School of Engineering

Massachusetts Institute of Technology
ENGINEERING WITH A BIG E: INTEGRATIVE EDUCATION IN ENGINEERING


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Introduction

This is the third long range plan for MIT's School of Engineering. The first plan was written in 1983 and led to Project Athena, MIT's $100 million program in computers and education, funded largely by DEC and IBM. The second plan, written in 1989, led to the concept of virtual centers and recognition of the need for education and research on large scale (engineering) systems.

This present plan was drawn up in response to fundamental changes which engineering schools are encountering. Rather than follow the traditional outline of a long-range plan (mission statement, vision, strategy, implementation plans), we chose to concentrate on the vision—a vision of engineering education and research that is so different from that of the past fifty years that it merits the major focus.

After describing our view of the world into which we are moving, and the many names that have been coined to describe the response of engineering schools, we deal briefly with the process we followed to arrive at the conclusions summarized here. Then we discuss our response and how we expect to implement it in terms of undergraduate education, graduate education and research. The final section of the paper deals with some general concerns and some observations in closing.

I. The Vision

"May you live in interesting times" says the ancient Chinese curse. We are certainly experiencing interesting times in engineering education, not because we are cursed, but because of forces for change which affect our entire global society. The end of the Cold War, shifts in government spending patterns; the domestic economy and related changes in organization, staffing and approach taken in American industry; and similar changes world-wide are all a part of the story. As a result, engineering schools and, more generally, all research universities are facing profound adjustments of a magnitude not seen since the 1940's when the sea-change brought about by World War II led to the Engineering Science movement.

At that time, engineers at MIT's Radiation Laboratory (for example) recognized that scientists and mathematicians were better prepared to cope with the technical challenges of new technologies, such as radar, than were they. Vannevar Bush, MIT's first Dean of Engineering, was in charge of all the research activities during the war. His post-war writings emphasized the role of science, and led to the creation of the National Science Foundation. As a result of his work and the Engineering Science movement it fostered, there was between 1945 and 1968 a major increase in the time an undergraduate engineering student spent on basic science and mathematics. There also was a concomitant decrease in the amount of time students spent on laboratory work and relatively specialized professional education. To say that the approach was fruitful is to commit an understatement of truly global proportions. The successful effort to put humans in space, as well as the enormous strides in electronics, telecommunications and computers, are some of the better-known products of the strongly science-based engineering of the last forty to fifty years.

In Engineering Science one is given well-defined technical specifications, and uses basic engineering and science principles to produce a result. This result will be the same regardless of the context in which it is done. The results of a fundamental investigation in fuel combustion chemistry, for example, do not vary depending on who is asking the questions. The sea-change we are now undergoing comes from an understanding that the practice of engineering is to a greater and greater degree not context-free. To continue the example, the combustion products of interest depend less and less on their intrinsic or theoretical significance and more and more on their role in the environment and their associated regulatory significance.
Education and research activities will have to be modified in a fundamental way to accommodate these changes. While we surely do not envision the elimination of the context-free view (much less the elimination of Engineering Science!), we do wish to emphasize the addition of some contextual influence on the process and the end-result of engineering calculations and designs. By context we mean to include the business and organizational context, the needs and desires of customers, and the social, political, economic, environmental and cultural context of the task.

If we as engineers and engineering educators do not take these critical considerations into account, others will do it for us, in the process defining a distinctly subordinate role for engineers. If we want our graduates to be leaders in the process of applying the promise of technology to today's problems and challenges, we need to undertake some fundamental shifts.

Such a context-sensitive view of the nature of engineering leads to an emphasis on areas that were paid relatively little attention in engineering curricula as recently as a decade ago. These include manufacturing, design, engineering management, and the environment. Since we do not see a major reduction in the emphasis on basic science, mathematics and engineering science content, and especially since we have not discovered a more efficient way to present all this material, there is a need for additional time, not only in first professional degree programs, but also in subsequent educational programs for practicing engineers.

