ROBERT J. THOMPSON and ALEXANDER KOSSIAKOFF

THE MASTER'S DEGREE PROGRAM IN TECHNICAL MANAGEMENT

The JHU/APL Technical Management Program is designed to help scientists and engineers become successful managers. Management is presented as an art that the student learns by solving problems in a simulated management role under the tutelage of experienced managers, as well as by lectures, reading, and class discussion. This article presents the curriculum and describes the distinctive features of the instructional approach.

INTRODUCTION

A graduate program in The Johns Hopkins University G. W. C. Whiting School of Engineering leading to the degree of Master of Science in Technical Management is now in its ninth year at the JHU/APL Education Center. The program is also offered at the University's new Montgomery County Center. Its objective is to assist professional scientists and engineers, who either have already assumed management responsibilities or who aspire to a future career in management, in developing their skills for effectively managing technical projects and directing the efforts of technical professionals. In this program, students learn what managers do, what kinds of problems they must deal with, and what tools and techniques they can use. An integrated curriculum introduces the students into management, teaches them basic skills in managing work and dealing with people, and presents the opportunities and challenges of introducing technological change and developing new products.

The program has several distinctive features. Management is taught primarily as an art that the student can best learn by doing, as well as through lectures, readings, and interactive discussion. A scenario is presented in which the student plays a management role and deals with realistic situations. Each problem is assigned before the principles it illustrates have been discussed, so that the students' minds are fully engaged before the classroom lecture or discussion. Both the problems and the lectures are organized around a series of "lessons to be learned": specific, practical principles the student can remember and apply to similar situations in the future. For example, an important lesson is that the technical manager must understand the technology he manages.

The value of the program is directly related to the quality of the faculty, and JHU/APL is endowed with skilled, experienced managers who are members of the university community and who enjoy teaching. Some of the faculty and guest lecturers are also drawn from the neighboring technical community. All instructors are practicing managers who share their experiences with the students in interactive discussions and problem reviews. Each course is taught by two instructors and several guest lecturers, exposing the students to a broad range of experiences and viewpoints.

The students are generally mature scientists and engineers who have five or more years of professional experience and who have recently made or expect to make the transition into management. They are drawn from a broad cross section of the neighboring technical community and show considerable diversity in education, work experience, and viewpoint.

THE NEED FOR THE PROGRAM

Technical products are becoming more complex, more esoteric, and more expensive, while our society is becoming more dependent on them, both for national defense and in commercial applications. The research, development, production, and often the operation of high-technology products and systems require the coordinated effort of many skilled specialists trained in a variety of disciplines. Successful management of such an effort requires a thorough understanding of the technology involved combined with highly developed skills to organize, motivate, and direct the specialists to meet exacting goals of performance, schedule, and cost.

As technology has grown more complex, so has the manager's job. Being a technical leader in the field is no longer enough. Today's knowledge workers have their own agendas and cannot be directed simply by saying, Do as I say or Follow me. Nor, because of the high risks and costs involved, can the new manager afford to learn by trial and error. He needs to learn fast and learn right. (Throughout this article we use "he" in lieu of the awkward "he or she." An increasing number of technical managers are women, as are about 20% of the students in the Technical Management Program.) Serious problems therefore arise when the scientist or engineer moves into a supervisory or project management position and finds that neither his professional education nor his experience as a technical professional has prepared him for dealing with the complex and often frustrating problems inherent in accomplishing his work through others, or for planning, organizing, and directing the efforts of diverse individuals and groups to exacting technical, cost, and schedule requirements. The transition is severe and frequently traumatic. An all too common consequence is that an effective technical specialist becomes an ineffective technical manager, to the detriment of his coworkers, the organization and its products, and his own career.

Transition into Management

The kinds of knowledge and skills that an aspiring manager needs to acquire may be better understood by examining in more detail the transitions he experiences as he pursues a management career. Technical organizations frequently use "matrix" management, in which project or program managers are responsible for the execution of projects from inception to completion and must employ the skills of appropriate technical groups as the project advances from conception through design, development, testing, and production. Functional or line managers are responsible for establishing and maintaining the expertise of the organization's technical specialty groups and for overseeing their work on the successive projects that use their talents. Many managers will operate in both capacities in the course of their careers. The two managerial roles, however, are sufficiently distinct that the Technical Management Program is divided into two tracks, project management and organization management, as shown in Fig. 1.

The newly appointed manager, whether of a technical project or a technical group, suddenly finds that the useful output of his project or group is produced by people other than himself; he is no longer a direct technical contributor. The project manager also finds that the success of his project depends on numerous technical disciplines or specialties, including some that he knows relatively little about. He must balance technical objectives and risks that he may not fully understand against cost and schedule commitments that are also not entirely of his own devising but based on the inputs of others. When technical crises occur, as they will, the project manager is responsible for resolving them and deciding the course of action. He must make system-level decisions on the basis of limited and imperfect knowledge, and do so expeditiously but not hastily. He constantly walks a line between getting overly involved in technical detail, at the risk of micromanaging and losing the big picture, or being insufficiently involved in technical problems, at the risk of losing technical control and becoming a high-level bookkeeper. He is responsible for everything on his project, but by himself can do almost nothing.

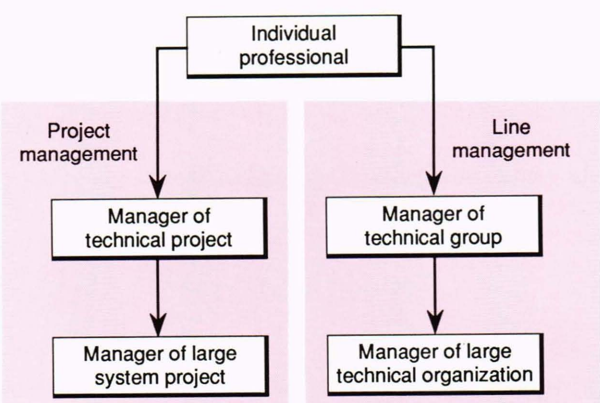


Figure 1—Transitions in the life of the technical manager.

The new technical group supervisor finds that, although he is working harder and longer than ever, he can no longer see tangible accomplishments at the end of the month, let alone the week or the day. In fact, he has no directly measurable work output, and his worth to the organization depends on the level of performance of other professionals whom he can guide but cannot effectively give orders to. Recognition for new ideas and successful products goes to the individuals directly responsible, but overall responsibility for technical difficulties, schedule slippages, and cost overruns in the group rests with the supervisor. He must find his satisfaction in the professional accomplishments of the group rather than his own technical contributions.

