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TOWARD A NEW TECHNOLOGY AND POLICY PROGRAM (TPP) CURRICULUM

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Toward a New Technology and Policy Program (TPP) Curriculum
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The mission of the MIT Technology and Policy Program (TPP) is:

> “Provide an integrative education to scientists and engineers who wish to lead in the development and implementation of responsible strategies and policies for exploitation of technology for the benefit of their communities” (Hastings, 2000).

Embedded in the TPP mission statement are several educational requirements: (1) a comprehensive and diverse set of solid analytical skills needed to develop and assess strategies and policies, (2) the flexibility to manage the conflicting interests and values that are present at all stages of the policy process, and (3) the ability to provide leadership at each stage in the policy process. With these concepts in mind, the TPP Curriculum Development Committee will work to place TPP at the forefront of educating the “leaders (researchers and practitioners) of the fields of technology and policy studies” (Hastings, 2000).

I. Objectives

The purpose of this working paper is to serve as a discussion piece by synthesizing many of the ideas and concerns that have arisen in the process of developing a new TPP curriculum for September 2001. The focus point is a draft template for a new TPP curriculum. In order to provide a context for this ‘strawman’ curriculum, the paper first presents the main findings of the committee’s analysis to date, an overview of TPP in the context of Engineering Systems, and a set of criteria for evaluation. The appendices contain information on other graduate programs similar to TPP in order provide benchmarks as well as some philosophical discussion of the relationship between the Technology and Policy Program and Integrated Assessment methods.

II. Findings

In the course of the meetings of the TPP Curriculum Development Committee, as well as through conversations with additional faculty and students, three central findings have emerged to help inform the curriculum development process. These are the goals that motivate the changes to the TPP curriculum that are proposed in this paper. First, there is a need to deepen and broaden the TPP curriculum. Second, TPP should engage other educational programs more fully, particularly within ESD. Lastly, TPP should articulate and build upon the idea of Engineering Systems, recognizing that this requires a more integrated understanding of the broader social systems that are vital aspects of Engineering Systems.

Several more specific findings, some related to the intellectual content and others stemming from more practical considerations, are articulated below:

- There is a core set of knowledge, concepts and skills that every TPP graduate should gain through the program. This core set of knowledge should be taught in a rigorous and integrated manner.
- Uncertainty, both in the technical and social systems involved, is a core consideration for almost any technology/policy issue. Therefore, students should have a strong base in the probabilistic and statistical methodologies as they are applied in both engineering and the social sciences. The development of strong quantitative and other analytical skills in dealing with uncertainty is a critical requirement for TPP.
- The experiences provided by the ProSeminar are an important part of the program. Through the in-class exercises, case studies and negotiations, students gain new insights and also begin to form a

sense of community through those experiences. However, these types of activities need to be better integrated with the rest of the TPP "core subjects."

- There is a need for greater rigor in the methodological components of the TPP curriculum, both to deepen the substantive content of the program, as well as to enhance the image of TPP within the MIT community.
- The experience of completing an in-depth Master's Thesis is fundamental to the TPP educational experience.
- TPP should position itself to serve as a platform for the educational programs of the Engineering Systems Division (ESD). Placing TPP in a leadership role, around which other ESD programs can come together, could promote a greater degree of interchange within ESD.
- The development of leadership skills should be a central part of TPP. A subject incorporating leadership could serve as a platform subject for all of the ESD programs.
- Coursework in Microeconomics is an important knowledge base for understanding issues in technology/policy.
- Students should develop skills in both quantitative and qualitative methods for analysis from both the engineering and the social science perspectives.

III. TPP in the Context of Engineering Systems

TPP resides within MIT's Engineering Systems Division (ESD). We suggest that this implies a subtle shift in TPP from a focus on *technology* to a perspective that looks more extensively at e*ngineering systems*. Therefore, an integral part of the TPP intellectual endeavor should be to train students to approach problems from an Engineering Systems perspective.

"Engineering Systems" can be described as Complex, Large-Scale, Integrated, Open Systems (CLIOS) with an important technology component.[1] Systems are *complex* when comprised of a group of related units or subsystems, for which the degree and nature of the relationships is imperfectly known. CLIOS have *large-scale* impacts, meaning large in magnitude, geographic expanse and long-lived. CLIOS are tightly *integrated* through feedback loops between the subsystems. *Open* means that CLIOS are highly inclusive in their consideration of social, political and economic factors. Transportation systems, information and communication networks, energy systems and the environment can all be categorized under the broader heading of engineering systems. *Most importantly, these open and inclusive systems incorporate natural and physical systems as well as social systems, which are governed by human behavior.* As a result, all of these engineering systems display characteristics such as a high degree of complexity, unpredictability and counterintuitive emergent behavior.

Students are typically drawn to TPP by the opportunity to gain exposure to a more diverse set of issues beyond those they may have encountered in their previous technical work and research. For many students, this "broadening" experience represents an opportunity to explore new intellectual currents and pursue alternative career paths. A current TMP student summarized the nature of this engineering systems shift in the following manner:

> A student coming to TPP with a traditional engineering background learned to recognize and understand what was outside of their engineering "box". Now, that same engineering student will come to TPP to enlarge and redefine that "box", to understand how the technical systems are actually part of a much broader and more open system made up of interconnected social, economic, legal, political, and cultural systems.

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[1] This description of Engineering Systems is based upon Sussman, J.M. (2000) "Toward Engineering Systems as a Discipline".

This shift to an engineering systems perspective represents a broadening of the perspective by making more explicit and stronger links to the social and political aspects. Engineering systems also provides a useful unifying framework for TPP, since it fosters both a common language and a set of organizing principles among the students, whose policy interests and technical concentrations are very diverse. Through TPP, students should develop a consistent framework for characterizing engineering systems. An engineering systems perspective leads students to ask questions such as:

- What are the subsystems – technical, economic, legal, social, political and otherwise – involved?
- What are the degree and nature of their interaction, and where are the important feedback loops between subsystems?
- What competing values or interests are involved?
- What are the nature and primary source of the system's complexity – is the complexity mainly internal to the technological 'artifact' or related to the social components of the system?
- What is the nature of the uncertainty of the system? When are the subsystems inherently unpredictable, and when is the uncertainty due to the interaction of the subsystems?
- What is the scale (geographic, temporal, etc.) of the system; what is the magnitude and scope of its impacts?

Once students learn to extract the core characteristics and concepts of engineering systems by asking questions like those listed above, they are better informed for choosing the appropriate analytical methods. What is important is to understand the assumptions, strengths and limitations of the various methods – such as cost-benefit analysis, risk assessment, simulation modeling – and to identify where they fit in the context of an engineering system and in the context of policy development. Furthermore, by looking at the open, uncertain and evolving nature of engineering systems, students will understand that these analytical methods do not provide a definitive 'solution', rather that they are used to inform and support an ongoing and dynamic policy process.

The idea of engineering systems fits well with many of the themes that have typically been highlighted by TPP.

