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AN OPTIMUM ORGANIZATIONAL STRUCTURE FOR A LARGE EARTH-ORBITING MULTIDISCIPLINARY SPACE BASE

James M. Ragusa

John F. Kennedy Space Center
Kennedy Space Center, Fla. 32899

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16. Abstract

The purpose of this exploratory study was to identify an optimum hypothetical organizational structure for a large Earth-orbiting, multidisciplinary research and applications Space Base manned by a crew of technologists. Because such a facility does not presently exist, in situ empirical testing was not possible. Study activity was, therefore, concerned with the identification of a desired organizational structural model rather than with the empirical testing of the model. The essential finding of this research was that a four-level project type total matrix model will optimize the efficiency and effectiveness of Space Base technologists.

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James M. Ragusa
NASA, John F. Kennedy Space Center

INTRODUCTION

This study was concerned with the determination of an optimum hypothetical organizational structure for a large earth-orbiting multidisciplinary research and applications Space Base manned by a mixed crew of 50 to 100 domestic and foreign technologists. Designed for a useful ten-year operating life, Space Base would be assembled and supplied with equipment, personnel, and food by a reusable Space Shuttle. This facility would serve to greatly expand advancements in the sciences, exploration, public and private services, and foreign relations. For discussion and analysis purposes, organizational structure was defined to be the established pattern or deliberate grouping of relationships among the components or parts of a formal organization to achieve specific goals. It was characterized by planned division of activities, leadership, and communications responsibilities. Another salient feature was the presence of a hierarchy of authority needed to plan, control, and direct, and coordinate the concerted efforts of the organization toward its goal in an orderly manner.

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James M. Ragusa
NASA, John F. Kennedy Space Center

I. BACKGROUND

Space Base Background and Program Objectives

This study was concerned with the determination of an optimum hypothetical organizational structure for a large earth-orbiting multidisciplinary research and applications (R&A) Space Base. The facility would support a heterogeneous crew of 50 to 100 male and female scientists, engineers, and technicians working for extended periods on a variety of R&A experiments and projects. While this space community does not presently exist, it is planned to be operational within the next two decades. Several photographs of artist's concepts of a Space Base and a modular laboratory mockup are contained in Appendix A.

National interest in this type of facility began on February 13, 1969, with the appointment of a Space Task Group by President Richard M. Nixon. The purpose of this ad hoc group was to study the direction and pace of post-Apollo manned space flight programs. Significant recommendations presented to the President in September, 1969, relating to future space programs included

1. Development of a modular 12-man Space Station laboratory by 1975, to be followed in 1985 by a much larger permanent Space Base. This latter laboratory would be created by modular additions to the Space Station, and would accommodate a crew of 50 to 100 people, including large numbers of scientists and engineers of various skills.

2. Development of a reusable Space Shuttle which can be flown over and over, perhaps 100 times, to provide logistics in the form of supplies, crew rotation, and exchange of scientific instruments and data--to support Space Station and Space Base activities.[1]

To delineate Space Base program objectives, NASA identified the following activity categories and examples:

1. Technology Forcing Function--This program is intrinsic in the development, use, growth, and continual updating of a major space facility and its equipment.

2. Sciences--The combined environment, facilities, and crew of the Space Base will provide excellent research opportunities in many disciplines (e.g., astronomy, life sciences, physics, and chemistry).

3. Exploration--This Space Base Program will provide essential data acquisition, equipment development and qualification, and operational concept demonstration and training for future manned missions to the moon and planets.

4. Public Services--Global surveys in Earth resources and meteorological disciplines will be conducted primarily for the development of better equipment and techniques, but also for the collection of user-oriented data.

5. Foreign Relations--The Space Base Program provides a focal point for productive international cooperation and joint ventures, including the use of foreign nationals as members of the onboard technical team.

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[1]William J. Normyle, "Future Goals of NASA Described," Aviation Week and Space Technology, October 13, 1969, pp. 39-42. [Emphasis added].

6. Private Sector Support--Unique materials and manufacturing research will come out of the program, as might production services that exploit the zero-g and hard-vacuum environment.

7. Orbital Operations--The Space Base will provide a servicing and maintenance platform for both unmanned spacecraft in Earth orbit and in transit to and from the moon and deep space.[1]

Space Base is intended to be a large facility in earth orbit supporting highly flexible multidisciplinary R&A activities similar to advanced, existing facilities on earth. There will be some differences, however, since the Space Base will utilize and exploit the unique features provided by low-earth orbit (270 nautical miles), such as weightlessness, unlimited vacuum, and rapid earth and unobstructed celestial viewing. The flexibility of design for this facility would allow support of R&A activities, and interplanetary missions which are not presently defined in detail.[2]

Space Base will be a semipermanent facility with a minimum operational life of ten years with resupply.[3] The facility will allow large numbers of international and domestic technologists the opportunity to carry out varied R&A activities as well as female scientists and engineers

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[1]National Aeronautics and Space Administration, Space Base Concept Data, Volume 1, June, 1970 (Huntington Beach, Calif.: McDonnell Douglas Astronautics Company, 1970), p. 9.

[2]Ibid., p. 5.

[3]Ibid., p. 57.

who will be allowed to participate as crew members.[1] These technologists, as well as the Space Base, will be relatively autonomous from earth control, thus reducing the requirement for round-the-clock mission control activities on the ground.[2] The highly skilled specialists will be afforded an opportunity to conduct experiments, develop new technologies, materials, and processes that cannot be accomplished on earth. In time, other government agencies will be given the opportunity to use the facility for work in their own areas of responsibilities in much the same way that government-owned ground-based laboratories are used today. The facility will provide an opportunity to implement cooperative international programs in the sciences and beneficial earth applications.[3]

It is envisioned that a portion of the total in-orbit crew will be devoted to Space Base operations. This group will be responsible for system operation and status, safety of the entire crew, onboard procedures, coordination with group personnel, scheduling of facilities use, and information management. Another group assigned to medical

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[1]Nieson S. Himmel, "Advanced Space Station Concepts," Aviation Week and Space Technology, September 22, 1969, p. 100.

[2]National Aeronautics and Space Administration, Statement of Work: Space Station Program Definition (Phase B), April 14, 1969 (Washington, D. C.: Government Printing Office, 1969), p. 1-6.

[3]Ibid., pp. 4-30-4-31.

operations will cater to the general health of the crew. Needed physiological and psychological services would be provided by a multidisciplined medical team. Yet another in-orbit group assigned to Space Base maintenance will repair and maintain subsystems and experiment equipment, will perform assembly and modifications, and will provide housekeeping and food services as necessary. Engineers and technicians will be required for specialized skills in instrumentation, system operation, and repair.[1] This group may be responsible for the various logistics activities required.

Purpose of the Study

The broad purpose in conducting this study was to add to the body of knowledge regarding the role of organizational structure in human endeavor. The current research effort was designed to identify an optimum hypothetical organizational structure for a Space Base. The primary question answered by this research was what is the preferred organizational structure for optimizing the mission accomplishments of the various technologists who will work and live in a large multidisciplinary earth-orbiting Space Base?

To answer the primary question of the study, the following elemental questions were considered:

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[1] *Ibid.*, p. A-8.

1. What known Space Base program requirements are important to organizational structure selection, and what assumptions must be made?

2. What related studies provide insight into Space Base organizational structure selection?

3. What variables are important to the selection of an organizational structure for a Space Base?

4. What type of organizational structure best serves the needs of technical professionals?

5. How appropriate to Space Base are the multitude of social systems and environmental situations involving isolation, confinement, and situational danger; and what can be learned from the most applicable analogs with regard to Space Base organizational structural selection?

6. What evaluation criteria should be used to select the preferred Space Base organizational structure?

7. What variations to basic classical and modern organizational structural models should be considered for Space Base use and why?

8. What analyses can be used to assess feasible classical and modern organizational structures and select the preferred one?

For discussion and analysis purposes, Space Base organizational structure was defined as the established pattern or deliberate grouping of relationships among the components or parts of a formal organization to achieve specific goals. It was characterized by planned division of activities, leadership, and communications responsibilities; and the presence of a hierarchy of authority needed to plan, control, direct, and coordinate the concerted efforts of the organization towards its goals. Other definitions are specified in the study when required, and are listed in Appendix B.

While the next section discusses the need for organizational structure in professional organizations, it should be realized that the right structure will do much to ensure Space Base program success. Properly selected, organizational structure will enable on-board NASA managers to accomplish objectives and plans through various activities. A few of the more significant ones include: (1) establishing and maintaining the organization's characteristic and processes in good functioning order, (2) coordinating activities, (3) managing resources, (4) maintaining crew morale, health, and safety, and (5) providing training and indoctrination.[1] While these activities are diversified, they have one thing in common - they all require resource management, especially human activity.

Need for the Study

High Program Costs

The high costs anticipated for future programs such as Space Base, dictate that program objectives be maximized through effective and efficient operations. While a dollar cost has not been estimated for a full-duration Space Base program, part of the cost will be associated with crew

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[1]National Aeronautics and Space Administration, Crew Operations Study of Command Structure, by Samuel C. Campbell, Perry L. Gardner, and Robert H. Schaefer (Bethpage, New York: Grumman Aerospace Corporation, 1971), p. 8.

operations of the facility and selection, training, and transportation of personnel. These costs will probably be in the millions of dollars.

The American taxpayers, their congressional representatives, and the President's Office of Management and Budget have recently put pressure on NASA to provide more benefits from space activities at a reduced cost. These desires have caused NASA's Deputy Administrator to note that because budgets are imposed by external forces NASA has little control over budgetary constraints, but NASA can and must do something about the high cost of doing business in space. He, therefore, concluded that NASA's biggest challenge was achieving that goal.[1]

The Need for a Productive Crew

While an optimum organizational structure will not guarantee that Space Base will be a low cost program, it will greatly aid that goal through productive crew performance. One justification used to identify an optimum organizational structure for a twelve-man Space Station by Campbell, Gardner, and Schaefer of the Grumman Corporation was that since the crew was probably the most important component of the total system, it must be used as productively

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[1]George M. Low, "NASA's Attack on the Cost Problem," Address given at the National Security Industrial Association and Armed Forces Management Association Symposium, Washington, D.C., August 16, 1972.

as other resources.[1] This need supports the view of Likert, who strongly believes that, "of all the tasks of management, managing the human component is the central and most important task because all else depends upon how well it is done."[2]

Campbell, et al. went on to say that while it is difficult to predict crew productivity, evidence derived from similar earthbased analogs indicated that crew performance will most likely degrade with time. They concluded as a result of their studies that organizational structure was an important means of achieving and insuring long-term crew productivity.[3] In the opinion of the researcher, the concern for crew productivity over extended periods of time for the much larger Space Base crew makes the problem even more serious.

Unique Crew Composition and Environment

It was envisioned in this study that the technologists required for Space Base R&A activities and operations will have qualifications different from those of the astronauts who will command Space Shuttle vehicles and participate in other

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[1]NASA, Crew Operations Study of Command Structure, p. 1.

[2]Rensis Likert, The Human Organization: Its Management and Value (New York: McGraw-Hill Book Co., Inc., 1967), p. 1.

[3]NASA, Crew Operations Study of Command Structure, p. iii.

manned programs. The Space Base crew will include people with a variety of skills and cultural backgrounds which must be recognized. These people must be organized to function productively through harmonious interpersonal relationships. In addition, problems can arise because technologists have certain distinct characteristics, attitudes, and needs which must be satisfied if optimum mission results are to be achieved.

In addition to a varied crew composition, the Space Base program will place in-orbit NASA managers in the unique situation of managing groups of highly skilled, non-astronaut trained or non-space disciplined personnel in a space environment. In spite of limited training and exposure to space, these technologists will be expected to live and work in an autonomous environment under conditions of semiconfinement, isolation, and zero gravity. They will work and live with the world and their ground-based colleagues, to a certain extent, looking on.

The need to consider unique crew composition and environment of space crews was recognized by Campbell, et al. who acknowledged that a properly designed organizational structure provided the mechanism and a link between sociological-psychological considerations and the human engineering aspects of physical configuration. When an organizational structure provides clear avenues of communications, responsibility, and authority while being responsive to the crew's human needs, energies can be better directed toward the mission and its goals.[1] But clearly, the problem and main challenge for those who develop organizations, according to Etzioni, is to construct human groupings that are as rational as possible, which at the same time produce a minimum of undesirable side effects and a maximum of satisfaction.[2]

Research on research within the planned Space Base was, therefore, justified to identify an organizational structure which makes orderly, effective, and efficient R&A activities and operations possible. If an optimum Space Base organizational structure can be identified at an early date, facility design considerations, personnel selection criteria, and training plans can be developed and implemented in the intermediate future. In the longer run, organizational structure testing in analogous environments and other useful management studies will do much to ensure the ultimate success of the total program. If these actions are taken, the United States can probably enhance its prestige and preeminence in major fields of science and technology for the benefit of all mankind through a program the nation can afford.

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[1]National Aeronautics and Space Administration, Space Station Crew Operations Study: Technical Proposal, by Samuel C. Campbell, Perry L. Gardner and Robert H. Schaefer (Bethpage, New York: Grumman Aerospace Corporation, 1970), p. 1.

[2]Amitai Etzioni, Modern Organizations (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1965), p. 2.

Methodology

This section presents an overview of the sequential, analytical, and systematic methodology used in the study to obtain and analyze data and reach conclusions. The use of this methodology provided an answer to the primary study question through the development of answers, from various sources, to the elemental questions.

Henry Tosi discusses the contention of Lykken that replication is required for corroboration of theories within the domain of the social sciences. Tosi also lists and defines the degree of replication identified.

> Lykken briefly outlines three replication strategies: (1) literal replication is exact duplication of the first research; (2) operational replication is duplication of the sampling and experimental procedures; and (3) constructive replication occurs when an independent researcher begins with the findings of a study and uses other constructs of the concepts in the first to examine the hypothesis.[1]

The methodology used for this study was, to a certain extent, an operational replication of a NASA funded, Grumman Corporation analysis to identify a preferred Space Station command structure.[2] The methodology of the present study served as an extension, with certain modifications, of the Grumman effort with the application being Space Base instead of Space Station. Data collection and analysis activities,

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[1]Henry Tosi, "Organizational Stress As a Moderator of the Relationship Between Influence and Role Response," Academy of Management Journal, XIV (March, 1971), 12.

[2]NASA, Crew Operations Study of Command Structure.

like those of the Grumma[illegible] h[illegible] the following phases: (1) data research, (2) de[illegible] of organizational structural evaluation criteria and a set of feasible models, and (3) evaluation of feasible models and selection of the optimum one. In general, these phases are contained in Sections II, III, and IV, respectively.

Data Research

Sources of data

Data were obtained from a number of sources for a variety of reasons. More specifically, these sources included (1) reviews of primary and secondary literature, (2) visitation and examination of certain Space Base analogs where appropriate and practical, and (3) interviews with knowledgeable persons.

Primary and secondary literature was obtained from NASA and various univers[illegible] libraries. These documents consisted essentially of [illegible] and NASA developed and/or sponsored publicatio[illegible] various other publications relating to the subject. The bibliography contains a listing of appropriate books, a[illegible]cles, and miscellaneous materials reviewed. This literatu[illegible]lls into two general categories: organization/management th[illegible]ioral science, and analogs/space activities. The [illegible] category contained a copious quantity of information; the second was more restricted.

A large portion of this literature was identified by the use of NASA's RECON (reconnaissance by REmote CONtrol) system. A remote terminal located at the John F. Kennedy Space Center, Florida, was used to electronically search the literature stored in NASA's Scientific and Technical Information Facility in College Park, Maryland. Both the NASA RECON system and University Microfilms of Ann Arbor, Michigan indicated, however, that limited applicable information exists for Space Bases, and that no dissertations or theses have been written on the topic under analysis. The primary and secondary data which was found was essential to section II and subsequent chapters, as was information obtained from the visitations/examination and interview activities discussed next.

A number of Space Base analogs were visited and examined by the researcher during the study. These included Space Station mockups, a nuclear powered submarine, and the Ben Franklin research submersible. The Space Station mockups visited were located at NASA's Marshall Space Flight Center (MSFC) in Huntsville, Alabama. Tours through fourteen feet and thirty-three foot diameter facilities were accomplished on November 16, 1971. These full-scale Space Station versions with their supporting documentation provided insight into the physical environment and constraints in which crew personnel would have to work and live.

A nuclear powered Fleet Ballistic Missile (FBM) submarine was visited on December 10, 1971. The submarine was the USS Nathanael Greene (SSBN 636), normally on operational patrol. The vessel was on a training mission at the time, operating at a maximum depth of 200 feet in preparation for a training launch of one of its Poseidon missiles. The last visit was to the Grumman/Ben Franklin research submersible on December 28, 1971. On that day the submarine was in dry dock at its berth in Riveria Beach, Florida. It was from this port that this vessel began its training/certification dives and its historic thirty day Gulf Stream drift mission on July 14, 1969.

There are several reasons why visitations were made to only these analogs. The first was that analysis accomplished by the researcher, discussed later, indicated that the analogs visited (and several others) had the most similarity to Space Base. The second reason was that while it would have been ideal to visit and examine first hand a number of analogous Space Base environments, this was impossible. The reasons were that some are no longer operating programs, others are not even in existence, and some situations because of their diversity or location were not feasible to visit for economic reasons. Fortunately, a large body of literature exists for these analogs; therefore, visitation is desirable but not mandatory.

Personnel interviews with knowledgeable individuals provided additional primary data. NASA, military, and contractor management, and operating and planning personnel at various levels were interviewed to ensure thorough coverage. This multilevel approach permitted cross-checks to assure accuracy of reporting. Unstructured questions with follow-on questions were asked with continual refinement of questions as the interviews proceeded. The purpose of using interviews was to identify and/or verify significant factors and considerations which affect organizational structure. Results of these interviews are presented in subsequent sections when appropriate and significant.

<u>Specific topics investigated</u>

Topics relating to Space Base organizational structural considerations which were investigated during this study were (1) program requirements and assumptions, (2) related studies, (3) general and specific organizational structural variables, (4) the nature of professional organizations and technical professionals, and (5) applicable analogs.

The identification of program requirements and assumptions was necessary to answer the first elemental question: What known Space Base program requirements are important to organizational structure selection, and what assumptions must be made? The requirements identified in several NASA and contractor sources were considered by NASA to be mandatory and essential to ensure program success. In addition to these requirements, certain reasonable assumptions were made by the researcher to simplify, clarify, and restrict operational and other related considerations. These requirements and assumptions, although part of data research, are contained in the last section of this chapter.

A number of NASA and contractor related studies were investigated to answer the second elemental question: What related studies provide insight into Space Base organizational structure selection? The results of this review are contained in section II, as are the discussions of the remaining specific topics.

An in-house NASA study concerned with both Space Station and Space Base was used to develop a Statement of Work to be used for follow-on contractor efforts. In addition to the identification of program requirements, general functions for Space Base crew activities were proposed.[1] As a result of the Statement of Work, two contractors investigated Space Base programmatic and physical design considerations. Little attention, however, was paid to organizational structure in these studies except to identify, in general terms, major groups of personnel which would be required.[2]

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[1]NASA, Statement of Work, pp. A-2-A-18.

[2]NASA, Space Base Concept Data, and National Aeronautics and Space Administration, Space Base Definition: Volume 1, July 24, 1970 (Downey, Calif.: North American Rockwell Corp., 1970).

Two concurrent and independent studies by two NASA employees at different centers took a slightly different approach to investigating the Space Base than did the contractor efforts. These studies established a hypothetical line organizational structure, and then investigated the effect of this structure on physical facility design and crew skills. Little consideration was given to other types of structures.[1]

Two other pertinent studies were useful to the present study. The first, the Grumman study, was invaluable because of the methodology developed and used. This methodology led Campbell, et al. to the selection of an optimum line functional organizational structure for a twelve-man Space Station.[2] While the results of the Grumman study were not considered to be applicable to Space Base because of the differences in program crew size and other major factors, the methodology used was of immense value to the present study.

The second and final related study was performed by Sells, and was an analysis of a hypothetical 500-day mission to Mars and back by a crew of six. This study was important

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[1]National Aeronautics and Space Administration, Fifty-Man Space Base Population Organization, by Georg von Tiesenhausen (Marshall Space Flight Center, Ala.: NASA, 1970), and National Aeronautics and Space Administration, Earth-Orbiting Space Base Crew Skills Assessment, by Robert T. Gundersen (Manned Spacecraft Center, Tex.: NASA, 1970).

[2]NASA, Crew Operations Study of Command Structure.

because of its development and use of a comparison method for determining the appropriateness of various social systems.[1] This technique was used in the present study to identify the environmental situations most analogous to the one envisioned for Space Base. The results of this analysis are contained in Appendix C and in subsequent discussion of relevant data from applicable analogs.

A study of general and specific organizational structural variables was made to provide an answer to the third elemental question: What variables are important to the selection of an organizational structure for a Space Base? The variables sought were those which were generally considered to be important for organizational structural selection.

