TEACHING POLICY TO COMPUTER SCIENCE STUDENTS

by

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INTRODUCTION

The success of computer science is yielding new fruit: a growing intersection of computing and public policy. The more computing affects daily life, the more questions about the balance of private and public interests that arise—and the more answers that are offered by people outside of the field. Computing's intersection with public policy is growing in part because people are looking more critically at computing. The benefits of computing drive the information economy, but popular discussions of computing point to negative experiences: failures of major computer systems supporting air traffic control, exploitation of networked systems to compromise privacy of financial records, and so on. As government responds, computing is as likely to be assimilated into older policy frameworks as to motivate new ones. Examples include the expansion of consumer fraud activities at the Federal Trade Commission to on-line environments and medical device regulation at the Food and Drug Administration to cover software in medical devices. As these examples suggest, policy may touch on computing from new directions and in new ways. The results will alter the incentives and resources—the forces of supply and demand—for computer science and engineering. The changing climate for research, education, and applications makes public policy trends relevant to all computer scientists.

How can computer scientists make sense of public policy? How can they prepare for impacts on their work? A course of study can help. Although the long history of regulation has spawned telecommunications policy courses and degree programs, there is little consideration of policy on the computing side. What does happen is primarily outside of computer science departments; attention in computer science may emphasize related issues, such as ethics. An informal examination of course offerings across the country[1] reveals choices on computing and the law, computing and society, and specific technology-policy arenas, such as electronic commerce. Although other fields have traditions of studying policy issues, computer science departments can also benefit from such study. How to do so raises questions about content, its placement, and teaching approach. Content choice begins with an understanding of what public policy is; see box 1.

Box 1 : What is public policy? A simplified overview

There is no monolithic definition of public policy, but key parameters can be defined. Public policy relates to actions take by the government. "Government" exists at many levels, which may or may not act in concert: local (e.g., municipal), state or province, federal or national, and international or multilateral. In the United States, government (at different levels) involves an executive decision-making and implementation function, a representational legislative body, and a judicial or court system. These entities complement each other. For example, at the federal level, Congress may pass a law calling for regulation; an executive branch agency will develop and enforce the regulation; the courts may be called upon to decide whether the regulation is consistent with the law and/or the overarching principles of U.S. law found in the Constitution; and what the courts do may drive new rounds of action in Congress and agencies. Thus, "public policy" is more than "law."

Like government, "action" also has many forms, which vary in terms of the amount and kind of intervention. Examples include leadership or exhortation (this may involve various forms of outreach); development and enforcement of regulation of economic behavior (e.g., pricing or market entry), product characteristics (e.g., design or performance), or professional behavior (e.g., licensure or liability); administrative programs such as research funding or controls associated with national security programs; and taxation, tax credits, and user fees. Government action affects the incentives perceived by private parties and sets some rules for their behavior.

THE MIT COURSE

The Electrical Engineering and Computer Science (EECS) department at the Massachusetts Institute of Technology (MIT) hosted an experiment in teaching public policy to computer science graduate students. I was invited to develop what became Special Subject 6.967, Computing Public Policy, in spring 1998. This article provides an overview of the course and lessons learned. Although 6.967 was idiosyncratic, these observations provide concrete illustrations of content and process issues.

Public policy analysis is undertaken by people who support decision-makers in government (both inside the government and in the interest groups that seek to influence government decisions). It is also undertaken as scholarship by people in academia and other research organizations. Policy analysis draws on an assortment of social science and quantitative and qualitative analytical methodologies. Policy analytic scholarship can be very quantitative, drawing on techniques found also in science and engineering. Public administration is the public sector version of management science; paralleling the business environment, public administration includes both the "business" of making and implementing policy decisions and associated scholarship. People in both policy analysis and public administration have many kinds of background (although law, economics, and political science are prominent), and they may draw on (or have been, at earlier career stages) practicing scientists and engineers of various kinds. Public policy relates to the kinds of issues (e.g., economic and social impacts) that may be addressed by professional ethics, but it can and should be differentiated.

Public policy looms large where ethics and other factors shaping private action seem to fall short. Information security is the obvious illustration—codes of ethics have proliferated since the Internet Worm of 1988, and in the same period so, too, have government actions. Ethics drives private policy, at the individual and organizational level, and private policy influences and is influenced by public policy. Computer scientists can benefit by greater appreciation for both.

6.967 was designed to be comprehensive (see box 2) and focused on the United States context. Class topics were selected because of their importance, differing disciplinary emphases; and different balances of history and current events. Selected topics are highlighted below. The comprehensive approach can work as a one-shot survey or a foundation for focused courses. It shows how diverse policy really is and allows full consideration of the issues, players, and options that bear on how public policy relates to the development and use of computing systems.

All of the topics in 6.967 illustrated tradeoffs in policy-making. A central question throughout the course (and public policy generally) was, What should be the province of private action and what should engage government? A more focused version is, What won't the free market do—and should government help? Arriving at answers requires understanding of the

Box 2: Public Policy Topics Covered in 6.967

- Research support—where it all begins—general and specific
- The producers—policy aimed at computing and communications industries, from competitiveness to antitrust, regulation, and trade, plus standards-setting
- Special role of government needs—national security as driver of technology development and federal agencies as consumers of information technology, with Year 2000 as a case study
- Side effects of computing—such as privacy and employment impacts—and how to gauge and mitigate them
- Public-interest and other advocacy—emergence, proliferation, and impact, with case study of education as an arena where advocates contend but doing the right thing proves difficult

organization and responsibilities of government, the nature of public-private boundaries, whether technology (of a different kind or deployed differently) will really make a difference (and if so, what kind), and who pays and who benefits under different options.

ON THE SUPPLY SIDE

The launching point for 6.967 was research and development (R&D). It is the aspect of public policy most familiar to academic computer scientists, connecting directly to science and engineering. R&D policy permits a historical perspective on timing, causality, and other aspects of change in both computing and public policy. In this category fall stories about the Department of Defense (DOD). DOD underwrote early public policy for computing via programs of World War II vintage, and it continues to dominate research support, although its roles in technology deployment and transfer have diminished. The ARPANET (packetized data communications),

- Information infrastructure—networking and information economics (including intellectual property and speech issues), business competition and cooperation across categories, and the Internet as case study

- Trustworthiness (information security, reliability, and safety) and cryptography policy—clash or coordination of national security, economic security, law enforcement, and individual rights

- International issues—economic development, sovereignty, and the internationalization of previously domestic policy issues

- Emerging technologies—embedded systems and ubiquitous computing case study

- Computer science and engineering labor market—number and nature of computing specialist jobs, supply and demand for talent, and career trends

- Making an impact—opportunities and prospects for leadership, broadening the application of computer science expertise, integrating public service into technical careers

SIMNET (networked simulation), Ada (programming language), wireless and mobile communications, and encryption illustrate the varied impact of this large and complex agency on computing—and also how the influence of a government agency can change. Questions facing today's policy-makers (and computer scientists!) include, What might happen if DOD support diminished greatly? Should it? What if other federal agencies cannot generate comparable funding?

The saga of the recent High Performance Computing and Communications Initiative (HPCCI) and its derivatives informs current trends. In the late 1980s and early 1990s HPCCI embraced most of the funding for computer science research, becoming a target for budget-cutters and others. Contemporary structures are more diffuse. Questions to consider include, How has government promotion of computing evolved as computing industries have grown and assumed technical leadership? How has the rise of computer science as a discipline affected academia, industry, and government? Where have federal goals for computer science research come from, and how should they be set? Can the federal government support emerging areas adequately? How much support is "enough"—and how do we know?

Today's central R&D policy question in computing recurs in political settings: Does the vitality of computing industries obviate the need for federal research support? Answering it requires understanding of computer science, fundamental and applied research, plus players and parameters in public policy. 6.967 students seemed quite willing to question the merits and organization of government support for research; in retrospect, a faculty-student debate could be fun. Appendix 1 outlines the essential R&D policy unit of 6.967 (excluding DOD material).

As a force promoting the supply of computing, R&D policy is complemented by policy addressing the structure and competitive conduct of computing-related industries. Industry policies shape the incentives for investment in and selection of alternative technologies. Tax credits for R&D spending, differential regulation of voice communication via telephone networks and the Internet, and requirements to report exposure to risks (such as the Year 2000 (Y2K) problem among publicly-traded companies) are illustrative.[2] Students can examine industry policies to explore how consistent are government efforts (industry criticizes export control as anti-competitive), the balance between law and its enforceability (controls on exports of software are difficult to enforce), and the politics of policy development (national security interests tend to prevail on export control matters).

Today's news puts a spotlight on antitrust. Blending law and economics, antitrust invites discussion of how technological trends affect industrial structure and conduct, and how well policy adapts. Antitrust also illustrates the role of politics in policy making, beginning with what happens when the goals and mechanisms of the policy area tend to be misunderstood. 6.967 contrasted the 1970s AT&T and IBM cases and the 1990s Microsoft, Intel, and MCI investigations. Students pondered the apparent link between market power and research effort among computing companies and its implications.