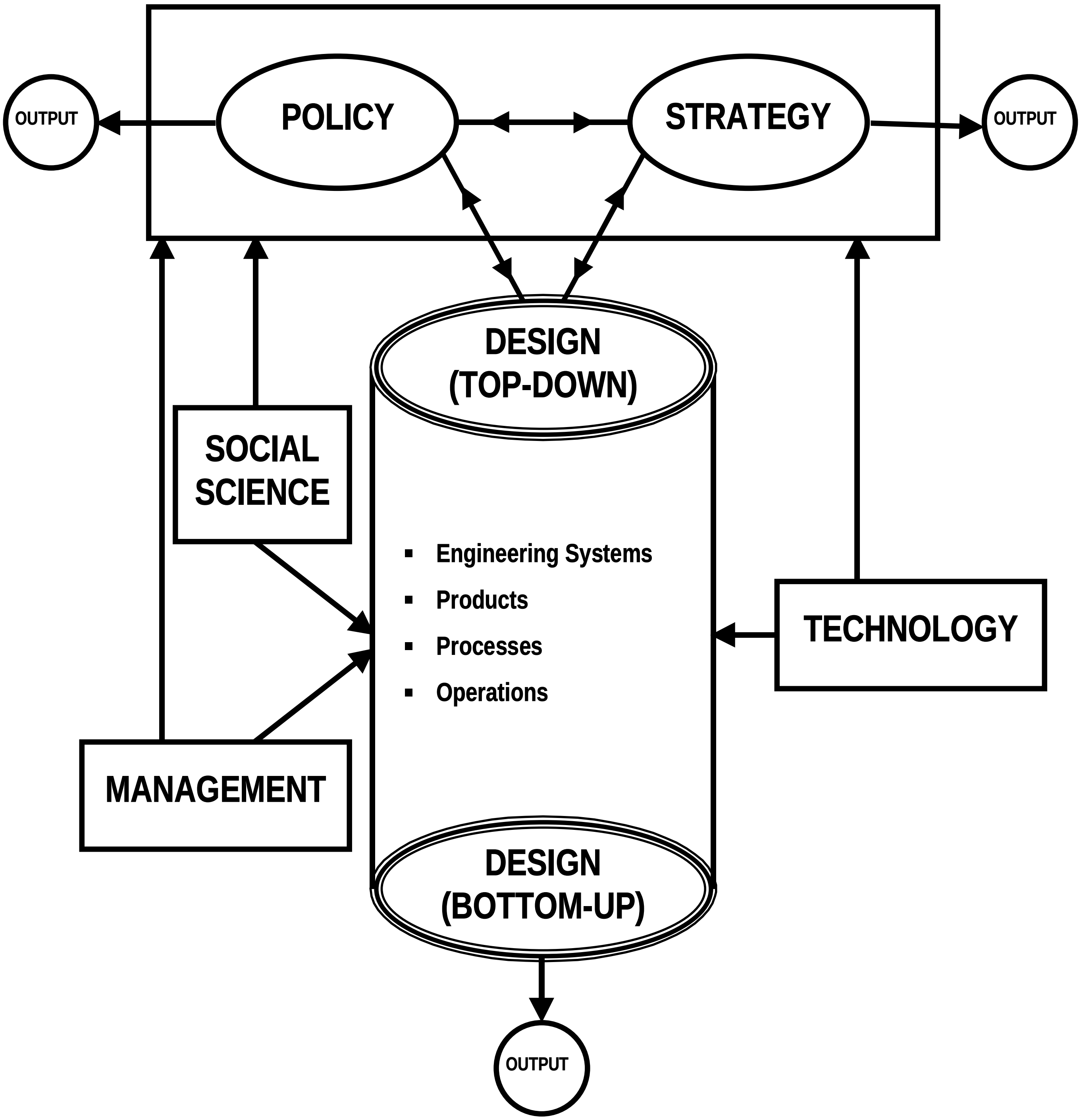
- "Uncertainty Is Everywhere" – Uncertainty is pervasive in Engineering Systems due to the complexity, non-linearity and frequently counterintuitive behavior of CLIOS. How does one assess the different levels and types of uncertainty (technical and non-technical) and their impact on policymaking? Different policy analysis tools are required depending upon the level of uncertainty in the system – decision analysis, scenario building, options, etc. How does one choose? Moreover, certain manifestations of uncertainty, such as indeterminacy and ignorance, cannot be assessed through though traditional analytical techniques, and therefore require policymaking based on social and political decision processes.

- "There Is No Right Answer" – Due to the boundaries of study, dealing with open systems that consider economic, political and social factors means that there is no optimal or unique solution. Tools such as negotiation and consensus building can help generate a workable and acceptable answer.

- "Where you sit is where you stand" – By looking at systems in a more open manner, such as CLIOS, the number and range of decisionmakers and stakeholders increases dramatically. How does this impact the policymaking process? How does one clarify their role in the system, and how does that role impact the relative value they give to different variables? How then does one interact with other actors involved (which actors one has to account for depends where the boundaries have been drawn in this 'open' system)?

In view of the above definition of Engineering Systems, it should be noted that TPP differs from some of the other programs within ESD due to its manner of drawing the boundaries of Engineering Systems. TPP educates students to demarcate Engineering Systems to the broadest extent possible, treating systems as highly open. In this manner, TPP is concerned with a more externally-based form of complexity, placing the social, economic, legal and political factors at the core of the technology/policy issue. Other ESD programs such as Leaders for Manufacturing (LFM) or System Design and Management (SDM) often use a more circumscribed definition of the relevant systems, and therefore are concerned with a more internally-based form of complexity which is more directly related to the technological system or process. However, the approaches in these programs have important similarities, and differ more in emphasis than in concept.

The following diagram tries to capture the universe of ESD academic programs. These programs, in the aggregate, are concerned with the development of policies and strategies related to the design of engineering systems – defined as CLIOS with an important technology component – informed by knowledge in social science, management and technology. Both a) top-down high-level design issues with direct interfaces to policy and strategy and hence external complexity, and b) bottom-up design issues dealing with internal complexity are of importance.


OUTPUT
POLICY
STRATEGY
OUTPUT
DESIGN
(TOP-DOWN)
SOCIAL
SCIENCE
Engineering Systems
Products
Processes
Operations
TECHNOLOGY
MANAGEMENT
DESIGN
(BOTTOM-UP)
OUTPUT

IV. The Curriculum Development Process

The approach taken in generating the draft TPP curriculum template was to conceive of an ideal structure for the program, before introducing resource-related constraints such as who will develop and teach particular subjects. The central questions guiding this exercise include the following:

- What is the *"core" knowledge and skill base* of TPP, and more broadly speaking, of ESD?
- What should be the *structure of the curriculum* – for example, number of credits and sequence of subjects – to integrate this core knowledge?

The meetings of the TPP Curriculum Development Committee have been the central forum to begin answering these questions. Additional insights have been gained from discussions with current and former TPP students, discussions with other individuals familiar with TPP, and cross-comparison with other similar programs.

V. The New TPP Curriculum: Content and Criteria for Evaluation

Intellectual content

In attempting to decide what knowledge and capabilities comprise the "core" intellectual basis of TPP, one could define four different areas of intellectual content.

- <u>Domain Knowledge</u> reflects the individual student's interest in a particular technology and policy area. This interest will often, but not always, be articulated in terms of an engineering system – such as energy, transportation, information technology and the environment – rather than by a discipline or department. Therefore, the domain knowledge requires an in-depth understanding of not only the technical and scientific system, but more importantly, the socio-economic, legal and political systems which together form the broader engineering system.

- <u>Concepts</u> are the principles that guide certain ways of thinking about technology/policy and societal issues. Some of these concepts are related to the policymaking process, including the role of institutions, constraints inherent in public processes, and the effect of counterintuitive behavior and unintended consequences. There are also concepts related to Engineering Systems such as uncertainty, nonlinearity and feedback loops. Concepts should be thought of as the 'key points' or 'takeaways' from a model or framework.

- <u>Methodology</u> includes the *methods*, *models* and *frameworks* used for gathering information, analyzing problems and designing options in both technology and policy. For the purposes of this working paper, models are defined as mathematical representations of a system, whereas frameworks are the qualitative organizing principles for analyzing a system. Methods are the techniques and procedures used to support the analysis. A variety of both quantitative and qualitative tools derived from engineering, management and the social sciences will fall under this category.

- <u>Integration</u> refers to the perspectives and skills that are necessary for addressing issues at the interface of technology and social systems. TPP students should learn how to work with multiple stakeholders, to deal with high levels of uncertainty and multiple layers of complexity, and to identify and negotiate tradeoffs between different values. These abilities are complemented by the development of personal skills in communication negotiation, team building, management of multiple actors and leadership.

These four areas of intellectual content reflect the unique nature of the TPP educational experience, which is intended not only to impart the core analytical skills, but also to enable students to move beyond the *analytical* stages of policymaking to the *formulation* and *implementation* of policies. In this sense, TPP aims to train policymakers, rather than just policy analysts. Learning to move beyond the analytic tools is especially important in issues characterized by deep uncertainty, where the best assessment techniques are inadequate and social decision processes begin to be as important, if not more important.

Criteria for evaluation

The strength of the TPP curriculum can be evaluated using three suggested criteria:

- Breadth indicates an understanding of various relevant perspectives and an ability to draw upon analytical methods, theories and knowledge from a range of disciplines and systems.
- Depth connotes a high level of proficiency in individual quantitative and qualitative analytical methods and a detailed knowledge of specific technological and social systems.
- Integration is the ability to (1) recognize and understand the complex relationships between problems and systems; (2) evaluate, contrast and compare content and methods from a wide range of disciplines and fields of study (while critically reviewing and reconciling the sometimes disparate approaches); and (3) synthesize and communicate ideas and problem solving approaches across disciplinary, professional and other boundaries.

Breadth provides the comprehensive perspective needed to deal with technology/policy issues, while depth provides technical expertise in the performance of rigorous analysis of critical components. Integrative skills enable students to contribute effectively throughout each phase of the policy process, going beyond the engineering to bring out the social, economic and institutional considerations that are crucial to the development, implementation and improvement of policy.

> "Any course or program must be more than the pieces of the disciplines from which it is constructed. Self-synthesis, the assumption that students can integrate materials and ideas themselves, is inadequate" (Klein, 1996).

With the above as background, we now present a draft strawman curriculum for consideration and discussion.

DRAFT STRAWMAN CURRICULUM

Introduction to Technology and Policy (15)[2] [required]
This subject is divided into two intertwined paths, requiring substantial coordination and integration of material in terms of both concepts and issues. Both paths would most likely be team taught – Path 1 by several faculty from science and engineering and the social sciences, depending upon the expertise that is necessary to cover the various topics, and Path 2 by two faculty (as the ProSeminar is currently taught).

