CASE STUDIES

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Organization and Management of Project Athena

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Abstract

Project Athena is a $100 million, eight-year project to install a large network of high performance workstations for education and research on the campus at the Massachusetts Institute of Technology (MIT). Project Athena appears to be the largest existing centrally managed educational computer system in the country. It presently supports 10,000 users on 1300 workstations, 135 laser printers, and 80 file servers. The system is designed to be expandable to support up to 10,000 workstations. The primary project sponsors are MIT, Digital Equipment Corp., and IBM. Development is now essentially complete, and the system will be turned over to MIT for operation and maintenance in June, 1991. The project has been very successful in technology transfer; the X Window System, the X Toolkit, and the Athena authentication service have become industry standards.

This paper describes the organizational, legal, and administrative aspects of the project that allow two competitors to work together in a cooperative manner under the MIT umbrella.

Introduction

In May, 1983, MIT announced the establishment of a five-year program to explore new, innovative uses for computing in its curriculum. The technical needs of higher education were rapidly moving beyond the capabilities of conventional pedagogical techniques and major computer manufacturers were developing high performance graphics workstation networks that were expected to be affordable by the end of the project. MIT's faculty believed the workstation networks could overcome the obstacles impeding learning by providing easy visualization of concepts, powerful simulation tools for homework problems, productivity aids that allow a student to accomplish more in less time and with better quality, and the ability to improve education in design by solving realistic problems using sophisticated computer-aided techniques.

Project Athena's objective is to improve the quality of education at MIT by fostering innovative uses of a network of high performance graphics workstations. Athena's mandate is to explore diverse uses of computing in support of education and to build the base of knowledge needed for a longer term, strategic decision about how computers fit into the MIT curriculum.

The initial deployment is 1300 workstations owned by the Institute. Later, all stu-

dents and staff will be encouraged to purchase private workstations, and the system will be extended to support approximately 10,000 workstations. The system software is based on the UNIX operating system, and includes additional MIT-developed software that implements a server-based distributed system. A significant part of the project is the development of instructional software; presently there are 125 projects that have been funded to develop instructional software.

Athena is administered for Digital by its External Research Program; it is the largest project in this division. Athena is the largest educational project ever undertaken at MIT. The workstations now being deployed did not exist at the beginning of the project: based on technology projections, it was assumed that they would become available when they were needed.

Digital Objectives

Digital Equipment Corp. joined Project Athena for the following reasons:

- to help improve the quality of higher education and, thus, the quality of the graduates entering the technical labor force
- to use Athena as a means for assisting in the development of technologies for the next generation of large workstation networks (once developed, Athena would then become an ideal testing ground for these technologies)

Athena was attractive as a means for development and testing of next-generation technologies because its environment was similar to the environment of large industrial and governmental users. While the conventional wisdom might suggest that the educational computing environment is somehow unique, the Athena experience was that it is not very unique. Athena had to support several thousand workstations using heterogeneous hardware for a user community with a broad range of skill levels and for an environment requiring a variety of applications. The usual requirements of high availability, broad functionality, low-cost maintainability, security/integrity, and ease of use exist at MIT, just as they do at an industrial/commercial organization. Consequently, the Athena system is broadly general purpose.

On a more tactical level, it became evident in the early 1980s that the advent of workstations and local area networks (LANs) would substantially change the nature of campus computing. It appeared that timesharing, the nearly universal approach to campus computing, would be replaced by networks of workstations. Therefore, it was important for Digital to be involved in an early implementation of a workstation network. Moreover, the environment ideally would require a large number of workstations in a diverse and hostile environment, preferably in a multi-vendor situation.

The campus workstation network provided a testing ground for Digital products and computing strategies. Inevitably, problems of scale were encountered. Campus staff provided leadership in identifying the problems and developing solutions to the problems, as well as implementing and testing the solutions.

Digital's tactical objectives for Athena were as follows:

- understand the new model of campus computing and communications enabled by the advent of workstations and LANs
- participate in the design and development of a large campus-based workstation network
- test Digital products and computing strategies in a large, hostile, and multi-vendor environment supporting a wide range of disciplines
- identify problems of function and of scale in a large workstation network

- use MIT expertise to develop high-quality solutions to the problems discovered, and to test the validity of those solutions in an operational environment
- understand the strategies of co-existence in a multi-vendor environment
- transfer the resulting expertise, technology, and designs to Digital Engineering

The MIT environment met all of the above requirements very well.

