

AC 2007-2194: TECHNOLOGY AND INFORMATION MANAGEMENT PROGRAM

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Technology and Information Management Program

Abstract

This paper describes a new graduate program in Technology and Information Management (TIM) being developed by the Jack Baskin School of Engineering at the University of California, Santa Cruz. As a University of California graduate program, it proposes¹ to offer both the M.S. and Ph.D. degrees, with the M.S. intended to prepare its graduates for careers in “high-tech” firms of Silicon Valley, California, and elsewhere. We view TIM as a new and distinct discipline within engineering, combining technology management, systems engineering, and information technology. As an engineering program, TIM addresses both the Management of Technology (MOT) and the Technology of Management (TOM). In MOT, initial emphasis is on the development of theory, analytical results, methods and tools that more closely couple economic factors into engineering and product decisions of firms. This includes studies of the role of information technology in the management of complex systems of both technology and people. In TOM, the emphasis is on development of both theory and software to enable organizations to manage large collections of data in a way that preserves and enhances the information and knowledge that data represents, as well as enabling people in an organization to retrieve that information in a timely and comprehensible way, in areas from manufacturing to sales to services, and across the enterprise functions of analysis, planning and operations. In summary, the domain of the TIM program is: 1) the management of technology and innovation, with emphasis on analytic approaches to complex problems whose solutions have both technological and financial components, and 2) the development of technology of management. Information technology, and information systems and services are core components of both.

Background

The central technology in most complex systems today is information technology, and the most rapidly changing business environments are in the areas of information technology and complex system design. The design and management of these complex systems presents challenges to enterprises and to individual executives and managers. This is especially true in organizations which are in, or critically depend upon, rapidly changing technologies and rapid introduction of new products and services in competitive environments (a definition of “high tech” enterprises). By using, synthesizing and extending ideas from traditional fields such as computer science, economics, and business management, TIM studies and teaches its students how the use of information technology can lead to more effective management of enterprises (to achieve “competitive advantage”), and more generally, addresses problems in the design and management of complex systems involving people, technology and organizations.

Research and teaching programs combining technology, systems, and management are much needed especially today, as firms deal with more complex decisions in a global environment, and address such topics as “out-sourcing” and “off-shoring” of many of the traditional technology enterprise functions and engineering and support tasks to lower cost regions and countries such as India and China.

The challenges faced in “high tech” enterprises require the integration of technology and business understanding to solve complex interdisciplinary problems. Management of the

development and commercialization of technology is one continuing challenge. To rapidly respond to changing markets, executives and engineering managers must have an understanding of technologies as well as the analytical skills to develop viable solutions that may be theoretically sophisticated but can be implemented in a timely fashion. Designing and managing complex systems in technology contexts requires a range of skills that include knowledge of the relevant technologies and an understanding of the operational, financial and marketing dimensions of the business enterprise. In addition, managers must develop leadership skills and skills in human interaction, including the skills to interact with and manage individuals from different backgrounds and cultures and in diverse (and geographically distributed) teams; an understanding of organizational structures and their relationship to integration of new developments; and the skills to market new ideas and developments within the organization. Successful managers in high technology enterprises must be able to develop a vision of their product or service and to articulate and market that vision within their organization in order to obtain the necessary resources and to achieve the maximum impact of their work within the organization.

Approach

Management in all types of enterprises, and especially high tech enterprise, must address:

- The efficient and productive operation of their enterprise (i.e. **operations**), including new product development, marketing and supply chain management;
- The strategic and financial management of the enterprise, including capital investments, product related portfolios, and economic choices (i.e. **strategy**); and,
- The ability to extract, develop, store and effectively use knowledge (from raw data) for productivity and for profit-enhancing decision making (i.e. **knowledge management and services**).

Traditional graduate management programs address topics in operations and strategy. What makes TIM unique is that information technology and knowledge developed from data gathered in the operations of enterprises pervade the TIM curriculum and research, and this dimension of “knowledge management and services” is at the core of the approach in TIM to operations and strategy.

