

CHAPTER 5

Project Athena at MIT

MIT gave the name "Project Athena" to a large-scale experiment in educational computing that it began in 1983, an attempt by the world's premier school of engineering to regain its sense of lost leadership in institutional, especially academic, information-processing systems. Understanding Athena requires a close look at the specifics of MIT history and culture, but the story of the project's development also has much in common with other policy stories discussed in this book. Not surprisingly, the Athena case embodies many features of a classic policy dialectic: institutional designers (in this case MIT engineers and sponsoring computer companies) create a policy object, the Athena system, which they put out into a larger arena (MIT as a whole). There, other actors respond to the object, guided by their own interests and frames. As they compete to control the object, it evolves in ways that differ from the intentions of any one of them.

The case of Athena is made more dramatic by the fact that its institutional actors, its architects and its challengers, held conflicting views of the project that corresponded to pre-existing political and cultural divisions within MIT and, more generally, to pre-existing notions about the relationship between technology and social progress.

Since the Athena project was a new stage on which to replay familiar patterns of controversy within MIT, it is not surprising that unlike the case of German early retirement, the main actors never enjoyed a Golden Age of consensus. In this case, the early debates on Athena's design foreshadowed conflicts that were to surface even more sharply during Athena's implementation.

Those who were skeptical and resistant to Athena "talked back" to her designers, who had a hard time facing the disjuncture between their intentions and the meanings Athena had for her intended users. A fundamental frame conflict persisted: the skeptics and resisters remained, for the most part, skeptical and resistant. The advocates and defenders continued to advocate and defend, seemingly undeterred by what the skeptics took as compelling evidence of Athena's failure to produce its intended educational effects.

Yet a pragmatic resolution of the controversy was achieved through a series of "policy adjustments" that accommodated the real political threat posed by Athena's skeptics and resisters. This accommodation, together with the cooling effect produced by the disappearance of most of the external funding for the project, led to a "reframing" of Athena and to the more-or-less stable outcome which is Athena at MIT today.

Before we explore the details of our story, it is important to note that we, its authors, have the ambiguous status of insider-outsiders to the events that we recount. Both of us are professors at MIT who have been present throughout Athena's evolution. Both of us were members of MIT's Division for Study and Research in Education (DSRE), a short-lived program of educational research that MIT shut down just as it began Athena. DSRE was home to several of Athena's principal challengers, a group that included ourselves. We codirected a study of Athena that figured in the debates about the project that took place in the late 1980s.¹

In addition, Sherry Turkle, a sociologist, was active in early discussions about the form Athena should take, and Donald Schön was from 1990 to 1992 head of the Department of Urban Studies and Planning, a department committed to the future educational use of the computer through its Computer Resource Laboratory, whose creation Athena made possible.

Thus, there is no question that we are interested parties, and, as such, we see this chapter as part of a continuing dialogue about educational computing within MIT. However, we shall try to distance ourselves from our insider roles, making use of our special access to the events and ideas of the Athena story in order to illuminate the issues around educational computing at MIT and the nature of the policy dialectic that unfolded around it.

ORIGINS (1978-82)

The Athena story begins in the late 1970s, when a series of commissioned task forces produced reports that anticipated much of Athena's

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design and set out its underlying rationale. The main architects of Athena were in fact the individuals who commissioned these reports, chaired the committees that produced them, and approved of their recommendations, most notably Gerald Wilson, then dean of the School of Engineering, Michael Dertouzos, then and now director of the Laboratory for Computer Science (LCS), and Joel Moses, then chair of the Department of Electrical Engineering and Computer Science (EECS), and now dean of the School of Engineering. All of these individuals were past or present members of EECS, a department that by the late 1970s claimed a third of MIT's undergraduate majors.

Sensing the loss of MIT's leadership in institutional computing, excited by the educational potential of distributed computer systems, and keenly aware of a window of opportunity created by workstation vendors willing to give MIT large numbers of computers at no cost, these three men conceived of Project Athena. At the core of their conception was the image of a distributed computing system that would be "coherent"—a system of "common interfaces reflecting the language of science and engineering [that] would enable MIT people to share and build upon each other's programs, data, and knowledge."² This system was to represent the leading edge of the advancing field of institutional computing. The Athena architects saw the project as the successor to Project MAC, the MIT computer laboratory that had pioneered the development of time-sharing systems in the 1960s and became the Laboratory for Computer Science in 1975. Unique in their day, the time-sharing systems developed at MAC had enabled multiple users to gain simultaneous access to mainframe computing. In the years that followed, MIT played a major role in developing the next generation of institutional computing: free-standing workstations that functioned as "intelligent" computers in their own right. This trend, coupled with the rise of powerful minicomputers (whose performance began to resemble that of mainframe computers and whose cost was a great deal less), made time-sharing systems obsolete. Departments were now able to have their own computers. Athena would balance these centrifugal forces.

In the report of his 1979 Ad Hoc Committee on Future Computational Needs, Professor Dertouzos asserted that the force driving educational computing at MIT was, in the first instance, technological.³ The institute faced certain indisputable technical facts: there would be an enormous increase in the number of computers at MIT, they would cost progressively less and less, and they would incorporate a range of important technological advances that could be turned

toward educational uses. In his 1982 report on computers and education for the School of Engineering, Professor Moses, too, asserted that "by simply implementing the ideas various people are working on, and by providing reasonable access to our students, we will need a massive infusion of new computing equipment."⁴ Moses also claimed there was "a pent-up demand for more traditional uses [of the computer] that would necessitate a major expansion of our computing resources devoted to education."⁵ He seemed to believe that it was inevitable that education, along with other fields of human activity, would be transformed by the computer.

Both Dertouzos and Moses argued from the inevitable to the imperative: in their view, MIT must regain its lost leadership in academic computing. "In light of the excellence MIT expects of itself," Dertouzos concluded,

We should not be simply satisfied with adequacy but should strive to achieve and maintain leadership in the use of information processing. . . . [This] is now and promises to continue being a major component of world-wide technological progress. . . . MIT [should] exert a pioneering influence in the development and judicious use of this technology for the educational, research, and other purposes of a major university.⁶

Dertouzos was convinced, as he has put it more recently, that "the technological growth of computers would go on relentlessly to the end of the century, making computing as ubiquitous and pervasive a factor as money! It was therefore inevitable that computing would touch education, along with everything else."⁷ For him, it was unthinkable that the world's leading technological institute, with education at its core, should not experiment with the educational uses of the dominant emerging technology.

From this position followed three important consequences. First, because the essence of Athena was an effort to regain technological leadership, it would have to use state-of-the-art information-processing technology. Second, because the state-of-the-art is always a moving target, Athena would have to be continually changing. Athena would be a technological experiment for which MIT would be the "laboratory," just as with Project MAC, MIT had been the laboratory for the development of time-sharing. Third, Athena was to be a distributed, networked system that would be a world leader not only in the sophistication of its workstations and the terminals at its periphery, but in the software and operating system at its heart.⁸ Athena's architects decided

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that UNIX, the computer operating system developed by Bell Laboratories and widely considered the wave of the future for "distributed computing," should be the network's standard.⁹ The system also would have to be uniformly coherent, not only in its hardware and software, but in the computer languages it supported.

Indeed, the image of coherence became Athena's technological and aesthetic leitmotif. For its architects, Athena's beauty would lie in coherence, efficiency, flexibility, and universality. The accumulating riches of Athena (libraries of software and dynamic databases) would be continually growing and changing as a result of work done at its periphery. Moreover, Athena would not only provide access to central stores of information but would function as a communications network through which individuals would be able to exchange information with one another and with sources external to MIT. Its power would depend on the excellence of the "complex of pipes"¹⁰ that would make up its infrastructure, designed to be extended eventually to include all of the institute's information processing functions—those related to research, libraries, and administration as well as to education. This view of Athena reflects a faith that, from the right technology, good things will come. Specifically, it defines an "MIT way" of proceeding with research on technology and education: build the ultimate in technically sophisticated information systems, and they will yield the most powerful educational results.

Athena's founders were bemoaning MIT's lost leadership in institutional computing at a time of dramatic change in the computing industry. By the early 1980s, distributed networks of advanced microcomputers were becoming the leading edge of the computer field as a whole, threatening to displace systems based on mainframes and minicomputers. The Athena architects saw Athena not only in reference to the network services of other great research universities such as Stanford, Berkeley, and Carnegie-Mellon, but in relation to the great telecommunications companies, the stock exchanges, and large service organizations. MIT's plans for Athena were thus of considerable interest to leading-edge computer companies that hoped to sell to these markets.

For the Digital Equipment Corporation (DEC), MIT looked like an excellent site in which to develop and test technology that it saw as the basis for its future business. Indeed, the design for Athena crystallized just as DEC lost out to IBM in its bid to provide computers for Carnegie-Mellon's new computing system. From the point of view of Athena's designers, DEC's prospective gift of numerous high-technology

workstations precisely matched the specifications of Athena's emerging design and presented a window of opportunity that MIT could not afford to pass by.