Finance

The initial estimate of the cost of development and installation of the Athena system was $70 million. This budget was to carry the project through the five years of development to completion. The plan was then to turn the system over to the MIT Information Systems department. Each of the two major sponsors, Digital and IBM, committed about $25 million in equipment, personnel, maintenance, and cash. In addition to the $50 million from the two primary sponsors, MIT agreed to raise $20 million from other sources.

At the end of the five-year period, the project was not complete. System development was only approaching completion and the development of instructional software was just getting started. However, the system appeared to be living up to expectations, and there had been significant benefit to the sponsors. Both sponsors and MIT then agreed to a three-year extension of the funding. The support by the sponsors on a yearly basis was approximately the same as it had been for the first five years, bringing the total amount of sponsor support to over $100 million for the eight years of development.

MIT realized prior to the start of the project that a significant effort had to be made to develop instructional software. Very little instructional software existed at the start of the project, and very little of what existed was based on workstations and Unix. The bulk of the instructional software was written for personal computers or character-oriented timesharing. Therefore, MIT made $8.5 million available to the faculty to develop instructional software. The method of allocating the funds for instructional computing is described below.

The original cost of Athena, including operations, depreciation, workstation purchase (by students), and maintenance cost, was set at a maximum of 10 percent of tuition. This cost objective was selected somewhat arbitrarily, because it was believed to be the maximum affordable by students. The tuition at MIT is about $15,000 per year. Over a four-year period this would be $60,000. Ten percent of this amount is $6000. An economic model of the project was developed in 1987, in which half of this amount was allocated for purchase of a personal workstation and about half to support the infrastructure (including support staff, depreciation of Institute-owned equipment, maintenance, and software.) Thus, workstation purchase and all other costs would each be five percent of tuition.

The initial startup of Athena is now over, and the yearly operating cost is about $3.5 million. Not included in this amount is equipment depreciation and some free maintenance provided by the sponsors. The total annual cost of the project on an on-going basis is estimated at $6 million to $8 million, not including workstation purchase. Project costs based on current experiences are meeting the original objective for infrastructure cost because this amount is about five percent of tuition.

It is not now possible to purchase a workstation meeting the MIT specifications for $3000, as indicated by the economic model. Recent product developments have used the technology improvements to boost performance rather than lower cost. However, a workstation meeting the MIT requirements should not be much more expensive than a personal computer. It is possible to purchase personal computers for under $2000, so it

is possible that workstations meeting the MIT objective could be available for under $3000 in the near future (assuming an educational discount).

Digital provided a significant portion of the budget in the form of a grant that included hardware, software, and people on site. The people on site were software engineers who assisted in the development of the Athena system and application software. Hardware grant money was dispersed as follows: file servers and peripherals (42 percent), workstations (34 percent), minicomputers (8 percent), terminals (7 percent), communications (4 percent), printers (3 percent), and miscellaneous (2 percent).

Organization

The organizations related to Athena include the Athena project itself, the Athena Executive Committee, the Resource Allocation Committees, the Athena Study Committee, and the organization of the sponsors at Athena. Although each of these organizations has a mission of its own, they interact to a considerable extent. The following section describes each of these organizations.

The Project—Two alternatives existed for the placement of the project in the MIT organization when it started. It could have been made part of an Information Systems department which reported to the vice president responsible for all administrative computing and central timesharing services. The department is also responsible for all communications on campus, including the telephone system and LANs. The other alternative was to set up the project as an independent organization.

The second alternative was selected for four reasons. First, the existing Information Systems department personnel lacked the necessary skills in Unix, C, workstations, and distributed computing. Second, the Athena project was so large that it could benefit from being a separate organization. Third, the time scale of the project was relatively short compared to the size of the task to be done. This required that expedited procedures be used. Fourth, the skills of the Information Systems department personnel were largely absorbed in integrating several formerly independent computing systems.

Professor Steve Lerman of the MIT civil engineering department was the project director. The dean of engineering has overall responsibility for the project and he, in turn, is responsible to the provost. Prof. Lerman's first task was to develop an organization. The initial project organization, as shown in Figure 1, was fairly conventional. The supervisors of system software, user services, and supervisor of operations reported to the project director. Prof. Lerman also had an assistance director who is responsible for looking after the detailed day-to-day operations. A technical director is responsible for the technical integrity and consistency of the project.

