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Project Athena

Success in Engineering Projects
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Abstract

In a large-scale engineering project, it is difficult to define success. Many times, the goals of the project change so frequently that it is impossible to say whether or not the goals of a project were met. In addition, there are often unexpected outcomes and results that cause the project to be more successful than ever imagined. This was the case with Project Athena, a campus-wide computing project at MIT from 1983 to 1991 developed by engineers at MIT, DEC, and IBM. Although the educational goals of the project were never completely achieved, the project created a distributed network environment that helped define a new paradigm in the world of computing.

1 Introduction

What is success? In engineering, this question is often very difficult to answer. For example, the iMac was a very successful engineering project at Apple Inc., and OS/2 Warp is a clear illustration of an unsuccessful project. However, there are many projects that fall in the middle, such as MiniDisc technology. While very popular in Asia and Europe, the MiniDisc has had little growth in the United States. In very large engineering projects such as these, it is quite difficult to determine whether a project was successful. Some aspects may be successful, while others may be completely unsuccessful.

How does one define success? Some may argue that a successful project is one that meets a stated objective. In many cases, determining this objective may be very easy to do, because the intended goals are clearly understood in the initial proposal. It seems logical to say that a flashlight is successful if it can be turned on and off. However, what if the flashlight burns out a bulb after five minutes of use? Or, what if it uses up batteries five times faster than that of a competitor? Is it still a success? As you can see, the line between success and failure can be quite difficult to judge, even on simple engineering projects.

One solution to this problem entails defining success by whether or not the end result satisfies a set of initial goals. If these goals are met, the project is successful; otherwise it is not. So, in the previous example, the goals of the project might be to 1) build a flashlight that can be turned off and on and 2) have a battery-life of more than 50 hours and 3) have a bulb that lasts for 150 hours. Therefore, a successful engineering process will meet the criteria of these goals. However, if the batteries only last for 45 hours, is the project truly unsuccessful? What if the batteries only last for 45 hours, but the light shines twice as bright as the previous model? Then, is it a success? What if, even though the technical goals were not fully achieved, the new model sells ten times better? As you can see, even with a clear definition of success, it is often quite difficult to make a fair evaluation of a project.

Another problem with the previous definition of success is that in large engineering projects, the goals that are stated at the beginning of the project may differ from the goals of the project at a later state, and then from those finally achieved. The reason this may occur is because not everything done in an engineering project can be predicted. Sometimes things are achieved that are never expected. These unexpected results can either make the project a wild success or a dismal failure.

A final thing to consider when evaluating whether or not a project is successful is: what happens in the event of conflicting goals? If senior management thinks a flashlight that uses fewer batteries is more important, while the engineers feel that a flashlight that burns brighter is more important, which goal should have more weight when evaluating the project? If one goal was achieved and the other was not, is the project a success? What if it was impossible to achieve both goals? If there are conflicting goals, does that mean that it is impossible to have a successful project?

This paper argues against the common belief that engineering is a carefully planned and executed endeavor and instead proposes that engineering is a process that results from the interaction of competing groups, each with their own goals, within a loose project framework. Thus, in order to measure the success of an engineering project, it is necessary to understand success through the perspective of the major goals and participating groups.

We take the case example of Massachusetts Institute of Technology's (MIT) Project Athena and show the difficulty of making an overall evaluation for an engineering project of this scale. We examine the major goals of this engineering project as well as several key groups who were involved and show how each of these forces competed to push Athena in different directions at different stages of the project. Each of these forces has their own measure of success for the project, and by understanding success within the context of each of these forces, a more complete evaluation of the overall project can be made.

We will begin by giving a brief history of the Athena project. We will then take a deeper look at the two main focuses of the project, namely the educational and technical goals, and analyze their influence on the development of the project. Then, we will look at the three major contributors to Project Athena, the faculty at MIT, Digital Equipment Corporation (DEC) and International Business Machines (IBM), and examine their impact on Project Athena. Finally, we will draw conclusions on how this case study relates to the engineering world in general, in terms of evaluating a project's success.

2 Background

2.1 Prehistory of Athena

MIT first began using digital computers in 1947, when a computer called the Whirlwind I was brought to campus. Many of the most important inventions relating to computers – such as core memory and time-sharing, were invented at MIT. In 1962, for example, MIT began the Multiplexed Information and Computing Service System (MULTICS) on campus. This was the first attempt to bring computers to the students, and it had a large impact on computing at MIT. Each student was allocated a set amount of time they could use the mainframe computer; however, once that time ran out, they were unable to run any more programs.

In the early 1980's, the world of computing was changing. The days of mainframe computers were quickly passing, and the era of workstation computing was emerging. Leading computing science researchers were beginning to realize that distributed network computing would be the next paradigm in the computing world.

Until the beginning of the Athena project in 1983, MULTICS was the only computing resource available for educational purposes at MIT. In fact, a student could very likely complete an undergraduate degree in science or engineering without ever using a computer. Going back to 1982, almost any research project that wanted to use a computer could obtain one, either through contracts or grants from the government, or perhaps an interested company. However, if a faculty member had the initiative to use computer modeling and simulation to help teach a class, the task of acquiring a computer was hopeless.[1] The educational budget was extremely limited and, in the early 1980's, computers were extremely expensive, costing approximately $5,000 for a computer with 64k RAM. Moreover, in 1979, MIT was only spending about $10 million per year on computing, with 57% going to research, 21% going to administration, and only 6% going to education.[2]

In the late 1970s, some professors began to be concerned with the current state of computing at MIT. With a frustrated energy accumulating, they began to channel this fervor into a long-term goal to develop MIT's computational resources for educational purposes. But even though faculty members had been exhibiting educational concerns since the mid-1970's, the Athena project did not begin to take form until 1983. This long interval of time leads us to believe that factors other than the concerns of certain faculty members propelled the development of the Athena project. The Ad Hoc Committee on Future Computational Needs and Resources at MIT was formed in 1978. It recommended that MIT do the following four things:

- establish ten regional centers of computation within MIT
- acquire new resources (5 medium-scale computers and 400 terminals)
- initiate experiments in education, office automation, graphics, personal computers, computerized classrooms, mixed media, and library use
- establish a campus-wide network.[3]

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[1] Interview with Professor Jerome Saltzer, Athena's Technical Director, November 11, 1999
[2] Champine, George A., *MIT Project Athena: A Model for Distributed Campus Computing*, Digital Equipment Corporation, 1991, page 5
[3] Champine, page 6

At this point, however, no commitment to action was made – a project as revolutionary as the recommended procedure would require a much stronger source of funding and leadership.

In early 1982, Carnegie Mellon University (CMU) became the first campus that decided to go into network computing in a big way. They started the Andrew system, a joint project between CMU and IBM to build their vision of what computing would be like in the future. It was a workstation-based system that was created to increase the "quality and quantity of education delivered"[4] at CMU. In addition, they wanted to increase computer literacy and allow easy access to highly reliable computation. Their computing environment was created based on these goals, and today Andrew is considered one of the "largest and most successful advanced campus computing systems."[5]

Other universities were also attempting to increase computing use on their campus at this time, as well. Dartmouth had a history of being on the forefront of campus network computing, as they were one of the first colleges to begin using time-sharing terminals in clusters located around campus. However, since they were used to their old network, which had been around since the 1960s, they were not looking to switch to a new network at this time, but rather to increase the support of their current network. Other universities also were trying to increase computing use on their campus. The liberal arts college of Drew University in Madison, New Jersey, announced in 1984 that all incoming freshmen would be provided with Epson QX-10's. This increased their number of applicants in the year after the announcement by 49 percent.[6] Brown University was the only other university besides CMU and MIT to start researching a workstation-based computing network in the early 1980's. In June of 1983, Brown started its Institute for Research in Information and Scholarship (IRIS) project, whose main emphasis was to define the qualities of the optimal student workstation. This project was funded by Apple, IBM, and the Annenberg/Corporation for Public Broadcasting.

2.2 The Beginnings of Project Athena

A year after Andrew began, MIT started to seriously consider the use of computers for educational purposes. Various academic departments, particularly within the School of Engineering, developed the Joint Computer Facility. From their own educational funds, these departments scraped together enough money to buy a handful of computers for educational use. While these resources were nowhere near adequate to begin a computing revolution, the group used their efforts to convince others of the importance of computers in education. For instance, they recognized the shortage of educationally oriented computing in annual reports and highlighted the potential benefits computers may have in undergraduate education. Thus, the efforts of individual professors slowly opened each departments' eyes to the benefits of instructional computing, bringing them one step closer to the acceptance of the educational goals.

In fact, the Dean of the School of Engineering, Gerald Wilson, took an interest in this problem in 1982, and added his considerable influence towards the development of a solution. With the help of the Director of the Laboratory for Computer Science, Michael Dertouzos, and the head of the Electrical Engineering and Computer Science Department, Joel Moses, Wilson

[4] Champine, page 11
[5] Champine, page 11
[6] Waldrop, M. Mitchell. "Personal Computers on Campus", Science, April 26th, 1985. page 438

decided to develop a first-class computational environment for undergraduate engineering students. MIT realized that they could not support a project as large at Athena without a major commitment from sponsors for equipment donation and money. So, MIT began to search out proposals from hardware vendors. After reviewing all the proposals, MIT selected DEC and IBM as the sponsors for Project Athena. With DEC and IBM willing to contribute millions of dollars in grant money, equipment, and even their own programmers, Project Athena was officially born as an institute-wide project in 1983.