The context-sensitive view we espouse returns us to a view of engineering similar in some ways to that held prior to World War II. Application of handbook formulas dominated the practice of engineering in that era, an approach which was supplanted by the Engineering Science movement with its emphasis on the application of principles. Engineers, prior to the war, made up in breadth what they lacked in depth. We are deeper on the fundamentals now, at the expense of some loss in perspective. Prior to World War II engineering faculties had very close relationships to industry and to the practice of engineering. These were partially lost during the Engineering Science era and need to be regained. Undergraduate engineering education as well as Masters programs in the pre-war era were clearly largely intended to educate students for the practice of engineering, rather than to provide entrees to doctoral research programs as was often the case during the Engineering Science era. Freshman engineering students tended to bring with them an unusual amount of hands-on experience with equipment, such as ham radios or automobiles. This experience has been increasingly lost in the past few decades (with the cardinal exception of students' experience with the digital computer!). This change in the students coming to us needs to be addressed in colleges and universities at the present time.

We searched for a long time for a phrase that properly characterizes the approach to engineering education and research that we envision. For a time we called it Post-modern Engineering, following the analysis of Professor Thomas Hughes of the University of Pennsylvania, the dean of American historians of technology. In this view Engineering Science is Modern Engineering, and Post-modern Engineering is a reaction to it, similar to the reaction of Post-modern Architecture to the Bauhaus movement and its stark lines. While the envisioned approach is indeed a reaction, it differs from Post-modern Architecture in that it builds on the past, rather than simply rebelling against it. For a while, we called the new approach Context-sensitive Engineering, a more commonly understandable name, which suffers somewhat from the implication (erroneous) that we expect future engineers will bias their answers to suit the desires of their customers or employers.

Norman R. Augustine, Chairman and CEO of Martin Marietta Corporation, uses the term "socioengineering" in his challenge to engineering educators, issued at the University of Colorado Engineering Centennial Convocation. [1] His list of crucial ingredients of an engineering education for our time includes an emphasis on systems engineering and a requirement of five or even six years' study to qualify for a first professional engineering degree. We will discuss each of these points below.

MIT President Charles Vest used the word "integrative" when he described our new approach as "Integrative Education in Engineering" in his "Report of the President for the Academic Year 1992-1993". [2] He noted the need for more exposure of students to the analysis and management of large scale, complex systems. This means not only integration of the involved technical disciplines, but also "an increased understanding of the larger economic, social and political and technical system
within which scientific principles and engineering analysis and synthesis operate in order to create technological change.” Integrative is also the key word in a recent article by J. Bordogna et al; their vision of engineering education for the 21st century is based on the concept that “the engineer’s essential role in organized society is an integrative one” in that the engineer’s task is “construction of the whole”. [3]

Professor Richard Lester, who heads our Industrial Performance Center, suggested “interpretive engineering” to emphasize that the process of taking into account contextual influences is not simply one of adding additional considerations that operate in the same way as the conventional in guiding us to design solutions. “Interpretive engineering” suggests, he feels, the interaction between the various influences which take place along the way to arriving iteratively at a true context-sensitive solution.

With due respect to these descriptive terms, we have adopted, in a slightly lighter-hearted vein, the phrase “Engineering with a Big E”. It was suggested by Professor Earl Murman as a pun on the phrase, “Manufacturing with a big M” used in the Leaders for Manufacturing (LFM) Program, operated jointly by the School of Engineering and the Sloan School. It denotes a view of manufacturing that encompasses a much larger context than is traditionally viewed as manufacturing, including design, marketing, and in fact much of the rest of the industrial enterprise. “Engineering with a Big E” is thus intended to imply that an engineer needs to be concerned with a variety of larger contexts, e.g. the firm he or she works for; the customers of

that firm, public policy, the environment, etc. As noted above, engineering faculties immediately prior to World War II had a Big E understanding of the nature of engineering because they were much closer to the practice of engineering than engineering faculties of later decades. Implicit in the term Engineering with a Big E is a return to a greater emphasis on education for engineering practice as opposed to the relatively research-dominated view taken by Engineering Science.

The prevalence of so many terms to describe the changes in engineering education does not imply to us a fundamental disagreement over the nature of the change. Rather, it confirms the magnitude of the change that engineering needs to undergo.