Other categories of competition policy include economic regulation and trade policy. Telecommunications, which has a growing intersection with computer science, provides an arena for examining how regulation and antitrust interrelate, shaping both technology and industries. Telecommunications also contrasts with computing in standards-setting, which affects the course of technology development despite a problematic relationship with research.

SIDE EFFECTS OF DEMAND

Using computing has side effects, which trigger concern that can be more emotional than rational. Side effects are great fodder for discussing whether problems are transitional or enduring and whether computer science can help. For example, technology can both stimulate and alleviate electronic privacy concerns, but how technology changes will depend on public, market, and political reactions. The World Wide Web Consortium's Platform for Privacy Protection is one illustration of a technology response that anticipates policy, and it is debated as much as other approaches to the issue.

Discussion of side effects calls for analysis of how values color judgments about technology.[3] Readings and activities can bring out values of stakeholders and students, fostering discussion of what "should" happen, the positions taken by parties in private and public sectors, and the interplay of technical and nontechnical factors. Values influence how people weight concerns about social and economic impacts, and they interact with the trust that people place in government. The significant presence of foreign nationals in 6.967 reinforced the importance of values, given national differences in value systems and governments. For example, one Asian student noted that prior to the course he had been unaware of controversies relating to privacy. Values are central to the topic of equality of access to information infrastructure (including universal service and support for deployment in schools and libraries). Which strategy is "better"—considering costs borne by different parties at different times and when or where it may be better to wait than accelerate access—depends on value judgments.

Employment impacts relate directly to students' personal experiences. What people do as workers may be ground zero for the information economy: the use of computer-based systems affects people in all kinds of jobs and therefore the number, mix, earnings and advancement potential, skill requirements, geographic dispersion, disability/occupational illness and injury, labor-management relations, and so on across organizations and industries. The lack of understanding of employment impacts has shown up as fears about manufacturing and office automation in the 1980s and hype about an information-technology worker shortage in the 1990s.[4] 6.967 used employment trends as a vehicle for examining social and economic impacts that may motivate policy interventions of different kinds (such as immigration policy, occupational safety and health regulation, business investment incentives, education and training programs). It also addressed the narrower set of issues relating to supply and demand for computer scientists and related professionals as a tiny component of the total workforce (perhaps 2 million out of 125 million in the United States) with disproportionately large impact.[5]

CONGLOMERATE TOPICS

Both industry development and side effects have inspired new advocacy programs and organizations, changing the political landscape of computing and public policy substantially since 1990. Advocacy generates much talk and ’net traffic, but influence on policy is unclear. The story of the Electronic Frontier Foundation, which led the charge on civil liberties issues in the early- to mid-1990s but spun off a different organization (Center for Democracy and Technology) and retrenched, illustrates how computer scientists have teamed with lawyers to pursue an advocacy agenda.

In addition to civil liberties, a good issue for exploring advocacy interactions is computing in K-12 education. It provides an ongoing case study of what technologists, advocacy and government organizations have and have not been able to accomplish—despite the best of intentions and both public and private resources. 6.967 students demonstrated healthy skepticism about programs in this area, showing an encouraging appreciation for the role of context in the success of computing applications.

6.967 treated two multi-faceted topics in depth: information infrastructure and information systems trustworthiness. Information infrastructure combines technology, industry, and social aspects for networking and information (content) goods and services. It illustrates how a broadening circle of policy makers has become interested in computing and how their response integrates policies relating to computing and telecommunications. The development of the Internet and its applications is the obvious case study here; it integrates policies for R&D, competitiveness and competition, telecommunications, and social impacts.

Trustworthiness is another rich topic. Including information system security, reliability, and safety, it, too, relates to convergence of computing and communications systems. This topic—and especially its high-profile component, cryptography policy—brings out tensions between national security and economic competitiveness, the rise of law enforcement interests, and how these concerns are balanced with privacy and civil liberties. For example, the 1990s Clipper Chip program and subsequent efforts to promote government-accessible cryptographic keys yields such discussion questions as, What are the pros and cons of key recovery programs? If a business need for key recovery exists, why is government intervention needed? What would be needed to give confidence that key recovery will work as intended—how much depends on technology, how much on the law or other factors? 6.967 leveraged such questions to drive group debates, which forced students to deal with unpopular perspectives and conduct the research necessary to support or rebut them.

Late-1990s attempts to develop initiatives relating to critical infrastructure, including the President's Commission on Critical Infrastructure Protection, provide a case study that relates directly to both trustworthiness and information infrastructure. Critical infrastructure underscores how much larger and more complex is trustworthiness policy than the comparatively sexy portion associated with cryptography policy. Another kind of trustworthiness case study centers on Y2K computing problems. Y2K affords comparisons of government actions to manage its own computing environments and to influence computing environments across the economy. Y2K also allows comparisons among different levels of government and governments of different nations. Key questions include, What should the federal government do about the Year 2000 problem among federal and private-sector systems, and why? Is it doing enough of the right things? Can or should distinctions be made among different kinds of systems? Who bears what costs from Y2K problems? How can costs and their incidence change as a result of private and government action? 6.967 students discussed these questions in writing and in class, arguing either that the federal government should intervene (through regulation or financial support) in the private sector because it has a responsibility to protect citizens or that it should concentrate its efforts and resources on protecting its own systems, thereby protecting citizens in the context of their interactions with or dependence on the government. Computer scientists are quick to note that the Y2K problem is not technically hard, but its reverberations will affect how the public and policy makers think about (and act on) computer science.

TEACHING POLICY TO COMPUTER SCIENCE STUDENTS

Public policy offers a wealth of content, which obviously can be selected in different ways. 6.967 followed a crude taxonomy of supply, demand, and side effects, and tracked different kinds of government intervention (e.g., regulation) throughout. One alternative would emphasize kind of intervention, as illustrated by more focused courses on computing and the law. A second variable for designing a comprehensive course is the attention to the specifics of relevant technologies. 6.967 focused discussion on nontechnical aspects except when contemplating emerging technologies that might affect policies and in framing the term-paper assignment; additional technical content was provided via readings. An alternative approach would draw more on issues of scientific progress and technical design. Such an approach could be integrated with conventional computer science course-work.

A third variable is the attention to specific analytical frameworks from other disciplines and the related degree of development of relevant skills. For example, emphasizing a historical perspective might argue for selecting topics (or different content within the topic set) to assure that enough well-developed stories can be addressed. A number of courses around the country, including at MIT and Cornell, examine the history of computing. Research funding and side effects draw easily on history, but for any topic an important question is how conditions have changed with time.

A course that draws on multiple disciplines presents choices about how much to explain (and in what manner) about the concepts and methodologies of each discipline. Economics is key to policy analysis, and 6.967 wove elements of economics and to a lesser degree political science into discussions throughout. For example, the economics of industrial organization are key to understanding competition policy and also the evolution of information infrastructure and information services. Will "content" firms take over "conduit" firms? How do technology, business models, and policy shape what might happen?

Public policy is an arena where reading material is abundant and required. (See Appendix 2 for the 6.967 Reading List.) Government documents (congressional reports, legislation, executive orders, program descriptions and analyses, announcements of inquiries that could lead to new policy), scholarly articles, statements by advocacy organizations, and news clippings are all useful. Computer Science and Telecommunications Board (CSTB) reports are a natural resource.

Used for years in specialized courses, they are written in part by and for computer scientists, feeding discussion about how technologists can affect policy through such activities.[6] Reading provides access to the range of perspectives and the language of real-world statements by government units and interested parties. How something is said, or who says what, can be at least as important as what is said. Reactions to the style of readings was an unexpected source of discussion in 6.967. Policy-related reading is not necessarily matter-of-fact or direct, even when well-written. Style provides entrée for considering the problems of compromise, consensus, and persuasion.

Policy lends itself to story-telling by practitioners (in 6.967, myself and guest-lecturers), which brings home the reality that policy is made by people interacting with each other. Noted one student, "the most valuable part was learning from someone who's actually been there how policy decisions are shaped and influenced." Although public policy scholarship tends to drift toward the theoretical, real players can explain the limits of scholarship in fostering policy progress.

Public policy demands discussion, either in writing or orally in class. Debates on contentious issues (e.g., government access to encryption keys) help to build understanding of their complexity, especially for those assigned unpopular positions; exercises to develop consensus or otherwise work toward a resolution within diverse groups also help to hone analytical skills, appreciation for different perspectives; and ability to negotiate or compromise. It is hard to build and defend arguments in the absence of clear rights and wrongs and globally optimal solutions among policy problems. No doubt speaking for many, one MIT student pleaded for "less ambiguity, please!" The material did not lend itself to tests.