<u>Path 1 – Frameworks and Models for Technology and Policy</u> (9)
Students will explore the different perspectives on the policy process – agenda setting, problem definition, framing the terms of debate, formulation and analysis of options, implementation and evaluation of policy outcomes – using various frameworks including:

- Economics and Markets – individual and collective interests, market failures, institutional frameworks, efficiency and equity, negotiation and consensus building
- Law – regulation, legislative and administrative issues, relationship between law and policy, ethics and rights
- Business and Management – innovation, competition and cooperation, regulatory frameworks

In addition to the core frameworks, the subject would also cover some of the models most frequently used in the analysis of technology and policy issues. As defined earlier, frameworks are qualitative organizing principles for analyzing a system, while models are a mathematical representation of a system. The three exemplary models include cost-benefit analysis, risk assessment and system dynamics. Students will not only learn how these models are used (and possibly misused) in practice, but will also examine their underlying strengths, limitations and assumptions.

Furthermore, in order to understand how these models are used in a broader context, each will be examined within the context of one of the core policy frameworks. It should be noted that these policy frameworks use a much broader set of models than those examined in this subject, and in reality there is substantial overlap among different models and policy frameworks. Notwithstanding, for the purposes of the subject, one possible mapping of *frameworks* to *models* could be as follows:

- Economics and Markets – Cost-Benefit Analysis (including Life-Cycle Analysis)
- Law – Risk Assessment
- Business and Management – System Dynamics

While the purpose of this pairing of frameworks to models is to provide a context within which these models are used, it should be recognized that both the policy frames and methods emerge out of a larger social and historical context. In this manner, the subject will "deconstruct" the models to reveal their relationship with the social context in which these models are developed.

<u>Path 2 – Exercises in Technology and Policy</u> (6)
Students would work on developing the skills needed for studying and working on the interface between technology and societal issues. The exercises would be similar in content and style to those used in the current ProSeminar. Simulation exercises, case studies and group projects would illustrate the issues that emerge when dealing with multiple stakeholders, high levels of uncertainty, multiple levels of complexity, and value tradeoffs that are characteristic of engineering systems. Emphasis is on the development of personal skills in negotiation and

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[2] Parenthetic numbers indicate MIT units.

consensus building, team building and group dynamics, management of multiple actors and leadership. Students will be challenged to identify how their values and the values of other individuals both play into the policymaking processes. Assessment of communication and presentation skills will also be a core component of the subject, with emphasis on self-assessment.

The cases and exercises used in this subject will be explicitly linked with the models and frameworks covered in Path 1. An example of how these subjects could map onto one another is as follows:

> Harbor Co. negotiation – risk assessment, cost-benefit analysis, politics
> Simulation of climate change negotiations – international policy/politics, system dynamics, cost-benefit analysis

One goal would be to draw upon the technical expertise and policy experience of the ESD faculty in order to develop a solid and comprehensive set of technology and policy cases and exercises. These teaching tools could range from case studies lasting one class period, to more involved exercises and simulations spanning several weeks or months. It is possible that these teaching tools could evolve into a series of cases and exercises comparable to the case studies of Harvard Business School. Ideally, these "Policy Exercises for Engineering Systems" could be used not only in the other ESD educational programs, but could be more broadly marketable to other institutions dealing with issues at the intersection of technology and policy. As a part of this subject, students will participate in the TPP Thompson Island weekend, in which they will take part in case exercises as well as activities related to leadership and group dynamics. In addition, these latter activities should be integrated with concepts from Organizational and Behavioral Sciences – Introduction to Leadership.

Core Models and Frameworks (36) [required]

Applied Microeconomics (9)
The material covered in the subject would be similar to that of the current Microeconomics subject taken by TPP students through the Sloan School (15.011).

Organizational/Behavioral Sciences – Introduction to Leadership (9)
This subject fulfills two objectives. It starts by introducing an analytical framework for understanding organizational processes from strategic, political and cultural perspectives. It then moves on to focus on specific processes related to leading and working in teams, negotiation and conflict resolution, and managing diversity and change in organizations. Students will learn to assess and enhance their own leadership skills by examining their particular leadership style, observing and assessing the style of others, and practicing and receiving feedback on their own leadership styles as they move through TPP. They will also be challenged to identify how their personal values influence how they exercise leadership. The material in this subject builds on modules currently used in Sloan as well as in other ESD programs, in particular the subjects taught by Tom Kochan and Deborah Ancona.

Law, Technology and Public Policy (9)
This would continue in the same form as the subject currently team-taught by Nicholas Ashford and Charles Caldart. Topics cover a broad range of issues: the role of scientific evidence and experts, administrative and statutory law, intellectual property rights, standards for judicial review, occupational safety and environmental standards.

Political Economy of Technology/Policy (9)
The content of the subject would be based on Ken Oye's subject on Science, Technology and Public Policy. (See Appendix D for the current syllabus of 17.301/STS.082.) The subject is structured around the major economic and political theories of regulation and other forms of government intervention, using those theories as a platform to explore cases where issues of science and technology enter into the debate. Topics covered include (1) major justifications for and criticisms of public policies, (2) debates over policy responses to sources of market failures, (3) debates over the creation and assessment of knowledge, and (4) debates over ethics, with emphasis on cases involving uncertainty.

Methods (21) [required]

Uncertainty in Engineering Systems – Applied Probability and Statistics (12)
This subject would (1) introduce the analytical methods of systems engineering and policy analysis that require a fundamental understanding of probability and statistics, and (2) bring these methods together under a common conceptual framework of risk, uncertainty and stochasticity. Methods and topics could include: Probability Distributions, Regression Analysis, Applied Bayesian Methods, Sensitivity Analysis, Risk Assessment, Decision Analysis, Value of Information, Utility Theory and Risk Aversion, Investment and Options, Scenario Building, Simulation.

Advanced Methods and Applications (9)
Although it is anticipated that many students would complete *both* an Advanced Methods subject as well as one or two of the Modules, students would have the choice to fulfill this requirement with either three Modules or one Advanced Methods subject.

Methods Modules (Three 3-credit modules) (9)
In order to provide flexibility for students to develop skills in variety of methods, a designated set of methods will be developed as 3-credit modules. Each module would provide an intensive introduction to specific models and techniques, and focus on the application of these methods. Students would be encouraged to choose their modules so that they have diverse set of methods that are applicable to their Engineering Systems concentration. Methods modules could include the following:

- risk assessment
- cost benefit analysis
- system dynamics
- economic equilibrium modeling
- econometrics
- finance theory
- linear programming
- non-linear programming
- simulation
- game theory
- qualitative research methods (fieldwork, interviewing)
- case studies
- survey research and questionnaires
- epidemiology
- toxicology

The methods in above list could represent entire modules, or in some cases, several sets of methods would be combined within a single module. These modules are envisioned as

ESD modules, which would be available to all of the ESD academic programs. In this manner, this set of modules could serve as a platform subject for ESD, and support the development of these analytical skills for all of the ESD academic programs. Each 3-credit module would be a stand-alone module. However, there would need to be consistency in workload between modules. The number of modules we have listed above is ambitious. In reality, this number would be constrained by the time and resources available to teach each one of these.

Advanced Methods (9)
Alternatively, students could fulfill this component by taking one advanced subject in a chosen methodological area – such as those areas emphasized in the above list of methods modules. Although there will not be a restricted list of subjects that could fulfill this requirement, faculty advisors will review the student's selection to ensure that the subject is sufficiently rigorous in a methodology that is applicable to issues in technology/policy. Moreover, it is intended that the student will exercise his/her skills in these methods during the completion of the student's thesis.

Supporting Coursework (4) [required]

Seminar in Technology/Policy (2)
The Seminar would consist of two main activities: (1) presentations and highly interactive Q&A sessions with prominent guest speakers, including national players in the field of technology/policy, and (2) an 'issues and ideas' component, in which students would discuss and debate current issues in technology/policy.

Leadership Development (2)
As the second part of leadership development, following on the leadership components of Organizational/Behavioral Sciences, this subject promotes students' self-assessment of their own leadership skills as well as drawing lessons from the summer internship.

Engineering Systems Concentration (27)
The Engineering Systems Concentration would require a minimum number of subjects (approximately 3 subjects). Students would have substantial flexibility in defining their engineering systems concentration, creating a combination of subjects that comprehensively address the various technical, scientific, social, economic and/or political components. The coursework could be comprised of a combination of 9 and 12 credit subjects.

