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REPORT ON COMPUTING AND NETWORKING IN THE SPACE SCIENCE LABORATORY BY THE SSL COMPUTER COMMITTEE

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Space Science Laboratory
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The Space Science Laboratory (SSL) at Marshall Space Flight Center is a multiprogram facility. Scientific research is conducted in four discipline areas: earth science and applications, solar-terrestrial physics, astrophysics, and microgravity science and applications. Representatives from each of these discipline areas participate in a Laboratory computer requirements committee, which has developed this document. The purpose of this document is to establish and discuss Laboratory objectives for computing and networking in support of science. The purpose is also to lay the foundation for a collective, multiprogram approach to providing these services. Special recognition is given to the importance of the national and international efforts of our research communities toward the development of interoperable, network-based computer applications.

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PREFACE

Ten years ago, Laboratory management received two, nearly identical, requirements for the development of image processing systems from entirely separate groups within the Laboratory. The recognition of the value of collectively developed scientific computing systems precipitated the creation of a Laboratory level computing and networking initiative. In pace with changing information standards and technology, common computing within the Space Science Laboratory (SSL) is evolving from highly centralized toward distributed computing architectures. As with all change, there are new opportunities and new responsibilities. Problems of numerical analysis and data management are becoming approachable with the growth in available computing power and mass storage. However, with this growth has come an increase in the sophistication of the tools we would use to support our research. To achieve the successful utilization of modern computer systems requires a balance between the availability of these systems and competent technical support that is tuned to our research environment.

The Space Science Laboratory Computer Committee wishes to acknowledge the valuable contributions of the following individuals in preparing this report: Robert Dean/BCSS, Anita Hall/Nichols, Sharon Ing/MEVATEC, Edward Lundquist/BCSS, Edward Myszka/MEVATEC, Robert Newman/BCSS, Gary Tom/NTI, and Rodney West/MEVATEC.

TABLE OF CONTENTS

TECHNICAL MEMORANDUM

REPORT ON COMPUTING AND NETWORKING IN THE SPACE SCIENCE LABORATORY BY THE SSL COMPUTER COMMITTEE

INTRODUCTION

The focus of this report is to define and understand the objectives for Laboratory computing and networking. The overall purpose is to facilitate the individual's access to, and use of, reliable and maintainable computer and network resources. Whether applications execute on desktop systems or are provided through centralized or common services, individuals require a highly integrated environment. Laboratory computing activities involve desktop (i.e., office) computer systems and common services. Support is required for the individual's desktop hardware and software systems. Common services, involving support for areas such as data management, scientific computing, and communication, must be available from desktop systems and from dedicated areas within the Laboratory.

The use of computer networks and communication protocols is a fundamental part of implementing and integrating common services with desktop systems. We work in a networked environment extending between offices, laboratories, research institutions, and nations. The requirement is to integrate services throughout this environment, by the adoption of standards and through cooperation with the efforts of the network community to achieve widespread interoperability of systems and applications in support of scientific research.

A purpose of this report is to facilitate the creation of a management architecture which formalizes the processes of requirements definition, systems design, systems implementation, and systems operation and maintenance. The implementation of a highly integrated research environment requires a coordinated Laboratory effort and effective use of industry and governmental standards in data processing and communication. The management of Laboratory computing and networking must be consistent with relevant NASA and MSFC policies and plans, as well as accommodating the practices and standards used in our research communities.

This report will define the nature of each of these areas of computing and networking activities and their respective objectives. Functional requirements will be developed, with a focus on defining the nature and objectives for these Laboratory activities. A further purpose of this report is to promote the integration and effective use of laboratory computing sys-

tems. The purpose is also to project a direction for the continued development and operation of computing facilities that maximizes the benefit derived from these systems, while minimizing the required resources.

At the root of Laboratory computing and networking activities is our support of projects and missions. Research efforts often make use of computing and networking services such that a common Laboratory approach to providing these services is possible. The identification of these common elements of our research efforts and their generalized support within the Laboratory minimizes costs to individual projects, while maintaining required levels of support. However, unique elements of our research efforts will always exist. Laboratory computing and networking services must provide for the dedicated support of individual research projects, whether implementing a unique numerical algorithm or programming a custom graphical display of data.