Accustomed to working with professionals, I was struck by the lack of student familiarity with how large institutions work and/or any kind of politics. This naiveté may be unavoidable given the age and limited work experience of a student population, but it should be factored into activities and assignments. Some students would have liked role-playing exercises, which can foster political sensitivity; others were leery of that kind of activity. Taking a cue from graduate programs in business and public policy, a body of formal case studies (with role assignments and problem sets), games, and other simulation exercises already exists and might be adapted for a course like 6.967.[7]

Benefits in analytical writing alone could justify a policy component in a computer science curriculum. Small 6.967 writing assignments called for development of arguments and position statements on such topics as the rationale for continued government support for academic research, trends relating to avoid side-effects and their susceptibility to improvement through computer science, and options for government action relating to Y2K. The longer required term paper (see box 3) asked students to assess technical trends in an area and relate them to policy: In your area of research, what are the principal technical issues and trends and what are current and prospective policy issues? What kinds of information, assumptions, and analyses would help in addressing the policy issues? How might alternative technology developments alter policy concerns, and how might policy decisions affect the direction(s) of technology development? What are reasonable time horizons for these developments, and to what is timing sensitive?

Box 3: Illustrative term papers

- Impacts Of Strong Artificial Intelligence On U.S. Policy: Can A Machine Ever Have A Right To Liberty?
- Formal Methods: Summary of the Issues and Possible Policy Directions
- Intellectual Property Protection And The Emerging Technologies For On-Line Data
- [Malaysian] Multimedia Super Corridor
- Asymmetric Digital Subscriber Line Deployment: Law, Economics & Policy
- Ensuring Confidentiality Through Encryption: Examining the Role of Policy and Legislation
- Electronic Harassment
- An Assessment of Technology and Policy Regarding Automated Check Processing

The term paper intention was to get students to leverage their technical expertise while learning about relevant public policy. The student who wrote about implications of formal methods, for example, demonstrated insight in observing, "The mere fact that the academic community is so confused about why industry is very slow at adopting formal methods for their software processes implies that there is a big gap in perceptions about formal methods." The student who wrote about whether a computer system might ever deserve "rights" showed great ingenuity in exploring conditions and analogies under current law (while acknowledging how far the state of the art is from necessitating policy-making). Encouragingly, the student who wrote about electronic harassment noted how the class differentiated him from his peers: "I mentioned the paper I was writing for this class [to a graduate student in my group] and he immediately jumped on the technical aspects of dealing with electronic harassment. I think it's quite reflective of the mainstream stereotypes you've been seeing at MIT: He felt certain that the solution was technical and that he was going to do research on the topic. I, however, was less convinced that the solution was wholly technical. I certainly think policy has a great deal more impact. But in any case, I got him excited about it." This anecdote illustrates how policy arenas can motivate research within computer science and how that can happen more readily with exposure to policy concerns.

CONCLUSION

Many computer scientists overestimate how much time and effort may be needed to integrate public policy awareness into computer science research and education. The aftermath of 6.967 included discussions with department heads and other faculty about the relative merits of free-standing courses, mini-courses, or broad-based integration (mainstreaming) of policy content as context within science and engineering courses. A mainstreaming approach would engage faculty more broadly. A few faculty on different campuses have already begun this process based on their own recognition of the intersections of computing and public policy. For example, at MIT, Hal Abelson has developed (together with MIT's Program on Science Technology and Society (STS)) a line of courses that explore the intersection of computing, ethics, and law, and at Cornell Fred Schneider has drawn on policy issues in teaching about computer security.

The future for computing and public policy coursework depends on faculty and student support. The 6.967 experience attests to student interest (see box 4); comments by students suggest that courses within computer science attract them more than those outside. A course within or in partnership with a computer science department can better leverage understanding of how computing systems really are designed—and leverage awareness of public policy to inspire potential research directions.

Internalizing consideration of policy within computer science presents a getting-started problem—how can this work if the material and concept is unfamiliar? This is a make-or-buy decision. Developing internal capabilities obviates the cultural problems that come from bringing in people whose primary expertise relates to policy rather than computer science. Where this is not possible, engaging policy professionals, perhaps in partnership with computer science faculty, or promoting development or awareness of relevant courses in other departments are obvious options and in evidence on several campuses.

Today's computer science curricula may not accommodate a policy component easily. They are full, at least at the undergraduate level, in terms of course requirements and content of individual courses. At graduate levels there may be more flexibility, but issues of justifying new kinds of content exist for master's and doctoral programs, too. In addition to new material, policy study involves what may be unfamiliar modes of thought, notably elements of social science. Offsetting these deterrents is the fact that public policy offers abundant material for study of real-world applications and honing of analytical thinking. It is in the nature of public policy that there may be no answers, no "right" answers, or no answers that can be implemented. This ambiguity contrasts with the relative clarity of situations presented in typical computer science problem sets. And knowing about public policy can help expand the perceived solution space for a technical problem.

Box 4: Student comments on 6.967 as an addition to the curriculum

"I would have expected something like 6.967 to be a core or basic subject for TPP students in the computing area . . . at least, for someone like me with a pure technical background and no policy training before at all . . . [to help] me understand all the core problems and ideas about computing policy." (TPP graduate student)

"From some of the initial topics, I even became skeptical that public policy was meaningful. However, as the class progressed and you continued to provide information, pose questions, and listen to our discussions; I noticed that I began to get excited about the topics and, in essence, take ownership. . . . You showed us that public policy is something worth caring and thinking about." (EECS graduate student)

"Overall, I think it was a good class that addresses a very real need. The vast majority of computer science people I've dealt with, particularly those in universities, ignore the fact that by and large computers are not ends in and of themselves; they are tools to facilitate a wide range of essential and non-essential human activities. Decisions about how they are developed and used are as critical as the computations they are actually capable of performing. Allowing yet another generation of computer engineers to go through their education believing they can and should ignore the consequences of what they're creating is doing a disservice both to the students (future researchers, teachers, and business people) and the people who will eventually use the systems they create." (EECS/TPP graduate student)

Both technical and nontechnical considerations shape innovation. Hence a good, even "optimal," technical solution may not be chosen quickly (or at all) as a policy response. Of course, compromises in systems design and engineering are common in practice. But windows into private decision-making are limited compared to the public records that accumulate around policy choices. Which compromises are made, when, and by whom are key to understanding how policy can affect science and engineering—and vice versa. Such discussion should have a place in the education of computer scientists. Engaging with policy can be a positive-sum prospect for computer scientists.

"From what I have observed . . ., it will be very difficult to incorporate computing policy into the mainstream. EECS faculty do think themselves as the most prestigious on earth, they would not dilute their program by introducing non-technical subjects." (EECS/TPP graduate student)

"Of all the classes I've taken at MIT, few have really made an impact on how I think and feel (I can count them on the fingers of one hand). I have to admit that this one has. . . . Your patience and willingness to listen is what is unique about conveying your message. From that respect, I don't think an MIT Professor can teach the class in the same way. The way that the class is taught says to me, "Hey, we have some issues with computers and technology that affect society and we need to think about them. Yes, we don't all agree; but if there is a harm to society, we need to figure out what steps to take and take them." I think your message is powerful. . . . I know that I am very cynical about the American Government and not very hopeful that it can do things to benefit the country it governs. You've shown me that you can be a voice if you stick to your guns. I think you (and consequently your class) do bring something to MIT that would be otherwise lacking." (EECS graduate student)

NOTE: EECS refers to Electrical Engineering and Computer Science; TPP refers to the Technology and Policy Program (TPP). Most 6.967 students were EECS graduate students, a few were TPP or joint EECS/TPP students.

END NOTES

[1] They can be found variously at, for example, Cornell University, George Washington University; Georgetown University; Harvard University; MIT; the University of California at Berkeley, Irvine, and San Diego; the University of Indiana; the University of Michigan; and San Diego State College.

[2] Other policy concerning "suppliers" includes competitiveness, a topic whose popularity ebbs and flows. There are associated debates about export controls (motivated by national security, historically applied to high performance and information security-related technologies) and standards setting (treated very differently in telecommunications, general-purpose computing systems, and specialized (e.g., safety-critical) computing systems). Attitudes toward international competition and cooperation and mechanisms that support or impede same yield cycles of policy interest and action.

[3] Values, of course, interact also with ethics; codes of ethics embody values.

[4] Employment impacts also drive considerable government investment in statistical programs—which in turn are demanding appropriate computing technology to meet their needs. The Bureau of the Census and Social Security Administration were early and important customers for computing, and a new federal initiative, Digital Government, aims to couple mission agencies (including those that host statistical programs) and computer science researchers.

[5] Much of the 1998 debate about a possible U.S. shortage of computing specialists reflected deficiencies in data and analytical frameworks, risking possibly inappropriate responses in employment and training policy. 6.967 examined what it takes for credible analysis of the computer science labor market and who has what stake in different kinds of conclusions.

[6] The author has been the executive director of the Computer Science and Telecommunications Board, which makes her as familiar with the books as she is partial to them. CSTB is an operating unit of the National Academy Complex, which includes the National Academies of Sciences and Engineering and the Institute of Medicine.

[7] Alternatively, contributing to the development of such materials—assuming, perhaps unrealistically, that time were available to do so—could be illuminating for faculty.