II. The Process

We began the process of formulating a long range plan by creating three committees within the School. One, under the chairmanship of Professor Michael Dertouzos, Director of the Laboratory for Computer Science, dealt with changes in the School’s relationships with industry. The second, under the chairmanship of Associate Dean John Vander Sande, dealt with undergraduate education and First Professional Degree programs. The last, under the chairmanship of Professor Earl Murman, head of our Department of Aeronautics and Astronautics, dealt with aspects of graduate education that we now call Second Professional Degree Programs. Reports from each of these committees [4,5,6] were sent to approximately forty MIT faculty members, largely the members of the three committees. The committee members included all heads of departments and directors of research centers and laboratories within the School. A three day retreat was then held in June, 1993 to discuss the reports and related issues. Remarkably there was clear general agreement regarding the need for major changes in how we approach engineering education and research.

Further discussions related to aspects of the new vision took place during the Fall of 1993. The Sloan School of Management faculty, under the leadership of Dean Glen Urban, agreed to work with the School of Engineering on a joint Second Professional Degree Program. In a separate but related action, President Charles Vest appointed an Institute-wide Task Force on new relations with industry, chaired by Professor Merton Flemings, head of our Department of Materials Science and Engineering. This Task Force has four members who participated in similar discussions in the Dertouzos Committee noted above. Finally, the School’s Education Committee, chaired by Professor Vander Sande, has continued its discussions of First Professional Degree education.

This essay is a synthesis of all these discussions. It summarizes the current state of the response we are developing to the “interesting times” that we face. This response is three-fold, and deals with undergraduate and First Professional Degree education, with graduate education and with research, the traditional concerns of an engineering school.
III. First Professional Degree Programs

The discussions that led the Electrical Engineering and Computer Science Department (EECS) at MIT to its present Five Year First Professional Degree Program started in 1985. The concern then was an Engineering Science-based concern, namely, that there was insufficient time in four years of undergraduate engineering education to cover all the technical material that a practicing engineer should know. Thus much of the discussion went under the banner "Four Years Are Not Enough."

Two important insights emerged from that set of discussions. The first, noted by Professor William Siebert, was that our seventy-five-year-old cooperative education program in electrical engineering and computer science satisfied many of our goals. This program leads to the award of an SB as well as an SM degree in five years. In effect, it was proposed that nearly all of our EECS undergraduates become co-ops, with some doing the SM thesis at a company site under faculty supervision, and some doing a comparable thesis on campus.

The nature of the SM thesis that co-op students complete was an important related issue. Under the Engineering Science approach, the usual on-campus SM thesis at MIT changed radically. A thesis that could formerly be completed in approximately one half of one semester in the 1950’s became a research project that averaged nearly two years in most departments in the School, and averaged three years in Computer Science. During the same forty year period the length of time required to complete a co-op thesis changed hardly at all. Many of us have long felt that the vast majority of our S.M. students (those who graduate and go on to work in industry or the public sector immediately thereafter), do not gain sufficiently from the research experience to justify its present length. By considering most of our undergraduates to be co-ops in essence, we could deal with this long-standing issue of the length of the SM program at the same time that we deal with other curricular concerns.

Another insight that arose out of discussions in EECS was the realization that one could restructure the undergraduate program in a more flexible manner. At MIT, nearly all freshmen take the same subjects emphasizing mathematics, science and humanities and social science. Certain engineering departments, EECS and Aeronautics and Astronautics in particular, have developed a common core of sophomore subjects that all their majors must take. Beyond this core students have some flexibility. The realization was that one can create several sequences, each consisting of three or four subjects, at the junior, senior and first year graduate level. Students can then choose the sequences they wish to take. This approach permits EECS undergraduates, for the first time, to major in EE or CS or even a mixture of the two, depending on the sequences they choose. In fact, it is now possible, in principle, to mix EECS sequences with sequences from other departments, for example a control sequence from Mechanical Engineering. Moreover, students who wish to leave with an accredited SB degree can simply choose not to take the graduate level components of the sequences in their program and still have a coherent program of a preprofessional nature. Such a four-year program would be excellent preparation for the professional schools, such as medical schools, as well as an entree to pre-professional engineering positions in industry or government. We believe that an undergraduate engineering education is destined to become a full-fledged alternative to a liberal arts education in the 21st century.