Each new manager discovers, as he attempts to carry out his job, that his plans and directions are routinely misunderstood and often ignored. His whole job now depends on successful communication, but usually neither he nor his colleagues have been well trained in effective interpersonal communication or even in technical report writing. Generally, the transition can be very frustrating and the newly appointed manager needs help.

Transition within Management

When the first-level manager is promoted to a middle-management level, he finds the transition almost as profound as the earlier one. He had become by this time a successful group supervisor, and, by guiding and directing the work of others, the impact of his individual effort had expanded dramatically into the directed effort of "his" team, in which he took great pride and satisfaction. Now he has been appointed to head an organization of several groups—a branch, division, or department—with several technical group supervisors reporting to him. On paper his authority has grown considerably; in practice his direct authority may be severely diminished. He is now a manager of managers, each of whom has his own objectives and agenda and feels no need to be told what to do or to report regularly on what he is doing. Managing managers is a new game for our middle manager, and one for which he will generally find no rules. He is likely to discover that his new role is somewhat nebulous and quite different from any he has played previously, a role of influence rather than direct control as he becomes a goal setter, facilitator, teacher, spokesman, and advocate to higher management and to customers, and frequently a helper to his subordinates in solving problems or relieving them of administrative burdens.

Similarly, the program manager who had learned to plan, direct, and control the effort on his program finds, when promoted to manage a much larger program, that his direct control is diminished as he now works through a technical and business staff. He also spends much time and effort dealing with top management, subcontractors and suppliers, and especially with the customer.

There can be great satisfaction in being able to provide direction, motivation, and guidance to larger segments of the organization or larger programs. But there also can be continued frustration if the manager has not understood and prepared for his changing role.

THE CURRICULUM

The technical management curriculum is designed to help equip students for a management career by offering a series of interrelated courses in which they will learn what managers do, what kinds of problems they must deal with, and what tools and techniques they need to know. Throughout, the student plays the role of a manager, engaging in typical activities and confronting typical problems. The activities, techniques, and tools of management are presented in the lectures and reading. The instructors, who are experienced managers, share their knowledge and expertise in interactive discussions of the student problems, readings, and lectures. The courses are organized in three progressive levels, as shown in Table 1.

Introductory Courses

Introduction to Project Management and Technical Group Management are the starting points of the project and organization management tracks, respectively. Both courses are required of all degree candidates, since project managers and line supervisors, who must work together to carry out technical programs, need to understand each other's work. Also, many managers may play both project and line management roles during their careers. The transition from engineering specialist to manager is addressed by placing the student in the role of a newly appointed project engineer or technical group supervisor, where he learns the functions and responsibilities of the new job, encounters typical technical and personnel management problems, and begins to practice the methods and develop the skills required for their solution. An additional objective of the introductory courses is to ensure that the student will learn enough about the management environment to determine for himself whether he has the desire, aptitude, temperament, and commitment required to be an effective manager. The introductory courses are prerequisite to the more advanced courses in their respective options.

Table 1—Scope of the technical management courses.

Introductory courses
Transition to management
Managing technical tasks
Managing professional personnel
Intermediate courses
Basic management skills
System viewpoint
Dealing with people
Effective communication
Advanced courses
Transition to middle management
Interacting with customers
Computer applications
Technological change

Intermediate Courses

Five intermediate courses are designed to provide the student with basic management tools and skills and with the opportunity to practice their application. Three courses, dealing respectively with project planning, communications, and finance and contracts, make up a core program required of all degree candidates. A system engineering course is required for the project management option and a personnel management course is required for the organization management option.

Advanced Courses

The introductory and intermediate courses form an integrated structure offering a strong foundation in both work management and people management. The advanced courses build on this foundation. They are of two types. One course in each option addresses the management of today's larger projects and organizations. The others address special topics of significance in the management of high-technology activities in today's environment.

More detailed course descriptions are presented below.

THE APPROACH

Although many major universities have established graduate programs designed to teach management skills to engineers, the JHU program has features that distinguish it from the others.

Most university programs in engineering management, engineering administration, management of technology, and related areas are largely theoretical, combining courses from the business school with courses featuring analytical tools for use in program management or system engineering. Examples of management situations are often presented as case studies whose outcome is analyzed. Courses are generally taught by professors who have studied management from an analytical viewpoint but who have not themselves practiced it. These programs are valuable for broadening a student's understanding of business practices and analytical methods, but may have limited practical applicability.

The JHU Technical Management Program also covers management principles, techniques, and tools that can be learned and used. Overall, however, the management field lacks organized knowledge or generally accepted wisdom. It is largely experience-based. Since it is more an art than a science, the students can learn best by doing. They are placed in management roles and given realistic management problems to solve. These problems are then interactively discussed in class.

An art is best taught by a skilled practitioner, and this is a key feature of the program. Courses are taught by current or recent managers of large-scale projects or by middle- or top-level technical supervisors. All courses have two instructors and also feature guest lecturers who are specialists in specific areas of interest. This exposes the students to a broader range of experiences and points of view, and also makes possible participation by active managers who want to teach but who may not always be available.

The program has been developed as a unified entity, course by course, to ensure its integration into a coherent structure. The student first deals with simpler systems and smaller organizations, progressing to larger, more complex systems and organizations. The mechanics of management are presented first. Work management is discussed before people management, and interactions with subordinates and colleagues are discussed before the more difficult interactions with nontechnical peers, superiors, and customers. Three points are increasingly emphasized as the curriculum progresses: (1) management is an art dealing with people; (2) decisions must often be made on the basis of incomplete and ambiguous information; and (3) there are few "school solutions" to problems, since every situation is unique.

Lessons to be Learned

An important feature of the JHU program is the concept of organizing the courses around specific lessons to be learned. The focus is on the practical result to be achieved—improving the student's understanding and skills—rather than on simply imparting information. A lesson to be learned is an impression the student will carry away from a lecture or problem discussion; he will remember it and can call upon it in the future as the basis for action in a similar situation. Thus, the lesson is similar to the moral of a fable or parable, long recognized as powerful teaching tools. Identifying lessons to be learned in a given area of instruction has proved more effective to help an instructor organize his material than the more usual subject-heading outline.