ANALYSIS OF SPACE SCIENCE LABORATORY COMPUTING AND NETWORKING ACTIVITIES

Objectives of Computing and Networking Activities

The objectives of Space Science Laboratory computing and networking are summarized in Table 1. These objectives are a distillation of the requirements discussed in this report and are a recognition of the importance of computers and networks in supporting modern research. The report is offered to Laboratory management and the managers of Laboratory computer and network systems. It is the intent of the SSL Computer Committee that these objectives will lead to the development of strategies for implementing needed computing and networking services and facilities.

COMPUTING AND NETWORKING ISSUES AND PLANS

Issues and plans will be discussed for each of the identified areas of concern. The requirements discussed in each area are expected to lead to implementation planning that may involve hardware, software, and support personnel. No specific implementation plan or strategy is called for in this report. Two issues, product lifetimes and standards in computing and networking, have been identified as overarching each of the areas discussed below and will be discussed first.

The existence of an intrinsic lifetime for both hardware and software systems should be recognized. Many of the existing desktop and centralized computer systems are obsolete and require upgrade to the capability and maintainability of modern technology. In addition, today's non-

TABLE 1. SUMMARY OF SSL COMPUTING AND NETWORKING OBJECTIVES

Desktop Systems
- availability and support of viable office computer systems

Scientific Computing
- highly integrated, distributed Laboratory computing environment

Data Management
- protection and integrity of data, programs, and related data assets

Communication
- effective, interoperable network services ranging from the desktop to the international scientific community
  - easy-to-use, interoperable mail services
  - network conferencing for desktop, conference room, and Laboratory systems

Document Handling
- document exchange solutions promoting internal and external document portability

Scientific Visualization
- facilities and support for effective scientific visualization

Output Devices
- easy-to-use, network-based production of color and black and white hardcopy
- production of high quality graphic image sequences on video media

Laboratory Data Acquisition Systems
- support of laboratory control and data acquisition systems

Applications
- generalized scientific applications, making optimum use of commercial off-the-shelf products
- expertise in the use of scientific applications

Management Information Systems
- desktop system interoperability with Laboratory and Center MIS facilities

Engineering Systems
- standardized engineering systems that are compatible with the Center's design and repository systems

Mission Science Operations
- science mission operations area within the Laboratory for manned and unmanned missions

obsolete computing systems will become obsolete within a few years. Product lifetimes average 5 years or less. The purpose of acknowledging finite product lifetimes is not to promote use of the latest-and-greatest systems. The purpose is to recognize that there are practical limitations to our long-term use of both computer hardware and software systems. These limitations are brought about by incompatibilities resulting from product upgrades, by limited life cycles in commercial products and resulting vendor support, and by increasing frequency of repair.

Standards in hardware, software, and networks are another important aspect of Laboratory computing and networking plans. Industrial and governmental standards both constrain ADP system design and open new opportunities in systems integration and interoperability. GOSIP, POSIX, X.500, and DCE are only a few of the standards that must be examined.

Desktop Systems

Today's scientist works in a networked research environment. Desktop systems are a window into that environment, supporting local applications and processing and supporting access to remote people, information, and analysis tools. The implementation of common services is in recognition of the many common applications and processes shared by all or most researchers in the Laboratory. The objective is to bring common services to each desktop system as an integrated extension of the individual's local computer resources.

The objective of integrating workplace services leads to a requirement for minimum desktop system configurations, whether based on a personal computer or on a workstation. What constitutes a minimum system configuration changes with time and is dependent on each individual's specific requirements. In 1980, 64 thousand bytes of internal memory was sufficient. Today, 64 million bytes of internal memory and 1 billion bytes of disk storage are often required. Current desktop equipment includes "dumb" terminals and obsolete personal computers. Integrated document handling requires desktop implementation of word processing packages for many personnel within the Laboratory. Communication hardware and software are also required on desktop systems, to enable electronic document and data exchange. The configuration of desktop systems has become a complex task. The specialized skills required to configure and maintain operating systems, communication software, and other application packages necessitates dedicated support personnel.