The decision was made not to develop networking capability in Athena but, instead, to purchase those services from MIT's department of telecommunications. To ensure close cooperation between telecommunications and Athena, the networking personnel were colocated with the Athena project personnel.

The MIT Athena staff increased in size over the life of the project to eventually reach a total of about 75 full-time equivalent MIT people. In addition, each sponsor provides up to five software engineers on site. MIT retains veto power over sponsor people assigned to the project in order to maintain appropriate standards.

The Digital and IBM software engineers are assigned to the MIT supervisors, and are treated the same as MIT personnel. Each sponsor also provides an on-site manager, who is responsible for meeting the staffing commitments for that company, making sure that the appropriate contracts are made and that other legal matters are handled, and ensuring that technology transfer takes place in both directions. The sponsor man-

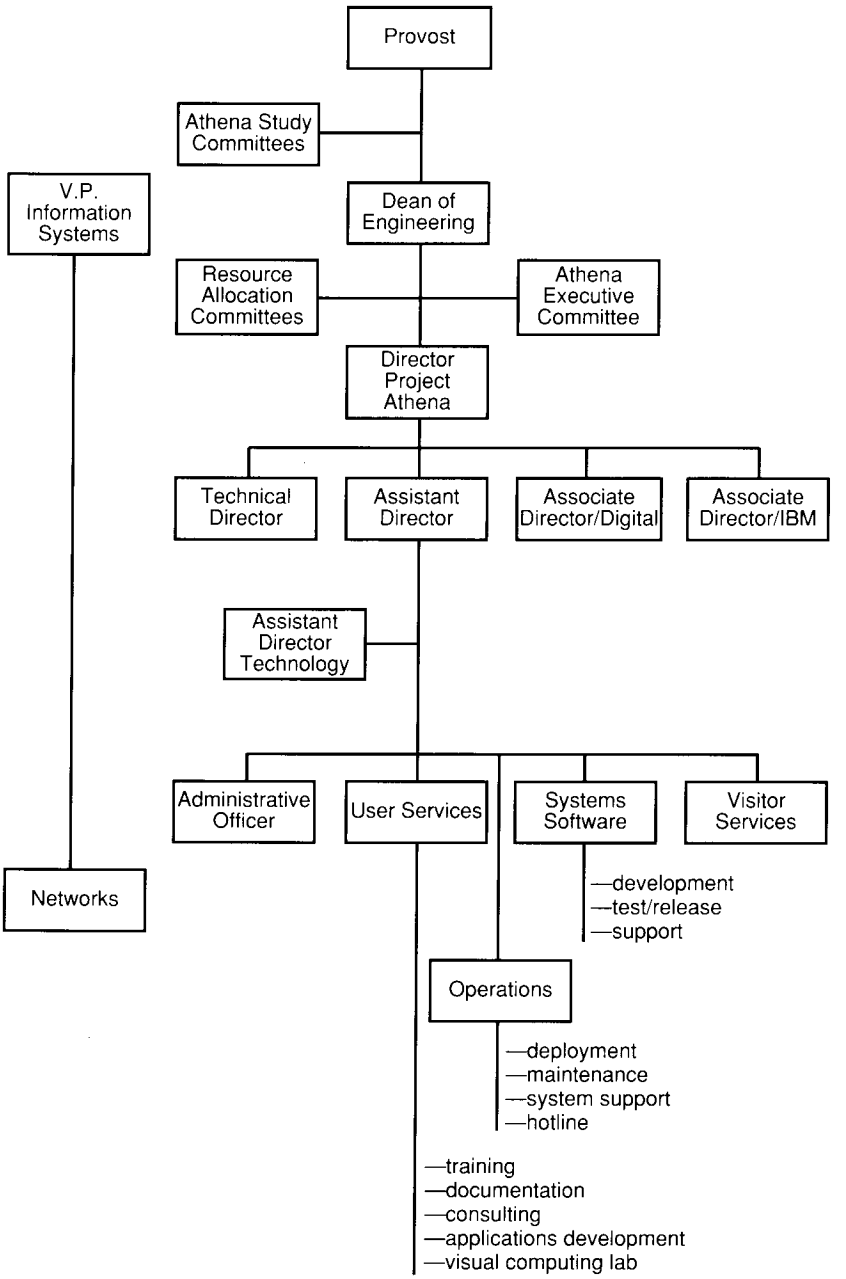

Figure 1. Initial Athena Organization

agers also assist in selecting products from the parent company, and ensure that orders are processed properly. In some cases the managers have strong technical skills and make a significant technical contribution to the project.