TIM expects to admit graduate students with strong analytical and engineering backgrounds. The “typical” TIM students are expected to be engineering graduates (BS minimum), with some industry experience, including possibly managerial training and responsibility, who want to develop the skills that TIM offers, and use these in management within their industry. In its curriculum and its research, TIM will employ the analytic “systems” approach of modeling, analysis and optimization, coupling these with the latest developments in information technology. Graduates will acquire expertise in the development and use of information technology, decision support systems, and analytic approaches to decision making under uncertainty, plus an in-depth knowledge of business in the “high-technology” areas.

Graduate students in the TIM program will take an extensive coursework in engineering and information technology, just as in other engineering programs. But unlike most engineering programs, TIM students will take courses that teach how the technology they study can be used to support the management of commercial enterprises and complex systems. TIM students will

also study analytical methods in the context of TIM subtopics such as organizing and retrieving information and knowledge, designing systems composed of technology and of people and organizations with (possibly different) economic interests, and managing risks and resources in commercial enterprises. These uniquely-trained graduates will be prepared to take leadership roles in existing companies or to help create new enterprises. Our doctoral graduates will have the breadth of knowledge to identify important research questions that require both an understanding of information technology and of organizations and management, and will have the depth of analytical knowledge to address these questions. This will make them exceptionally well equipped for careers in research.

The academic degree programs will educate and train professionals in two major areas of expertise: TOM and MOT. In TOM, the emphasis will be on the “knowledge engineering and services”: the analysis, design, and implementation of information systems and information technology to provide integrated business-technology solutions for end-to-end (from business process to software to information technology infrastructure) automation of the enterprise, in particular high-tech enterprises. Those emphasizing TOM will also learn the basics of MOT, as the managers of technology will apply the tools and systems of TOM, and thus drive requirements for TOM capabilities. In MOT, the emphasis is on the comprehensive management, development, and commercialization of technologies and products, from high-level business and technology strategy through product development, operations and risk management, to marketing and distribution. MOT students will learn the basics of TOM, as they will be applying these systems and tools as managers. Complementing the education and training in these two areas, the program will develop students’ understanding of, and skill in, leadership and management of human resources.

Students / Careers

TIM will offer a unique opportunity for its graduate students to build on their engineering background while developing a new understanding of the business issues facing their companies. To acquire this set of skills today in most schools would require graduate students to pursue studies both in engineering and in a business school, and to synthesize on their own what they have learned from both of these in the context of their industry careers. TIM will instead bring both of these domains together in an integrated curriculum and focus, enabling students to acquire the tools to address the complex problems faced by managers in these technology companies. Working engineers in local industry with interests in management in advanced technology enterprises are expected to be a major source of graduate students in TIM. (Note that it is anticipated that 80-90% of the TIM M.S. students will have full-time jobs in Silicon Valley, and will therefore be enrolled part-time in the TIM program. Ph.D. students on the other hand are expected to be 80-90% full-time TIM students.)

Some of the possible tasks that graduates of this program should be equipped to address in their industry or academic positions include:

- New product / Service development
- Portfolio management (product and services)
- Risk Management (multidimensional and temporal)
- Services management / E-business

- Marketing / Product Positioning
- Supply chain management (including global supply and value chain management)
- Manufacturing and outsourcing
- Business intelligence / decision support system design
- Knowledge management systems
- Enterprise systems design and management
- Entrepreneurship and intrapreneurship

Curriculum

Education for technology management requires courses that provide an understanding of system-level product development, enterprise-level supply chain management, marketing and e-business, and the management of human resources in the team and organization. Successful executives and managers will be those who can exploit opportunities and resources and employ risk management approaches, enabled by information technologies, in designing product portfolios and achieving rapid and effective product design and delivery. Relevant technologies in the research of TIM, related to the development of tools for management decision making (TOM), include: knowledge management, information systems, network and database design and management, decision support systems and data visualization, data mining and machine learning. Students in this program will also have the opportunity to learn analytic techniques relevant to formation of new enterprises, going beyond traditional (experience-based) entrepreneurship. Managers and entrepreneurs also require an understanding of the human and social elements, and the ability to incorporate these in their management practice, in managing groups, relating to other groups in or as partners of the enterprise, and in responding to customers. The skills and ability to communicate across all functions and levels within and outside the organization, as well as leadership and people skills, are important qualifications for these future managers. We also anticipate that many of the graduates of the program will be able to develop and manage sophisticated “business intelligence” platforms and other information systems that drive enterprises or are marketed as services by new enterprises. The TIM doctoral students will develop both theory and new tools to support management decision making, e.g., fusing sophisticated stochastic optimization with advanced knowledge management methods in a real “high-tech” industrial context.