Project Athena began as a five-year project to look into the use of computers in education. Its mandate was "to explore diverse uses of computing and to build the base of knowledge needed for a long term strategic decision about how computers fit in to the MIT curriculum."[7] However, after these three years were finished, it was determined that the project would need three more years of funding in order to really accomplish its goals. At this point, DEC and IBM agreed to donate more money for the last three years.

On June 30th, 1991, Project Athena officially ended. By this point, the students were very used to having computing resources available on campus, and the administration and faculty at MIT realized that Athena had become an integral part of student life. Therefore, the network produced by Project Athena – the Athena system itself, was adopted as MIT's academic computing infrastructure, with plans to extend it to the research and administrative activities of the Institute.

Today, Athena is one of the most used academic computing environments in the world. There are over 600 workstations (1,300 total computers) placed across the campus, in locations known as "clusters", where students and faculty can go 24 hours a day 365 days a year to do class work, do research, write papers, chat with each other, do personal work, and have access to the internet. In 1997, 96% of undergraduate and 94% of graduate students had Athena accounts, and there are over 18,000 users across the MIT campus. On a typical day 6,000 users access their personal files and software on the system.

2.3 Goals

In the 1983 White Papers of Athena, initial statements of the motivations and goals of the project asserted four initial goals:

- To develop computer-based learning tools that are usable in multiple educational environments
- To establish a base of knowledge for future decisions about educational computing
- To create a computational environment supporting multiple hardware types
- To encourage the sharing of ideas, code, data, and experience across MIT

The remainder of the paper seeks to analyze these initial goals and study how the Athena project evolved from these original thoughts. Furthermore, the paper explores how the developments of the project shaped these initial goals, developments affected by educational and technical needs, as well as the interests of the MIT faculty, Digital Equipment Corporation, and IBM.

[7] Champine, page XV

3 Education

The development of Project Athena was strongly motivated by the desire to improve the quality of education at MIT. Although education was always touted as one of the major goals of the Athena project, different people had different opinions on what the specific educational goals were. This section will look at each of these specific educational goals, and evaluate their success individually.

3.1 Initial Education Goals

Before the use of computers in education, academic disciplines were taught at most universities using pencil and paper. Since such education required the students to solve everything by hand, it necessitated the need for "clean problems with closed-form analytic solutions."[8] These clear-cut questions and answers hardly prepare students for the complexities of the industrial and commercial world. With computer-aided techniques in the classroom, however, problems could be presented in a more realistic fashion. Furthermore, the use of workstations and computer simulations could allow students to work on modeled experiments that are too expensive or dangerous to be done in a conventional laboratory.

Another advantage of computers in education was their role in data gathering and manipulations. Manually dealing with large amounts of data was very time-consuming and frustrating, with most of the student's time spent on grungy, tedious calculations. While such data collection was crucial in industrial and commercial occupations, the data gathering process held little academic value. With the proper computational resources, however, large amounts of data could be dealt with quickly and effectively, allowing students to concentrate on more worthwhile educational objectives while using techniques that they will need in the workplace. Proper computational support therefore allows instructors to more completely teach an academic discipline, incorporating realistic design techniques into the students' education.

In addition to preparing students for their entrance into the workforce, the Athena project also sought to teach students a better intuition of the concepts taught in class. Initially, many of the fundamental concepts in science and engineering are difficult for students to grasp. Professors hoped that Athena could assist students in understanding the material with the use of computer simulation, animation, or graphical representation, rather than by presenting an "abstract symbolic representation of the concept" in the traditional way.[9] For example, the flux flowing through a magnetic iron core can be more easily understood through computer simulation than the standard presentation of Maxwell's Equations. By helping students visualize the material they are learning, computers can help students gain a solid understanding of the foundations of their academic disciplines.

Thus, simply stated, the main educational goal of Athena was to get computing into the classrooms, to give students a more realistic study of the academic disciplines and aid the visualization of abstract concepts.

3.2 Developing Athena for Educational Use

[8] Champine, page 43
[9] Champine, page 44

From the beginning of the project, two very different assumptions about educational goals were formed. Some developers felt that Athena's main goal was to provide computer access for the students. From their perspective, providing workstations for students would help undergraduates learn how to use computers and thus enhance their ability to use software tools in a classroom environment. In fact, Professor Jerome Saltzer, the Technical Director of Athena declared, "It was not a goal to inject computers into education in the sense of teaching devices. Instead the notion was access to students, let faculty come up with ideas."[10] However, many other contributors to the project believed that Athena was created for the sole purpose of producing educational software tools for students. According to the Dean of Engineering Gerald Wilson, Athena's development of educational software would "augment the students' learning experience."[11] Therefore, the educational goals of the project were unclear from the beginning, allowing these two areas of work to grow separately and distinctly.

3.2.1 Providing Computer Access to Students

For Athena to provide academia with computational resources, it first needed to provide students with access to computers. Before Project Athena began, students were using the time-sharing MULTICS system. They would wait in line for a computer at two in the morning and many complained about the lack of computer availability.[12] Athena hoped to revolutionize computing at the Institute, using a distributed computing model to "make computers the birthright of every student".[13]

Professor Jerome Saltzer led the efforts to deliver computers to the students, stepping in as Athena's technical director in the Fall of 1983. Generally, Saltzer is credited with providing the Athena project with leadership and a sense of direction. His first few months as director were spent reviewing current projects and deciding which to continue and which to terminate, an issue we more formally discuss in the technical section of this paper. However, despite Saltzer's technical focus, the key criterion he applied to his review was "Is this important in supporting educational activities?"[14] Without the enforcement of his main criterion, it is likely Athena would have never met its goals of computer access for students.

3.2.2 Educational Tools

While student access to computers was clearly a vital goal of Athena's educational plans, much of Athena's initial focus resided in creating educational tools. In fact, the first Athena press release published on May 27th, 1983 clearly stated "Athena will integrate computers into the educational environments in all fields of study through the University in ways which encourage new conceptual and intuitive understanding in our students."[15] From Lerman's perspective, the educational goal of Athena had three parts: to innovate, to approve as many educational projects as possible during Athena's five years, and to see what the faculty could

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[10] Interview with Professor Jerome Saltzer
[11] Interview with Professor Gerald Wilson, Dean of School of Engineering, November 19, 1999
[12] Interview with Gerald Wilson
[13] Interview with Professor Jerome Saltzer
[14] Interview with Professor Jerome Saltzer
[15] "MIT Launches Major Experimental Program to Integrate Computers Into Education; Digital Equipment Corp., IBM Providing Support", First Athena Press Release, provided by the News Office at MIT, given to the press on May 27, 1983.

come up with. Lerman referred to this method of innovation as the "let-a-thousand-flowers-bloom model".[16]

Throughout the course of Project Athena, Lerman held numerous educational workshops and brainstorming meetings to encourage the development of computer tools for the classroom. These meetings sought to stimulate faculty interest in developing innovative educational tools, pinpoint some of the key learning problems students have in classes, and decide how to tackle these problems with computing. For example, in the Athena brainstorming meeting of October 10th, 1986, various faculty members put their heads together to produce an extensive list of possible flagship projects, including the creation of a calculus tutor, a multilingual dictionary, freshman math and physics visualizations, and support for writing and reading. Furthermore, the group proposed to create a database of old problem sets and notes for specific courses, as well as a guide to getting an MIT education. Also, the group attempted to identify key learning problems of students. They concluded that projects should focus on developing visualization skills and design skills, attempting to map mathematical formulas into intuition, and creating abstractions for complexity using model construction. As Gerald Wilson describes, "We were talking about people doing chemistry experiments on computers. We were talking about learning environments that were very different than before."[17] These goals remained fairly constant throughout the course of Project Athena, as further brainstorming meetings and educational workshops show.

Overall, 125 educational projects were funded during the course of Project Athena. Some of the more successful projects included the Athena Writing Project and the Aeronautical and Astronomical Engineering simulations. The purpose of the Athena Writing Project was to develop an integrated classroom system for teaching courses in scientific and expository writing. This electronic on-line system included computerized tools for editing and annotating papers, presenting class-work, and filing elements of course writing assignments. Even today, many of the Athena Writing Project services are still in use, such as the Athena text editor it provided.

Faculty members of the Aero/Astro department also began developing software tools, including several computer simulation modules. The nature of this department required the analysis of concepts very difficult to produce in a classroom environment, such as the aerodynamics of flight vehicles, molecular gas dynamics, and rocket propulsion. Thus, the goal of the project was to model these phenomena through computer simulation. For example, while professors could not bring a real wind tunnel into a classroom environment, they could easily present the students with hands-on visualizations of a computer-modeled wind tunnel.

These projects were particularly successful because of their large size and curriculum-wide applications. Generally, projects with more than one faculty member fared better than the others since group members could encourage each other, as well as bounce ideas off each other. Furthermore, both the writing project and Aero/Astro project had applications in more than one specific area. Text editors could be used campus-wide, while the aerodynamics modules revolutionized the entire Aero/Astro educational curriculum. Therefore, strength in numbers as well as broad ranges of system usage helped make these programs a success.

