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The Future of Management: The NASA Paradigm

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Management Challenges From a New Space Era

The prototypes of 21st century management, particularly for large-scale enterprises, may well be found within the aerospace industry. The space era inaugurated a number of projects of such scope and magnitude that another type of management had to be created to ensure successful achievement. The pushing out of the space frontier may prove to be a powerful catalyst not only for the development of new technologies but also for the emergence of *macromanagement.*

With further extension of human presence into space during the next 25 years, new opportunities will be offered to those responsible for such projects, whether in the public or in the private sector. Satellite expansion, a space station, and possibly a lunar outpost will require new technologies and systems for more complex missions that involve multiple locations and greater numbers and varieties of personnel. Whether in activities of the National Aeronautics and Space Administration, the Department of Defense or military branches, the aerospace industry or new commercial enterprises, there will be a passage from the way space operations have been managed for the first quarter century of development to the way they must be led and administered in the decades ahead.

The challenges will be not just in terms of technology and its management but also human and cultural in dimension (see my paper "The Influence of Culture on Space Developments" in this volume). A recent NASA study, *Living Aloft*, begins to describe the human requirements for extended space flight involving diverse spacefarers (Connors, Harrison, and Akins 1985). In an article on extraterrestrial society (1985), William MacDaniel, professor emeritus, Niagara University, aptly described the multiple challenges in terms of just one undertaking of the next decade—a space station:

> Any way that we look at it . . . NASA will be confronted with management problems that will be totally unique. Space station management is going to be an entirely new ball game, requiring new and imaginative approaches if serious problems are to be resolved and conflict avoided.

MacDaniel, a sociologist and cofounder of the Space Settlement Studies Project (3SP) at his university, then analyzed one people management dimension that results from the sociocultural mix of international scientific and engineering teams and onboard space crews. The multicultural inhabitants of the space station will have to cope with many practical aspects of their cultural differences—differences that alter their perceptions and ways of functioning relative to everything from communication and problem-solving to spatial needs and diet. Whether the orbiting of increased numbers of people for longer periods of time is done by the U.S.A. or the U.S.S.R., Japan or Europe, project leaders will have to include managing cultural differences and promoting synergy among their priorities (Moran and Harris 1982).

In any event, futurists, students of management, and those concerned with technological administration would do well to review the literature of emerging space management for its wider implications. NASA offers a paradigm, or demonstrated model, of future trends in the field of management at large.

The Apollo Heritage in Innovative Management

A transformation is under way from industrial designs of organization and styles of management to a new work culture (Harris 1983 and 1985a). In an AT&T report on emerging issues, the term *metaindustrial* was used to designate the new management and the approach to human systems that is evolving (Coleman 1980). One catalyst for this transition may very well have been the inauguration of the space program by NASA around 1960. NASA, in conjunction with its partners in the aerospace business, innovated in more than space technology. Because of the very complexity of the Apollo lunar mission, NASA also invented new ways of organizing and managing.

> The Apollo project which landed a team of American astronauts on the Moon is generally considered as one of the greatest technological endeavors in the history of mankind. But in order to achieve this, a managerial effort, no less prodigious than the technological one, was required.
>
> (Seamans and Ordway 1977)

It is my contention that much of what is currently being characterized as the "new management" is partially the heritage of that space effort, a harbinger of tomorrow's management. This idea is especially pertinent to the building of large-scale technological projects, whether on this planet or in space. Those engaged in complex endeavors that involve many systems, disciplines, institutions, and even nations will have to apply in even more creative ways the legacy that the Apollo program gave to management (Levine 1982). Investigations should be directed to what constitutes *macromanagement*. McFarland (1985) sees this term as meaning "postindustrial management," while I understand it to refer to "the management of macroprojects" (see fig. 15).