The research areas in TIM are varied, and research advisors in each will tailor the sequence of classes for their students to develop appropriate depth in analytical methods and technology.

Typical Research Areas

TIM is uniquely positioned to excel in research directions that transcend the boundaries of traditional disciplines such as Operations Research (OR), Industrial Engineering (IE), Management Science and Engineering (MSE), and Computer Science (CS). TIM Ph.D. students, working directly with the TIM faculty, as well as collaborating with other outstanding faculty in both the School of Engineering and the Economics Department and Psychology Department of the Division of Social Sciences, will become top researchers in TIM-related areas. Areas we consider to be the key research directions of TIM are listed below and briefly described. It should be noted that these areas transcend the traditional boundaries of OR, IE, MSE, and CS.

- **Integration Engineering and Enterprise Management:** This area involves the integration of business, technology, and management perspectives, to enable an entity to achieve enhanced growth and profitability, using methods from stochastic models, optimization, game theory, and knowledge management, and drawing upon the disciplines of engineering, economics, computer science, psychology, organizational theory, management, and financial engineering. These methods will address new needs such as modeling outsourcing and integrating optimization and knowledge extraction.
- **New Product, Service and Technology Development:** This area involves the design and development of products and services, the design and risk management of product portfolios, and pricing. The combination of resource allocation in service and enterprise systems, capturing delays, demand characteristics, resource costs, and game theoretic interactions of multiple decision makers with local objectives and information are other important research issues in this field. This field also includes characterizing and enhancing/optimizing learning in multiple teams, working in multiple firms and locations, including those in the semiconductor, software, network, e-business, bioscience, and consulting areas.
- **Real Options and Financial Engineering:** This area involves the development of mathematical, statistical and computational techniques to address the management of risk and allocation of resources in technology development and deployment. It employs methods, such as options theory, that were originally developed to solve financial problems, in the context of technology management.
- **Management and Optimization of Complex Systems (including Supply Chain Management, Manufacturing, Services, and Operations Management):** This area involves the modeling, analysis and optimization of complex systems including information systems and networks, and other systems for flow control, pricing and quality of service. It addresses problems in supply chains, including improvement of models and control methods for management of all activities involved in sourcing, procurement and logistics.
- **Information Retrieval and Knowledge Management:** This area involves the use of data mining, machine learning, and natural language processing techniques for the organization, representation, retrieval, analysis, and communication of information on the Internet, intranets, and within an organization. Recently, there has been an emphasis on semantic mining and knowledge management, where domain knowledge (of management and business systems in high tech and other firms) can be exploited. Some applications include personalized search engine, text/data/semantic mining of trouble tickets and network data traffic dynamics, anomaly detection in airline and space data, diagnostics, routing of requests to the appropriate source in help desks and customer service centers.

Expected Impact

Technology and Information Management, in partnership with other SOE programs, serves to meet the needs of industry and the State of California. These programs will enable UCSC to attract capable students and train them to play important roles in the emerging technologies of the 21st century. The M.S. and Ph.D. degree programs in TIM will be specifically geared toward strengthening the workforce in the management of information systems and technology by providing highly skilled and knowledgeable professionals and academics who will support

advances in Technology and Information Management research. With TIM, together with the other programs in the School of Engineering, UCSC will be in a unique position to fully exploit Santa Cruz's location as the UC for Silicon Valley. Based on in-depth conversations and survey with industry leaders, we believe that Silicon Valley firms have significant interest in a technologically-oriented management program that can help provide skills to employees who will learn to manage and lead successful teams.