However, while a few of these projects succeeded, many were never completed. In fact, only about one-third of all CAE projects were ever used in a classroom environment.[18] Lerman attributes this low success rate to a shortage of funds as well as technological frustrations.

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[16] Interview with Professor Steve Lerman, Director of Project Athena, November 18, 1999
[17] Interview with Gerald Wilson
[18] Champine, page 46

Because of the great number of educational projects funded, most projects struggled from being under-funded. In addition to the cost, the skill levels required to develop instructional software proved to be much greater than initially assumed. Better development tools were needed. In particular, many professors claimed that over 50% of development time was spent creating good user interfaces. Improving the efficiency of developing these interfacings was clearly needed to increase the amount of instructional software produced.[19]

Furthermore, the inherent characteristics of technical and educational goals hindered the development of educational software. As Lerman states, "the technology required innovation while the education required stability."[20] The Athena technical system was in a constantly changing state during the first few years of the project, shifting between file systems and correcting UNIX shortcomings as it strove fulfill deployment plans. Since faculty attempted to build their educational tools on top of Athena's technology, every change in the Athena network disrupted the educational goals. These constant transitions created much frustration among some of the original project groups.

Ideally, the main educational projects should have waited until Athena's rate of change slowed down until beginning project implementation. However, instead of using the first years for design, as they should have, faculty members excitedly raced to begin project implementation. Lerman attributes this too-early eagerness to issues in management of expectation.[21] In order to create interest in Project Athena, it was necessary to get faculty members excited about the projects. However, once this excitement took hold, project members wanted to start on their projects as soon as possible, causing a conflict in interests among technical and educational initiatives. Therefore, while some useful educational tools arose from Athena's main educational projects, several factors contributed to the disappointing turnout of successful projects.

3.3 Athena's Final Educational Goals

As Athena neared the end of its eight-year experiment, most faculty members agreed that the project had established a good working model of distributed computing. With the technical system completed, however, many professors still strove to fulfill Athena's initial educational goals of using such technology for educational purposes. Numerous committees met to discuss the educational future of Athena and several educational center proposals were submitted as continuations of Project Athena.

For example, one of the largest educational proposals introduced the concept of CETI, a Center for Educational Technology Integration. The proposal praises Athena for its technical and service management breakthroughs for distributed systems, and its potential impact on higher education. Interestingly enough, the proposal elaborates on Athena's technical successes but never mentions Athena's attempts to create educational tools for students. Instead, CETI proposes to achieve the educational goals Athena first initiated. CETI goals included a continuation of Athena's educationally valuable developments, the creation of a simple, integrated educational computing environment for higher education, and the construction of the necessary distribution and support mechanisms for widespread university acceptance.[22]

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[19] Champine, page 66
[20] Interview with Steve Lerman
[21] Interview with Steve Lerman
[22] Proposal for the Center for Educational Technology Integration, MIT Archives

Yet another faculty interest in 1990 was the TCF, The Campus of the Future. This proposal also sought to revitalize the educational atmosphere of MIT with Athena's technological achievements. Again, the proposal offered high praise for Athena's distributed system accomplishments but added no remarks about the educational efforts of the Athena project group. TCF proposed a working relationship with CETI, foreseeing a campus seamlessly connected with wireless computers. With a portable-computing device in each student's possession, students could easily access various educational tools while in the classroom itself. These and many other educational proposals flooded the Athena offices as the project drew to a close.

There were many groups trying to make recommendations for post-Athena projects and, while many faculty members agreed that such actions would greatly benefit the academic world at MIT, none of the proposals ever went into effect. In regard to Project Athena, corporations poured money into this project since it would use their equipment in a potentially revolutionary computing experiment. Since these post-Athena proposals lack the same monetary power, the ideas never took shape.

However, even today, MIT faculty members are trying to fulfill these educational dreams. A recent MIT/Microsoft alliance has created $25 million in research funds associated with a new program called I-Campus. In a recent article in The Tech, Professor Hal Abelson, chair of the MIT/Microsoft alliance, declares "We are mainly looking for programs with educational utility; things which use existing stuff in new ways."[23] Therefore, the educational goals of Athena still play a prevalent role in the Institute's concerns today.

3.4 Evaluating Athena's Educational Success

In a large-scale engineering development such as Project Athena, it is difficult to determine success without first analyzing the specific goals of the project. Athena's educational goals can be divided into two specific parts, the desire for computer access for all students and the interest in developing educational tools for classrooms. The analysis of Athena's educational success depends strongly on one's criteria for success, as well as one's definition of educational goals. To those who regarded Athena as a system to provide students with computer access, the project was a phenomenal success. Those who believed Athena would provide students with academic resources, on the other hand, were sorely disappointed with the results.

While the initial goals of Athena clearly state plans to develop exportable, computer-based learning tools, the main successes of the Athena system lie within the realm of computer access. Athena's distributed network model clearly revolutionized the way students use computers, and is accepted among the MIT community today as one of the most important achievements of the Athena project. By 1990, Athena had already begun to view the technical aspect of the project as a finished product. In fact, when Saltzer stepped down from his position as technical director in 1988, he fully believed that the computer-access aspect of Athena seemed under control. After Saltzer left, Earll Murman, the director of Project Athena at the time, never appointed a new technical director, believing that "if the technology is working, why change anything?" Furthermore, while new proposals, such as CETI and TCF, were emanating from strong educational concerns, these same proposals displayed great confidence in the technical areas of Project Athena. The initial CETI proposal refers to Athena as the largest distributed,

[23] Levine, Dana, "I-Campus Soliciting Student Proposals", The Tech, Vol. 119, Number 61, November 23, 1999, front page

truly inter-operable, yet heterogeneous, computing environment on any campus in the world. Therefore, by the late 1980’s, Athena had begun to view the computer-access component of the project as a finished product.

However, regarding the development of educational tools, Gerald Wilson sums up the general sentiments of Athena’s contributions as "The dream of developing education tools was the shot we missed. Even though that was the focus, we didn’t make it."[24] The lack of progress in developing these tools was reflected throughout Athena’s eight years of development. For example, numerous brainstorming sessions and educational workshops were conducted, but each meeting demonstrated exactly the same concerns and ideas. In fact, had these meetings not been dated, it would have been difficult to organize them in chronological order. These difficulties clearly demonstrate the stagnancy of computational progress in the realm of education. Furthermore, various post-Athena proposals sought to achieve the same educational goals Athena strove to achieve, another strong indication that little progress was made in this area during Athena's development.

A letter by Professor Hal Abelson, written in June of 1985, clearly expresses many of the same feelings of failure with respect to educational software development. Though still in its early stages of development, Abelson expressed a deep concern that Athena was already exhibiting many failure symptoms. He claims that, although much activity has taken place, nothing of real educational significance has occurred. To get Athena back on track, however, Abelson urges the establishment of several faculty groups to actively pursue central educational objectives, instead of funding many small projects. It is interesting to note that this recommendation parallels Wilson and Lerman’s regrets involving Project Athena’s educational software results.

Since the termination of the Athena project in 1991, Athena has today grown to fulfill some of the education goals it was not able to attain during the course of the 8-year experiment. Today, Athena provides many educational tools for student use, many of which have been licensed from third party software developers. While perhaps the excitement of building “home-grown” educational tools have died down, the concept of providing students with software to enhance their academic curriculum is alive and well.

Therefore, the Athena project is generally regarded as highly successful in providing students with computers, but extremely disappointing in creating tools for the academic environment. Without separating Athena’s educational goals into these two distinct categories, an evaluation of Athena’s success would have been difficult and confusing. However, by analyzing the goals and achievements of the Athena project piece by piece, a measurement of success becomes clear. The success of an engineering project such as Athena can only be defined when clear goals and criteria are identified.

[24] Interview with Gerald Wilson

4 Technical

The evaluation of Project Athena's technical success is much easier to make in comparison to the educational aspect of Athena. This ease of evaluation can be attributed to the early establishment of clear technical goals, and the leadership of Professor Jerome Saltzer, the Technical Director of Athena and head of the Athena Technical Committee. This committee directed the development of the campus network, hardware, and support systems. However, before the arrival of Professor Saltzer in fall of 1983, it had been unorganized and weakly structured, a group without a clear direction or unified focus. Therefore, Saltzer's role in the project was crucial to the success of Athena.

From the perspective of the Athena Technical Committee and Professor Saltzer, Project Athena was a complete success. The project resulted in many tangible technical contributions, a campus-wide computer infrastructure, X Windows, Kerberos, and Hesiod, to name a few, and even some unexpected social benefits such as access to E-mail and Zephyr. The Athena project also served as a prime example for other universities to follow for the creation of campus-wide computing systems around the world. In fact, during the course of the project, over 100 colleges and universities came to the MIT campus to study Project Athena. Eventually, the project was such a big technical success that MIT decided to maintain the Athena network as an integral part of the campus. MIT shifted the support of the Athena infrastructure to the MIT Information Systems group, a group that continues to maintain Athena's operations today.

4.1 Athena Technical Committee's Goals

The technical goals of Project Athena were clearly identified at the beginning of the project, even before the project was officially announced in May of 1983. Professor Gerald Wilson, the Dean of Engineering, clearly remembers that the concept of distributed computer workstations using central services was "a goal right out of the box. The people on the computer science side saw the revolution coming."[25] Furthermore, the need for a coherent system, one in which the user interface remained consistent across all platforms, became very apparent when considering a system with multiple hardware and software vendors. Therefore, in creating Athena, one of the Academic Technical Committee's primary goals was system coherence. These goals manifested themselves in many technical decisions, including the choice of the UNIX operating system. Wilson remembers, "We wanted to be generic – that's why UNIX was chosen. We were going to have a system that was independent of particular boundaries of specific vendors."[26].

