BIG E ENGINEERING COMMITTEE
FINAL REPORT	O/C

DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02139

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MEMORANDUM

DATE: September 16, 1996

TO: Big E Engineering Committee

FROM: Professor Thomas W. Eagar Tom

RE: Final Report

Enclosed is our final report. Thank you for your help over the past year-and-a-half. I believe that our efforts will have a significant impact on the future of the School of Engineering based on the outcome of the recent retreat.

TWE:cc
enc.
cc: Dean R. Brown
Dean J. Vander Sande
Dean D. Savicki
Professor J. Moses, Provost

Final Report of the Committee on

Hiring and Promotion of Faculty Interested in Big E Engineering

Professors T. W. Eagar (Chair)
D. A. Lauffenburger
T. L. Magnanti
E. M. Murman
D. Roos

September 15, 1996

The primary conclusions expressed in this report have been articulated previously at MIT by half a dozen committees and working groups over the past twenty years. In the present report, there is a sense of urgency that unless action is taken in implementing changes necessary to address these conclusions, the MIT School of Engineering is in danger of losing its preeminent position as a world leader in Engineering Education and Research.

Hiring And Promotion Of Faculty Interested In Big E Engineering

EXECUTIVE SUMMARY

Leadership in Engineering Education and Research requires that MIT have strengths in both the functional aspects of engineering science as well as the integrative aspects of engineering systems design and engineering management. Many faculty members and a number of MIT Committees over the past two decades have called for a stronger emphasis on the integrative role of engineering. In order to expand MIT's activities in engineering systems and engineering integration, we propose that the School of Engineering create a Division of Engineering Systems that cuts across the eight Engineering Departments. This Division would report to an Associate Dean, would have a faculty rank list and budget, with the authority to develop curricula, admit students and hire and promote faculty. All faculty members of the Division would be selected in a two-key system, in which their rank list appointment is shared equally between the Division and at least one department. In this time of fiscal constraint, we propose that the faculty slots of the Division be created through Zero Based Faculty Budgeting (ZBFB) in which all unfilled faculty positions would be returned to the Dean of Engineering at the end of each academic year.

INTRODUCTION AND CHARGE TO THE COMMITTEE

The rapid changes occurring in the world provide the MIT School of Engineering with opportunities to restructure itself to become more adaptable, both internally and externally. In order to seize this opportunity for change, in May 1995, Dean Joel Moses created four committees to review what has occurred in recent years and to propose actions that the School should take to adapt to the changing world. This report contains recommendations from one of those four committees. The charge given to this Committee by Dean Moses stated:

> "Our system is not ideally matched to the hiring and promotion of faculty interested in certain Big E areas. How can we change our hiring and promotion policies and practices (including some reorganization of the School) to enable such faculty to flourish?"

The Committee met seven times from June 1995 through April 1996. After an initial presentation of the Committee's report to Engineering Council in May 1996, Dean Robert Brown asked the Committee to expand on several topics. At the initial meeting in 1995, we agreed that Big E Engineering includes a number of different multidisciplinary activities such as engineering systems, policy, engineering management and the like. Big E is closely coupled with large scale systems, where the connections and interactions between the subsystem components are as important as the subsystems. Also, in many large scale systems the social, political, economic and institutional aspects of the system design are as important as the technical aspects.

The committee felt that it was important to consider Big E Engineering in relationship to the range of challenges the School of Engineering will face in the future. Therefore, it chose to redefine its charge as follows.

> "Does the MIT School of Engineering have the appropriate mix of faculty and researchers to provide leadership in Engineering Education and Research over the next several decades? Are the people, the organizational structure, and the rewards in place for MIT to exercise its leadership in Engineering well into the next century?"

The Committee further decided that it would not start with a clean slate, but would attempt to build upon the work of prior committees and scholars. (Appendix A, Appendix B)

THE HIERARCHY OF ENGINEERING

Engineering involves the application of scientific and mathematical principles to the design, construction, and operation of structures, equipment, and systems in an economic, efficient, and socially responsible manner. These structures, equipment, and systems can be subdivided into substructures, components, and subsystems, each of which may be further subdivided, creating a hierarchy of engineering challenges as shown in Figure 1.

An organization that provides leadership in engineering education and research must contribute in a meaningful way to nearly all, if not all, levels of this hierarchy. Engineering management involves the necessary interactions between each of the functional boxes in Figure 1. MIT faculty and graduates are known as much for their ability to manage these interactions as they are for their contributions within each functional box. This integrative skill has long been recognized as essential to engineering leadership, but the purposeful development of this skill has been an elusive feature in much of the curriculum and research activities of the School. A host of terms has grown around the management of these interactions: team building, concurrent engineering, multidisciplinary engineering, cooperative research, flexibility, agility, customer needs, holistic design and the like.

THE PROBLEM

As generally agreed, the MIT School of Engineering currently is outstanding at educating students to work within the functional boxes, especially at the lower hierarchical levels. The problem is that the current curriculum and research fails to adequately address the interactions between the functional areas. In addition, in an increasingly technological world, MIT's preeminent position in Engineering causes others, outside of MIT, to look to us for answers throughout the entire hierarchy. Our current methods of hiring and promotion tend to favor faculty who work at the lower levels of the hierarchy and within the functional boxes where the answers are more deterministic, easier to articulate mathematically, and more readily "publishable" in archival works. Higher in the hierarchy, the solutions are influenced less by the tools of physics, chemistry, and mathematics and more by human relations, policy, and economics. The conclusions are less objective and become more complex and ambiguous the higher one rises in this hierarchy. In addition, the ability to be influential at these higher levels becomes more dependent on the engineer's ability to communicate. In many ways, work at the higher levels of the hierarchy involves a different form of engineering creativity, a type that is more difficult to measure and to evaluate. As a result, some people believe that engineers working at the top of the hierarchy or at the interactions between the functional boxes are less likely to be hired, promoted, and rewarded in the present system. The Committee believes that MIT must have scholars working at the top of the hierarchy and at the interfaces, as well as within the boxes. Some scholars believe that society's demand for work at the top and at the interfaces is outstripping the demand for work within the boxes. With its tradition of excellence within the boxes, MIT is well-positioned to respond to this call for leadership at the top and at the interfaces.

