few external users
- NIST Molecular Measuring Machine project was funded by FASD for some collaborative work with EDL to evaluate the testbed software and usefulness

FACILITIES

- Workstations:
  - UNIX based
  - Uses a file server, with large disk and more memory, to store the environments and language tools that are needed to run software applications
  - Computers: Suns, Silicon Graphics, Personal Computers
  - Most organizations working with EDL use UNIX-based systems. These organizations generally have Suns, Silicon Graphics, Personal Computers.
  - Color printer in facility. However, configuration and support are not adequate to provide for color screen images - this capability would be useful.
- Software:
  - Research Agreement for use of ICAD software
  - ProEngineer (license plus maintenance)
  - Software packages from a number of universities
  - No database system
  - Difficult to maintain the environment
- Physical facilities:
  - Obtained surplus furniture as available
  - Electronic CYPHER lock—invaluable for testbed access
  - Fluorescent lighting—not a good idea due to the glare—need to set the monitor color intensity way up
  - Open laboratory layout is very useful for demonstrations

STAFF RESOURCES

- Staffed by project leader and one or two graduate students on a part time basis

TIME TO SET UP

- Backups are not supported by FASD Global Systems Support (GSS)
- There is no loaned equipment.
- Performed own installations—could contract to GSS. Software installations are done in on-going basis.

ADMINISTRATION AND MANAGEMENT

- Project funding from DARPA, including funds for laboratory equipment
- Administration for new software:
  - Developed Cooperative Research and Development Agreement (CRDA) with ICAD for use of their software
  - Some software was received from universities via electronic network access—no licensing or other type of agreement was necessary in these cases.
  - Requirements for software applications before being accepted at the testbed:
    - Documentation for installing and executing the software
    - Installation tested at the developer site before the software is sent to NIST
- External access to testbed software:
  - DARPA partners access testbed through Internet network
  - Use a software utility to include a password to restrict access to approved external users. Accounts on NIST computers are not necessary to access the testbed.
- System support:
  - Network communications between NIST Buildings 304 and 220 have been very reliable.
  - Printer support has not been as good due to its consideration as a lower priority task.
- Documentation:
  - Laboratory reference book that describes the facility is very useful. This should include the software available, who to contact, etc.

FUTURE PLANS

- Facility not expected to grow very much in the future. The window of opportunity for expansion, via additional funding, is probably gone. The first two years of a new facility is typically the window of opportunity for funding.
- Future focus: strictly on design knowledge representation research

OVERALL EXPERIENCE

Problems:

- Laboratory facilities are expensive to maintain. Many distractions, including non-project related demonstrations are bound to arise.
- System support:
  - Dependency on FASD GSS sometimes causes difficulty due to time constraints.
  - Dedicated, non-standard equipment is very expensive to support.
  - Training for outside software and installation is expensive. Funding must be available for support staff to install software.
  - Need system administrator privileges for the hardware to perform some installation activities—this impacts the system security.
  - EDL is responsible for its own backups, rather than have internal support do them. Backups are very important, but are a time-consuming task.
- Cost of using and maintaining complex software is expensive
  - Additional software is sometimes needed to support a given package. This can be a significant expense.
  - Need to maintain the environment and keep up with knowing how to run the software.
  - Often, a version of some underlying software needs to be the same as that used during development of the application. This can be a big problem. Not so much a problem with commercial software, but is a problem with university software.
  - Software maintenance with a software vendor may be required and can be expensive.
  - Training may be necessary on some software packages and can be very expensive in both time and cost.
  - The work required to use the software packages in the EDL was underestimated. A person must spend (in some cases) one-third to one-half time on a continuous basis to maintain sufficient proficiency to use a particular package. This problem was true for all the software packages installed in the testbed; it was one of the biggest problems for the EDL testbed.
  - NIST tends to discourage maintenance and training costs for donated software.
- It is difficult to get people to use the laboratory facilities, even with the availability of superior equipment, due to its location.

Recommendations:

- Do not underestimate software cost. Only obtain software that is necessary.
- Laboratory posters are very valuable for promotion and demonstration purposes.
- X-Windows software alleviates the need to be physically in the testbed for some software.

- Understand the requirement of the environment before bringing in new software.

RESOURCES AVAILABLE TO OTHER TESTBEDS

- ProEngineer:
  - Requires license and maintenance cost
  - A serious user on a system like ProEngineer needs approximately 3 weeks of training

ADDITIONAL COMMENTS

- History of the laboratory:
  - Started with meetings with DARPA five-and-one-half years ago
  - Before this, a DARPA team went to Japan to study Japanese methods for manufacturing automobiles
  - DARPA wanted to get NIST involved, so helped NIST create a facility for developing a framework for integration.
- EDL is working with top researchers throughout country. Some software, such as ALPHA-1 from the University of Utah, is outstanding. In this case, coding and documentation was done by professional programmers. Students do their experimentation—when it is decided to add something to system, professionals do the software development.
- Operating system versions, licensing, and utilities are a concern.

SUMMARY RECOMMENDATIONS - ALL TESTBEDS

OBJECTIVE

- Need to define the role of the testbed and to define its services
- Need to develop a detailed project plan

FACILITIES

- Physical facilities:
  - Highly recommend using Room B107 of Building 220 to take advantage of the existing 18 KVA UPS
  - Need better lighting—check NIST guidelines.
  - Electronic CYPHER lock is recommended for the facility entrance.
  - Open laboratory layout is very useful for demonstrations.
  - Laboratory posters are valuable for promotion and demonstration purposes.
  - Locate the testbed near the NIST personnel who will use it—otherwise, it will likely be under-utilized.
- Hardware and Software:
  - Isolate the testbed to ensure reliable operation.
  - Use a generic environment for testbed users to simplify support issues.
  - Install a separate ethernet network for the testbed.
  - Testbed should have its own file server and a backup to the file server.
  - Software backups are critical.
  - All software for the testbed (commercial or free) should be selected only if necessary. Requirements for accepting software are recommended. Do not underestimate software cost.
  - Multiple software and/or hardware platforms are expensive to maintain and should be avoided if possible.
  - Use supported software or commercial software.
  - Leveraging other testbed resources (e.g., software applications) is recommended, but do not ignore the self-sufficiency recommendation.
  - Gbase with tools and a citation database system are available from the Process Planning Testbed.
  - Access to ProEngineer and other design tools can likely be obtained through the EDL.

STAFF RESOURCES

- Recommend use of focused university grants for definable tasks.

- System administrator for testbed is recommended—at least to help set it up, and then to be available part-time when needed.
- A coordinator is recommended to coordinate testbed activities and to maintain the schedule.
- Contract to FASD GSS for software installations.

TIME TO SET UP

- Need to establish a detailed schedule for the testbed implementation.

ADMINISTRATION AND MANAGEMENT

- Documented procedures for scheduling and using the testbed are necessary.
- Provide a User's Guide for the testbed that contains procedures, list of software, etc.
- Maintain a log book for any updates, changes, backups, etc. done on the file server.
- Need to have a security system procedure for external users.
- Decide whether to use the FASD Yellow Pages system for user verification or a separate Yellow Pages for the testbed.