The greatest challenge, as Saltzer later noted, was to produce a network of workstations that were coherent – machines "that were transparently user-independent."[27] Furthermore, Saltzer also states, "The goal is so five [UNIX] wizards can manage a thousand computers, rather than one-to-one."[28] This characteristic was important in allowing a small staff of permanent system administrators to support a network of thousands of UNIX systems.

The development of the infrastructure for Project Athena followed two main phases. In the first phase, Project Athena used 50 time-sharing computers, donated by DEC, as a temporary

[25] Interview with Gerald Wilson
[26] Interview with Gerald Wilson
[27] Interview with Jerome Saltzer
[28] Interview with Jerome Saltzer

platform to begin building the software and hardware infrastructure. The second phase began with the introduction of the so-called "3 M" workstations, workstations named for their one million pixels of display, one megabyte of main memory, and one MIPS. However, the "3 M" hardware was not available until 1985 when IBM shipped the first PC's to MIT to be installed. Thus, it was not until December of 1986 that UNIX workstations supporting the Athena software were donated by DEC and installed around campus. Furthermore, the technical committee experienced a great deal of deployment difficulties in porting UNIX to the workstation environment, since such a task had never been executed before.

It is interesting to note that although a mysterious "third phase" of workstations was recalled by many of our interviewees, including Jerome Saltzer, Steve Lerman, and Gerald Wilson, it was never mentioned in any Athena publications. This phase involved the transition from Athena computing stations on campus to student-owned PC's which would eliminate the high cost of the periodic upgrading of workstations. However, unlike the Andrew Project at CMU, Project Athena did not begin with the intention of moving to student-owned computers. In fact, Ralph Swick, a DEC developer on the Project Athena staff, found that the PC's and Macs that were within the price range of students had environments that were too different to support all Athena services and courseware.

4.2 Some Initial Project Changes

The initial software subsystem structure of Project Athena focused on off-the-shelf software delivered by IBM and Digital. However, after about a year, it became clear that this approach was not viable since the modules were not designed for a large distributed network. Furthermore the Technical Committee lacked a clear focus, instead relying on several leader-less project groups who rarely communicated as a whole. As a result, the committee's projects were disorganized and had made little progress, creating a great deal of frustration among the committee members. In retrospect, Saltzer explained "the main concern at the time was there were some extremely ambitious projects being carried on by little teams of people who probably would never come out the other end. There were too many projects going on and no one could quite see what the coherent whole might be, if there were any."[29]

When Jerome Saltzer joined Athena in late 1983, he began his first role as technical director by eliminating those projects that did not directly enhance Athena's educational goals or that could easily be acquired from the industry. As a result, Saltzer cancelled approximately two thirds of the current projects, keeping those projects that focused on key subsystems that supported education and were unavailable from any vendor or other software project.

For example, Saltzer decided to discontinue the RPC (remote procedure call) project, since already half a dozen people were doing RPC work in the industry. The notion that Project Athena should have yet another remote procedure call seemed bizarre, since Saltzer felt RPC should be an industry standard, rather than having many different variations of it. Furthermore, it was not clear that RPC would be a useful function to have. Therefore, Saltzer decided to wait for the industry to standardize the function, and then use the industry standard if it turned out to be useful.

Another discontinued subsystem was a remote file system. It was clear that some type of shared file system would be needed, such that students could walk up to a workstation and access their files, even though the files weren't located on the workstation itself. However, looking

[29] Interview with Jerome Saltzer

over the industry's developments, Saltzer noted that Sun Microsystems was building a promising remote file system which would be available within the next year. Therefore, Saltzer decided to terminate MIT's remote file system project to wait for Sun's NFS, since building such a system themselves would take an enormous amount of time. In the interim, Athena used the more limited program called Remote Virtual Disk that had been developed at the Laboratory for Computer Science (LCS).

However, Saltzer decided to preserve the X Windows system since its development would directly contribute to the student's ease of use of the computational facilities. While other windows programs existed at the time, such as Carnegie Mellon's Andrew File System and Sun Microsystem's News System, prospects for delivery on those products were weak. Furthermore, it was not clear that either of those products would even be successful. On this basis, Saltzer decided to continue work on the X Windows system.

Finally, he identified some new projects that filled gaps in the technical plan. Kerberos and Hesiod provided a comprehensive login system that allows users to have a single password/login for a session and allowed users to authenticate themselves to each other and the Athena services.

4.3 Technical Achievements: Tangible Contributions

Project Athena was the first large scale distributed network of graphics workstations that relied on a central service for file systems, applications, authentication, and other resources. In fact, by 1986, all undergraduate students had access to accounts on Athena and could log in to any Athena machine and have their workstation interface customizations. This widespread use of Athena as early as three years into the project provides a strong indication of Athena's technical success.

"X Windows is probably the single most visible result of project Athena,"[30] according to Ralph Swick. X windows developed a lot of interest in the computer industry. It suggested both that open source software could be viable and useful for corporations and that university-industry projects could lead to commercial products. Support for X Windows version 11 became a standard in the UNIX environment and Kerberos became an important contribution to the growing field of distributed computing.

Athena's newly created access to computers also meant that faculty could rely on email to communicate with students. The single largest surprise to the Athena developers was the popularity of the Zephyr communication system and other communication tools. Wilson remembers, "We used to track how many people logged on, when it got to be 5000 people a day, they began to wonder what they were doing."[31] Communication between students became a "major, unexpected, positive outcome."[32] Quite unexpectedly, email and zephyr became the largest uses of the Athena network, becoming an immediate technical success for Athena because students were given an unprecedented ability to communicate in real time. Zephyr instances were created to post and answer questions relating to classes and even general campus news.

Project Athena has also served as a prime example for other universities and organizations interested in implementing a large scale distributed computing environment. MIT

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[30] Interview with Ralph Swick, DEC Engineer on Project Athena, November 19, 1999
[31] Interview with Gerald Wilson
[32] Interview with Gerald Wilson

supported these external efforts by providing the Athena Release Tape, a digital copy of the entire Athena Software system, at the cost of the media. This tape included all the fundamental technical developments of the Athena project, with clear hardware specifications and open source code. This encouragement allowed many universities, including the University of Massachusetts, Amherst, and Bond University, in Australia to implement the system or a modified version of it in a successful manner.

4.4 Results of Technical Decisions on Educational Projects

In recent interviews, both Professor Wilson and Professor Lerman noted that the developing subsystems disrupted educational project's software development. For example, the technical goal of running Athena software on graphics workstations meant that software written for non-graphics system would need to be rewritten. The transition from the early time sharing systems to workstations running a custom operating system, and later the transitional to vendor supplied operating systems, both altered the development environment and made existing code obsolete. Finally, later in the project, the X Windows standard X10 developed by MIT was replaced by version X11, which was established by the X-Consortium. The new version was required in order to secure support in industry, and this industry support was necessary for MIT to secure X Windows for future vendor software. However, the decision to move to X11 required the rewriting of educational software, creating great distress among faculty members.

5 Faculty

The members of the MIT faculty comprised one of the significant groups whose influence and efforts helped to shape Project Athena into what it is today. In the early stages of the project, there was much disagreement on what exactly a campus computing environment should provide. While the faculty did not stand as a completely united group within Project Athena, in general the faculty stood united on the common goal of creating educational software. While their ultimate goal to improve education through the use of computers was aligned with the general goals of the project, poor communication and conflicting expectations early in the project caused much polarization between the faculty and the rest of the Athena staff. This section discusses how the faculty started with different initial goals than the rest of the Athena project, how their efforts changed the priorities and focus of the project and how this shift in focus moved the project into new areas of research and development

5.1 Differing Initial Goals/Expectations

The initial expectations of the faculty for Athena differed greatly from the reality of the project. There were three major sub-goals outlined in the initial project proposal:

- fostering and supporting innovative uses of computing in education by the MIT faculty
- designing and implementing a new computing environment to serve MIT's educational needs well into the 1990's; and
- constructing and operating a computational facility distributed across the MIT campus of sufficient scale to make educational computing an accessible utility.[33]

While the different groups involved with the Athena project agreed on these project goals, each group had a different opinion on the priorities of these goals. This failure to match expectations with results stemmed partly from miscommunication early in the project and partly from a huge underestimation on the size and the scope of the endeavor. The faculty's initial goals and expectations differed from the reality of the project. This difference demonstrates how Athena did not, in fact, begin with an emphasis on educational software development, contrary to what is suggested when looking at the initial project goals. Athena's educational goal was something that the faculty had to actively pursue, competing against the other forces involved.

5.1.1 Delay in Deployment

The faculty believed that Project Athena promised a system with quick deployment. The idea of computers in education had been discussed for years even before the announcement of the project in late May of 1983. According to Wilson, "There were a lot of faculty who had many ideas that they wanted to explore in terms of developing educational tools."[34] Many members of the faculty were eager to try out their ideas and research. They saw Athena as a means of obtaining the necessary hardware infrastructure and system support. Many of the participating faculty believed that system deployment would be quick and trivial, some believing that it would only be a matter of months before a system was up and running after which progress on

[33] Champine, page 20.
[34] Interview with Gerald Wilson

curriculum development could begin. In reality, however, it would be years before any significant work would be done in meeting the educational goals of the project.