ADVANCING THE FIELD(S)

QUESTIONS FOR CLASS: 1-pager assignment.

- ***If we are still mining the innovations of the 1960s and 1970s, is a vigorous federal R&D effort necessary? Do we have enough CS—will conditions generate enough more? Is there a government interest in the composition of C&C R&D***
- ***The fascination with e-commerce attests to the healthy industrial base associated with C&C. Is it time for government to step back and let industry take care of deciding on emphases and resource allocation for C&C R&D?***

1. Federal funding (external research) as focal mechanism

1.1. Rationale

1.1.1. Economic benefit, attainment of capability

1.1.1.1. Incomplete appropriability and risk aversion as government motivations that change with time and context

2. Why not depend on industry? How similar/different is its R&D?

2.1. Growing tendency for industry to deem academic research as irrelevant or poorly matched

2.1.1. Systems research generally (complexity, scale)

2.1.1.1. VLSI: industry money has been key at Stanford for launching areas that haven't gelled enough to ask for federal support, including for research faculty sans track records

2.1.2. Security/trustworthiness

2.2. Issue where need one-of-a-kind machines (ASCI program today and bragging rights v. claims of loss)

2.3. Activity-Measurement difficulty (D, R, and R&D)

2.3.1. Industrial Research Institute statistics, NSF statistics

2.3.2. Ambiguity of restructuring (apparent devolution?) at historic big players (ATT+, IBM)…uncertain growth at new players (Microsoft, Disney)

2.3.2.1. IRI: changes in mgmt orientation given overall economy…

2.4. Differences in kind?

2.4.1. Product targeting and development

2.4.1.1. Shorter time horizons in general (user interface design/eval and value of long observation periods and iteration)

2.4.1.2. Cost control (wireless, entertainment modeling and simulation)

2.4.1.3. Focus on specific customers, lock-in and path-dependency, time-to-market pressures (network goods)

2.4.1.4. In the aggregate, most benefits from innovation accrue to consumers (better/cheaper products) rather than to the innovators… hence greater emphasis of industry research on technology than science… why not free-ride?

2.4.2. Proprietary v. open (technology v. science): what happens with increased privatization of research project selection and results?

2.4.2.1. Concern for "appropriability" constrains basic research in industry (cf. "precompetitive)

2.4.2.2. Nondisclosure agreements/Intellectual property rights issues for industry-supported academic research

2.5. Note that some government funding goes to industry R&D (approximately $23 billion/year through 1990s), also to tech tran programs—but this is a small amount of "industrial" R&D $)

2.5.1. DARPA and trustworthiness

2.6. Search for post-Cold War rationale (see Cohen-Noll article)

1. Congressional study (1997-1998):
2. On what broad national goals should federal science policy be based?
3. (a) What is the government's role in supporting basic and applied research? (b) How can the government best encourage an effective level of industry investment in pre-competitive research?
4. How can the nation enhance and make the most effective use of government/university/industry research partnerships?
5. What is the most effective role for the states in supporting university research, and how can the federal government best support that role?
6. (a) Given the increasingly international nature of science, how can the nation best benefit from and contribute to international cooperation in research? (b) What types of multilateral science agreements are needed to facilitate international collaboration?
7. How can the federal government best help meet national needs for science and math education at all levels?
8. How can the nation most effectively leverage federally funded R&D in the face of increasingly constrained resources?

2.7 National Science Board 12/97 working paper

2.7.1 Main points

Continued rationale for federal research funding

"Changes in nat'l priorities do not negate the potential of research benefits which are long term and uncertain in detail… A nation requires a robust high-tech industry, a scientific talent base, and a vigorous research activity to prosper over the long term."

Value in comprehensive coordination of federally funded research (coordination v. control)

Value in priority-setting…need for methodologies (how to set priorities)

2.7.2 What are key issues for setting priorities in CS/E? (objectives v. priorities?)

3. Federal research funding: who, how, w/what effects and when

3.1. What is computer science – where is research needed? Experts disagree...

3.2. Big v. small science in computing

3.2.1. Specific capabilities v. S&T infrastructure

3.2.1.1. (Large) systems projects v. individual PI

3.2.1.1.1. Systems get attention... (ARPANET/Internet)

3.2.1.2. Contrast to other fields (e.g., physics, astronomy) where big science=big instruments

3.2.2. Agency division of labor and coordination

3.2.2.1. DARPA/NSF and others

3.2.2.2. NSA, Joint Technology Office, NSA–DARPA–DISA

3.2.3. Current v. cumulative perspectives (scale factors)

3.3. Mission v. fundamental (applied v. basic, etc.)

3.3.1. Real distinction or label/justification?

3.3.1.1. Opportunistic labeling impedes analysis

3.3.1.2. Military (6.1,2,3); elsewhere in terms of programs

3.3.2. "Can't shoot—gotta compute": broadening modeling and simulation

3.3.2.1. January 1998 Natural Resources Defense Council criticism of Accelerated Strategic Computing Initiative as engaging university researchers in work that relates to nuclear weaponry; DOE argues that the program relates to maintenance of the stockpile…

3.3.3. Intellectual inspiration or inhibition from application?

3.3.3.1.1. Does it matter? To whom?

3.3.3.1.2. *Computing the Future* flap (what is a Faustian bargain?)

3.3.3.1.3. Core and "broaden"

3.3.3.1.4. Attempt at community-wide v. narrower authorship, "volunteer"

3.3.4. Feedback from applied research and deployment

3.3.4.1. Examples: information infrastructure, manufacturing, education, crisis management, human–computer interaction (D&E)

3.3.4.2. Cf. Commercial user impetus (historic v. new roles in mfg and services—services newer)

3.3.4.2.1. Mfg: product and process design, shop floor control, M&S, enterprise management/integration

3.3.4.2.2. Citibank support for Santa Fe Institute

3.3.4.3. Relate to technology forecasting challenge

4. Rise of large initiatives: HPCCI to NII . . . NGI/UA/KDI . . . ITC

4.1. Nature of "initiatives": Multiple roots blended

4.1.1. Critical mass/multiple elements

4.2. Creatures of bureaucracy (implies costs/strings)

5. High Performance Computing and Communication Initiative: first "CS/E" initiative—but not wholly CS

5.1. Origins in supercomputing, networking, and computational science R&D; grass roots impetus

5.1.1. 1980s context: competitiveness challenges, telecom restructuring… mid-1980s organizing, 1989 Office of Science and Technology Policy report

5.1.2. No urgent military/government needs…synthetic

5.1.2.1. Yet fear of Asian overtaking in supercomputing (important to military, national pride)

5.1.2.2. Aimed at a "paradigm shift" (parallel processing, beyond vector processing)

5.1.3. "De facto": Official trappings lagged actual launch

5.1.3.1. Grass-roots efforts of program managers in mid-'80s

5.1.3.2. Computational scientists-supercomputing users /Ken Wilson and networking/Internet impetus

5.1.4. Initiative/program, not project (and therefore, to science policy leaders, not "big science")

5.2. Interaction consumers and developers of advances: Challenges objective

5.2.1. Weather modeling, energy (production, conservation, management), environment (pollution, ozone)…

5.2.2. Grand Challenge teams (x-disc, multi-institutional)

5.2.3. Software-hardware interactions (motivate software development to test and stretch the hardware; prior supercomputer graphics/visualization in 1990s desktop machines)—applications, software, algorithms, plus hardware design

5.2.4. Networking infrastructure (enable science, education)

5.2.5. What about grand challenges in CS? (cf. Nat'l Challenge report)

5.3. HP goals and accomplishments: (1) parallel processing (paradigm established), (2) teraflop computing (tech feasible [1 tril]), gigabit networking broadly deployed—switching, hwr/swr, interfaces, protocols (tech feasible); PhD production (increased…)

5.3.1. Capabilities v. companies—political challenges given thinness of supercomp market and aggregation/mass of $$

5.3.1.1. GAO, CBO, and CSTB assessments

5.3.1.2. "Supercomputing" by definition small demand (v. CBO critique WRT broader market stimulation)