The hierarchical model of Figure 1 provides two different dimensions of the engineering integrator. One type of integrator will have skills at managing the interactions vertically between three or more levels of the hierarchy. In contrast, a horizontal integrator working on issues toward the top of the hierarchy will evaluate the economic, social, and institutional factors between alternatives at the same level of the hierarchy, e.g., what ratio of air, bus, rail, automobile, bicycle or foot transportation is the best for a given society? (A more detailed discussion of these issues is provided in Appendix D.) Both types of integration involve the engineering and technologies of systems.

The Committee concluded that to be a leader in Engineering Education and Research well into the next century, MIT will require a mix of faculty, staff, and students interested in each area of the hierarchy, viz.

we need people working within the functional boxes and we need people managing the interfaces between these boxes of both a horizontal and vertical integrative style.

THE CURRENT STATE

If one accepts that integrators of both horizontal and vertical interests are needed as educators and role models for our students and because society looks to MIT for answers at each level, one next asks, do we have enough such integrators on our current faculty? The Committee notes that any individual faculty member might study a mix of both functional and integrative problems.

Seeking to understand the diverse interests of the present faculty, the Committee issued a questionnaire to the Engineering Department Heads and Center Directors in September 1995 asking how many vertically and horizontally integrative faculty (full time equivalents) they had in their organization and whether they felt that this was the correct number for the future. While there was considerable scatter in the responses to such a subjective question, several significant trends emerged.

- Respondents felt that MIT should have approximately twice as many vertical integrators as horizontal integrators.

- Approximately one-third of the faculty interests should be devoted to integrative studies, although the range for any one faculty member might vary from zero to 100 percent.

- The School of Engineering currently has about one half as many faculty spending time in integrative activities as is desirable.

Thus having validated the assumptions implicit in Dean Moses' charge to the Committee, we returned to his original charge which was,

> "How can we change our hiring and promotion policies and practices (including some reorganization of the School) to enable [integrative] faculty to flourish?"

THE CURRENT ORGANIZATION

Most of the current Departmental organizations in the School of Engineering, while recognizing the need for more integrative faculty, focus primarily on working within the functional boxes, or with working on the interactions between one or two boxes. In addition, the Departments are in various stages of development with regard to Engineering Systems. Several have a systems orientation while others are oriented more functionally. Stated more simply, each of the individual Departments would love to have these more integrative faculty available within the School of Engineering, but rarely can a Department justify having more than a very few faculty whose teaching and research emphasizes such large scale integration. Almost no Department with the possible exception of Civil and Environmental Engineering, feels that it has a critical mass of such large scale integrators, nor do the Departments envision that they can allocate enough positions to achieve critical mass on their own. On the other hand, the faculty with interests in such large scale integration want to be able to interact closely across departmental boundaries, to develop interdisciplinary academic programs, to admit graduate students to those programs, and to hire and promote integrative colleagues.

MIT has already created several successful Big E educational and research programs. The integrative faculty have worked hard to develop important new academic programs such as Leaders For Manufacturing (LFM), the Technology and Policy Program (TPP), System Design and Management (SDM), Operations Research (OR) and the Master of Science in Transportation (MST). Research centers such as the Center for Transportation Studies (CTS), Center for Technology, Policy and Industrial Development (CTPID) and the Industrial Performance Center (IPC) have fostered large scale interdisciplinary research projects. Two Virtual Centers, the Program For Environmental Engineering Education and Research (PEEER) and the Technology, Management and Policy Program (TMP) were started several years ago by the School of Engineering to initiate and coordinate interdisciplinary activities within the school and to interact with colleagues in management. MIT has been a leader in demonstrating how successful interdisciplinary educational and research activities can be undertaken.

There are, however, several difficulties with the existing situation. Big E Faculty are spread between these various center and educational programs. They lack a common home to collectively develop their intellectual agenda. As a result, there is not a critically sized group of faculty that can collectively plan and implement future Big E activities within the school. This is reflected by the need to establish an ad hoc faculty review committee when non traditional faculty members are considered for promotion or tenure.

The school is faced with a dual challenge. First, how can the departments become more involved in Big E activities? Second, how can the faculty within those departments work together school wide to develop a Big E intellectual agenda that provides a framework and related methodology to work on large scale systems problems.

Of the eight departments within the School of Engineering, at least three, Aeronautics and Astronautics, Nuclear Engineering, and Ocean Engineering have a systems focus, although the focus is on a particular industry, technology, or environment in each instance. Civil Engineering also has a strong group of faculty studying engineering systems and faculty with such interests exist in the remaining four departments as well. One of the problems encountered is that school-wide systems curricula would be desirable but no single department has the faculty resources to develop a curriculum on its own. While engineering systems subjects exist within the School, they are most often specific to a single department, are limited in number and in scope and lack the coherence and richness of an Engineering Systems Curriculum that the faculty of the MIT School of Engineering is capable of developing.

Professor Richard Lester has suggested a list of six key elements that might be included in an Engineering Systems Curriculum. This list is reproduced in Appendix E.

The Committee concluded that the School of Engineering should create a broad and rich curriculum in Engineering Systems, addressing societal needs, that cuts across the School (and the Institute). The focus of this curriculum would be on the Engineering and Technology of Systems.

