Project Athena Facilities—an Overview for Faculty

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Introduction

This document provides an overview of the system design, the facilities, and the style of operation that surrounds Project Athena. It is intended for faculty members who wish to learn what Project Athena provides and in what ways its facilities might be useful in teaching. Students and others who encounter Project Athena facilities may also find perspectives of interest here. For readers who have seen or heard earlier descriptions of Project Athena's hopes, goals, plans, and problems, this document describes what is actually in operation now, and it gives a current perspective on Athena's future.

This document has three main sections:

1. Background: Goals, Strategy, and the System Design (6 pages)
2. Facilities: Hardware, Software, and Administrative (7 pages)
3. The Future (3 pages)

The final three pages of the document contain information on how to get started and where to go to find out more.

1. Background: Goals, Strategy, and the System Design

(Readers interested in quickly discovering what tools they can assign their students to use may wish to jump directly to the description of the system design on page three. The intervening two pages contain mostly whys, hows, and therefores.)

1.1. Athena's goal and strategy

The goal of Project Athena is to provide a new educational environment at M.I.T., one that takes advantage of modern computer and communications technology.

- With the aid of grants from its two major sponsors, Digital Equipment Corporation and IBM Corporation, Project Athena provides engineering workstations of a price-performance class that, while out of reach of student pocketbooks today, may well be typical of student-owned computers by 1991. These workstations can do significant scientific and engineering computations and then display the results using effective graphics.
- Project Athena replaces M.I.T.'s traditional atmosphere of scarcity of computing for education with one of abundance comparable to that of the research

community, by providing a large number of workstations in public places. One view of this widespread availability of computing is that it simulates a future environment in which most students own personal desktop computers that they can use for assigned homework. For routine assignments in all but the largest classes, faculty need not make advance plans or special arrangements. Instead, one can simply assume that all students have access to computing facilities for homework. The primary limit is the instructor's ability to imagine ways to use computing in the particular class.

- The systems that Project Athena deploys demonstrate a very high level of *coherence*. Coherence means that any program will run on any Athena workstation. Although there are currently two brands of workstations and several sub-varieties, they all run the same operating system, provide the same application programming interface (even in the display area), and have the same sets of tools, application libraries, and programming libraries. Although there are exceptions to this general principle, the coherence that has actually been achieved is remarkably high.

- Coherence applies not only among Athena's brands of computers, but also between successive experiences in using Athena. Because a common set of tools, such as display editor, word processor, spreadsheet, window system, and mail system are used throughout Athena, when a student learns one of these tools in some class, that experience is available to build on in the next class. If a student is encountering a tool for the first time, there is a good chance that a roommate or a fraternity member has already used that same tool in some other class and can assist.

- Computer network technology has matured sufficiently that Athena can provide effective communications and information sharing facilities. For example, an instructor can distribute a class assignment or a set of programs that help demonstrate some class topic by placing them in a network-accessible directory that any student can explore at any workstation. In the reverse direction, a student can turn in homework electronically, ask questions by electronic mail or message, or work with a teaching assistant to untangle a typographical mistake in the homework assignment from across the campus.

Project Athena was formulated with a five-year development cycle to both create the environment described above and also encourage and support the development of novel education applications by interested faculty. To accomplish those two tasks the project began by deploying, in 1984, a complement of off-the-shelf hardware from its two vendors, and it initiated a grant application and allocation process for faculty who had ideas how to use the facilities. Although the off-the-shelf hardware (a collection of small time-sharing systems from one vendor and of personal computers from the other) did not provide much relief from scarcity, nor did it have many of the system features or coherence described above, it approximated the eventual system design closely enough that three years of application development and experience with live teaching situations could be obtained. Over 100 faculty development projects have been undertaken, with the result that most undergraduates now encounter at least one subject each semester that requires use of Athena facilities in doing homework.

Meanwhile, a second generation of computer hardware, network, and software was under development. This second generation, installed experimentally on a small scale during the 1986-87 academic year, has now largely replaced the original complement of hardware, and is in the process of expansion in scale. As of February, 1988, approximately 450 Athena workstations were publicly available, and that number should climb to around 1000 over the next two years.

In 1983, the originators of Project Athena faced a fundamental choice about the short- and medium-term approach for harnessing modern computer technology for teaching. The choice was between immediate application breadth and immediate computer power; it appeared impossible to attain both simultaneously:

1. The personal computer, as represented at the time by the IBM PC and the Apple II, provided systems with a very broad catalog of available applications. Although the power of these processors was low, one could hope to ride up the curve of improving technology to obtain significant computing and display ability in a few years.

2. The engineering workstation, as represented at the time by examples from Sun and Apollo, provided a platform on which one could do real engineering and scientific computation. They had operating systems that could handle large programs and flexible, effective displays. Although expensive, one could hope to ride down the curve of dropping prices to reach a student-affordable workstation in a few years.

On the theory that these two short-term approaches will in the long term converge to the same result, and because the two largest vendors of computer systems were willing to make a big investment in exploring the second choice, the originators of Athena chose that approach. That choice makes certain kinds of application proposals straightforward, and it makes others difficult. Faculty who happen to use engineering workstations in their office or laboratory will find the environment familiar and research applications easily movable to the classroom. Faculty who use smaller personal computers in their office will find the opposite. For better or for worse, this decision provides the starting point for the rest of the system design. Interestingly, in the four years since that choice was made, the cost differential between the two approaches has narrowed from a factor near 20 to a factor closer to three, yet the other basic strengths and weaknesses of the two directions have not changed significantly.