A survey of management literature was made which indicated that the most applicable set of general variables were those identified by Koontz and O'Donnell. These variables were objectives and plans, capability of personnel, environment, and authority.[2] After review and evaluation by the researcher, the more specific variables used in the Grumman Space Station analysis[3] and others

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[1]S. B. Sells, "A Model for the Social System for the Multiman Extended Duration Space Ship," Aerospace Medicine, XXXVII (November, 1966), 1105-135.

[2]Harold Koontz and Cyril O'Donnell, Principles of Management (New York: McGraw-Hill Book Company, 1968), pp. 236-37.

[3]NASA, Crew Operations Study of Command Structure, pp. 3-5.

determined to be significant were included. These specific variables were then placed under appropriate general variable categories, and are discussed in section II.

The nature of professional organizations and technical professionals was the next specific topic studied. The ultimate purpose of this investigation was to answer the fourth elemental question: What type of organizational structure best serves the needs of technical professionals? A review of the literature on this topic revealed that a formidable number of references existed. To restrict the review of this literature and to answer the elemental question, only the following sub-topics were, therefore, considered: professional organizations, the characteristics of technical Professionals, and technical professionals and the organization.

The remaining specific topic was concerned with Space Base applicable analogs. The purpose of this investigation was to provide answers to the broad two-part fifth elemental question. This question was how appropriate to Space Base are the multitude of social systems and environmental situations involving isolation, confinement, and situational danger; and what can be learned from the most applicable analogs with regard to Space Base organizational structural selection?

To answer the first part of this question, the Sells methodology was used by the researcher as the basis for the analysis of Appendix C. Twenty-two social systems were compared to the Space Base social system and ranked. An analysis of system similarities by descriptive categories was also performed. To answer the second part of the question, an in-depth analysis by the researcher identified the correlation between the most applicable analogs and the general and specific organizational structural variables. This fruitful effort greatly reduced and directed the follow-on analog data research (review of literature, visitations, and interviews).

Development of Organizational Structure Evaluation Criteria and a Set of Feasible Models

The next phase of the study methodology was concerned with the use of the data collected and analyses performed during the first phase. Results thereby obtained were used to provide a rationale for evaluation criteria identification, and to develop a number of feasible organizational structural models which should be evaluated. The ultimate purpose was to use the results of this second phase to evaluate and select the preferred organizational structure for Space Base from the alternates contained in section III; this phase provided answers to the sixth and seventh elemental questions.

The sixth question was what evaluation criteria should be used to select the preferred Space Base organizational structure? To answer this question, data obtained from the specific topics investigated were used. These data were grouped into the following categories: Program requirements and assumptions, management concepts and practices, and applicable analog data. The second category included those data from the Space Base related studies, general and specific variables, and professional organization and professional topics. The result of this extensive effort by the researcher was a comprehensive list of criteria with sources and rationale, identified by general and specific variable categories. The listing was an essential requirement for subsequent evaluation efforts.

The seventh question was what variations to basic classical and modern organizational structural models should be considered for Space Base use and why? To provide insight and an ultimate answer to this question, a four level Grumman "level-of-authority model" used for Space Station feasible model development was used. These organizational levels were command, discipline, function, and task.[1] As a result, a number of hypothetical Space Base organizational structural models were identified. Unlike the Grumman and all other related studies, however, modern project as well as classical model variations were considered.

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[1]NASA, Crew Operations Study of Command Structure, p. D-2.

This screening was accomplished by the researcher to determine if the models should be considered further. Screening criteria developed by Grumman were used to determine if each model was realistic and practical, had sufficient differences, provided for a decision making capability, and satisfied Space Base program requirements (and assumptions).[1] This initial screening allowed reduction of models identified to a more manageable and feasible set.

Evaluation of Feasible Models and Selection of the Optimum One

The final phase of the study methodology used the results of the other two phases to evaluate and select the optimum hypothetical Space Base organizational structure from the feasible set. This evaluation and selection, contained in section IV, answered the eighth elemental question and the primary study question.

The eighth question was what analyses can be used to assess feasible classical and modern organizational structures and select the preferred one? Essentially a continuation of the Grumman developed methodology, the final study analysis was partially accomplished by three evaluation teams and partially by the researcher working alone.

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[1] *Ibid.*, pp. D-5-D-7.

The function of two pilot evaluation teams was to verify the practicality of a team evaluation process in this application and the appropriateness of the criteria and model variations. The final, primary evaluation team consisted of five knowledgeable NASA, contractor, and academic representatives who were familiar with one or more of the following areas: program requirements and study assumptions, management concepts and practices, and applicable analog data. This team's purpose was to objectively and individually score each of the organizational structural models in the feasible set depending on how well each of the evaluation criteria were satisfied.

The concluding [illegible] of this final phase of the methodology was accom[illegible]ly by the researcher. Using evaluation data which r[illegible]ed from the primary team's assessment, quantitative and qualitative analyses were performed. The quantitative analysis was concerned with how well the eval[illegible]els scored and ranked in relation to each othe[illegible] The [illegible]tative analysis consisted of an evaluation and reassessme[illegible]f differences between the highest scoring models with respect to how well weighted "discriminating" criteria were satisfied.

These criteria discriminated because of their wide variation in scoring between models. The rationale for using these criteria was that while all criteria considered have some importance for Space Base organizational structure consideration, those which discriminate between models are of higher importance for evaluation purposes. In summary, the quantitative and qualitative analyses, and the sequential methodology which provided data led to a rational approach to the selection of an optimum model.

While this study's methodology has been identified as an operational replication of the Grumman study, there are some significant differences contained in the present study. First, the Sells methodology for identifying similarities between social systems was used. Second, a broader range of variables were evaluated. Third, consideration was given to modern organizational structures as well as classical varieties. These differences were not intended to be a criticism of the Grumman methodology or the study team members. However, the need to expand the methodology was required due to differences in Space Base requirements and assumptions, and because the applicable analogs were less obvious to the researcher.

Limitations

It must be realized that the methodology used and the study subject have limitations. First, the methodology was not of the rigid quantitative type strongly desired for social science studies. This study does not seek empirical validity or rigorous proof because the subject, by its very futuristic nature, does not lend itself to such analyses. The study does, however, attempt to quantify the subjective, as will be shown in sections III and IV; and relevant experimental findings of laboratory research are used when appropriate.

The second limitation was that some feel that when studying organizations it is difficult, if not impossible, to study structure by itself. Kast and Rosenzweig respond by indicating that two separate phenomena are involved. They suggest that structure and functioning (processes) can be viewed as the static and dynamic features of the organization, respectively, and that for some social systems, the static aspects (the structure) are most important, while in others the dynamic aspects (the processes) are more important.[1] For the purposes of the present study, organizational structure was the area of concentration, while processes are of secondary but related importance.

The third limitation was that Space Base is a social system which will not be operational for two more decades. It could be argued that the present study was premature and has limited value. The problem was further complicated by the fact that the majority of R&A mission activities are not only undefined, but have not even been conceived yet.

There are several responses to this last apparent

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[1]Fremont Kast and James Rosenzweig, Organization and Management: A Systems Approach (New York: McGraw-Hill Book Co., 1970), p. 171.

limitation. The first was that any study on the subject of Space Base organizational structure will have some value for long-range planning purposes, as previously discussed. The second was that while the organizational structure selected by the present study may not be the one finally used, what was considered important by the researcher was the methodology used to select that structure. The application of the three-part methodology to the stated Space Base problem may become the most significant long-run contribution this study makes. Finally, since there are several unknown aspects to Space Base activities, assumptions can be made which will suffice for this study's purpose and can be updated as more information becomes known, thus utilizing the methodology's flexibility.

Space Base Program Requirements and Assumptions

The introductory portion of this chapter identified Space Base background and program objectives. Contained in that discussion are program requirements considered by NASA to be necessary to ensure program success. These requirements, as well as assumptions the researcher considered as program requirements not yet formally identified in existing Space Base documentation, are listed because of their importance to subsequent sections:

1. The Space Base will be operational by 1985.[1]

[1]Normyle, p. 39.

2. The Space Base crew size is expected to be maintained between 50 to 100 technologists of various skills.[1]

3. The Space Shuttle will be used to provide Space Base logistics in the form of supplies, crew rotation, and exchange of scientific instruments and data.[2]

4. A variety of multidisciplinary R&A activities will be accomplished concurrently within the Space Base.[3]

5. International as well as domestic technologists will participate as Space Base R&A crew members.[4]

6. The Space Base will support R&A activities and interplanetary missions which are not defined in detail at present.[5]

7. The Space Base will be a semipermanent facility with a minimum operational life of ten years with resupply.[6]

8. Female, as well as male, technologists will comprise the Space Base crew.[7]

9. The Space Base will be as autonomous from earth control and support as possible.[8]

10. Support operations personnel will function to satisfy the needs of the R&A technologists who use but do not operate the Space Base.[9]

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[1] Ibid. [2] Ibid., p. 40.

[3] NASA, Space Base Concept Data, p. 9.

[4] Ibid.

[5] NASA, Space Base Concept Data, p. 5.

[6] Ibid., p. 57. [7] Himmel, p. 100.

[8] NASA, Space Station Program Definition, p. 1-6.

[9] Ibid., p. A-8.

11. Initial crew size will be 50 members. As the Space Base facility grows in size, the crew will increase to 100 technologists.[1]

12. The vast majority of crew members, especially those involved with R&A activities, will be non-astronaut trained and will have been selected using criteria without overly restrictive physical or mental requirements.[2]

Assumptions are made for this study to simplify, clarify, and restrict variables. They included the following:

1. The great majority of Space Base personnel will be technical professionals, i.e., scientists and engineers, while a much smaller group will be technicians and semiskilled personnel. The technicians of the Space Base era will, however, be as capable as today's technical professional because of rapid advances in the state-of-technology and knowledge requirements.

2. Some in-orbit training and indoctrination will be required because some R&A technologists will participate for extended periods and new crew member indoctrination will be a recurring requirement.

3. R&A technologists and support operations personnel will participate in Space Base duty for varying (yet unspecified) lengths of time.

4. Nonroutine and around-the-clock activities and support operations will be accomplished within the Space Base when required. This will allow R&A technologists the flexibility to perform activities during "nonstandard" hours for various technical reasons. Support operations personnel, in addition to supporting nonroutine activities, will be required to

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[1] Ibid., p. 3-6.

[2] National Aeronautics and Space Administration, Guidelines and Constraints Document: Space Station Program (Phase B), March 20, 1970 (Manned Spacecraft Center, Tex.: NASA, 1970), p. 25.

operate and maintain the Space Base on an around-the-clock basis.

5. Personnel changes will be made within the Space Base as required to replace technologists because their work is complete, or to reassign them to higher priority work.

6. The Space Base will either be of a modular design as envisioned by the Space Task Group with major components sized to fit into the Space Shuttle cargo bay, or it will be a more centralized design placed in orbit by another vehicle--with the former being more likely.

7. In-orbit Space Base managers will be technically trained in either a scientific or engineering discipline and will be NASA employees. This assumption, therefore, restricts discussion of whether nontechnical personnel can manage technologists--especially within the Space Base.

8. Permanent party and transient technologists will comprise the Space Base crew at any point in its operational life. The permanent members will be NASA employees assigned to the program on a full time basis. The transient members would be international and domestic technologists usually involved in one time only R&A activities.

9. Crew members will be approximately divided between R&A and support operations. This ensures that adequate supporting personnel are available to assist those involved in accomplishing Space Base objectives.

Summary

This section has provided an introduction into the nature and scope of the present study. It was seen that this study was concerned with the identification of an in-orbit hypothetical organizational structure which would optimize the activities of a large, mixed crew of 50 to 100 technologists participating in futuristic Space Base activities. These technologists were identified as scientists, engineers, and some technicians performing R&A activities and support operations generally autonomous from earth.

Organization structure was defined as the established pattern or deliberate grouping of relationships among the components or parts of formal organizations to achieve specific goals. The study problem pinpointed was to identify an optimum structure at this point in time, based on what is known about the program and others like it. The need for the present study was justified for several reasons, the primary one being that information will be needed by NASA to ensure that an orderly, effective, and efficient Space Base program results.

The three-part methodology used was essentially an operational replication with modification of a previous study of Space Station organizational structural determination. Data collection and analysis consisted of (1) data research, (2) development of organizational structural criteria and a set of feasible models, and (3) evaluation of feasible models and selection of the optimum one. This methodology was not rigorous in its approach or design, since the nature of the subject does not lend itself readily to empirical testing. Finally, Space Base program requirements were abstracted from background and program objective information, and assumptions were made to further simplify,

II. REVIEW OF RESEARCH AND WRITINGS

This section provides insight into the volume and type of literature relevant to the subject or organizational structural determination for a Space Base. The review of research and writings discussed here represents the first part of the study methodology; data research.

An initial literature search was confined to published writings from NASA sources with the belief by the researcher that previous work had been conducted in the area of Space Base organizational structural analysis. After an extensive review of this literature, it became apparent that only limited research had been accomplished. With this knowledge, the inquiry was broadened to include general management literature relevant to organizational structure. What was revealed was a relatively large amount of information, such as organizational structural variables, structural forms and functions, professional organizations, and technical professionals.

The literature investigation was further expanded to include data for the analogous situations identified in Appendix C and briefly described in Appendix D. Although a number of analog research projects had been conducted requiring the use of organizational structures in analogous situations, none concerned themselves with structural analysis per se. The objective of this survey, then, became an eclectic review of these analogs, to identify the best of the appropriate data available relevant to the study subject.

A number of interviews and visits to applicable analogs and mockups were accomplished at various locations. The purpose of these activities was to determine if any studies useful to this research would be supportive of published literature. The findings revealed that only limited interest has been given to organizational structure as a separate study consideration.

Because of the variety of research and writings which are relevant to this study, this section was organized into four parts. The first deals with a survey of Space Base related studies, some of which had attention given to organizational structural considerations. The second identifies general and specific organizational structural variables which are important to structure selection for various organizations, including a Space Base. The third concerns the nature of professional organizations and technical professionals. Finally, the fourth section discusses data from applicable analogs which are relevant to Space Base organizational structural considerations.

A Survey of Space Base Related Studies

Concurrent with the President's Space Task Group activities, NASA initiated an in-house effort to develop a Space Station/Base Program Definition Statement of Work in early 1969. Contracts were to be awarded for in-depth eleven-month contractor studies.[1] Contained within the Space Base portion of the Statement of Work were guidelines for the program concept, crew considerations, and a number of possible centralized configurations.[2]

Of significance to the present study was the specific but limited guidance provided within the crew considerations section. Three general functions were envisioned for Space Base crew activities. First, an operations group would be charged with command and control of the entire Space Base system. Within their responsibilities would be system operation and status, resupply, safety of the entire crew, onboard procedures, coordination with group personnel, scheduling of activities and facility use, and information management. The capabilities and training of these personnel was envisioned as being similar to that required for a nuclear submarine.[3]

A second group, Space Base maintenance, would be responsible for maintenance repair of subsystems and experimental equipment when needed; performance and assembly and

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[1]National Aeronautics and Space Administration, Statement of Work: Space Station Program Definition (Phase B), April 14, 1969 (Washington, D. C.: Government Printing Office, 1969), p. 2-2.

[2]*Ibid.*, pp. A-2-A-18. [3]*Ibid.*, p. A-8.

modifications; accomplishment of housekeeping tasks; providing food service; unloading, storing, inventorying of cargo; and providing technical support to the experimentation program as required. Various engineers and technicians with specialized backgrounds would be needed to perform this function. A third group, experiment operations, would employ the latest techniques to conduct useful R&A activities. Special apparatus would be brought up with particular investigators. These technical professionals would not be encumbered with base operations or maintenance tasks, and would represent the majority of Space Base inhabitants at any one time.[1]

The McDonnell Douglas Astronautics Company, one of two study contractors, investigated programmatic and design considerations for the centralized Space Base. The approach used in the Space Base portion of the study was to review program objectives; requirements in terms of user and other mission support, and Space Base support personnel needs; and mission analysis. Two important assumptions were made to ensure that the return of results of R&A user personnel were maximized. First, R&A operations should be separated (in time) from support operations activities, with two shifts of work probably required to satisfactorily accomplish R&A activities. Second, the crew should work approximately fifty-six hours per week, with length of a given work day

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[1] *Ibid.*, pp. A-8-A-9.

varying with the experiment, operation, and individual capabilities and motivation.[1]

As a result of this analysis, it was determined that all Space Base crew members could be assigned to two organizational groups, namely, R&A User (and other mission support) Activities and Operations. A commander was included in the latter group. Based on this basic organizational composition, further analyses considered vehicle design requirements, operational considerations, and subsystem functional requirements.[2] No other analyses affecting Space Base organizational considerations were performed.

North American Rockwell Corporation, the other study contractor, took a slightly different approach to the Space Base segment of the Statement of Work, but ended up with similar conclusions. A centralized design was identified through a systematic approach that included establishing capabilities and requirements to satisfy mission objectives, selection of a preferred configuration including subsystems which satisfied identified requirements from various candidates, and a description of a growth sequence for the preferred configuration.[3]

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[1]National Aeronautics and Space Administration, Space Base Concept Data (Phase A Definition): Volume 1, June, 1970 (Huntington Beach, Calif.: McDonnell Douglas Astronautics Company, 1970), pp. 6-48.

[2]Ibid., pp. 53-71.

[3]National Aeronautics and Space Administration, Space Base Definition: Volume 1, July 24, 1970 (Downey, Calif.: North American Rockwell Corporation, 1970).

In establishing capabilities and requirements to satisfy mission objectives, a conclusion important to organizational structural considerations was reached. The contractor study team recommended that the three groups of personnel identified in the NASA Statement of Work be placed in two organizational elements. They were Space Operations and Scientific Investigation, and Vehicle Operations. The maintenance personnel were to be shared between these elements on an as-needed basis.[1]

In early 1970, von Tiesenhausen, of NASA's Marshall Space Flight Center, established a hypothetical, baseline social and functional organization for a fifty-man Space Base, and showed how the requirements and activities of the personnel affect Space Base layout.[2] The rationale used to design the organizational structure was that "no similarities (to the Space Base) have been found with either strictly military discipline-oriented crew operations or with civilian science administration-oriented situations." The author, therefore, concluded that a mix of military-type discipline and a free and scientifically-oriented organization should be used for a Space Base. Because of this conclusion, it was proposed that the total fifty-man population be divided into three groups: Base Command and Management, Base

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[1] Ibid., pp. 1-166-167.

[2] National Aeronautics and Space Administration, Fifty-Man Space Base Population Organization, by Georg von Tiesenhausen (Marshall Space Flight Center, Ala.: NASA, 1970).

Operations, and Scientific Faculty. Seven, eighteen, and twenty-five people were planned for each group, respectively.[1]

In another exploratory Space Base study published in 1970, Gundersen of NASA's Manned Spacecraft Center proposed a possible organizational structure, and then performed a crew skills assessment and discussed problems associated with facility design aspects. The methodology used to identify the suggested organizational structure was to consider general Space Base objectives, the activities and organizational structure of a nuclear submarine, and the staffing and physical configuration of off-shore drilling rigs.[2]

The Space Base organizational structure proposed was that of a military line organization similar to that of a nuclear submarine. Using a crew size of sixty-nine, the author suggested that there be two major functional groups as follows: the Operations Department and the Technical Projects Department--thirty-four and thirty-five people, respectively. A Space Base commander and his deputy, located at a higher hierarchical level than the Operations and Technical Projects functional managers, were considered

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[1] *Ibid.*, p. 3.

[2] National Aeronautics and Space Administration, *Earth-Orbiting Space Base Crew Skills Assessment*, by Robert T. Gundersen (Manned Spacecraft Center, Tex.: NASA, 1970).

as part of the Operations Department.[1]

After the line organization was proposed and functions identified and staffed; crew skills, weekly schedules, compartmentation, and distribution were determined. A few of the more significant conclusions important to the present study identified were that a line organization consisting of Operations and Technical Project Departments with a nominal crew size of sixty-nine should be adopted, and cross skills are important in crew selection.[2]

The most significant related study was concluded in May 1971 by the Grumman Aircraft Engineering Corporation. Its purpose was to identify an organizational structure which would effectively organize the resources of a twelve-man Space Station. Identification of factors in the Space Station work/living environment, which correlated with crew performance, allowed the selection of an organizational structure from various candidates which deliberately maintain crew performance at a high level.[3] The methodology used to select the optimum organizational structure in the Grumman study was used extensively in the present study, and is, therefore, described in more detail in subsequent chapters.

Basically, the study utilized an evaluation team of

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[1] *Ibid.*, pp. 11-14. [2] *Ibid.*, pp. 22-23.