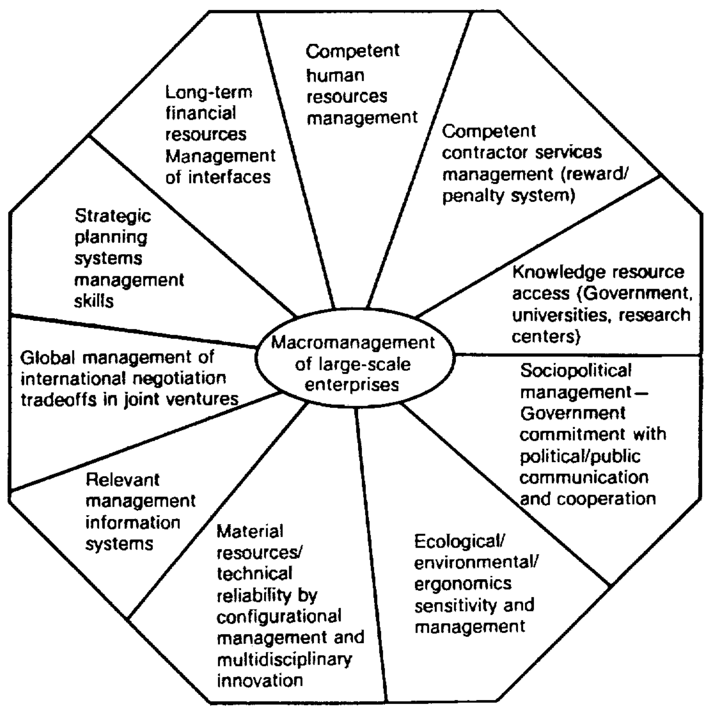

Figure 15

Macromanagement of Large-Scale Enterprises

The management of long-term projects costing $100 million or more will have many aspects. Examples of such "macroprojects" are rebuilding American infrastructure and building a space infrastructure.

In the inaugural issue of *New Management*, the editor listed 10 orientations that lead to organizational excellence today (O'Toole 1983). An organization can excel if it is oriented toward

1. Tomorrow—attuned to the long-term future
2. People—developing human resources
3. Product—committed to the consumer market
4. Technology—employing the most advanced tools
5. Quality—emphasizing excellence, service, and competence
6. External environment—concerned for all stakeholders
7. Free-market competition—imbued with the spirit of risk-taking capitalism
8. Continuing examination and revision of organizational values, compensation, rewards, and incentives
9. Basic management concerns—making and selling products or providing services
10. Innovation and openness to new ideas—nurturing and encouraging those who question organizational assumptions and propose bold changes

Dr. O'Toole was later (1985) to elaborate on this theme in a book entitled *Vanguard Management*.

An examination of the history of the Apollo Program indicates that NASA leaders followed such principles. A possible exception is the third item, which does not quite apply to a public agency, but leaders among the aerospace contractors must have had this concern for the consumer (in this case NASA itself) or the Moon mission would not have been so successful. NASA, over two decades ago, anticipated the emergence of metaindustrial management. The very scope and complexity of putting humans on the lunar surface forced such innovations.

Among the many management innovations to come out of the space program was the matrix organization, with its emphasis on team management. The complexity of the Apollo undertaking necessitated its creation because traditional management approaches proved inadequate. Among the many space contractors, TRW Systems in Redondo Beach, California, was a leader in this process, which was eventually to become a chief feature of the "new" management two decades later. Their vice president at the time, Sheldon Davis, pioneered team building as a means to help technical people work together to reach a common goal (Harris 1985a). Other contractors used the project management and team strategy as a form of ad hoc organization for new starts. General Dynamics, for instance, could quickly assemble experienced team members for its Shuttle-Centaur project from previous work groups that had developed the Atlas-Centaur rocket.

A principal exponent of the matrix as a way of managing complex space projects was Hughes Aircraft. One of its executives, Jack Baugh, did a doctoral dissertation in 1981 on how decision-making is accomplished through a matrix organization. His thesis was that matrix management is essential to an aerospace project when simultaneous decisions are needed in a situation of great uncertainty generated by high information-processing requirements; when financial and human resources are strongly constrained; when the decision-making process must be speeded up; and when the quantity of data, products, and services would otherwise be overwhelming. Obviously, managers outside the space fraternity agreed, adopting the method.

Today a profile of a metaindustrial organization would include these characteristics (Harris 1983 and 1985a):

- Use of state-of-the-art technology, ranging from microcomputers to robotics
- Flexibility in management policies, procedures, and priorities, continuously adapting to the market—a norm of ultrastability (that is, building continuous change into the system)
- Autonomy and decentralization, so that people have more control over their own work space and are responsible for decisions yet work under integrating controls
- Open, circular communication with emphasis on rapid feedback, relevant information exchange at all locations, networking, and the use of multimedia
- Participation and involvement of personnel encouraged, especially through team, project, or matrix management
- Work relations that are informal and interdependent, cooperative and mutually respectful, adaptive and cross-functional

- Organizational norms that support competence, high performance, professionalism, innovation, and risk-taking, even to making allowance for failure occasionally
- A creative work environment that energizes people and enhances the quality of worklife, so that it is more meaningful
- A research and development orientation that continually seeks to identify the best people, processes, products, markets, services, so as to achieve the mission

It is interesting that many of these qualities were identified 15 years ago as essential to the interdisciplinary character of large-scale endeavors (Sayles and Chandler 1971). These were also the characteristics practiced, to a great extent, by NASA management in the Apollo era (Levine 1982). They are considered essential for organizational excellence now and in the future, particularly for large-scale programs such as renewing the American infrastructure or developing a permanent presence in space.