One final piece of background: Originally, workstations from Digital Equipment Corporation were to be used for applications originating in the School of Engineering, while workstations from IBM were to be used for applications of the other schools of M.I.T. Because M.I.T. students cross school boundaries every day, that distinction was never very workable. Today the distinction is gone; its only vestige is to be found in the physical locations of machines in the older public clusters. Faculty are welcome to develop, and students are free to use, any application on any Athena workstation. In fact, because students expect all applications to be available at every workstation, Project Athena strongly encourages faculty to verify that their applications do work in both environments.

The remainder of this document describes in overview the second generation, workstation-based, Athena system.

1.2. The System Design

The primary component of Project Athena is a network-attached low-end engineering workstation. Athena workstations come with two nameplates, the Digital VAXstation and the IBM RT/PC. A majority of Athena workstations are placed in public areas, such as the fifth floor of the Student Center, where any student can use them. Some workstations are allocated to departments that have set up departmental workstation clusters to provide a common location for students and teaching assistants to meet face to face. There are five on- and off-campus living groups experimenting with Athena workstations in their home environments. An experimental classroom in M.I.T. Building 37 allows faculty to try ideas for direct classroom use. Three lecture halls

have an Athena workstation attached to a projection display for lecture demonstrations. Finally, several small development clusters provide faculty and teaching assistants with application development facilities near their offices.

The current design of the Athena workstation requires that it be attached to the M.I.T. campus network. This network provides a 10 Megabits/second backbone that visits (so far) 25 different campus locations that have high concentrations of computers; in each of those locations a gateway connects a local area network to the backbone. The local area network extends through one or more buildings, providing attachment for Athena workstations as well as many other computers. These local area networks deliver data rates of at least four Megabits/second to and from individual workstations. The campus network is installed and maintained by the M.I.T. Telecommunications office; Project Athena is currently the network's largest single customer. In the case of off-campus living groups, a local area network links the group's Athena workstations together, and a low-speed telephone line provides a path back to the campus network.[1] Direct network attachment is intended to be only a temporary requirement. A future generation of the Athena workstation should be usable when not network-attached, though one must expect that a workstation not on the network will not enjoy access to the large library of network-delivered services, data, and programs.

Clients and Servers

The software that comes with an Athena workstation uses a "client/server" model, which means that the workstation, acting as a client, obtains many services from other computers, acting as remote servers, over the network. For example, private mail accumulates at a post office server until the addressee picks it up; files to be printed on a laser printer are queued on a print server to assure orderly use and accounting.

NFS. The most important service is remote file storage, implemented with a version of the Sun Microsystems Network File System (NFS). About 20 VAX 11/750 computers, each with one or more large disks, are located in a few machine rooms around campus; each of these computers acts as an NFS server. This set of servers provides a small, private file storage locker for each undergraduate student as well as class library storage for faculty to use in teaching and in developing teaching materials. Conventionally, when a student logs in at an Athena workstation, the workstation automatically attaches the student's private locker to the file system of the workstation in a way that makes that student's files appear to reside on the workstation. The student may also explicitly attach any other locker or class library that is on any Athena NFS server. The system demands authentication (a password) of each user at workstation login time, and the creator of each file controls whether that file is private or public. An important property of NFS is that it supports coherence: text files created using an RT/PC can be read by a VaxStation and vice-versa. (Any file may be passed among machine types through the medium of NFS, although files containing binary values in the format of one of the machine types won't make sense to machines of the other type.)

Backup. Project Athena provides limited backup against disk failure in its NFS servers by making a complete copy of the contents of each disk approximately once each week. If a serious disk failure occurs (the experience is that each semester one or two of the 100 disks do fail in such a way that a replacement disk must be installed and data restored from a backup copy) the users whose files were stored on that disk will be set

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[1]That low speed constrains certain applications severely; off-campus workstations are configured differently to compensate, but even so they are not completely equivalent to on-campus ones.

back anywhere from a few hours to a week, depending on when the most recent backup copy was made. There is no provision for convenient retrieval of individual files that a user may have accidentally deleted. This level of backup is less than some users may be accustomed to from centrally-administered time-sharing services; it is more than some users do for themselves when using personal computers. Users who have files that would be hard to reconstruct are encouraged to provide additional backup, perhaps by making a copy on a 1.2 Megabyte high-density 5 1/4 inch diskette, which is the standard removable medium on most Athena workstations. Users with private workstations should also be aware that there is no automatic backup of the files stored locally on their workstation. However, keeping copies of a valuable file in at least two places, such as one on a private workstation and one in an NFS locker, would be expected to be a moderately safe and reliable approach.

RVD. A second network-based storage service, known as Remote Virtual Disk (RVD), provides high performance access to shared, large, read-only libraries. Most of the system software actually resides on 15 VAX 11/750 computers acting as RVD storage servers. Placing it there rather than on the workstation provides economy of storage and also the ability to perform software updates by a central change, rather than by visiting every workstation. This form of storage is largely invisible, and would not need to be mentioned, except for one important detail: the data rate of network traffic between even a few clients and an RVD server is greater than the current generation of network gateways can sustain, so every Athena workstation must be attached to a local area network that also attaches an Athena RVD library server. This constraint currently limits the range of locations for Athena workstations to seven of the 25 local area networks managed by the M.I.T. Telecommunications office.