[3] NASA, *Crew Operations Study of Command Structure*, pp. ii-iii.

five people to score how well six organizational models satisfied fifty-eight criteria. Scores were summed and the models were ranked. After analysis, a "line item" model was selected as the optimum Space Station model. Characteristic of the model was its subdivision of all Space Station operations into small manageable units (or line items). Each had an individual (task leader) formally assigned responsibility for task accomplishment, and coordination of team activities. These task leaders were viewed as a valuable link to the next higher organizational tier, but were considered part of the command team. Task activities were performed by technologists in life science and engineering team units.[1]

The final study was performed by Sells in 1966 to identify analogous situations to a hypothetical 500-day manned mission to Mars and return by a crew of six. The comparative methodology developed and used consisted of a subjective assessment by the author of the relative degree of similarity between eleven comparison social systems and the Mars mission social system under study. Each of eleven systems received similarity scores using a three-point scale, for fifty-six system characteristics under seven descriptive categories. These categories were: objectives and goals, value systems, personnel composition,

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[1] Ibid., pp. 10-12.

organization, technology, physical environment, and temporal characteristics.[1] The systems were then ranked by the sum of scores received. The highest scoring systems were considered most similar to the system under analysis. In terms of closeness of fit, Sells identified the following systems by descending order of similarity to the extended-duration Mars manned space ship:

1. Submarines
2. Exploration parties
3. Naval ships
4. Bomber crews
5. Remote duty stations
6. POW situations
7. Professional athletic teams
8. Mental hospital wards
9. Prison society
10. Industrial work groups
11. Shipwrecks and disasters

The methodology also provided a means of investigating similarity by descriptive categories on a percentage basis. This technique clearly indicated categorical areas of similarity (and dissimilarity) for the most similar systems.[2]

Variables Important for Organizational Structure Selection

General Considerations from Management Literature

The problem of selecting an organizational structure for any group of people who use coordinated activities,

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[1]S. B. Sells, "A Model for the Social System for the Multiman Extended Duration Space Ship," Aerospace Medicine, XXXVIII (November, 1966), 1105-135.

[2]*Ibid.*, p. 1135.

authority, and leadership to achieve goals is that important variables must be identified. This was no simple task since there was no totally acceptable set of variables identified in the literature, nor was there agreement as to how organizational structure determination was to be accomplished. Litterer acknowledges that there is no final organizational form universal for all organizations even though there are regular aspects and components for some.[1] Further, the problem of organizational selection was complicated by the need for a variety of structures appropriate to the various types of organizations which can exist.

Numerous writers have acknowledged that situation is important to organizational structural selection. Galbraith concludes that current organization theory research in the area of organization structure is directed toward ways to define situations that distinguish when alternate organizations forms are more or less effective.[2] Litterer feels that it is important that organizational structure be formed in response to conditions, rather than the way that it conforms to a universal ideal, and that there are a multitude of ways that structural components

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[1]Joseph A. Litterer, The Analysis of Organizations (New York: John Wiley & Sons, Inc., 1965), p. 330.

[2]Jay Galbraith, "Organizational Design: An Information Processing View," in Organizational Behavior and Design: Perspectives and Perceptions, ed. Victor F. Phillips, Jr. (Arlington, Va. Air Force Office of Scientific Research, 1969), p. 29.

can be arranged, depending on the particular situation that the organization faces.[1] With the importance of situation recognized, a search of relevant literature was accomplished to identify a set of variables sensitive to the Space Base environment.

Koontz and O'Donnell indicate that several fundamental inputs must be considered in the formulation of activity groupings and authority relationships. The input variables that these writers identify are objectives and plans, capability of personnel, environment, and authority.[2] The first variable is concerned with objectives and plans and is considered of key importance because all enterprise activities naturally arise from these. The goals that the organization hopes to achieve are identified by objectives and accomplished through plans. In addition, objectives serve as standards to measure organizational performance.

The second variable, that of capability of personnel, is significant because organizations must be manned by trained people. Activity grouping and authority provisions of an organization must take into account human capabilities, limitations, and customs. This consideration does not indicate that structure should be designed around individuals instead of around goals. However, frequently the capabilities

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[1]Litterer, p. 318.

[2]Harold Koontz and Cyril O'Donnell, Principles of Management (New York: McGraw-Hill Book Company, 1968), pp. 236-37.

of people are the constraining factor for the organization architect. Just as the strength and weakness of materials are considered by an engineer, so must the organization designer consider his material--people.

The third variable, environment, is synonymous with situation and conditions. Structure, like any plan, must reflect the environment in which organizational members are expected to accomplish work. The structure must permit contributions by members of the group and must help them gain objectives efficiently in a changing future. The workable organizational structure can never be simply mechanistic.

The fourth variable, authority, is essential to any organization because authority relationships must be acknowledged and used by management. Authority depends on such social institutions as private property, representative government, and the host of customs, codes, and laws that both restrict and sanction individuals in operating a business, a church, a university, or any group venture.

Specific Variables from the Grumman Study

The Grumman study of Space Station organization structure,[1] was found to be significant to the present study primarily because of the methodology used. Another reason

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[1]NASA, Crew Operations Study of Command Structure, p. 222.

important to this section was that the study identified and considered variables important for a hypothetical Space Station--an analog found in the analysis of Appendix C as having the highest ranking similarity to Space Base. From an analysis of many possibilities, the Grumman study team concluded that seven specific situational variables significantly affected the selection of organizational structure. These specific variables were identified as:

1. Multidisciplinary scientific operations
2. Crew size
3. Space Station with users on board
4. Mission duration
5. Duty cycle
6. Arrangement of space
7. Space Station autonomy[1]

Since these specific variables are important to the present study, they are discussed in some detail. "Multidisciplinary scientific operations" were a requirement of the Space Station program, and the Grumman study team recognized that heterogeneous mixes of crew personnel and activities would present a more demanding situation than would homogeneous ones. "Crew size" was considered important because increased crew size affects the number of authority tiers in the structural hierarchy. In addition, size provides the potential for the formation of numbers of subgroups. As groups become large (greater than twenty members), more limited opportunity for personal contact and more formal organization is required.

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[1] Ibid., pp. 3-5.

The "Space Station with users on board" variable considered that a crew consisting of various technologists poses a different situation than one where the entire crew will be composed of trained astronauts. It was felt that with users on board, greater benefits would accrue if training were devoted to R&A activities and the interface of these activities with the Space Station. The alternative was to try achieving marginal efficiency by requiring users involvement in operations.

The "mission duration" variable was emphasized because, in spite of exceptionally high motivation levels anticipated in crew members, the planned three to six month Space Station mission duration in a fairly confined area was expected to cause deterioration of performance. The relatively high cost of transportation of crewmen justified placing a premium on the most effective performance possible. The "duty cycle" variable was included in the list by the Grumman study team because around-the-clock manned operations required an organizational structure which would accommodate multiple shift crews. In addition, it was believed that the extent of automation of physical systems played a significant role in duty assignments.

"Arrangement of space" as a variable accommodated the fact that crew unity and performance are affected by the physical configuration of working and living areas. The segregation or integration of crew member activity affects environmental stresses if not properly considered. "Space Station autonomy" was felt to be important because the extent to which the organization is autonomous from ground command and control strongly affects structure. Day-to-day decision making on board requires a structure which was independent and relatively self-sufficient.

Variables Used for the Present Study

Since this chapter is concerned in part with organizational structural considerations from management concepts and practices and applicable analogs, it is necessary to introduce the structural variables which are used in the present study at this point. Without this identification it would be virtually impossible to classify the multitude of data which are available. Table 1 represents a composite of general and specific variables of organizational structure which have been discussed, and two specific variables which have not been yet. This classification scheme was used throughout the remainder of the present study.

The general variables of Table 1 are of course the Koontz and O'Donnell variables discussed earlier.[1] The specific variables are closely related to those identified and used in the Grumman study. The correlation between

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[1]Koontz and O'Donnell, pp. 236-37.

the seven factors used by Grumman[1] and the nine used in the present study is shown in Table 2.

TABLE 1

ORGANIZATIONAL STRUCTURAL VARIABLES
USED FOR THE PRESENT STUDY

<u>Objectives and Plans</u>

Multidisciplinary R&A Activities
Crew Size

<u>Capability of Personnel</u>

Crew Composition
Crew Selection and Training

<u>Environment</u>

Mission Duration
Environmental Factors
Autonomy of Operations

<u>Authority</u>

Authority and Responsibility
Communications, Coordination, and Integration

In most cases, as Table 2 shows, the specific variable titles are either identical or have been modified only slightly. The "multidisciplinary R&A activities" variable is identical to "multidisciplinary scientific operations." The former, however, better describes the mission of Space Base. The "crew composition" and "crew selection and training" variables are merely an expansion

[1]NASA, <u>Crew Operations Study of Command Structure</u>, pp. 3-6.

of "Space Station with users on board." The Grumman "duty cycle" heading was deleted for Space Base consideration because it is not felt by the writer to be an important specific structural variable. Certain aspects of this variable, however, such as multishift and nonroutine work, are considered in subsequent analysis.

TABLE 2

CORRELATION BETWEEN SPACE BASE AND SPACE STATION ORGANIZATIONAL STRUCTURAL VARIABLES

Space Base	Space Station
<u>Objectives and Plans</u>	
Multidisciplinary R&A Activities	Multidisciplinary Scientific Operations
Crew Size	Crew Size
<u>Capability of Personnel</u>	
Crew Composition	Space Station with Users on Board
Crew Selection and Training	
<u>Environment</u>	
Mission Duration	Mission Duration
Environmental Factors	Duty Cycle
Autonomy of Operations	The Arrangement of Space
	Space Station Autonomy
<u>Authority</u>	
Authority and Responsibility	
Communications, Coordination, and Integration	

The "environmental factors" variable directly relates to the "arrangement of space" category identified in the Grumman study. The reason for the change in heading was that less emphasis was placed on the physical arrangement of space and equipment for the present study, and more on the "environmental factors" themselves. Finally, "autonomy of operations" was more appropriate to Space Base than was the "Space Station autonomy" heading for obvious reasons.

The Space Base authority subcategories of "authority and responsibility" and "communications, coordination, and integration" were added for several reasons. The first was that authority and responsibility relationships are of significant importance to the present study, as will be seen later. Second, these relationships are an essential part of the definition of organizational structure used as the basis of the study. The processes of "communications, coordination, and integration" are felt to be essential to any analysis of Space Base structure, and especially for the modern organizational structures which are discussed later.

Professional Organizations and Technical Professionals

The previous section of this study discussed variables important for organizational structure selection. No specific references were made to professional organizations or to those professionals who are essential to their success. For that reason, discussion in this section concerns these organizations and people in relation to a study elemental question introduced in section I, namely, what type of organizational structure best serves the needs of technical professionals? Topics are, therefore, restricted to the following: (1) professional organizations, (2) the characteristics of technical professionals, and (3) technical professionals and the organization.

Professional Organizations

Professional organizations, as described by Etzioni, are those where knowledge is produced, applied, preserved, or communicated. Included in this category are research organizations, universities, colleges, other schools, large general hospitals, and therapeutic mental hospitals.[1] For the purposes of this study, discussion was limited to research (and development) organizations. The rationale for this restriction is due primarily to the analog analysis contained in Appendix C which showed that various earthbound R&D labs were found to be an appropriate analog for Space Base, while mental hospital wards were not. Universities, colleges, other schools, and large general hospitals were not considered in the Appendix C analysis because they lacked sufficient

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[1]Etzioni, pp. 77-78.

environmental similarity to Space Base, and were, therefore, excluded for the purpose of this study.

Characteristics

According to Etzioni, professional organizations are characterized by their goals, certain situational factors, authority relationships, and the high proportion of professionals employed (at least fifty percent).[1] In addition to the variables Etzioni identified, structure was also considered.

Goals

The goals of R&D organizations may be many and varied, but the National Science Foundation reports that generally these goals are concerned with research--investigation or inquiry which is either of the basic or applied variety, and development--the systematic use of scientific knowledge directed toward the production of useful materials, devices, systems, or methods including design and origination of prototypes and processes.[2]

Situational factors

According to Etzioni, several situational factors describe the parameters of professional organizations.

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[1] *Ibid.*, pp. 77-78 and pp. 91-93.

[2] National Science Foundation, *Reviews of Data on Research and Development*, Report NSF 62-9 (Washington, D. C.: Government Printing Office, 1962), p. 8.

They are externalization and internalization, single and multiple professions, and private and public organizations. The first factor relates to the division between internal and external professionals and administrative activities. Etzioni states that ideal professional organizations are identified by internalized professional functions and externalized administrative functions. The example given was that of schools which have few administrative problems because of their narrow scope and reliance on many others to administer to the nonprofessional needs of clients. The second factor concerns the administrative responsibility to serve as an arbitrator among different professional groups. And finally, the third factor relates to how the professional organizations are owned and financed, and who pays the professionals.[1] Using Etzioni's framework, the Space Base organization would be considered to be an internalized, multiprofession, public professional organization.

Johnson, et al. conclude that professional organizations frequently have conflicting situational requirements. They must provide for nonuniform events and innovation and, at the same time, must utilize the traditional bureaucratic mechanisms for routine activities.[2] Classical models are not usually adequate to satisfy these

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[1]Etzioni, pp. 91-93. [2]Johnson, et al., p. 61.

requirements. Research by Delbecq indicates that the bureaucratic organization model is not an appropriate solution strategy for creative decisions, even though it is for programmed or computational decisions.[1]

Authority relationships

Etzioni indicates that authority relationships between professionals and nonprofessionals in professional organizations are such that professionals usually have superior authority over the major objectives of the organization. In addition, it is pointed out that with these types of organizations, there are differences in authority relationships when contrasted with classical beliefs. In the bureaucratic organizational model, according to Etzioni, the line serves as the structure of authority having a single center of authority for decision making and control. Conversely, in professional organizations there is no line in this sense, and authority is usually shared between professionals and administrators. As an example of this sharing, Etzioni identifies "service organizations" in which instruments, facilities, and an auxiliary staff are provided to professionals to accomplish their work. These professionals usually are not subordinated to administrators nor are they necessarily employed by the organization.[2]

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[1]André L. Delbecq, "Managerial Leadership Styles in Problem-Solving Conferences," in Academy of Management Journal, VII (December, 1964), 225-68.

[2]Etzioni, pp. 77-86.

Etzioni further clarifies authority and structural relationships by identifying three areas of activity in professional organizations:

1. Major objective activities carried out by professionals almost completely under the authority of the professionals who perform the activities or direct the semiprofessionals (technicians) and nonprofessionals who perform it.

2. Secondary activities performed by administrators and nonprofessional personnel under their control.

3. Secondary activities performed by professionals such as allocating resources, preparing statistics, and participating in public relations activities.[1]

There is no established hierarchy in the first category, and much individual autonomy. Johnson, et al. report that control for this group is exerted through professional norms and colleague interactions rather than structure.[2] A hierarchy does exist in the second category, but it does not involve professionals. The third category has a clear hierarchy and administrative predominance.

It is in this last category that misunderstanding of the nature of professional organizations exists because it appears that professionals are part of the administrative line structure. In reality, only secondary functions are performed, unlike the first category where major activities occur and professional authority and autonomy exist.[3] From

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[1] Ibid., pp. 86-87. [2] Johnson, et al., p. 61.

[3] Etzioni, p. 87.

these considerations it is easy to understand why in many professional organizations, major conflicts can exist between professional knowledge, individual autonomy, and administrative authority.

In summary, Etzioni indicates that one way to solve the dilemma of combining professional and administrative authority is by dividing responsibilities. This is accomplished by allowing professionals to control goal activities while administrators control the means to accomplish those goals. The whole structure is then supervised by talented middlemen who possess greater administrative skills and authority than the average professional, and more professional authority and competence than the average administrator. These supervisory talents are obtained by professionally-oriented administrative training and experience.[1]

Structure

Many observers of modern society, and specifically Bennis, have noted that the accelerated growth of science, R&D activities, and intellectual technology have caused a need for change in organization and structures. Bennis believes that a need exists to develop adaptive, temporary systems of diverse specialists, solving problems, linked together by coordinating and task evaluative specialists,

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[1] Ibid.

in organic flux. For lack of a better phrase, he calls these "organic-adaptive" structures.[1]

Bennis, like Miles[2] and Toffler,[3] feels that the key word in these types of structure is "temporary." The need for adaptive, rapidly changing temporary systems requires organization around problems to be solved by groups of relative strangers who may represent diverse professional skills. This need will create organic rather than mechanistic (bureaucratic) models. Kast and Rosenzweig also observe that there has been a movement away from rigid bureaucratic form toward more dynamic, flexible structures. They conclude that the permanent, structured positions of mechanistic systems are being replaced by an adaptive-organic system with less structuring, more frequent change of positions and roles, and more dynamic interplay among various functions.[4]

Dale describes the organic method of structuring organization as being a system under which jobs are very loosely defined to produce a flexible organization in which

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[1]Warren G. Bennis, "The Decline of Bureaucracy and Organizations of the Future," in Changing Organizations: Essays on the Development and Evolution of Human Organization, ed. by Warren G. Bennis (New York: McGraw-Hill Book Company, 1966), pp. 9-12.

[2]M. B. Miles, "On Temporary Systems," in Innovation in Education, ed. by M. B. Miles (New York: Bureau of Publication, Columbia University, 1964), pp. 437-90.

[3]Alvin Toffler, Future Shock (New York: Random House, Inc., 1970).

[4]Kast and Rosenzweig, p. 205.

each person performs tasks which he does best. He notes that it is occasionally suggested that the organization becomes "autonomous" in that the members themselves divide the work up according to ability.[1] Shepard sees organic-adaptive structures allowing for shifts to cooperative group effort rather than that of individuals, to shared responsibility from that which is delegated, to confidence from obedience, and to problem solving rather than antagonistic arbitration.[2]

The shift in organizational structure is obviously from the mechanistic or bureaucratic structures developed by the classicists to more modern flexible, even temporary, organic-adaptive structures. Kast and Rosenzweig caution, however, that these modern structural arrangements may not be ideal for all types of organizations since they represent polar points on a continuum. They indicate that for some elements of an organization, such as R&D, organic structures would be best; while for others, like production, mechanistic structures are better.[3] Table 3 contrasts the differences, identified by Hower and Lorsch, in organizational characteristics between organic and mechanistic

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[1]Ernest Dale, Planning and Developing the Company Organization Structure, Research Report No. 20 (New York: American Management Association, 1950), p. 137.

[2]Herbert A. Shepard, "Changing Interpersonal and Intergroup Relationships in Organizations," in Handbook of Organization, ed. by James G. March (Chicago, Ill.: Rand McNally and Company, 1965), pp. 1115-143.

[3]Kast and Rosenzweig, p. 206.

organizational structures.[1]

TABLE 3

ORGANIZATIONAL CHARACTERISTICS OF ORGANIC AND MECHANISTIC STRUCTURES

Organizational Characteristics Index	Types of Organization Structure	
	Organic	Mechanistic
Span of control	Wide	Narrow
Number of levels of authority	Few	Many
Ratio of administrative to production personnel	High	Low
Range of time span over which an employee can commit resources	Long	Short
Degree of centralization in decision making	Low	High
Proportion of persons in one unit having opportunity to interact with persons in other units	High	Low
Quantity of formal rules	Low	High
Specificity of job goals	Low	High
Specificity of required activities	Low	High
Content of communications	Advice and information	Instructions and decisions
Range of compensation	Narrow	Wide
Range of skill levels	Narrow	Wide
Knowledge-based authority	High	Low
Position-based authority	Low	High

In recent years, there have been several organizational designs which reflect the new organic-adaptive

[1]Ralph M. Hower and Jay W. Lorsch, "Organizational Inputs," in Systems Analysis in Organizational Behavior, ed. by John A. Seiler (Homewood, Ill.: Richard D. Irwin, Inc., and The Dorsey Press, 1967), p. 168.

approach to modern organization theory. The most significant one is project management.

Project management

Baumgartner, in tracing the developing of project management, indicates that this concept was developed in the early 1950's when the Air Force and large segments of industry were faced with the problem of developing an ICBM system in half the time usually required. He relates that the solution was found in "projectizing"--organizing and managing the effort primarily on the basis of technical, cost, and schedule objectives, rather than on the basis of existing structures and procedures. The success of the concept led to wide spread application in industry and the government.[1]

Kast and Rosenzweig believe that the project management approach is one of the most important developments in the structure of organizations. They indicate that the approach was geared to the changing managerial requirements in R&D, procurement, and the utilization of large-scale military, space, and civilian projects. The pressure of accelerated technology and short lead times in these areas made it essential to establish a structure and system which would provide for the overall integration of many diverse

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[1]John Baumgartner, "Project Management," in Handbook of Business Administration, ed. by H. B. Maynard (New York: McGraw-Hill Book Company, 1967), p. 5-70.

functional activities. These requirements made it necessary for organizational structure to be dynamic rather than static with emphasis placed on flexibility rather than permanent relationships.[1]

The need for integration in organic-adaptive, project management organizations is closely related to systems theory as well since this approach requires that the parts or subsystems be brought together to accomplish the objectives established. Both applications are consistent with the definition of Lawrence and Lorsch who indicate that integration is the process of achieving unity of effort among the various subsystems in the accomplishment of the organization's task.[2]

According to Kast and Rosenzweig, approaches to project management can be placed on a continuum. They believe that on one end is the "staff" form where a project manager with little authority serves in an advisory capacity to the chief executive. On the other end, the project manager has complete authority over all activities of the project or program. This latter approach is commonly used for major space program and military activities. Between these extremes is an approach more commonly known as

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[1] Kast and Rosenzweig, pp. 194-98.