The complete redesign of the Electrical Engineering and Computer Science Department First Professional Degree program was led by Professor Paul Penfield, head of the department; the new program is now in its second year of operation. Its implementation necessitated the creation of a new Master's level degree, called the Master of Engineering (M. Eng.). The research-oriented SM degree is still available in EECS for students coming in with undergraduate degrees from other institutions. Other departments in the School will use the M. Eng. degree, but with variations on the approach. In particular, the Aeronautics and Astronautics Department will offer a year-long integrative design experience during the fifth year (first graduate year) of its program. [7] We also anticipate that the Civil and Environmental Engineering, Mechanical Engineering, Nuclear Engineering, and Ocean Engineering Departments will adopt the M. Eng. concept or the sequence approach to restructuring the undergraduate program in the next few years.

We note that Carnegie Mellon University’s electrical and computer engineering department has embarked on a similar structure
using sequences for its four year bachelors program. They are considering expanding the approach to a five year program as proposed here.[8]

Student financial support for the fifth (first graduate) year of M. Eng. programs is likely to take quite a different form from that typical of SM programs. Students in our traditional SM programs expect to receive support through research and teaching assistantships available from MIT as well as through fellowships, often garnered by the students from outside organizations. The research and teaching assistantship route is not likely to be available to most M. Eng. students. An expansion of the Engineering Internship Program and an increase in the number of other co-op assignments in industry appears to be the most promising support mechanism.

Although the five year programs were initially designed for Engineering Science-based reasons, they naturally satisfy many of the needs of Engineering with a Big E. For example, the Aero/Astro year-long design subject will give students experiences close to the current practice of engineering. The added year in the five year programs gives the students additional time that can be spent taking professionally oriented subjects that broaden their perspective, such as subjects in technology and policy or the environment.

For example, we are experimenting this semester with a new course offering, "Strategic Analysis for Environmental Planning and Design", which seeks to engage students in the study of complex technical systems which must perform well in a social context.

The example chosen is the problem of creating and implementing a policy which is both effective and achievable for dealing with air pollution in the Los Angeles region. Professor Michael Golay is coordinating the efforts of a diverse team of faculty members drawn from six of the eight Engineering departments as well as the School of Humanities and Social Science and the Department of Urban Studies and Planning. The goal is not simply to come up with a technical solution to control emissions, but to develop a policy which is consistent with the social, economic, political and historical context of the region.

Perhaps the major impact of the new programs is that they will have a clear emphasis on preparing students whose aim is the practice of engineering, as distinguished from others whose aim is to continue on for the Ph.D. and thereafter seek careers in engineering research.

But whether the student is focused on a four-year experience leading on to graduate work in another field (e.g., law or medicine), the M.Eng. degree, or a research-oriented SM or Ph.D. degree, we owe him or her an undergraduate engineering education which is honest about the complexities and uncertainties of engineering as it is practiced.

The earlier-noted lack of hands-on experience of our entering students is a related—and major—issue in undergraduate engineering education. My predecessor as dean, Gerald Wilson, undertook a re-examination of hands-on activities for our undergraduates. Professor Penfield and Professor J. Kim Vandiver began using the laboratory of the late Professor Harold Edgerton for teaching freshman seminars that involve a variety of design and project experiences. Fortunately, the Edgerton Foundation has provided for an endowment to fund much of this effort. The School’s Education Committee is now engaged in discussions of a possible school-wide “design-build-operate” requirement of sufficient depth and duration to provide hands-on experience in relating theory to practice, to require teamwork and working with others under conditions of ambiguity and uncertainty, and to introduce students to the design process and the nature of engineering practice. This renewed emphasis on hands-on experience is an important component of Engineering with a Big E.

We are also considering the development of a new subject, “The Nature of Engineering.” This subject is aimed at introducing students to the essence and framework of engineering inquiry; synthesis, construction and control of physical systems. One possible way of offering this material is through small freshman seminars, with each faculty member tailoring the discussion to his or her field of specialty.