Because those in the management of research and development, especially those coming from engineering and technological fields, may have some misconceptions about the management process, I have included figure 16. This paradigm by R. Alec Mackenzie (1969) illustrates the comprehensiveness of management activity. The conceptual model is a multidimensional approach to the art and science of managing both human and material resources effectively. It highlights, among its central facets, the management of change and differences. This paradigm still seems relevant for managing large-scale undertakings, whether on Earth or in orbit. From my viewpoint as a management psychologist who has served as a NASA consultant, it would appear that the main difficulties facing space management in the future will be found on the right side, in the people dimensions. Unfortunately, this opinion was confirmed by the Presidential Commission on the Space Shuttle Challenger Accident, which concluded that there had been a human systems failure within NASA and its contractors, particularly in regard to information flow and decision-making.

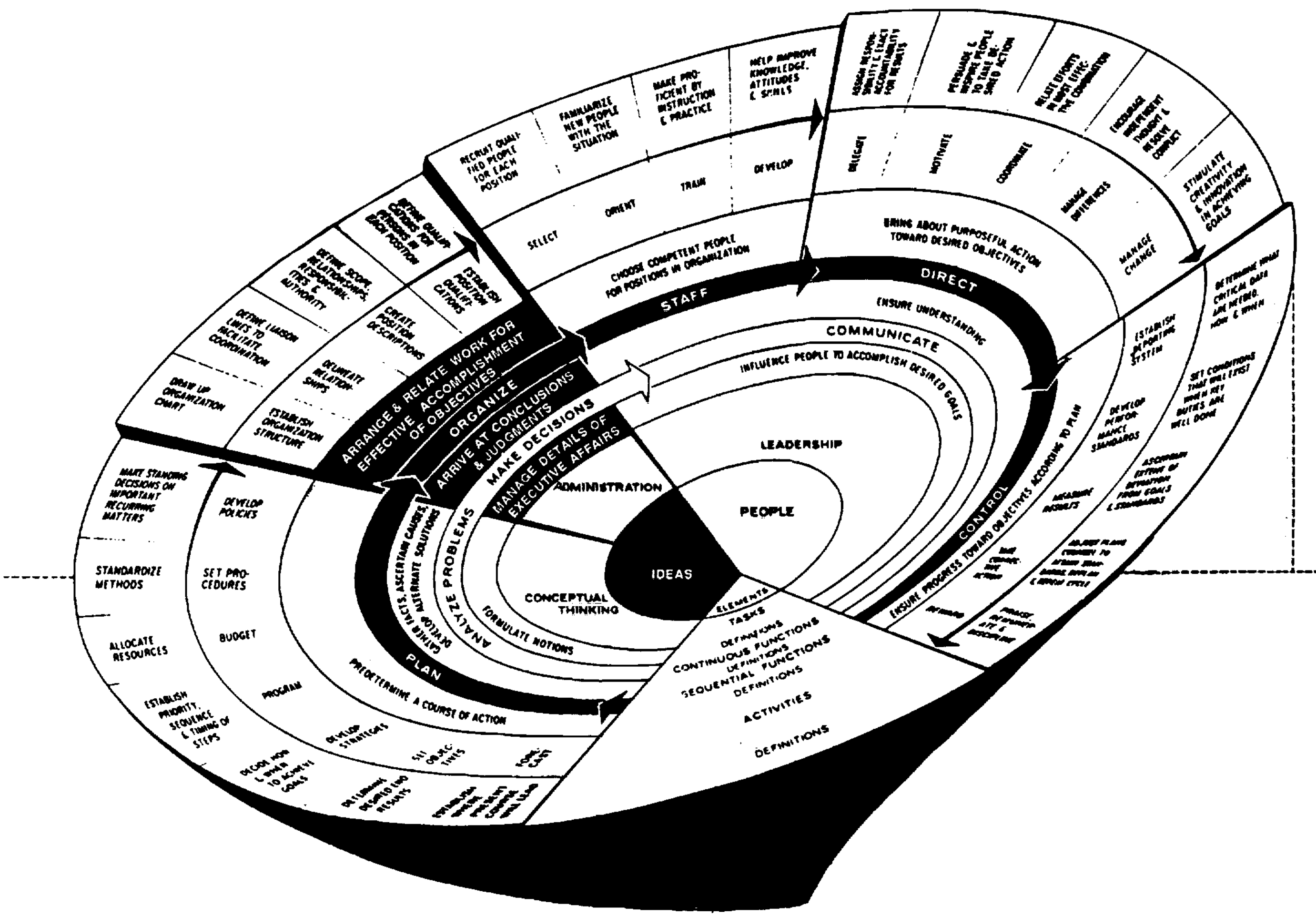

Figure 16

The Management Process

From R. Alec Mackenzie, 1969, "The Management Process in 3-D," Harvard Business Review **47** *(6—Nov.-Dec.): 80-87.*

Perhaps the origins of many 21st century management styles may be traced someday to the 20th century management of research and development institutions. Mark and Levine (1984) make a case for such a thesis by pointing to the Federal Government laboratories that promoted the technology development that resulted in macroprograms like the Manhattan Project, the Apollo missions, and the Space Shuttle. They document both technical and managerial innovations produced by bringing together advanced R&D people in relatively small, quasi-independent groups dubbed "skunkworks." Such groups produced some of the most successful modern aircraft. That form of management was eventually popularized by Tom Peters (1982, 1985) as a central theme of the new management leadership.