Although Athena had been originally conceived as a project to serve the School of Engineering, then-provost Francis Low insisted that it be extended to the institute as a whole.¹¹ He believed that in an undertaking of this scale there simply could not be "haves" and "have-nots." Seeking to comply with Low's policy decision, Wilson and Dertouzos met with Lewis Branscomb, then IBM's chief scientist, and obtained, with help from him and others at IBM, a second large donation of computers. They decided to divide MIT into two computational worlds: DEC would supply technology for the School of Engineering and IBM would be used for all the rest.¹² Seeking this second gift was to have important consequences. Among other things, we shall see that it created roadblocks to the goal of achieving system coherency.

The original design for a project in the School of Engineering, now expanded to include the whole institute, rested on several sets of assumptions, some stated, some unstated. For example, the network and the sophisticated terminals attached to it were expected to be available and working with reasonable reliability during most of the period 1983-85, the time-frame of what was declared the original Athena experiment. This turned out to be a false assumption. The technology was late in arriving, and the suppliers often changed their plans for the number and types of machines they could deliver. Large numbers of students and faculty were expected to be willing to pay the price of learning to use UNIX, Athena hardware, and the set of languages that Athena approved for the project: C, Fortran, Forth, and LISP. This turned out to be a false assumption. The designers believed that the standards of the coherent system would not seriously constrain the imaginations or excessively challenge the competencies of the faculty members who were expected to develop new "courseware" for the Athena system. This too, turned out to be a false assumption. Finally, it was decided that to create an educational good in the domain of undergraduate teaching, one should exclude graduate students and the use of computers for research purposes. This turned out to be disruptive because profoundly countercultural: MIT routinely integrates graduate students and research into the undergraduate program.

In addition to highly problematic starting assumptions, there were others that spoke directly to the relationship of the network to the educational purposes that were its declared reason for being. These included a model of the "instrumental computer" as an educational tool, a

"thousand flowers" view of software development, and a "federal" model of project management. It is to these that we now turn.

EDUCATION: THE INSTRUMENTAL COMPUTER

Athena's designers conceived of the project as a quest for lost technological leadership in institutional computing and as a large-scale experiment in undergraduate education. But there was a lack of symmetry: the technological goals were concrete and understood in terms of specifics, while the educational goals were somewhat vague and communicated mixed messages. For example, there would often be some talk of doing exciting new things with computers followed by other talk about computers helping us do the old things, just more efficiently.

These mixed messages are apparent in the earliest documents relevant to Athena. For example, in his 1982 report Moses noted that he was "on the whole . . . excited by the range and number of ideas" for educational uses of computers that had been discussed in meetings he had held with interested faculty, although "no revolutionary ways of teaching traditional material were uncovered." Nevertheless, he had faith that once the network was in place and computers more widely available, we would discover revolutionary ways of teaching traditional material, even though he could not say just what these would be. In any case, he said, "If we do not create a relatively uniform environment in which computing is readily available to our faculty and students, no such revolution will likely take place."¹³ In other words, the vagueness of Athena's initial educational intentions was justified in principle: given the right tools, MIT faculty and students would invent the educational uses of the computer.

It is significant that Moses wrote here of revolutionary ways of teaching traditional material. Athena's founders did not, for the most part, intend to change MIT's traditional subject matter or central pedagogical assumptions. For example, they thought that MIT students would still learn thermodynamics in the usual ways. But they did expect that the computer would make traditional instructional processes incomparably more efficient. Wilson would later say that the Athena educational experiment consisted of testing whether the computer could be used "to make the teaching of science and engineering more effective and efficient."¹⁴ The computer would be used to shorten the time required for the performance of cumbersome numerical calculations. Students would solve problem sets and submit them to their instructors for correction, all by computer. Computers would facilitate the analysis of

complex systems, present graphic displays of systems otherwise hard to visualize, and provide access to large databases.

In sum, Athena's founders thought, for the most part, in terms of the instrumental computer, by which we mean a computer that would be a more efficient educational medium without requiring any change in educational objectives, pedagogies, or ways of understanding subject matter. The computer would be a "useful tool," a phrase that became a universal refrain in the justifications of Athena.

Some of the writings that prepared for Athena's birth presented a somewhat different image of educational computing. The Task Force on Education and Computers, established in 1979 and chaired by Professor Dertouzos, suggested the image of a ladder that would lead from mundane to sophisticated applications of the computer. Text processing and calculation would be at the bottom of the ladder. Graphic models and simulations that would allow students to conduct "what if" experiments were to be in the middle. At the top would be such things as "intelligent tutors" and "higher level languages and programming environments where students can program and experiment with new situations."¹⁵ The applications at the top of the ladder would lead to "paradigms for building a deeper and greater student experience." So it was not surprising that the report concluded that "perhaps the biggest asset of computers for education lies in helping the student gain a *deeper* understanding to traditional modes. . . . The main areas for future use of computers in education involve qualitative changes rather than efficiency improvements."¹⁶

These suggestions seem to have been overwhelmed by what turned out to be the main and more instrumental thrust of Athena's vision of computers in education. In any case, for some faculty members involved in the early discussions of Athena, even the highest rung of the committee's ladder of applications implied little real change in traditional education. For example, Professor Robert Logcher of the Department of Civil Engineering, who championed the idea of an intelligent tutor, saw it as a knowledge-based system that would relieve overworked faculty of the chore of grading and commenting on the problem sets around which much of MIT's traditional education was based. It was a time saver, not a paradigm changer.

Most often, in the pattern of the early Moses report, hoped-for radical educational changes were simply expected to follow from technical ones. For example, a paper coauthored in 1985 by Steven Lerman, a civil engineering faculty member who was Athena's first director,¹⁷ stated that Athena would "provide students with a deeper understand-

ing of fundamental principles" and "better prepare them to utilize the techniques and methods of the practicing scientist and engineer of the future," going beyond "mere calculation" to "discover along the way many more innovative ways to employ computers effectively in the educational process." But once the authors had boldly announced their vision of computer-based education, they did not go on to say how the required changes might actually be brought about. At the conclusion of their article they turned instead to a detailed technical description of the Athena system. Alternative educational ideas, evoked as possibilities in a few early documents, became minor themes in a story line dominated by the idea of the computer that helps you to do the old things more efficiently.

SOFTWARE DEVELOPMENT: A THOUSAND FLOWERS

Even in the report of the 1979 ad hoc committee, Dertouzos recommended the support of experiments in educational computing, and Athena's eventual design, as described in Lerman's 1984 "Introduction to Project Athena," included some \$12 million over the five years of the project to support educational experiments.¹⁸ Athena had a clear model of the form of such experiments: the MIT faculty would develop instructional software to be used in teaching traditional MIT subject matter. Professor Logcher, looking back on the early days of Athena in a later, October 1987, interview, noted that the idea was that "there are a lot of bright people around here and if you give them some resources, they're going to do interesting things. That's MIT's attitude towards a lot of things."

In this way, Athena's design rested on the belief that, once the network was in place and discretionary resources were made available, a thousand flowers would bloom. It rested on the belief that substantial numbers of MIT faculty would want to invest their time in the development of educational software, and that they would be able to develop it without detracting substantially from their main research pursuits. They would do it, so to speak, "with their left hands." Finally, it rested on the assumption that their imaginations would not be constrained nor their competencies excessively stretched by the challenge of developing new courseware within the parameters of the coherent system. All of these assumptions would be sharply challenged, as we shall see, in the later phases of Athena's development. At the beginning, however, they seemed obviously true to Athena's engineering architects.

ATHENA'S ADMINISTRATION: THE FEDERAL MODEL

The development and maintenance of the network, the development and enforcement of standards for coherence, and the conduct of experiments in educational computing all would require an administrative structure. In his 1979 report, Dertouzos had argued for a mix of decentralization and centralization, stressing that the maintenance of common standards of hardware and software would require central administrative control, whereas a network-based laboratory for experiments in educational computing would require flexible administration and local ownership and control of computers. Moses, in his 1984 "Report on the Computing Environment at MIT in 1990," recommended creating a central organizational unit to oversee certain campuswide information services that are "near natural monopolies," and for which there are important economies of scale.

In the administrative structure eventually adopted by Project Athena, an Athena executive committee, under Dean Wilson, became the principal vehicle for oversight of Project Athena, and a central Athena office was created, under Lerman, to fulfill a variety of functions. It would provide hardware and software, develop software tools for system users, modify the operating system, install and maintain approved software languages, develop software network interfaces, and so on. For all of these purposes, Athena's central office grew to include some fifteen to twenty technical staff members, in addition to technical staff supplied by DEC and IBM.