As noted previously, the Committee did not attempt to start with a clean slate design. Rather, it reviewed and built upon the prior reports of various scholars (Appendix B) and MIT Committees (Appendix C). Based upon the wisdom of our predecessors, and in the context of our present situation, the Committee developed an organizational structure that we believe is adaptable to our situation.

THE PROPOSED SOLUTION

The committee strongly endorses the need for Engineering School departments to hire more Big E faculty and to develop an Engineering Systems curriculum.. However, the committee believes this is a necessary, but not sufficient response to meet the challenges of the 21st century. The Committee believes that we need a new organizational structure to accommodate Big E activities and to help Big E colleagues achieve the critical mass that they require to flourish.

Some have suggested creating a new department of Big E faculty, but the committee does not favor this approach. A separate department has the potential of creating an isolated group of faculty and pulling valuable resources from the existing departments.

The solution that the committee proposes is based on creating an organizational unit with porous boundaries that would cut across the eight departments and interact with them. This would be accomplished since the majority of faculty within this unit would have joint appointments and a primary objective of the unit would be to work with the eight engineering departments to increase their Big E educational and research activities. The unit would interact with colleagues in the other Schools of MIT to develop Institute-wide interdisciplinary activities. The Committee, therefore, proposes a new organizational structure for the School of Engineering that combines the traditional departments (presumably the same eight departments as present) with a new Division of Engineering Systems cutting across the eight Engineering departments. This Division would be organized as follows.

•The head of the Division would be an Associate Dean of Engineering. The title of Associate Dean acknowledges that this is a school-wide activity.

•The Division would have a faculty rank list and budget. It would have responsibility for curriculum, teaching assistantships and the like. The Division would have the authority to admit students, grant degrees and be responsible for interdisciplinary academic programs such as LFM, SDM, TPP, MST.

•Every faculty member in the Division would be selected in a two-key system. The faculty within the Division, as well as the faculty within at least one of the eight Departments, would need to approve the hiring of the faculty within the Division. Although most of the participating faculty are likely to be senior, certainly at the outset, we believe that junior faculty appointments would be appropriate. The two-key system requires that the large scale integrative faculty contribute to the educational programs and objectives of the Departments.

The Division would consist of two types of faculty.

1. Faculty of the Division would hold joint appointments and would be selected by the two key system. Several of these initial faculty positions would be filled with existing faculty transferring half of their rank list from their Department to the Division. Although the majority of the Committee felt that the objective would be for all faculty in the Division to be affiliated with at least one department, each Committee member recognizes that special cases might arise in which the School would permit a faculty member's rank list to reside solely within the Division. In addition, one can envision, faculty from other Schools, being associated with this Division within the School of Engineering.

2. Some faculty would be affiliated with the Division and would participate in educational and research activities on an episodic basis. These faculty would maintain their full Departmental appointments.

In this era of budget restraint, the Committee believes that the School of Engineering can create this Division at a relatively small one-time cost with no new recurring costs, by instituting a policy of Zero-Based Faculty Budgeting (ZBFB). ZBFB would require all unfilled or released faculty positions to be returned to the Dean of Engineering each year for reallottment to the Division and the Departments. As previously stated, some of the initial Division rank list positions would be filled with a few existing faculty transferring half of their rank list from their Department to the Division. The remainder of the rank list slots in the Division would come from a "tax" on the open slots of existing departments. The Division Dean would be able to negotiate the hire of a new faculty member by sharing one-half slot from the Division with one-half slot from a given Department. In this way, the departments have an incentive to help the Division find faculty with integrative interests appropriate to the disciplines of the department.

CONCLUSION

This Committee has not presented any conclusions that have not been articulated previously by many of our colleagues. In order to remain preeminent in Engineering Education and Research it is essential that the School of Engineering develop faculty with a diverse range of interests. The leaders of the School of Engineering continue to believe that we need to attract and retain a larger number of faculty with interests in Big E engineering. We propose a divisional structure to accomplish this objective while requiring that these faculty remain committed to the educational programs of the individual Departments.

While the Committee has developed this organization proposal as a means of hiring, nurturing and retaining Big E engineering faculty, this organizational structure (or a similar one) may be useful in a number of other contexts. For example, programs cutting across Schools might benefit from a similar organizational academic structure. We believe that this framework can provide flexibility across the Institute as well as across the School of Engineering.