The Impact of Organizational Culture

The work culture affects organizational planning, decisions, and behavior. MIT professor Edgar Schein (1985) maintains that the work culture is the mechanism for conveying—explicitly, ambiguously, or implicitly—the values, norms, and assumptions of the institution. Organizational culture is embedded and transmitted through

- Formal statements of philosophy or mission, charters, creeds, published materials for recruitment or personnel
- Design of physical spaces, facades, buildings
- Leader role modeling, training, coaching, or assessing
- Explicit reward and status system, promotion criteria
- Organizational fit—recruitment, selection, career development, retirement, or "excommunication"
- Stories, legends, myths, parables about key people and events
- Leader reactions to or coping with organizational crises and critical situations
- Design, structure, and systems of the organization
- Policies, procedures, and processes

In another paper in this volume ("The Influence of Culture on Space Developments"), I analyze the effect of the organizational culture on NASA and the aerospace industry. Figure 17 is a diagram of space organizational culture, which illustrates the many dimensions of a system's expression of identity. Since research indicates that excellent organizations manifest strong functional cultures, NASA obviously did this during its Apollo period. Has it been doing so in the Space Shuttle phase of its development? The 1986 setbacks and subsequent investigations would indicate a negative response. One outcome of current reorganization needs to be a strengthened NASA culture.

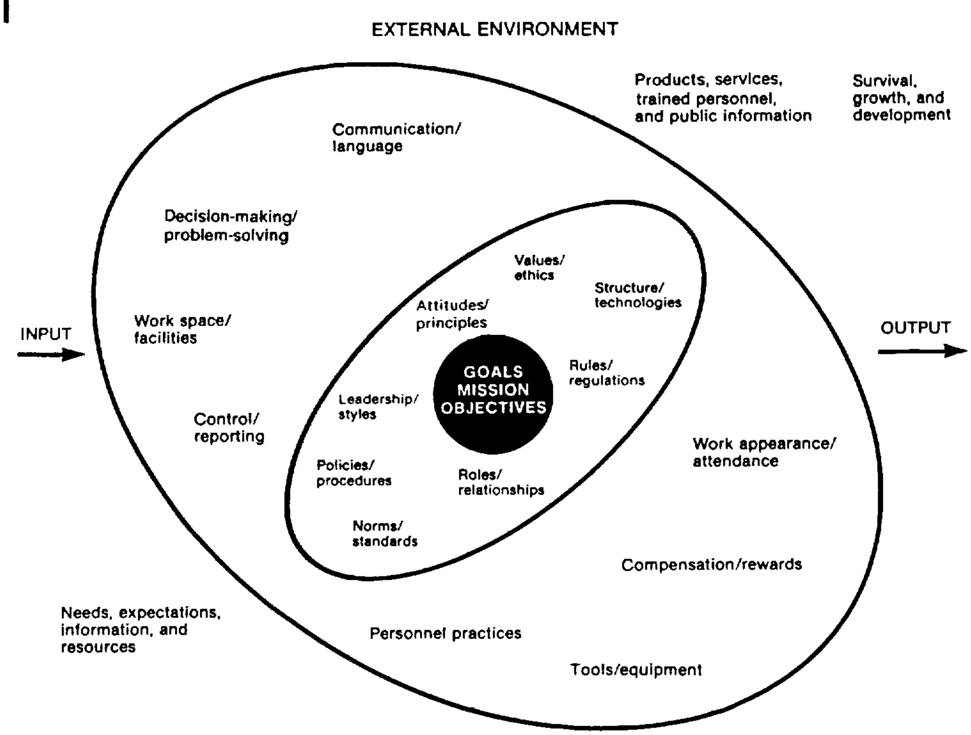

Figure 17

Space Organizational Culture

In 1984, our study team considering space management concluded that a survey and analysis of NASA organizational culture from its headquarters to the field centers would facilitate change and renewal as further space development is planned. If plans for a lunar base are to be effectively implemented, then a transformation in management attitudes, styles, strategies, and operations at NASA may also be necessary. In the post-Apollo era, NASA and its contractors drifted back into an industrial, more bureaucratic style. The work culture, whether of NASA as an organizational system or of its aerospace contract partners, must shift from this industrial or bureaucratic mode back to the mode of enterprises characterized as *metaindustrial*. Only then, it seems to me, will the main actors in the space business be positioned to take advantage of the vast resources on the "high frontier" (O'Neill 1977).