5.3.1.3. End of Cold War: demise of market for speed at any cost

5.3.2. Expanding circle of universities for PhD production and NREN access: maintain top tier, enhance next

5.3.3. Mosaic claim

5.4. Morphing—Goal evolution: From speed to scale and scope

5.4.1. Tent metaphor: speed vertical, scale horizontal

5.4.1.1. Reliability (will the tent stay up?)

5.4.1.2. Software Productivity (how long to move tent site?)

5.4.1.3. Malleability (can tent's shape be changed?)

5.4.1.4. HCI (can people move the tent?)

5.4.1.5. Intelligent search/retrieval (can people find what they want inside the tent?)

5.4.2. HPC Act of 1991 (PL 102-194)

5.4.3. Rise in communications interest: NII (1993 Agenda for Action report)

5.4.3.1. Tension between urgent/practical needs and long run research

5.4.3.2. From 4 to 5 components (IITA)—1994+

5.4.3.3. Information Infrastructure Task Force/Technology Policy Working Group ambiguity

5.4.4. National as well as Grand Challenges

5.4.4.1. Growth in concern with circumstances of C&C use

5.4.4.2. How to broaden and facilitate…broaden benefits and support

5.4.5. Broadening of set of players

5.4.5.1. 12+ agencies…orthogonal IITF/TPWG

5.4.5.2. Increased industry role

5.4.5.3. Lure of $1 billion, concerns about exclusion and detriment

5.5. Boundaries: Scope and opportunism, orphans

5.5.1. Big fat target—everything under one umbrella

5.5.2. But, even early on: what wouldn't fit under umbrella?

5.5.3. Today: what about HPC other than clusters of commodity processors?

5.6. Characteristics: organization… vision? marketing?

5.6.1. Working consensus to grow, sustain

5.6.1.1. Blue Books (digests of plans, programs)

5.6.1.2. National Coordination Office

5.6.2. Working consensus to phase out, transform

5.6.2.1. Outreach process

5.6.2.2. Blob diagram (overlay new emphases on old)

5.6.3. The delayed and diluted Advisory Committee (belatedly renamed the President's Information Technology Advisory Committee or PITAC)

5.7. Brooks/Sutherland Report Recommendations

5.7.1. Continue to support IT research ($; HPCCI)

5.7.1.1. Report changed debate: extend v. kill

5.7.1.2. HPCCI element IFF match objectives

5.7.1.3. NSF centers (grand compromise): suppt evolution C&C techs, app scientists should get cycles, etc., paid for elsewhere

5.7.1.4. Grand Chal $ from HPPCI IFF support underlying C&C

5.7.2. Cont strong experimental swr/alg program for parallel

*5.7.3. **Stop direct $ commercial hwr development/industrial stimulus*

5.7.3.1. Maintain university-based precompetitive computer architecture

5.7.3.2. T-flop as direction rather than goal

5.7.4. Increase emphasis on networking/comm (turn the ship, Next Generation Internet anticipated)

5.7.4.1. Scale, physical distribution

5.7.4.2. Develop research program: large, reliable, high performance, distributed info systems (cf. networks/comm)

5.7.4.3. Ensure NC research supports info infrastructure tech development as well as new apps/paradigms

*5.7.5. **Strengthen NCO…coordinate, PR; avoid central management*

5.7.5.1. Earlier WRT Advisory Committee

5.7.6. Base mission procurements on mission needs only, at lowest decision-making level

5.8. Progeny: CIC (Computing, Information, and Communications); DLI (Digital Libraries Initiative), NGI (Next Generation Internet), UA (Universal Access), KDI (Knowledge and Distributed Intelligence), IT^2

5.8.1. 3/95 "America in the Age of Information"

5.8.1.1. Blob diagram: truly new—high confidence, human-centered

5.8.2. Specific agency issues: DOE funding challenged, NASA's reduced overall

5.8.3. Leadership less clear or strong: DARPA and NSF and DDRE/OSTP/NCO uncertainties

5.8.4. Enduring problems of explaining, justifying to overseers and stakeholders

5.8.5. PITAC high profile as redress

Cross-cutting issues

6. Mix and match/Interdisciplinarity: enrichment or contamination?

6.1. Growing emphasis among funders, hallmark of initiatives

6.1.1. Company of the future controversy WRT broadening

6.2. Curse of being a tool—practical problems of collaboration

6.2.1. "Challenge" problems

6.2.2. Domain problems (e.g., manufacturing)

6.2.2.1. Manufacturing cross-cut initiative contemporaneous with HPCCI—military and competitiveness/economic development drivers

6.3. Science/engineering-based v. other (applications, impacts)

6.3.1. Collaboratories (science and social science, information science)

6.3.2. Crisis management (science and social science)

6.3.3. Usability/interfaces and multiple computing-related, social science, and art/design disciplines

6.3.4. Digital libraries (for science v. humanities)

6.4 Implications for the field (is there a "Macro CS"?)

COURSE OUTLINE AND READING LIST

1. **Class 1: Course introduction and overview: focus, approach, expectations**

2. **Class 2 and 3: Overview of CS/E in federal policy—scope and history**

Material Covered:

A. What is the big picture, the broad policy space?

   a. Is C&C policy "managed" in the US federal government? How so? Would more or less "management" be better? How so? Is it feasible?

   b. C&C policy addresses science, technology, industry, governance, and more. Is it possible to harmonize support for human/intellectual capital with support for utilitarian objectives (e.g., national security, economic competitiveness, specific systems or missions) or will they at best coexist? On what basis are tradeoffs made?

B. Why has the federal government supported C&C research?

   a. What has been most important about past federal support?

   b. Does the fact that federal support draws on tax dollars ("the public") justify special conditions or expectations? Does it matter if expectations relate to research output (e.g., ownership of intellectual property such as patents) or to political leanings of researchers? If so, how do such conditions or expectations affect the conduct and output of research?

C. If we are still mining the innovations of the 1960s and 1970s, why is a vigorous federal R&D effort necessary?

D. How does the federal government compare to private industry as a supporter of C&C technology development? (Consider objectives, output, and process.) To what extent are they substitutes? Complements? Capable of cooperating?

Readings:

Science/Technology Policy:

Stephan, Paula E. 1996. "The Economics of Science." *Journal of Economic Literature*, 34, September, pp.1199-1235.

Cohen, Linda R. and Roger G. Noll. 1994. "Privatizing Public Research." *Scientific American*, September, pp. 72-77.

Brooks, Harvey. 1986. "National Science Policy and Technological Innovation." *The Positive Sum Strategy: Harnessing Technology for Economic Growth,* National Academy Press, Washington, D.C., pp. 119-167.

Kline, Stephen J., and Nathan Rosenberg. 1986 "An Overview of Innovation." *The Positive Sum Strategy: Harnessing Technology for Economic Growth,* National Academy Press, Washington, D.C., pp. 275-305.

Office of Technology Assessment. 1992. *Federally Funded Research: Decisions for a Decade.* U.S. Government Printing Office, Washington, D.C. Executive Summary

Davis, Otto A., and Morton I. Kamien. 1969. "Externalities, Information and Alternative Collective Action."

Arrow, Kenneth J., et al. 1996. "Is There a Role for Benefit-Cost Analysis in Environmental, Health, and Safety Regulation?" *Science*, 272, April 12, pp.221-222.

Noll, Roger G. 1996. "Reforming Risk Regulation." Brookings Discussion Papers in Domestic Economics, April.

Computing/communications-Specific Policy:

CSTB. 1992. *Computing the Future: A Broader Agenda for Computer Science and Engineering*
Chapter 7: Institutional Infrastructure of Academic CS&E

CSTB. 1995. *Evolving the High Performance Computing and Communications Initiative to Support the Nation's Information Infrastructure*
Preface
Executive Summary
Chapter 1: U.S. Leadership in Information Technology

CSTB. 1994. *Rights and Responsibilities of Participants in Networked Communities* Chapter 8: Common Themes

David, Paul A. 1991. "Computer and Dynamo." *Technology and Productivity: The Challenge for Economic Policy."* Organization for Economic Cooperation and Development, Paris, pp.315-347.

CSTB. 1993. *Information Technology in the Service Society: A Twenty-First Century Lever*
Chapter 6: Information Technology in Services: Implications for Public Policy

CSTB. 1995. *The Changing Nature of Telecommunications/Information Infrastructure*
Introduction and Overview

CSTB. 1996. *Computing and Communications in the Extreme: Research for Crisis Management and Other Applications*

Overview and Summary

Chapter 1: Application Needs for Computing and Communications (pp 10-34, 53-54) Chapter 3: Summary and Findings: Research for National-scale Applications

HPCCI and Related:

CSTB. 1992. *Computing the Future: A Broader Agenda for Computer Science and Engineering*

Preface

Executive Summary

Chapter 1: Computing–Significance, Status, Challenges

Chapter 5: Recommendations

CSTB. 1995. *Evolving the High Performance Computing and Communications Initiative to Support the Nation's Information Infrastructure*

Chapter 2: The High Performance Computing and Communications Initiative

Chapter 3: Recommendations

Committee on Information and Communications, National Science and Technology Council. 1995. *Strategic Implementation Plan: America in the Age of Information.* Office of Science and Technology Policy, The White House, Washington, D.C.

3. Class 4 and 5: Research support and initiatives: interdisciplinarity (and specific research agendas), DOD technology interests

Material Covered:

A. Who supports CS/E? Where, how, and why? How did the current system arise?

   a. DOD support for research was dominant in the post-WWII period, declined in the 1970s (when energy, environment, and health grew in emphasis), and returned in the 1980s. What might happen if DOD support diminished greatly? Should it? What if other federal agencies cannot generate comparable funding?

b. NSF consolidated C&C support into a new directorate in the mid-1980s (CISE). How can its effectiveness be appraised? How can it be enhanced?

c. Historically important supporters of C&C (ONR, AFOSR, NIST/NBS) have much more minor roles today. Does that matter?