All of the personnel from the member companies have appointments as visiting scientists or visiting engineers at MIT. In addition, the managers from the sponsoring companies have appointments as associate directors. They participate in the day-to-day management of the project, along with the project director, assistant director, and technical director. The MIT vice president of information services also participates in the day-to-day management of the project. He is able to bring campus management information systems (MIS) expertise to the project, and is able to coordinate Athena activity with other MIS activity on campus.

Initially there had been apprehension about co-mingling personnel from two competitors in close proximity in a single team. In actual practice, there is no indication of competition or friction between the two competitors. Indeed, it is difficult or impossible to tell which individual belongs to which company, as they all have the same objectives. These individuals are quite objective in their work, and it is not unusual for a person to argue against the best competitive interests of the parent company and for the best interests of the project. (In this regard, the Athena experience is the same as that of the Microelectronics and Computer Technology Corporation (MCC), where members of competing companies often worked on the same technical teams).

The Athena Executive Committee—In addition to the project itself, an organization was needed to establish objectives from MIT's standpoint, to set policy, and to represent the system's users. The Athena Executive Committee, chaired by the dean of engineering, has been established to meet these needs. Although the membership changed from time to time, its membership generally included the upper echelon Athena personnel, the IBM and Digital representatives, and academic and administrative personnel at MIT.

Resource Allocation Committees—Two Resource Allocation Committees, one for Digital equipment and one for IBM equipment, were established to allocate the funds for instructional software. The two committees have similar functions, but differ in details of operation.

Procedures were established so that the faculty could submit proposals to obtain funds and equipment to develop instructional software. The proposals presented the scope and benefits of the intended instructional development. The funds support faculty released time for the development effort, and students and professional staff hired to do the programming.

Project Athena Study Group—One of the initial objectives of Athena was to provide information to support a decision on the MIT approach to educational computing after the project was complete. In order to provide a faculty evaluation of the project, the Project Athena Study Group was established during the summer of 1985. The group is chaired by the dean of architecture and planning. Membership is drawn from the faculty and management of Athena. Funding for a number of evaluation studies has been provided by MIT's provost.

Contracts

Two separate contractual arrangements, one between Digital and MIT and the other between IBM and MIT, were made in support of the project. Establishing separate contracts avoided the problem of having both IBM and Digital contractually obligated to each other.

The agreement between Digital and MIT was split into two separate contracts, one contract covering the donation of equipment, software, maintenance, and on-site manpower as this was an outright donation with nothing requested in return. The other contract covered the cash donation with Digital receiving certain non-exclusive rights to software developed through Athena.

MIT retains ownership of all intellectual property developed through Athena. Because the primary objective of Athena was the improvement of higher education, however, all system software developed with Athena funding has been made available to the public for a nominal or no cost, provided that the MIT copyright notice is retained.

Digital-Athena Relationship

Project Athena is administered for Digital by the External Research Program which is directed by Jack McCredie. (The External Research Program is the means by which Digital tracks and utilizes research done at colleges and universities. Digital presently has about 300 external research relationships at 120 leading colleges around the world.) A full-time on-site manager, George Champine, is also provided for day-to-day management of Digital responsibilities. The Athena staff presents reviews of progress, status, and plans on a quarterly basis to a committee chaired by Sam Fuller, vice president of Corporate Research and Architecture for Digital. Digital senior management personnel also review progress and plan on a yearly basis.

Technology Transfer

Most research and advanced development activities meet with limited success in developing new ideas and technologies that result in marketable products. Success is even more limited when the R&D organization is physically and/or organizationally separated from the receptor organization. The major problem is usually technology transfer.

One exception to this typical scenario is the Athena Project. Athena has been remarkably successful in developing, transferring, or stimulating new technologies in spite of being physically and organizationally remote from any receptor organization. Its successes are even more significant since its charter specifies that its mission is development and operation rather than research or advanced development.