In order to manage allocation of the funds it expected to raise for support of faculty development of educational software, Athena adopted a model reminiscent of federal research and development programs. Two faculty resource allocation committees were to put out requests for proposals, select projects for funding, and monitor project performance. Athena hoped that its "thousand flowers" would be elicited and selected through a centrally administered peer-review system—interestingly, one that bypassed the departments as centers of institutional initiative and decision making. Again, there were critical tacit assumptions: faculty would not be put off by a selection process staffed by members of other disciplines than their own and would willingly accept a central administrative structure that bypassed their own departments.

ATHENA'S CHALLENGERS

From the earliest days, Athena had challengers as well as advocates. One group consisted of MIT faculty who were strong advocates of edu-

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cational computing but highly critical of Athena's style of pursuing it. They did not see the future in terms of a unified computer environment, as all of Athena's founders did, and they did not see the computer primarily in terms of the more efficient teaching of traditional subject matters, a view held by at least some of Athena's founders and emphasized in Athena's actual development. Rather, this first group of challengers saw the computer as a highly personalized conversational partner, an incubator of microworlds for the conduct of thought experiments, and, in Professor Seymour Papert's words, a new repertoire of "things to think with." Rather than focus on the ways in which computers could make traditional teaching more efficient, these faculty members thought that Athena should emphasize the creation of computer environments where students and faculty might come to see and do things in new ways.

Additionally, there were some who challenged Athena's starting assumptions about technology and education. Professor Joseph Weizenbaum, a computer scientist, and Professor Kenneth Keniston, a psychologist, stressed the opportunity cost of the Athena initiative and argued that one must not confuse technical and educational sophistication. It should not be assumed, they said, that a leading-edge distributed computer network would also be leading-edge in its educational consequences. One of us, Turkle, questioned whether the emphasis on a coherent system would conflict with the richness and diversity of the computer cultures that were spontaneously arising within MIT. She stressed the computer's ability to contribute to, rather than constrain, the natural pluralism of the MIT community. She believed that computers could facilitate a range of learning styles among MIT students and faculty, and argued that the advantages of a uniform and centrally imposed computer environment needed to be carefully weighed against its costs.

Finally, Professor Harold Abelson, a computer scientist, was a forceful and persistent critic of what he saw as Athena's overriding technological emphasis. He believed, as he wrote in a 1985 memorandum to the Project Athena Study Group, that

the major thing we need to keep in focus is a view of Athena as an educational experiment. This needs to be emphasized because the great majority of current Athena activity is concerned, not with education, but with building the technological infrastructure to support "the Athena experiment." My guess is that if we went out at present to interview people working with Athena, we would mostly get reactions to the current state of the implementation, the current prob-

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lems of building the system, and so on. So we need to put priority on framing the issues in such a way that Athena activities continue to be viewed in an educational context.

Abelson believed that the main significance of educational computing would lie not in relieving the drudgery of number crunching or the burden of correcting students' problem sets, but in the transformation of subject matter. Therefore, he thought, Athena's educational impact should be mainly judged by the "curricular shifts [that] have come about as a consequence of Athena, both within specific subjects as well as across departments and programs."¹⁹

Although they came to their criticisms of Athena from different starting points, all of Athena's challengers shared Abelson's skepticism about what they saw as the technocentrism of the Athena design. They believed that educational considerations should drive the design of Athena's technological and institutional arrangements, not the other way around, and that Athena's experiments should be designed, at least initially, with an eye to the *educational* questions raised by the computer. These included: How do computers enter into the process of thinking, learning, and teaching? Specifically, how might computers change how faculty and students think about their subject matter?

For Turkle, especially, the computer was more than an instrumental machine. She saw it as having powerful subjective effects, changing, for example, how people saw themselves as learners. She thought there should be an attempt not only to chart Athena's educational effectiveness in teaching the old things in a new way, but to study if and how the system afforded new learning experiences. For this, it would be necessary to study the experiences of faculty and students as they used the new system.

This last point, the idea of educational research and evaluation, became a lightning rod for controversy. Neither Athena's designers nor the two MIT provosts who approved Athena were enthusiastic about a specifically educational evaluation. Indeed, when serious evaluation of student experience with Athena was proposed—by Professor Keniston, in faculty discussions held during Athena's design phase, or by Schön and Turkle during the discussions of their early reports on Athena—the idea was actively resisted.

Although the word "hypothesis" was widely used in conjunction with the idea of Athena as an educational experiment, there was little or no discussion of hypothesis testing. Athena's founders did not propose to study how students actually used educational software. Rather, they took the educational effectiveness of their proposed innovations for

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granted. "We just wanted to get something in place," Professor Logcher said in an interview conducted in 1989. "We were convinced that the group hypothesis would be so *obvious* [our emphasis] that no one would question it. . . . That's typical around here. . . . These are engineers as opposed to social scientists. . . . There was no concern that I saw of actually going through a formal activity of an evaluation process." In his preamble to the Report on the Computing Environment at MIT in 1984, Professor Moses wrote simply, "We assume that Project Athena will be successful."

Behind the reticence about evaluation was the belief, widespread among the engineers involved in the design of Athena, that there were no educational first principles and no methods of educational research capable of providing valid information about the effectiveness of educational computing. So it was not surprising that John Deutch, who succeeded Francis Low as provost, saw no reason to fund an evaluation of Athena. He thought it would be unlikely to yield useful knowledge and might actually undermine the enthusiasm essential to Athena's success. Common sense was a better alternative, he thought, because the effectiveness or ineffectiveness of educational software should be easy to detect. As Professor Moses exclaimed in a 1989 interview, "If [the software's] effects are not dramatically obvious, don't do it!"

THE EARLY DEBATES

Very little real communication took place between Athena's champions and their challengers. The two groups thought and argued from different frames, and because the design for Athena was of a piece with MIT's traditional view of itself and what Weizenbaum and others critical of MIT had called its "religion," the early debates over Athena were conducted as though between an orthodox and a heretical community, between partisans and critics of "the MIT way."

For the champions, the imperative of technological leadership in computing systems and the attractions of "coherence" were axiomatic. For the challengers, these tenets were at best open to debate and at worst a cover for a technically inspired engineering adventure that some thought had little educational focus or little to do with the computer's real educational potential. For Athena's champions, educational evaluation was irrelevant and an intellectual charade; for Athena's challengers, traditional educational evaluation might not be the right idea, but some attempt to understand the impact of this new, intensified computer presence was essential.

Moreover, the challengers and engineer-architects each tended to see the other as a self-appointed elite that threatened to usurp control. For the challengers, the threat came from engineers driven by technological rather than educational vision. For the engineer-architects, it was the humanists, social scientists, and what they called "educationists" who were threatening progress in the name of a nonexistent educational theory. Professor Dertouzos lumped these categories together and called them "humano-romantics," good humoredly contrasting them with "techno-romantics" like himself. In a later elaboration of these terms,²⁰ Dertouzos pointed out that when "confronted with impossible questions," both groups surrender to their beliefs—"the first, in the omniscience of the human spirit; the second . . . in the truth of science and the miracles of technology." "Devoid of any relevant facts," he went on to say, "either sect is a prisoner of their belief systems, equally encumbered or liberated, depending on the observer's religious affiliation!"

In addition to the champions and challengers, there was a third group among the MIT faculty that might best be called "reticents." This group included some individuals who saw the computer as irrelevant to the real work of education, and others who saw themselves as users rather than developers of existing software. Some reticents had already created computer environments in their departments or laboratories, which were scheduled to be cleared away to make room for Athena. Many of them resented—in silence, for the most part—Athena's intent to root out these settings as though they were slums.

As it turned out, the challengers were easily defeated by Athena's designers, who had the support of the central MIT administration and who represented MIT's most powerful school and department. Athena's design bore few if any signs of influence by the challengers, most of whom either dropped out or were relegated to the sidelines. Later on, however, the challengers' voices would be heard again, and MIT's central administration, whose role until now had been relatively minor, would re-enter the process to negotiate among conflicting views of Athena.

IMPLEMENTATION (1983–86)

Project Athena began operation in 1983 with Steven Lerman as director. Because shipments of advanced workstations were delayed, the project first relied on IBM PCs and older time-sharing systems. By 1985–86, however, Athena had introduced individual workstations, interconnected and supported by numerous machines dedicated to management and file service. By fall 1986, what Lerman called "the

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first true workstation cluster" had opened for public use; and by 1987 no fewer than four hundred workstations were distributed across twenty clusters, a few faculty and staff offices, and selected student living groups.

By fall 1986, student utilization of Athena was high and steadily increasing. By fall 1989, over 80 percent of undergraduates and about 50 percent of graduate students had Project Athena accounts.²¹ Although Dean Wilson had been able to raise only about \$12 million of the \$20 million for educational projects that he had originally projected—an outcome he found profoundly frustrating—new computer-based curricula were being developed in about fifty subjects, including foreign languages, chemistry, civil engineering, aeronautics and astronautics, mechanical engineering, materials sciences, and architectural design. Eleven of these had been designated by the Athena office as "flagship projects."