A. What are the pros and cons of major cross-agency initiatives?

  a. What does it mean to take a "strategic approach"? Is it desirable?

B. Should "government" have a vision? Where have federal support goals come from? How should goals be set?

  a. What are "priorities" for CS/E funding and how should they be set?

C. How can a large, diverse field be covered adequately? How should tradeoffs be made in the face of resource constraints? How are they made?

  a. Historically, diversification of the talent pool (beginning with geography and institution) has been balanced with reward for quality. What does it take to cultivate a robust and productive research community as the field becomes broader and more diverse in all respects?

D. What conditions or qualities may be most important in shaping future needs for C&C R&D? How much do they resemble or differ from those of the past? Is the federal government likely to be able to meet emerging R&D needs?

E. Are industry efforts sufficient to sustain progress in C&C? Why/why not?

  a. Are industry dollars comparable to federal dollars for R&D support?

F. How much support is "enough," and how do we know it?

Readings

DOD-centric:

CSTB. 1997. *Ada and Beyond: Software Policies for the Department of Defense*
Executive Summary
Chapter 1: The Changing Context for DOD Software Development
Chapter 2: Software Engineering and the Role of ADA in DOD Systems

CSTB. 1997. *The Evolution of Untethered Communications*
Executive Summary
Chapter 3: Commercial – Defense Synergy in Wireless Communications
- 3.5: Defense Technology Policy Issues
- 3.6: Summary

Chapter 4: Conclusions and Recommendations

CSTB. 1997. *Modeling and Simulation; Linking Entertainment and Defense*
Preface
Executive Summary
Chapter 1: Introduction
Chapter 3: Setting the Process in Motion

4. Class 6 and 7: Side effects overview: job change, equitable access, privacy

Material Covered

A. What's good/bad about "progress" in C&C (e.g., what trends, associations, or causal relationships) and why? Are things getting better/worse and why?

   How can values relating to various side-effects be characterized? Do they matter? Where, when, and why?

   a. Are side effects typically unintended consequences?

B. Given the experience of the past 30+ years, are we better able to anticipate consequences? If so, so what?

C. Where does responsibility for achieving better outcomes lie? What is the role of scientists/technologists where symptoms arise in use?

D. What might happen if action in such domains as health care result in de facto national identifiers?

E. How flexible is the balance between technology and practice/procedure in protecting privacy of electronic personal information?

F. What if universal service were compelled now?

   a. Is socioeconomic inequality a fact of life—and if so, what does that imply for technologists and policy?

   b. What are the consequences if some people are unable to use C&C?

G. Where is the science in making technology more socially comfortable?

H. Is there a public policy interest in facilitating group interaction via the Net?

I. What do changes in the industry-occupation mix imply for future C&C opportunities and challenges?

Readings (to be revisited in “Do the Right Thing”, Class 18 and 19):

General:

CSTB. 1996. *Keeping the U.S. Computer and Communications Industry Competitive: Convergence of Computing, Communications, and Entertainment*
Chapter 3: Societal Implications

CSTB. 1994. *Rights and Responsibilities of Participants in Networked Communities*
Executive Summary
Chapter 1: The Nature of Electronic Networks
Chapter 2: Networks and Society
Chapter 3: Legal Considerations for Electronic Networks
Chapter 7: Privacy

CSTB. 1994. *Realizing the Information Future: The Internet and Beyond*
Chapter 4: Principles and Practice

Froomkin, Michael A. 1996. “Flood Control on the Information Ocean: Living with Anonymity, Digital Cash, and Distributed Databases.” *University of Pittsburgh Journal of Law and Commerce*, 15 (395).

Johnson, David R. and David G. Post. 1996. “Law And borders—The Rise of Law in Cyberspace.” *Stanford Law Review*.

Privacy:

CSTB. 1997. *For the Record: Protecting Electronic Health Information*
Preface
Executive Summary
Chapter 1: Introduction
Chapter 2: The Public Policy Context
Chapter 3: Privacy and Security Concerns Regarding Electronic Health Information
Chapter 6: Findings and Recommendations

CSTB. 1996. *Continued Review of the Tax Systems Modernization of the Internal Revenue Service: Final Report*
Chapter 4: Privacy
Chapter 5: Security

Information Infrastructure Task Force. 1997. “Options for Promoting Privacy on the National Information Infrastructure: Draft for Public Comment.” Information Policy Committee, April.

Westin, Alan F. 1995. “Privacy Rights and Responsibilities in the Next Era of the Information Age.” *Toward an Information Bill of Rights and Responsibilities,* The Aspen Institute, Washington, D.C. Pp. 71-106.

Usability and Usefulness:

CSTB. 1997. *More Than Screen Deep: Toward Every-Citizen Interfaces to the Nation's Information Infrastructure*

Chapter 2

Schement, Jorge Reina. 1995. "Divergence Amid Convergence: The Evolving Information Environment of the Home." *Crossroads on the Information Highway.* The Aspen Institute, Washington, D.C. Pp. 135-160.

CSTB. 1993. *Information Technology in the Service Society: A Twenty-First Century Lever* Summary and Overview

CSTB. 1995. *Information Technology and Manufacturing*

CSTB. 1995. *The Changing Nature of Telecommunications/Information Infrastructure*
Part II - Regulation and the Emerging Telecommunications Infrastructure
- Cost and Cross-Subsidies in Telecommunications
- Economic Ramifications of the Need for Universal Telecommunications Service

Employment Change:

Luker, William, Jr., and Donald Lyons. 1997. "Employment shifts in high-technology industries, 1988-96. *Monthly Labor Review*, June, pp. 12-25.

McConnell, Sheila, et al. 1996. "The Role of Computers in Reshaping the Work Force." *Monthly Labor Review,* August. Pp. 3-56.

Wolfe, Edward N. 1996. *The Growth of Information Workers in the U.S. Economy, 1995-1990: The Role of Technological Change, Computerization, and Structural Change.* C.V. Starr Center, New York University, New York.

5. Class 8 and 9: Security and trustworthiness: concepts and challenges.

Material Covered

A. What has changed (in technology, the economy, society) since 1990, and what does that imply for public policy relating to trustworthiness? What is changing in the late 1990s that may affect public policy relating to trustworthiness in the early 21st century?

B. Are there absolutes in balancing interests (public and private) relating to trustworthiness?

C. What are the most effective government levers for stimulating private action—and what happens when government "control" erodes?

D. What is the role of government for infrastructure deemed "critical"? How might government interests be contrasted among information infrastructure in general, specific subsets, and public key infrastructure?

E. Are there any kinds of C&C safeguards that demand government involvement? What and why?

Readings:

Subcommittee on Investigations and Oversight. 1989. *Bugs in the Program: Problems in the Federal Government Computer Software Development and Regulation.* Committee on Science, Space, and Technology, U.S. House of Representatives, U.S. Government Printing Office, Washington, D.C.

CSTB/BOTCAP. 1989. *Growing Vulnerability of the Public Switched Networks*
Preface
Executive Summary
Chapter 1: Introduction
Chapter 2: National Security Emergency Preparedness Initiatives to Date

CSTB. 1991. *Computers at Risk: Safe Computing in the Information Age*
Executive Summary
Chapter 1: Overview and Recommendations
Chapter 2: Concepts of Information Security
Chapter 5: Criteria to Evaluate Computer and Network Security
Chapter 6: Why the Security Market Has Not Worked Well
Appendix A: The Orange Book (pp 243-245)
Appendix C: Emergency Response Teams
Appendix D: Models for GSSP
Appendix E: High-grade Threats

CSTB. 1994. *Rights and Responsibilities of Participants in Networked Communities*
Chapter 5: Electronic Vandalism

Office of Management and Budget. 1995. National Information Infrastructure Security Issues Forum Releases "NII Security: The Federal Role." June.

Security Working Group of the FNC, et al. 1995. *Federal Internet Security: A Framework for Action.*

Libicki, Martin C. 1995. *What is Information Warfare?* National Defense University, Washington, D.C.
Chapter 10: Summary
Chapter 11: Looking for the Elephant, pp. 61-65

Libicki, Martin C. 1997. *Defending Cyberspace and Other Metaphors.* National Defense University, Washington, D.C.
Essay One: Perspectives on Defending Cyberspace
Essay Four: The Retro Revolution
Essay Six: Point, Counterpoint, and Counter-Counterpoint

Congressional Budget Office. 1996. *Emerging Electronic Methods for Making Retail Payment.* U.S. Government Printing Office, Washington, D.C.

6. Class 10 and 11: Security and trustworthiness: cryptography policy, law enforcement

Material Covered:

A. Why are "equity" issues difficult in public policy?

B. What is the difference between contrasting law enforcement with business and privacy interests, and crime prevention with crime prosecution?

C. Does cryptography pose risks for society if it is used to facilitate the accomplishment of illegal or criminal designs?