There were a number of reasons for this misconception. Athena required much more system development work than previously thought to create a distributed network system across UNIX platforms. Athena was initially proposed as a time-sharing system, a model of computation that was an established, mature technology with a quick, routine deployment. Thus, it was not surprising that most faculty members assumed a quick deployment.

Within the first year, however, the impacts of the project's slowly developing technical infrastructure became apparent. The shortcomings of the relatively new UNIX operating system in a distributed workstation environment created many problems. Before Athena could be operational, the project team would first have to develop the infrastructure and system, a task that was initially greatly underestimated in terms of the money and time that was needed. While the faculty wanted something simple, the project team wanted a system that would have growth potential which would necessitate a complex system. Another issue that delayed deployment was that IBM was late with the delivery of the system hardware. This delay in deployment resulted in a necessary delay in the faculty's goals. Faculty members were eager to start developing software, and believed that they had been promised a system that would allow them to begin. When Project Athena was announced, "the faculty became excited and it would have been to difficult to sequester the technology until it was done."[35] In reality, it was a while before the educational goal of the project would even begin to be realized.

5.1.2 System Flexibility

Professors expected Athena to be customizable to their specific needs whereas the Athena project team wanted a "one size fits all" approach that would be within costs and maintain the scalability and coherence of the system. The faculty often saw the coherent version of Athena as fulfilling mid-range computing needs and not offering what they believed to be critical for certain applications such as 3D rendering, high-end graphics, and color. Many faculty members also did not want either DEC or IBM computers but instead expected LISP machines[36], which were the most powerful machines for computer science research at the time. They even accused Wilson and Dertouzos of "settling for guano."[37]

Athena emphasized homogeneity on a system that was anything but homogenous. Before Athena, each department approached computing in a different way and while some of these differences were due merely to preferences of particular faculty members, others reflected the needs and priorities of a department. Standardizing every department's computing environments under a single system was a difficult problem. Participation in Project Athena meant the scraping of previous departmental computing systems and adopting the Athena model of computation. Not everyone was happy with this because it meant less departmental control over the computing structure. Professors did not realize that Athena would not allow room for customization to their own needs and their department's needs.

Consequently, Athena ran into problems when attempting to implement a standard across all departments. At the beginning of Project Athena, everyone, including members of the faculty, wanted something different. No one knew enough at the time to formulate early design decisions.

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[35] Interview with Steven Lerman

[36] Interview with Gerald Wilson

[37] Wilson, 'settling for guano' means settling for less than par. [Literally, 'guano' means bird feces.]

There were many debates over issues such as C vs. Basic and DOS vs. UNIX. Many professors had their own favorite application that they wanted Athena to support.

5.2 The Faculty Shifts Athena's Goals

The faculty found themselves initially stymied in pursuing the educational goal of the project since the technical goal of providing a distributed computing system took priority at the beginning of the project. Through the faculty's influence however, the priorities of Project Athena gradually shifted in 1983, moving away from the technical goal of research, towards the educational goal of curriculum development.

5.2.1 Demanding System Stability

The development of curriculum software began from the start of Project Athena. Unfortunately, it took a couple years for the system to stabilize enough such that significant progress in this area could be made. Wilson said,

> We wanted to do a lot of innovative things, ideally we wanted to tell the faculty, all these things are coming, give us three years while we develop them, when we have a stable platform, we'll give it to you. As system evolved, people got angry that they had to change tools.[38]

Because the educational goals and the technical goals seemed to be in direct conflict the faculty often found themselves working against the other goals and priorities of the Athena project team. This was true especially during the earlier stages of the project when the concentration was on deployment, rather than educational software development. Through 1986, much emphasis was focused on developing software to support distributed systems for UNIX and to create user interfaces. Because the system was under so much development, faculty and users began to complain about the constantly changing system and the resulting unreliability and instability. Wilson said that with every upgrade "there'd be a lot of anger, but meanwhile there'd be a lot of complaining that the old system couldn't do this or that."[39]

5.2.2 Jerome Saltzer's Influence

Professor Jerome Saltzer "was to finally bring some reality, and some understanding that [there were] milestones to achieve in a finite amount of time."[40] Before Saltzer joined the project, the technical staff of Athena treated the project as a research endeavor. For example, they even wanted to write their own operating system for Athena. Saltzer was from a member of the faculty and he recognized the need to reach a stable system quickly, throwing away anything that resembled research and not education that in the project. With his leadership and vision, along with the faculty's influence, Athena began to approach a system that the faculty had originally envisioned, one that could provide the stability and tools necessary for curriculum development.

[38] Interview with Gerald Wilson
[39] Interview with Gerald Wilson
[40] Interview with Gerald Wilson

5.3 Faculty Moves Athena into New Areas

Through the changing focus of the project, the faculty brought Project Athena into many new areas or research and development. The project shift from a technical goal to an educational goal opened up many new areas for Athena's efforts to move into.

5.3.1 Creating Development Tools

One problem facing early developers of instructional software was the lack of software development tools such as graphics, human interface development support, and courseware development tools. Professors did not realize the limitations of Athena since, at the time, all of this was available on stand-alone systems that cost much less. Through their pursuit of the educational goal of the project, the faculty identified the need for development tools and brought Athena into this new arena of work.

5.3.2 Establishing Faculty Support

At the beginning, there were few members of the faculty that supported Athena. While the faculty wanted to explore the idea of using computers in education, Athena gave very little support initially in realizing this goal. There was also very little incentive for professors to work on courseware development. The time that was spent developing educational software took time away from research endeavors. For non-tenured faculty, working on Athena software development was impractical compared to working to securing tenure. Even for tenured professors, there was little reward for working on instructional software. In fact, such work was seen as being divergent from departmental objectives. Many of the faculty members became disillusioned with the project after it was clear that the initial concept of a quickly deployed system was unrealistic.

As the project progressed however, it slowly gained more support from the faculty. By the fall of 1988, professors' opinions began to move from negative to neutral. There were several reasons for this shift. All graduate students were given accounts so professors no longer had to worry about who had accounts and who did not. The system settled into a much more stable and reliable environment and there were also an increasing number of success stories of how computers were helping in education as was mentioned previously in this paper. Courseware development tools also became more extensive and easier to use.

Most importantly, a significant effort was made to open communication between the Athena project group and the faculty. To respond to the need for further communication, Athena hired a faculty liaison. A faculty newsletter called the Athena Insider was started to open yet another channel of communication and was published several times a semester. Before, faculty who were interested in developing software for curriculum found themselves isolated within their departments. There was no structure to help facilitate the exchange of ideas between faculty and to help them learn from one another. Lerman also provided many forums to try to understand what the faculty wanted.[41]

In 1988, a faculty-based organization was proposed for the purpose of "continuing and improving the curriculum development initiatives."[42] There were three goals of this proposed

[41] Interview with Jerome Saltzer

[42] Charter for Athena Faculty Affiliates, MIT Archives Project Athena collection AC247, Box 4, Folder 12.

group. The first was to provide an intellectual center for faculty who were interested in using computers in education. This would establish a common base from which the faculty could draw ideas. The second was to assist faculty members with obtaining the resources and tools needed for curriculum development projects. The third goal was to foster communication between the technical direction and the educational goals of Project Athena so that educational initiatives would be maintainable and of high quality. Faculty members were given the opportunity to learn what they needed to know in order to do development work on Athena. Previously there had been little infrastructure to provide developers with the training and tools that were needed. For example, Motif training became available in 1990 to aid people who were interested in developing software for applications under Athena. In this way, the faculty took on an active role in defining the future direction of Athena.

5.4 Faculty Evaluation of Project Athena

The faculty, in general, had hoped to achieve many ambitious educational goals through Project Athena. They were the group who represented the educational goal, working to integrate computers into their classes and curriculum. As was discussed previously in this paper, while there were some successes, in general, most faculty members did not realize the magnitude of the task at hand. Wilson stated that his biggest “disappointment in Athena is how few of the educational software projects ever panned out."[43] The few successes in the development of educational curriculum were hard won. A few professors understood the difficulties that they faced and were willing to continually work towards achieving the goal of developing software for their classes despite having to work on an unstable, unreliable system with many problems. While it could be argued that there were some successes from the faculty’s point of view, these successes came at a high cost of valuable time and money.

[43] Interview with Gerald Wilson

6 Digital Equipment Corporation

One of the major sources of funding for Project Athena was Digital Equipment Corporation (DEC). Over the entire course of the Athena project, DEC provided approximately 50 million dollars worth of money, equipment, and services. Therefore, their goals and desires affected the project greatly. In this section, we will discuss the history of how DEC became involved in Project Athena, their reasons for doing so, and how their goals and agenda affected the project as a whole.

6.1 How DEC Became Involved

In the early 1980's, Digital Equipment Corporation was a powerful company with a promising future. They sold various types of workstations and terminals, and although they sold various pieces of software, they still considered themselves primarily a hardware company. However, in the early eighties, DEC's management realized that they were a bit behind the time technologically. They were one of the last mainframe computing corporations to realize the importance of personal computers. In addition, the DEC engineers realized that network computing would be the next paradigm in computers, and realized the importance of being a world leader in this arena. The senior management of DEC, however, realized that they were lagging behind the other corporations, and were looking for ways to correct the problem. A strategic decision was made in the uppermost levels of DEC to partner with a leading computer science university, where network computing was being investigated, and to learn about the technology through this partnership.