Scientific Computing

Data processing, data analysis, modeling, and simulations all require computing resources. All levels of computer systems are utilized by Laboratory personnel, i.e., desktop systems, mid-level or "departmental" computers, and super computers. Whether computing resources are provided within the Laboratory or provided by the Center, such as with the Engineering Analysis Data System (EADS II), it is required that these resources be accessible from desktop systems. The objective is to execute computationally intensive tasks on the most appropriate system. A truly distributed computing architecture allows more computationally intensive task elements to be easily "farmed" out progressively to more powerful computers. A highly integrated, distributed computing environment is an important objective for Laboratory scientific computing.

Data Management

Scientific measurements originate from distributed ground systems, shuttle missions, free flying spacecraft missions, and in-house laboratory experiments. These measurements, when combined with processed measurement products, simulation results, and modeling, lead to the requirement for an organized approach to managing data. The first step in data management is that of implementing digital storage systems. The second step is that of providing for widely distributed access to that stored information. The third step is to provide for the orderly identification of desired data subsets through the implementation of relational database tools. Of growing importance is Laboratory participation in national data archival, distribution, and access activities. Literature database service is another form of nationally available information systems to which we need to develop access.

Scientific data products are intrinsically valuable, as a result of the required large investments in time and manpower. In order to insure the safety of this information, routine backup must be provided, whether that data resides in desktop, project, or centralized Laboratory storage systems. Disaster recovery planning and appropriate off-site storage of backup media will be an important part of data management. In addition, the electronic protection of on-line data, programs, and related data assets is required.

Existing centralized storage facilities are grossly inadequate to hold the required volume of information. Storage on erasable, on-line media and on long-term, non-volatile media is required. Required local storage capacity is in addition to EADS II capacity. It is required that implementation be an integrated, distributed addition to Laboratory systems. Current requirements for storage capacities must be measured in units of terabytes (tera = 10^{12}).

Communication

Computer networks play a fundamental role in supporting an integrated work environment. Networks extend the individual's desktop system to resources within the Laboratory, Center, and beyond. The most often used network services are electronic mail and data transfer. Although these services are discussed below in the context of local Laboratory functionality, they are also used to connect us to the rest of the world. Collaborative interaction with others in our respective research communities is necessary for the vitality of our research. In addition to mail and file transfer, networks provide access to a myriad of other equally important facilities or services that are available in our international network environment, such as information exchange bulletin boards, specialized high performance computers, and mission scheduling systems. An ongoing effort to optimize and maintain a robust network architecture and implementation is an important objective in support of the mission of the Space Science Laboratory.

The exchange of electronic mail between laboratory desktop systems is often difficult, if not impossible. Where mail services exist, personnel make use of diverse systems, including CEO mail, NASAmail, OMNET, MS MAIL, CC MAIL, VAX mail, and UNIX mail. In concert with Information Systems Office efforts toward a unified mail system, Laboratory electronic mail can evolve toward easy to use mail systems and message gatewaying between dissimilar systems. The process involves the extension of mail services to all desktop systems and the configuration of local and Center services that support the transport of mail between systems.

The ability to transport information, whether documents or data, between desktop, laboratory, and Center computer systems similarly depends upon the use of common data exchange languages and the implementation and maintenance of gateway services. The configuration and maintenance of compatible communication products on these systems is an important element of this activity. Another important gateway service manages access to information exchange systems, e.g., USENET, which provide valuable answers to many data system and network problems.

Network conferencing is a relatively new capability that is now becoming available. Network conferencing ties researchers together in an interactive dialog where graphics and text can be freely exchanged. It is an extension of teleconferencing and video conferencing, where distributed researcher workstations are included in the same highly interactive environment. The scientific objective of such a system is to approach the scientific workshop experience, without the usual travel to a common location. Researchers are usually required to come together at one site, while bringing with them all the information they can carry and anticipate needing. In a workshop, researchers collectively view graphic displays of data, draw diagrams, discuss scientific issues, and develop reports of their progress. Although network conferencing does not replace face-to-face interactions, it offers greatly expanded opportunities to interact with distant colleagues. The implementation of network conferencing capabilities from desktop and conference room systems will mark the next revolution in our changing network research environment.

The communication of scientific concepts, mission plans, and management strategies to our local colleagues and management is another important issue. The use of view graphs and slides in our existing meeting rooms significantly limits our ability to convey the content of models, simulations, or data with which we are involved. It is recommended that one of the existing Space Science Laboratory meeting rooms be modified to support computer displays of scientific and presentation information, easily viewable from all locations within the room. The room's facilities should be integrated into the Laboratory's computing and networking environment, like any other desktop system.