Authentication and Naming

Two important Athena network services are largely hidden from view of Athena users, but all network applications make use of them: authentication and naming.

Authentication. In a client/server environment with workstations as the clients, network services cannot rely on the workstation to check a password as a way of authenticating the identify of a user, because the workstation will be either physically located in a public place or privately owned, and in either case is subject to uncontrolled tinkering. A different approach is needed for reliable user identification. The Athena authentication system, named Kerberos (after the three-headed dog that guards the gates of Hades), provides this different approach. When a user logs in to an Athena workstation, giving a name and a password, Kerberos provides credentials for that user on which all other network services rely. The credentials, consisting of the user's name and related information encrypted into a bit string called a *ticket*, serve as hard-to-forge evidence of the workstation user's identity. As an example, the post office (described in the next section) demands a valid Kerberos ticket naming the addressee before it will release that addressee's mail to a workstation. In addition to mail and notice service, network file and disk service, remote file copy and remote login all require Kerberos tickets.

Naming. To use a network service, the client must discover which Athena computers act as hosts for that service. An online name lookup service named Hesiod (after the writer who first catalogued the names of the gods) provides a comprehensive and highly-available directory of other network services. For example, when a workstation is turned on one of its first actions is to ask Hesiod which system library (RVD) server the workstation should use. When a user logs in, the workstation asks Hesiod for directory information about the user such as which NFS server contains that user's locker and where the user's mail can be picked up. Similarly, a student attaches a class library by

giving its name; the attach command invokes Hesiod to learn which NFS server exports that file system. When a user prints a file, Hesiod supplies the actual network address and connection parameters for the requested printer.

This design makes the authentication and naming services central to the use of all other network services. To maintain high availability there are several identical copies of each of those two services. Switching among them is automatic and hidden from user view. To achieve consistency and reliability without getting too complicated, update of the data of these (and other Athena network) services is by complete replacement once or twice a day, rather than by immediate modification of individual data entries.

Again, both Kerberos and Hesiod act behind the scenes; in most uses of Athena, the user is quite unaware that either service is involved.

Electronic Mail, Post Offices, and Notices

Some faculty find that electronic mail is one of the most useful tools available to augment the educational environment. Every undergraduate student has a registered name, used for logging in and for receiving mail. A set of post office servers collect mail for users; when an Athena user logs in at a workstation, a mail management system is available to collect mail from the post office, store it in the user's private (NFS) file system, and reply or send new messages. Throughout Project Athena, mail is addressed simply with the name of the user, or of a mailing list, which is a user-maintained list of user names. The Athena mail system interconnects with the electronic mail exchange system used throughout M.I.T.; all Athena mailboxes appear from the outside to be on a single computer named "Athena.MIT.EDU". The mail system also interconnects with many outside mail systems; the policy on whether or not students may dispatch messages to a particular outside network depends on the agreements that M.I.T. has arranged with that network.

The publication "Essential Mail" provides a first-level discussion of how to use the electronic mail facilities.

An experimental system named "Zephyr", still under development but expected to be deployed during the 1987-88 academic year, provides delivery of short-lived notices to users currently logged in at a workstation. Notices may be sent, for example, between individual users, by a teaching assistant to currently active class members, from a system operator to all the users in one building, or from a post office to a user to announce arrival of a new piece of electronic mail.

2. Facilities: Hardware, Software, and Administrative

2.1. Hands-On Hardware Facilities

Workstations

As of mid-February, 1988, the following numbers of Athena workstations were deployed in various public and semipublic locations for use by students and faculty:

Location	DEC VS	IBM RT/PC	total
Building 1-142	19		
Building 2-225	12		
Building 4-035, 167	23	11	
Building 7-321	7		
Building 11-113, 116, 124	29		
Building 16-034		18	
Building 37-312, 318	28	12	
Building 66-080	24		
Student center	35	30	
Living groups	48	4	
Departmental clusters	78	26	
In or near faculty offices	45	9	
Totals	348	110	458

Roughly 100 more are scheduled for installation in the next several months. In addition to the above counts of workstations in the hands of the user community, approximately 150 workstations are in the offices of the Athena staff, consultants, and operators, and another 60 provide various network services. Finally, some 300 IBM PC/AT and PC/XT computers (relics from the initial off-the-shelf phase of Athena) are in use, mostly in laboratories (see the discussion of laboratory workstations, below) and by individual faculty members.

Printing Facilities

Project Athena provides about 20 small laser printers in various locations around the campus, and one high-volume laser printer on the second floor of M.I.T. Building 11. In addition to multi-font text, these printers can produce copies of graphic images directly from the display of an Athena workstation. (The speed of the image conversion process differs between printers by more than an order of magnitude; if one contemplates much use of graphics image output one should learn which printers do it quickly.) The high-volume laser printer and some of the smaller printers accept files in the PostScript page description language. As time goes on, Project Athena will probably convert all of its printers to use the PostScript standard.

The Athena administration periodically reviews the policy on use of Athena printers in light of amount of use, costs, and new printer capabilities. At the moment, any registered Athena user has unlimited use of both the low and high-volume laser printers. Current usage patterns suggest that limits really are needed; the most likely approach is to make low-volume printers impose a page-count limit on each print job, and to impose a fee per page printed on the high-volume laser printer.