In spite of these tangible accomplishments, Athena's implementation ran into a series of unexpected troubles from the point of view of her engineer architects. These ranged from technical delays and difficulties and an unexpected and disappointing pattern of student use, to outright hostility from the School of Science.

TECHNICAL DELAYS AND DIFFICULTIES

The advanced computers expected from DEC and IBM were two years late. The temporary systems were pieced together, programs were bug-ridden, and computers were constantly crashing. The flavor of this period is eloquently conveyed in a letter written in 1987 by a programmer in one of Athena's software development projects. "Basically," she wrote,

the worst part has been that in trying to use the computer with students, almost nothing has been even reasonably reliable, ever. Students regularly encountered problems with the system: the computers were down, the terminals were not functioning properly, or something had been changed without any notification. Lecture demos would be planned only to find that the system driving them had been modified and wouldn't work. The programs we wrote were based on graphics and systems libraries which either changed themselves or performed differently as the hardware was changed. Thus we would find that previously developed programs would no longer work properly in the current environment. We not only couldn't rely on maintaining what we had done, but we were given almost no concrete information in order to make future plans. Everything was

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always in flux, contradictory rumors abounded and little could be counted on.

These conditions were in part due to delays in the delivery of equipment, changing expectations about equipment, and technical problems with equipment once it arrived. They were also due to Athena's decision to make improving and updating the technical infrastructure an overriding priority even when it meant throwing curriculum developers and users into confusion.

Students were the most conspicuous victims of Athena's instability, suffering most immediately from its frequent crashes, bugs, and unannounced changes. Sometimes whole classes would groan audibly at the very mention of the word "Athena." Given the love-hate relationship that MIT's undergraduates have traditionally maintained with the institute (MIT is commonly referred to as "this place"), Athena came to be seen as one more unnecessarily inflicted evil.

Some faculty members also began to grumble openly. They, too, resented Athena's unreliability and the inconvenience caused by its recurrent changes. As one faculty member put it, "My computer knowledge is about to become obsolete for the sixth time!" In an environment where time is the most precious commodity, many faculty members simply chose not to use the Athena system.

FACULTY DISAPPOINTMENT WITH STUDENTS' USE OF ATHENA

While students complained about what happened to them when they tried to use Athena, many of MIT's engineering faculty were shocked at *how* students used it. By 1985 it was apparent that approximately 70 percent of the student use of Athena was for things that the Athena planners had pretty much written out of the project as too "mundane"—things like word processing, electronic mail, and computer games. Reactions to this state of affairs among the engineering faculty ranged from amusement to horror. Had MIT procured \$50 million dollars worth of equipment and engineered the most sophisticated on-line time-sharing network of its kind in order to support uses that could have been served as well or better by Macintosh computers or IBM PCs at a small fraction of Athena's cost?

DISAPPOINTING FACULTY RESPONSE

When Athena asked faculty for proposals to develop new courseware, the response was disappointing. Although some 111 proposals were

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funded in Athena's first five years, their quality fell well below the expectations of Athena's architects. With few exceptions a small number of devoted computer champions, together with their younger faculty protégés, made the serious investments in developing new courseware. In the metaphor of the Athena architects, fewer "bright people" had come forward to do "interesting things" than had been expected. The thousand flowers metaphor began to seem hollow.

LACK OF ENTHUSIASM FOR EDUCATIONAL COMPUTING

Our case study work in the MIT departments of physics, civil engineering, chemistry, and architecture revealed that some reactions to Athena were really general reactions to the idea of educational computing. For example, some faculty members feared that students who came to rely on the computer's virtuosity in performing complex calculations would lose contact with the reasoning that underlay those calculations, and that the faculty would then become unable to detect and correct the students' misunderstandings. Some faculty members and students saw the computer as a threat to cherished activities that they saw as being at the heart of their disciplines. Architects, for example, feared the computer's infringement on the work of drawing. Some chemistry professors resented the idea that computers might enter the lecture hall and interfere with their presentation of chemical theory. Professors of civil and mechanical engineering saw computers as subverting the delicate work of structural analysis. Wherever such sacred space existed in a discipline, some of its practitioners feared the intrusions of the computer.

RESTRICTIONS INHERENT IN "COHERENCE"

On a more general level, faculty bristled at the constraints imposed by the demands of the "coherent" system. For example, there was a widespread belief that they could receive Athena funding only if they used Athena-approved machines, computer languages, and the UNIX operating system that often seemed cumbersome and hard to learn. Many faculty members continued to favor Macintosh computers or IBM PCs, and wished to work in languages such as Logo or BASIC rather than, for example, the Athena-approved C. A number chose to bypass Athena and develop computer-based curricula on their own. In fact, Athena did fund some projects that did not play by the rules, but a significant portion of faculty found that the hassle of pleading for an exception was simply too great.

TWO CLASSES OF PEOPLE

Because of its technical emphasis, it was inevitable that Athena tended to see MIT as a two-class system. The "higher" class, which it favored, was composed of the computer sophisticates, who liked to use UNIX and UNIX-based features such as the X Window System, which permits flexible textual and graphic interaction with many simultaneous tasks. The "lower" class consisted of computer novices, who found UNIX unmanageable, or other faculty members, who considered Athena's advanced features unnecessary to their preferred applications. In the Athena culture, the second group felt devalued. Among humanities professors, for example, Athena reinforced a long-held belief that they were the institute's poor relations.

Resentment over Athena's two-class system was not limited to the humanities and social sciences. It was evident, too, in the School of Science and extended even to some parts of the School of Engineering. Early in Athena's history, when Dean Wilson urged his engineering faculty to come up with more exciting proposals for new courseware, a professor of chemical engineering explained in a widely disseminated memorandum that the Athena community contained two very different subgroups—the "computer community" and the rest of the engineers who wanted only to "teach non-computer engineering with the aid of computers." The latter had little interest in Athena's technical niceties, he thought; they only wanted workable software and had no interest in developing it for themselves. This memorandum reflected a feeling, shared by many silent faculty members who resisted or were indifferent to Athena, that Athena had been undertaken by a small, elite group, without the participation or approval of the larger MIT community.

MIT'S INCENTIVE SYSTEM

Even the long-term champions of computers and education were dissatisfied with Athena, which they came to see as a trap for their younger faculty protégés. The history of Athena dramatized that software development, far from being an "exercise for the left hand," was an extremely demanding task. MIT's promotion and tenure process focuses single-mindedly on front-running research in a discipline, and the development of educational software did not count in this system. Faculty members who chose to devote themselves to educational software ran a great professional risk and would find it almost impossible to qualify for advancement.

Moreover, even if software development were to be accepted as rele-

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vant disciplinary research, where were the senior faculty who could help their younger colleagues turn that activity into acceptable research papers? Who could read and criticize such papers? It was clear that younger faculty hoping for tenure would invest in Athena at their peril.

THE SPECIAL CASE OF THE SCHOOL OF SCIENCE

Most of MIT's scientists responded with indifference to Athena's blandishments. As Joel Moses ruefully expressed it in an interview in 1989, "We failed to win the hearts and minds of our colleagues in the School of Science." Indeed, Athena made some science faculty members angry. The Department of Physics, in particular, was a center of resistance to Athena. Some physicists had no use at all for computers in education, finding them a threat to "real physics." Professor Victor Weisskopf, a distinguished member of the physics faculty, was famous for saying, "When you show me this result, the computer understands the answer, but I don't think *you* understand the answer." Other physicists who did want to use the computer in education, to connect personal computers to laboratory instruments in order to speed up data processing and analysis or to write a computer-based physics text, found their initiatives stymied by Athena's policies, in particular those that restricted choice of machine, operating system, and computer language.

In looking at faculty reticence toward Athena, a distinction between "announced policy" and "policy in practice" is useful. For example, the Committee on Resource Allocation that oversaw Athena grants to the School of Science refused to provide support for faculty salaries during the academic year—apparently because Professor Deutch, then dean of the School of Science, worried that some faculty members might use Athena monies to avoid their obligation to support part of their salaries through externally funded research.

Athena's refusal to support the salary of Professor Robert Hulsizer, a highly respected member of the physics faculty who had proposed to devote his final years at the institute to an in-depth reworking of the physics curriculum using computers, became an issue that angered that department as a whole. The physicists took it as a sign of Athena's arrogance and insensitivity to their needs. Their reaction puzzled Dean Wilson, who was unaware of the Resource Allocation Committee's action within the School of Science. Wilson protested that the Athena Executive Committee, which he headed, had an explicit policy of supporting the faculty's academic-year salary. What else, after all, would curriculum development funds support? Yet the physicists' belief that

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Athena would not support faculty salaries persisted long after the School of Science's Committee on Resource Allocation had reversed its position. The combination of the technical restrictions (the sense that in order to get things done one had to "fight" with Athena) and the sense that Athena had been unreasonable, shortsighted, and bureaucratic in the Hulsizer case, caused a few physicists who were actually computer enthusiasts to turn sour about Athena. They came to feel that Athena was preventing, not helping, them from making advances in educational computing.