Advanced Proseminar (9) [required of students for whom there is an appropriate Advanced Proseminar]
The concentration would also include a 9-credit subject similar to the current Advanced Proseminars (Global Climate Change, Energy Systems and Economic Development, Telecommunications Modeling, Industrial Ecology). Ideally, the set of Advanced Proseminars would be sufficient to address the broad range of interests of the TPP student body. However, it would be necessary to periodically review the interests of TPP students and to develop new Advanced Proseminars whenever a critical mass of students involved in a particular Engineering System emerged.

Because the Advanced Proseminars can realistically focus on only a limited set of Engineering Systems, these subjects would not be required of students whose Engineering System concentration did not overlap with any of the Advanced Proseminars. In that case, students would be required to take an additional Engineering Systems elective, preferably one with a substantial policy component.

Master of Science Thesis [required]
Through their individual thesis work, students will integrate the knowledge and skills developed over the course of the program. Students will be expected to build upon their domain knowledge and use an appropriate set of methods in order to provide a comprehensive assessment of a particular technology/policy issue. This will be the core integrative exercise for students. It will challenge them to synthesize the concepts, methodology, and domain knowledge of their engineering system concentration, in order to apply this set of knowledge to a concrete technology/policy issue.

TPP lies on the spectrum between the two extremes of a purely professional program and an academic program. Therefore, while development of professional skills for working in the field of technology and policy is important, the program also emphasizes the theoretical underpinnings of these issues. For this reason, the Master of Science Thesis continues to be an integral part of the program's requirements.

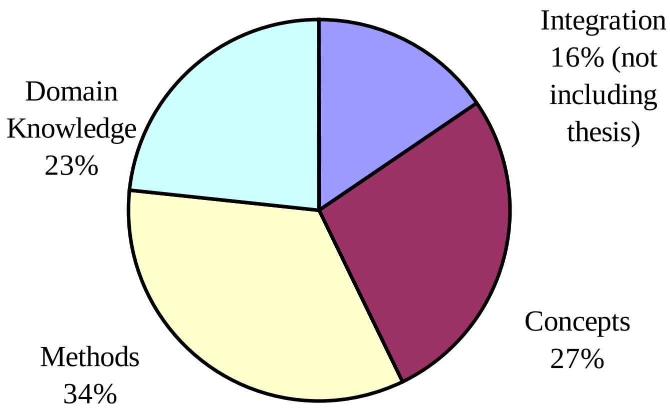
Matrix of Subjects and Content

The following matrix identifies how this coursework addresses the four areas of intellectual content. Since a subject may contribute to several areas of intellectual content, we have attempted to estimate approximately what fraction of each subject would contribute to each of the four areas.

SUBJECTS	TOTAL UNITS	DOMAIN KNOWLEDGE	INTEGRATION	CONCEPTS	METHODOLOGY
INTRODUCTION TO TECHNOLOGY/POLICY					
Path 1 – Frameworks and Models	**9**		2	5	2
Path 2 – Exercises in Technology/Policy	**6**		4	2	
CORE MODELS AND FRAMEWORKS					
Applied Microeconomics	**9**			3	6
Organizational/Behavioral Sciences	**9**		3	3	3
Law, Technology and Public Policy	**9**			6	3
Political Economy of Technology/Policy	**9**			6	3
METHODS					
Uncertainty in Engineering Systems	**12**			3	9
Methods (modules) *or* Advanced Methods	**9**				9
SUPPORTING COURSEWORK					
Seminar in Technology/Policy	**2**		2		
Leadership Development	**2**		2		
ENGINEERING SYSTEMS CONCENTRATION					
Engineering Systems Electives	**27**	18			
Advanced ProSeminar		*6*	*3*		
Masters Thesis		**X**	**X**	**X**	**X**
Total number of subject units **not including thesis*	**103**	**24**	**16**	**28**	**35**

The following chart shows the share of coursework that fulfills each area of intellectual content: domain knowledge, concepts, methodology and integration.

Distribution of course units by intellectual content



Although there is a relatively even distribution of content, slightly greater emphasis is placed on the "Methods" component of the program. "Integration" has fewer devoted class hours, however, as discussed below, many of the "Integration" skills and concepts will be an implicit part of the learning process throughout the TPP program. Furthermore, with respect to the Integration component, the Master's Thesis is intended to address all four areas as the core integrative exercise.

VI. Review of the Draft Curriculum

Evolution of TPP Core Knowledge
The required subjects in the draft curriculum represents the core set of knowledge, concepts and skills that we suggest every TPP graduate should have.

The table below provides a comparison of the new curriculum with the old curriculum. Although some modifications have been made to the current curriculum required for the new TPP class of 2000, we have compared the strawman curriculum to that of 1999, since that has been the traditional format of the TPP common core. See Appendix C for a more complete description of the curriculum for the incoming TPP class of 1999.

OLD CURRICULUM **(Class entering in 1999)**	**NEW CURRICULUM**
COMMON CORE **Block 1: Core Subjects** ESD.801 Introduction to Leadership (3) ESD.11 Proseminar (12) ESD.1xx Advanced Proseminars (9) ESD.87 Thesis Seminar (3) ESD.811 Internship Seminar (units arranged) **Block 2: Analytic Framework** ESD.71 Dynamic Strategic Planning (9) 15.011 Applied Micro-economics (9) ESD.131 Law, Technology and Public Policy (9) **INDIVIDUAL PROGRAM** **Block 3: Concentration** Four subjects in technology and policy/social sciences (approximately 36) **Block 4: Thesis**	**REQUIRED CORE** **Introduction to Technology/Policy (15)** Path 1 – Frameworks and Models for Technology/Policy (9) Path 2 – Exercises in Technology/Policy (6) **Core Models and Frameworks (36)** Applied Microeconomics (9) Organizational/Behavioral Sciences (9) Law, Technology and Public Policy (9) Political Economy of Technology/Policy (9) **Methods (21)** Uncertainty in Engineering Systems (12) Methods Modules (Three 3 -credit modules) *or* Advanced Methods (9) **Supporting Coursework (4)** Seminar in Technology/Policy (2) Leadership Development (2) **Engineering Systems Concentration (27)** Includes an Advanced Proseminar (9) when available. **Thesis**
~ 90 Total Units	**103 Total Units**

Comparison with Existing Curriculum

The draft curriculum, with 103 required units (as compared to the former requirement of 90 units), provides a more comprehensive, integrated and rigorous set of required core subjects. However, the expanded set of requirements also may limit to some extent the students' flexibility in designing their own program. With the addition of 13 units in this strawman curriculum we are making a slight tradeoff between flexibility and increased rigor, although there is substantial flexibility in two components – Methods and Engineering Systems Concentration.

In order to highlight specific differences and similarities between the two curricula in greater detail, we will review which components of the curriculum: (1) require major modifications or the development entirely new subject material, (2) have minor modifications in content, structure, or requirement status, or (3) remain essentially unmodified.

Major Modifications

- Path 1 would represent a new subject, although it would integrate many of the models and frameworks that are covered in current subjects such as the Proseminar and Dynamic Strategic Planning (DSP).
- Uncertainty in Engineering Systems would reflect much of the material in DSP (such as decision analysis under uncertainty, options analysis, and risk aversion in utility analysis) while incorporating a broader set of models and frameworks related to uncertainty and applied probability and statistics.
- The Methods Modules and Seminar in Technology/Policy are both entirely new in terms of both content and structure.
- Organizational Science and Leadership, although building upon material from subjects currently offered in Sloan and for the LFM and SDM programs, would represent a new perspective and framework for TPP's core program.
- Political Economy of Technology/Policy, a new subject for TPP, is currently being offered as a subject in Political Science, and cross-registered with Science, Technology and Society.
- Leadership Development would be a new subject emphasizing leadership skills and linking the content of the subject to Organizational Science and Leadership, which students will have taken in the previous year.

Minor Modifications

- The content of Path 2 would be similar to the cases and exercises used in the current Proseminar, although with a reduced number of credits, since the frameworks and models that are currently included in the Proseminar would be introduced in Path 1.
- Advanced Methods, although a new requirement for TPP, would be selected from a variety existing subjects in other departments. It would be expected that the subject would be both rigorous and relevant to the engineering system concentration of the student.
- The Engineering Systems Concentration would be similar to the current elective structure of TPP, giving the students a large degree of flexibility in selecting their concentration subjects. However, the Advanced Proseminar would be included in the concentration rather than as part of the common core. This means that only those students for whom a relevant Advanced Proseminar was offered would be required to take this subject.

Unmodified

- The Master's Thesis would continue to be a core component of the program, allowing students to integrate and deepen the knowledge, concepts and methodologies which they have developed over the course of their classes and research. The TPP Master's Thesis Committee, chaired by Joel Clark, is working to establish guidelines for the acceptance of theses, in order to ensure that all theses have a substantial policy content. Toward this purpose, students will be required to designate a policy reader to supervise and provide input regarding the policy contribution of the thesis.
- Law, Technology and Public Policy and Applied Microeconomics are both unmodified.