IV.
Second Professional Degree Programs

With the rise in importance of research after World War II, the SM degree at MIT, as noted earlier, became a research degree usually resulting in a publishable paper. This confusion of the role of the SM with that of the Ph.D. has
been a boon for faculty research, but also led to the aforementioned increase in the duration of on-campus SM programs. The emphasis on research in graduate engineering education points to a fundamental problem: engineering schools have largely ignored the career needs of their graduates in industry. They have left it to business schools to provide the major mid-career boost for those destined for leadership. While engineers moving up the ranks in engineering management do need business-related education, gaining an MBA not surprisingly tends to reorient them toward professional management. They may turn away from technical involvement and in the process become poor managers of engineering.

While there are several periods in the life of a working engineer or engineering manager where additional education would be beneficial, the Second Professional Degree Programs (SPDs) described below are aimed at engineering graduates who have worked in industry for about five years, and are about to embark on careers that are different from those of ‘bench’ engineers whose orientation is more technical. These careers and their respective programs usually have a management component. "Pure" management education, as noted, is not the answer, at least in many cases. Engineering-oriented management is required; engineering schools need to recognize its value and significance, and thus meet the needs of engineers in industry. The program we are especially interested in involves the management of the design of large systems, such as planes, cars and telecommunications software. As engineering faculty are beginning to understand, the product design and development process is closely related to the fundamental restructuring going on in business today, most prominently the flatter organization structure.

MIT offers a number of successful SPD programs, including (for example) the Technology and Policy Program, the Management of Technology Program, the Construction Engineering and Management Program, and the graduate programs of the Center for Transportation Studies. The most recent and successful of these, the Leaders for Manufacturing Program (LFM), is jointly sponsored by the School of Engineering and the Sloan School of Management. Students earn an SM in some engineering field and an SM in management in a two-year, full-time program.

Industry leaders we have consulted believe that candidate students for the Second Professional Degree program we envision in large-scale design will not be able to spend as much as two years away from their jobs. They are sufficiently mature and valuable to their companies that both they and the firms will be seeking an arrangement whereby they can continue to contribute while enrolled in their course of study. Nor is it necessary that the course of study include the full complement of management subjects at this stage in their careers.

We have identified two major differences between the proposed SPD program and LFM. One is that the emphasis in the new program is on issues such as product development, systems engineering, and software architecture. It is interesting to note that different fields of engineering have developed different terms for what is basically a similar set of concepts and processes. In the aerospace industry the term systems engineering embraces many of the same issues that the automobile manufacturers refer to as product development and those in the telecommunications software industry call software architecture. Certainly there are differences among these three terms, but their commonality shows, we claim, that there is a need in industry that is unmet by universities which have not yet abstracted the common notions.

The second major difference between LFM and the proposed SPD program is that an important mode of delivery of the new program will be TV, either live or on tape. Taped versions would enable teaching subjects using, for example, the Tutored Video Instruction mode popularized at Stanford University. In this mode a group of students and a tutor (usually a former student working at the company) watch a taped lecture. The tutor stops the tape whenever a question is raised and the entire class tries to answer it. This interactive mode can have very beneficial results. Our Center for Advanced Engineering Studies has developed and applied a variety of video techniques over the past 26 years, which positions us well to build on this experience in planning and developing for remote delivery of SPD instruction.

We envision that students will begin their experience with one semester (summer, fall or spring) on-campus. This will help create a cohort of students with relatively similar experiences, albeit in somewhat different industries. Another fifteen to eighteen months will be spent at a company site, taking subjects remotely and
working on a project under the joint supervision of a company mentor and a faculty member. The students will probably return to the campus for short periods of time, and the faculty will visit them at their companies at least as often as they now do with co-op students.

We believe that by working together with the Sloan School we can create a joint program that will lead the nation in large scale design the same way that LFM has led in manufacturing. The proposed program will build on subjects developed for the LFM. The Sloan School has identified this proposed joint program as a major new initiative in its Five Year Plan. Professor John D. C. Little and I are chairing a joint committee to explore and further develop the proposed Second Professional Degree Program.