[2] Paul R. Lawrence and Jay W. Lorsch, "Differentiation and Integration in Complex Organizations," in Administrative Science Quarterly, June, 1967, p. 4.

matrix project management.[1]

Figure 1 illustrates a typical model of a matrix project management organizational structure.[2] As is shown, the project manager reports directly to the president or general manager on a line basis, but he has personnel assigned to his project from the various functional areas. The functional managers serving in a line capacity such as engineering, manufacturing, and marketing are responsible to a general manager only for their specialized activities. Two flows of authority and responsibility thus exist under the matrix project management form. The first is the vertical flow of functional manager authority and responsibility. The second is the horizontal flow of project manager authority and responsibility which crosses the vertical superior-subordinate relationships which exist within the functional organization.

The functions of a project manager are varied, but the main ones are organizing and controlling all necessary activities to achieve project goals. Since his activities are superimposed upon the functional organization, new and complex relationships are created requiring integration of activities, and the development of effective

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[1]Kast and Rosenzweig, pp. 195-96.

[2]David I. Cleland and William R. King, Systems Analysis and Project Management (New York: McGraw-Hill Book Company, 1968), p. 177.

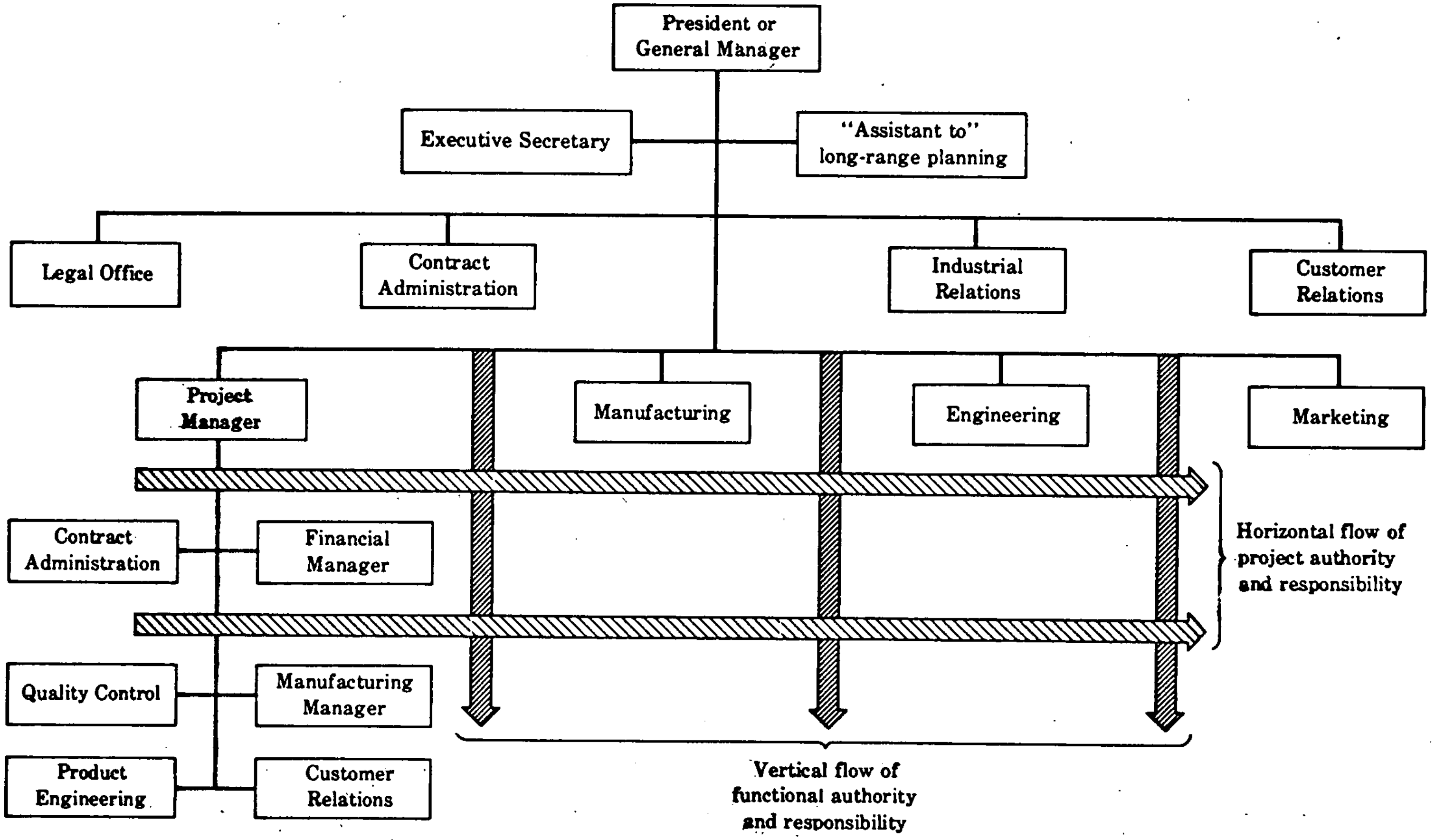

Fig. 1.--A matrix project management organizational structure.

information networks.[1] According to Cleland, the project manager must concentrate his attention on the major problems of the project and serve as a focal point. This concentration is significant because it places the responsibility for resolution of problems on an individual who has the proper perspective to integrate the important matters of cost, time, technology, and project compatibility in total.[2]

While project management strives to eliminate many of the problems of older structural arrangements, it is not without problems of its own. Kast and Rosenzweig report two problems. The first is that project activities are finite, since projects have an anticipated end. Once complete, reassignments of personnel must be made so that new activities can be accomplished. The inherent temporary nature of this type of structure requires people to learn that change is inevitable. Second, since project management is interfunctional, conflicts are created within the normal or functional organizational structure. These conflicts result because project management does not operate in a classical manner with a well defined hierarchical structure, unity of command, or clear-cut

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[1] Kast and Rosenzweig, p. 195.

[2] David I. Cleland, "Why Project Management?", in Business Horizons, Winter, 1964, p. 83.

authority and responsibility relationships.[1] While these problems have not precluded the widespread use of matrix management, they have caused concern for some and have required that people adjust to this split authority situations and to expect a changing organizational environment.

The Characteristics of Technical Professionals

Dominant characteristics

Identification of highly consistent characteristics of productive scientists has emerged from the research of Roe, Barron, Sanders, Knapp, Cattell, and others. The methodologies employed by these researchers were highly varied and included clinical interviews, projective techniques, empirically developed biographical inventories, and factor-based tests.[2] The following are the traits of productive scientists found in study after study:

1. A high degree of autonomy, self-sufficiency, and self-direction.

2. A preference for mental manipulations involving things rather than people: a somewhat distant or detached attitude in interpersonal relations, and a preference for intellectually challenging situations rather than socially challenging ones.

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[1] Kast and Rosenzweig, pp. 197-98.

[2] "Reflections of the Conference Participants and the Editors," in Scientific Creativity: Its Recognition and Development, ed. by Calvin W. Taylor and Frank Barron (New York: John Wiley & Sons, Inc., 1963), pp. 385-86.

3. High ego strength and emotional stability.

4. A liking for method, precision, and exactness.

5. A preference for such defense mechanisms as repression and isolation in dealing with affect and instinctual energies.

6. A high degree of personal dominance but a dislike of personality-toned controversy.

7. A high degree of control of impulse, amounting almost to over control: relatively little talkativeness, gregariousness, and impulsiveness.

8. A liking for abstract thinking, with considerable tolerance of cognitive ambiguity.

9. Marked independence of judgment, rejection of group pressures toward conformity in thinking.

10. Superior general intelligence.

11. An early, very broad interest in intellectual activities.

12. A drive toward comprehensiveness and elegance in explanation.

13. A special interest in the kind of "wagering" which involves pitting oneself against uncertain circumstances in which one's own effort can be the deciding factor.[1]

Beveridge believes that the two attributes which best describe the research worker are a love of science and an insatiable curiosity.[2] These attributes allow the researcher to comply with the general essence of research which requires that a clear object be in view, while at the same time maintaining an alertness for unexpected

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[1] Ibid.

[2] William B. Beveridge, The Art of Scientific Investigation (New York: Random House, Inc., 1950), p. 186.

opportunities. Blood summarizes by indicating that several personality characteristics have been identified for creative people in all fields. First and foremost, they are dedicated to their work. They possess a strong commitment to their goals and are highly self-confident in pursuing their objectives. Second, they tend to be independent and nonconformist, at least intellectually. They generally seek their own goals and pursue them in their own way. These people, in sum, are intensively dedicated and self-reliant individuals.[1]

A detrimental characteristic

An undesirable characteristic, frequently identified in the literature as being associated with creative technical professionals, was their inability to communicate. Technical professionals, according to Sanders, have an average or perhaps below average ability to communicate in all areas except their own technical speciality. The special terminology, technical dialects, and abbreviated references often confuse technical specialists who enter other technical fields. Precise terminology which promotes communications within similar specialities leads to gross inefficiency or near chaos with other groups, especially

[1]Jerome W. Blood, ed., Optimum Use of Engineering Talent (New York: American Management Association, 1961), p. 168.

nontechnical people.[1] Technical people cannot rephrase words so others can understand, as those in other professions can.[2]

Technical Professionals and the Organization

Potentials for conflict

Management literature indicates that many reasons exist for conflicts between individuals and organizations. Technical professionals, because of their characteristics (favorable and unfavorable) and motivation, compound the problem. A number of writers identify the following as the most significant potentials for conflict:

1. The language barrier
2. The decision-making credibility gap
3. The recognition paradox
4. The need for management controls
5. The loyalty of professionals

The language barrier

This first potential for conflict is integrally related to the detrimental characteristic previously described. The problem is essentially created by new technical languages developed because of specialization. The result is a communications barrier between technical

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[1]Royden C. Sanders, Jr. "Interface Problems Between Scientists and Others in Technically Oriented Companies," in The Management of Scientists, ed. by Karl Hill (Boston: Beacon Press, 1964), p. 80.

[2]Val Cronstedt, Engineering Management Administration (New York: McGraw-Hill Book Company, Inc., 1961), p. 4.

professionals and management. Cronstedt summarizes the problem by recognizing that higher level management is often embarrassed when it realizes that it is not fully equipped to understand the language of its technical professionals. The resulting sense of inferiority which develops brings on defense mechanisms, which naturally creates a certain enjoyment for the professionals as they watch their superiors squirm.[1]

This problem can lead to a lasting barrier between these groups. Undoubtedly, many instances have occurred in which a breakdown in communication has resulted in mutual distrust. Levin and Kirkpatrick describe what is perhaps a typical but undesirable situation created when a scientist is unable to communicate an innovative idea to management. Since management generally has better communications with consultants, the most likely situation is that it will turn to established consulting firms to get done the research recommended by the scientist.[2] Going outside the firm does little to develop mutual trust and breaks down the language barrier.

Communication, then, is a major management problem in professional organizations, because lack of it creates

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[1]Cronstedt, p. 5.

[2]Richard I. Levin and C. A. Kirkpatrick, Quantitative Approaches to Management (New York: McGraw-Hill Book Company, 1965), p. 9.

barriers at interfaces between groups. The barriers created usually produce more inefficiency, wasted effort, and embarrassment than any other organizational failure.[1] It appears that the seriousness of the communication problems is directly related to organization size.

The decision-making credibility gap

The second problem is related to the language barrier described above, because technical professionals frequently feel that management does not understand their difficulties. This leads to deeper seated problems and accusations that company management is making decisions which conflict with technical facts. Conversely, management often feels that its decisions are probably not understood because of the inept method with which the technical mind usually meets a management or business situation.[2]

According to Overton, if a professional organization is to be viewed as a system which depends on a decision-making flow from producing technical professionals to higher levels of management and vice versa, then it must be realized that this interface action is of paramount importance.[3] Without credibility between these diverse groups, conflict and distrust can be the only result.

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[1]Sanders, p. 80. [2]Cronstedt, p. 5.

[3]Lewis M. Overton, Jr., "R&D Management: Turning Scientists into Managers," Personnel, XLVI (May-June, 1969), 56-57.

The recognition paradox

The recognition paradox results because, in seeking isolation from supervision, technical professionals build up a barrier which prevents personal and professional recognition by management.[1] Even though technical professionals seek recognition from colleagues and external profession sources, the recognition of supervisors has been found to be important.

In a study of a major R&D laboratory, it was found that the technical professional relied principally on the supervisors rather than the organization to provide needed recognition. Those involved stressed that they wanted more feedback that included not only appropriate recognition, but also suggestions for talent enlargement. Little faith was placed on so-called "dual ladders of advancement" and other "gimmicks" designed to provide opportunity for financial and organizational advancement.[2] Approval and recognition of professionals by the scientific community is often a critical motivational factor, but "official" recognition from a professional's supervisor is also important.[3] While this need for recognition is not unique to technical professionals, it is an important conflict consideration.

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[1] *Ibid.*, p. 59. [2] *Ibid.*, p. 60.

[3] Blood, p. 176.

The need for management controls

The underlying source of this difficulty is that technical professionals have personal motivations and goals that make it very difficult for them to understand and accept management controls. Conversely, management controls become necessary to integrate complicated projects or programs to keep each part in phase with the other parts.[1] This is especially true as the professional organization gets larger or becomes multidisciplined. Care must be taken, however, since control inevitably means that administration procedures become formalized with red tape and bureaucracy creeping in, and this is the danger to creativity. Sanders indicates that the line has been drawn. Technical professionals need freedom to be creative, and management needs controls for continuity of action and results.[2] The problem becomes one of scientists and engineers defending their role as professionals against the need to conform to supervision and control.

Obviously a balance is needed to ensure that the personal goals of technical professionals and the goals of the organization are satisfied. Kaplan feels that the needs of each seem to be incompatible, but that since each group needs the other, some reconciliation must be found.[3]

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[1]Sanders, pp. 87-88. [2]*Ibid*., p. 103.

[3]Norman Kaplan, "Organization: Will It Choke or Promote the Growth of Science," in *The Management of Scientists*, ed. by Karl Hill (Boston: Beacon Press, 1964), pp. 103-04.

Without the organization, its management, and its supporting function, R&D to any significant extent would not be possible. Likewise, without creative technical professionals, professional organizations would serve no useful purpose.

The loyalty of professionals

The last problem relates to the loyalty that scientists have for their profession, rather than their organization. Their training and the professional ethics they practice provide ties which management frequently does not understand. Often conflicts result when short range organizational goals are not compatible with the methods or professional ethics of scientists and engineers.

Determinants for organizational success

It is said that when Diogenes, the philosopher, was asked by Alexander the Great if there was anything he could do to help him, that Diogenes replied, "Only stand out of my light."[1] It is easy to get the impression that technologists feel the same way about organizations.[2]

A review of pertinent literature indicates that there are a multitude of factors which are important to the success of professional organizational activity. Four

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[1]Quoted in the Annual Report (New York: Carnegie Corporation, 1962), p. 9.

[2]Kaplan, p. 103.

significant factors are selected because of the frequency with which they appear. They are (1) that an organizational environment which stimulates creativity is essential, (2) that flexible organizational policies must exist, (3) that managers are trained technical professionals, and (4) that staff functions are mandatory within the organization to support R&D. Although each of these factors is related, they are treated separately.

Organizational environment

It should be obvious that an environment for creativity, the first factor mentioned, is absolutely essential to any professional organization. Blood indicates that creativity depends on an organizational environment which provides an opportunity for recognition and investigation of pertinent problem areas, and reinforcement to encourage and sustain the creative effort.[1] The organizational climate needed must provide for some isolation and nonconformity.

Rudsepp reiterates this requirement by indicating that

> When ready to think creatively, the creative scientist or engineer will, if possible, isolate himself from the encumbrances of his environment in order to put himself in a receptive, leisurely mood. This enables him to freely entertain thought and ideas

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[1]Blood, p. 170.

> that are directly or even remotely and tenuously connected with the problem he is tackling.[1]

This psychological distance from associates and the working environment has proved successful in the past, and for that reason, is desired. Allowance for these considerations, according to Siepert, is the direct responsibility of management, and is accomplished by various administrative actions which bear on the environment rather than on the man himself.[2]

Flexible policies

The second important factor necessary for R&D success, closely related to the first, is that of flexible organizational policies. Raudsepp writes that the best climate for research cannot be one in which undue pressure for organizational conformity exists. This conformity tends to inhibit creative thinking and any originality by making the individual uncomfortable.[3] With regard to the reaction of technical professionals to management actions, Siepert points out that these people have the following relevant attributes: curiosity, self-reliance, extreme capacity for concentration, reluctance to conform to any

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[1] Eugene Raudsepp, Managing Creative Scientists and Engineers (New York: The Macmillan Company, 1964), pp. 39-40.

[2] Albert F. Siepert, "Creating the Management Climate for Effective Research in Government Laboratories," in Hill, p. 89.

[3] Raudsepp, p. 108.

constituted authority, and determination to operate with shared rather than delegated authority.[1]

To accommodate these attributes, Raudsepp states that organizations must relax their systems of controls, procedures, and operations to ensure that organizational forces for conformity are reduced. Organizational policy must be flexible enough to provide the individuals more freedom and autonomy while maintaining necessary organizational goals.[2] While this balance may be difficult to maintain at times, it should be a goal sought by the professional organization.

Trained technical managers

The responsibilities of managers of technical professionals involved in R&D are identified by the literature of various writers as

1. Providing an interface
2. Providing management control
3. Ensuring results

Managers traditionally serve as an interface between upper management and employees. Blood feels that managers play an extremely important role in organizations, but even more so when they supervise professional activities. It is only through these men that upper management can approach and deal with creative technical professionals[3] and vice

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[1]Siepert, p. 88. [2]Raudsepp, p. 110.

[3]Blood, p. 176.

versa. Since the manager serves in an interface capacity, effective communication is the primary means of implementing this function. As a communicator representing upper management, the manager's job is to penetrate language barriers, to span decision-making credibility gaps, and frequently to interpret management directives and policies for those who work for them.

A second function the manager serves is to provide effective control. It is through this single individual, working in both technical and interpersonal areas, that program objectives can be satisfied and organization control can be maintained.[1] Control in an R&D environment is a somewhat different challenge because of the individuals involved. Managers must consider the often extreme variations in abilities, personalities, and interests of their people.[2] The direction as well as control of the individuals becomes a delicate and personal thing, and only after a certain time passes can the manager determine if a loose or relatively tight rein should be maintained.[3]

The manager's third responsibility is to ensure that all results are achieved. Without some output, even basic research is worthless to an organization. These results may be in the form of failures because, strangely enough, failures in R&D organizations have their merit.

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[1]Overton, p. 56. [2]Blood, p. 177.

[3]Siepert, p. 88.

Bradley believes that the requirement for results is that the intelligent, communicating manager establish goals so that resources can be effectively committed. Priority among "right things" both in timing and commitment must be weighed against achievable results.[1] The establishment of what are the "right things" is the difficult part of ensuring results. This necessitates that the manager distinguish good creative approaches from conventional or poor ones,[2] so that unproductive projects be stopped. It also requires that resources be allocated in proper proportions. The ability to ensure that results are achieved is the challenge to management.

Etzioni believes that strain is created in professional organizations by nontechnical administrators. The dysfunctional situation created is that the hierarchy of lay authority is in inverse relation to the hierarchy of goals and means of technical professionals. The result frequently is the subversion of goals. He goes on to say that the manager maintains a strategic position doing much to neutralize conflicting pressures and mobilizes those factors which support primary goals.[3]

By choosing a manager from the ranks, many organizational problems are eliminated. Overton indicates that

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[1] W. E. Bradley, "The Job of the Modern Research Manager," in Research Management, XI (May, 1968), 167-75.

[2] Kaplan, p. 79.

[3] Etzioni, pp. 84-85.

the managers who possess technical knowledge and are able to make decisions regarding the group's work are acceptable to the group.[1] Siepert states that there is no substitute for having managers who have contributed in the past and who have developed a reputation with their peers.[2] These managers are expected by upper management and the people who work for them to be perceptive, quick to pick up new ideas, and always alert to developments in technology. However, even though certain technical proficiency norms are expected of them, it is necessary that they be competent in administrative skills as well.

The ideal manager of technical professionals is not easy to find for several obvious reasons. They must be technically capable, must possess some administrative ability or a capacity to develop it, and must understand human nature. Sanders identifies specific qualities sought in these managers (and technical professionals as well) as being

1. Technical and administrative ability and judgment
2. Scientific and personal integrity
3. Balanced skepticism
4. Persistence
5. Courage of convictions [3]

Trained technical managers are difficult to find but are needed to serve as an interface, provide management control, and ensure results. They do much to eliminate

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[1]Overton, p. 61. [2]Kaplan, p. 91.

[3]Sanders, p. 82.

language/communication problems when accepted by the group and provide necessary reinforcement.