HIERARCHY OF ENGINEERING

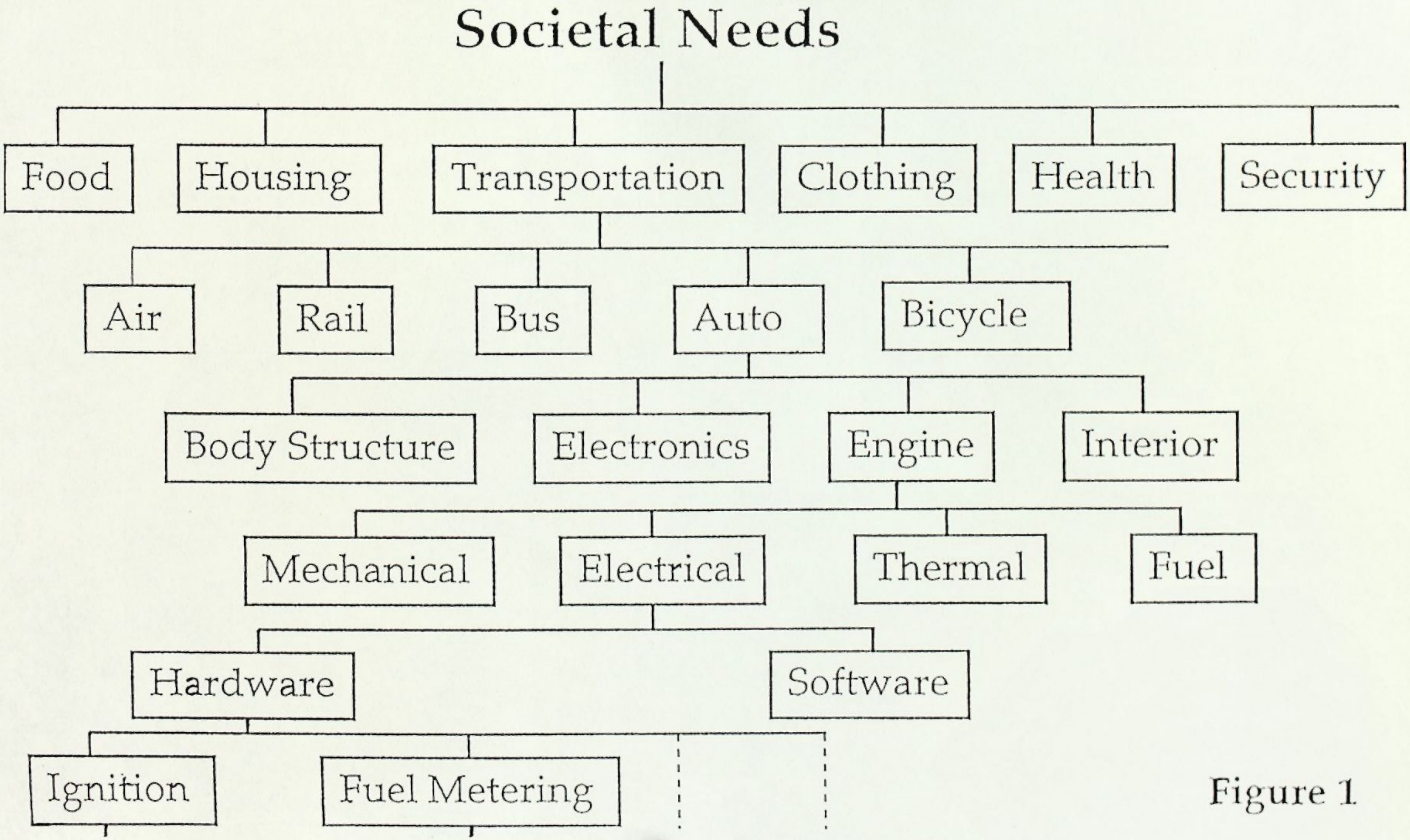

Figure 1

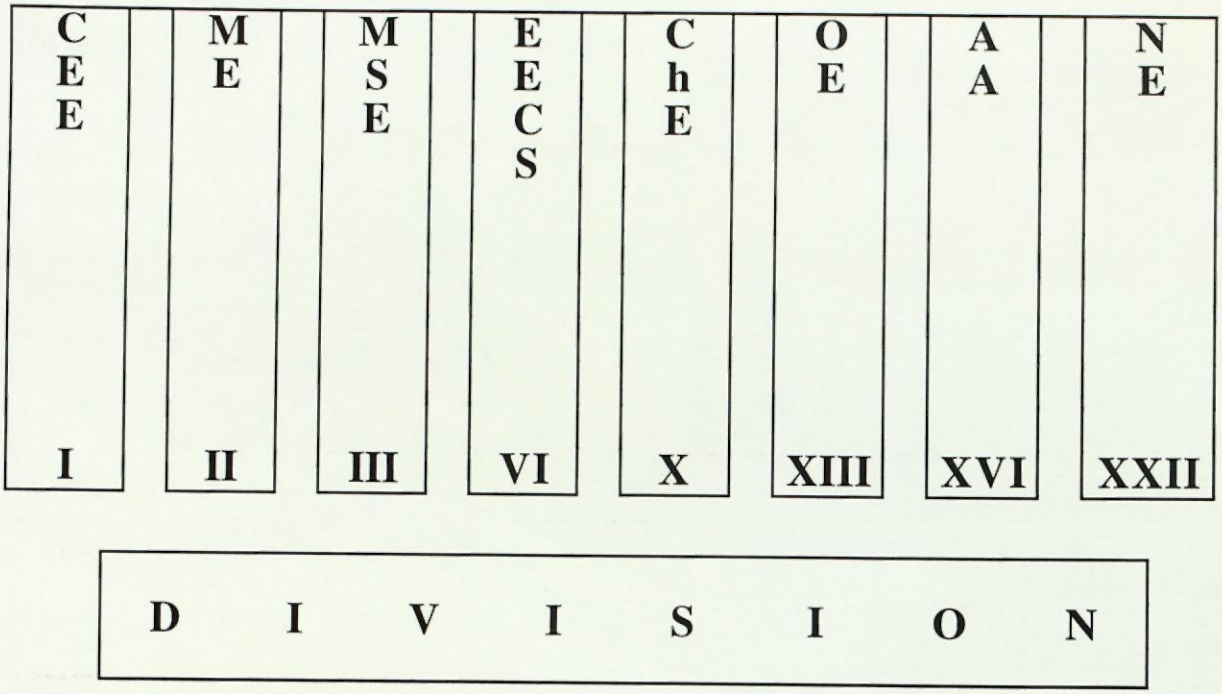

Figure 2.
Proposed Organizational Structure

Appendix A

RECENT COMMITTEES CONCERNED WITH SCIENCE AND TECHNOLOGY POLICY AT MIT

School of Engineering Committee on Industrial Links (1993)