Breadth, Depth and Integration

Returning to the three criteria for evaluation, we can now review how the new TPP curriculum addresses these three components.

- Breadth – Path 1 – Frameworks and Models for Technology/Policy is intended to provide a broader and more comprehensive introduction to the various core frameworks in technology/policy. With respect to methods, the flexibility offered by the modular format allows for greater breadth by offering a wide-ranging set of quantitative and qualitative methods from both engineering and social sciences.
- Depth – Through the methods modules and Advanced Methods, students can achieve a greater degree of analytical depth in their chosen set of methods. Additionally, Path 1 – Frameworks and Models for Technology/Policy has a more in-depth introduction to three exemplary models in technology/policy. The Engineering System concentration provides depth in the domain knowledge relevant to the students' interest.
- Integration – Paths 1 and 2 of the Introduction to Technology/Policy are designed to build the integrative skills of TPP students. By providing a comparative survey of models and frameworks, this will foster students' ability to compare, contrast and synthesize. The Seminar in Technology/Policy is also intended to provide a structured forum for integration of issues in technology/policy. These two subjects should leverage the unique diversity of the students in TPP. Much of the learning that occurs in TPP is linked to the interaction between students. Therefore, students should be encouraged to draw upon their own personal, cultural, educational and professional background as much as possible. Finally, on an individual level, the Master's Thesis will continue to be the core integrative experience for the student.

VII. Further Considerations for Curriculum Development

Implicit versus Explicit Learning

In developing both the curriculum structure and individual subject material, it is important to differentiate between what needs to be taught and what students need to learn. While some concepts should be covered *explicitly* in the coursework, other concepts and skills will be communicated *implicitly*.

Some of the more implicit concepts include:

- Values
- Communication (written and verbal)
- Negotiation
- Systems thinking
- Diversity
- Leadership

While concepts such as values, cannot be explicitly "taught" in any traditional sense, coursework and subject material can be designed to reveal the differences in value systems that form the basis of many of the most contentious issue in science and technology policy. Although, this more implicit type of learning may be more difficult in a classroom setting, it is important to surface concepts such as values, so that students can identify their own set of values, and communicate more effectively across different value systems. These implicit concepts will be interwoven as cross-cutting issues across multiple subjects. Many of these skills, rather than being taught, will be developed by students in situations ranging from in-class exercises such as negotiations and group projects to involvement in various student societies. Notwithstanding, subjects need to be deliberately structured to foster this implicit mode of learning, by providing a forum for discussion and debate, and allowing for feedback (from peers as well as faculty) on a students' skills in communication, negotiation and leadership.

Example of Explicit and Implicit Learning: Leadership

Leadership provides an outstanding model of how to integrate these explicit and implicit modes of learning. In the first-semester subject, Organizational/Behavioral Sciences and Introduction to Leadership, students would be introduced to the various modes of learning about leadership:

- Cognitive Learning (readings and classroom discussion)
- Practice (exercising leadership as the opportunities arise daily)
- Modeling Others (assessing diverse people's leadership styles)
- Reflection (keeping a "leadership notebook")
- Feedback (from peers, faculty, mentors, others--seek it out)

Students would then be challenged to develop their own leadership skills by continuously asking the following questions.

- Will you engage in any Leadership activities?

  Technology Policy Student Society (TPSS) or Graduate Student Council Governance, TPSS Seminar Series, TPSS Career Series, Summer Internships.

- What skills do you want to work on while you are here?

  Diagnosing situations, building relationships both inside and outside of MIT, influencing others, negotiating, mobilizing others for action, giving speeches, teaching, creating change, creating a learning environment, understanding yourself?

- How might you go about gaining those skills?

Make a notebook. Keep a log of leadership encounters. Use it to learn from others (modeling), and to eventually write your own leadership signature. Keep it for use in classes that discuss leadership.

Many of these issues will be raised again in the Leadership Development subject in the third semester, which will build upon students' experiences in summer internships or other leadership-related experiences.

Identification of Leading Issues

As stated by Dan Hastings, the stretch goal of TPP is to "show our leadership by being at the leading edge of every new techno/policy issue" (Hastings, 2000). The Seminar in Technology Policy provides students with the opportunity to discuss the leading issues in technology and policy, and to hear from the national players in this field.

In addition, TPP should establish a periodic review of the subject selections available to TPP students, to assure that TPP provides the subjects that examine the major emerging issues on both the national and international level.

Time sequence

The time sequence will often be dictated by practicalities such as subject availability and time conflicts. Nonetheless, ideally there would be a progression in terms of *depth* (in the methods components and the engineering systems concentration) as well as *integration* (culminating in the thesis). Typically, the distribution of credit hours would follow a rough pattern of 3-3-2-1, although this would vary by student. This tapering down of subject load enables students to gradually shift their focus to research and their master's thesis.

- **First Semester (33)**

Introduction to Technology/Policy – Path 1 and 2 (15)
Applied Microeconomics (9)
Organizational/Behavioral Science and Leadership (9)

- **Second Semester (30)**

Uncertainty in Engineering Systems (12)
Law, Technology and Public Policy (9)
Advanced ProSeminar *or* Engineering Systems Concentration (9)

Preparation of Thesis Proposal

- **Summer Internship [optional]**

- **Third Semester (26)**

Political Economy of Technology/Policy (9)
Engineering Systems Concentration (9)
2 Methods Modules (6)
Leadership Development (2)
Thesis Proposal Due on the third week of the fall semester

- **Fourth Semester (14)**

Seminar in Technology/Policy (2)
1 Methods Module (3)
Engineering Systems Concentration (9)

Completion of Thesis

Modules versus Integrated Coursework
There are different approaches to creating an integrated curriculum, which provides students with the skills and perspectives of multiple disciplines in an *integrated* yet *flexible* manner. One approach is to provide integrated subjects drawing from material in multiple disciplines, while another is to provide shorter, single-disciplinary modules.

Larger integrated subjects that incorporate a variety of single-discipline perspectives and methods in a comparative manner "provide more coherence and linkages between otherwise unlinked curriculum elements" (Thissen, 2000). The Introduction to Technology/Policy and Uncertainty in Engineering Systems are two examples of this type of larger integrated subject. In contrast, smaller and more flexible part-semester modules allow the students themselves to select and develop their own portfolio of different disciplinary skills and frameworks, although the individual subjects themselves do not stress integration. The Methods Modules are structured in this manner. Our approach attempts to balance the need for the coherence provided by integrated coursework with the flexibility provided by a modular structure.

An additional consideration, related to the use of modules, is whether any of these components could be delivered more effectively during the Independent Activities Period (IAP). The three-unit methods modules would be obvious candidates for IAP subjects. However, offering some of the full-semester subjects during IAP could relieve some of the subject load of the first two semesters.

Completing a Second Master's
Given the large number of TPP students pursuing dual-degrees, the curriculum must maintain enough flexibility for those students pursuing a second Master's. It would also be advantageous if some of the new subjects developed for the new TPP curriculum were cross-registered and therefore could be used to fulfill subject requirements for other departments. The minimum number of credits for two degrees at MIT is 132 total credits, with 66 in each degree program. The draft TPP curriculum would require 103 credits. In order to obtain two degrees, a student would leverage the Engineering Systems Concentration (27 credits) to fulfill the requirements of both TPP and the second degree. This would account for nearly half of the 66 credits required for a second degree, meaning that students may need to take three additional subjects in order to complete the second degree. There may be more specific subject requirements for other degree programs that need to be taken into consideration when planning the TPP curriculum.

Resources outside of ESD
Students will also be encouraged to draw upon the resources available through other MIT and non-MIT programs. For example, many students take technology/policy subjects offered at the John F. Kennedy School of Government and the Science, Technology and Society (STS) program at MIT. A brief description of these programs is found in Appendix B.

Distance Learning
While the future distance delivery of subjects will be an important consideration as TPP works to collaborate with other programs internationally, the focus of this working paper is on developing a two-year program for students residing in the Boston/Cambridge area.

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APPENDIX A:
TPP and Integrated Assessment methods

Integrated Assessment methods provide an interesting framework for thinking about the Technology and Policy Program. There are several similarities between Integrated Assessment methods and the educational objectives of TPP including: dealing with highly complex issues, integrating knowledge and methods from multiple disciplines, and working at the interface between science, technology and policy.

Definition of Integrated Assessments

The term 'Integrated Assessment' (IA) covers a wide range of methods that combine technical knowledge from multiple disciplines in order to assess policy options and inform policy makers dealing with highly complex issues which require expertise from multiple disciplines.[3] IAs have been developed primarily to deal with environmental issues such as acid rain and global climate change. Rather than generating new scientific findings, integrated assessment is instead "recognized by its purposes… assembling, summarizing, organizing, interpreting, and possibly reconciling pieces of existing knowledge, and communicating them so that they are relevant and helpful for the deliberations of an intelligent but inexpert policy maker" (Parson, 1995).