The document "Printing from an Athena Workstation," provides more information.

Laboratory Workstations

With part of the cost paid by interested departments, Project Athena has supported a data acquisition and experiment control system for use in undergraduate laboratories, consisting of an IBM Personal Computer with a real-time interface and controlling software, and using a floppy disk to transfer data for analysis on a standard Athena workstation. Various departments have deployed several dozens of these systems; they have proven to be effective in certain laboratory teaching situations. A loose-leaf notebook entitled "The Project Athena Laboratory Computer," describes this system.

Special Facilities: Color and Video

A small cluster of Athena workstations (located in the "fishbowl" on the first floor of M.I.T. Building 11) is equipped with videodisk equipment, cable TV connections, and special color displays that permit work with moving video on the same screen used for computer display. A small advanced development group provides support to faculty who are experimenting with this hardware.

Faculty interested in exploring possibilities of use of this limited facility should contact the Athena Faculty Liaison for more information. (See the last section of this document for telephone numbers.)

2.2. Software Facilities

The User's Working Environment

The Athena system presents its users with a library of ready-to-use tools and application packages, under the supervision of the UNIX[2] operating system. The choice of UNIX is a direct, and probably the most significant, consequence of the decision to base Athena on engineering workstations rather than on personal computers. UNIX is both widely used and widely implemented on engineering workstations, but its availability is limited outside that domain. UNIX comes in two closely related but not quite identical families, Berkeley UNIX (the one adopted by Athena and found at most universities) and UNIX System V (the one appearing most often in commercial environments); a majority of application programs written for either one can be moved ("ported") to the other with modest effort.

The X Window System. Project Athena has augmented UNIX with a display interface, named the "X Window System", which in the last year has become adopted as an industry standard for almost all engineering workstations. The X Window System provides two major features. First, it allows the user to organize a display screen into several separate sections, called windows, each of which can display the result of a separate activity. For example, one window can contain the graphical output of a simulation program, while a second window contains the text of a report the user is preparing that analyzes the simulation; the user can open a third window to look up a word in a dictionary or some other library reference, then go back to writing the report with the result of the reference lookup still on the screen. The second major feature of the X Window System is that it provides a machine-independent application programming interface for information display. This second benefit is the one that really matters when importing or exporting software; it is explored in more depth in the section below entitled "The Athena Standard Programming Environment".

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[2] UNIX is a trademark of AT&T Bell Laboratories.

UNIX Commands. UNIX provides a command interpreter, known as the "shell," and a large library of standard commands to create, name, list, sort, edit, and compare files. One of the standard shell's features is that a user may express a chain of commands, arranging that the data output of one be the data input to the next. Although the method of expressing such sequences is somewhat cryptic to a beginner, it is this feature that is usually contemplated when someone describes UNIX as having a "powerful" command language. There are alternative shells with slight variations in their syntax, and also experimental shells that provide less cryptic interfaces, though with a corresponding loss of ability to express complex scenarios briefly. The trade press has produced several popular books of both tutorial and reference material for users of UNIX.

Third-Party Application Packages. Project Athena augments the standard UNIX library of commands with a set of site-licensed third-party application packages. The most important of these is a text editor named "emacs" (in the gnu-emacs version), probably the most popular editor found on engineering workstations. This editor requires a fair amount of effort to learn, but once mastered it rewards the user with an extremely powerful and easy-to-use facility for creating, rearranging, modifying, and examining text.[3]

Other third-party applications include a text formatting system (Scribe), a spreadsheet (2020), a symbolic algebraic manipulator (Macsyma, currently available only on the VAXstation), a laboratory analysis package (RS/1, currently available only on the VAXstation), and two mail-handling systems. One of these (mh) is a freestanding mail reading and sending facility; the other one (rmail) is built in to the emacs editor, and acts as an extension of that editor's repertoire of editing functions. Finally, a database management system (RTI Ingres) is available, although the current version operates only in the older time-sharing environment. Prospective users of Ingres should inquire of the Athena Faculty Liaison about its availability.

Four further documents in the Athena "Essential" series, "Essential Workstation," "Essential Emacs," "Essential Scribe," and "Essential Mail," introduce the new user to the most commonly used of these subsystems. For all the subsystems, the original vendor provides comprehensive user's manuals.

Both the command language of UNIX and the current reportoire of application packages can be fairly characterized as both

- more difficult to master
- more powerful in effect

than the corresponding packages for the personal computer world. The increased effort required to master the system makes the initial encounter with Athena facilities somewhat more of a challenge than desirable. As time goes on, it is expected that newly-available subsystems will provide gradual improvements in usability, user friendliness, and ease of learning, while maintaining the underlying power of the engineering workstation. A recently-added window-based mail reader (named xmh) is an example of this direction of improvement.

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[3] The choice of editors is a topic that provokes wars of religious fervor, usually ending with no clear resolution; Athena's choice of emacs as a general editor is somewhat arbitrary, based on its adequacy for the job, high quality support, and wide availability. Recognizing the religious battles involved, the system also allows users to import and use their own favorite editors, and the editors that come with Berkeley UNIX are in the standard command library. Although emacs is the recommended editor, it is not required in any context.