Staff support

The last necessary factor is that of staff support. It should be realized that in any particular organization, the R&D function can be either a line or staff function depending on what the product or service of the organization is. When R&D is a line function (as it will be with the Space Base), a supporting staff is needed to ensure productive output from technical professionals.

Cronstedt elaborates on the need for supporting staffs by indicating that technical professionals are spenders who need others to find funds and programs so they can continue their work, designers and draftsmen to provide their services, and shops to build prototypes. The structure of the professional organization then can be envisioned as being similar to a classical military line and staff organization. He indicates that soldiers fight the battles as a line function, and an administrative group serving as a staff provides these people with everything they need to perform their tasks.[1]

Supporting staffs usually consist of technicians who reduce the diversion of professional talents to non-professional activities. These trained and valuable

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[1]Cronstedt, pp. 26-27.

individuals do much to relieve technical professionals of the tasks which do not require their special abilities. There are many necessary steps in the performance of R&D activities which are essentially routine and require a relatively low order of skill, and can be performed by high school graduates with a science major, or those who have had a year or two of junior college.

Relevant Data from Applicable Analogs

An elemental question important to this study was how appropriate to Space Base are the multitude of social systems and environmental situations involving isolation, confinement, and situational danger, and what can be learned from the most applicable analogs with regard to Space Base organizational structure selection? To answer the first part of this question, a methodology developed by Sells was used to determine which social systems are applicable analogs to Space Base.

Appendix C contains the analyses and rationale for the determination of appropriate Space Base analogs used in this study. Those analogs found to be most similar, by descending order follow:

1. NASA Space Station
2. Various oceanographic research ships
3. National Science Foundation (NSF)/Navy United States Antarctic Research station
4. Various earthbound R&D laboratories
5. Grumman Ben Franklin research submarine
6. Navy/Dept. of Interior/NASA/General Electric Tektite II laboratory

7. NASA/McDonnell Douglas Ninety-Day Space Station simulation
8. Nuclear submarines
9. Navy Sealab II
10. NASA Skylab

The salient aspects of these analogs are briefly described in Appendix D.

Those situations found in the analysis to be least similar and, therefore, excluded for further study were

1. Various exploration parties and expeditions
2. Remote aircraft control and warning (AC&W) stations
3. Industrial work groups
4. Routine transoceanic aircraft flights
5. Wartime bomber crews
6. NASA Apollo spacecraft
7. Off-shore/remote drilling rigs
8. Professional athletic teams
9. Shipwrecks and disaster situations
10. Prisoner of war groups
11. Prison societies
12. Mental hospital wards

To answer the second part of the elemental question, which was concerned with what can be learned from the most applicable analogs, further analysis was required. Table 4 was developed by the researcher from the results of Appendix C, and a review of appropriate literature, visitations, and interviews. These sources of data also served as the basis for the brief applicable analog descriptions contained in Appendix D.

Table 4 after Space Base, lists the ten most applicable analogs in descending order of similarity. The general and specific variable categories shown are those identified previously in this section. Cross-hatched cells

TABLE 4

CORRELATION MATRIX BETWEEN APPLICABLE ANALOGS
AND ORGANIZATIONAL STRUCTURAL VARIABLES

	Objectives and Plans		Capability of Personnel		Environment			Authority	
	Multiple R&A Activities	Crew Size (No. of people)	Crew Composition	Crew Select. and Training	Mission Duration (Months)	Environ. Factors	Autonomy of Operations	Authority and Responsib.	Comm., Coordin., and Integration
Space Base	Y	50-100	He	M	C	Y	Y	M	M
Space Station	Y	6-12	He	M	3	Y	Y	M	M
Oceanographic Research Ships	Y	V	He	M	V	M	Y	M	L
Antarctic Stations	Y	8-340	He	M	3 and 12	Y	Y	M	L
Earthbound R&D Labs	Y	V	He	L	C	N	M	M	M
Ben Franklin	Y	6	He	M	1	Y	M	M	L
Tektite II	Y	5	Ho	S	1	Y	M	M	L
Ninety-day Space Station Simulation	Y	4	Ho	S	3	Y	M	S	L
Nuclear Submarines	N	125	Ho	S	2	Y	Y	S	S
Sealab II	M	10	Ho	S	1/2	Y	N	S	L
Skylab	Y	3	Ho	S	1-2	Y	N	S	S

Key:
- Y - Yes
- N - No
- S - Stringent
- M - Moderate
- L - Little
- C - Continuous
- V - Variable
- He - Heterogeneous
- Ho - Homogeneous

(more than one-half of the total) indicate those specific variables and analogs which were considered by the researcher not to warrant further investigation or discussion. Space Station and Skylab are not included in subsequent discussion because of their hypothetical nature. Emphasis was therefore placed on empirical data available for the remaining eight analogs. A key to all entries was included to aid in understanding.

Objectives and Plans

Multiple R&A activities

As Table 4 indicates, almost all of the analogs listed were found to be similar to Space Base with respect to multiple R&A activities. The only exceptions were nuclear submarines and Sealab II. Little was found in the data of the similar analogs which was helpful in drawing conclusions for use in Space Base organizational structural considerations. Since multiple R&A activities were an objective and an integral part of all plans, a concerted effort was made to ensure that desired results were achieved.

Assigned priorities

One method of achieving desired results in a number of analog situations was to assign priorities to all R&A activities. Either prior to the mission or by direction of responsible individuals during the early phase of activities, priorities were assigned. This action was observed to assist in resolving conflicts over the allocation of resources. These priorities thus served as a guideline to the decision-making process.

Crew size

From Table 4 it is seen that analysis of crew size for the applicable analogs offers little help in obtaining useful data. There were no instances where the size of the analog crew matched the 50-100 population of Space Base consistently. Three analogs did, however, have crew sizes which on occasion matched the desired population requirements. After careful analysis, however, it was found that no significant generalizations could be drawn which would be important to this study.

Capability of Personnel

Crew composition

As Table 4 indicates, the five highest ranking analogs are similar to Space Base with respect to heterogeneous crew composition. In the case of these analogs, a variety of crew members was needed because of the unique skills they possess to satisfy mission requirements. The heterogeneous crews were thus needed to accomplish multi-faceted objectives and plans. In a few of the cases, both male and female technologists are routinely utilized. These situations are oceanographic research ships and earthbound

R&D labs.

Both male and female scientists serve as chief scientists on research ships of the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. In addition, scientific crews are usually composed of mixed members. Female members of these teams are selected, like male members on the basis of best qualifications. The effectiveness of female leaders and team members has been found to be a function of the particular skills, ability, and motivation of the particular individuals involved--just like any other leadership or task situation. While some interpersonal problems have been reported on oceanographic research missions involving mixed crews, crew dress, manners, and language have consistently been found to improve.[1]

Sex does not seem to be a factor which differentiates one group of technical professionals from another in earth-bound R&D labs either. An interesting comparative investigation was made of professional women and men at work in a large, defense-based, R&D organization. The results pointed overwhelmingly to the underlying similarities between the two groups within an organizational culture which provided essentially equal opportunities. Differences arose primarily from the residential immobility of the married professional

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[1]John Schilling, Public Information Officer, Woods Hole Oceanographic Institution, telephone interview, September 22, 1972.

women, and other minor differences were attributed to occupational group or marital status rather than to sex.[1]

Diverse backgrounds

The composition of members involved in continuing Antarctic activities consists primarily of civilian scientists, and Navy officers and enlisted men. The ratio of scientists to military personnel varies from station to station, but, in general, the smaller the station, the more equally divided is the ratio. Usually, Antarctic groups are composed of a wide variety of scientific and occupational specialities. Scientists are selected to provide various scientific skills needed to satisfy station objectives.

Gunderson notes that in the Antarctic a large diversity of occupations and social and educational backgrounds exists. As a result, he feels that psychological differences tend to be associated with these social background differences. Truly, the wide range of cultural, background, and personality characteristics are evident between scientists and Navy cooks. The author concluded that in these small and closed groups, adverse effects upon communications, teamwork, and accomplishment can

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[1]Evelyn Glatt, "Professional Men and Women at Work: A Comparative Study in a Research and Development" (unpublished Ph.D. thesis, Case Institute of Technology, 1966).

result.[1]

Perhaps the classic example of diverse backgrounds was that of the crew of the Ben Franklin, which consisted of six technologists who were needed to ensure mission success. The key individual of the group was Jacques Piccard. According to Phillips, the forty-one-year-old Piccard had established himself as a deep-sea explorer in 1960, when he and a Navy Lieutenant set a new depth record of 35,800 feet beneath the surface of the Pacific Ocean in the bathyscaphe Trieste. In addition, he had made 115 sea dives.[2] The captain of the ship was Donald Kazimir, a former U.S. Navy submariner, employed by the Grumman Aerospace Corporation. Even though Kazimir was the youngest member of the crew at thirty, Piccard indicated that he "has solid experience with the sea."[3]

The principal aide to Piccard and Captain Kazimir was Erwin Aebersold, another Swiss. As a trained pilot, experienced in instrument flying, it was natural that he served as the pilot of Ben Franklin. Aebersold had worked with Piccard for seven years previously and was considered to be "a precision-minded technologist." The

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[1]E. K. Gunderson, "Mental Health Problems in Antarcitica," Archieves of Environmental Health, XVII (October, 1968), 561.

[2]McCandlish Phillips, "Deep-Sea Explorer: Jacques Ernest Jean Piccard," The New York Times, August 20, 1969, p. 24C.

[3]Jacques Piccard, "Piccard Drifts with Gulf Stream," The New York Times, August 20, 1969, p. 24C.

remainder of the crew consisted of a life engineer and two oceanographers. The life engineer, Chester May, was employed by NASA's Marshall Space Flight Center, and was responsible for gathering data which might be useful for future space activities. One of the oceanographers was Frank Busby, a civilian normally employed by the U.S. Naval Oceanographic Office. Piccard indicated that Busby "knows perhaps more about research submersibles than any other living man." The other oceanographer was Kenneth Haigh, an exchange scientist from the British Royal Navy assigned to the U.S. Navy. Haigh was a specialist in echo soundings.[1]

Principal investigator participation

While it was seen that a number of analog crews had diverse backgrounds required by the nature of the mission, another consideration was that participation by principal investigators (P.I.) was on occasion necessary. In the case of the Antarctic, according to Gropper and Patterson, the National Science Foundation considers it a distinct advantage to have the P.I. participate in at least one Antarctic mission. The main advantage of this participation was considered to be that the P.I. will have a much more accurate picture of field conditions, thus enabling him to be more realistic in his demands of field

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[1] *Ibid*.

teams. After this participation, a P.I. may choose to have a co-investigator conduct later field activities. Regardless, the P.I.'s primary experience will be of value.[1]

Varying crew size

The crew size of activity teams for efficient and effective operations has been found to vary for different analogs because of objectives and plans and other considerations. Gropper and Patterson report that typical Antarctic research project teams are usually composed of four scientists including the P.I.[2] In addition, von Tiesenhausen reports that experience in numerous (R&D) organizations and with a great variety of teams, indicates that coherence requires an optimum group size of between seven and twelve individuals.[3]

Another viewpoint was expressed by the teaming structure of Martin Marietta's corporate research laboratory called the Research Institute for Advanced Studies (RIAS). This laboratory, staffed by approximately 100 people, has found that interdisciplinary program and research teams which consist of from seven to fourteen

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[1]B. A. Gropper and N. P. Patterson, Trip Report--U.S. Antarctic Research Program, National Science Foundation (Washington, D. C.: Bellcomm, 1971), p. 3.

[2]Ibid., p. 2.

[3]NASA, Fifty-Man Space Base Population Organization, p. 3.

members optimize results.[1] A general conclusion reached from these findings was that an optimum number of team members does not exist, but that ranges from four to fourteen members have been found to be successful on numerous occasions for a variety of R&D activities.

Crew selection and training

A number of analogs, like Space Base, plan or place only moderate emphasis on crew selection and training. Table 4 indicates that this condition exists for oceanographic research ships, the Antarctic, and the Ben Franklin situations. In each of these cases, crew selection was not based on as stringent physiological or psychological testing as was required in several of the others. Extensive training was not mandatory or accomplished during the analog missions either. Generalizations applicable to Space Base use are, therefore, difficult to assess.

Dual selection

While the ninety-day Space Station simulation conducted by the McDonnell Douglas Astronautics Company was not identified as having close similarity to Space Base with respect to crew selection and training, it did offer one useful conclusion. A recommendation made was that a dual approach to crew member selection should be made based

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[1]Dr. David L. Goldheim, Manager for Marketing, Martin Marietta Corporation, Research Institute for Advanced Studies, private interview, August 16, 1972.

on the programmatic criteria of suitability for the program in terms of skills and educational level, as well as acceptable physical health and identification of existing health problems.[1]

Crew selection

As with the previous consideration, Sealab II was not found to possess close similarity with Space Base in relation to crew selection and training. One criterion did, however, develop from the empirical studies of Helmreich and Radloff. The researchers concluded that the most effective social organization for a confined environment was one where crew members are selected based on unique skills and knowledge which they communicate to others who are motivated to learn and who have their own skills to share. The interaction by these individuals who serve as teachers and learners, tends to maximize rewards and increase interpersonal understanding in closed environments.[2]

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[1]National Aeronautics and Space Administration, Final Report: Definition Study for an Extended Manned Test of a Regenerative Life Support System (Huntington Beach, Calif.: McDonnell Douglas Astronautics Company, 1971), p. 115.

[2]Robert Helmreich and Roland Radloff, Environmental Stress and the Maintenance of Self-Esteem (Austin, Tex.: University of Texas, 1969) quoted in Robert Helmreich, The Tektite II Human Behavior Program (Austin, Tex.: University of Texas, 1971), p. 22.

Environment

Mission duration

The Space Base mission has previously been defined as being continuous for a useful life of ten years. Based on this consideration, as Table 4 indicates, only earth-bound R&D labs had any similarity at all. This similarity, however, did not correlate well because R&D labs located on earth have continuous operations usually on a one or two work-shift-per-day basis. Conversely, Space Base must operate on an around-the-clock work/living basis with varying mission duration for most of the crew members.

Because of probable frequent visits by the Space Shuttle, the likelihood of individuals having to stay longer than six months will be small. For many, one-month tours of duty, especially for transient P.I.'s and technologists will be the case. No applicable analog, therefore, was found useful in providing data which would be useful for Space Base organizational structure considerations.

Environmental factors

As Table 4 indicates, eight of ten analogs were identified as having environmental factors associated with them which were similar to Space Base. The only situations which did not were oceanographic research ships and earth-bound R&D labs. Since it would require extensive discussions to elaborate on all similar analogs for all the environmental factors involved, only data from a relatively few are included in this discussion. In addition, only data for the specific area of rewards versus costs are presented.

Rewards versus costs

Radloff and Helmreich in their Sealab II investigations hypothesized that there must be a more-than-proportional relationship between rewards and costs (risks, financial and personal loss, etc.); i.e., reward must exceed cost as an incentive which makes people volunteer for work in hostile environments. Various balances between reward and costs are shown in Figure 2.[1] The model was intended to represent approximate locations and relative interrelationships. As can be seen, in general, the farther to the left and above the diagonal line, the more desirable the situation is for the individual or group. Correspondingly, the less desirable outcomes are located farther to the right and below the diagonal line.

In considering the environments for the cases presented where similarity to Space Base was found, an obvious question was why are scientists, engineers, and others motivated to participate in such activities? Certainly these environments are abnormal compared to those of more conventional R&D laboratories. The danger to life is real,

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[1]Roland Radloff and Robert Helmreich, <u>Groups Under Stress: Psychological Research in Sealab II</u> (New York: Appleton-Century-Crofts, 1968), p. 123.

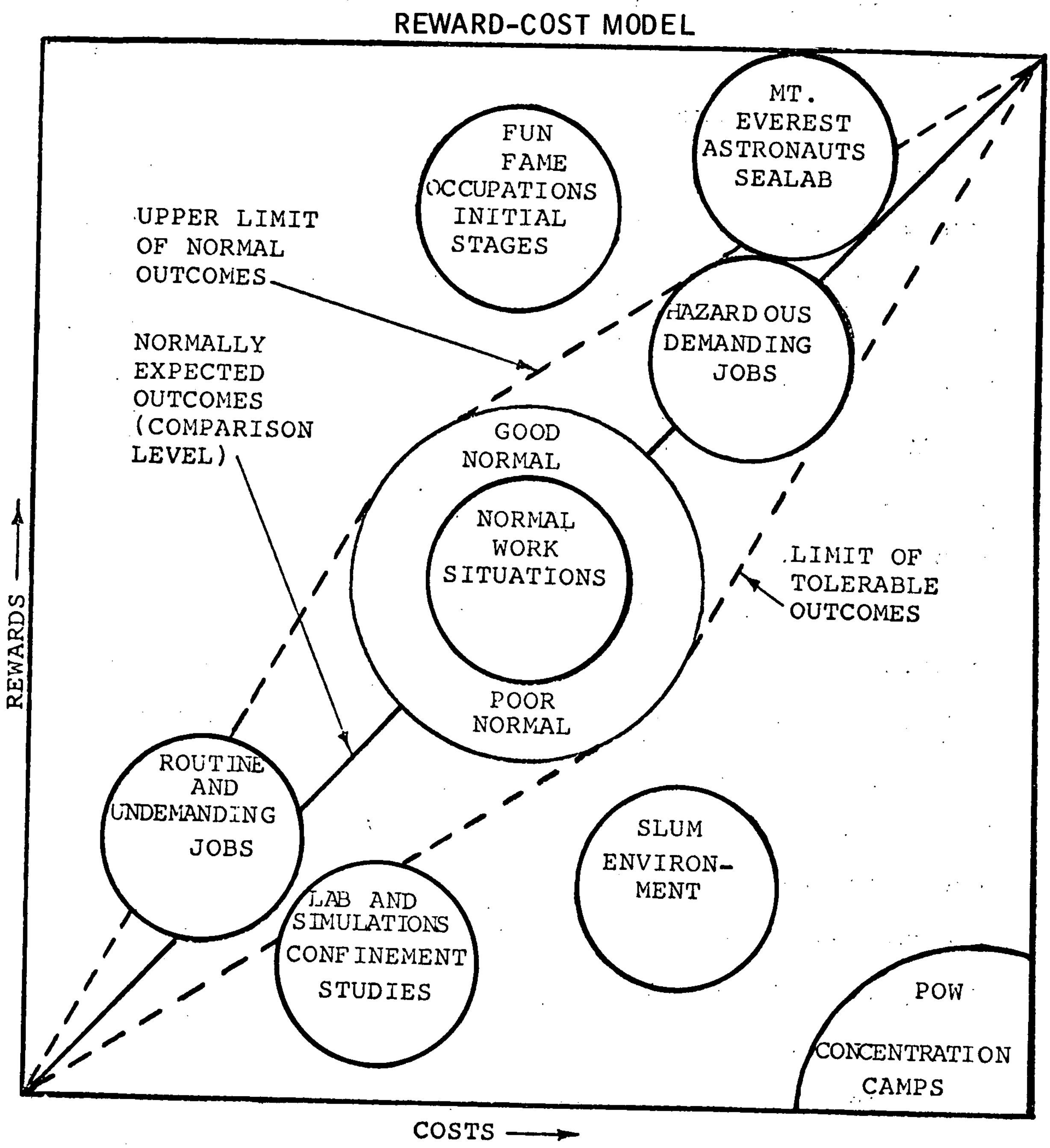

Fig. 2.--Rewards and costs in exotic environments.

and the personal inconveniences are significant. Yet, with minor exceptions there were no indications that volunteers were lacking. In fact, a number of qualified backup group members were usually available.

Studies by Mullin on Antarctic activities indicate that there are various reasons for a man to volunteer for isolated duty in a unisexual environment. He feels, however, that "for a few men it was obvious that separation from home, wife, children, and family responsibility meant for them the subtraction of an element of stress in their personal adjustment."[1] This then was their reward, but what are other reasons?

Gunderson found in his studies that high levels of expressed motivation prior to arrival in Antarctica were negatively correlated with emotional adjustment for the military personnel. Importantly, the author found that this did not hold true for the civilian scientists. Gunderson reasons that the Navy men with their favorable and perhaps unrealistic expectations of rewards, were most likely to be disappointed by the experience. Another reason hypothesized was that the Navy men expected certain immediate rewards, such as approval of associates and supervisors, favorable results of promotional exams, or orders to the next duty station. The scientists on the

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[1]C. S. Mullin, Jr., "Some Psychological Aspects of Isolated Antarctic Living," American Journal of Psychiatry, CXVII (October, 1960), 323-25.

other hand expected their professional rewards and satisfactions at some distant time period.[1]

It can be reasoned that Space Base R&A activities and support operations are closer to the hazardous demanding job area than any other, as are Space Station, Antarctic stations, and nuclear submarines. The Ben Franklin, Tektite II, and Skylab activities are similar to the highest risk and reward circle which includes Sealab II. Oceanographic research ships and earthbound R&D labs would be considered normal work situations, while the ninety-day Space Station simulation falls within the low-cost and reward studies circle. Undoubtedly, time is a critical variable which causes uppermost relationships to shift downward and to the left. With the passage of time, the rewards decrease at a faster rate than do costs. For example, a second Ben Franklin voyage along the Gulf Stream probably would not provide as much recognition for the crew as did the first.