Although several analogies can be drawn between TPP and IA, there is a fundamental difference between the two. IA intends to inform and support the policy-making process, while TPP trains students to be an active part of the policymaking process itself. This difference highlights the importance of the "culture" component of TPP, which develops the skills needed to move beyond the policy analysis stage and become influential members of the policymaking process itself.

Three Dimensions of 'Integration'

The three primary dimensions of integration include 1) integration of technical and social issues, 2) integration of methods and models from multiple disciplines, and 3) integration of research communities and social actors, including policy makers, decision makers, and stakeholders.

- Integration of Issues – to confront exceedingly complex issues such as global climate change that span multiple issues related to the physical environment, socio-economic and technological systems, political interests and governmental institutions.

- Integration of Disciplines – to gain a comprehensive understanding of complex technology/policy issues that is not based on disciplinary boundaries, rather on boundaries defined by the problem, therefore requiring methods and models from various disciplines.

- Integration of Science and Policy – to ensure that the problem is framed according to the needs of the policymaker, not according the research interests of the scientists; to foster communication and interaction between the scientific community analyzing the issue, and the policy community that will translate that analysis into policy action.

Relevance to TPP

These three types of integration can provide some guidance for the content of the TPP curriculum. First, students with an engineering background may not know how to frame an issue according to the policy problem. There is a strong temptation to fall upon the conceptual (engineering) framework with which one is the most comfortable, but which may result in addressing only a narrow set of issues. This may require a certain degree of 'de-programming' in order to deal with unstructured and messy problem

3 See Dodder (2000) for a discussion of Integrated Assessments (in the context of the Mexico City Air Quality Project).

situations (Thissen, 2000). Second, students need to develop flexibility in their methodologies (quantitative and qualitative) and learn to critically review and reconcile a variety of disciplinary approaches. Third, the dialogue between the technical/scientific community and the policymaking community is not automatic, and requires strong communication skills if one hopes to achieve technically-sound and scientifically-informed policy outcomes.

The experience of past integrated assessments highlights some of the issues encountered when dealing with a complex policy issue using the methods of multiple disciplines.

General issues:
- combining the subjective and objective aspects of the analysis
- ensuring the legitimacy of the analysis and the value judgements it may contain

Modeling and analytical issues:
- propagating uncertainty
- dealing with models of different resolutions and scales
- choosing between top-down and bottom-up analysis
- validating and calibrating results of different models

Issues at the science/policy interface:
- fostering dialogue between the scientific/technical community and the policy community.
- defining the set of stakeholders
- incorporating stakeholders' concerns and preferences
- understanding the different roles of policy makers and decision makers

Nevertheless, a basic underlying lesson of IA is the need for a policy framework which "attempts to integrate technical, social and economic aspects of [technology/policy] problems in a systematic and consistent way" (Bohnenblust and Slovic, 1998).

APPENDIX B:
Background Material for Related Subjects

The AAAS Guide to Graduate Education in Science, Engineering and Public Policy provides an overview of programs in the US. It categorizes the programs according to the five types listed below.

The link for this online guide is www.aaas.org/SPP/DSPP/SEPP/Sepslpc.htm

Programs in Science and Technology Studies:
- Cornell
- Eastern Michigan
- Rensselaer Polytechnic Institute
- Virginia Tech

****Programs in Science and Technology Policy:**
- **The George Washington University
- **University of Minnesota
- Princeton

Public Policy Programs:
- University of Chicago
- Duke
- Georgia Institute of Technology
- University of Pennsylvania
- Rutgers
- University of Texas

****Engineering/Public Policy Programs:**
- **University of California at Berkeley
- **Carnegie-Mellon (Engineering and Public Policy – EPP)
- **Massachusetts Institute of Technology (Technology and Policy Program)

Other/Interdisciplinary Programs:
- University of Delaware (Energy and Environmental Policy; Ph.D. in Technology, Environment and Society)
- Duke (several interdisciplinary programs)
- Florida State University (Public Administration)
- Indiana University (Public Affairs and a number of joint degrees)
- University of Oklahoma (Science and Public Policy-joint degree)
- Syracuse (Public Administration with a focus on technology)
- University of Washington (Public Administration and a number of joint programs)
- Washington University (several joint programs)

The programs with the most relevance to TPP in terms of curriculum are those marked with **. More detail on the curricula of these programs is provided below. Other curricula can be taken from the web page above, or are available in hard copy from Rebecca Dodder.

CARNEGIE-MELLON
ENGINEERING AND PUBLIC POLICY (EPP)

www.epp.cmu.edu/recovered/grad_epp.htm

Subject Requirements:

<u>CORE (Subjects on policy research and problem-solving skills)</u>

- Introduction to Applied Policy Analysis – 12 units
- Decision Analysis Fundamentals – 6 units (mini)
- Introduction to Optimization Methods for Policy Analysis –6 units (mini)
- Dynamic Systems for Policy Analysis – 6 units (mini)
- Workshop in Applied Policy Analysis – 6 units (full semester)
- EPP Project Management – 12 units

<u>TYPE A (Subjects in engineering, science, applied math and statistics)</u>

- Probability and Estimation Methods for Engineering Systems –9 units
- Approved math elective – 9-12 units
- 36 units of technical subjects in area of focus

<u>TYPE B (Subjects in social science and social analysis)</u>

- Applied Microeconomics – 12 units
- 27 units of subjects in social science and social analysis in area of focus, with at least 6 of the units in the area of political science, regulation or law.

Overall, students are expected to take at least 126 units beyond the B.S. degree to fulfill the requirements for a Ph.D. in Engineering and Public Policy:

A minimum of 42 units in core subjects
A minimum of 54 units in Type A subjects
A minimum of 39 units in Type B subjects

Candidates for the M.S. degree must complete a minimum of 108 units:

A minimum of 48 units in core subjects
A minimum of 27 units in Type A subjects (12-704 plus two technical subjects)
A minimum of 24 units in Type B subjects (90-908 plus one social science/social analysis subject)
A minimum of nine units in independent research (19-750)

In addition, students must pass the Qualifying Exams, at least at the M.S. level, as described below. Joint M.S. programs may impose additional requirements.

UNIVERSITY OF CALIFORNIA AT BERKELEY
JOINT MASTER OF PUBLIC POLICY/MASTER OF SCIENCE PROGRAM

School of Public Policy link: www.violet.berkeley.edu/~gspp/
College of Engineering link: www.coe.berkeley.edu

Subject Requirements:

It should be noted that this is a very small program (one to three students accepted each year). There is really no curriculum, as there are only loose formal rules beyond the public policy and engineering degree requirements. Students' programs tend to be highly diverse and innovative.

The joint program requires the first-year core program in Public Policy, required subjects specific by the relevant engineering department, and a year of electives plus thesis to be arranged specifically by the student, the Goldman School of Public Policy and the department within the College of Engineering.

The first-year core program includes:
- Introduction to Policy Analysis
- The Economics of Public Policy Analysis
- Law and Public Policy
- Political and Agency Management Aspects of Public Policy
- Decision Analysis, Modeling, and Quantitative Methods

GEORGE WASHINGTON UNIVERSITY
MASTER OF ARTS IN
SCIENCE, TECHNOLOGY, AND PUBLIC POLICY (STPP)

www.gwu.edu/~elliott/academicprograms/ma/stpp/curric.html

Subject Requirements:

STPP is a career-oriented program within the Elliott School of International Affairs. The multidisciplinary 36 credit M.A. program in Science, Technology, and Public Policy includes:

- A core field (minimum of 12 credits) in science, technology, and international affairs, which allows students to concentrate on areas of particular interest, such as space policy, the environment, or the politics and economics of research, development and innovation in specific sectors (including information technology).

- Elective field (minimum of 9 credits), which reflect individual academic interests and career goals.

- A 6-credit analytical competency requirement, which provides career-enhancing, marketable skills in policy analysis and public administration, economic theory or statistics.

- A 3-credit research project, that addresses a policy problem in the area of science, technology, and international affairs.

- A three-credit interdisciplinary capstone subject that integrates previous coursework through a series of papers and a policy exercise.

- To provide practical, hands-on skills, the program may include up to three credits of special skills-based workshops, designed to supplement substantive graduate coursework with practical skills and knowledge that students will need to perform effectively in the workplace.

UNIVERSITY OF MINNESOTA
MASTER OF SCIENCE IN
SCIENCE, TECHNOLOGY AND ENVIRONMENT POLICY

www.hhh.umn.edu/gpo/degrees/mste/

Subject Requirements:

The M.S. program requires 40 semester credits. Within this total, students must complete 22.5 credits in the required subjects listed below. Six additional credits can be used to complement a student's previous training: appropriate subjects in science or its history or philosophy for those with social science backgrounds or appropriate subjects in the social sciences for those with natural science backgrounds. Students may elect either a Plan A (thesis) or Plan B (nonthesis) program. For those pursuing a Plan A program, the master's thesis will be awarded 10 credits, and students will have to complete a minimum of 1.5 additional credits.