D. What are the pros and cons of key recovery programs? If a business need for key recovery exists, why is government intervention needed to affect the market? What legal/regulatory framework is needed to give confidence that key recovery will work as intended? How will key recovery work internationally?

E. What is known about the utility of key recovery in achieving law enforcement objectives? What is the evidence that encryption is/will be a problem? What other ways can data be hidden?

F. What does it mean to call for 'no restrictions on domestic (U.S.) manufacture, sale, or use of encryption'?

G. What can scientists/technologists do to help resolve issues in this arena?

Readings:

CSTB. 1996. *Cryptography's Role in Securing the Information Society*
Preface
Executive Summary
Chapter 2: Cryptography: Roles, Market, and Infrastructure
Chapter 3: Needs for Access to Encrypted Information
Chapter 4: Export Controls
Chapter 5: Escrowed Encryption and Related Issues
Chapter 6: Other Dimensions of National Cryptography Policy
Chapter 7: Policy Options for the Future
Chapter 8: Synthesis, Findings, and Recommendations
Glossary
Appendix E: A Brief History of Cryptography Policy
Appendix F: A Brief Primer on Intelligence
Appendix G: The International Scope of Cryptography Policy

Denning, Dorothy E. and William E. Baugh, Jr. 1997. "Encryption and Evolving Technologies as Tools of Organized Crime and Terrorism." Working Group on Organized Crime, National Strategy Information Center, Washington, D.C., July.

Perl, Raphael F. 1997. "Terrorism, the Future, and U.S. Foreign Policy." Congressional Research Service, Washington, D.C., July.

Perl, Raphael F., et al. 1997. "Terrorism: Background and Issues for Congress." Congressional Research Service, Washington, D.C., July.

7. Class 10 and 11: Paying for progress: networking infrastructure economics, information economics and policy

Material Covered:

A. How important is symmetry in bandwidth between provider and consumer? Why? How fast should it be attained—and at what cost(s)? How should it be supported?

B. Is the computer industry's frustration with LEC investment in local loop capacity justified? Why/why not?

C. If money were no object, would we know how/where to invest in information infrastructure?

D. Is Huber's faith in lock-out technologies (e.g., encryption) sufficient to support the case for minimal government intervention in information markets?

Readings:

Networking Economics:

CSTB. 1995. *Keeping the U.S. Computer and Communications Industry Competitive: Convergence of Computing, Communications, and Entertainment.*
Chapter 1: Overview
Chapter 2: Trends and Directions

CSTB. 1994. *Realizing the Information Future: The Internet and Beyond*
Chapter 5: Financial Issues
Chapter 6: Government Roles and Opportunities

CSTB. 1995. *The Changing Nature of Telecommunications/Information Infrastructure*
Part III - Public Investment in Telecommunications Infrastructure
- Telecommunications Infrastructure from the Carrier's Point of View
- Federal investment Through Subsidies: Pros and Cons

CSTB. 1996 . *The Unpredictable Certainty: Information Infrastructure Through 2000*
Chapter 1: Introduction and Summary
Chapter 2: Making Technology Work: Individual and Organized End Users
Chapter 3: Where is the Business Case?
Chapter 6: Public Policy and Private Action

Information Infrastructure Task Force. 1993. *The National Information Infrastructure: Agenda for Action.* Washington, D.C.

Information Economics:

Noll, Roger. 1993-1994. "The Economics of Information: A User's Guide." *The Knowledge Economy,* The Aspen Institute, Washington, D.C. Pp. 25-52.

Arrow, Kenneth. 1962. "Economic Welfare and the Allocation of Resources for Invention." Originally in *The Rate and Direction of Inventive Activity*, Princeton University Press, Princeton, pp. 609-625.

Huber, Peter. 1997: *Law and Disorder in Cyberspace: Abolish the FCC and Let Common Law Rule the Telecosm*. Oxford University Press, New York.

CSTB. 1994. *Rights and Responsibilities of Participants in Networked Communities*
Chapter 4: Free Speech
Chapter 6: Intellectual Property Interests

Cohen, Julie E. 1997. "*Lochner* in Cyberspace: The New Economic Orthodoxy of 'Rights Management.'" Presented at the Telecommunications Policy Research Conference, Washington, D.C., September 5 draft. Revised version published in *Michigan Law Review* (97:2), 1998.

8. Class 12 and 13: The Internet

Material Covered:

A. Should the federal government continue to support technology development strongly related to the Internet?

B. What are reasonable objectives for a next phase of or successor to the NGI?

C. Should the U.S. government take an active role in Internet governance—and if so, what should it emphasize? How do you assess the action taken regarding DNS?

D. Is regulation of the Internet inevitable?

Readings:

CSTB. 1994. *Realizing the Information Future: The Internet and Beyond*
Chapter 2
Appendix A (pp. 237-242)

CSTB. 1996. *The Unpredictable Certainty: Information Infrastructure Through 2000*

Clinton, President William J. and Vice President Albert Gore, Jr. *A Framework for Global Electronic Commerce*.

Werbach, Kevin. 1997. "Digital Tornado: The Internet and Telecommunications Policy." OPP Working Paper Series, Office of Plans and Policy, Federal Communications Commission, Washington, D.C., March.

National Coordination Office for Computing, Information, and Communications. 1998. "Next Generation Internet Implementation Plan." Washington, D.C., February.

9. Class 16 and 17: IT in government: systems modernization, e-dissemination and governance

Material Covered

A. What can we learn (more generally) from US government agency experiences and mishaps?

B. What do long-term constraints on agency funding and talent imply for technology needs?

C. How can the new "Digital Government" initiative best promote mutual interests of researchers and agency officials? How can research interests be leveraged and stimulated by mission government needs?

Readings:

Cohen, William S. 1994. *Computer Chaos: Billions Wasted Buying Federal Computer Systems.* Investigative Report, Subcommittee on Oversight of Government Management, Governmental Affairs Committee, U.S. Senate, Washington, D.C.

CSTB. 1996. *Continued Review of the Tax Systems Modernization of the Internal Revenue Service: Final Report*
Summary and Major recommendations
Chapter 1: Background

CSTB. 1996. *Computing and Communications in the Extreme: Research for Crisis Management and Other Applications*
Overview and Summary

Executive Order #13011, Federal Information Technology, July 17, 1996.

Information Technology Reform Act of 1996.

Government Performance and Results Act of 1993.

Office of Management and Budget. 1996. "Management of Federal Information Resources," Revision of OMB Circular No. A-130. Federal Register, Vol. 61, No.34, February 20, pp.6428-6453.

Office of Management and Budget. 1995. "Evaluating Information Technology Investments: A Practical Guide." Version 1.0. Office of Information and Regulatory Affairs, Washington, D.C., November.

Collins, Eileen. 1997. "Performance Reporting in Federal Management Reform." National Science Foundation, Arlington, VA, March 14.

Executive Order #13073, Year 2000 Conversion, February 4, 1998.

Office of Management and Budget. 1998. "Progress on Year 2000 Conversion: 4th Quarterly Report," As of February 15. Washington, D.C.

General Accounting Office. 1998. Year 2000 Computing Crisis: Strong Leadership and Effective Public/Private Cooperation Needed to Avoid Major Disruptions. Statement of Gene L. Dodaro, March 18.

10.   Class 18 and 19:   Do the right thing: advocacy as a policy factor

Material Covered:

A. What does it take to be a successful advocate in the C&C arenas?

B. Who are the digerati and how should their influence be appraised?

C. Some arenas, such as health care, successfully engage people with personal or familial stakes (e.g., people with certain diseases). What does it take to motivate support for C&C causes?

D. Why has promoting the interests of people disadvantaged in various ways proven difficult?

E. Government at different levels doesn't supply automobiles to people to meet job and household needs. Should C&C be regarded differently?

F. Why has that promotion been concentrated among nonprofit organizations and outspoken individuals?

G. What does it take to increase and broaden attention to social dimensions—and what would happen with more such attention?

Readings:

Minow, Newton N. 1993. "The Wasteland Revisited: How Vast Is It Now?" *Aspen Quarterly*, Spring, pp.13-29.

CSTB. 1994. *Realizing the Information Future: The Internet and Beyond*
Chapter 1: U.S. Networking: The Past is Prologue
Chapter 3: Research, Education, and Libraries
Appendix B

Cornfield, Michael and F. Christopher Arterton. 1997. " 'Is This for Real?' Democratic Politics and the Internet." *The Internet as Paradigm.* The Aspen Institute, Washington, D.C. Pp. 85-101.

Communications Workers of America. 1994. *Preserving High-Wage Employment in Telecommunications.* Washington, D.C.

Council of Economic Advisors. 1994. *Economic Benefits of the Administration's Legislative Proposals for Telecommunications.* Washington, D.C.

CSTB. 1997. *More Than Screen Deep: Toward Every-Citizen Interfaces to the Nation's Information Infrastructure*

11. Class 20 and 21: Computing, communications, and education: a problematic arena

Readings:

CSTB. 1994. *Realizing the Information Future: The Internet and Beyond*
Chapter 3: Research, Education, and Libraries

Oppenheimer, Todd. 1997. "The Computer Delusion." *The Atlantic Monthly,* July, pp.45-62.