The persistence of the physicists' belief that Athena did not fund faculty salaries may have reflected what was by then an entrenched hostility toward Athena. Many of the physicists saw Athena's regulations as a form of censorship jeopardizing their academic independence. Additionally, they bitterly resented the very idea of engineers trying to tell scientists what to do.

"ATHENA IS NOT ABOUT EDUCATION"

As Athena matured, in the period 1984–87, both faculty members and students increasingly voiced the opinion that Athena was not about education but about technology. In chemistry and mechanical engineering, for example, the faculty was astonished that, although computer graphics had been identified from the outset as a major educational opportunity, Athena had failed to develop a usable graphics package. Some faculty bitterly noted that Athena meetings were wholly taken up with technical matters rather than with questions of education. More and more faculty members began to pick up Professor Abelson's original concern that Athena had never addressed the fundamental questions posed by the educational uses of the computer. Why, they asked, was the project being presented to the world as an experiment in education?

ANALYZING THE CONFLICTS OF ATHENA'S SECOND STAGE

Athena provoked conflict for two main reasons. First, once Athena moved out into the larger MIT environment, the various MIT audiences saw it in the light of their own interests and frames. Indeed, the conflicts that followed Athena's early implementation reflected quite precisely the internal divisions of the MIT social world—for example, divisions among the schools and departments, between graduate and undergraduate students, between computer enthusiasts and computer skeptics. Athena's presence simply made these divisions more visible.

Second, Athena provoked conflict because of contradictions inherent in its original design—contradictions that were masked, in part, by untested assumptions about how Athena would be seen and used.

To begin with, Athena had committed itself to its technology (including hardware, operating systems, and languages) before its educational programs evolved. As a matter of principle, it had justified its commitment to "technology first" by its assumption that innovative educational developments would arise only after the technologically sophisticated network had been put in place, and because it had been put in place.

However, relatively few faculty members were tempted to develop new computer-based curricula; many preferred machines, operating systems, or languages that Athena prohibited in the name of coherence, and those who tried to use the growing commercial stock of educational programs found they could not do so on Athena's UNIX-based network. Hence, many faculty members felt their intellectual creativity was constrained by the very system that was supposed to liberate it.

As a large-scale intervention in classrooms and laboratories, Athena's success was bound to depend on its reliability and stability. But as an enterprise committed to technological development, necessarily reliant on continuing experimentation, Athena was bound to produce, at least in its early years, an environment of unreliability and instability. For many faculty members and students, the promise of future benefits was simply not worth the trouble of dealing with Athena's present difficulties.

Finally, in spite of its espoused commitment to educational innovation, Athena emphasized computer applications that exploited the technically sophisticated features of its machines, treating as mundane and second class the educational purposes for which most students and faculty actually wanted to use it.

How can we best understand these contradictions? One interpretation, frequently voiced at MIT in the late 1980s, was that Athena gave lip service to educational objectives but was really, from start to finish, a technological adventure shaped by MIT's close alliance with the computer industry. For some, this interpretation implied a certain cynicism in the insistent and continuing statements by Athena's engineers and architects that they were committed to the educational purposes of their experiment.

A more plausible interpretation is that its founders' strong belief in and commitment to technology blinded them to the contradictions inherent in Athena's design. It kept them, too, from listening to nega-

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tive messages from the field that would have alerted them to these contradictions. Athena's engineer-architects shared a faith that educational benefits would inevitably flow from the world's most advanced institutional computing system. Their faith caused them to misread the needs of their student market and their faculty colleagues, and the degree to which continual upgrading of the Athena network would interfere with its educational purposes. Finally, their belief in cutting-edge technology caused them to resist the idea that competing (and, for them, "lesser") technologies such as the Macintosh computer and the DOS operating system would flourish, adapt to competition, and become the basis for new educational software.

Similarly, the founders' belief in the technical beauty of the coherent Athena system blinded them to the multiplicity and diversity of computer cultures that both existed and were growing up at MIT and, therefore, to the desirability of decentralized policies for the choice of hardware, software, and operating systems. As a result of their belief that MIT faculty would find courseware development "an exercise for the left hand," they did not appreciate the resistance many faculty members actually felt toward developing new computer programs. Their mistaken belief grew out of a confidence in the natural superiority of MIT citizens in all things technical, a confidence that the normal rules would not apply to this population. Their tendency to equate technical with educational sophistication also prevented them from considering the possibility that sophisticated technology might yield results that were educationally mundane. Indeed, they were not able to consider the possibility that mundane technology might produce significant educational results. More fundamentally, their overriding faith in the socially beneficial consequences of advancing information technology blinded them to the possibility that the most advanced distributed computing system might not stimulate educational innovation at all.

The fact that these misreadings persisted for a number of years, in the face of mounting counterevidence from the field, testifies to the power of the founders' faith. That faith had been challenged directly, by Professor Abelson, in the debates about Athena held at MIT in the early 1980s. However, for Athena's engineer-architects, it was the challengers, skeptics, and resisters who were blind to the beauty, power, and benefit of the coherent system. As Professor Moses was still saying nearly ten years later, "They just didn't see the beauty of the idea!"

POLICY ADJUSTMENT (1987-89)

By January 1987, as the voices of disaffection grew louder, MIT's administration began to face up to Athena's long-term financial implications. Originally, Athena was to have run for five years as a separately funded project and was then to be incorporated into MIT's normal budget. In its first phase, supported mainly by gifts from DEC and IBM and curriculum development grants from other firms, Athena had placed only a modest demand on MIT's general funds. Now, however, Dean Wilson estimated that Athena's regular future operation would cost MIT between \$2 million and \$5 million per year, the equivalent of earnings on some \$100 million of endowment. The replacement costs for equipment, turning over every five years, would come to an additional \$1 million to \$2 million per year. It had become clear that MIT would have to support whatever additional curriculum development it chose to undertake out of its own funds; industry resources for this purpose had been hard to get to begin with and now seemed to have dried up. In the light of these hard facts, Provost Deutch asked Wilson to come up with alternative programs and financing strategies for Athena's future.

By 1987, doubts about Athena's future and the fallout from the disappointments of Athena's early days had taken their toll on the morale of Athena's technical staff. Some had already quit; others were threatening to do so. So both budgetary and human resource concerns weighed heavily on Wilson and the Athena Executive Committee as they became increasingly aware of the conflicts Athena had stirred up within MIT.

THE PASG STUDY OF ATHENA

In 1986, Provost Low had appointed a faculty evaluation committee, chaired by Dean John DeMonchaux of the School of Architecture and Planning, but when Professor Deutch replaced Low as provost, he feared that an evaluation of Athena might undermine the enthusiasm of the founders, which he saw as essential to Athena's success. Only at the insistence of Margaret MacVicar, the dean for undergraduate education, did Deutch reluctantly agree to make available a nonrenewable grant of \$100 thousand for Athena's evaluation.

Dean MacVicar, who was to play an increasingly important role in Athena's development, was a physicist best known for having conceived and built up the Undergraduate Research Opportunities Program (UROP), perhaps the most durable and significant of the educational

innovations MIT had undertaken in the 1960s. She had a deep understanding of how MIT worked as an institution and a long-standing commitment to undergraduate education. To her it would seem natural that Athena should be assessed as an educational experiment.

Several members of Dean DeMonchaux's group had participated in the early Athena debates, and some had also been associated with MIT's Division for Study and Research in Education, a home for educational research within MIT that ironically had been abolished just as Athena started up. With strictly limited funding and ambivalent administration support, the group was reluctant to attempt a full-scale evaluation of Athena. Preferring to undertake studies of Athena, they chose to call themselves the Project Athena Study Group (PASG). However, they had a hard time agreeing on just what to study. After about a year, Dean MacVicar called on the committee either to define its studies or dissolve itself, and PASG proposed three studies: an archival history of Athena's early years, a study of Project Athena in MIT student living groups, and a series of case studies of Athena-supported projects in four MIT departments. This last was led by Professors Schön and Turkle.

By January 1987, the case study team presented a first working paper to its steering committee. It contained a preliminary sketch of its findings, including a report on the contradictions in Athena's design already described. The steering committee included Professors Dertouzos and MacVicar, and the working paper was promptly transmitted to Dean Wilson. It immediately provoked stormy reactions.

Dertouzos told Schön and Turkle, "The bugs you have detected are of the *essence* of MIT." The working paper referred to Athena's treatment of the thousand flowers as a "Darwinian" strategy. This, Dertouzos said, was a criticism that assumed a competing, coherent theory of education that did not exist. "The MIT way," on the contrary, was to "throw things at people and wait to see who can swim upstream, trusting that the brightest people will produce . . . the crazy ideas that make MIT great!" As against a coherent theory of education, Dertouzos believed in the beauty of a coherent technical system that would enable a thousand educational flowers to bloom.