Document Handling

The creation of scientific papers and reports is the primary product of Space Science Laboratory scientists. In addition to the ability to exchange documents freely between laboratory desktop systems, including secretary, manager, and researcher systems, it is vital that documents can be interpreted upon arrival. Driven by both internal and external requirements, a wide spectrum of word processing and desktop publishing packages are currently in use within the laboratory. These packages are often not compatible, preventing the exchange of text between systems. As a result, scientists often assume responsibility for the clerical preparation of correspondence, reports, and research papers.

Similarly, presentation charts and graphic displays of data for inclusion in documents can often not be exchanged. The use of computer systems by the Center's graphics artists and the growing acceptance by research journals of electronically submitted papers mandates a collective approach in our handling of documents.

The identification of several interoperable word processing packages, compatible with the Center's graphics support services, collaborating researchers at other institutions, and international research publications, is one of the Laboratory's computing objectives. The implementation of these packages and movement toward effective use of professional typists and secretaries is part of this objective.

Scientific Visualization

Scientific advancement hinges on our ability to communicate ideas and to organize and relate measurements to theory. Whether involving theoretical concepts or mountains of data, this is accomplished through the creation of visual displays of information. In today's era of exploding computational and visual technologies, we are driven to the power and efficiency of graphical computer displays of data. As a result of this pervasive need among science disciplines, an industry has developed whose focus is scientific visualization. Like that for computer science, the field of scientific visualization is characterized by sophisticated techniques and complex tools. It is also characterized by its infancy. The integration of sophisticated visualization techniques with the need for interactive, real-time manipulation of the underlying data, models, and simulations is yet to be accomplished. A recognition of the limits of visual perception and power of animated sequences of visual images also continues to be sought.

The effective implementation of visualization techniques, utilization of software and hardware tools, and the development of applied image processing concepts requires specialized knowledge. The common need for these capabilities is most efficiently provided through generalized laboratory services. Local expert support in the field of visualization can follow this growing industry, develop generalized visualization tools, and train research staff in the use of these tools. The development of expert systems for the automated inspection of the volumes of scientific measurements being acquired will also greatly aid in the understanding of that data.

Output Devices

Researchers require a variety of output devices to which text and graphics can be sent. Black and white printing of computer and document text is the most commonly used output device. Although black and white printing of graphic images must be available, the printing of graphic images in color is often required. Options must exist for the frequent printing of graphic images at reduced expense, with increased speed, and for the highest quality printing of color graphic images for presentation and publication. It must also be possible to easily assemble graphic image sequences onto video media for presentation and analysis.

With the existing heterogeneous hardware and software environments, the Laboratory printing system should be network-based, wherever possible. Network protocols, for printing, should be implemented in order to support the greatest number of computer platforms. Printing should be as transparent as possible, e.g., making use of a computer system's native print spooling software. The process of sending text for printing should be as direct as possible, minimizing the number of intervening systems. Information about network printers, e.g., physical location, type, and network address, should be maintained centrally and made readily available to Laboratory personnel. A uniform interface for the individual's access to printing services should also be sought.

Laboratory Data Acquisition Systems

An important element of Laboratory research activities is in-house experimentation. More and more often experimental, laboratory systems involve the use of computers for control and data gathering. The basic constituents of laboratory data control and acquisition systems nearly always involve similar elements, e.g., analog to digital conversion, data storage, and sequential command and control. The identification of hardware and software commercial products suitable for experimental systems is a continuing problem. The commonality of such systems offers the opportunity to provide Laboratory level support in the definition of experimental computing system requirements, implementation of those requirements, and their maintenance.

Applications

In addition to the diverse development and usage of researcher specific computer applications, there exist generalized scientific applications that are useful across a science discipline and among many disciplines. Applications, such as these, that are in current use within the Space Science

Laboratory are: graphic and data analysis applications, e.g., Khoros, Explorer, AVS, VIS-5D, McIDAS, LinkWinds, IRAF, PV-WAVE, and IDL; mathematical and numerical libraries, e.g., IMSL and NAG; word processing and text formatting applications, e.g., WORD, WORDPERFECT, Framemaker, and TEX; communication software, e.g., PATHWORKS, LANMAN, and TCP/IP packages; and EADS II applications, including the EADS II image processing system. Multimedia tools, e.g., SGI Showcase and Powerpoint, can also be expected to become more prominent.