The Athena Standard Programming Environment

Programming Languages. The Athena system provides three programming languages: Scheme, C, and Fortran. Scheme is the dialect of LISP that is taught in introductory Electrical Engineering and Computer Science subjects; it is thus familiar to a large percentage of undergraduate students. It is especially well suited to small and modest sized "one-shot" programs for a homework set such as to evaluate and display a function or test an algorithm. It is not commonly used for major application subsystems created by the faculty. One reason is that only a Scheme interpreter is usually available; compilers occasionally appear but are not systematically supported.

The "native" language of UNIX is C; applications written in C can make use of every feature and library of the system. For that reason, as well as availability of a wide spectrum of debugging tools, most newly-written large applications at Project Athena are done in the C language. In addition to regular and optimizing C compilers, an interpreter named Saber-C provides a significant aid for program developers. Fortran (the Fortran 77 dialect) is also available. It is used primarily for ease of porting software between Athena and non-UNIX systems.

At various times, three other programming languages have been discussed or used in connection with Athena: Common Lisp, CLU, and Pascal. Common Lisp is an industrial-strength language that has been late to appear in a form usable in the Athena environment, and it is somewhat extravagent in its use of resources—it really requires the next larger size (both in speed and memory space) of engineering workstation. A few Athena workstations are equipped with large memory for use by Common Lisp applications, and some classes are developing large application packages designed for it, but it is not recommended for routine use at this time. CLU is an object-oriented language developed within the M.I.T. EECS Department as a research project, and that department uses it to teach software engineering. On Athena facilities, a compiler is currently available only on the VAXstation. Pascal was originally expected to be a popular language, but that popularity never materialized at M.I.T., so Athena support for it has been withdrawn.

Program Libraries and Toolkits. Several libraries of application subroutines are part of the standard Athena system; they are intended to make it easier to develop applications. UNIX itself comes with a library containing about two hundred standard functions, mostly to manage files and input/output. As mentioned before, the X Window System provides a standard, machine-independent interface to all display devices. The combination of the UNIX and the X libraries represent an industry standard programming interface that is very widely available; applications that use these two libraries can generally be ported from one UNIX workstation type to another simply by moving the source files and recompiling.

In addition to those two standard libraries, the libraries of several third-party vendors are also part of the standard Athena system. There are some 300 standard mathematical subroutines of the Numerical Algorithms Group (NAG; the RT/PC version is still in experimental status), an implementation of the industry standard Graphical Kernel System (GKS), a Fortran plotting package named Penplot, and a Fortran graphics application scaffold named BLOX. Two experimental toolkits intended for rapid development of display-oriented applications are just now becoming available: the X Toolkit and the IBM Andrew Toolkit. They are described in the section below on the future.

Importing and Exporting Programs. An important consideration in the development of teaching applications is whether or not one can save time by importing an existing

program or, if a development project must be undertaken, whether or not the result can be exported to other environments.

As mentioned earlier, application programs written in the C language, using the UNIX and X libraries, and not intentionally made machine dependent (e.g., not containing code that reinterprets integers as character strings) will, once debugged on either variety of Athena workstation, usually port to the other variety of workstation simply by recompiling. The degree of commonality between these two environments is substantial, and skeptics who have been burned by claims of easy portability in the past will find that they need to recalibrate themselves on this pair of systems. (One reason is that a majority of the individual components of Athena's UNIX system are compiled for both the RT/PC and the VAXstation from the same set of C-language source programs.)

Porting programs to and from other Berkeley UNIX environments, such as that of the SUN Microsystems SunOS, Digital's Ultrix, or IBM ACIS 4.3, is generally only a little more difficult, assuming that the application makes use of the X Window System (or makes little use of display interfaces). If the application uses a direct hardware interface for sophisticated display, then the effort of porting can be quite large and the time required depends on the programmer's expertise in display programming. A related problem is that some vendors are still distributing an older version of the X Window System (called Version 10) which is not compatible with the industry standard X Window System Version 11 now used at Athena. Version 10 of the X Window System was used in the prototype workstation system at M.I.T., but it is now obsolete and is being phased out. Conversion of applications from X Version 10 to X Version 11 is a tedious but systematic project.

Moving between Athena's Berkeley UNIX and System V UNIX environments introduces a few additional hazards, most of which show up only if the application makes use of more sophisticated UNIX facilities, particularly interprocess communication (which varies wildly from system to system) or memory sharing, which is not available in Berkeley UNIX.

Finally, there are two ways to construct an application that could be quite difficult to import or export. The first way is to use one of the third-party programming libraries, such as NAG or GKS, which may not be available at other sites. Conversely, a system developer elsewhere may have used some third-party library not available at Project Athena. The second way of falling into an exportability dead end is to make use of network services, such as name service or authentication, that currently are available only on the M.I.T. network. Although Project Athena is making an effort to export its developments in the area of network services to vendors so that they might become more widely available, there is no assurance of success in that venture. Project Athena can make the code available to other sites, but those sites may not be prepared to accept the responsibility of running the corresponding services.

Project Athena advises importers of major applications always to attempt to obtain source, rather than binary, implementations, because little snags in binary programs can cause big problems, and also to ensure availability of applications on both IBM and Digital workstations at Project Athena.

2.3. Project Athena Administration

Project Athena is operated and administered by a very small staff; administration is decentralized and automated as much as possible. Twice each year the registrar provides a list of all registered undergraduate students to Athena's Service

Management System, which enters students not previously registered into a database of prospective users. The User Services staff enters the names of interested faculty and graduate teaching assistants into this same data base by hand. When a prospective user decides to become a real user, the procedure is quite simple: sit down at any Athena public workstation, log in using the identity "register," and answer a few questions. Over the course of the next 24 hours the Service Management System will prime all of the Athena network services (the authentication service, the name service, the network file system, and the post office) to recognize this user and to provide a home directory for personal files.