Dean Wilson, for his part, was incredulous that he could be seen as failing to promote Athena's educational purposes. Had he not struggled to raise the funds for curriculum development? Had he not made it clear, in word and deed, that he stood fully behind Athena's educational purposes? Moreover, he resented criticism from the nonengineering schools about Athena's design. In many ways, Wilson felt a victim of his colleagues' short historical memory. His design concept for Athena had been built around the needs of the engineering school. He had

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never sought to serve other constituencies. When Provost Low had insisted, the project had accommodated the *administration's* demands that it serve all of MIT. It was unfair to criticize Athena for not adequately serving these other communities.

Dean MacVicar felt that Athena had polarized the institute. Francis Low had insisted that Wilson broaden Athena to include all of MIT in order to avoid haves and have-nots. Yet in practice Athena had created a two-class system, roughly corresponding to enfranchised engineers and disenfranchised others, thereby producing what MacVicar called a "positively explosive climate of anger." She thought that Athena's designers misread what they had created because they saw it only from the perspective of the enfranchised. "They thought they had an elephant," she said, "and it turned out to be a giraffe!"²²

The PASG study was only one of several channels for negative reactions to Athena that were reaching Athena's decision makers in January and early spring 1987. There were, as well, the student press, the informal comments of students and faculty, and Dean MacVicar's independent sounding of MIT opinion. Through such channels Athena's designers learned that they had alienated large segments of their market, and that if they persisted in their policies they would probably stir up enough political opposition to cause Athena's demise.

Despite anger and hurt feelings, Dean Wilson and his colleagues heard and responded to these messages. Findings of the PASG study that had seemed incendiary when they were first presented—such as the need for greater decentralization of Athena's management, permission for students and faculty to use the technology for technically mundane uses (word processing, electronic mail), and relaxation of the constraints of the coherent system—became accepted in the Athena Executive Committee's discussions as obvious changes to be implemented. The committee developed a new strategy of accommodation, softening the policies that seemed to have provoked the greatest resistance to Athena while taking steps to insure the survival of what it saw as most central to the Athena program. This strategy of "sacrifice the periphery, salvage the core" was pursued in stages.

First, the executive committee decided to extend Athena for a second three-year term, arguing, as Dean Wilson put it, that the extension would be necessary in order to "complete the educational experiment." Crucial to this decision was the fact that Athena was still far from having achieved its announced technical objectives. Only a small fraction of the originally intended workstations were in place (and most of these for less than a year), the more significant curriculum development projects were still in their infancy, and discontent with Athena was high.

Athena was continued, at least in part, because it could not have been discontinued at that point without an implicit declaration of failure.

The next period of roughly six months (from January to June 1987) came to be known as "Athena's learning curve." While Professor Lerman and Dean Wilson were negotiating the new three-year extension with DEC and IBM, and Lerman headed a committee to plan Athena's next phase, Athena's managers looked for ways to accept what they felt they could not change. They reformulated students' mundane uses of Athena as acceptable as a first stage of involvement with the computer or as one element of a pattern of demand that also included more sophisticated applications. Thus reformulated, mundane computer use was more than tolerable, it was desirable. Widespread faculty disinterest in developing new courseware could be accepted if the metaphor of a thousand flowers were dropped and the focus shifted to the flagship projects. They made peace with the idea that most faculty members who wanted to use computers in their teaching would rely on commercially available software.

At the same time, there was some softening of the policies and practices that had most irritated faculty and students. Proposals that had been rejected because they used computer languages such as BASIC or Logo that were not "Athena-approved" got a second look, and many were now supported as exceptions to a too-strict rule. Athena no longer rejected proposals for support of faculty salaries during the academic year. In response to faculty's irritation with Athena's insistence on separating educational and research uses of the computer and undergraduate from graduate education, Athena announced that some additional workstations would be placed in faculty offices, where graduate students would of course have access to them.

Even in the reticent and bristling Department of Physics, the new accommodations were perceived as soothing. In 1988, the new chair of the Physics Department, Professor Jerome Friedman, remarked at a faculty meeting that "Athena had a learning curve, and I think they have a different policy now which is a much more reasonable one."

There were, of course, limits to how much leeway Athena had for its new policy of accommodation. Budgetary constraints dictated that the "wiring" of faculty offices to enable them to house Athena workstations would go very slowly. The new contract with DEC and IBM would leave little room for educational expenditures, with the result that Athena would devote most of its resources to installing and maintaining equipment and ensuring the smooth operation of the network. Policy reforms, such as the establishment of an educational outreach

group, would be ignored, for the most part, in the practice of Athena's second phase. Nevertheless, certain of Athena's spending priorities did change. Recognizing that faculty and students were upset and genuinely disrupted by Athena's unreliability, Lerman decided in the last days of his tenure as director to concentrate on making the system more reliable and easier to use.

Turning the pejorative distinction between "two classes of people" into a basis for constructive action, Athena's policy makers proposed a new model of Athena as a two-tiered system. Faculty outside the School of Engineering who were interested in computers and education would be brought under Athena's umbrella. They would be accepted as "valuable and legitimate," in the words of the report Lerman wrote for the planning committee.²³ Also, they would receive certain network services. Nevertheless, their interests would be categorized as "lower end," in contrast to the "higher-end" uses of engineering workstations.

In order to make the two-tiered system work, Athena's architects knew they had to address a technical issue that had long been controversial: the question of Athena's operating system. DOS had shown resiliency and commanded faculty loyalty; UNIX had not overtaken it as rapidly as expected, nor had software applications capable of running on UNIX proliferated at the expected rate.²⁴ Moreover, during the early Athena years, the Apple Macintosh had grown in popularity in academic circles. It had become a major environment for commercially available educational software whose importance to MIT faculty Athena had underestimated. Such developments had taken Athena's architects by surprise; they were left with a technically advanced system that could not run most commercially available educational software. To solve this problem they proposed an immediately effective transition phase of operations during which there would be *two* Athena systems. One would be UNIX-based and dedicated to higher-end computing, primarily in the School of Engineering. The second, mainly DOS-based, would include the hardware and software preferred by faculty and students in the other schools. UNIX would be made easier to use, and software for converting DOS to UNIX would be devised.

During the transition phase it was anticipated that the cost of powerful computers would drop so that more MIT students could, perhaps with some subsidy, purchase their own. Within a few years, ownership of individual machines would become close to universal. By the end of the transition phase, Athena would become a complete computer utility—in Professor Dertouzos' words, "a telephone system." It would be physically integrated with MIT's new digital phone system, and anyone

would be able, by plugging into it, to gain access to a range of Athena services, and certainly to the full range of lower-end services.

With their plans for a two-phase approach to a two-tiered system, Athena's designers believed they found a way to preserve the core of their original idea. By giving up what they now saw as the "romantic" extension of a full range of Athena services to all the schools, the "pure" vision of Athena could be frankly reserved for the School of Engineering, as its architects had originally intended. The wishes of the other schools would be respected until new technology or educational priorities led them to catch up.

REFRAMING THE PROBLEM (1989-90)

In June 1988, Steven Lerman resigned as Athena's director and was replaced by Earl Murman, who had been a member of the Athena Executive Committee, chair of the faculty committee that reviewed curriculum proposals for the School of Engineering, and leader of Athena's flagship project in the Department of Aeronautics and Astronautics.

With new management, a new plan of action, and a new contract with DEC and IBM, the Athena system began to flourish in its new direction. By spring 1989, about six thousand different individuals had used Athena at least once, and over 90 percent of all MIT undergraduates used it on a regular basis, most often for word processing, electronic mail, and games. In addition, over fifty MIT subjects made some use of Athena each semester in classroom lectures, demonstrations, or problem sets. In order to handle the rising demand for its services, Athena streamlined its operation. It halved its original goal of two thousand workstations and concentrated on making the network services operate smoothly.

DEC, along with many other companies with UNIX products, had now commercialized several of the main technological developments stimulated by Athena, including the X Windows System and the Kerberos authentication system.²⁵ These and other Athena-based developments were reported to be major sources of new business for the computer industry. Considerable progress had been made toward creating the complete computer utility. It was now possible to use many different machines, including the Mac II, as Athena workstations. Lower-end terminals were installed in Athena clusters to provide for mundane uses. It was now possible to gain access to electronic mail by dialing up Athena through a modem and a dedicated phone line, or by plugging

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into a digital phone on the MIT system. It would soon be possible, via Ethernet hook-ups, for students and faculty to plug into the full range of Athena services, including graphics and X Windows, from remote terminals. Interestingly, one aspect of the complete computer utility has never developed as planned: UNIX has not become easier to use, but rather, in the words of Dertouzos, "has gotten harder and harder to use as its functionality increased. It is now the kitchen sink!"²⁶

All of these successes were advanced by the Athena office as signs of educational success. They were also advanced as surrogates for any more systematic evaluation of Athena's educational impact.