Michael Dertouzos (Chairman), Department of Electrical Engineering and Computer Science
Merton Flemings (Vice Chairman), Department of Materials Science and Engineering
Rafael Bras, Department of Civil and Environmental Engineering
David Hardt, Department of Mechanical Engineering
Dan Hastings, Department of Aeronautics and Astronautics
Dick Larson, Department of Electrical Engineering and Computer Science
Dave Marks, Department of Civil and Environmental Engineering
Sanjoy Mitter, Lab for Information and Decision Systems
Fred Moavenzadeh, Department of Civil and Environmental Engineering
Dan Roos, Department of Civil and Environmental Engineering
Jeff Shapiro, Department of Electrical Engineering and Computer Science
Yossi Sheffi, Center for Transportation Studies
Dan Wang, Department of Chemical Engineering
Pat Winston, Artificial Intelligence Laboratory

Structuring Science, Technology and Policy Studies at MIT (1989)

Joel Clark (Chairman), Department of Materials Science and Engineering
Bernard Frieden, MIT School of Architecture
Henry Jacoby, MIT School of Management
Kenneth Keniston, Department of Science, Technology and Society
David Marks, Department of Civil Engineering
Daniel Roos, Department of Civil Engineering
Harvey Sapolsky, Department of Political Science

Dean of Engineering's Review Committee of the Technology and Policy Program (1987)

David Marks (Cochairman), Department of Civil Engineering
Arthur Gelb (Cochairman), The Analytic Sciences Corporation
Joel Clark, Department of Materials Science and Engineering
Jack Kerrebrock, School of Engineering
John D.C. Little, MIT School of Management
Harvey Sapolsky, Department of Political Science
Lawrence Susskind, Department of Urban Studies and Planning
Steven R. Tennenhouse, Department of Applied Biological Sciences

Engineering Council on Technology and Policy (1985)

Daniel Roos (Chairman), Department of Civil Engineering
Kent Bowen, Department of Materials Science and Engineering
Fernando Corbato, Department of Electrical Engineering and Computer Science
Frances Ogilvie, Department of Ocean Engineering
Neil Todreas, Department of Nuclear Engineering
James Wei, Department of Chemical Engineering
David Wormley, Department of Mechanical Engineering

Provost's Committee on Technology, Policy and Society Studies at MIT (1984)

John D.C. Little (Chairman), MIT School of Management
Joel Clark, Department of Materials Science and Engineering
Paul Joskow, Department of Economics
David Marks, Department of Civil Engineering
Norman Rasmussen, Department of Nuclear Engineering
Alexander Rich, Department of Biology
Harvey Sapolsky, Department of Political Science
Lawrence Susskind, Department of Urban Studies and Planning

Dean of Engineering's Committee on Engineering and Human Affairs (1979)

Ira Dyer (Chairman), Department of Ocean Engineering
Jonathan Allen, Department of Electrical Engineering and Computer Science
Richard de Neufville, Department of Civil Engineering
Kent Hansen, Department of Nuclear Engineering
F. Herbert Holloman, Center for Policy Alternatives
David Marks, Department of Civil Engineering
Frank McClintock, Department of Mechanical Engineering
Amadeo Odoni, Department of Aeronautics and Astronautics
Leon Trilling, Department of Aeronautics and Astronautics

Provost's Committee on Applied Social Science and Public Policy at MIT (1979)

Robert Solow (Chairman), Department of Economics
Alan Altschuler, Department of Political Science
Richard de Neufville, Department of Civil Engineering
Arnaldo Hax, MIT School of Management
Langley Keyes, Department of Urban Studies and Planning
Daniel Kleinman

Appendix B

BIBLIOGRAPHY
BIG E ENGINEERING COMMITTEE
1995-1996

"Clusters and Divisions: A Variant on the Keil Proposal", Joel Moses, June 2, 1995, pp. 1-5.

"Engineering Education for the Workers of the Future", Don E. Kash & F. Karl Willenbrock, Issues in Science and Technology, Summer 1992, pp. 30-34.

"Multidisciplinary Programs in Universities", Appendix V, Dale R. Corson, attendee, Conference: Reinventing the Research University, pp. 277-291.

"The Only Constant is Change", T. W. Eagar, AWS Henniker Conference: Joining Strategy for the 21st Century, Henniker, NH, July 1994, pp. 1-26.

"Report on Engineering Design", E. S. Taylor, Chairman, Reprinted from The Journal of Engineering Education, Vol. 51, No. 8, April, 1961, pp. 645-660.

Scholarship Reconsidered: Priorities of the Professoriate, Ernest L. Boyer, The Carnegie Foundation for the Advancement of Teaching, Princeton University Press, 1990, p. 1-147.

"Socioengineering (And Augustine's Second Law Thereof)", Norman R. Augustine, The Bridge, Fall 1994, pp. 3-14.

COMMITTEE REPORTS

New Directions, School of Engineering Committee on Industrial Links, Michael Dertouzos, Chairman, June 7, 1993, pp.1-21.

Structuring Science, Technology, and Policy Studies at MIT, White Paper Committee, Joel Clark, Chairman, September 6, 1989, pp. 1-38.

Summary Report, Ad Hoc Committee on Technology, Policy, and Society Studies at MIT, John D. C. Little, Chairman, September 10, 1984, pp. 1-11.

First Draft: Multidisciplinary Efforts in Engineering and Society, Committee on Engineering and Human Affairs, Ira Dyer, Chairman, August 3, 1979, pp. 1-68.

Appendix C

SUMMARIES

COMMITTEE REPORTS

<u>New Directions</u>, School of Engineering Committee on Industrial Links, Michael Dertouzos, Chairman, June 7, 1993, pp.1-21.

<u>Structuring Science, Technology, and Policy Studies at MIT</u>, White Paper Committee, Joel Clark, Chairman, September 6, 1989, pp. 1-38.