Resources for Faculty

Any faculty member may register as an Athena user by calling the Athena Account Administrator, followed by a registration session at a workstation. In addition, if a faculty member wishes to set up a class library for delivery of homework sets, programs, data, or whatever, a call to the Athena Faculty Liaison can obtain a disk storage locker for that purpose. A project that involves development of new software usually receives a separate allocation of storage space for that development and some suggestions on how to organize the storage space.

Whether or not special resources are needed, contact with the Faculty Liaison is a good idea, if only to alert that office of your interest. The liaison office maintains a mailing list to alert faculty and developers of changes that may affect their planned use of Athena facilities.

Private and Departmental Workstations. Many faculty members have also found it useful to request that their departments pay the cost of installation and network fees for an Athena-granted workstation for use by themselves or their teaching assistants. Such installation requests can be entertained, subject to equipment and network availability. (Network availability is often the main impediment to private workstation installations.) Several departments have arranged for installation of a few Athena workstations as a development site for the use of their instructional staff. If you are in the Architecture, Urban Planning, Civil Engineering, Mechanical Engineering, Ocean Engineering, or Electrical Engineering Departments, you can take advantage of such facilities. If not, proposing creation of a departmental facility may encounter fewer obstacles and lower total cost than proposing installation of several isolated workstations.

Resources for Students

In addition to deployment of several hundred workstations, Project Athena provides several other resources for students:

- Both on-line and paper documentation for beginners and advanced users.
- A series of intensive minicourses on subjects such as "Word Processing on Athena", "Using RS/I," or "Introduction to emacs," both during regular semesters and during the January Independent Activities Period.
- An on-line consulting facility places students (indeed, any Athena user) in contact with a small staff of student consultants and consulting volunteers.
- Recognized student activities can also become Athena users; they may use Athena facilities for their own administration, and also for export of applications and data to their own members or to the M.I.T. community.

Restrictions on Use

By contract and by policy, Project Athena facilities are for educational use. As is customary with most M.I.T. policies, that policy is broadly interpreted. Students are encouraged to make wide use of the facilities in both curricular and extracurricular applications, within the general guidelines of a statement of "Principles of Responsible Use," which is posted in Project Athena public workstation clusters. Faculty users are expected to follow the same general guidelines, and to respect the boundary between teaching applications and research, administrative, and personal applications. Software developers should be aware that the M.I.T. policy on software rights has specific provisions on ownership and rights for software developed with substantial use of Athena facilities. And finally, faculty should be aware that the security of the Project Athena network storage facilities is not adequate for maintaining privacy of sensitive information such as class grades and letters of recommendation.

2.4. Application Examples

The faculty provide the educational applications that students use with Project Athena facilities. As mentioned earlier, more than 100 faculty-proposed projects have been undertaken with Project Athena's initial financial support. Some of the ways that faculty have used Athena facilities in teaching are:

- Revision of the urban planning curriculum around computer-aided drafting, mapping, spread-sheet and database tools.
- Designing airfoils with a wind-tunnel simulator, designing antennas with an interactive electromagnetic field simulator, designing single-loop feedback systems with an interactive network analyzer, designing bridge spans with automated structural analysis, and designing ship hulls with hydrostatic analysis tools.
- Learning French with an interactive video of a search for an apartment in Paris.
- Discussing Biology homework via electronic mail and bulletin boards.
- Visualizing random variables and queues in teaching probability.
- Teaching technical writing with on-line revision in the electronic classroom. (Some Humanities faculty have discovered that asking students to revise their papers is now a realistic request.)
- Participating in a super-power confrontation in a Political Science on-line game.

Project Athena maintains a demonstration center in M.I.T. Building E40, and encourages faculty to submit examples of interesting educational software for others to try. A half-inch thick report entitled "Faculty/Student Projects: December 1986" summarizes the project proposals made as of that date; it is especially useful in providing leads to other faculty members who have already explored various uses of computing in their classes.

3. The Future

This section sketches out the thinking that underlies current Project Athena planning for the future. The initial five-year project period ends in June, 1988, after just nine months experience with the full-scale workstation environment. In the light of the short period of actual workstation use, a three-year continuation has been negotiated among M.I.T. and Athena's two primary sponsors, Digital and IBM. The main purpose of this three-year continuation is to allow more time for M.I.T. to assess the value of high-function engineering workstations as teaching tools. The continuation is intended to be a time of stability of the underlying system, to allow faculty developers a maximum rate of progress in exploring teaching applications. Assuming the assessment during the three years comes out favorably, the continuation would end with a graceful integration of much of Athena's activity into the fabric of M.I.T. In addition, the extension allows an opportunity for a substantial amount of polishing and smoothing of the system as well as laying the groundwork for that graceful integration.