One important lesson to be learned is that change is a distinguishing characteristic of high-technology organizations. Technology is highly dynamic and constantly presents new opportunities, new products and applications, and thus new challenges to technical managers. Technical organizations and programs must adapt to change or they will suffer obsolescence and be outdistanced by competitors. The manager may often feel like the Red Queen and Alice when they had to run as fast as they could just to stay in the same place. The program teaches that the successful technical manager facilitates change and that, paradoxically, the technical organization attains stability not by resisting change but by being flexible and adaptive enough to exploit changes in its technical environment (i.e., by evolutionary development).

An unusual feature of the program is that the problem or reading is generally assigned to the student before the principles it illustrates have been presented in a classroom lecture—the reverse of the customary academic procedure. The student thus grapples with the problem before coming to class and is fully engaged with the subject and eager to discuss it. This enhances the effective use of limited classroom time. The lecture can then be an interpretation, elucidation, or generalization of the material that the student has already encountered. In some of the advanced courses, lectures have been put in written form for the students to read in advance. Classroom time can then be spent in informal interactive discussion of problem situations, questions and answers, and exchange of experiences.

In addition to optimizing the value of the limited contact time between students and instructors, our approach emphasizes learning by doing. Effective learning requires that the student incorporate the material into his own experience. Listening for the first time to a lecture in an unfamiliar subject area may not effectively associate or connect the material to anything in the student's previous experience, so it is less likely to be integrated and recalled. As far as possible, the problems are designed to offer simulated management experience that the student will recall when he encounters a similar situation. Interpretation of a reading assignment also engages the mind. This approach more nearly resembles the combination of practice, theory, criticism, and example used in teaching art or music than it does the teaching of a knowledge-based subject.

"Scenario" Problems

Another notable feature of the teaching approach is the emphasis on what we call scenario problems, in which the student is placed in the role of a manager having to deal with a specific problem. This role-playing, or more properly role-thinking, offers a learning experience that may be recalled in the future. It gives the student a vicarious managing experience, and so is quite different from the case study approach used in many management courses, wherein the student is an observer and analyst and compares his analysis with an outcome that is later revealed. Observation and analysis, which are typical of the theoretical approach to teaching management, can be very useful to specialists on corporate, military, or legislative staffs, for example, but less useful to practicing line or project managers.

Unlike the case study, which is usually based on a real situation and has but a single outcome, in the discussion of a scenario problem, each student will arrive at a somewhat different solution, often with different expected outcomes. The student learns that, whereas there are certain guiding principles to be followed, in complex situations there is usually no school solution, but rather a range of approaches that may be comparably valid and may produce comparably satisfactory (or unsatisfactory) outcomes. He also learns that there generally are no ideal solutions, but that one needs to effect compromises and avoid the less desirable outcomes. Since the student will learn lessons he can retain and apply in the future, the scenario problem is an implementation of the lessons-to-be-learned concept.

To offer a familiar and consistent setting for scenario-based problems, a mythical company called Space Technology Applications, Incorporated (STA) has been created. In various courses the student plays the role of project manager, engineering group supervisor, assistant chief engineer, major program manager, and chief engineer of the company.

STA is based partly on the APL Space Department, partly on a division of a large aerospace company that one of the authors was associated with, and partly on material gleaned from annual reports of medium-sized aerospace and electronics companies. The structural breakdown of the company and its engineering department are shown in Figs. 2 and 3, respectively; a summary of the company's business profile is presented in Table 2. The students are given extensive background material (about 70 to 80 pages of text and figures) on the company: its history, projects, organizational functions, engineering group descriptions, and bibliographies of the key personnel with whom the student interacts. The company is dynamic, and significant changes in the organization, projects, and personnel occur as the student progresses from project engineer or technical group supervisor to chief engineer. These changes also keep up with advancing technology and cost inflation and the needs of new student problems.

Technical Breadth

The objectives of incorporating a high degree of technical content in our program are twofold. The first objective is to impress on the student that he must know and understand the technical content of what he is managing. The most serious problems in high-technology systems usually arise from technical deficiencies in the engineering concept or design. The manager must be able to deal with those problems. If he does not appreciate the nature of the problem, he is at the mercy of the specialists who do—or think they do. He must understand the technical context of management decisions in order to do his job.

The second objective is to give the student opportunities to learn new technical material outside his specialty, to give him some tools for quick learning, such as aggressive questioning of experts, and to help him develop some confidence that he can quickly learn what he needs to know to make technical decisions. Lack of confidence in his ability to learn new technologies is a major problem for a manager who, as he grows older and moves up the organizational ladder, may become a paper shuffler and lose technical control of his project or organization. The manager who maintains his grasp of the basics, consistently adopts a system viewpoint, and is not intimidated by the jargon of the experts will find it easy to pick the brains of those experts and incorporate new information into his broad knowledge base.

The diversity in both the technology presented and the background of the student body are such that probably no one student will be familiar with all the subject matter, but every technical subject will be familiar to some students. By selecting teams of students with diverse backgrounds to work together on problems, the students learn from each other.

THE STUDENTS

The Technical Management Program is designed for the needs of three classes of students: (1) scientists and engineers who have mastered their technical specialty and aspire to careers in management; (2) those who have recently assumed positions of management responsibility (either informally as technical team leaders or more formally as project engineers or first-level line supervisors) and want to learn how to operate in the management environment (about half the students); and (3) experienced managers who want more formal training in management tools and methodology and a broadening of their outlook. The average age of the students is in the mid-30s, ranging from the late 20s to over 50.