This model, as well as the discussion which followed, was an attempt to answer the question of why people volunteer for activities which have high risks. The answer was simply that various rewards are either high, or are perceived to be high by the individual, and outweigh the costs.

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[1]Gunderson, p. 564.

Autonomy of operations

A few analogs were found, like Space Base, to have autonomous operations in the conduct of their activities. They were oceanographic research ships, Antarctic stations, and nuclear submarines. The main reasons for this autonomy was found to be the nature of the mission and the operational environment. A review of research and writings did not produce any significant generalizations which were felt by the writer to warrant further consideration for Space Base analysis.

Authority

Authority and responsibility

Table 4 shows that the six highest ranking analogs have moderate authority and responsibility relationships to Space Base. Those environments found to be similar were Space Station, oceanographic research ships, Antarctic stations, earthbound R&D labs, the Ben Franklin, and Tektite II. Since authority and responsibility within earthbound R&D labs have already been discussed previously in this section, only the other analogs are considered.

In the literature describing the four remote cases, there were no major incidents of technologists refusing to take direction or orders. This is not surprising for the underwater activities because of their unique and nonroutine nature. One might, however, expect some difficulty in the Antarctic for various reasons. A reason might be the attitudes of the scientists with regard to their belief of higher status. After all, the facilities exist so they may do their experiments and collect data. Another might be the relative routine of activities.

Perhaps the most significant reason for a lack of problems in the Antarctic was that the majority of those in residency are military personnel. Also, the records of many of the scientists indicated a short career or exposure to military life. Discipline learned in the military may have been a relevant factor. Another possibility is that in most areas (especially the underwater activities), the organizational hierarchy was fairly short. Still another reason may be that the missions were fairly short for the underwater activities, up to sixty days. Even with the one year Antarctic activity, there was a realization that the end was already in sight, and that others had "played to rules of the game" before.

Personal freedom

In several of the analog situations noted, it was found that benefits were derived when crew members had personal freedom to vary procedures and manner of task accomplishment on their own initiative. Work in these isolated situations had been found to be the most meaningful of the social roles and is therefore important. Giving individuals the freedom to vary work accomplishment helps to promote morale, to prevent boredom, and to foster efficient performance.

For example, work was found to be an essential part of Antarctic station life. Gunderson's studies show that "emotional responses to the Antarctic environment can be largely attributed to changes in self esteem and group status, which in turn are related to the perceived importance of one's job." The scores of scientists on a scale indicating feelings of "usefulness" remained unchanged over the Antarctic winter. The scores for the Navy men showed a significant reduction. There was also a direct correlation found between a reduced feeling of usefulness of Navy men and emotional symptomatology near the end of winter.[1]

Performance and emotional health are then a direct function of work itself. Rohrer finds that work soon became the most meaningful of the social roles, and that an individual who is able to occupy himself working is better able to adjust to isolation. It is understandable why some men seek additional work functions to occupy their time, and an example given was the physician who also served as the housing officer. The value attached to work roles was somewhat different from what one might think,

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[1]Gunderson, p. 564.

and Rohrer found that the cook often has a higher status within the group than the scientists do. Another high-ranking position is held by the radio operator who maintains the only link to the outside world.[1] Each man has work responsibilities to perform and these activities are not only essential to the survival of the group, but to the well-being of the individual as well.

<u>Communications, coordination, and integration</u>

Very little similarity to Space Base was found when considering communications, coordination, and integration. Only earthbound R&A labs, which have already been discussed in relation to this specific variable, were found to be analogous. There were, however, several aspects of this variable which were considered important enough to discuss briefly.

Line of communications

In each of the analogs, either explicitly or implicitly, it was realized that lines of communications between all groups were needed for critical and safety-associated announcements. For obvious reasons, these communication channels were needed to ensure uniform and efficient response to dangerous situations. A number of methods were utilized, such as audio and visual alarms,

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[1]John H. Rohrer, "Human Adjustment to Antarctic Isolation," <u>U.S. Office of Naval Research Reviews</u>, June, 1959.

emergency procedures, and periodic training. All of these methods, however, require that a line of communications and hierarchical relationship exists between crew members and an individual with authority and responsibility to direct necessary action through other lines of communications. The line organization of a nuclear submarine can be considered a prime example of how hierarchical relationships provide for the necessary line of communications.

Bidirectional communications

While not specifically identified as a similar analog with respect to this specific variable, ninety-day Space Station simulation data indicated another need for bidirectional communications. A conclusion stated in the final report was that it was important that bidirectional communications between managers and crew members existed. The reason given was that crew members prefer to be informed as to the purpose and rationale of all tasks. During the simulation, it was found that arduous and unpleasant tasks were performed by crew members with no complaints when they were fully aware of and thus involved in what was being attempted and why.[1]

Two-way audio and video

Studies have indicated that two-way communications

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[1]NASA, Final Report: Definition Study for an Extended Manned Test of a Regenerative Life Support System, p. 276.

diminish the sense of isolation between space/underwater and ground personnel. In addition, their communication systems aid coordination and integration. For example, Antarctic studies by Lewis indicate that while men miss being with their families, the use of the station's radio and telephone system to talk to their families was very helpful to morale.[1]

Helmreich reports that it appears that a two-way video link played an important role in maintaining good relations between Aquanauts and surface personnel during Tektite II activities. It was concluded that this video link reduced the feeling of isolation and overt hostility between the two groups, as had been the case with the similar environment of Sealab II.[2]

<u>Summary</u>

This section consisted of a review of research and writings important to organizational structural determination for a Space Base. This review, an important part of the study methodology, involved four areas of investigation. The first was concerned with Space Base related studies. The second discussed and identified general and specific variables which can be used to select

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[1]Richard S. Lewis, <u>A Continent for Science</u> (New York: The Viking Press, 1965), p. 278.

[2]Helmreich, p. 37.

an organizational structure and categorize data. The third discussed professional organizations and technical professionals. Finally, data were identified and discussed by general and specific variables for a number of applicable analogs.

A survey of Space Base related studies accomplished by six NASA and contractor study groups/individuals was presented. While none of these studies had as its sole purpose Space Base organizational structural identification, a number provided some useful inputs to this study. The first study, a NASA Statement of Work for follow-on contractor Space Base investigation, identified three organizational functions, namely, operations, maintenance, and experimental operations. Two contractor study teams working independently concluded that these functions could be placed in two organizational groups, with the maintenance function either located in one group or shared between the groups. Studies performed by two NASA employees from different centers identified a basic line organization as a Space Base organizational structural model. Then they went on to investigate other areas of interest. Finally, a relevant Grumman Space Station study, and another by Sells were discussed and modified for use for Space Base analysis.

Variables important for the design of organizational structure, both general and specific, were identified. It was determined that while a totally acceptable set of general variables does not exist, the categories of objectives and plans, capability of personnel, environment, and authority would suffice for the present study. Nine specific variables were discussed and included with the general variables to serve as a set important for the design of Space Base organizational structure, and as a classification scheme for subsequent data gathering and analysis. These variables were multidisciplinary R&A activities; crew size; crew composition; crew selection and training; mission duration; environmental factors; autonomy of operations; authority and responsibility; and communications, coordination, and integration.

The discussion of professional organizations and technologists was included to identify data relevant for subsequent considerations. Professional organizations were identified as those where the primary objective was to produce, apply, preserve, or communicate knowledge--like Space Base. Characteristics of these organizations were described in terms of goals, situational factors, authority relationships, and structure. Organic-adaptive project (matrix) structures were described. The somewhat unique characteristics of technical professionals were listed, with scientists and engineers being described as intensively dedicated and self-reliant individuals who frequently are unable to communicate with others. The individuals and their relationship to the organization were described in terms of a number of potentials for conflict and detriments for organizational success.

The final portion of this section was concerned with data relevant to Space Base organizational structural selection obtained from the most applicable analogs. These appropriate and significant data were included and discussed using the variable categories previously identified. In most cases, a review of literature, visitations, and interviews provided useful data from which specific considerations were included. More than one-half of the time, however, only limited or no data at all were considered by the researcher to be relevant. These collected data, as well as Space Base program requirements and assumptions, were necessary to accomplish the conduct of the study.

III. CONDUCT OF THE STUDY

This chapter, primarily concerned with the second phase of the study methodology, indicates how useful study data were rationally obtained. These data were necessary for the subsequent identification of an optimum hypothetical Space Base organizational structure from a large number of possibilities. The general technique used was for the researcher to develop organizational structural evaluation criteria, develop organizational structural models, and reduce these possibilities to a much smaller feasible set. In addition, evaluation scores and instructions were identified for use by members of two pilot evaluation teams and members of a carefully selected primary evaluation "panel of experts" to score each model quantitatively against how well the criteria were satisfied.

Development of Evaluation Criteria

The technique used to develop evaluation criteria (and rationale for each) was eclectic in nature and used the pertinent sources of data discussed in sections I and II. Three significant areas investigated were (1) Space Base program requirements and assumptions; (2) management concepts and practices--as they relate to organizational structural variables, professional organizations, and technical professionals; and (3) applicable analog data.

Table 5 contains a list of criteria identified from these areas. These criteria were placed in the general and specific structural variable categories previously identified in Table 1. The source of each, by significant area of investigation as well as rationale used, are included. In total, forty-six criteria were identified: Space Base program requirements--sixteen; management concepts and practices--nineteen, and analog data--eleven.

Development of Organizational Structural Models

A multitude of organizational structural models which could be used in Space Base exists. Classical and modern structural variations were discussed in section II and included the mechanistic (bureaucratic) and matrix forms. Many combinations and varieties are also possible. This section of the study discusses some of these variations and develops a number of models--some of which are used for further analysis.

The Grumman "Level-of-Authority" Model

Because of the organizational structural possibilities, a rationale was needed for development and identification purposes. This rationale was provided by the

TABLE 5

CRITERIA WITH SOURCES AND RATIONALE FOR ORGANIZATIONAL STRUCTURAL MODEL EVALUATION

Criteria	Source/Rationale
Objectives and Plans	
1. Multidisciplinary R&A Activities	
1.1 Variety of R&A: The organizational structure shall allow a variety of R&A activities to be accomplished concurrently.	Program requirements and assumptions: Space Base objectives of R&A, public and private sector support, space explorations, and orbital operations require a variety of concurrent activities for mission success.
1.2 Undefined activities: The organizational structure shall have the flexibility to support R&A activities and interplanetary missions which are not defined in detail at present.	Program requirements and assumptions: The probability of long range Space Base program success will be increased if organizational structure is flexible enough to accommodate change.
1.3 Assigned priority: The organizational structure shall accommodate R&A activities and interplanetary missions with assigned priorities.	Applicable analog data: Priority assignments assist in resolving scheduling conflicts, and serve as a guideline to the decision-making process.
1.4 Situational requirements: The organizational structure must provide for conflicting professional organizational situational requirements.	Management concepts and practices: The organization structure for an internalized multiprofession, public professional organization such as the Space Base must provide for nonuniform events and innovation, and at the same time use certain traditional bureaucratic mechanisms for routine activities.

TABLE 5.--Continued.

Criteria	Source/Rationale
Objectives and Plans	
2. Crew Size	
2.1 Large crew: The organizational structure will accommodate a Space Base crew consisting of 50-100 members.	Program requirements and assumptions: The Space Base will be manned by a large number of technologists.
2.2 Crew growth: The organizational structure shall accommodate a crew which will vary in size of from 50 initially to 100 as the program matures.	Program requirements and assumptions: Space Base maximum crew size will vary during the life of the program. In the initial build-up phase, only 50 crew members will participate. Later, as the Space Base is physically expanded, the crew will be increased to a maximum of 100 members.
2.3 Many technologists: The organizational structure must allow support operations personnel to satisfy the needs of a large population of R&A technologists who use but do not operate the Space Base.	Program requirements and assumptions: Support operations personnel will function to assist in every way possible to ensure that the various needs of R&A technologists are effectively, efficiently, and safely satisfied. Functions performed include subsystem operations, flight control and orientation, data management, medical services, maintenance, logistics and resupply, food handling, and housekeeping.
Capability of Personnel	
3. Crew Composition	
3.1 Mixed crew: The organizational structure shall accommodate male and female crew members.	Program requirements and assumptions: Crew members will be selected solely on qualifications.

TABLE 5.--Continued.

Criteria	Source/Rationale
Capability of Personnel	
3.2 Multination crew: The organizational structure shall allow international, as well as domestic, technologists to work productively.	Program requirements and assumptions: The Space Base will provide a focal point for productive international cooperation and joint ventures.
3.3 Diverse backgrounds: The organizational structure shall accommodate technologists of diverse occupations and social and educational backgrounds.	Applicable analog data: Psychological differences are associated with groups with diverse backgrounds, on occasion causing adverse effects upon communications, teamwork, and accomplishment.
3.4 Task leader: The organizational structure shall accommodate a task leader assigned and responsible for each major R&A activity.	Management concepts and practices: The likelihood of timely and efficient task accomplishment is increased if an individual is identified as being responsible for its success.
3.5 P.I. participation: The organizational structure shall allow for participation by principal R&A investigators on occasion.	Applicable analog data: Occasional participation by principal investigators gives them a much more accurate picture of field conditions, and enables them to be more realistic in their demands on field personnel.
3.6 Varying crew size: The organizational structure shall allow for R&A activity teams consisting of from four to fourteen technologists.	Applicable analog data: Efficient and effective R&A team size has been found to vary between four to fourteen individuals including the team leader, participating technologists, and the principal R&A investigator.

TABLE 5.--Continued.

Criteria	Source/Rationale
Capability of Personnel	
4. Crew Selection and Training	
4.1 Minimum astronaut training: The organizational structure will accommodate crew members with a minimum of astronaut-type training and physical conditioning.	Program requirements and assumptions: The widest range of skilled technologists shall participate in Space Base activities. This will require that personnel who lack flight training, extensive testing, and exposure to the space environment will be utilized. The present physical/medical requirements for astronauts should apply only to those personnel required for extra/intravehicular activities.
4.2 Dual selection: The organizational structure shall allow for a dual approach to crew member selection, i.e., consideration will be given to education/skills and general health.	Applicable analog data: Two general criteria should be used to select crew members. The first is based on the programmatic criteria of suitability for the program in terms of skills, cross skills, and educational levels. The second relates to acceptable physical health and the identification of existing health problems.
4.3 Crew selection: The organizational structure shall accommodate crew members who are selected partially based on their unique skills and knowledge and who are motivated to learn.	Applicable analog data: The most effective social organization for a confined environment is one in which crew members have unique skills and knowledge which they communicate to others who are motivated to learn and who have skills to share. The interaction by individuals who serve as teachers and learners tends to maximize rewards and increase interpersonal understanding in a closed environment.

TABLE 5.--Continued.

Criteria	Source/Rationale
Capability of Personnel	
4.4 Training and indoctrination: The organizational structure shall accommodate the training and indoctrination of long and short duration crew members.	Program requirements and assumptions: Some in-orbit training and indoctrination will be required because of the possibility that some R&A personnel may participate in Space Base R&A activities for extended periods. Indoctrination of new crew members will be a recurring requirement.
Environment	
5. Mission Duration	
5.1 Ten-year life: The organizational structure shall be flexible enough to allow maximum return from a highly worthwhile R&A program over a full ten year period.	Program requirements and assumptions: This requirement allows for the effective accomplishment of a program which may continuously change and require updating to meet changing budgets, technologies, and national/international interests.
5.2 Varying tours: The organizational structure shall have the flexibility to accommodate crew members who remain in the Space Base for varying tours of duty.	Program requirements and assumptions: The organizational structure must not be sensitive to a specific mission duration since R&A technologists and support operations personnel will participate in Space Base duty for varying (yet unspecified) lengths of time. In addition, the organizational structure must be flexible enough to permit increases in stay time as the program matures and extended manned operations are better understood.

TABLE 5.--Continued.

Criteria	Source/Rationale
Environment	
5.3 Multishift work: The organizational structure must be flexible enough to accommodate multishift R&A activities and support operations.	Program requirements and assumptions: Multishift R&A activities and operations are needed to maximize program results and to insure the safety and well being of the Space Base crew. Many R&A activities will require either continuous coverage or must be accomplished during "nonstandard" hours for various technical reasons. In addition, many maintenance, repair, and housekeeping functions must be accomplished when they will not conflict with R&A activities.
5.4 Replacement: The organizational structure shall have the flexibility to allow for periodic replacement and reassignment of some crew members before certain long-run R&A activities and continuous support activities are completed.	Program requirements and assumptions: Success of the Space Base program will depend on the ability of the in-orbit organization to adjust to personnel changes due to crew member replacement or reassignment to higher priority work. Some task rotation keeps crew members fully occupied, and provides backup capability in the event of illness.
6. Environmental Factors	
6.1 Rewards vs. costs: The organizational structure shall serve to ensure that there is a more-than-proportional relationship between rewards and costs.	Applicable analog data: Studies indicate that personnel reward must exceed cost as an incentive which makes people volunteer for work in hostile environments.
6.2 Cohesive group. The organizational structure shall create a cohesive	Management concepts and practices: Group unit connotes unity of purpose

TABLE 5.--Continued.

Criteria	Source/Rationale
Environment	
organization and cohesiveness within groups.	and promotes effective performance.
6.3 Work schedule: The organizational structure shall allow for work schedules that bring various groups together.	Management concepts and practices: Work schedules which allow for varied individual and group contact reduce the formation of informal subgroups and factions and increase overall unity and cohesiveness.
6.4 Professional satisfaction: The organizational structure shall allow technical professional crew members to satisfy professional needs and goals.	Management concepts and practices: The probability of retaining trained individuals is increased if the achievement of professional goals is emphasized. This also reduces training costs and improves morale.
6.5 Human capabilities: The organizational structure shall allow for the maximum use of cross skills and the full range of human capabilities.	Management concepts and practices: The maximum contribution to organizational activities is achieved by people whose capabilities are fully used.
6.6 Full employment: The organizational structure shall provide for full employment of crew members (except during off-duty hours).	Management concepts and practices: Full employment is a goal of efficient organizational activities, which require the completion of scheduled and operational tasks with the human resources available.
6.7 Various construction: The organizational structure shall be appropriate for either a modularly constructed or centralized Space Base design.	Program requirements and assumptions: Since Space Base design has been finalized, the organizational structure identified should be compatible with either the modular or centralized designs.

TABLE 5.--Continued.

Criteria	Source/Rationale
Environment	
7. Autonomy of Operations	
7.1 Autonomous operations: The organizational structure shall allow autonomous Space Base operation.	Program requirements and assumptions: Cost effectiveness dictates that operation of the ten year life Space Base be as independent from earth control/support as possible.
7.2 Planning and scheduling: The organizational structure shall allow, to the maximum extent possible, in-orbit mission planning activity/support operation priority definition, and work scheduling.	Program requirements and assumptions: The crew of the Space Base needs a capability for mission planning, priority definition, and activity scheduling; with consideration given to work/rest-cycle variations, equipment sharing, number of crewmen available for duty, crew skill proficiency, scheduling conflicts, and requirements for team tasks.
7.3 Nonduty work: The organizational structure shall have the flexibility of allowing certain technical professionals to work on R&A activities during "nonduty" hours.	Management concepts and practices: Creative technical professionals frequently do not know what an eight-hour workday means, and preoccupation with problem solutions is often incessant and endless. They are frequently characterized by their love of science and an insatiable curiosity.
Authority	
8. Authority and Responsibility	
8.1 General definition: The organizational structure shall allow for	Management concepts and practices: Studies indicate that determination of who

TABLE 5.--Continued.

Criteria	Source/Rationale
Authority	
general authority and responsibility definition.	does what, when, and how will help to prevent conflicts.
8.2 Various managers: The organizational structure shall accommodate trained technical managers at various Space Base hierarchical levels.	Management concepts and practices: Trained technical management of all phases of the activities of technical professionals is essential to organizational success. These managers provide an interface between technologists and higher management, and ensure management control is accomplished.
8.3 Unity of command: The organizational structure will use the unity of command principle when possible.	Management concepts and practices: Coordination of work efforts and the utilization of resources can be best achieved by a single authority. The decision-making process may involve many people, but final authority must be vested in a single individual.
8.4 Span of control: The organizational structure shall provide for moderate and workable spans of control.	Management concepts and practices: Good management practice dictates that spans of control shall be neither too narrow or too wide. Generally, a span too narrow does not fully employ managers, and a span too wide overextends their control and direction depending on the work environment and types of personnel involved.
8.5 Work flexibility: The organizational structure shall allow for flexibility in crew member work activity definition.	Management concepts and practices: A well defined series of tasks results in specific assignment of personnel to accomplish them. This reduces the systems' ability to

TABLE 5.--Continued.