3.1. Support for the Development of Applications to Teaching

One of the main components of Project Athena's first five years was an intensive fund-raising activity, coupled with a grant-like allocation system to distribute those funds to faculty with ideas on applying Project Athena facilities in teaching their classes. During the continuation, it is *not* expected that such centrally-administered funds will be available. Instead, the primary responsibility for funding curriculum development will return to its traditional home, in School, Department, and individual faculty budgets. One form of support that Project Athena can provide is hardware from its grants, such as a workstation for use in development. Hardware allocation from the grants can also be used as a form of co-funding, to make proposals for curriculum development funds more attractive to prospective outside sponsors. In addition, Project Athena is discussing the possibility of operating an office that can provide help for faculty who are looking for sources of funds and seed money for curriculum development projects.

3.2. System Changes

During the summer of 1987, the facilities of Project Athena underwent a major upheaval as they changed from a time-sharing base to the workstation client/server model. This upheaval required most users to learn new conventions, most developers to reverify that their programs worked after recompilation and reloading, and some developers to modify previously working applications to get them to work again. The rate of change of Athena facilities during that time was the greatest it has been during the lifetime of the project.

Looking ahead, the rate of system change should be far lower for the next several years. The reason is that the basic architecture of a client/server model has enough flexibility to accomodate a wide range of technology improvements. In particular, when new software is installed, in many cases it is now much easier to allow the old software to continue to be available for use for a substantial period of overlap. Finally, many of the changes that are currently anticipated are additions to, rather than replacements for, the current repertoire of commands and programming libraries.

One area that will change in the next two or three years is hidden from the user or application developer, but it should have the effect of improving the quality of the experience of using Athena facilities. That area is the addition of features to make installation and update of software quicker and more reliable; features to increase

system robustness and reduce unnecessary dependence on availability of network services; and engineering to allow the Athena software to be used in a wider range of environments.

A second area of anticipated change is that of making it easier to develop applications that use information display. A category of software known generically as "toolkits", and consisting of high-level libraries that provide a coherent, layered, and simplified view of the display environment, is beginning to appear. Two such toolkits are expected to be available this Spring.

The first of these, developed as an extension of the X Window System, is known as the X Toolkit. The X Toolkit consists of a set of subroutines that implement commonly used display paradigms, such as buttons, menus, and text windows. The second new toolkit is the IBM Andrew Toolkit, sometimes called the Base Environment or Base Editor. This is a second-generation toolkit under development as part of the Andrew System at Carnegie-Mellon University. The IBM Andrew Toolkit contains a high-level library of facilities such as equation, image, line-drawing, and table editors, cut and paste tools, and related fast prototyping facilities.

Project Athena intends to add both of these toolkits to its repertoire of programming libraries as soon as they appear; other similar tools to aid development of display-oriented applications will probably be installed for experimentation as they become available.

Since toolkit technology is a new field, the toolkits themselves are likely to evolve fairly rapidly, and prospective users should plan to track that evolution. In particular, both the X Toolkit and the Andrew Toolkit are still under active development by parties outside of M.I.T. However, they provide such an improvement in development ease that they may be worth using despite a likely need to adjust to future releases.

A third area of likely change is in the area of user interfaces. Window-oriented, Macintosh-like user-friendly interfaces will probably start to appear as options alongside the traditional UNIX command interface. The size and scope of user tools will expand as rapidly as they can be built or imported.

There are no changes currently planned in the array of programming languages. One stubborn gap in the programming repertoire is Common Lisp. Implementations continue to appear, but they also seem to continue to require facilities one or two steps up from the standard Athena workstation's size and speed.

3.3. Other Kinds of Change

During the 1988-1991 period, four other kinds of change of Athena facilities, deployment, and style should be expected:

- If workstation prices continue to drop and living-group network facilities become economically feasible, there will probably be an opportunity for on-campus students to obtain personal Athena workstations, located in their rooms.
- At some point, the Athena software environment should become available to research groups that wish to purchase the appropriate hardware and software licenses.
- As Athena facilities expand, they should become available, perhaps via such research groups, to graduate students.

- Communication and interchange between the world of desktop personal computers and the Project Athena engineering workstation environment should become practical. Owners of personal computers who are willing to pay the extra cost of network attachment should find some software becoming available that permits access to Project Athena file storage, mail, and printing facilities. Initial attention will undoubtedly be paid to the two most popular PC communities, the IBM PC and the Apple Macintosh.

The New Telephone Switch May Help

The installation of a new telephone system owned by M.I.T. is being accompanied by the pulling of extra wires to every office, classroom, and dormitory room, as well as installation of extra optical fiber lines between every on-campus building and three concentrating locations. These extra wires and fibers are intended for expansion of the data communications network on which Athena operates, and should remove what has proven to be a primary bottleneck on expansion of Athena workstation deployment.

The Planning Process

The planning of specific activities for the three-year extension is just getting underway with the formation of working groups including faculty who have been active in working with Project Athena. A comprehensive plan should be available for public review and comment sometime during the Spring term, 1988

For More Information and Action

To Get An Account:

Call the Project Athena Account Manager at extension 3-1325.

To Get Started on a Development Project:

Call the Project Athena Faculty Liaison at extension 3-0170.

For Documentation:

Much documentation is available; the problem is selecting. Project Athena has developed a set of brief user guides, called the "Athena Essentials" series, each of which provides in a few pages the essence of how to cope with some aspect of the system, such as receiving mail, using a word processor, etc. On some topics there is a second such document for more advanced users, in the "More" series. There are full reference manuals for the workstations, their operating systems, and the packaged applications and libraries. Finally, for seasoned system hackers, a notebook called the Athena Technical Plan provides technical detail on each of the system components that were developed by Project Athena staff.