To gain full value from the program, students must be sufficiently experienced and professionally mature to comprehend and cope with the types of managerial prob-

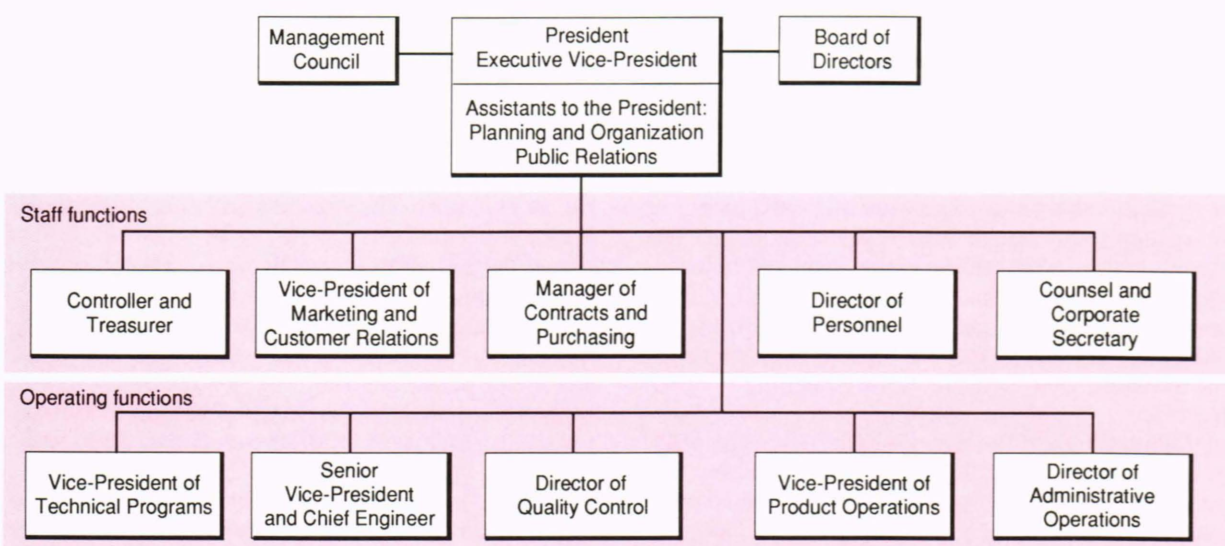


Figure 2—Organizational structure of Space Technology Applications, Incorporated.

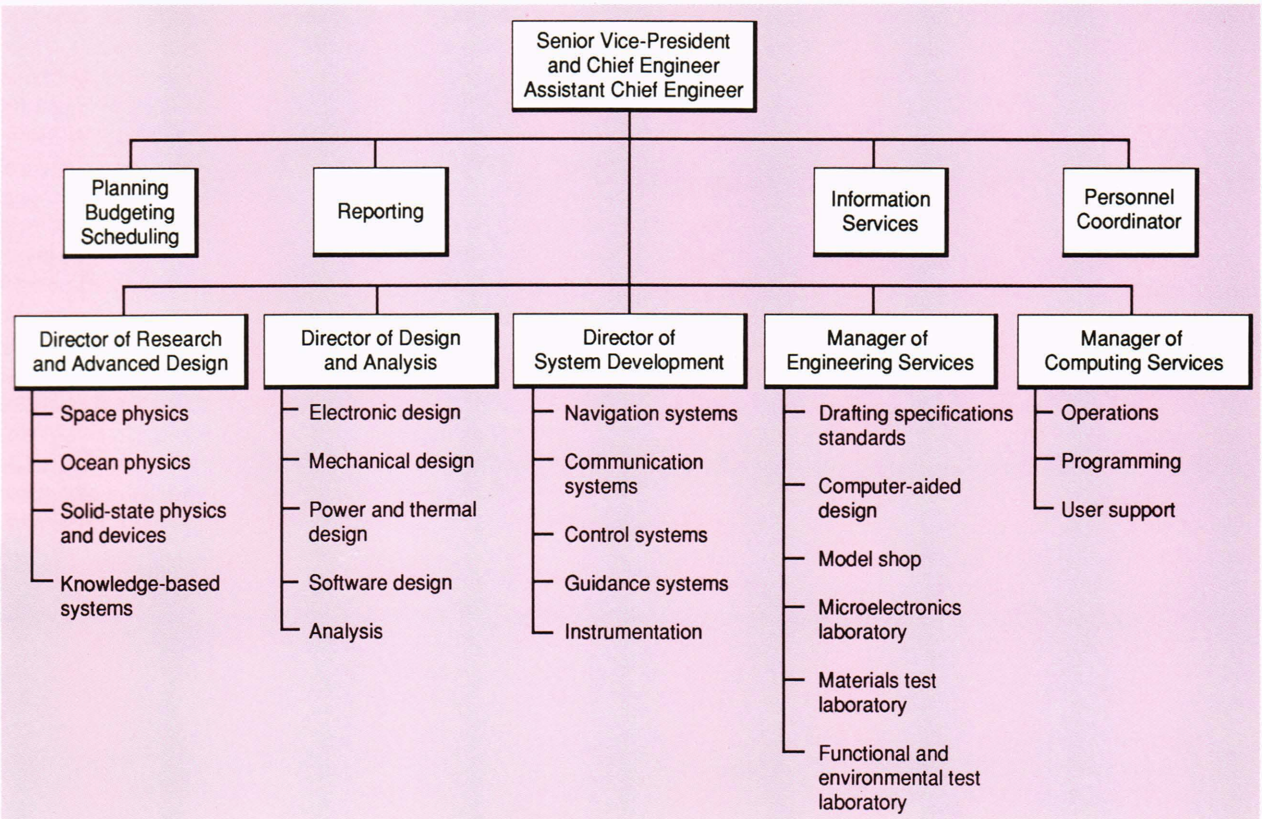


Figure 3—Engineering department of Space Technology Applications, Incorporated.

Table 2—Business profile of Space Technology Applications, Incorporated, an engineering research and development company.

$100 million/year gross business
800 employees (550 technical personnel)
66% in-house; 33% subcontract
75% government (DoD and NASA); 25% nongovernment

Product	*% of Effort*
Navigation satellites	20
Communication satellites	20
Scientific satellites	15
Space instruments	15
Ocean instruments	10
Biomedical instruments	5
Transportation systems	5
Special projects (independent research and development, bid and proposal)	10

lems they will face. They also need the self-confidence that comes from being well established and recognized in their specialty. And, since the program stresses that a technical manager must understand the work he manages, a solid technical background is essential. Consequently, admission is generally limited to candidates who have a bachelor's degree in physical science, engineering, or mathematics and at least five years of professional work experience. They must also meet the scholastic requirement for graduate students of the G. W. C. Whiting School of Engineering.

The academic and employment backgrounds of the students vary considerably, which brings a desirable diversity of experiences and viewpoints into the classroom discussions. The principal dichotomy is between the hardware-oriented engineers and the software specialists, who comprise two distinct cultures. Since the contemporary manager must deal with both cultures and see to it that they interact effectively, it is excellent experience for the students to become familiar with the jargon and the particular technical and organizational problems of the "other half," and to appreciate the similarities and differences between hardware and software development and application.