Management consultants see organizations as energy exchange systems. Institutional culture can encourage use of the psychic and physical energies of its people in achieving organizational goals. This is the lesson of the Apollo Moon project. On the other hand, institutional culture can undermine or dissipate the efforts of its people. In order for NASA and its corporate aerospace partners to develop space vigorously in the next 25 years, they must confront the following cultural issues.

(1) The mind-set of the engineer and technologist requires expansion to include generalist thinking. Too often present approaches exclude consideration of human issues, and the contribution of the managerial and behavioral sciences to planning and decision-making are downplayed.

(2) More synergistic relationships in space endeavors should replace obsolete competitive postures by individual companies. The tasks of exploiting space resources are so immense that global space agencies need to collaborate more effectively. Inside NASA, the power games between headquarters and its centers must give way to mutual cooperation. Archaic antitrust regulations must be gotten around to permit aerospace companies to work together to solve common problems, be they matters of quality control on launch pads and space vehicles or greater sharing of

research and development knowledge. The large space corporations can do more for the nation's space program by joint venturing and sharing than by competitive duplication. Furthermore, new ways for synergistic inclusion of university and Government research laboratories should be explored—again as in the Apollo era (Levine 1982). Perhaps the model currently being developed by the European Space Agency is worthy of emulation in North America; it involves cooperation both between nations and between institutions.

(3) As space endeavors reach out to include business participation beyond that of the aerospace companies, attitudes toward and regulations of contractors deserve revision. Perhaps the NASA tradition of partnership with its suppliers is more appropriate than the Department of Defense mentality of seeing its contractors as "users." Space enterprises would benefit from marketplace concerns for satisfying clients and customers (Webb 1985).

(4) Technology development timespans have been lengthened, rather than shortened, because those in the space arena have become more bureaucratic, less entrepreneurial and innovative. From goal-setting to implementation, Apollo's mission was accomplished in less than a decade. Now NASA planners use a 12-to-15-year timeframe from inception to completion of a new technology. Meanwhile, the growing high technology industry (an industry that is a direct spinoff of space technology) has shortened its development timeframe. With due regard to spacefarer safety, perhaps the time has come to reexamine the cultural assumptions by which the practices of redundancy, over-design, over-preparation, over-study, and excessive timidity become embedded habits and traditions. Certainly, such cultural proclivities are less justified in unmanned missions and nontechnical areas, like conference management and reporting. There is reasonable and acceptable risk in the experimental situation of

space flight. What seems more important is effective management of quality control on equipment and parts that go into space transportation systems and habitats.

(5) Organizational renewal implies a continuing process of clarification of roles, relationships, and missions. It requires change from the ways we always did it to the adaptations and inventions necessary to remain a player in the emerging 21st century "space game." Perhaps the habitat modules of space stations and lunar outposts would be better designed by architects and hotel chains than by traditional aerospace vehicle designers. Perhaps the functions of such space facilities should be privatized, so that the NASA centers can take a role more supervisory than operational, thus freeing them for more basic space research and development.

A case relative to cultural issue 2, on synergistic relationships, is the industry-university Consortium for Space and Terrestrial Automation and Robotics (C-STAR). Led by David Criswell of the California Space Institute and sponsored by the NASA-related University Space Research Association, business and academic researchers applying automation and robotics to the space station and other ventures on the high frontier have combined their brain power and established a joint data bank (see, for example, C-STAR Study Group 1988).

The experience with the Shuttle would seem to confirm that NASA moved the project too quickly from research and development into operations. In the transition to 21st century space management, the private sector may dominate the space transportation business and commercial launches, leaving NASA to pursue a technological and scientific research role.

These are but a few of the issues that deserve consideration by management leaders in the space community who would revitalize their organizational cultures and design a management strategy attuned to future demands.

New Roles for Earth- and Space-Based Managers

The five issues just listed are basically cultural and point up the need for planned changes. At our summer study, resource speakers provided numerous suggestions for renewing the American space program and bringing it to new levels of achievement. Several of the more telling comments relate to our topic.

- William E. Wright, Defense Advanced Research Projects Agency, said that the aerospace industry culture is extraordinarily conservative. It suffers from a syndrome: "If it hasn't been done for the last 20 years, forget it." The industry and NASA are not bold enough in their planning and requests for funding. A major program comes into being because someone champions it (puts his reputation on the line and helps bring it into being).