A rack in M.I.T. room 11-112 carries copies of the most often requested user documentation, and an on-line NFS locker named "athenadoc" contains all Athena-written documentation in a form suitable for display on any Athena workstation. Reference copies of much documentation can be found on racks in the larger Athena workstation clusters; many of those documents are also available for purchase from the Information Services publications office in room 11-209. The UNIX system is, to a limited extent, self-documenting with a uniformly-accessed collection of on-line manual pages that describe each command and library routine. Reference and tutorial books on UNIX and on the C, Fortran, and Scheme languages are for sale at the Coop.

The next page contains the current edition of a bibliography entitled "Short List of Athena Publications."

Acknowledgements

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Short List of Athena Documents

Revision C

March, 1988

Free	Available free from the rack in 11-112.
IS	Sold through the IS Publications Office, 11-209, M-F 10-4, (25)3-6325
Racks	Reference copies available in major Athena clusters.
Book	A book rather than a conventional vendor manual. Usually sold through IS, or, if noted, the MIT Coop.
man	Online "man page." Type: **man *topic***

Project Athena
History and Goals

Computing in Higher Education: The Athena Experience
(by request x1300)
Faculty/Student Projects Booklet (by request x1300)
Questions & Answers about Project Athena (by request x1300)

Athena Administration

Essential Athena (free)
Athena Reference Card (free)
Newsletter, occasional (free)
Applying for Curriculum Development Funds (by request x1348)
Listmaint Instructions (by request x1325)

Unix and Workstations

Athena Workstation (free)
More Unix: The C Shell (free)
Introducing the Unix System, McGilton & Morgan (book, racks, IS)
The Unix Programming Environment, Kernighan & Pike (book, racks, IS)
An Introduction to the C Shell (racks, IS)
Unix User's Reference Manual (man sections 1, 6, 7) (racks, IS)
Unix User's Supplemental Documents (racks, IS)
Unix Programmer's Reference Manual (man sections 2, 3, 4, 5) (racks, IS)
Unix Programmer's Supplemental Documents, Vol 1 (racks, IS)
Unix Programmer's Supplemental Documents, Vol 2 (racks, IS)
Unix Systems Manager Manual (racks, IS)

X Window System
man X

Athena Workstation (free)
Xlib C Library Reference Manual (racks, IS)

Emacs Editor
man emacs

Essential Emacs (free)
Emacs Quick Ref (free)
More Emacs (free)
GNU Emacs Users Manual (racks, IS)

Scribe Text Formatter
man scribe

Essential Scribe (free)
Scribe Pocket Guide (racks, IS)
More Scribe: MIT Thesis (free)
More Scribe: Report (free)
More Scribe: Resume (free)
Scribe Users Manual (racks, IS)
Scribe Database Administrator's Guide (racks, IS)

Mail Handler (mh)
man mh

Essential Mail (free)
Mh Manual in Unix User's Supplemental Documents (racks, IS)

Printers & Hardcopy **Graphics Output** man printers	Printing from Athena Workstations (free) How to Use the Xerox 9700 (unsupported SIPB document) How to Use the Apple Laserwriter (unsupported SIPB document)
C Language man cc, man lint man ld man 2 *system call* man 3 intro	Essential C (free) More C (free) Saber C User's Guide and Saber C Reference Manual (racks, IS) The C Programming Language, Kernighan & Richie (racks, book-IS) The C Primer Plus (racks, book-Coop) The C Answer Book (racks, book-Coop) C manual in Unix Pgmr's Supplemental Doc, Vol 1 (racks, IS)
Fortran Language man f77, man ld man 3f intro	Essential Fortran (free) Fortran 77 for Humans, (racks, book-IS) f77 Language Manual in Unix Pgmr's Supplemental Doc, Vol 1 (racks, IS)
Franz Lisp Language man lisp, man liszt,	Franz Lisp Manual (racks, IS) Lispcraft, (racks, book-IS)
Scheme Lisp dialect man scheme	Essential Scheme (free) Scheme V 7 Reference Manual (racks, IS)
dbx debugger man dbx	some discussion in *Essential Fortran* dbx manual in Unix Programmer's Supplemental Documents Vol. 1 (racks, IS)
Penplot Graphics man penplot	Penplot Reference Manual (racks, IS) Athena Guide (free--available only at IS)
ProChart Presentation Graphics	Prochart Manual with Athena Notes (racks, IS--by Dec '87)
GKS and CChart **Graphics Libraries**	GKS Manual (racks, IS--by Dec '87) CChart Manual (racks, IS--by Dec '87)
NAG Numerical & Stat Library man nag	NAG Mini Manual (racks, IS) 6-Volume Library Reference Manual (racks, special order through IS)
20/20 Spreadsheet man 2020	20/20 User Guide(racks, IS)
RS/1	Essential RS/1 (free) RS/1 User's Guide (racks, IS) RS/1 Pocket Guide (IS)
RTI Ingres Database	Introduction to Ingres (racks, IS) Ingres Reference Manual (racks, IS) Equel-C Interface Library (racks, IS) Equel-Fortran Interface Library (racks, IS)
$MATRIX_X$	$MATRIX_X$ User's Guide (on request from Applications Programmer)
MACSYMA	Introduction to Unix MACSYMA (sold by Symbolics, 577-7500) VAX Unix MACSYMA Reference Manual Version 11 (sold by Symbolics, 577-7500)