The introductory classes are limited to about 20 students. The advanced classes are generally smaller, allowing a high level of student participation.

At the APL Center, about 375 students have attended 130 classes since the program began in 1980; 109 graduates have received master of science degrees, and about 150 students are now enrolled. The newer Montgomery County program, which started in 1986, has enrolled about 80 students, none of whom has yet graduated.

The composition of the student body is diverse in education, work experience, organizational affiliation, and management status. About 70% of the students are employed by neighboring industrial organizations, 20% are from government, and 10% are APL staff. Most of the industrial employees are federal government contractors. About 20% of the students are women.

FACULTY AND PROGRAM COORDINATION

Currently, more than 40 instructors are actively engaged in the program; over half are upper-level organization managers or managers of major programs. On average, each brings to the program over 20 years of technical and general management experience gained in private industry, in government service, or at APL. About 20 guest lecturers on special topics include independent consultants and experts from other universities, government, and industry, as well as APL managers and staff specialists.

Instructors are carefully selected on the basis of their demonstrated success in managing projects or technical organizations and their interest and skill in communicating their management experience to prospective managers. Since success in management requires exceptional ability to communicate with a diverse audience, effective managers, as a rule, make very capable teachers.

About three-fourths of the technical management faculty are members of the Principal Professional Staff of APL, a rank equivalent to tenured faculty. About a dozen non-APL faculty are drawn from the management ranks of nearby industry, primarily from the Defense and Electronics Systems Division of Westinghouse Electric Corporation.

The APL staff has been a particularly rich source of faculty because of its diverse activities in developing missile, space, and other complex systems for the Navy, NASA, and other government agencies, and its broad range of research, analysis, and evaluation programs. The staff traditionally works closely with both industry and major government laboratories and understands their organizations, methods of operation, and special abilities. Through APL's service in many programs as a technical agent for the government, the staff has acquired experience in all phases of major system acquisition and operational evaluation.

Among the several research universities that operate major research and development laboratories, JHU is the only one that has established graduate programs organized and primarily taught by members of its laboratory staff. JHU/APL is unique in having available as teachers experienced and practicing technical managers who are also members of the university community. Our managers find time to teach within their busy schedules because they enjoy it and because they recognize the value of the program to aspiring young managers. Also notable is the cohesion of the faculty, enhanced by monthly faculty luncheons where the status and progress of the courses and students are reported and common problems aired.

Although statistics do not adequately convey the quality of the faculty, it is worth noting that positions of the technical management faculty now occupied or recently held by APL staff members include: an assistant director, the chief scientist and former director, three major department heads, three associate or assistant department heads, five branch supervisors or assistant supervisors, ten group supervisors or assistant supervisors, and eight program or project managers. Several instructors or regular guest lecturers have also had significant non-APL experience, up to vice-president level in the aerospace industry and flag rank in the Navy.

Academic oversight of the program is provided by a program committee that reports to the Dean of the G. W. C. Whiting School of Engineering. The committee establishes the curriculum and course schedules, selects and nominates the instructors, sets the admission criteria, reviews applicants for admission, certifies candidates for graduation, and is generally responsible for the quality of the program. The APL members also serve as the students' academic advisors and teach in the program. The authors of this article have been Chairman and Vice-Chairman of the Program Committee since its inception. Other current members include J. R. Austin, Head, Submarine Technology Department; J. J. Boland, Professor, Geography and Environmental Engineering, Whiting School of Engineering; E. J. Hinman, Head, Fleet Systems Department; and G. L. Smith, Assistant Director for Research and Exploratory Development. The administration of the program is facilitated by Samuel Koslov, Director of the APL Education Center, and J. L. Teesdale, Supervisor of Education and Training and Assistant Director of the APL Education Center.

INDIVIDUAL COURSES

The technical management curriculum comprises 13 courses grouped into three categories—two introductory, five intermediate, and six advanced—and is organized into two parallel tracks: project management and organization management (see Fig. 4). To qualify for the master of science degree, students must complete seven required courses and three electives under either option. Students who select both options complete nine required courses and one elective. Over half the students elect both options; the remainder are about equally divided between project and organization management. A description of the individual courses follows.

Introduction to Project Management

Introduction to Project Management deals with the problems a newly appointed program manager encounters in achieving the transition from technical specialist to manager. Emphasis is placed on the functions, roles, and responsibilities of the project manager and his interactions with the technical personnel working on his project, under his management, and for his customer. The previously described STA scenario is used, and the specific project that the student is to manage is described.

The general methodology of managing a project throughout its life cycle from concept formulation to operational use is presented, including project organization, planning, and assignment of work; execution, direction, and control; and assessment and reporting.

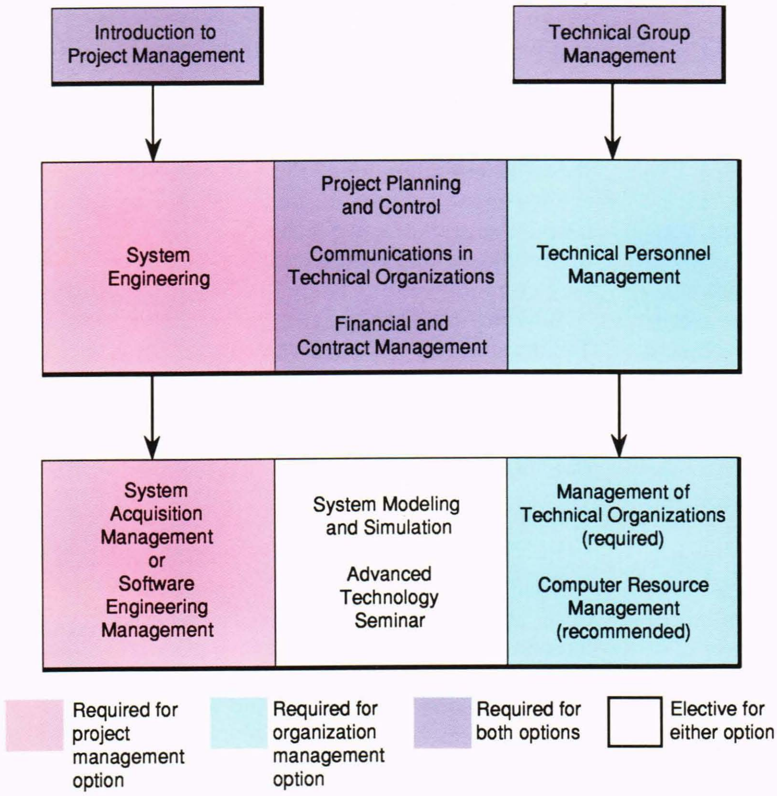


Figure 4—Course organization of the technical management curriculum, showing the two introductory courses (top row), the five intermediate courses (middle row), and the six advanced courses (bottom row).