- Peter Vajk, SAI, and Michael Simon, General Dynamics, presented a "stock prospectus" for the establishment of a fictional corporation, "Consolidated Space Enterprises." It envisioned nine companies that could profit by serving customer needs and functions on the space station. Four were providers of such space services as transport, repair, research, and products; three were housekeeping companies that would provide hotel, power, and communication services; two were support companies providing special space services and fuel. The concept of commercial operations on the station, each "feeding" on the other's needs, is not only stimulating to thought but also changes the roles and relationships of public and private participants in space undertakings.

- Peter Vajk, now an independent space consultant, also cited examples of new, more sophisticated management information systems that can alter the role of space project managers. New computer tools, such as relational data base management systems, give managers a better capability to search the literature, while new software like "Hypertext" from Xanadu Corporation (Menlo Park, CA) provides greater access to documentation.

- Ronald Maehl, RCA, pointed out that management issues related to a space station and lunar base represent a departure from traditional NASA management practices. First, there is the matter of managing the development of such projects and precursor missions; then there is the issue of operational management of a space facility when it is functioning. There are precedents in the experience of the National Oceanic and Atmospheric Administration (NOAA) and commercial operators with meteorological and communication satellites. There are new challenges relative to man/machine interactions, operational cost containment, and private participation in such space activities.

These four inputs of experts are but indications of new developments related to the management of tomorrow's space enterprises—developments that warrant more research and call for policy changes by NASA headquarters and its centers. Organizational energy and resources directed to such issues, particularly that of the differences between developmental and operational management, would have greater payoff than the internal struggles of NASA centers to control future programs.

Analysis must be made of the expertise and skills needed by Earth-based managers of projects that are hundreds or thousands of miles away from them. New space project managers have much to learn in this regard from previous project managers of unmanned probes by spacecraft, such as Voyager and Viking, Pioneer and Mariner. The tasks range from limited controls to teleoperations, or the control on Earth by an operator of a machine that is at a remote location such as in space. Management problems experienced include "queuing time" (signal delays between operator command and machine response and between machine response and verification or receipt of data). The management of automation and robotics in space was the subject of another California Space Institute study for NASA (Automation and Robotics Panel 1985).

As more manned space operations occur at more locations, we will need a new infrastructure on this planet to support them. Instead of a single mission control center, there may be regional support centers—some under Government or military auspices and some run by private corporations. For the next 50 years, we are likely to experiment with a variety of Earth-based management plans for space activities, beginning with the space station and a lunar base.

Even more interesting will be management in space of either manned or unmanned ventures. People onsite at a lunar outpost will require more freedom for decision-making and creative problem-solving than the astronauts currently enjoy with mission control in Houston. Decentralized, onsite space management will come into prominence with the building of the space station. Now is the time to begin planning for the practical matters to be faced by station managers, especially when the personnel and organizational components come from various sources beyond NASA itself. In regard to an operational lunar base, research is needed now on such management concerns as communications and leadership and how these functions should be divided between the Earth and the Moon.

Mixed crews (men and women, military and civilian, public and private sector workers, Americans and other nationalities, scientists and other professionals) will invoke more complex management challenges and responses. The people who, in increasing numbers, visit a space station or lunar outpost by 2025 will include more than astronauts or even "astrotechnicians." They will include a broad segment of Earth's society, from politicians to tourists.

In past colonial explorations, trading companies were formed to manage operations in new, remote environs. Perhaps this previous solution could be replicated in a Space Trading Company. If the bold plan for future space developments outlined by the National Commission on Space (Paine 1986) is to be implemented, then more innovative ways for funding and managing space projects will have to be invented. Whether it is financing a fourth orbiter or building a space station, there are historical precedents for national lotteries, selling shares or bonds in space technological venturing, and other forms of public financial participation beyond annual congressional appropriations. The commercialization of space will be a profound force in altering the management of space projects (Webb 1985).

As the crews in tomorrow's space habitations increase in size and heterogeneity, as well as in length of stay away from this planet, planners must expect more stress and strain and must provide space inhabitants with more autonomy, reminds Ben Finney, a University of Hawaii anthropologist, later in this volume. To maximize safe, effective, congenial performance by such pioneers, new programs in behavioral science should be instituted. Studies should be made of team development and group dynamics, new leadership training and responsibilities, and even wellness programs in space communities. Such a program should be part of a planned "space deployment system" I am proposing to facilitate acculturation in a strange, alien, sometimes hostile space environment (Harris 1985b).

For multicultural crews to function well in space, participants must be able to deal with remoteness, they must be self-sufficient and multiskilled, and they must be sensitive to other people and respect the norm of competence. Because space stations in both low and geosynchronous Earth orbit and a lunar or a martian base are such costly, risky, and long-term programs, they will require new management mechanisms that can provide continuity and consistency regardless of personnel changes.