V. Relations with Industry

A major corollary to the Engineering Science movement was the development of a relationship between engineering schools and the Federal government that is far deeper than that which existed prior to World War II. The Federal government in the first two decades after the war supported engineering research not just because of the needs of the military, but also for the general welfare, based in part on the arguments of Vannevar Bush. The School's faculty and staff presently have a total research volume of about $150 million, but industrial support is approximately a quarter of this amount. While both numbers are large, this is of little comfort since neither the Federal support or the usual industrial support are likely to grow with inflation, and may in fact decline over the coming years, although for different reasons.

While research universities are undergoing profound changes in their relations with the Federal government, the changes in industrial research laboratories may be even greater. Time has become a greater constraint than ever before, and the ability of central research laboratories to help a company produce new products or processes quickly is coming into question. Industry is also undergoing a profound change in its approach to management, with increased emphasis on cooperation and teamwork. These changes have led to significant downsizing of central research laboratories, and the creation of cross-functional product development teams. In such teams researchers work closely with product developers, marketers and others. Not only do these teams create structural changes, but they also make necessary a cultural shift. Members of central research laboratories tended not to trust engineers in development divisions, and vice versa. Bringing people closer together is a necessary condition for trust. And increased trust is necessary for successful technology transfer.

Some people believe that the decline of the central research laboratories will lead to increased funding for research in universities. They argue that industry's current tendency is to outsource activities they no longer can support in-house, and that this presents an opportunity for universities. Such a shift in funding may indeed occur in some companies for a period of time, but it is not likely to be sustained. The same dynamics that have led to the decline of the central research laboratories will probably lead companies to conclude in similar fashion that university-based research is no more likely to yield marketable products. Only if we know how to be team members — insiders in the new approach — can we expect to maintain and build our base of industry research funding. It is also vital in terms of creating the experiences for our students which will best prepare them for the years ahead.

The process of technology transfer is at the heart of the matter. American industry will surely decline if we do not respond to global challenge and speed up the R&D process. Many have noted that students are the universities' ultimate technology transfer mechanism. Unfortunately, the process by which we train students is relatively slow. Moreover, unless academia keeps abreast of the issues most important to industry further delay will be inserted into the technology transfer process because the education of the students will not be well matched to current needs.

There are two classic mechanisms by which faculty and students have kept abreast of these industrial needs. Co-operative programs are one such mechanism, as we have mentioned several times. The other is faculty consulting. The weakness of both of these approaches is that they usually involve only one person at a time, are often narrowly focused, and are also not usually an integral part of the education and research programs of engineering schools. What we believe is necessary in the future, for the health of both industry and academia, is closer cooperation.
between faculty members and their students with teams of developers, marketers and manufacturing engineers from industry. In particular, it is important for universities to begin working on problems that are critical to the success of their industrial partners.

Historically, universities could not be relied on to work on industrial problems of critical importance. One key issue is the problem of time. University research takes a relatively long time, often because the focus is on education. This issue will surely remain, but we need to be constantly mindful of it. Indeed, part of Engineering with a big E is teaching our students to appreciate the need for accurate work under severe time constraints, for they will surely be challenged to provide it as soon as they leave the university and take their places on industrial project teams.

Another issue is that critical industrial projects often involve company confidential information. Our engineering faculty and students have dealt with company confidential information for decades in consulting and co-op activities. In addition, it is not unprecedented for universities to delay publication of papers and theses for some months in order to allow sponsors to purge those documents of company confidential information. In most such cases, the work has been done at the company site, i.e., off-campus. It is likely that the new mode of interaction that we suggest will also involve off-campus interactions, but possibly in university-sponsored development parks.

A related concern of industry is that universities have for at least a decade tended to retain title to university-generated intellectual property and grant a license to an industrial firm even if the effort was solely sponsored by that firm. A major argument for this is the need to keep ‘march-in’ rights that permit the university to give the license to someone else if the first licensee does not perform sufficiently well. This may work acceptably on peripheral matters, but it is not likely that companies would permit universities to keep title to work that is of critical importance to them.

We are pleased to say that the MIT administration is aware of the need to explore new ways of working with industry. Arrangements are under consideration whereby work done off-campus between cross-functional industrial teams and teams of faculty and students may be kept on a non-disclosure basis with title residing with the sponsoring company. Discussions have also been going on for some months now between MIT engineering faculty and various U.S. companies to determine which will become the first ones to interact with the Institute on such an experimental basis.