Criteria	Source/Rationale
Authority	
	shift its resources to accomplish other lesser defined tasks, and ultimately leads to a highly specialized crew. Therefore, the degree of specialization is inversely related to flexibility of crew assignment.
8.6 Personal freedom: The organizational structure shall permit personnel to vary procedures and manner of task accomplishment on their own initiative.	Applicable analog data: Work, in isolated situations, has been found to be the most meaningful of the social roles, and is therefore important. Giving individuals the freedom to vary work accomplishments helps to promote morale, prevent boredom, and foster efficient performance.
9. Communications, Coordination, and Integration	
9.1 Group decision making: The organizational structure shall allow group decision making where practical.	Management concepts and practices: Group decision making serves as an aid to communications, coordination, and integration. Group decisions ensure that all relevant inputs are made and properly evaluated. This action also promotes morale.
9.2 Quality and speed: The organizational structure shall have provision for quality and speed in decision making.	Management concepts and practices: Managers need an organizational structure which assists them in rendering sound decisions. This requires good information inputs, and an analytical process that yields unambiguous unbiased judgments. These decisions must not only be appropriate to the situation, but must be

TABLE 5.--Continued.

Criteria	Source/Rationale
Authority	
	arrived at and acted on within time constraints.
9.3 Line of communications: The organizational structure shall allow for lines of communication between groups for all critical and safety-associated tasks.	Applicable analog data: Open lines of communications will ensure uniform, efficient response to dangerous situations.
9.4 Bidirectional communications: The organizational structure shall provide bidirectional communications between directors/managers and crew members.	Applicable analog data: Crew members prefer to be informed as to the purpose and rationale of all tasks. Arduous and unpleasant tasks are performed by crew members with no complaints when they are fully aware of and thus involved in what is being attempted and why.
9.5 Technical professional communications: The organizational structure shall allow and encourage communications between technical professionals and managers.	Management concepts and practices: Since technical professionals are generally not considered to possess the ability to communicate, the organizational structure must allow this difficulty to be overcome by ensuring that adequate communication channels exist. In this way, accomplishments and support requirements will be made known, and needed recognition and support can be provided.
9.6 Two-way audio and video: The organizational structure shall be compatible with the use of two-way audio and video communications.	Applicable analog data: Studies made indicate that two-way communications diminishes the sense of isolation between space/underwater and ground personnel. In addition, these communication systems aid coordination and integration.

TABLE 5.--Concluded.

Criteria	Source/Rationale
Authority	
9.7 Minimum interfaces: The organizational structure shall include a minimum number of communication interfaces to achieve objectives effectively and efficiently.	Management concepts and practices: Communication theory indicates that the number of steps, or communication links, in terms of people that are required for information to get from the originator to the person who is ultimately responsible for the action should be as few as possible.
9.8 Feedback: The organizational structure shall allow for accurate and timely feedback of R&A activity progress.	Management concepts and practices: Managers use lines of communication to allocate resources and make decisions. Accurate and timely information is needed for quality management decisions.
9.9 Creative climate: The organizational structure shall create a climate for creativity for those technical professionals involved in R&A activities.	Management concepts and practices: An organizational environment which stimulates creativity through communication, coordination and integration is essential to technical professionals.

methodology used in the Grumman Space Station study previously identified. The technique was based on an organizational pyramid model which considered four distinct hierarchical levels of authority shown in Figure 3. These levels are command, discipline, function, and task.[1]

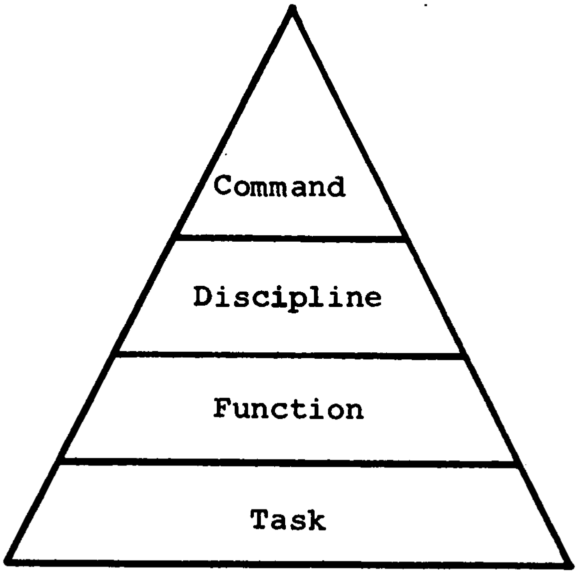

Fig. 3.--The Grumman "level of authority" organizational pyramid model.

As the model shows, the command level is located at the apex of the pyramid. Major authority and responsibility for all Space Station operations and activities is here, and a manager or commander was assigned. At the next level , the discipline level, two major disciplines for the Space Station existed. These disciplines were comprised of related functions and were called the scientific and operations disciplines with a manager assigned to each. The function level, the next lowest, represented the level at which a number of related tasks were logically grouped. Included as Space Station functions were experiments, maintenance, and repair. At this level, an individual was

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[1]National Aeronautics and Space Administration, Crew Operations Study of Command Structure, by Samuel C. Campbell, Perry L. Gardner, and Robert H. Schaefer (Bethpage, New York: Grumman Aerospace Corporation, 1971), p. D-2.

identified as having authority and responsibility for the accomplishment of each functional group.[1]

The task level, located at the base of the pyramid, contained all tasks that must be performed by the Space Station crew during the mission. Typical required tasks would be calibration for an experiment, star sighting for navigation purposes, and housekeeping. No individual authority or responsibilities for task accomplishment were implied at this level--just that all tasks be included.[2] The writer feels that while the Grumman organizational pyramid was developed for Space Station considerations, it was equally applicable and useful for Space Base analysis, as will be seen in the discussion which follows.

Some Hypothetical Space Base Organizational Structural Models

Figures 4 and 5 show the correlation between the Grumman level-of-authority model and two Space Base hypothetical organizational structures. The structures proposed are classical and matrix in nature, and each serves as parent models from which others are developed. As the classical structural model portion of Figure 4 shows, personnel are assigned to each authority level. Space Base, R&A, and Support Operations Directors are located at the command and discipline levels, respectively.

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[1] *Ibid.*

[2] *Ibid.*

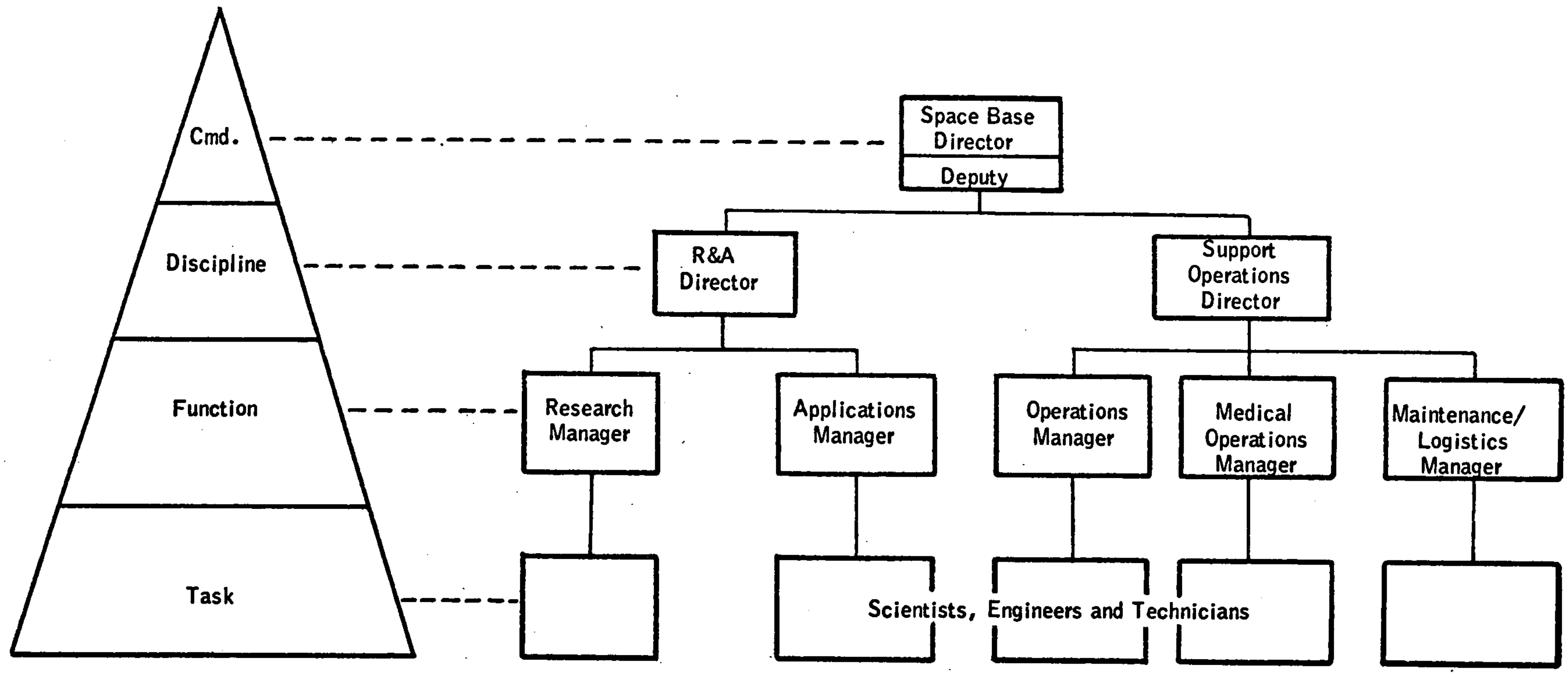

Fig. 4.--The correlation between the "level-of-authority model" and a hypothetical classical organizational structure for a Space Base.

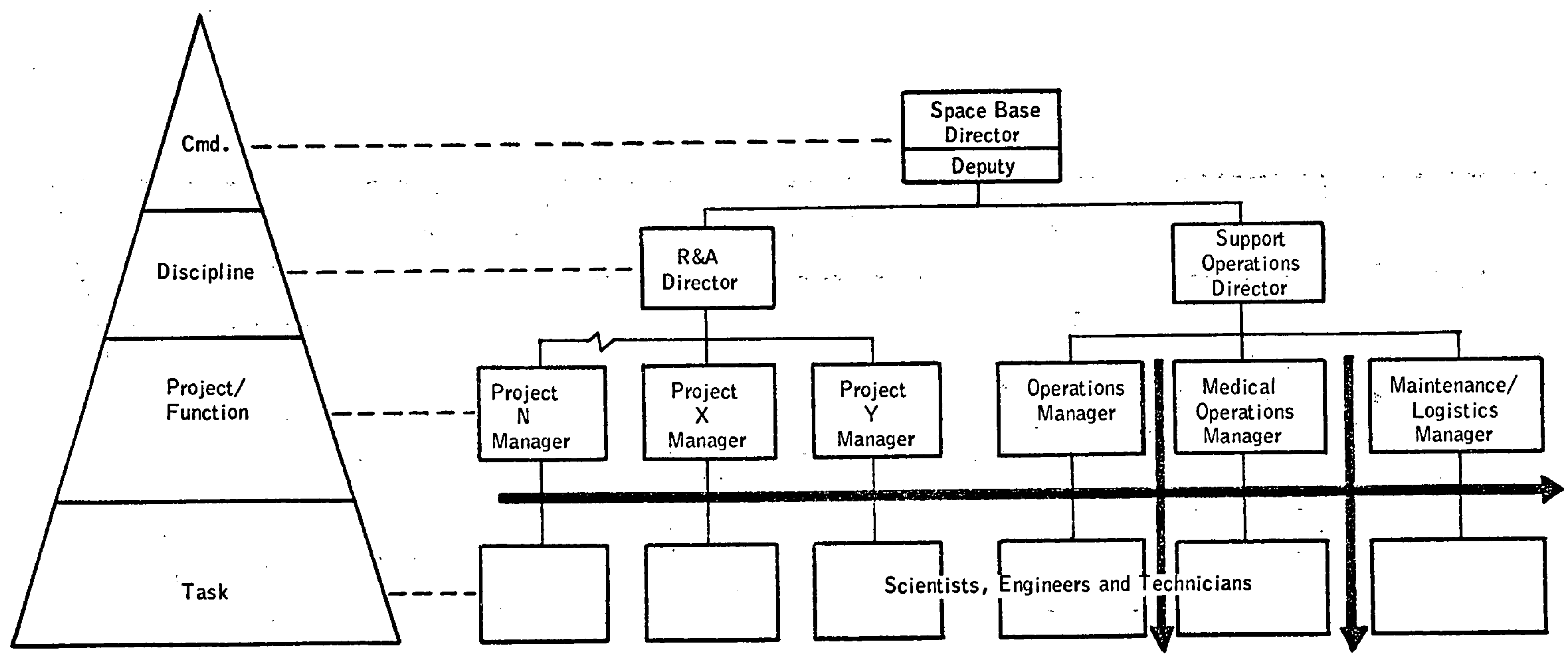

Fig. 5--The correlation between the "level-of-authority model" and a hypothetical matrix organizational structure for a Space Base.

Functional managers for research, applications, operations, medical operation, and maintenance/logistics are identified at the function level. The task level is staffed with the remaining technologists who comprise the Space Base crew. This model is very similar to the functional Space Base organizational structures suggested by von Tiesenhausen[1] and Gundersen.[2]

The matrix structural model portion of Figure 5 also shows assignment of personnel to various levels. Major titles are identical, except that the R&A Director has a varying number of project managers assigned to him instead of functional R&A Managers. The number of project managers and projects is a function of mission objectives and planned manning levels, with variability indicated by a broken line. The lines with arrows on this matrix model are included to indicate horizontal project and vertical functional authority and responsibility. These characteristics are typical of matrix organizations and were discussed in section II.

The organizational titles shown in Figures 4 and 5 have been selected to serve as the basis for all subsequent study discussion. Close examination reveals that discipline, functional, and project titles shown are a preliminary

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[1]NASA, <u>Fifty-Man Space Base Population Organization</u>, pp. 3-5.

[2]NASA, <u>Earth-Orbiting Space Base Crew Skills Assessment</u>, p. 53.

attempt by the researcher to establish several Space Base organizational structural possibilities. Personnel assignments are based on program requirements identified and assumptions made in section I.

Organizational Structural Model Combinations Based on Authority Assignments

The technique used by Grumman to generate organizational structural model variations was to vary the level and number of authority assignments. For example, total authority was assigned to personnel at the highest level, or it was shared between members of lower levels, such as the discipline and task levels.[1] This same technique was used in the present study for Space Base analysis. Statistically there are thirty different combinations in which these assignments could be made.[2] Figures 6 through

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[1]NASA, Crew Operations Study of Command Structure, p. D-3.

[2]The general formula for determining possible combinations is:

$${}_{n}C_{r} = \frac{n}{r!(n-r)!}$$ Where n is the number of items in the population and r is the number of items considered from the population.

$$\text{Total combinations} = \left({}_{4}C_{1} + {}_{4}C_{2} + {}_{4}C_{3} + {}_{4}C_{4}\right)\left(\text{No. of repetitions}\right)^{*}$$
$$= (4 + 6 + 4 + 1)\ (2) = (15)\ (2) = 30$$

*both classical and matrix models are considered.

See Robert Mason, Statistical Techniques in Business and Economics (Homewood, Illinois: Richard D. Irwin, Inc., 1967), pp. 319-20.

11 indicate these combinations.

Figures 6 through 8 contain organizational structural models which are classical in nature; i.e., they are variations of line-functional structures. Figures 9 through 11 are organic and are based on variations to the more modern matrix organizational structural model. Model numbers one (Figure 6) and sixteen (Figure 9) represent the classical and matrix models shown in Figures 5 and 6, respectively.

These figures illustrate a multitude of considerations important to this study's analysis. The "level-of-authority" model column represents variations of Figure 3. In each of the figures, authority responsibility was either shared between levels or located at a single level. Authority location within the "level-of-authority" model is shown cross-hatched. It should be observed that as authority was assigned to lower levels, higher and intermediate unassigned levels were eliminated because they no longer served any purpose.

Numbers were assigned to each model in the model number column for accounting purposes, and the arrows containing the model numbers indicate that each "level-of-authority" model has a resulting organizational structural model. These models are variations of the hypothetical Space Base organizational structure portion of Figures 4 and 5, without titles. The cross-hatched areas represent

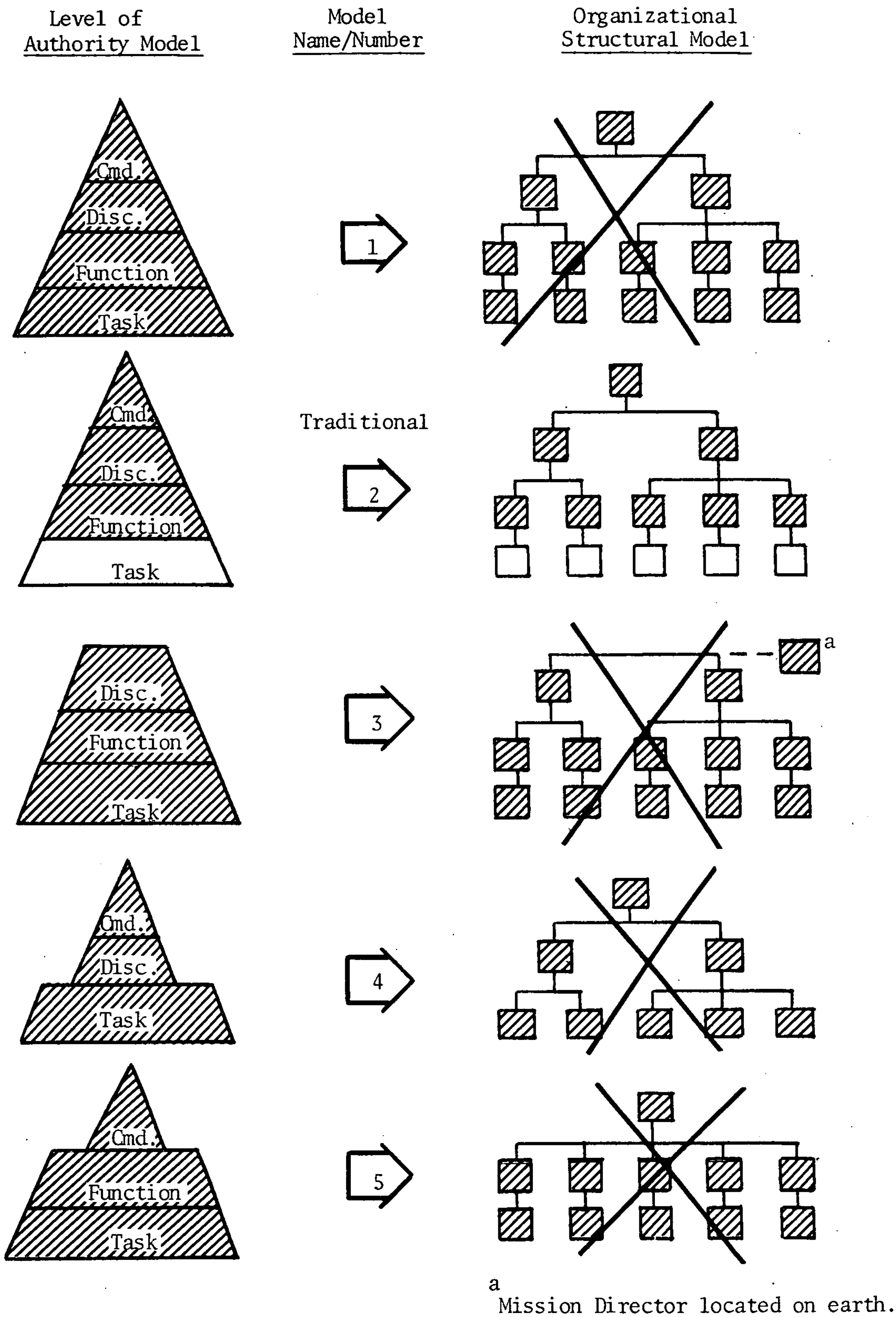
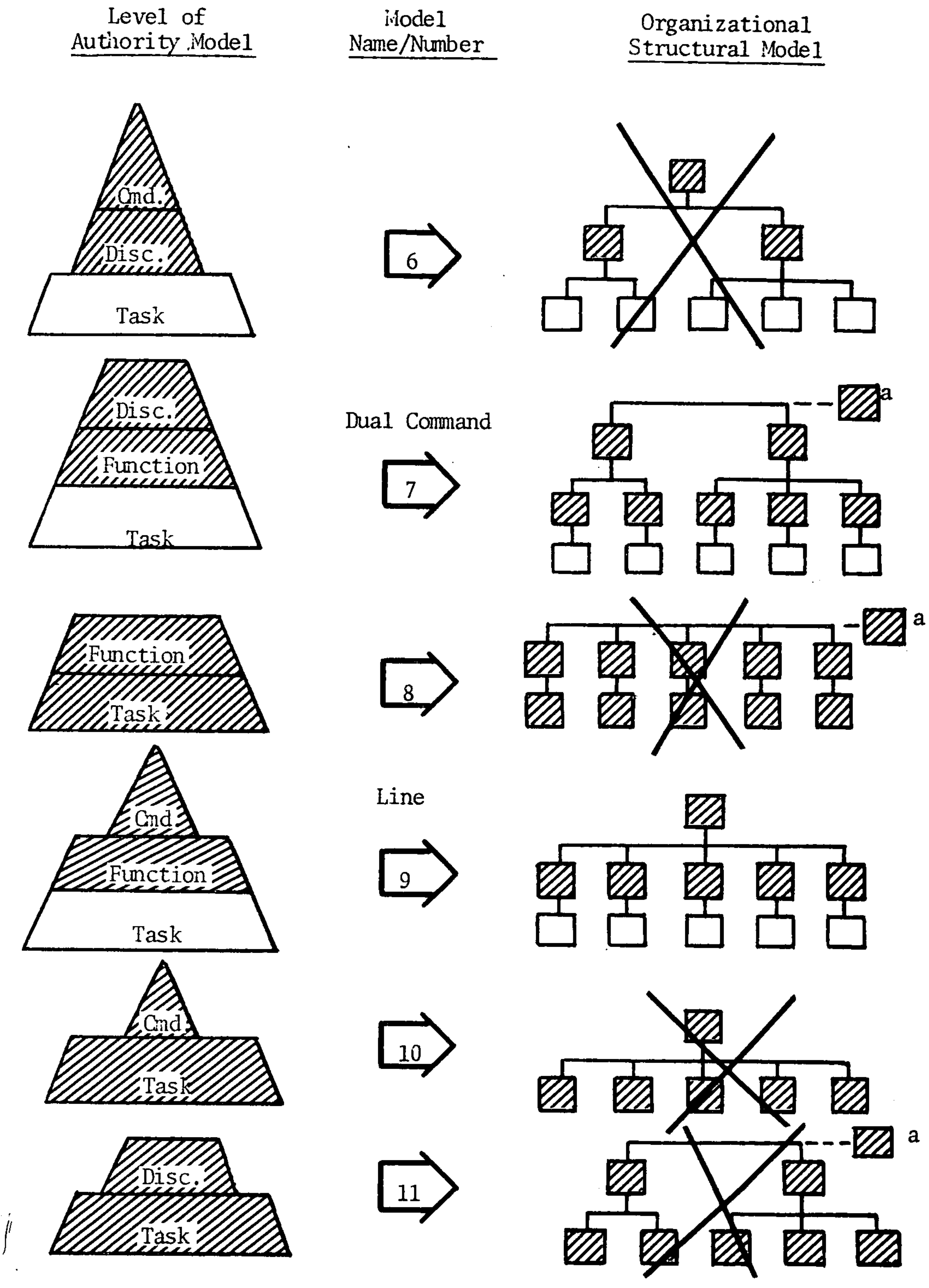


Fig. 6.--Classical models with authority shared between four/three levels.