<u>Summary Report</u>, Ad Hoc Committee on Technology, Policy, and Society Studies at MIT, John D. C. Little, Chairman, September 10, 1984, pp. 1-11.

<u>First Draft: Multidisciplinary Efforts in Engineering and Society</u>, Committee on Engineering and Human Affairs, Ira Dyer, Chairman, August 3, 1979, pp. 1-68.

Summary
New Directions
Committee on Industrial Links
Michael Dertouzos, Chairman
June 7, 1993

MIT must change in response to external changes. The changes must be:

1. **All Encompassing**: The needed change must affect instruction, research and organization, since the education of our students rests on the effective integration of all these components.

2. **Pervasive**: The needed change should affect a large part of MIT, since we strive to address problems and issues that are increasingly multidisciplinary and therefore need and derive strength from the many disciplines of our institution.

3. **Practical and Socio-technical**: To address the societal needs ahead, the change we seek should involve students and faculty with real, significant and often complex socio-technical problems.

4. **Actively Involving Industry and Government**: For the same reason, we need to work closely with people within government and industry who know about, contribute to and share the consequences of this complexity.

5. **Delivery and Impact oriented**: To exercise leadership in a world that is increasingly dependent on technology, we must be willing to provide results that make a big difference to society.

6. **Exciting**: In a world of shrinking budgets, it is tempting to seek shelter by cutting costs. We see a world ahead that is full of exciting opportunities and increased revenues for MIT, if we would only rise to meet the challenges.

7. **Rooted in our proven leadership in Science and Technology**: The kind of change we seek, if carelessly pursued can lead to dilettantism and shallow breadth. It is imperative that we retain our strong leadership **in** Science and Technology, and build the needed change on top of this proven foundation.

8. **Big**: The challenges ahead are too big to be addressed by incremental approaches. We believe that the needed change should be as big as the post WWII change that led to Engineering Science.

9. **Involving Nimble and Networked Teams**: The rapid changes in technology call for interdisciplinary MIT research teams that can be rapidly assembled and disassembled to address an ever changing array of problems and projects.

Summary
<u>*Structuring Science, Technology, And Policy Studies at MIT*</u>
White Paper Committee
Joel Clark, Chairman
September 6, 1989

- **Purpose:** For engineers and scientists to appreciate and influence the larger context in which they work and for social scientists to collaborate with engineers and scientists to see how this would come about. The aim being for an outcome leading to innovative research and educational programs.

I. Focus for formation of a Science, Technology and Policy Unit (STP) at MIT: Understanding the policy implications of large-scale, complex systems subject to conflicting economic, technical, environmental, and social objectives.

II. Objectives for STP

a. provide educational opportunities for a new type of professional with expertise in technology policy studies
b. educate a new breed of engineers and scientists who will provide responsible leadership by knowing the social context of technical activities
c. identify issues and help to set national policy and agenda
d. provide objective analysis which helps policy makers adopt policy
e. establish quality control, career guidance, and evaluation for those who choose policy as a profession

III. Separation of Technology, Policy, and Society Program (TPSP) into two programs

a. The Science, Technology and Society Program
b. The Science, Technology and Policy Program

IV. STP Success dependent on:

a. Core group of faculty to enthusiastically devise
   1. joint research projects
   2. educational programs
   3. interdisciplinary connections
   4. engage a broader group of faculty and students in these discussions
b. TPSP will build upon the Center for Technology, Policy and Industrial Development (CTPID) and Science, Technology and Society (STS) for relevant perspectives
   1. technological
   2. scientific
   3. social
   4. historical
c. Cooperation and communication should be established with:
   1. Center for International Studies
   2. Center for Energy Policy Research
   3. Center for Business and Economic Research
   4. Center for Transportation Studies
d. Appropriate level of funding
e. Director of TPSP would:
   1. report to Provost
   2. sit on Engineering Council
f. If organizational issues cannot be resolved, an alternative organizational structure should be formed

Summary

Summary Report

Ad Hoc Committee on Technology, Policy And Society Studies at MIT

John D. C. Little, Chairman

September 10, 1984

- **Definition**: Public policy research may be defined as the consideration of societal implications of decision alternatives for public problems, along with the development of methodologies for performing the relevant analysis.

- **Position**: We live in a complex society in which science and technology are continuously introducing change, which creates a stream of public policy issues. These issues need technological expertise, understanding of the policy-making process, and analytic skill in order to bring the proper resolution.

I. Committee charges

a. Define policy studies and their proper role at MIT
b. Identify and review existing activities
c. Prepare recommendations

II. Policy activities at MIT

a. Individual service efforts
b. Departmental activities
c. Interdepartmental centers

III. Criteria for successful policy activities

a. Quality of research
b. Impact in the world
c. Contribution to education
d. Independence from sponsor influence
e. Coupling with departmental faculty
f. Leverage of general funds
g. Fit with MIT strengths
h. Viability

IV. Specific Recommendations

a. Many existing activities are doing will and should simply be left alone
b. A new, MIT-wide centerpiece for policy teaching and research related to engineering and science should be formed within the School of Engineering with the following key components:
   1. A graduate level teaching program built largely out of the present technology and policy Program (TPP) but expanded and extended in certain ways. As in the case of TPP, the faculty and, to some extent, the courses would be drawn from existing departments.
   2. A sponsored research activity that would include the current CPA, but would have goals and a charter more like the new directions CPA is trying to take than it's past experiences.
   3. A working group of social scientists that would be recruited across MIT to assist in the teaching and participate in the research.
   4. A visitors program that would encourage relevant policy-makers and policy-researchers to come to MIT and interact with students and researchers here.
   5. The new centerpiece organization would be called the Technology and Policy Center (TPC)
      a. The teaching program of the Technology and Policy Center (TPC) will be an enhanced version of the Technology and Policy Program (TPP).