It remained the case that very little new educational software was being developed by MIT faculty. With a few exceptions, mostly in the School of Engineering, emphasis had shifted to the use of such commercially available software packages as matrix-processing systems and spreadsheets. However, from the point of view of Athena's leadership, there was now considerable evidence that MIT's lost leadership in institutional computing had been restored. Thousands of visitors flocked to inspect Athena. Universities around the world monitored its progress, and its architecture and network technology were widely copied not only by universities but by a wide range of commercial enterprises.

During Athena's second phase, the administration established the new Institute Committee on Academic Computation for the 1990s and Beyond, with Dean MacVicar as its chair. Faced with the budgetary implications of a long-term future without external donor support, the administration, in the person of Dean MacVicar, took visible leadership of a group that included representatives of all the schools and of the undergraduate and graduate student populations. Athena's founders were represented by only one individual, Professor Dertouzos.

The committee's attention focused on MIT's total expenditure for computation in research, administration, and education, an expenditure that amounted to some \$20 million in a total institute budget of about \$400 million. Athena's expenditures came to about \$6.2 million, including a yearly contribution of \$2.4 million from MIT's general funds. In the face of such large numbers, MIT faced the future of educational computing as a massive investment decision. The committee reformulated the problem of the future of academic computing in these terms, emphasizing issues of opportunity costs, financing strategies, and fairness.

But the committee could not address these issues without turning, once again, to the problem of assessing Project Athena's educational impact. It discovered, as might be expected, that opinions about

Athena varied dramatically throughout the institute. Now, however, differences of opinion seemed to have crystallized around the schools, whose positions Dean MacVicar described as follows.

The position of the School of Engineering was essentially the position of Athena's founders. For them, retreat from Athena's original vision of MIT in the forefront was unthinkable. Professor Dertouzos, representing this view, believed that Athena should continue to promote educational development projects on state-of-the-art computers, maintaining a single operating system that would support machines from different vendors. It was his conviction that MIT,

as a premier institute of technology . . . could not afford not to pioneer in exploring and using the new information processing technology; it could not afford to sit on its haunches for a decade, only to find out that some other place had successfully mined a major new technology, unless it was prepared to cede its leadership.²⁷

The School of Architecture and Planning, with its computer resources laboratory linked to Athena and developed largely with Athena funds, displayed enthusiasm for MIT's continued support of academic computing. The School of Science retained a slight but significant interest in educational computing, preferring, however, to do its own thing in its own way. The Sloan School of Management, which had never seen Athena as addressing its problems, had developed its own, DOS-based, computing system for research and educational uses; nevertheless, it saw some "cross-platform connectivity and services" as desirable. The School of Humanities and Social Sciences, awakened to the large sums being spent on Athena at a time when it was having to reduce its own faculty, argued that these funds would be better spent on pressing needs such as faculty salaries and research support.

In the face of the conflicting views of the schools, the committee made further inquiries into Athena's effects on education. Although they recognized that Athena had "supported a large number of educational experiments some of which had won national or international awards and otherwise contributed to education," their endorsement of Athena as an educational experiment was ambivalent.²⁸

In the end, they produced a carefully qualified endorsement of Athena, noting that the experimental program had taken many risks, succeeding in some respects and failing in others. They firmly endorsed the continued pursuit of MIT's leadership in academic computing, arguing, just as Dertouzos had, that MIT would be relegated to also-ran status if it permitted an erosion of its academic computing resources, educational initiatives, and leading-edge technical capabili-

ries. In taking this position, the committee was resisting any pressure to undermine what had become an externally valued MIT resource. Project Athena now existed as a widely admired and imitated institutional computer system; the School of Engineering identified this leadership position with its own prestige, and MIT identified its prestige with the School of Engineering.

But since several of MIT's schools either had no interest in educational computing or had developed their own systems outside of Athena, these developments had to be reconciled with a decision to invest in MIT's continued development of an Athenalike system. To do this, the committee invented yet another version of the two-tiered system. It introduced as its principal educational strategy the idea of Basic Educational Services and Tools: services of broad interest to all parts of MIT, including electronic mail, an on-line teaching assistant service that could be used in any course, a computerized course catalog and registration service, and electronic access to scholarly databases at MIT and elsewhere. "Coherence" would be redefined to mean that users could gain access to Basic Educational Services and Tools not only through UNIX-based machines but through machines using DOS or Macintosh operating systems. In addition, in a section of its report that reflected the voice of Athena's challengers, the committee proposed that MIT support carefully targeted educational development projects in the computer environments favored by various schools or departments, "nourishing diversity . . . not only in content but in the form and feeling of computer use."²⁹

Along with these recommendations, the committee recognized that the School of Engineering would continue, with funds it raised for itself, to pursue the original Athena model; it would develop state-of-the-art educational computing in a UNIX-based system that preserved coherence in Athena's original sense of the term. Implicitly, the committee seemed to be saying that the institute's priority of maintaining technological leadership would be justified by providing universal access to Basic Educational Services and Tools. In effect, the committee redefined "fairness" in educational computing. Provost Low's standard of fairness, aimed at avoiding a division between computer haves and have-nots, had led to treating Athena as a uniform good, making no distinction between types of uses or users. To the MacVicar Committee, "fairness" now meant universal access to a basic level of computer services that everyone in the MIT community could find useful.

The committee was careful to state that if budgetary choices had to be made, priority should go to these basic services. It estimated that the incremental costs of academic computing would range from a floor

of about \$6 million to a ceiling of about \$12 million per year. The higher end of the range, which would maintain MIT's leadership position, would cover both the support of basic educational services and diverse educational development projects; the lower would cover basic services alone. As of this writing, in a climate of increasing fiscal austerity, a newly appointed president and provost of MIT have decided to continue MIT's support of Athena at a level below the committee's floor, sufficient only to maintain the basic network.

CONCLUSION

THE POLICY CONVERSATION

One of the most striking features of the story of Project Athena is the disjunction between the original intentions of its designing system and the meanings constructed for Athena in the context of its use. In contrast to the engineer-architects' expectations that Athena would be used for technically sophisticated and educationally innovative purposes, students used Athena mostly for such "mundane" purposes as electronic mail, word processing, and electronic games. Faculty, who were intended to see Athena as a liberating opportunity, often ignored it or found its coherent system an impediment to their preferred approaches to educational computing. The faculty champions of educational computing came to see Athena a trap for their younger protégés. Science faculty, who tended to see the computer only as a research tool, read Athena as an attempt by engineers to usurp control of the science curriculum. Perhaps most shocking to Athena's designers was that what they had conceived as a grand experiment in undergraduate education should be widely seen as a technological enterprise that was not about education at all.

These discrepancies between the original intentions of policy designers and the meanings constructed for a policy object in use are central to the idea of a "policy conversation." This term does not refer to a literal conversation; it is not a verbal interchange among individuals in a policy forum, which we call "policy discourse." Policy conversation is a metaphor for policy design seen as communicative interaction between designers and those who use or have a stake in the policy object. A policy object sent out into its larger environment functions as a message. Other actors in the environment who come into contact with that object must somehow make sense of it and figure out how to respond to it. The message of the policy object is not objectively contained in the

thing itself, nor is it directly transmitted from the mind of the designer to the mind of the user.³⁰ Users and other stakeholders *construct* the meaning of the policy object. They in turn send messages back to the designing system by the ways they interpret, use, or otherwise respond to the deployed object. The exchange of verbal and/or action messages between designers and users of a policy object is central to the design process. Its quality is critical to design rationality.

As in literal conversations, the meanings intended by "speakers" in a policy conversation may be very different from the meanings constructed by "hearers." The intended users of a policy object may not "get" the meanings intended by the designers, and even when they do, they may prefer the meanings they themselves construct. So, in the early retirement case described in the previous chapter, the firms interpreted the state's 59er rule, which was originally intended to smooth the way for returning veterans, as a splendid way to gain state subsidy for the restructuring of their work force in response to the pressures of international competition. Similarly, in the Athena case we have observed that students who received Athena interpreted it as, among other things, a word-processing tool (though, in their view, a cumbersome and unsatisfactory one) for which they felt an urgent need, and they proceeded to use the system in that way. When Athena's designers first became aware of this pattern of utilization, they read its meaning in their own terms: not as information about the computer uses that were of most immediate interest to students, but as a perversion of their vision, a mundane use of the technically sophisticated system for which the designers held such high hopes. Similarly, many faculty members, especially in the School of Science, read the strictures of Athena's coherent system as an attempt to deprive them of their favored computers, languages, and applications as well as an affront to their intellectual and administrative autonomy as MIT faculty. Athena's designers initially read the scientists' angry reactions and subsequent avoidance of Athena not as a message about their preferences but as evidence of their failure to appreciate the beauty of the Athena idea.