Distinctive Features of TIM

The TIM program adds three new features that are not commonly available in either traditional Industrial Engineering Departments or Management Schools. While it has components in common with both, these key features make it unique. TIM is focused on enhanced profitability and growth of firms through:

- The fusion of Knowledge Management (using information systems) with more traditionally-taught Operations and Strategy.
- Faculty and students with a deep understanding of technology obtained an engineering education and background.
- Active engagement with Silicon Valley firms through research, consulting and course projects and internships (amplified through our Silicon Valley presence).

Other distinctive features of TIM are:

- The emphasis on integration of management science and expertise in technology domains, with research and curriculum addressing complex systems challenges such as product design and supply chain management
- The integration of technology and business perspectives in the education of graduates for positions in the management, development, and commercialization of technology
- The emphasis on the use of information systems and information technology as a unifying framework for the management, development and commercialization of technology

UC Santa Cruz is developing a worldwide reputation for excellence in engineering. The School of Engineering (SOE) at UCSC is poised for growth, in partnership with initiatives such as the University Affiliated Research Center (UARC) and the Center for Information Technology in the Interest of Society (CITRIS). In addition, the University of California Office of the President (UCOP) has provided seed funding for the TIM program to be launched in the new Silicon Valley Center.

The expertise of the TIM faculty expands the dimensions of engineering in the SOE, complementing existing strengths, and covering new dimensions concerning the management of technology. There is also considerable potential for joint research with the Social Sciences Division (SSD), particularly Economics, on outsourcing models, for example. TIM will build upon the University's long commitment to interdisciplinary research and teaching.

In other academic institutions addressing the management of technology (e.g. Harvard, Berkeley), these programs are joint efforts between engineering and the business school. Some of the analytic research and teaching relevant to TIM is found in programs in engineering, in systems or operations research, and other topics are the domain of economics and some in business schools. The engineering school departments address the individual technologies, and computer science programs are the usual home for research and teaching in information technology. Our plan for TIM brings all these together in an engineering program that is focused on management in the “high technology” sector, specifically addressing complex systems topics found in the industries in our local area (Silicon Valley), especially in the computer, semiconductor, nanotechnology, networking, and bio-tech industries. Our focus on the comprehensive integration of technology and management, all in one program in the School of Engineering, distinguishes our program from similar programs.

The uniqueness and value of the TIM program lies in the integrated systems approach to coverage of both the technology and business aspects of “high tech” enterprises. Our proposed M.S. and Ph.D. programs in TIM will provide graduates with the knowledge and skills required to make important contributions to the development and use of information systems and information technology, and tools for analysis and optimization of complex systems, in the operations and management of enterprises that are essential to the economy of California.

Our focus on the comprehensive integration of technology and management, all in one program in the School of Engineering, distinguishes our program from similar programs.

Location

The University of California, Santa Cruz, is the UC campus closest to Silicon Valley, and has established a “Silicon Valley Center” at the NASA Research Park in Mountain View, at the former Navy base called Moffett Field. The UC Santa Cruz campus is located across the Santa Cruz Mountains from Silicon Valley, approximately 37 highway miles from the Silicon Valley Center. UC Santa Cruz and its Baskin School of Engineering are the primary UC presence in Silicon Valley. A substantial fraction of the engineering faculty live in the Silicon Valley, where they also consult with companies (and have spouses working in the local firms.) Our proposal is to have the TIM program administered as a department of the Baskin School of Engineering. TIM faculty and graduate students will have offices at both the Santa Cruz campus, and also have a major presence at the Silicon Valley Center (SVC) location, including offices for faculty and graduate students, and facilities to support research projects, especially those involving work with local firms. This will give TIM close connections to industry in Silicon Valley and also the growing industry of the Monterey Bay region, enabling broad access to industry resources and interactions. The Silicon Valley Center enhances synergy with the UARC (NASA funded) and the proposed UC Bio-Info-Nano R&D Institute (BIN-RDI) at NASA Research Park. Linkages between on-campus and SVC activities will be enabled by use of conferencing and distance learning utilizing the Internet, and by faculty (many living in Silicon Valley) sharing time between the two locations.