The natural place to look for a partnership for DEC was Carnegie Mellon University. The Vice President of Engineering at DEC was a CMU alumnus, and CMU was the first campus that decided to go to workstations in a big way.[44] When CMU announced their plans to develop a workstation-based campus-computing environment, DEC's external research manager, Dieter Huttenberger thought that they would be heavily involved in the process. However, when IBM signed an exclusive agreement with Carnegie Mellon to provide research and financial support in exchange for exclusive rights to the software produced, the people at DEC began to get very nervous. They viewed CMU's agreement with IBM as a "slap in the face."[45] Plus, DEC did "not want to lose out to IBM."[46] They realized that if they did not act quickly, they would be completely left behind in the workstation marketplace.

When MIT began soliciting sponsors for resources and money, DEC's management viewed this as "the last and possibly only chance to get back in the game with a big name university."[47] DEC was also not deterred by MIT's desire to have more than one sponsor. In addition, Ken Olsen, the President of DEC was an alumnus of MIT, and a strategic decision was made by him that "Digital would be the primary donor in the Athena activity."[48]

6.2 DEC's Reasons For Participating

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[44] Interview with George Champine, DEC Associate Director of Project Athena, November 19, 1999
[45] Interview with George Champine
[46] Interview with George Champine
[47] Interview with George Champine
[48] Interview with George Champine

DEC's management felt that there was a lot to be gained from an alliance with a major research university. One such goal was to develop an understanding of the technology from a hands on standpoint. Although MIT published papers on everything they produced, there was much tacit knowledge that could only be gained by actually working on product development. There was not a lot of research going on at DEC in distributed computing, and therefore there were not very many engineers at DEC that understood the technology thoroughly. However, the managers at DEC knew that if their engineers were allowed to work at MIT for a few years, they would quickly gain knowledge only available at MIT. This knowledge would allow them to develop products when they returned to DEC that would help the company become a leader in networking technology.

Although DEC's management did not value the collegiate level educational tools being developed by Project Athena, they were interested in software that could be developed for students in the k-12 public school system. They felt that this was a much larger possible market than college level courseware, and were therefore interested in the products that could be sold to it. This was one of the few software products DEC hoped to get out of Project Athena.

DEC's managers also hoped that working at MIT would help their employees to understand the marketing side of workstation technologies. In the early 1980's, DEC had few successful products that were in the software and the networking computer market. By joining with MIT, they hoped their marketing personnel would be able to observe the technology and learn how it could be sold to other major companies and to the general public.

Public relations exposure was also very important to Olsen and others at DEC. Olsen knew that if their name was associated with a renown university such as MIT, it would help increase their name recognition and improve their reputation in the computing market. Also, he knew that with a project as large scale and as technologically important as Athena, there would be a lot of newspaper and technical journal coverage of Athena. Olsen hoped that every one of these articles would mention their name and therefore create a lot of free advertising.

DEC's management was also motivated by the goal of customer loyalty. They knew that if MIT students were using DEC hardware products throughout their college experience, then once they graduated, they would still want to use DEC hardware. Although it seemed this market was small compared to the large hardware sales of DEC, MIT students were graduating into influential positions in the computing industry that could have long term benefits to DEC. This would allow DEC to sell products to many new companies.

Another goal of DEC was to make their hardware products the standard of academic computing environments across the United States. DEC hoped that by helping MIT develop a network-computing environment, other universities would realize the importance of computers in education and soon set up computer networks of their own. In addition, if MIT's project would be successful, other schools would want to adopt the Athena environment as their own. Since the Athena environment would be written on DEC machines this would result in a large amount of hardware sales and profits for DEC. Although they realized that the goal of Project Athena was to write something that could be used on any type of hardware, they knew that if DEC machines were used this would give them a competitive advantage over the other vendors.

In addition, Olsen wanted to donate something large and important to MIT. He felt that he owed the university a "debt of gratitude."[49] This affected the initial proposal, and also every other proposal that he was involved with. Every request for more money or services that Olsen

[49] Interview with George Champine

saw that involved MIT he immediately approved. This became extremely important later on in Project Athena, when MIT asked for an extension of the original five-year grant.

6.3 MIT's Choice of Sponsors

After they received the proposals from all the potential sponsors, MIT had to decide which one to accept. At this point, politics began to come into play. MIT was only seriously examining the proposals from three corporations – IBM, DEC, and Apple. IBM and DEC had been long-term sponsors of MIT's research in the past. Since both had donated resources and money to previous computing projects, picking one over the other could have serious financial consequences. Although Apple had not been as large a sponsor and was a newcomer to the world of computing, it was already revolutionizing the personal computing environment. Choosing sponsors was a difficult dilemma for MIT to overcome; however, in early 1983, MIT declared that DEC would be the sole sponsor of the project. Two months later, when the project was extended in scope at MIT, IBM was named as a secondary sponsor.

DEC's reaction to MIT's announcement that there would be joint sponsors was typical of that of a large corporation. Although publicly they said that it would be a benefit to the project, it actually hindered several of their goals as a corporation. For example, the fact that MIT supported two different types of hardware forced the engineers to develop a system that would be hardware independent. Although this had been a stated technical goal at all times, it was contrary to what DEC really wanted. Also, DEC's management was still upset about IBM being chosen to sponsor CMU's Project Andrew, and therefore from DEC's perspective, IBM was the worst possible corporation MIT could have selected for joint sponsorship of Project Athena. DEC's management had hoped to gain something from the MIT alliance that IBM would not gain from the CMU sponsorship. Unfortunately, with the announcement of IBM as a secondary sponsor, this became impossible.

6.4 Contract Negotiation

Negotiating the complex contract was the next step in the process. DEC sought specific goals out of their participation in Project Athena. The corporation was willing to contribute millions of dollars and it expected specific returns on the investment. Looking at the revisions and rewrites of the contract, it was clear what DEC's management wanted from the joint partnership. They wanted to be able to use any of the knowledge or research gained from MIT in their labs to build and design new products. In addition, they wanted to be able to license any software produced and be able to modify and or sell it directly to the public, without having to get specific permission from MIT. Although they were asking for a lot, DEC was donating a lot of time money and equipment, so MIT agreed to their demands. In the end, it was decided that DEC would produce:

- 63 VAX 750s and mix of terminals
- 1600 advanced workstations
- 5 full time staff for 5 years
- maintenance for 5 years
- access to required Software

And, in exchange, MIT agreed to:

- Install and operate equipment

- Form a campus network
- Provide a staff of 20 professionals
- Fund 10-12 million in faculty based projects
- Insure security of confidential information
- Develop distributed operating system, and "coherence technology"

In addition, the following issues were resolved:

- If Project Athena results in “coherence technology”, or within two years MIT says they cannot finish project Athena, then MIT and DEC will enter into negotiations to lead to a license agreement under which DEC shall be given a royalty bearing worldwide, and non-exclusive license to use and sublicense it worldwide
- In negotiating the royalties the parties will take into consideration DEC’s ongoing contributions.
- MIT will get all patents, rights, copyrights, trade secrets, and trademark rights
- DEC will pay MIT $500,000 per year for five years for research
- DEC will be the most favored licensee
- DEC will provide on sits staff not to exceed three personnel

6.5 Problems with IBM and DEC

However, these contract negotiations were just the beginning of problems that were caused by the joint IBM-DEC-MIT alliance. Many problems arose from having two vendors. At the beginning of the joint project, DEC and IBM were “were worried about having their people on the same floor.”[50] Since they were major competitors in the marketplace, each group was worried that their engineers would not work well with the engineers from the other team. In addition, there were “issues of monopoly [and] collusion”[51] between the two groups, and especially the upper management of each corporation. Many of these problems were managed by George Wilson, who says that after about the first year, the problems “pretty much disappeared.”[52] After the first year, DEC engineers working on the project, such as Ralph Swick, felt “we were left quite free, we considered ourselves part of MIT.”[53]

There were still small problems between MIT and DEC, however. One large issue was the problem of deployment. In the beginning, MIT went to DEC and asked for machines so that they could get exposure on campus. DEC immediately complied, and quickly sent 500 machines to MIT. Unfortunately, the actual deployment of these machines was not as quick as DEC’s management would have liked. The deployment of the DEC machines went very slowly because “MIT had to install the cabling and drill holes in the floors of buildings that were a hundred years old.”[54] At one point, there were several hundred DEC machines sitting in a warehouse and “[Champine’s manager] was rather unhappy about that.”[55] This problem also occurred when MIT tried to deploy machines into the dorms and living groups.

These problems, however, did not damper DEC’s dedication to the project. After the first five years, when it became apparent that Project Athena was much larger than it was originally

[50] Interview with Gerald Wilson
[51] Interview with Gerald Wilson
[52] Interview with Gerald Wilson
[53] Interview with Ralph Swick
[54] Interview with George Champine
[55] Interview with George Champine

thought, the management of Project Athena went to Olsen and asked for a three-year extension of hardware, engineers, and money. When this presentation was made, he immediately approved the extension at the presentation, only considering it for a few minutes. This quick decision shows how happy DEC was with the MIT partnership.