For those pursuing a Plan B program, 8.5 credits of additional electives must be chosen in consultation with their advisers. Plan B students also take a capstone seminar or workshop (3 cr.) in which they complete their Plan B papers.

<u>REQUIRED SUBJECTS</u>

- PA 5012 Politics of Public Affairs
- PA 5021 Economics for Policy Analysis and Planning I
- PA 5701 Science and State
- PA 5711 Science and Technology Policy
- PA 5721 Energy and Environmental Policy
- PA 5722 Economics of Environment and Natural Resource Policy

<u>Two of the following:</u>

- PA 5032 Intermediate Regression Analysis
- PA 5033 Multivariate Techniques
- PA 5034 Community Analysis and Planning Techniques
- PA 5035 Survey Research and Data Collection

Students who have not taken prior coursework in statistics will need to take PA 5031 Empirical Analysis I in place of one elective subject.

JOHN F. KENNEDY SCHOOL OF GOVERNMENT
MASTER IN PUBLIC POLICY

POLICY AREA CONCENTRATION IN
SCIENCE, TECHNOLOGY AND PUBLIC POLICY

www.ksg.harvard.edu/catalogue/index.htm

The MPP program requires two years (four terms) of full-time study in residence at the school. MPP candidates complete eighteen units of academic credit, eight of which are required subjects. Of the remaining ten credits, three must be earned in a specific Policy Area Concentration (PAC). One of those PACs is Science, Technology and Public Policy.

Core Curriculum
First-year required subjects include:
- The Responsibilities of Public Action (api-601)
- Markets and Market Failure (api-101)and Economic Analysis of Public Policy (api-102)
- Quantitative Analysis and Empirical Methods (api-201) and Empirical Methods II (api-202)
- Mobilizing for Political Action (pal-110) and Political Action Skills (pal-111m)
- The Strategic Management of Public Organizations (stm-101)
- Financial Management in Public Sector Organizations (stm-401m)

Spring Exercise
Spring Exercise is a unique subject, providing practice in integrating the skills of the core by requiring students to develop and present a professional analysis of a real policy problem. Spring Exercise takes place in the two weeks before spring break. During that period, the other core subjects are suspended, and MPP faculty participate in the exercise.

In the second year, all students engage in the Policy Analysis Exercise (PAE), in which they examine an existing public- or nonprofit-sector problem presented by a client organization, and develop a recommendation that the client can implement. The PAE, which can be carried out individually or in small groups, culminates in a 40-page paper.

Many MPP graduates point to the PAE as one of the true highlights of their Kennedy School education. They work with a real-world client — but under the close supervision of faculty advisors with expertise in the topic area.

Elective subjects
In most cases, students enter a PAC by selecting an introductory survey subject in their first term. They develop the concentration further in the second year through a subject focusing on advanced topics and related methods in that field, and a policy-oriented seminar which culminates in the Policy Analysis Exercise. Students take at least three electives within their PAC. Beyond this requirement, the choice of electives is entirely up to the individual.

For the PAC in Science, Technology and Public Policy, a selection of the subjects offered is listed below:
- Science, Technology and Public Policy
- Seminar in Science, Technology and Public Policy
- Critical Perspectives on Policy Analysis
- Technology, Innovation and Economic Growth
- Science, Power, and Politics

- Autonomy and Information: Relationship Between Individual and Government in the Digital Age
- Virtual Diplomacy
- The Internet: Business, Law and Strategy
- Internet Commerce and the Information Economy
- Information and Media Regulation and Public Policy
- Issues in Science and Technology: Designing and Conducting S & T Assessments

MIT – SCIENCE, TECHNOLOGY AND SOCIETY

DOCTORAL PROGRAM IN THE HISTORY AND SOCIAL STUDY OF SCIENCE AND TECHNOLOGY

Students take at least ten subjects in the doctoral program prior to taking general exams in their third year. All graduate students take three required subjects: a seminar in historical methods, a seminar in social theory and analysis and an integrative seminar. Students also choose two foundation subjects designed to provide substantive, disciplinary knowledge. Foundation subjects are offered in history of technology, history of science, ethnographic methods, social studies of science, and history of medicine. Five other seminars complete the Program's ten-subject requirement. A first- and second-year paper are requirements to proceed to general examinations and the dissertation.

Some of the graduate seminars offered in 1998-99 included "Systems and Self" (Turkle); "Aspects of 19th Century Physics" (Buchwald); "Introduction to Environmental Studies" (Keniston, Marx, Conway); "Language, Gender and Science" (Keller); and "Analysis of Strategic Nuclear Forces" (Postol).

<u>Requirements</u>

Languages: All students must demonstrate a reading knowledge of two scholarly languages other than English (non-English speaking students may use their native language for one of these). Options exist for substituting either statistics or competence in a field of science or engineering, when necessary for dissertation work, for one of the languages.

Research papers: At the end of their first and second years of graduate study, students demonstrate scholarly competence by the submission of research papers. The second-year paper should be a research paper of publishable quality.

General Examinations: Students take general qualifying exams when they have completed coursework, usually at the end of the second year or beginning of the third year. The exam consists of three parts:

1. One of the four following areas: social study of science and technology; cultural perspectives on science and technology; history of science; history of technology;
2. The history and historiography of a field of history or methods and theoretical foundations of a field of the social sciences;
3. The development and/or organization of a particular science or branch of technology (reflecting individual programs).

Dissertation: Upon a student's satisfactory completion of the general exams, s/he selects a dissertation committee of three professors, who help direct the student's dissertation and evaluate it on completion.

APPENDIX C:

TECHNOLOGY & POLICY PROGRAM
MASTER'S CURRICULUM FOR TPP 1999

COMMON CORE

Block 1: Core Subjects

ESD.801 Introduction to Leadership (3 units)
The subject focuses on a weekend workshop off-campus, held at the beginning of the fall semester.

ESD.11 Proseminar (12 units)
The core integrative subject, focusing first on problem identification, values, and interests: and second on the paths to defining and implementing effective policies. Through a series of case study projects, it builds the students' capabilities for teamwork and presentation.

ESD.1xx Advanced Proseminars (9 units)
A choice of one of several advanced subjects which require student teams to develop and present plans to deal with specific issues in technology policy.

ESD.121 Strategic Analysis for Environmental Planning and Design
Subject focuses on practical understanding of procedures to successfully design complex technical systems that must perform well in social context. Computer-based models examine effect of alternative strategies, define tradeoffs between energy use, environmental quality and costs to develop policy consistent with social, economic, political and historical context of region.

ESD.123 Industrial Ecology
Quantitative techniques for (1) life cycle analysis of the impacts of materials extraction, processing, use and recycling (2) economic analysis of materials processing, products and markets.

ESD.126 Energy Systems and Economic Development
A team based policy research subject focused on evaluation of energy technologies and their implementation within developing countries. The subject focuses on one or more specific nations, carries out a resource assessment, and develops an energy strategy that is congruent of technical potential, cultural requirements and environmental constraints.

ESD.87 Thesis Seminar (3 units)
Assists students in developing thesis proposals.

ESD.811 Internship Seminar (units arranged)
An optional subject that integrates summer internships into the educational program.

Block 2: Analytic Framework

ESD.71 Dynamic Strategic Planning (9 units)

Covers the theory and practical use of optimization, evaluation and dynamic strategic planning.

15.011 Applied Micro-economics (9 units)
An intermediate, analytic subject given in the MIT Sloan School of Management.

ESD.131 Law, Technology and Public Policy (9 units)
Or an equivalent law subject

INDIVIDUAL PROGRAM

Block 3: Concentration

Each student is also required to take a coherent sequence of four subjects in technology and policy/social sciences. Students are free to choose policy subjects that best integrate with their individual programs. We do not restrict the subjects from which you may choose. Thus, a student who's interest is in energy might choose a program that combines electrical and nuclear engineering subjects and one regulatory policy subject.

Block 4: Thesis

A major professional work that builds upon the student's concentration. It integrates the technology and policy of an issue, placing the technical problem in context and providing leadership regarding what can and ought to be done.
Thesis work normally spreads over two semesters. The student prepares a thesis proposal in the first semester and does the intensive work on the thesis during the final semester.