Effective use of these applications depends upon the availability of an expert to answer questions, to resolve problems, and to guide the researcher. In the past, this service has been provided in a limited way by other researchers, who achieve some level of success with a given application. The consequence is that these researchers are often distracted from their primary responsibilities by those seeking help with one application or another. Neither the effective use of personnel nor a robust use of common scientific applications have been achieved. Both can be accomplished by employing dedicated expert personnel who support research use of common scientific applications. The effective use of applications will also be enhanced through the use of on-screen application guides and use of self-documenting applications.

SSL Management Information Systems

Space Science Laboratory utilization of the Center's MIS System is limited to Branch level management through to the Laboratory Director and Director's office staff. Individual researchers do not currently have access to this system. The consequence is the general inability of Laboratory and Center management to easily exchange documents with researchers and the inability of management and researchers to schedule appointments and activities. The reason for this continued limitation is the incompatibility between existing management information systems and scientific research systems.

An objective of this plan is to develop an approach to management information systems that is consistent with the research focus of the Laboratory and is interoperable with Center MIS systems. The development of this capability, its implementation, and maintenance will require the participation and cooperation of both local personnel and those of the Information Systems Office.

Engineering Systems

The Space Science Laboratory participates in the Center's standardized engineering design systems and supports specialized engineering activities. Existing in-house facilities are inadequate, limited, often obsolete, and not well integrated nor connected with the Center's distributed engineering design and repository systems. The MSFC IEE committee proposes a collective approach for defining engineering system requirements, their implementation, integration, and connectivity with other S&E systems. The collective approach for integrating our engineering environment is needed and will be an integral part of this Laboratory's engineering work.

Mission Science Operations

Behind the demanding requirements of mission critical tasks associated with a shuttle or free-flyer mission is the important process of managing mission science data. Mission science operations or the management of mission data involves the reduction of level 0 data, data storage, generation of level 1 data, and data distribution. Although the details of each mission differ, the process and the facilities are often very similar.

The need exists today to develop a general-purpose science operations center within the Space Science Laboratory. The objective is to consolidate the costly process of developing and staffing science operations facilities for every new small and intermediate class mission. A general-purpose facility can be developed in cooperation with the Mission Operations Laboratory. A requirements definition study should be undertaken within the Space Science Laboratory to identify requirements for implementing and operating a multi-purpose science operations center. Support for system design engineering can be sought from the Mission Operations Laboratory. Implementation and operations can be accomplished cooperatively. Operational activities must include continuing requirements definition and proactive evaluation of staffing and systems performance.

A vital aspect of supporting a science operations center within the Space Science Laboratory is the ability to establish and maintain controlled interoperation with the various mission operations centers. Traditionally, mission operations centers have instituted closed network environments. Such closed environments prohibit the application of needed computing resources to near real-time flight data. The computing resources that can be brought into the mission operations environment are most often severely limited, leading to the need for network connectivity to a facility like an SSL Science Mission Operations Center. The development of the "air-lock" concept between mission operations centers and an SSL Science Mission Operations Center is an important objective. The "air-lock"

concept is to electronically interconnect these centers so as to insure the integrity of flight critical systems, while providing for the flow of science data and the support of instrument management.

SUMMARY

This report reviews the use of computers and computer networks in the Space Science Laboratory. Objectives are identified for the purpose of guiding the robust implementation of services and facilities that can be expected to greatly enhance the quality and effectiveness of our research efforts. Today's desktop or office computer system is embedded in a worldwide web of researchers, computers, and information. The opportunities for enhanced scientific dialog and use of new, powerful research tools are great. Equally great is the complexity of navigating this worldwide web of resources. This report has explored the scope of our computing and networking activities and has stated objectives directed toward the fulfillment of the potential of these information systems.

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REPORT ON COMPUTING AND NETWORKING IN THE
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This report has been reviewed for technical accuracy and contains no information concerning national security or nuclear energy activities or programs. The report, in its entirety, is unclassified.

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