Relationship to Engineering / Information Technology

The focus of TIM is the management of technology, particularly by making effective use of information systems to achieve this goal. Some of the technologies of particular interest include: semiconductors, computers, software, networks, biotechnology and nanotechnology. The

development of technology has traditionally been decoupled from the management and commercialization processes. More recently, there has been significant interest in using concepts from finance (such as options) to consider the economics of technology decisions. Another active research area is the systems- and management-level understanding of technology management, including global engineering design capacity management and the optimal design of product review cycles. The critical dependency of competitive organizations on information systems and technologies (IS and IT) have been clearly established in the past decade.

Information Technology plays three key roles within private (and public) institutions:

- To support organizational efforts to improve productivity and profitability
- To allow the broadening of the scope of employee tasks, activities and entire jobs through extensive computer support
- To support key business strategies such as Supply Chain Management and Data Mining for Customer Relationship Management to achieve and sustain a competitive advantage

The demands of global economy put a premium on creating an agile, resilient and responsive organization, and this depends on the effective use of Information Systems and Technology to achieve necessary productivity. However the economic turmoil of the recent past indicates that there is a significant gap between Information Systems and Technology and the ability to use this for sustained profitability, namely the management of this Technology. Management of Technology (MOT) requires an understanding of IS, plus the elements of the specific technology under consideration, and the economics underlying the business, including investment, supply chain management and the economics of e-business.

TIM builds on existing strengths in the Jack Baskin School of Engineering. For instance, faculty members in TIM have worked on process learning and yield management in semiconductors, and the associated economics. This leads to potential synergies between the nanotechnology faculty and the TIM faculty. Consequently, TIM expects to build on the strength of School of Engineering (SOE) in Nanotechnology to develop methods for the management and development of these nano systems. Equally, new faculty in TIM are working on exciting areas such as scheduling and pricing in data and wireless (“WiFi”) networks, which expand the current strength SOE in networks. TIM faculty who have worked extensively on supply chain management also plan to build on faculty strength in Economics to develop methods for technology value chain management and to interact with the strong Software Engineering Group in SOE to develop novel statistical methods for software management. Finally, the TIM faculty are performing research on product portfolios in technology firms – another key and emerging area of research.

The proposed programs draw on the expertise of UCSC faculty from several departments, including Applied Mathematics and Statistics (AMS), Computer Engineering, Computer Science, Electrical Engineering, Economics, and Psychology. These faculty members bring their in-depth knowledge to the preparation of graduate students in the classroom, and provide exciting research opportunities for graduate student research.

Timetable for Development of the Program

The program is under review by the administration and senate committees of the campus during the current (2006-7) academic year. It is anticipated that this will lead to final University of California System-wide approval during 2007-08.

The Baskin School of Engineering long-range plan includes a future department in Technology and Information Management. Four ladder rank faculty have been hired to date, and in addition one senior faculty member from engineering (with a background in industry management, IT and systems) is leading the program as a search is developed for hire of a permanent department chair. Plans are to continue hiring until the full initial complement of eight faculty are in place.

As of this writing, thirteen different TIM courses have been approved and offered. Additional new courses will be developed and submitted for approval as faculty are hired. Two of the planned four core courses have been approved and are being offered, and their descriptions are given in the **UC Santa Cruz General Catalog 2006-08**¹. Proposals for the other two core courses are being developed for approval, and summaries of these courses are given in the TIM Graduate Proposal².

Master's Degree Requirements

Core Courses (4 required):

- TIM 205: Management of Technology I¹ (5 units)
- TIM 206: Optimization Theory and Applications¹ (5 units)
- TIM 215: Organizations and Leadership (5 units)² (New course-- to address topics in people management and organizations in "high tech" enterprises.)
- TIM 240: Technology of Management: IT Architectures and Knowledge Engineering² (5 units) (New course -- to provide a review and survey of IT systems and architectures, middle-ware and applications.)

Two TIM Graduate Seminars are also required.