b. The research arm of TPC should encourage collaborative policy research involving engineering and applied social science faculty
c. The visitors program will enhance the visibility and effectiveness of TPC
d. TPC should have unified physical space to accommodate students, visitors, research activities and administrative needs
e. The management structure of TPC should reflect its interdisciplinary nature

c. Establish Policy Studies Coordination Committee to report to the Provost
1. advise the Provost on policy research matters
2. provide advice, counsel, and information to the TPC
3. stimulate communication among policy research activity
4. to ameliorate jurisdictional disputes among policy centers (with the assistance of the Provost)

V. Summary

a. Strengthening and focusing policy activities at MIT by means of the establishment of a Technology and Policy Center (TPC) starting from the interdepartmental educational program of the present TPP and add a research component.

b. Recommend the establishment of Policy Studies Coordination Committee, to be chaired by the Director of TPC, to advise the Provost on issues of policy research and education and to provide a central coordination point for these matters.

Summary
<u>*First Draft : Multidisciplinary Efforts in Engineering and Society*</u>
Committee on Engineering and Human Affairs
Ira Dyer, Chairman
August 3, 1979

- **Ad Hoc Committee formed (May 1979) to review the possibility of establishing a multidisciplinary Division in the School to satisfy needs including:**
  1. Provide a focus for grad. level research and educational programs that are beyond the bounds of a single department and which have difficulty in finding an appropriate place in the School structure.
  2. Improve the ties between the SoE and other Schools at MIT and conduct joint programs with these Schools.
  3. Support a small number of faculty whose capabilities do not match the requirements of any one department, but who have a significant role to play in engineering research and education.
  4. Arrange freshmen courses and seminars that relate engineering to societal issues.
  5. Conduct multidisciplinary research, particularly in areas having management, social, economic and/or political implications.
     a. Committee conclusion: concerns should be limited to the important multidisciplinary area of engineering and society

- **Engineering and Societal Interactions Definition:** the management and direction of technological projects and activities in both the private and public sectors, including development of new technologies for social purposes and management of the undesirable side effects of technological applications.

- **Drawbacks of institutions of higher learning (MIT):**
  a. appointment
  b. development
  c. promotion of engineering faculty with interests in engineering and society hampered by the acknowledged limited ability of their colleagues in more established areas to evaluate their contribution and their potential
  d. admission and certification of grad. students in Trans. Studies and Technology and Policy programs
  e. lack of focus for ensuring that undergraduate engineers have the opportunity to include engineering and society subjects or experience in their programs

- **Committee Recommendations:**
  A. Establish a Faculty of Engineering and Human Affairs
     1. Duties: admit students, propose and offer subjects, propose degree programs, recommend students for degree awards, evaluate and propose faculty appointments and promotions.
        a. primarily joint appointments
  B. Further diffuse the basic ideas of Engineering and Human Affairs into undergraduate education
     1. Specific initiatives: provide exposure, to create an awareness of the importance of the social and ethical context inherent in the practice of the engineering profession.
        a. Develop and publicize subjects available to freshmen which present engineering in the broadest human context
        b. Encourage the diffusion into present subjects and curricula of examples and case studies to show how consideration of social and economic factors affects the formulation of an engineering problem. Provide seed support for the collection of examples and case study materials

c. Urge the Committee on Schoolwide Electives to highlight or commission school-wide elective subjects which deal with the context of engineering

d. Encourage the instructors of appropriate subjects to submit them for listing as acceptable to satisfy parts of the Humanities, Arts, and Social Sciences Requirement.

e. Support an office to advise students about career opportunities, subjects, and other educational opportunities in societal interactions with engineering.

f. Endorse and support the efforts of the Committee on Engineering Education to establish dual S.B. degree programs with the program of Science, Technology and Society and the Sloan School of Management.

g. Work to broaden the Engineering Internship Program to include placement of students in policy oriented positions in corporations and government agencies.

h. Expand and strengthen the cooperative programs developed by the School of Engineering and the Writing Program to improve the ability of students to communicate and encompass a broader discussion of the types of audiences and styles important in making technology related policy understandable and acceptable to people of our communities.

i. Hold occasional faculty workshops and working seminars to discuss ways of integrating that material which stresses social and economic context into the curriculum and of developing the form it might take to be the most useful in a given department or subject.

2. Implementation (none of the specific actions recommended here call for institutional changes.)

a. presence on the School's faculty of more colleagues trained in the social sciences

b. closer ties between policy research groups and undergraduate teaching

c. schoolwide organization such as the Committee on Engineering Education (directly or by delegation) and the Associate Dean should be designated explicitly to coordinate and periodically report on progress in this area.

C. Encourage the Dean to work with department heads in the SoE to increase the number of projects or programs which combine faculty in the applied social sciences with those in engineering

1. Purposes: To demonstrate the benefits of combining engineering and society concerns, by sharing in a research format contexts and concepts of engineering science and the social management of technology.

2. Small efforts might be carefully planned and nurtured with initial seed money from the School to demonstrate the scholarly interest and usefulness of combining engineering and societal concerns.

a. Establish a few additional strong island of activity where there is likely to be some impact on neighboring engineering projects.

D. Develop a better understanding of communication between technical and non-technical publics

1. Faculty workshops and seminars of topics similar to (B).

2. Faculty commitment to both present and inform the public on the latest results and implications of research and its impact and effectiveness on social welfare.

a. Methods: "Technology Review", ILP, forums, study program

Appendix D

(submitted by Professor Daniel Roos)

DESCRIPTION OF ISSUES FACING ENGINEERING SYSTEMS INTEGRATORS

In recent decades, our society has become increasingly mired in a series of these intractable "large-scale sociotechnical problems." Which trade-offs must we accept between industrial development and environmental quality? Who should bear the cost of developing the information highways of the future? How do we modernize and maintain our neglected transportation infrastructure? In which technologies should we place our hopes for post-Cold War defense conversion and technology transfer?