We use the term "back talk" to refer to messages sent back to policy designers that surprise them by violating their taken-for-granted assumptions and tacit "action frames," telling them, in effect, that the policy object as perceived and used by other actors is different from the one they intended to design and deploy. Actors in a policy arena can listen, interpret, and respond to such back talk in many different ways. How they do so determines much about the reliability of a policy conversation—that is, the extent to which participants in the conversation

reliably grasp the meanings intended by message givers and message receivers. In a policy conversation, as in a literal one, reliability of communication is distinct from the degree to which speakers and hearers agree with each other. The outcome of reliable communication is not necessarily a settlement of disputes; indeed, the better the participants understand one another, the more they may become aware of the depth of their disagreement. But reliable communication is a critical condition for the further inquiry that may result in acceptable policy adjustments, or even in pragmatic resolution of policy controversies.

At first, Athena's engineer-architects were inattentive to the back talk they received, denied it, or treated it as a failure of Athena's student and faculty users to appreciate or understand their work. But by 1987, after the PASG report had been submitted and MacVicar had communicated the results of her private inquiry, Athena's engineer-architects began to listen in a new way. Realizing that Athena had created an angry and explosive climate that threatened the very survival of the project, they adjusted their policies to accommodate the negative messages coming back from the field.

ATHENA'S POLICY ADJUSTMENTS

Once policy designers become aware of a discrepancy between the meanings they intend for their policy object and the meanings actually constructed by its users, they must set about dealing with the discrepancy. They have three options for how to do so. They can accept the object as defined by its users and abandon their original intentions for it. They can try to force the users to accept the object as they originally saw and wished it to be. Or they can try to modify the object, adjusting their policies in such a way as to make the object acceptable both to themselves and its users. These options are best seen as continuations of the design process; they carry new messages that once again are open to interpretation and response, and the choice among them is central to the character of the continuing policy conversation.

The choice of policy adjustments faced by the Athena architects may also be conceptualized as a choice between marketing, negotiation, and co-design.

- 1) In *marketing* the policy designers treat the policy object as a product and other actors in the environment as a market for that product. They design with a model of the users in mind. But when the users express dissatisfaction with the product, or reject it—"exiting," as Albert Hirschman would say³¹—the designers

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try to reshape the object in order to give it greater market appeal.

2) In *negotiation* designers and other stakeholders make competing claims on the policy object. When actors are dissatisfied with the degree to which their claims are met, they "give voice"—as Hirschman, again, would say³²—to their dissatisfaction. In this case, the designers treat the expression of dissatisfaction as the sign of a political dispute, which they try to settle by negotiation with the aggrieved parties, giving and getting concessions in order to secure a satisfactory compromise.

3) In *co-design* the expression of dissatisfaction is taken as an occasion for cooperative redesign of the policy object. The designers seek to involve users and/or other actors in a collaborative design process, in which all parties accept one another as legitimate contributors to the shared design task.

In practice, of course, these three ideal types blend into one another. A negotiation may include periods of co-design, for example; conversely, co-design may give rise to disputes that call for negotiation. Or, as in the Athena story, policy designers may adopt different strategies of adjustment at different stages of the design process.

In Part 3 of our Athena story, Athena's designers read student and faculty back talk as a market signal that could have serious political consequences. They neither negotiated with their challengers and resisters nor engaged them in co-design. Their invention of the two-tiered system was a marketing strategy intended to neutralize the political threat to Athena's continued existence.

In Part 4 of our story, Athena's policy was reframed. This time, however, the MIT administration, aware of the long-term budgetary implications of an Athena without external funding, took a much more visible role in determining Athena's future. MIT's budgetary constraints were central to the dilemma that triggered the new round of policy adjustment. On the one hand, the MacVicar Committee accepted the position of Professor Dertouzos and the School of Engineering that MIT's leadership in academic computing must be sustained. On the other hand, the committee realized that this acceptance carried a high opportunity cost that would be especially painful for the other schools. In response to these conflicting imperatives, the committee adopted an approach to policy adjustment that combined negotiation and co-design, hammering out a new version of a two-tiered Athena system that focused on providing basic educational services for the MIT community as a whole.

Parts 3 and 4 are two distinct policy windows. In these key moments

in the formulation of policy, we observe Athena's designers and administrators listening and accommodating to back talk that disconfirmed their expectations and revealed views that conflicted starkly with their own. In these windows we are able to observe policy adjustments that were in fact continuing the policy design conversation that had been under way for the better part of a decade. These adjustments followed a pattern of least change. The policy makers called a halt to their inquiries about Athena-in-use when they found what seemed like a workable accommodation that would enable Athena to proceed. Nevertheless, these successive, least-change adjustments did embody some institutional learning, did effect a pragmatic resolution of the controversies, and did result in an Athena system that could be declared, in several respects—widespread utilization by students and faculty, technological advance, commercial exploitation, international visibility—a success.

FRAME-CONSERVATISM

Throughout the first turbulent ten years of Athena's existence, the cultural frames held by Athena's founders, challengers, and resisters remained remarkably constant. At the end of the period, these frames were essentially what they had been at the beginning.³³

At a deeper level, then, the Athena story turns on a conflict of these frames, which correspond to two conflicting views of Athena's identity: a quest to regain MIT's lost technological leadership in institutional computing or an experiment in undergraduate education. This conflict first appeared in the early Athena debates, then, as Athena's difficulties began to surface, in the differing views held by Athena's protagonists and critics about how to interpret the flaws in its design, and, finally, at the end of our story, in the schools' divergent attitudes toward academic computing.

But although a significant number of Athena's observers, participants, and critics talked about this conflict from the earliest days, it was not obvious to Athena's designers. On the other side, Athena's challengers were not generally able to appreciate the importance of an advanced and coherent institutional network—what Athena's architects saw as its central idea. Or, when the challengers saw it, they did not grant it pride of place as an educational necessity.

Whether or not one sees Athena as having an identity conflict is largely dependent on whether or not one has faith that the world's front-running distributed computing system will yield, as an inevitable or likely consequence, positive educational change. This faith is of

course a particular version of a more general belief that technological advances will inevitably have positive social consequences.

Athena's founders and champions had this faith. It justified their model of educational reform, and it underlay their belief that once the Athena network was in place a thousand flowers of educational software would be elicited and naturally selected in the traditional MIT way. The design problem as they framed it was to make their technical vision into a reality so that the desired educational consequences would follow. Even if they could not predict these consequences, they saw no reason to believe in a method that put desired effects first. For example, in a reaction to an earlier draft of this chapter, Professor Dertouzos wrote:

At the bottom of this whole discussion lies, in my view, the basic question of how progress is achieved. There is hardly a person around that can accurately assess the societal benefits of television, synthetic drugs, radar, even gunpowder, decades or centuries after their introduction. Yet you seem to call for assessing the impact of a new technology *before* it is deployed, and accurately enough to guide its deployment. *Has this approach succeeded anywhere in the history of science and technology?*

In the end, it was the architect-designers' persistence in seeing their policy object through the lens of *their* intentions that provoked Athena's crisis of survival. Up to the point of this crisis the designers did not ask "What does Athena mean to its users?" but only "Did it work as we planned?" Policy intentions were taken as surrogates for outcomes on matters as small as Athena's support of faculty salaries and as large as the educational emphasis of the entire experiment. When the back talk was finally noticed, it was read as criticism of the designers' intentions for Athena rather than as manifestations of genuine pluralism within MIT as a social and cultural world. In all of these respects, the story of Athena illustrates a nonreflective policy conversation.

Athena's critics and skeptics lacked the implicit faith that social good would follow technical progress. Even as they became more diplomatic in their language—for example, when they worked on cooperative efforts to shape future MIT policy—the outlines of their differences with Athena's founders and champions remained clear.

Not surprisingly, the fundamental frame conflict persists at MIT. Protagonists and defenders continue to advocate and defend. Skeptics and resisters remain skeptical and resistant. Some of the challengers may have tried to promote a frame-reflective dialogue; if they did, it is

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clear that they did not succeed. Perhaps, as Professor Deutch seems to have believed, frame-reflection would have been incompatible with the visionary enthusiasm of Athena's champions. It is important to note that, had the founders not held to their faith—had they suggested, for example, that a coherent system might not work educationally in an institution that contained diverse computer cultures, or that technological instability might be incompatible with educational innovation—they might not have been able to strike the bargain with Athena's corporate donors.

The dividing line around which Athena polarized MIT is, of course, by no means unique to MIT. Rather, MIT mirrors a conflict of cultural metaframes in our society as a whole. But at MIT this larger social conflict takes on the character of a split between true believers and heretical doubters of a fundamental tenet in what amounts to an institutional religion about the role of technology in society. The Athena story, which exhibits the tenacity of these conflicting metaframes, reveals more about what MIT *is* than how it has changed.