National Center for Education Statistics. 1998. "Internet Access in Public Schools." NCES 98-031. U.S. Department of Education, Office of Educational Research and Improvement, March.

12. Class 22 and 23: The producers: competitiveness, standards, competition policy

Material Covered:

A. Is there a special government interest in the supply of C&C—in the computer sector? If so, is it general or properly focused in special areas (e.g., national security)?

B. What is a "U.S. firm"–and does it matter?

C. How well are R&D support and industry/competitiveness support coupled? Are they substitutes or complements?

D. Should the federal government be more or less active in the setting of C&C standards? Does the emerging concern with "critical infrastructure" change the assessment—or might it in time?

E. Should the federal government promote the breakup or lesser growth of Microsoft or let market forces play out as they will? Why or why not? What about Intel or any other dominant firm—does technology or market segment matter?

F. How might the political and policy awakening of more of the computer sector affect public policy toward it?

Readings:

Competitiveness:

CSTB. 1989. *Keeping the U.S. Computer Industry Competitive: Defining the Agenda*
Executive Summary
Chapter 1: Overview
Chapter 6: Turning Point

CSTB. 1991. *Keeping the U.S. Computer Industry Competitive: Systems Integration*
Executive Summary
Chapter 1: Overview
Box 2.3: Thoughts on Exporting (p. 27)
Chapter 5: Prerequisites for Progress

CSTB. 1995. *Keeping the U.S. Computer and Communications Industry Competitive: Convergence of Computing, Communications, and Entertainment*
Chapter 4: Promoting Competitiveness: Policy Issues and Obstacles

Schacht, Wendy H. 1997. "Industrial Competitiveness and Technological Advancement: Debate Over Government Policy." Congressional Research Service, Washington, D.C., June.

CSTB. 1988. *Global Trends in Computer Technology and Their Impact on Export Control*
Preface
Executive Summary
Chapter 1: Introduction
Chapter 7: Conclusions and Recommendations

Morris, Charles R. and Charles H. Ferguson. 1993. "How Architecture Wins Technology Wars." *Harvard Business Review*, March-April, pp.86-96.

Katz, Michael L. and Carl Shapiro. 1994. "Systems Competition and Network Effects." *Journal of Economic Perspectives,* 8 (2), Spring, pp. 93-115.

Farrell, Joseph. 1995. "Arguments for Weaker Intellectual Property Protection in Network Industries." *StandardView*, 3(2), June, pp.46-49.

Liebowitz, S.J. and Stephen E. Margolis. 1994. "Network Externality: An Uncommon Tragedy." *Journal of Economic Perspectives,* 8 (2), Spring, pp. 133-150.

Standards:

Board on Science, Technology, and Economic Policy. 1995. *Standards, Conformity Assessment, and Trade: Into the 21st Century*
Executive Summary
Chapter 1: Introduction
Chapter 2: Standards Development
Chapter 3: Conformity Assessment
Chapter 4: International Trade
Appendix A: New Developments in International Standards and Global Trade: A Conference Summary

Libicki, Martin. 1995. *Standards: The Rough Road to the Common Byte*
Executive Summary
Chapter 1: What Standards Do
Chapter 2: The Open Road
Chapter 3: Front Line Manufacturing
Chapter 4: To the Gigabyte Station
Chapter 5: Lessons and Prognostications

Besen, Stanley M. and Joseph Farrell. 1994. "Choosing How to Compete: Strategies and Tactics in Standardization." *Journal of Economic Perspectives,* 8 (2), Spring, pp. 117-131.

Regulation:

CSTB. 1995. *The Changing Nature of Telecommunications/Information Infrastructure*
Introduction and Overview
Part II - Regulation and the Emerging Telecommunications Infrastructure
- Introduction to Part II
- Government Regulation and Infrastructure Development
- State Regulatory Policies and Telecommunications/Information Infrastructure
- The Prospects for Meaningful Competition in Local Telecommunications
- Regulation and Optimal Technological Change: Not Whether, But How
- The Future of Telecommunications Regulation: The Hard Work is Just Beginning

Gilroy, Angele A. 1997. "Telecommunications Regulatory Reform." Congressional Research Service, Washington, D.C., July.

Harris, Robert G. and C. Jeffrey Kraft. 1997. "Meddling Through: Regulating Local Telephone Competition in the United States." *Journal of Economic Perspectives,* 11 (4), Fall, pp.93-112.

Noll, Roger G. 1996. "The Economics and Politics of the Slowdown in Regulatory Reform." Brookings Discussion Papers in Domestic Economics, April.

Nunno, Richard M. 1997. "Radiofrequency Spectrum Management." Congressional Research Service, Library of Congress, August 22.

Katz, Michael L. 1996. "Interview with an Umpire." *The Emerging World of Wireless Communications.* The Aspen Institute, Washington, D.C. Pp. 1-20.

Antitrust:

Blumenthal, William. 1996. "Epilogue: the issues that divide us." *The Antitrust Bulletin*, Fall, pp.585-591.

Merger Standards Task Force. 1986. *Horizontal Mergers: Law and Policy*. Monograph 12, Section of Antitrust Law. American Bar Association, Chicago, pp. 5-26.

Noll, Roger G. 1994. "The Role of Antitrust in Telecommunications." Presented at the Telecommunications Policy Research Conference, Solomons, MD.

13. Class 24: Emerging technical concerns: what's next? (embedded systems)

14. Class 25: International issues: a growing context

Material Covered:

A. What does the GII label imply for…?

B. How real are concerns about "cultural imperialism" via the Internet?

C. What special opportunities and challenges do newly industrializing nations pose for C&C technology development and deployment?

D. If, as Walter Wriston suggests, information infrastructure eviscerates government controls, what prospects does a global networked economy and society hold?

E. If, as some argue, traditional centralized institutions may lose influence, what, if anything, may replace them? How will these developments reflect or affect C&C?

Readings:

Board on Science, Technology, and Economic Policy. 1995. *Standards, Conformity Assessment, and Trade: Into the 21st Century*
Chapter 4: International Trade
Appendix A: New Developments in International Standards and Global Trade: A Conference Summary

Brotman. Stuart N. 1996. "Creating a Wireless World: Reflections on the International Cellular Communications Development." *The Emerging World of Wireless Communications.* The Aspen Institute, Washington, D.C. Pp. 141-165.

McGarty, Terrence P. and Jacob Davidson. 1997. "Comparative Deregulation of Far Eastern Telecommunications Markets." Presented at the Telecommunications Policy Research Conference, Alexandria, VA.

Primo Braga, Carlos A. 1997. "Liberalizing Telecommunications and the Role of the World Trade Organization." *The Information Revolution and the Future of Telecommunications*. The World Bank Group, Washington, D.C., June, pp.20-26.

Office of International Affairs, National Research Council. 1996. *Bridge Builders: African Experiences with Information and Communication Technology*. National Academy Press, Washington, D.C.
Introduction

United Nations Development Programme. 1997. *Human Development Report 1997*. Oxford University Press, New York.
Miscellaneous tables (handouts)

15. Class 26 and 27: Know your place: CS&E labor market principles, problems, prospects

Material Covered:

A. How many...of whom? Who knows? Who cares?

B. How are computing professional occupations evolving? What are short- and long-term trends?

C. Is there a shortage of computing professionals? What kind? How do we know?

D. Is the trend toward engaging computing professionals from around the world in research and product development "good"? Why/why not?

Readings:

CSTB. 1993. *Computing Professionals: Changing Needs for the 1990s*
Preface
Executive Summary
Chapter 1: Introduction
Chapter 2: Data and Taxonomy: Computing Professionals Are Hard to Count
Chapter 4: Supply: Who Enters the Profession?
Chapter 5: Training, Retraining, and More Retraining
Chapter 6: Conclusion and Next Steps

CSTB. 1994. *Academic Careers for Experimental Computer Scientists and Engineers*
Preface
Executive Summary
Chapter 7: Findings and Recommendations

CSTB. 1992. *Computing the Future: A Broader Agenda for Computer Science and Engineering*
Chapter 4: Education in CS&E

U.S. Department of Commerce and Information Technology Association of America reports

16. Class 28: The CS/E leadership challenge

Material Covered:

A. Vannevar Bush ("Science: The Endless Frontier," 1945) called for both federal support of basic scientific research and training and involvement of academic and industrial scientists in the policy process. How can more computer scientists/engineers become involved, to good effect?

B. How can the benefits of cross-disciplinary interaction best be pursued? Should computer scientists/engineers see it as a threat or an opportunity?

Readings:

CSTB. 1992. *Computing the Future: A Broader Agenda for Computer Science and Engineering*
Preface
Executive Summary
Chapter 1: Computing - Significance, Status, Challenges
Chapter 4: Education in CS&E
Chapter 5: Recommendations
Chapter 7: Institutional Infrastructure of Academic CS&E