6.6 DEC's Achievements

At the conclusion of Project Athena, DEC felt that the Athena project was a complete success. DEC's upper management viewed Athena as their flagship external research project. It tried to repeat this success several times after Athena, including a large similar research project at the University of California, Berkeley; however, the success was never as great as it was at MIT.

Of the six major goals DEC listed for supporting Project Athena, only two or three were actually ever realized. Project Athena never did produce any educational tools that could be used in the K-12 levels of school. In addition, according to George Champine, DEC did not gain any knowledge about the workstation market by participating in Athena. DEC was not adopted universally as the standard computer for educational institutions. It can be argued that DEC gained some customer loyalty by providing equipment for Athena, but whether this made any difference is extremely hard to prove. The last two goals, however, were extreme successes, and were also, fortunately for DEC, the most important.

The first, and the most important success for DEC was the understanding and knowledge gained from working on Project Athena. Many DEC engineers worked on the project, and then returned to DEC enabling them to be extremely productive in developing implementations of workstation technologies for DEC. In addition, there were many software projects at DEC that were a direct result of the MIT sponsorship. DEC had the first implementation of Kerberos, mainly because they knew and understood the technology long before it was ever presented in any paper or educational journal. In addition, DEC produced their own version of X Windows, which they called DECwindows, and included this on several hardware products that were engineered, such as the DEC Color Vaxstation II. Many of the technologies provided on this machine were a direct result of DEC's involvement on Project Athena.

Secondly, and almost equally important to the senior management at DEC, was the PR exposure gained from working with MIT on Project Athena. There were many news stories written about the project and its successes, and DEC was associated with MIT in almost all of them. In the computer industry, name recognition and association is extremely important to potential customers. And, being associated strongly with the MIT name helped DEC continue as a leader in the hardware and software market.

DEC always viewed their involvement with Project Athena as a complete and absolute success. All of the senior management at DEC was extremely happy with the results, and when asked if they would have done the project over again, simply replied "without a doubt."[56] This relationship that started with Project Athena and MIT allowed DEC to have a close relationship with MIT throughout their history as a corporation.

As found in this study of DEC, success in a specific engineering project is not always dependent on the initial goals of the project. What may be defined as an extremely important goal at the beginning of a project may later be defined as unimportant. In this example, although there were many goals that DEC had in the beginning of Project Athena that were not

[56] Interview with George Champine

accomplished, during the project, DEC determined that these goals were no longer important. Therefore, although these specific goals were not achieved, DEC still felt that the project was a success.

7 International Business Machines

The other major sponsor for Project Athena was International Business Machines (IBM). While IBM contributed almost an equal amount of money to Athena as DEC did, their achievements differed greatly. In this section, we will discuss how IBM's relationship with MIT and DEC affected the goals and success of Project Athena, from IBM's perspective.

7.1 IBM's Initial Involvement

One of the initial concerns of the Athena network was the ability to integrate different types of hardware into the system. Therefore the Athena project staff decided that it would be beneficial to the project to have more than one provider such that parts of the project could be sponsored by another company, encouraging a more robust and complete system design. As Gerald Wilson said, "The reason we went with two vendors is because suddenly it opened up to a much larger issue. The positive effect on that was that it made us not dependent on any one operating system."[57] In efforts to minimize the single vendor approach, MIT also accepted sponsorship for Project Athena from IBM.

In 1983, IBM was already involved in other academic research projects such as Project Andrew at Carnegie Mellon University (CMU) and the Supercomputer Program at Cornell. IBM participated in outside research activities such as these in hopes of satisfying three central goals: academic software development, technology transfers from research innovations, and the opportunities to showcase company products for marketing purposes.

7.2 Reasons for Participating

IBM had been involved in developing academic courseware since the 1960's. By participating in Project Athena, there was the expectation that IBM could develop a national standard for courseware. In fact, after Project Athena began, IBM established the Academic Computing Information Systems Group (ACIS) within IBM in 1987. This goal coincided with Project Athena's initiative to create software for classes and therefore supported a unified ground for determining success. Furthermore, IBM desired to use Project Athena to showcase new hardware and software for promotional uses.

The opportunity for technology transfer was also a significant reason for IBM's participation in Project Athena. Even though Project Athena was similar to Project Andrew, IBM felt that joining Project Athena would give them another chance to tap the genius of academic research. They would not give up this opportunity simply because of concurrent projects pursuits elsewhere.

Gerald Wilson had the following perspective: "IBM saw MIT as a richer community in the sense that there were more interdepartmental laboratories. There were programs between engineering and management computation and linguistics, artificial intelligence and philosophy."[58] However, because IBM was already the sole sponsor in the Project Andrew, there was concern from the Athena project staff that not enough attention would be paid to Project Athena in terms of dedication and the amount of resources that could be supplied. This was

[57] Interview with Gerald Wilson
[58] Interview with Gerald Wilson

indeed a viable concern and later on may have affected the ability for IBM to put forth a strong effort in Project Athena and reach their desired goals.

7.3 IBM's View of Athena

IBM's willingness to participate in multiple academic projects for the attainment of technology transfers defines a certain characteristic in IBM dealings with projects such as Athena. From the standard responses found in correspondence with MIT Project heads and from an interview Josina Arfman, one of the IBM technical staff managers, IBM may have treated Project Athena as another standard "industry research activity."[59] Arfman made it clear that Project Athena was indeed a gamble like other outside funded research projects. She stated that,

> So, what you hope for is the best case...that the technology that gets developed as a result of these projects that gets put back somehow into IBM products, either in hardware or software. Sometimes it works, sometimes it doesn't; but it's like any kind of research you do. There's no guarantee of any payoff. I don't know what the industry average is of success; but I would think it is not much higher than 10%.[60]

Because Athena was not as successful a showcase project for IBM as it was for DEC, IBM's level of commitment may not have been as strong. This attitude may be helpful in understanding why IBM's goals lacked clarity, as well as why difficulties arose in achieving the same level of contribution as DEC.

The final push that secured IBM's participation in Athena was the fact that DEC was already firmly committed to the project. The previous competition between the two companies for Project Andrew supports this argument. As the "winner" of Project Andrew, IBM officials were concerned about having both corporations working together on Project Athena. Later, this section will touch upon the wrinkles caused by this joint relationship and how this may have impeded the overall progress of the project.

7.4 Difficulties

From the start, there were difficulties in solidifying IBM's relationship in Project Athena because of the politics around IBM's involvement in other MIT projects. IBM had already settled a deal with the Sloan school for the contribution of a number of machines and it appeared to IBM that Project Athena was encroaching on this existing deal. However, to further support the argument that IBM joined the project to compete with DEC, IBM solidified commitment to Project Athena soon after DEC made it's first contribution of $50 million.

Since the beginning, the technical staff had difficulties in coordinating effective contributions to the project. The original negotiations with IBM resulted in a commitment to grant MIT equipment. The commitment was 430 workstations, using IBM PC/XT's, a megabyte of memory, a network interface card, and a high resolution graphics display each. The entire project was codenamed the PEACH workstation. The first three items were purchased from 3rd parties, and the last would be developed by IBM. Unfortunately, due to the poor organization of

[59] Interview with Josina Arfman, IBM Director of Technical Staff, November 26, 1999.
[60] Interview with Josina Arfman

both IBM and MIT, the agreement for equipment delivery was never formalized in the grant letter. Rather, it had evolved from earlier discussions, a reflection of the weak foundation in which the relationship between IBM and MIT was founded upon.[61]

Within MIT, the Athena project staff determined that Bill Filip, director of IBM's participation within Athena, was not a wise match. In Lerman's opinion, Filip did not have a good understanding of the project goals, and Filip's view of the original proposal did not agree with that of MIT. Instead of budgeting for customized PC/XT's that were catered to Athena's needs, the PC/XT's that were ordered lacked the proper memory specifications as well as the graphic resolution capabilities that MIT had originally requested.

In addition, there were discrepancies between the amount of equipment that was informally agreed upon and the amount that was budgeted by Filip. Instead of budgeting 430 workstations, the IBM equipment forms only budgeted for 150. According to Lerman, it appeared that the budgets for Athena were set before the first technical decisions were reached. The budgets were never revised to reflect the additional requirements of the PEACH workstation.[62]

There was also a question of the level of commitment IBM was willing to provide to Project Athena. Despite the concerns for equipment specifications and budgets, the final outcome for the PEACH delivery was a disappointment to the Project. By mid 1984, the ACIS announced that they would no longer recommend the deployment of PEACH at all. There were claims that PEACH was too difficult to maintain as a workstation because so many 3rd party pieces involved. In fact, the ACIS staff stated that if the PEACH design was to continue at Athena, IBM would only take responsibility for the part they built, creating serious doubt within MIT of ACIS' commitment to Athena.[63]

Further along in the project, IBM was attempting to push the PS2 into the market. Although the commitment of equipment was not an issue as in the PEACH agreement, the equipment itself was not suitable for Athena. IBM attempted to use PS2's as part of the Athena structure by running UNIX. Unfortunately, it was realized that it was too difficult to implement the PS2's because applications needed to be ported to the machines one by one. Project Athena was not using standard UNIX, but instead was using a version of UNIX that was special and was supposed to be enable portability across the different hardware that the project was using. Therefore, it required a lot of manpower and time that was not available to efficiently integrate the PS2's into the system. IBM and DEC also had conflicting approaches when it came to porting the applications onto new platforms. Some even suggested that the lack of organization and cohesiveness resembled a "circus show."[64]

It was not until 1990 when IBM was able to make a hardware contribution to Project Athena, the IBM RS 6000 file server. The engineers at IBM were very excited about the new product and, at the same time, the RS 6000 proved useful for Project Athena. Unfortunately, by 1990, the project had eighteen months until completion and the file server's role in the project did not have a great impact, nor did it leave a lasting impression at MIT. IBM was also disappointed that hardware did not have prominent visibility within the computing system. Because the contribution was a file server, most users were not aware it existed because they dealt primarily with the workstation interface, which was not from IBM.