Another management concern to be addressed more vigorously is that of multipurpose missions, such as one involving both civilian and military payloads (Brooks 1983). Economies of scale and piggybacking to contain costs are arguments for combined missions. Technical and management complexity and the issues of secrecy, foreign policy, and international cooperation may prove stronger cases for keeping commercial and defense space activities separate.

Space management would seem an ideal subject on which the Academy of Management and other scholars should focus their research and conferences.

Macromanagement in Space

As has already been indicated, large-scale and complex technical programs require a new type of macromanagement, whether to rebuild this planet's infrastructure or to create a space infrastructure. Figure 15 offers an illustration of the scope of such an undertaking from a management perspective. Long-term projects costing $100 million or more require the application of administrative skills across a range of activities that begins with strategic planning and extends to global or interplanetary management of material and human resources.

Macro-engineering projects have shaped our past and may well shape our future (Davidson 1983). Space programs, like Apollo and the Shuttle, have advanced the field and may be the force behind growth in an allied discipline—macromanagement. Most space programs are macroscopic because they share these characteristics:

(1) They involve difficult, complex engineering and management problems which must be resolved before the program is completed.

(2) They require significant public and private sector resources that must be committed over long timeframes.

(3) They include scientific and technical problems of unusual complexity, size, or circumstances, and the solutions often involve previously unknown technologies or resources.

(4) They have profound impacts on the environment, legal and regulatory situation, economics, and politics of the societies that develop them.

(Davidson, Meador, and Salkeld 1980)

Project management of large-scale enterprises has benefited from such new tools as the program evaluation and review technique (PERT), the critical path method (CPM), and project management space systems (PMSS) modeling. Developments in the supercomputer, software packages, and management information systems have made macroprojects more feasible and manageable. Many of these management innovations owe their origins and refinements to the Department of Defense and NASA.

Macromanagement of large-scale enterprises may very well become a dominant theme in 21st century management practice (McFarland 1985). As NASA seeks to implement plans for a space station in the 1990s and a lunar outpost by 2010, it will not only have to use macromanagement strategies, it may also pioneer in the process. As more corporations participate in space ventures rather than just those in the aerospace industry, NASA will face a new set of interface challenges with these new stakeholders. Already space entrepreneurs expect to launch satellites and a variety of other commercial space ventures that require creating synergy with NASA (Webb 1985). Some of these space enterprises will necessitate the adoption of macromanagement methods.

Research funding should be directed into matters of macromanagement by NASA, global corporations, universities, and others because it demands a new type of management thinking, style, and skills. For example, macroprojects, whether on Earth or in space, stand in need of leadership capable of

- Synergy—facilitating cooperation and collaboration in bringing together diverse elements, so as to produce more than the sum of the parts

- Intercultural skill—overcoming differences between peoples, groups, and nations, particularly through effective cross-cultural communication and negotiation

- Political savvy—gaining agreement and support for project goals from the various political or governmental entities, as well as from the public if their support is essential

- Financial competence—understanding the economic realities of a long-term project and capable of putting together the necessary funding to complete the undertaking, while containing excessive expenditures

- Interface management—taking the lead in bringing together on time the various resources (human, informational, technical, material) required to achieve project goals

- Cosmopolitanism—sensitive to global and interplanetary issues affecting the project, such as legal, ecological, environmental, and human concerns, and able to cope with such issues from an international rather than a national perspective

These are but a sampling of the qualities that are desirable in the new macroproject executive or manager. Perhaps no one person possesses all of them, but a management team may exercise such competencies together. Certainly, a traditionally educated engineer is not likely to possess many of these skills. Research on the education of macro-engineers has been under way at MIT under the conduct of Frank Davidson, and it is beginning at the University of Texas' Large-Scale Programs Institute under the direction of George Kozmetsky. Publications such as *Technology Review*, published by MIT Press, are also addressing these concerns. These efforts should be expanded to include macromanagement as a subject of study. Kozmetsky (1985) calls for transformational management strategies, thus indicating that macromanagement may be one of the central issues of 21st century management.

During our summer study, two resource speakers pointed out existing management models worthy of further analysis by space planners. To create the necessary infrastructures for tomorrow's space programs, consultant Kathleen Murphy (1983) proposed that we could learn from large development projects around the world. (See her paper in this volume.) Such major "greensite" projects have already resolved problems between owners and contractors—developing techniques of conflict resolution and negotiation and making reward and penalty provisions. And they have tested financial arrangements that might prove feasible for space development—including new financing models, joint ventures, consortia, R&D shared between Government and industry, and national bank syndicate investments.