Project management tools and methodology are introduced, and the students practice their use in the context of the scenario that focuses on the individual, the stresses to which he must adjust, and the decisions he must make in response to unanticipated but typical problems. The problem is usually presented first, and the methods or tools that will help the student to deal with it are then introduced and applied. This approach is designed to help the young project manager to acquire the attitude and viewpoint as well as the skills and methods he will find most helpful in doing his job.

The project engineer must achieve a balance between providing technical leadership and carrying out the planning and control necessary to complete the task on time and to cost. The organizational relationship of the project manager to the engineers in the technical groups who work on his project and to their line supervisors is examined. The need for sensitivity, active two-way communication, and continuous negotiation to maintain cooperative effort and avoid potential conflicts between line and project management is stressed.

Technical Group Management

Technical Group Management is the companion course to Introduction to Project Management. The two courses are independent and may be taken concurrently or consecutively in either order, but they are closely interrelated, since both are concerned with the transition from individual worker to manager.

The student plays the role of a newly appointed group supervisor in the engineering department of STA. The detailed scenario problem provides a realistic setting in which the new supervisor assumes responsibility for the group and experiences a succession of typical problems involving his interactions with individuals both within and outside the group. These problems point out the complexity of the supervisor's task and the multiplicity of relationships he must maintain with the individuals in his group and with his superiors and peers throughout the organization. Primary attention is focused on the development of the individual as a manager as he is introduced to and given the opportunity to practice management methods and skills in establishing goals and priorities; planning and organizing tasks and assigning work; developing task objectives, costs, and schedules; starting up and staffing new projects; closing out old projects; monitoring technical progress and identifying difficulties or deficiencies; and delegating authority and responsibility. Personnel management is introduced, including leadership, motivation, evaluation, professional growth, and conflict resolution.

The student learns that the technical group leader is primarily responsible for the technical quality, integrity, and productivity of his group, and his success depends on the efforts of others. To exercise successful technical leadership, he must be thoroughly familiar with the work of his group; the specific technical problems involved in the tasks; and the skills, abilities, and deficiencies of his personnel. Early problem identification and prompt direction of effort to reach a timely and cost-effective solution are hallmarks of the excellent group and the capable group supervisor.

System Engineering

The System Engineering course is required of all students in the project management option and is taken as an elective by most other students. It treats the technical leadership aspect of the project manager's task and stresses the need for the project manager to think like a system engineer as he manages and integrates the efforts of the engineering design and development, test, production, and logistics specialists who perform the detailed work on his project. Although the project manager should not become involved in the technical details at the component level, he must have a broad technical overview of the system and of the interactions among its component parts. He should understand thoroughly the system performance requirements; the basic technical concepts designed to meet those requirements; the operational environment; and the trade-offs, advantages, and risks involved in critical design decisions.

A high-technology system typically involves both hardware and software, and both mechanical and electrical components, and requires the expertise of a variety of technical specialty disciplines during its development. The project manager must learn to think broadly in terms of component or subsystem functions and interactions. A total system viewpoint is necessary to balance properly the technical requirements and performance objectives of the project against the cost, schedule, and other constraints—a balance that only the project manager can effectively accomplish—and to evolve a system configuration that can be most readily developed, tested, produced, and maintained.

System engineering principles and methods are introduced and applied to the solution of technical problems through the life of the project, from the initial mission need statement through concept formulation and engineering development, to production and deployment. Topics covered include requirements analysis and concept definition, functional specifications, design criteria and design trade-offs, risk analysis, configuration design and control, system performance validation, and design documentation. The scenario traces the development history of a moderately complex system, presenting the student with typical system engineering problems that illustrate important issues, apply system engineering methods and tools in their solution, and stress the importance of the system viewpoint.

Technical Personnel Management

The Technical Personnel Management course is required of all students in the organization management option and is an elective for other students. It treats the interpersonal relations, interactions, and problems of the technical group supervisor as he deals with the professional workers in his group. Although significant material from management science and behavior theory is presented and discussed, the principal emphasis is on the practical problems of accomplishing work through the efforts of others. The personnel being led are independent professional workers who must be treated as individuals. The elements involved in building and leading a capable technical organization range from goal setting and recruitment of professional personnel to personnel evaluation, counseling, and professional growth. The course stresses that the supervisor is largely responsible for defining the goals, setting the tone, and establishing the work environment of the group, and for providing the leadership, direction, and motivation required for innovative and effective technical accomplishment. The importance of establishing and maintaining effective two-way communications is emphasized.

Building on the scenario previously introduced in Technical Group Management, the student plays the role of the group supervisor dealing with activities and problems encountered during a typical year, including those calling for group leadership and those requiring one-on-one interactions with specific individuals.

Project Planning and Control

The Project Planning and Control course is required of all students, since all managers must learn to plan, measure, and control the work they manage. This course treats the organization of the project office; the planning, budgeting, scheduling, and assignment of work; the measurement and assessment of progress; and the actions required to correct for the inevitable deviations from the plan as unanticipated technical difficulties, cost escalations, or schedule delays are encountered.

The scenario presents problem situations arising in the management of a high-technology project, from the request for proposal to product delivery, emphasizing the continually changing role of the project manager in planning, directing, and controlling the work as it progresses through engineering design, development, and test. Particular attention is given to preparing the technical and cost proposals and initiating the work on receipt of a contract, since the subsequent success of the project largely depends on the quality and thoroughness of these initial planning efforts. The course stresses that the plan must be based on a thorough understanding of the technical requirements of the system to be developed and a realistic appraisal of the factors affecting cost and schedule performance.

The methodologies used include the work breakdown structure, which divides the total effort into a hierarchical set of deliverables down to the level of tasks that are individually assigned to technical groups, and the critical path method, which identifies the pace-setting tasks that need particular management attention. An expenditure and technical progress reporting system at the task level provides the manager with the oversight needed to monitor and control the program, identify problems promptly, and replan the effort as necessary.