Few of the new technologies that have resulted from Athena were envisioned at the beginning of the project. The project was funded on faith; *i.e.,* if highly capable people were put to work implementing a leading-edge system, then good things would result. If a business plan had been required for justification of Project Athena, it would surely have failed to meet the usual cost/benefit tests. The results, however, have more than justified the faith placed in it from the outset.

An aggressive program of technology transfer was carried out during the last two years of the program when results were becoming available. A monthly newsletter was generated and distributed within Digital to about 600 individuals who requested it. The newsletter was supplemented by technical reports sent to departments that might benefit from them.

A special working relationship was developed with Digital departments thought to be the most likely recipients of the Athena technology. Although primarily located in central engineering or corporate research, some Digital marketing organizations were included as well. The relationships were established initially by visiting the recipient Digital department and presenting individually tailored versions of the benefits of

working with Athena. After such visits, the recipient groups started coming to Athena. The Athena office at MIT has become a popular meeting place where groups of Digital people discuss specific technology topics (*i.e.,* multimedia workstations) being developed at Athena. They also attract groups of industrial participants meeting for the same purpose.

A very important element in the successful transfer of technology is the fact that Athena selected the "right" problem. This was a result of a "problem-directed" research approach as opposed to a "technology-directed" approach. The problem-directed approach is far more likely to yield information that can be transferred because there is a "needs-pull" or user demand for the solution to the problem. Further, a problem-directed research approach is more likely to address important problems than is a technology-directed research approach.

People

Individuals play a very important role for Digital at Athena. Digital maintains a group of five to eight resident engineers at Athena. These Digital residents were initially nominated by their home departments. Final selection was made by Athena and Athena retains control over the assignment and can terminate it at any time.

Employees are assigned to Athena for varying lengths of time, usually two to four years. This circulation of people results in significant technology transfer. It is a responsibility of the Digital employees at Athena to ensure technology transfer by keeping appropriate groups within Digital fully informed of the results of Athena research.

An Athena assignment is viewed as an opportunity to work with leading researchers from a variety of backgrounds on topics that are at the forefront of technology. The Athena environment frees the individual from administrative and management duties, and maximizes productivity in research. The employee's value to Digital is increased by this experience. The key factors in this process are proper selection of professionals at the beginning and communication between the employee and Digital during the assignment.

Athena Continuation

The three-year extension has been of benefit to the sponsors because a number of new initiatives have been undertaken during this extension. It is also of value to MIT because it allows time for the educational Athena objectives to be tested and evaluated, and it provides time to develop additional software to upgrade the system in several important areas.

The major initiatives for the extension period are:

- to develop improved tools for application (*i.e.,* interactive and instructional) software development
- to develop improved tools for system management
- to develop improved human interfaces to make the system and instructional software easier to use
- to continue and improve the interactive video system

By the early 1990s, it is hoped that workstation prices will decline enough to allow all students and staff members to purchase private workstations and connect them to Athena services via the campus communications system. By this time MIT will have completed the wiring of the campus with a LAN. Workstations can then be connected to the network from any office or public room on campus. At that point the objectives of

Athena will have been accomplished. Athena will be merged into the administration of MIT and will become part of the standard campus computing environment.

Conclusion

The MIT/Athena environment is very productive at developing technology leading to products or generating ideas and prototypes for products. There are four reasons for this success.

- The Athena development is similar to systems that will be implemented by major customers in the next few years and is, therefore, highly relevant.
- The Athena development team is physically located near the Digital Engineering department and teams from Digital visit Athena on a frequent basis. This proximity has contributed substantially to successful technology transfer.
- The on-site team of Digital people actively work to transfer technology to people responsible for developing products.
- MIT makes systems technology developed through Athena available to the general public at no cost, with rights of unlimited use and reproduction. Athena developments have become popular as emerging de facto industrial standards.

The Athena system is now essentially complete, and will be turned over to MIT for ongoing operation and maintenance starting in July, 1991. High quality computing is universally available throughout the MIT campus, and students are now graduating who have never known life at MIT without Athena.

The major successes of the Athena project include development of several defacto computer standards, successful technology transfer, and perhaps most importantly, the demonstration that two strong competitors can work together with an academic partner to accomplish objectives beyond the capabilities of any one of the groups.