The other input came from consulting engineer Peter Vajk, who observed that global projects concerned with new terrestrial materials may offer insights into the exploration for and exploitation of space resources. Like NASA projects, these projects are high-risk and capital-intensive. They involve very large costs for research and development, startup, and operations. They are beginning to use a macromanagement approach in which a corporate headquarters sets general policy, negotiates major contracts, and keeps accounting and systems records, while subsidiary facilities operate under distributed or semiautonomous management. Projects in new terrestrial materials, being technology- and skill-intensive, involve macro-engineering. They own, lease, or hire their transportation. They operate distribution centers, retail outlets, and sales offices. Their programs are extended in time and space throughout the deployment and operation phases. Their activities are transnational. They use sophisticated computer information networks involving high-rate data transfer. Vajk believes that macroprojects to develop nonterrestrial resources can operate like these Earth-based analogs: "Space is just a different place to do the same kinds of things we do on this planet."

But space is a place for large-scale endeavors of a peaceful and commercial nature. It opens opportunities for human institutions and governments to produce synergy, not war. It requires not only new mind-sets but new management. Over a decade ago, a classic work provided us with a charter for that purpose. In *Managing Large Systems: Organizations for the Future* (1971), Sayles and Chandler reminded us that such enterprises are interdisciplinary in character and integrate an array of scientific, technological, social, political, and other personalities and resources. This charter describes the large-scale programs of NASA, as was well understood by the key administrators of the Apollo Program.

In 1986 the National Commission on Space, appointed by the President, issued a report, *Pioneering the Space Frontier*. It recommends spending $700 billion on the U.S. space program for manned settlements on the Moon within 30 years; a new generation of spacecraft that could voyage to the Moon, Mars, and beyond; and a new space infrastructure for interplanetary factories, spaceports, and communities to accommodate eventually one million space travelers a day. Macroprojects, such as will be undertaken in space by the turn of this century, need more than bold vision; they need a system for managing continuity over long periods, despite fluctuations in personnel, policy, government administrations, and finances. Gaining a national consensus to support new space ventures is a cultural problem. Implementing plans for that purpose implies innovative approaches to space management, such as have been discussed here.

For existing space organizations, such as NASA and its aerospace partners, reeducation of personnel is in order to prepare for the future demands of space management in general and macromanagement in particular. New executive and management development programs should be designed to deal with these considerations. Technology or R&D managers need to become more general in their outlook, more open to new ideas outside their own fields and industries, more competent in management skills. For this to happen, schools of engineering and business will have to design joint curricula, while corporate specialists in human resources and development will have to cooperate with R&D professionals to create more appropriate in-house training.

Space management in the future will necessitate crossing traditional academic disciplines and industrial fields, as this quotation of Frank Davidson (1983) so succinctly implies:

> Space development is a critical case-in-point, because it will test the ability of our diverse, rather relaxed society to set long-range goals, to hue [*sic*] the line despite disappointments and setbacks, and to devise institutional arrangements that will assure continuity. . . . Low-cost approaches are indispensable, because an increasingly educated public will rightly insist on [a] return on investment. . . . Now is the time, therefore, for the aerospace community to reach out to the mining industry, the heavy construction industry, and the ground transportation industry, so that joint ventures on land and sea, as well as "up there" may set a pattern of partnership and a network of personal relationships which will benefit all systems engineering programs that are so necessary for the future health, safety, and prosperity of the Republic.

Conclusions

Under the leadership of NASA, plans are being made for space developments in the next 25 years. At a minimum, the program will include space and lunar stations that will be complicated to construct and manage, require a new generation of technology, and cost billions of dollars. From these bases in space, planners envision mining the Moon, possibly mining an asteroid, and eventually launching manned missions to Mars (maybe a joint mission with the Soviets). Such developments will require an organizational transformation of the National Aeronautics and Space Administration. This may involve structural changes that give the agency more autonomy and flexibility, especially long-term financing. Certainly, it should include planned organization renewal so that NASA builds on the technological and management innovations of its Apollo heritage. If the national decision is to go to Mars jointly with the Soviets, then the challenge will be the integration of the two countries' space management systems.

To become and remain fully metaindustrial, NASA and its aerospace partners will have to create a new work culture. For that purpose, I have proposed a survey and assessment of their current organizational culture, so as to ascertain what changes are necessary for future space management. For NASA, the management changes involve new relationships with the military and the private sector, as well as with international space consortia and possibly some new entities, such as a global space agency.

Obviously, the next 25 years in space will also alter the way we manage enterprises in space. Initially, we need more research on issues of leadership for Earth-based projects in space and space-based programs with managers there. The days of the traditional "mission control" may be waning. Second, we need to realize that large-scale technical enterprises, such as are undertaken in space, require a new form of management. Therefore, NASA and other responsible agencies are urged to study excellence in space macromanagement, including the necessary multidisciplinary skills. Two recommended targets are the application of general living systems theory (Miller 1978; see also his paper in this volume) and macromanagement concepts (McFarland 1985) for development and operation of a space station in the 1990s. Such management models may supply the positive orientation now needed in planning America's aerospace future.

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