Students are encouraged to become familiar with and use computer-based project management support tools. The course stresses, however, that although the computer is a valuable management aid, it cannot substitute for the manager's thoroughness in planning, vigilance in early identification of problems, and judgment in finding and applying corrective actions.

Communications in Technical Organizations

The objective of Communications in Technical Organizations, which is required of all students, is to help the student develop the communication skills essential to his effectiveness as a manager. Since the job of the manager is to get work accomplished through the efforts of other people, no skill is more important to him than effective interpersonal communication. The communications treated here are not simply transmitting technical information from one person to another but rather two-way, closed-loop communications that will result in appropriate actions by the participants to produce a desired result. Such management communications must persuade as well as inform, they must be correctly understood, and the recipient must in turn provide feedback. Skill in receiving communications (listening and reading) is emphasized along with skill in delivery (speaking and writing).

Communication difficulties include perception, cognition, semantic problems, unconscious distortion, and individual differences in receiving and processing information. The need to identify the knowledge base, cultural or individual biases, viewpoint, and area of interest of the recipient(s) is discussed. Techniques for effective oral and written communications are presented in the context of problem situations involving communications for various purposes (e.g., assigning work, reporting results, assessing performance, responding to complaints and grievances) that call for the student in his role as a supervisor to write letters, prepare internal memoranda, make formal and informal presentations, preside over or participate in meetings, and engage in one-on-one discussions. Writing assignments are discussed and speaking assignments are delivered in class for group evaluation and videotaped for self-evaluation. The emphasis throughout is on communication effectiveness, rather than simply the mechanics of speaking and writing.

Financial and Contract Management

Financial and Contract Management, also required of all students, is intended to give the student a working vocabulary and a sufficient background to deal comfortably with the financial and contractual aspects of his managerial job, and to interact with his peers in accounting, finance, and contract administration. The student is taught the basics of financial and management accounting and the contracting process. Financial subjects include elementary accounting principles; assets, liabilities, and owner's equity; direct and indirect costs; and revenues and profits. The use of financial reports, indices to financial positions, and financial management tools are discussed.

Contract management introduces the principles of contract formation and the distinctive features of contracting with the federal government. Subcontract management (e.g., request for proposal, competitive negotiation techniques, contract financing and cost reimbursement, and technical oversight of the subcontractor) is discussed, with emphasis on techniques for the timely resolution of technical, cost, or schedule problems.

Although the material is presented from the standpoint of the technical manager rather than the accountant or lawyer, all the essentials required to read various financial reports or to understand the basic principles of contract management and the major types of contracts are considered. The material is reinforced by case studies and assignment of practical problems for the students to solve.

System Acquisition Management

System Acquisition Management may be taken by project management option students to fulfill their advanced course requirement and is an elective for other students. It focuses on management activities and problems occurring throughout the acquisition cycle of a major defense system, from first recognition of a mission need to deployment of a successful operating system, perhaps a decade or more later. The example chosen for the class scenario is based on the actual acquisition history of a major weapon system, suitably modified to conform to current acquisition policy and practice. The key lessons learned are generally applicable to any major system acquisition by the federal government.

The student plays the role of the system prime contractor's program manager, managing a larger and more complex program than heretofore. The primary focus, however, is now outward: the interactions of the contractor's program manager with his customer and counterpart, the government program manager. The development of a cooperative and synergistic relationship among the procuring agency, government laboratories, university (or other nonprofit) laboratories that advise and support the government, and industrial contractors is essential to conduct successfully a major system developmental program. The contractor's program manager must understand the difficult job of his government counterpart and must help him to keep the program moving forward. Federal acquisition policies and procedures are presented, not just as dry legal documents, but to understand their rationale and the ground rules and constraints within which both the government and the contractor's program manager must work.

The responsibilities, strategies, and activities of both the government and the contractor's program manager are traced through the acquisition life cycle from mission needs and operational requirements through development, production, and deployment. Topics covered include government acquisition organization; the planning and budgeting cycles; the origination of new programs; system acquisition planning and contracting strategies; and program decision milestones and reviews. The student exercises concern the actions to be taken, the pitfalls to be avoided, the problems to be solved, and the decision makers to be convinced so that the program will pass each decision milestone and move to successful completion.

Software Engineering Management

Software Engineering Management may be taken to fulfill the advanced course requirement for the project management option and is a popular elective for other students.

All contemporary high-technology systems include embedded computers for their operation and control. As the power of computers has grown exponentially, so have the magnitude and complexity of the software used in their operation. The development and testing of software are frequently the pacing items in the performance, schedule, and cost of current military, space, or other complex systems. Project managers must understand software requirements and software development, and must be able to deal with software professionals.

This course is intended to give students a broad, general understanding of basic software design principles and to familiarize them with software development and test activities and products, as well as with the jargon of the trade. The principles and disciplines learned in prior courses are applied to the software development process, from requirements definition and analysis to introduction to the user environment, user support, and life cycle maintenance. The scenario problem used here is the development of the software employed in an event-driven real-time system. Such a software system cannot be treated as an independent entity, but must be specified and designed in the context of the requirements and design of its parent system in its real-time operating environment.

Methodology and tools are discussed, such as structured analysis and design, architecture and modularization, use of program design languages, and automated tools for detailed design. Federal and industry standards and specifications are presented, with particular attention to Ada (the DoD software standard). Other topics include configuration and interface management; verification and validation; software development and test facilities and tools; and progress measurement, documentation, and program maintenance. The student plans a software development program with activities, products, milestones, reviews, schedule, and cost, from concept definition to in-service maintenance.

Management of Technical Organizations

Management of Technical Organizations is a required course for students electing the organization option and an elective for other students. It focuses on problems in the management of high-technology organizations at the senior technical management level. The STA scenario is again used, but now the student is promoted to the role of the newly appointed chief engineer, the senior technical manager in his company. He must accomplish another transition, from manager of professional workers to manager of managers, where his effectiveness depends on his ability to lead and to persuade others to follow.