[61] Lerman, Steven. Letter to Paul Gray, June 9, 1984. MIT Archives Athena Collection AC247, Box 7, Folder 19.
[62] Lerman, Steven. Letter to Paul Gray, June 9, 1984. MIT Archives Athena Collection AC247, Box 7, Folder 19.
[63] Lerman, Steven. Letter to Paul Gray, June 9, 1984. MIT Archives Athena Collection AC247, Box 7, Folder 19.
[64] Interview with Josina Arfman

IBM's lack of success in terms of hardware integration proved to be the opposite of DEC. Project Athena was a showcase project for DEC whereas IBM had serious concerns in terms of dedication and complete support of Athena's development. There was a sense of "co-opetition", cooperation and competition, that influenced the way that the two groups worked together. While they were both part of the joint effort to create a distributed computing system, they were competitors in the computer industry. Also, although there were no signs of direct conflicts in terms the goals of Project Athena, there were conflicts in terms of style and methodology.

Professor Saltzer, the technical director of Athena, vividly remembered a particular member of the IBM technical staff that could not use any computer hardware that was not produced by IBM. Saltzer described the individual's mentality as one who's concept of the world was that "the only stuff worth touching [was] IBM's."[65] Whether the corporate cultural influences at IBM were strong enough to affect all members of IBM technical staff is hard to say; however, it was evident that the two companies had distinctive cultures within their respective companies that affected the way the individuals worked. To exacerbate the situation, IBM had not been able to successfully provide workstation hardware for the project until 1987. Therefore it was extremely difficult to enable certain IBM staff to assist in the project, since most of the hardware had been contributed by DEC. In the end, it was easiest for Saltzer to place those individuals on neutral projects, such as work on the DNS server, where they did not have to cross corporate barriers.

There were also concerns between the corporate culture of IBM and the academic culture at MIT. In the 1980's, the corporate image at IBM was established as men in dark navy suits and ties. On the other hand, MIT students on the Athena technical staff were very laid back in terms of dress and were known for prioritizing comfort over appearance. Josina Arfman recalled one student of very fair skin who apparently spent too much time in the sun and was sun burnt and peeling. Arfman hypothesized that because clothing would further irritate sun burnt skin, the student wore nothing but his boxer shorts around the lab. Coming from an environment where neckties were the norm, the relaxed atmosphere at MIT came as quite a shock to the professional taste of IBM employees. Overall, the cultural differences caused temporary delays in the progress of the project. The individuals eventually became accustomed to the differences and as the project grew more intense, the technical focus outweighed other differences.

Many important developments rose from the differences between the academic culture of MIT and the corporate culture of IBM. During the second stage of Project Athena after 1987, it was blatantly clear to the IBM technical staff that Project Athena was a heavily academic project. Arfman put it plainly, "[Athena] had the worst interface I have ever seen."[66] Since the main focus of the project was on access and computational functionality, the interface for users had been neglected. In 1987, the only user interface was a command line prompt. Granted that the prompt is an efficient interface for experienced users, as the Athena workstations became more accessible to the student population a more effective user-friendly interface would be needed. The IBM technical staff was a strong supporter of a more graphical interface and led the implementation for a dashboard. To MIT students, the user-friendly interface was secondary and almost an insult to the project, while to IBM staff it was an obvious and necessary addition, a strong exhibition of the MIT and IBM culture differences.

7.5 Success of Athena for IBM

[65] Interview with Jerome Saltzer
[66] Interview with Josina Arfman

Whether IBM was successful in Project Athena is subject to argument. From the perspective of technology transfer, the project was not extremely fruitful. The benefits that IBM received from Project Athena were mainly the technological developments that came out of the contributions Athena made to Open Software Foundation and to industry standards in general. For example, Kerberos was a very successful industry standard that IBM adopted. Therefore, there was not a direct pipeline from Project Athena to IBM technology; though one cannot say that IBM did not benefit at all.

Generally, there was lack of interest in Project Athena from corporate IBM. From old meeting notes and official slide documents, it was difficult to pinpoint any specific goals that IBM hoped to get out of Project Athena. Arfman commented that in 1987,

> There was no clear set of goals, there was no particular part of IBM development that had a strong interest in what was going on in Project Athena... One of my frustrations was I kept pushing certain technologies and I had no takers for it. I think over time there was a 'disconnect' between our technology people and Project Athena. Project Athena was more than anything else turning into just a giveaway program.[67]

Therefore, IBM's had its own goals for judging Project Athena's success. IBM's perspective on Project Athena changed when it became clear that certain goals were not progressing and as the relationship between IBM and MIT evolved. At one point, it was clear to IBM management that the initial goals were not going to be successfully reached and that the IBM technical staff should simply do its best until the completion of the project. In the end, one perspective of IBM's role in the project was that it "ended with a sizzle, not a bang".[68] The level of contribution provided by IBM at times slowed and altered the terms of success established by others, namely DEC and MIT.

[67] Interview with Josina Arfman
[68] Interview with Josina Arfman

8 Conclusion

We have shown that the evaluation of an engineering project that is driven by multiple goals, like Athena, is a difficult and complex process. How does one begin to assess the success or failure of a large engineering project such as Athena? History has a way of remembering such engineering endeavors as being either a failure or a success. In reality, such a general evaluation is remiss, perhaps even incomplete. Often, in such a project, it is unclear what criterion should be used to measure success since this is ultimately a personal question of determining what goals and issues were important to the project. Measuring the overall success of such a project becomes a difficult task because what is successful to one person might be a failure to another.

Another problem with assessing Project Athena's success is the lack of a "measuring stick" to compare to. Nothing exactly like Project Athena had been done before; therefore there was no accepted standard with which to make comparisons. A final difficulty with evaluating Project Athena is the nature in which the priorities of the goals changed throughout the project history. While an engineering project can be dominated by a specific goal at one stage, the focus can shift to another goal in order to move the project into the next stage of development. An evaluation of the project as a whole, for all these reasons, is meaningless without considering the criteria of the evaluation and understanding the prioritization of the goals. Success then can only be effectively measured within the context of the specific groups and goals of the project. For Project Athena, these shaping forces included the educational goal, the technical goal, the MIT faculty, DEC, and finally, IBM.

Athena's educational goal can be divided into two specific parts, the desire for computer access for all students and the interest in developing educational tools for classrooms. To those who regarded Athena as a system to provide students with computer access across the MIT campus, the project was a phenomenal success. Students received access to technologies such as email and the World Wide Web because of project Athena. Athena also provided a perfect forum for providing access to software packages such as Matlab or Mathematica. Those who believed Athena would provide students with academic resources, however, were disappointed with the results. In this context Athena failed in its goal to fundamentally change the way students were educated at MIT. However, today, the goal of access has proved to be integral to the way classes are taught at MIT. Professors and students constantly use Athena to communicate, and Athena has greatly helped in cutting down barriers between students and faculty. Therefore, although in 1991 Athena might have been considered a failure in its goal to fundamentally change the way students are educated at MIT, today, it might be considered a success.

When evaluated through a technological lens, Athena succeeded in developing the distributed network. A large part of this technical success lies in the development of the system software that was needed to adapt the UNIX platform to a distributed networking environment. Another indicator of technical success was the number of projects started under Athena that made significant contributions to the computing world, such as the X Windows system or the Kerberos authentication system.

Although the technical results of the project consistently overshadow the educational results, this was not because the engineers lost sight of the educational goals. Rather, the technical problems ironically became easier to solve than the educational goals. Creating educational software was a fundamentally hard problem, and the faculty of MIT was not equipped to solve it.

The faculty had hoped to use Project Athena to integrate computers with their curriculum. They were the main proponents of the educational goal of the project, and the few successes in the development of educational curriculum came at a high cost. Both IBM and DEC believed they gained valuable knowledge from participating in Athena. For DEC, the technical knowledge that was gained, as well as the publicity that they received, came as a significant benefit to them. IBM, on the other hand, saw its involvement with Project Athena as less of a success since the company did not gain as much of a technology transfer as they had initially hoped.

In conclusion, this paper has argued that engineering is not something that necessarily follows a predefined set of goals and instead, is often the result of the interaction of many competing groups. The different groups and project goals within Athena are the forces that have shaped and directed the project into what it is today. This paper has discussed how each of these forces brings a different perspective into the picture and how each of these perspectives gives a valid evaluation of Athena's success or failure. Thus, in order to measure the success of an engineering project, it is not enough to merely state that a project succeeded or failed. In order to effectively measure success, it is crucial to understand achievement through the perspective of the major goals and the participating groups in the project.

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