Such "problems" frequently occur at the nexus of technical, social and natural systems. They therefore profoundly affect such vital areas as communications, transportation, industrial development and environmental management. They severely tax our abilities to cope with technological change, to manage large projects and to reconcile the interest of diverse constituencies. Their scope and complexity demand unprecedented cooperation and new modes of cross-fertilization among technical experts, managers and policy specialists.

The "sociotechnical problems" have several characteristics:

(1) although increasingly driven by scientific and technological considerations, they require solution that transcend the technical realm;

(2) in scope, scale and complexity, they are extraordinarily challenging, they typically involve secondary or unanticipated consequences, less-than-obvious interaction effects, and variables beyond the control of the key players;

(3) the stakes are high and there are no quick fixes available -- issues that impact entire social systems, economies or ecosystems may have taken decades to develop, and may take many years to resolve (e.g. global climate change);

(4) they typically transcend any single industry or economic sector; hence they require comparative, trans-industry studies as well as in depth investigations of whole industries;

(5) proposed solutions are expensive to test and therefore may require long-term institutional partnerships and innovative funding arrangements;

(6) organic, dynamic systems are not easily equilibrated; they require constant tuning and adjustment;

(7) eventual solutions may entail threshold effects -- i.e.,. Nothing is truly resolved at the system level until all component issues have been addressed and integrated.

Over the past twenty years, a growing community of scholars and practitioners has increasingly come to regard these problems as the focal concerns of a legitimate new body of knowledge. They have carefully developed a distinctive interdisciplinary frame of reference and adopted an array of methodical techniques appropriate to the subject matter. These investigators have devoted considerable attention not only to specific research questions and case studies, but also to advancing our understanding of the general principles inherent in the operation of large scale sociotechnical systems.

Some have argued that we are witnessing a paradigm change in engineering practice. At the very least, we have experienced two important trends in rapid succession. In the first wave, driven by concerns with consumerism, productivity and global industrial competitiveness, engineering and industrial practice became sensitized to the "voice of the customer." As evidenced by the widespread impact of the TQM movement, the focus is on product quality. For example, those who once focused exclusively of design elegance have come to understand that "manufacturability", flexibility, adaptability, product reliability and sustainability are essential design criteria that fundamentally influence such key variable as time-to-market, return on investment and customer satisfaction. This has resulted in process redesign and improved integration of the market research, product design and manufacturing functions. It has also profoundly altered how we think about design issues.

As the next wave unfolds, we may be hearing "the voice of society." Consumers, regulatory agencies and other stakeholders are holding producers to loftier standards and insisting upon taking the longer term view with respect to environmental stewardship, responsibilities toward human resources, and other issues. And there are encouraging signs of growing awareness among manufacturers themselves that "green may be better," not merely in public relations terms, but also by imposing new levels of efficiency upon the production process with respect to consumption of raw materials, environmental clean up costs, liability issues -- all of which influence profitability. For example, some producers have escalated their environmental objectives from pollution control, to pollution prevention, and now to an increasing acceptance of "extended producer responsibility" that recognizes an obligation upon the manufacturer with respect to the ultimate recycling of both finished products and the raw materials of production.

As this broader approach to design and manufacturing has gained acceptance, corresponding strides have been made in the development and application of methodologies appropriate to understanding the structure of technical processes: i.e.,. How complex processes can be successfully integrated, modelled and manipulated; how to integrate traditional management functions with technical and design processes; etc. There is a growing acceptance that the "tools of the trade" must now extend beyond traditional preparation in a technical discipline to also include comprehensive analytical and decision techniques. Accordingly, technologists are paying greater attention to issues of complexity, risk assessment, planning for uncertainty, industrial ecology, organizational behavioral theory, sustainability and a host of other "externalities" related to the broader "acceptability" of the products and services they create.

Appendix E

(submitted by Professor Richard Lester)

KEY ELEMENTS OF A 'SYSTEMS ENGINEERING' CURRICULUM

(i) Organization

Engineering takes place within organizations, and the products of engineering projects are often used *by* organizations. Engineering practitioners should therefore understand the principles of organizational design, and their relation to the design of engineered systems.

(ii) Integration/Coordination

Engineering projects typically require resources to be integrated across a variety of boundaries -- functional divisions and departments within the firm, corporate boundaries, occupational and professional boundaries, and so on. Engineering leaders should be introduced to alternative approaches to integration, and should gain insight into the conditions under which each approach is likely to be most effective.

(iii) Interpretation

A basic assumption is that problems can be solved analytically, i.e., that the objective can be specified at the outset, as can the means for achieving it and the scientific and engineering principles that relate means to ends. But in many real-world situations neither the product nor its components, nor the elements of the productive process are self-evident or fixed at the outset. Rather, they emerge through a cycling back and forth between user, designer, and producer. Engineering in such situations is essentially an *interpretative* activity, with the engineer playing a role more akin to the way architects think of their relationship with their clients than the usual view of industrial engineering as an analytical optimization process.

(iv) Economic optimization

The techniques of economic optimization, including capital budgeting, accounting, and project management methods, are a basic part of the engineering repertoire.

(v) Communication

Engineering leaders must be capable of communicating effectively with divers constituencies, both specialist and lay, using a variety of traditional and, increasingly, new electronic media.

(vi) Politics

Regulation is often an important constraint on engineering design. But regulations are not static; rather, regulation and technology are continually evolving along interactive trajectories, with each one influencing the other. Engineers are participants in this process, which is at least partly a *political* process, and it is important for them to understand their role in these terms.