The scenario carries the student through his first year as chief engineer of a department of several hundred persons engaged in applied research, product development, and engineering support in an environment of rapidly advancing technology. He is presented with typical problems requiring a variety of technical, business, organizational, and personnel decisions and actions. His sphere of activity is enlarged as he interacts with corporate top management; his corporate peers in the marketing, financial, personnel, and legal areas; and STA's customers, as well as with his own subordinate managers. Topics presented include establishing technical, organizational, and business objectives and strategies; planning and implementing new product development; conducting in-house research to exploit new technology and meet new customer needs; and resolving significant problems and conflicts affecting his department. The role of the senior manager as a problem solver and as a leader in establishing values, setting goals, facilitating change, and providing an atmosphere conducive to creativity and productivity is emphasized.

Interactive discussion of the scenario problems is supplemented by extensive readings and lectures on management principles and practices.

Computer Resource Management

Computer Resource Management, an elective advanced course available to all students, is particularly recommended for students in the organization management option.

The acquisition and use of complex, expensive computer facilities and equipment are among the major responsibilities of senior managers in high-technology enterprises. Managers who must make these decisions seldom have adequate background experience to evaluate the claims and counterclaims of vendors or of their own in-house experts in this complex and rapidly changing technology. The aim of the Computer Resource Management course is to help the student acquire the level of computer literacy needed by a senior line manager. He should become familiar with the jargon and understand the key technical concepts, management issues, and problems that frequently arise.

The rapidly advancing computer technology offers continually increasing potentials at generally decreasing cost, and management must tread a fine line between premature procurement and obsolescence. A balance must also be achieved among a wide range of equipment, applications, and users. Sensitive technical, organizational, and personnel issues arise in areas of hardware and software control, software development versus purchase, user support services, and user charges. These are among the issues presented in the course.

Centralized general-purpose, special, and dispersed computer configurations are discussed. Their respective advantages and disadvantages are presented, together with their applicability to science, engineering, and financial and business management. Staffing, training, organization, and the interactions among computer professionals, engineering users, and managers are addressed. Technology trends such as distributed systems, parallel processing, and intelligent work stations are presented.

The STA scenario problem puts the student in the role of the engineering manager responsible for computer resources and technical applications, dealing with technical, personnel, and business problems and management issues. The student is also expected to become familiar with the computer resources of his own employer.

System Modeling and Simulation

System Modeling and Simulation is an advanced course and is an elective for all students. It addresses the fundamental characteristics of models and simulations, their development and use as aids in system development and operational evaluation, and the management issues involved.

Simulation is the process of designing a model of a real system and conducting experiments with the model in order to understand the behavior of the system or evaluate various strategies for its operation. As high-technology systems have become more complex and their development cycles longer and more expensive, it has become increasingly advantageous to test requirements, functions, conceptual designs, and interactions of the system with its operational environment by means of modeling and simulation, often long before a complete physical embodiment of the system exists.

Since models are simplified, imperfect representations of reality, modeling is both a science and an art, combining a rigorously disciplined approach with experience, judgment, and healthy skepticism. The project or engineering manager should be able to recognize when simulation is useful and cost-effective; choose the type of model; ensure that design, analytic, and operational expertise are used; see that documentation, configuration control, and cost control are maintained; and make use of the results.

This course is intended to give the manager sufficient familiarity with modeling and simulation so that he can recognize both their value and their limitations and manage their use optimally in system development, test, and evaluation. Topics presented include types of simulation, languages, probability, operations research, wargaming, aids to modeling, verification and validation, reviews, and credibility of results.

The students acquire hands-on experience with a simulation developed specifically for this course. Working in small teams, they prepare a plan, conduct the simulation, analyze the results, and report their conclusions regarding the characteristics, potentials, and limitations of the simulation itself, as well as the utility for specified missions of the system being simulated.

Advanced Technology Seminar

The Advanced Technology Seminar is an elective advanced course for all students. While the entire technical management curriculum stresses that management of high-technology enterprise essentially involves management of change and innovation, this course specifically addresses the impact of technological advances on an organization's products, processes, and personnel and facility needs. The manager must understand the potentials and the promise as well as the problems and limitations of emerging technologies. He must anticipate their impact on the effort he manages, including the products, the development and production processes and facilities, marketing and customer relations, and the internal organization and personnel.

The course objectives are to present the essential features and management aspects of emerging technologies that are most likely to radically change industry and society; to explore several examples of those technologies and assess their management implications; and to help the student learn how a manager can keep up with change and judge which new developments are most likely to have a major impact on his organization.

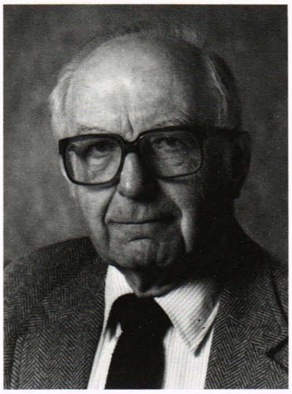
A review of the technical basis of microelectronic devices offers the background for projecting further advances in computer use, breadth of application, and continuing reductions in cost. Areas of application addressed include computer-aided design, manufacture, and engineering; office automation; factory automation and robotics; artificial intelligence and expert systems; neural nets; and laboratory, special-purpose, and personal computing. Other subjects such as recent advances in materials technology are also introduced.

Through reading and interactive discussion with specialists, the students become acquainted with each technology and the effect it is having in their own parent organizations. Students also prepare term papers addressing the technology, applications, impact, and management issues in a technical area that is new to them. These papers are presented and discussed in the final class sessions.

CONCLUSION

The success of the JHU/APL Technical Management Program since its inception indicates that it is meeting the needs both of the individuals to whom it is addressed and of their employers—the many private industrial firms, government laboratories, and not-for-profit organizations engaged in research, development, and engineering in the greater Washington–Baltimore area.

THE AUTHORS



ROBERT J. THOMPSON was born in San Francisco and graduated from UCLA. During World War II, he conducted research on rockets at Allegeny Ballistics Laboratory. He subsequently completed his Ph.D. in physical chemistry at the University of Rochester. Dr. Thompson carried out research and engineering of rocket propulsion systems at the MW Kellogg Co., Bendix Aviation, and Rockwell International, where he served successively as Vice President and Research Director of the Rocketdyne Division and Vice President and General Manager of the Solid Rocket Division. He joined APL in 1974 as Assistant to the Director, later served as supervisor of the Technical Information Branch, and is now on the staff of the Technical Services Department. Dr. Thompson has been active in both the Technical Management Program and the *Johns Hopkins APL Technical Digest* since their inception, and is now also helping to edit the new *APL Technical Review*.

ALEXANDER KOSSIAKOFF's biography can be found on p. 161.