Other Courses (electives):

- 10 or more units of either graduate courses (not seminars) in related disciplines outside the School of Engineering (requires advisory and grad director approval). A maximum of two SOE upper-division undergraduate courses may be counted as electives when necessary to strengthen a student's preparation for graduate studies (requires advisor approval).
- All remaining units must be graduate elective courses approved by the advisor and TIM graduate director. With appropriate preparation and/or student interests, proposals will be accepted to allow substitution of another graduate course for one of the core courses. This proposal will require approval of the faculty advisor and TIM graduate director.

- On campus students who will be serving as Teaching Assistants or who plan to pursue a Ph.D. must take TIM 200: Research and Teaching in Computer Science and Engineering (3 units) before or during their first TA assignment.

The core courses provide students with a solid understanding of the management of technology in an enterprise, the design of information systems to support the enterprise, use of analytical tools to make sound management decisions and engineering design choices, and understanding of business principles and practices to be a leader of an enterprise. Several TIM classes will include project work. These projects give students hands-on experience in applying the course materials to real-world problems, as well as give them the opportunity to benefit from each other's knowledge, as we expect the students to have diverse backgrounds.

Optional Elective Concentrations:

The broad range of elective options allows for the diversity of M.S. student interests. It also allows TIM M.S. students to specialize. For example, a student specializing in the following areas of Management of Technology and Technology of Management could take the corresponding elective classes:

Management of Technology: Integrating all aspects of the development of new technology including supply chain management, optimization and design.

TIM 208: New Product Development² (5 units) (New course-- to address strategic systems resource requirements and risk management in new product development)

CS 277: Database Systems³ (5 units)

TIM 220: Operations² (5 units) (New course-- to address enterprise resource management and capacity planning, material flows, supply chains, etc.)

TIM 225: Management of Technology II: Enterprise Value Chain Networks¹ (5 units)

TIM 230: Finance and Technology Strategy² (5 units) (New course – to address topics in financing of new projects, products and enterprises),

Technology of Management: Developing technology for the effective management of information throughout an organization, utilizing and evaluating information technology systems.

TIM 209: Knowledge Services and Data Analytics¹

TIM 245: Data Mining¹

TIM 260: Information Retrieval¹

CE 276: Software Engineering⁴

Ph.D. Requirements

Ph.D. candidates will be required to complete a minimum of 45 units of approved graduate courses, of which 30 units must be from courses offered by TIM (unless exceptions are approved by the faculty advisor and TIM graduate director). They must also complete an appropriate Ph.D. dissertation (with a minimum of 10 units of dissertation research or independent study credits).

The research areas in TIM are varied, and each will require a different sequence of classes to develop appropriate depth in analytical methods and technology. The selection of graduate courses will be done in consultation with the dissertation supervisor.

Conclusion

The TIM program is distinguished by its emphasis on and integration of technology, analytics, and operations (including marketing, finance, and knowledge management). The course offerings are therefore unique in reflecting both this combination and its integration.

We expect the TIM program to answer the identified needs in the “high-tech” companies of Silicon Valley, to produce engineering leaders whose education encompasses engineering, management, management of technology and the technology enabling effective management.

The uniqueness and value of the TIM program lies in the integrated systems approach to coverage of both the technology and business aspects of “high tech” enterprises. Our proposed M.S. and Ph.D. programs in TIM will provide graduates with the knowledge and skills required to make important contributions to the development and use of information systems and information technology, and tools for analysis and optimization of complex systems, in the operations and management of enterprises that are essential to the economy of California.

1. **University of California Santa Cruz General Catalog 2006-2008**, page 242 (see also http://reg.ucsc.edu/catalog/html/programs_courses/ismCourses.htm)
2. **Proposal for a Program of Graduate Studies: Technology and Information Management**, Jack Baskin School of Engineering, University of California, Santa Cruz, August 11, 2006
3. **University of California Santa Cruz General Catalog 2006-2008**, page 231 (see also http://reg.ucsc.edu/catalog/html/programs_courses/cmpeCourses.htm)
4. **University of California Santa Cruz General Catalog 2006-2008**, page 220 (see also http://reg.ucsc.edu/catalog/html/programs_courses/cmpeCourses.htm)