APPENDIX D:
17.301/STS.082 – SCIENCE, TECHNOLOGY AND PUBLIC POLICY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF POLITICAL SCIENCE

17.301J and STS.082J SCIENCE, TECHNOLOGY AND PUBLIC POLICY
Fall 2000
Professor Kenneth A. Oye Class: Tues and Thurs 11:00-12:30 E51-057
E38-272 Center for International Studies Hours: Thurs 4:00-5:00 and by appt E38-272

SUBJECT OVERVIEW: Beneath most fights over contemporary science and technology policy sit classic debates over balancing risks of market failure and government failure, credibly assessing knowledge, and managing tradeoffs across efficiency and ethics. This subject is structured around major economic and political theories of regulation, modified to take account of problems associated with integrating scientific and technical information into public and private decisionmaking. Cases will be drawn from antitrust and intellectual property rights, health and environmental policy, defense procurement and military strategy, strategic trade and industrial policy, and R&D funding, with some comparisons of practices of the U.S. and other countries.

I. Introductory Sessions: This unit provides a once-over-lightly survey of major justifications for and critiques of public policies. These justifications for public policies include classic microeconomic defenses of the role of government in mitigating economic market failure (listed below) and philosophical arguments on equity and individual rights. These justifications for public policies will be juxtaposed to critiques of government, including work on representational bias, influence costs and regulatory capture, organizational and bureaucratic politics, information incentives and regulatory rigidity.

II. Political Economy of Science and Technology Policy: The cases in this unit are ordered as responses to potential sources of market failure. For each category of market failure, we work through major theorists, examine precursor technical and nontechnical cases, consider problems associated with nominal solutions to these market failures, and then join in debate over selected contemporary cases.
A. Unstable Property Rights: Deeds, leases, patents, and copyright with ref to radio, music and software distribution, genetic engineering
B. Oligopoly and Monopoly: Antitrust policy with ref to oil, transport, telecommunications, and operating systems; strategic trade
C1. Environmental Externalities: Regulatory regimes with ref to hazardous air pollution and auto-fuel regulations
C2. Security Externalities: Export controls and domestic subsidies, with ref to embargoes, weapons financing, encryption limitations
C3. Health Externalities: Quarantines, inoculation, research with ref to 19th century epidemics and 20th century HIV
C4. Knowledge Externalities: Educational and research subsidies with ref to cases deferred to III-A (below)
D. Incomplete and Asymmetric Information: Health and safety regulations with ref to medical insurance, informed consent, food regulations
E. Coordination Problems: Standard setting with ref to VCRs, cellular standards, W3C, DVD; international regulatory harmonization

III. Generation and Assessment of Scientific and Technical Knowledge: These classes examine problems associated with creating and evaluating scientific and technical knowledge. How should resources be allocated

to research and educational areas? What sources of evidence are deemed to be credible in areas marked by substantial uncertainty? How should science be incorporated into public and private decisionmaking?
A. Setting Research Priorities: The role of peer review, logrolling / earmarking, expert panels, NIH / NSF / MIT / National Labs. Cases may include: (1) Energy: Synfuels, Fusion Research Funding; (2) Biomedical: AIDS Research Funding; and (3) Security: DoD Research.
B. Assessing and Using Scientific and Technical Knowledge: The role of universities, media, judiciary, OTA, NRC, HEI, OSTP, IPCC in addressing scientific controversies. Cases may include: (1) Security: C3I OTA and Ballistic Missile Defense OTA / DoD / MIT; (2) Environmental and Health Risk: Particulates EPA / HEI, GMOs FDA / WTO, Mercury NIEHS / OSTP, Climate Change IPCC, Butter / Margarine FDA, Breast Implants and Tobacco Litigation

IV. Concluding Sessions: These classes providing a structured review of the subject while addressing two cross cutting issues
A. Evaluating policy: Brief treatment of consequentialist and categorical approaches to evaluation, followed by discussion of situations where uncertainty over consequences may have the effect of disguising conflicts over ethical perspectives. Topics reviewed may include medical experimentation, gene patenting, expertise and democratic values, secrecy and deliberation in security affairs.
B. Improving policy: Technocratic views on improving the quality of initial decisions by using technical experts as policymakers and by deploying decision analytic techniques to make better use of available information. Alternate view of initial policies as necessarily imperfect "experiments" that generate information on side effects, relative costs, and legal / political constraints, information that may be used to foster policy adaptation and improvement.

ELIGIBILITY AND REQUIREMENTS: Undergraduate and graduate students from engineering, the sciences, humanities, and the social sciences are most welcome. If graduate credit is required, students may arrange with instructor to enroll in 17.958 Reading Seminar in Social Science. Grades will be based on participation in class discussion and preparation for debate (40%), a midterm exam (20%), and an essay pool final exam (40%).

READINGS AND LOGISTICS: Viscusi, Vernon and Harrington, ***Economics of Regulation and Antitrust*** (Third Edition) covers the basic economics of market failure and regulation, while classic and recent scholarly articles, popular articles, and forthcoming papers provide contrasting views and case material. Expect between 125 and 200 pages per week. Most selections available from JSTOR, websites or as email attachments. Text is available at MIT Press Bookstore. Discussion questions and final reading lists distributed as email attachments to facilitate access to web based reading sources. The materials sketched above and on the preliminary schedule below exceed what can be covered in a semester. Final selection of cases will be completed in consultation with the class.

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Date	General Topic	Core Issues	Historical Cases	Contemporary Cases
Thu Sep 07	Subject Overview Justifications and Critiques of Public Policy	Market failure vs. government failure	NA	NA
Tue Sep 12	Continuation			
Thu Sep 14	Unstable Property Rights	Encouraging investment and technological advance vs. limiting diffusion of fruits of innovation	Studies on growth and PR; Deforest-Sarnoff and radio	Pharmaceuticals, Amazon, LaMacchia, Napster, DVD, genetically modified seed
Tue Sep 19	Continuation			
Thu Sep 21	Imperfect Competition and Antitrust	Limiting pol and econ rents vs. reaping scale benefits and rewarding investment	Standard Oil, Alcoa, IBM, ATT-MCI, trucking and airline deregulation	Microsoft, Airbus-Boeing, net access, telecom mergers
Tue Sep 26	Continuation			
Thu Sep 28	Environmental Externalities	Internalizing externalities vs. providing rents and bearing influence costs	British smoke laws, Clean Air Act, CFCs and Montreal Protocol	MTBE, Tier II air regulations, sulfur trading, recycling standards, fumigant certification, MMPA, China coal, Kyoto
Tue Oct 03	Continuation			
Thu Oct 05	Security Externalities I - Embargoes, Controls and Impoundment	Limiting military diffusion vs. securing markets	Secrecy rules, COCOM and CHINCOM, Yamal pipeline	Patent impoundment, encryption standards, biological and nuclear export controls
Tue Oct 09	Columbus Vacation			
Thu Oct 12	Security Externalities II - Procurement	Providing defense vs. providing rents	Battleships and aircraft carriers, manned bomber	V22, ATF, SSN21, Kursk
Tue Oct 17	Disease Externalities	Limiting spread of disease vs. limiting factor mobility and freedom	19th century sanitation projects and shipping rules	Infectious disease including HIV screening and treatment
Thu Oct 19	Incomplete Information and Imperfect Consent	Shielding from risk & exploitation vs. limiting private exchange	Food safety, narcotics, gambling, occupational safety, child labor	COUHES and experimental protocols, food irradiation, GMO bans, bovine growth hormone
Tue Oct 24	Continuation			
Thu Oct 26	Adverse Selection and Tipping	Private rationality and collective irrationality; insurance and moral hazard	Energy panics, banking panics and lender of last resort	Genetic screening and medical insurance, mandatory vaccination
Tue Oct 31	Coordination Problems	Enhancing efficiency by standardization vs. conferring competitive advantage	VHS-Beta, Motorola cellular standard, CODEX and PIC, shipping safety standards, insurance regulation	WWW, domestic product and process regulations and WTO
Thu Nov 02	Continuation			
Tue Nov 07	Midterm examination			
Thu Nov 09	Setting Research Priorities and Funding	Providing public benefits through research vs. providing rents	US Synfuels, fusion, Japan nuclear power	Human Genome Project, defense research budgeting
Tue Nov 14	Continuation			
Thu Nov 16	Assessing Military Capabilities	Reducing biases through open process vs. security & secrecy	Missile Gap, C3I vulnerability, SDI and demise of OTA	Patriot, Ballistic Missile Defense
Tue Nov 21	Continuation			
Thu Nov 23	Thanksgiving Vacation			
Tue Nov 28	Assessing Environmental and Health Risks	Using expert vs. popular appraisals of risks	DDT, Lead, Dioxin, Asbestos	Particulates, methyl mercury, low level chemical exposures, breast implant litigation, IPCC and climate change
Thu Nov 30	Continuation			
Tue Dec 05	Continuation			
Thu Dec 07	Evaluating Policy	Setting standards for evaluation under uncertainty	NA	NA
Tue Dec 12	Improving Policy	Adapting goals and instruments under uncertainty	NA	NA