If these experiments prove to be successful, then the Institute may wish to broaden the initiative by creating a separate corporation to operate these new activities with industry. Alternatively, the Lincoln Laboratory may wish to create a division in Cambridge for this purpose. We wish to note that companies that participate in such activities with MIT do not simply gain from the R&D activities and the interactions with students and faculty, but also gain from the novel organizational structure. It may be that in the long run the organizational aspects will be the greatest benefit to industry.

The School of Engineering Committee, chaired by Michael Dertouzos, that dealt with these issues emphasized two additional points. First, that the Institute should be regularly involved in very large scale projects, such as building a prototype of the car of the future. Much of the prestige of the Institute has come from having worked on such projects in the past (e.g., RadLab, Project MAC, the Plasma Fusion Center). The Committee’s second point is related to the position of policy studies in the Institute, and in particular in the School of Engineering. This is an issue that has occupied the attention of every Dean of Engineering for the past twenty years. Policy research is increasingly central to engineering in areas such as the environment and competitiveness. Recent policy studies published in Made In America [9] and The Machine that Changed the World [10] have had great impact. We need to assure that we have an organizational structure at MIT that will keep policy research intellectually healthy and vital. Discussion continues as to how best to achieve this.

VI. Concerns and Observations

A recurring question concerns the extent to which developmental work will occur on or near the campus. Some worry that such work will displace the basic research in engineering and in other fields in the university. It is certainly true that certain resources have to be shared, and to that extent some existing efforts will have to be curtailed in order to
make room for the new initiatives. On the other hand, we neither plan nor expect more than about 20% of the total funded R&D in engineering to be developmental in nature within the next ten years, although the impact of that 20% on the education of students and on the faculty could be very great.

Some people equate R&D done off campus on a non-disclosure basis with classified research. We do not believe that the comparison holds up on closer inspection. Classified research can usually not be published at all, whereas results based on joint work with industry have been published for decades.

Some are concerned that Engineering with a big E throws out the baby with the bath water in its efforts to improve on the Engineering Science approach. While the concern is understandable we believe it can readily be addressed. We start from a recognition that the Engineering Science approach has been extremely successful in putting engineering on a firm foundation. We fully expect that engineering faculties will continue to teach and do research in this vein for the foreseeable future. The Ph.D. program will remain strongly based in engineering science. We would expect that many if not most new faculty hires would be in the Engineering Science mold.

Then what will be the source of the broader, more integrative view of Engineering with a big E? First, we will need some new faculty members with industrial experience. Certain issues, such as an understanding of large and complex systems, can only be gained at this time through long-term experience with such a system; such experiences are rarely obtained in a university setting. On the other hand, faculty members with extensive experience gained from a career in engineering education in the university may gain a broader perspective over time. As the areas of systems, design, and engineering management become better understood, a more abstract development of these areas will occur, along with more doctoral research leading to new junior faculty in these areas.

Finally, there are some fields (and some individuals) that are inherently multidisciplinary. In these fields, it makes sense to hire junior faculty members. Indeed, MIT has already responded to industrial/societal needs in the spirit of Engineering with a big E in certain such areas. Leaders for Manufacturing has already been mentioned, but programs such as the Technology and Policy Program take a systems approach and apply integrative thinking to the problem areas on which they focus. Thus the concept we are advancing here is one with which we should be familiar. It is time to apply it to the very core of what we do in the School of Engineering.

The implications of Engineering with a big E for faculty promotion and tenure need to be carefully considered, in the context in which such decisions are made. And of course, all that we are trying to do must take place in a time in which MIT is facing extraordinary needs to curtail expenses, reduce the size of the faculty and staff, and harden faculty salaries, in light of research funding uncertainties and changes in government policies.

The danger is not that we will do too much too soon and thereby cause irreparable harm. The real danger lies in turning inward and refusing to deviate from the practices of recent decades, however successful they may have been. Openness to new ideas and laboratory experimentation has served the great engineering science researchers well. We need to retain the same attitude as we consider the directions in which we must move in planning the future of engineering education at MIT and nationally.
References


8. Director, S., private communication