[a] Mission Director located on earth.

Fig. 7.--Classical models with authority shared between two levels.

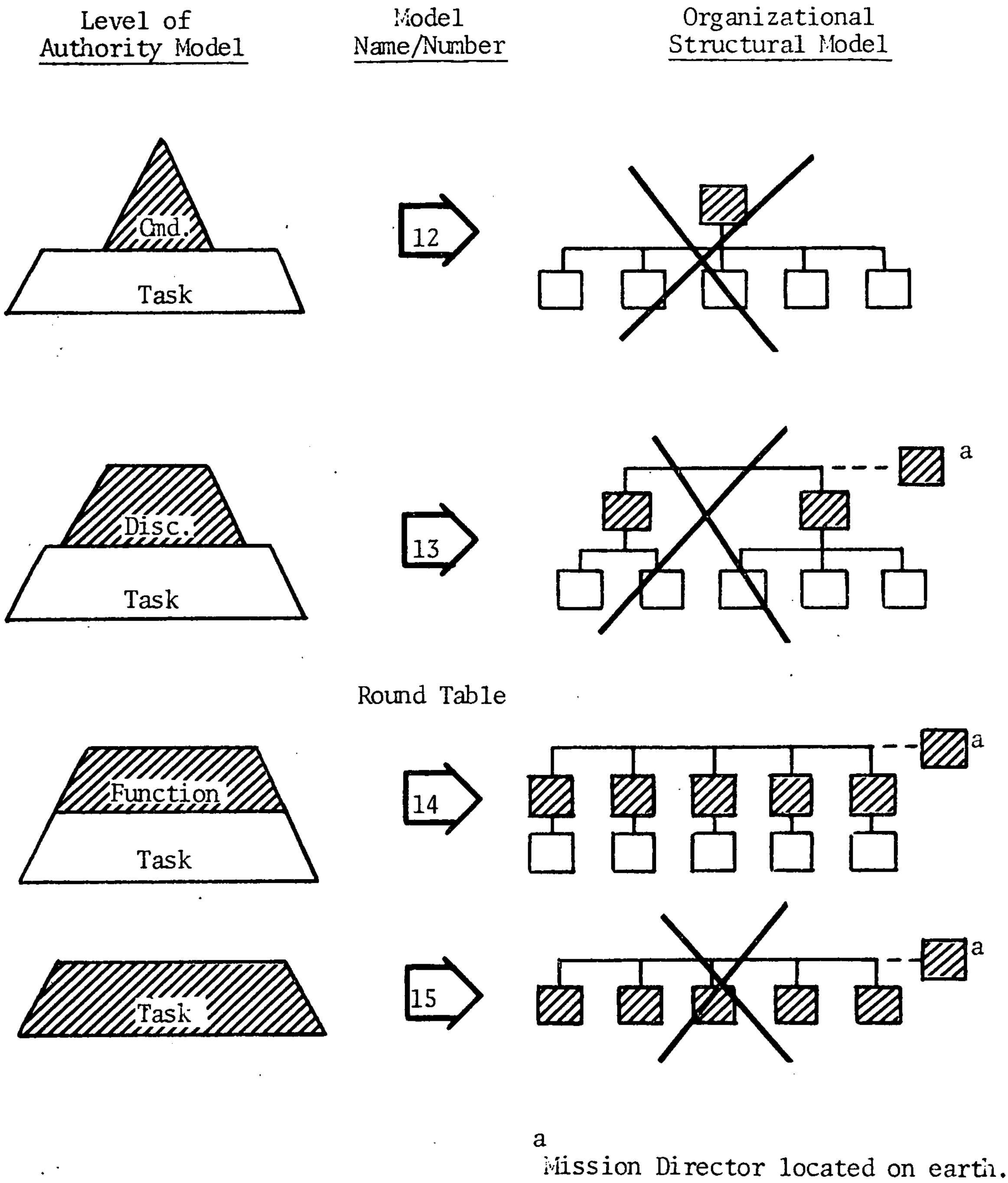
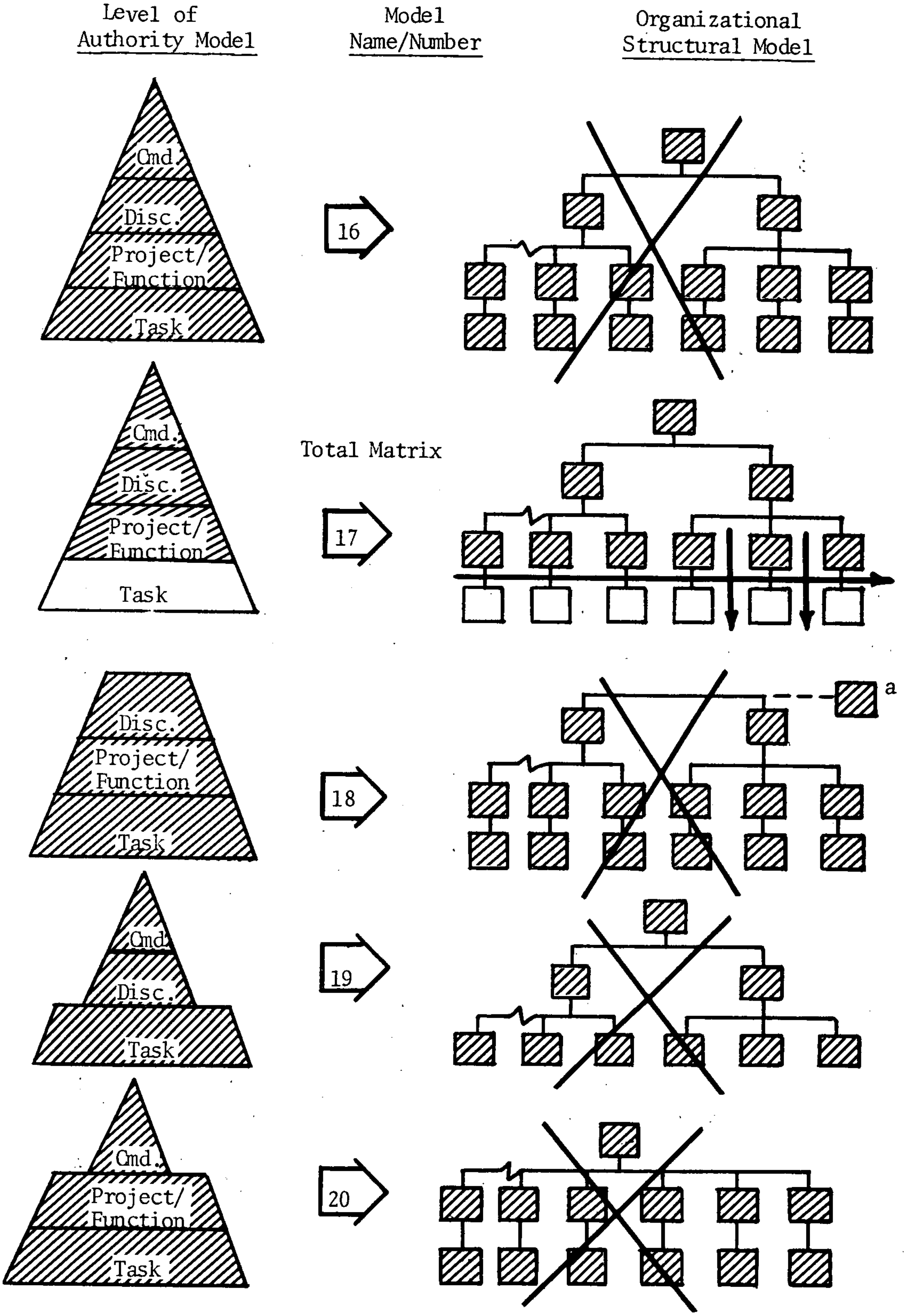
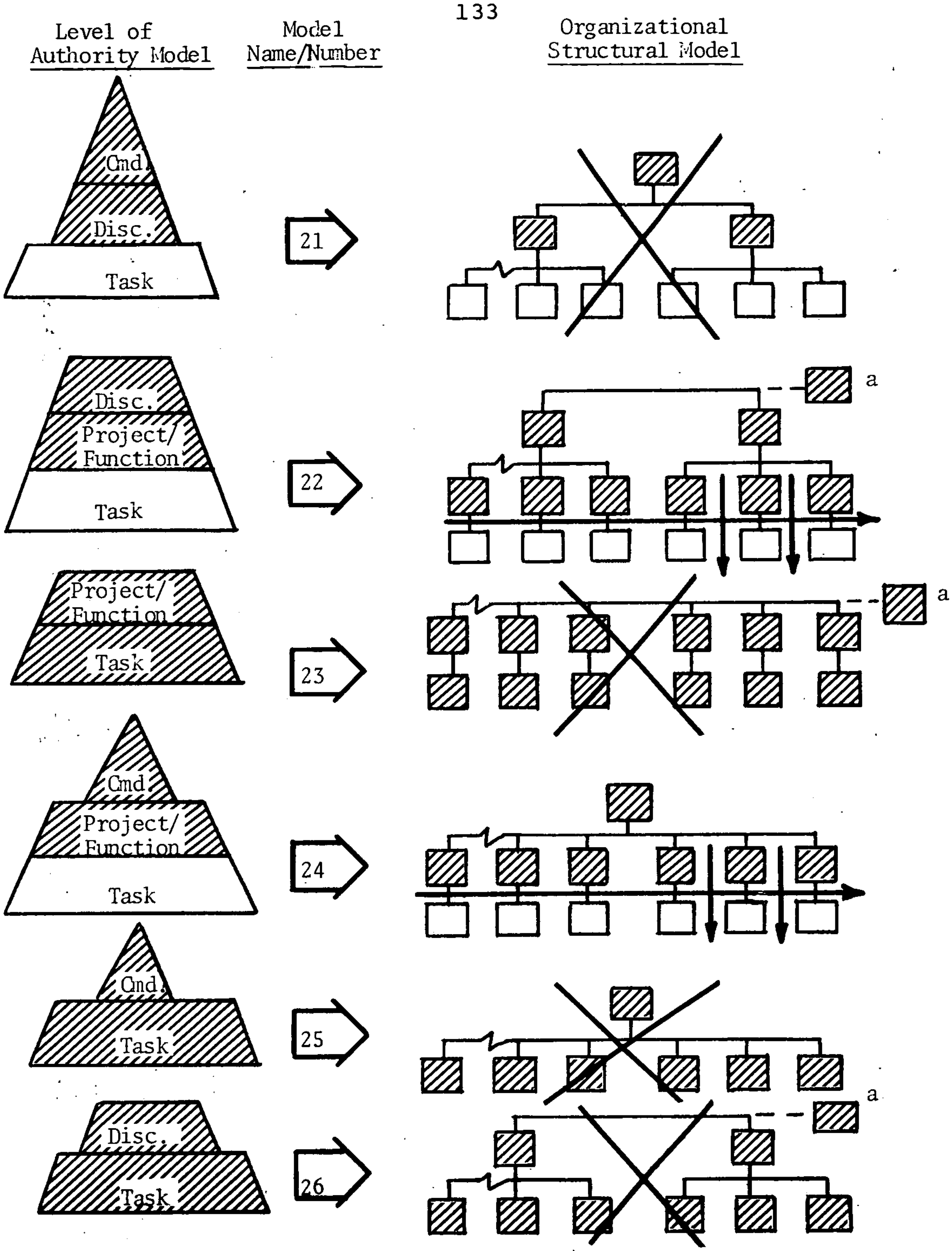


Fig. 8.--Classical models with authority located at a single level.



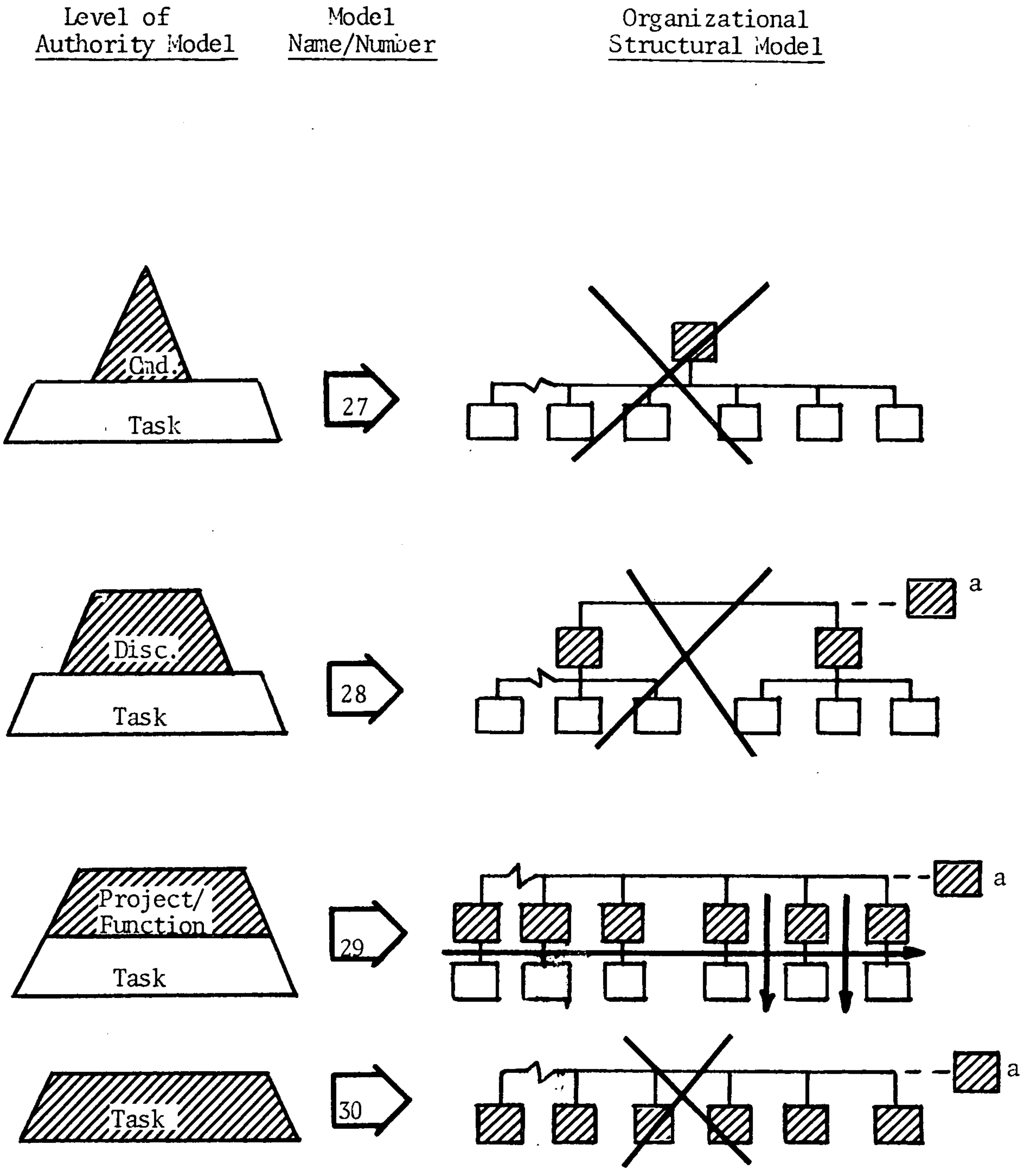
[a] Mission Director located on earth.

Fig. 9.--Matrix models with authority shared between four/three levels.



[a] Mission Director located on earth.

Fig. 10.--Matrix models with authority shared at two levels.



[a] Mission Director on earth.

Fig. 11.--Matrix models with authority located at a single level.

the location of either single level or shared multilevel authority assignments. Like the "level-of-authority" models, as authority assignments are moved downward, higher and intermediate unassigned structural levels were eliminated.

As noted in the figures, when a combination resulted in authority being shared at the same level, an earth-based Mission Director was identified. This assigned authority and responsibility were felt to be necessary in the event that those in authority reached a decision impass. No attempt was made to violate the program requirement of autonomous activities since the only purpose of the Mission Director was to serve as a final arbiter for unresolved, onboard problems. Fourteen models fit this situation.

Twenty-two of the thirty organizational structural models are shown crossed. The remaining eight are identified by a model name assigned by the researcher. The rationale for the identification of these models in this manner is presented in the next section.

Selection of a Feasible Set of Models

Screening Criteria

Because of the large number (thirty) of models generated using this technique, it was necessary to reduce the number to a more practical size for analysis. The reduction method used by the Grumman study team was to establish a set of criteria which could be used to screen out those models with limited value. The criteria used were practicality, differences, decision making, and program requirements.[1] The criterion of practicality eliminated models which lacked realism or were not feasible. Primary examples were those models where an excessively wide span of control resulted. The criterion of differences ensured that sufficient variation existed, so that each model could be independently evaluated against others.

The criterion of decision making was used to ensure that a clear cut, decision making capability existed. This criterion was not used to eliminate models which were not conventional, but only those which did not result in an eventual, final "ultimate" authority. Also considered under this criterion were those models which made communications, coordination, and integration between all Space Base personnel impossible. The final criterion was concerned with how well program requirements were satisfied by the specific model considered. Those models which would not accommodate the requirements identified in section I and associated with mission accomplishment were eliminated. For the purposes of this study, Space Base assumptions identified in section I were also included in this criterion.

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[1] Ibid., pp. D-5-D-7.

Organizational Structural Model Selection

Table 6 indicates the results of a screening by the researcher of the models contained in Figures 6 through 11. As the table indicates, twenty-two models were eliminated using the criterion of practicality primarily because of span of control problems. Several models generated (such as six, twelve, and thirteen) required that the total 50-100 member population of the Space Base be managed by one-to-three individuals with formal authority and responsibility assignments. In many cases, there was no span of control because authority was assigned in such a way that there were no superior/subordinate relationships. Examples were models one, three, four, and five. These spans of control in the Space Base situation were not considered practicable by the researcher.

The criterion of differences eliminated seven models, all of which were also rejected by the first criterion. The main reason that these models were eliminated was that they were identical in most respects to others considered. Several identical models were created in Figures 9 through 11, when matrix organizational structural models were formed. Examples were four and nineteen, six and twenty-one, and ten and twenty-five.

The criterion of decision making eliminated sixteen models because they did not provide a clear cut decision making capability. In the cases where models

TABLE 6

ORGANIZATIONAL STRUCTURAL MODEL
SCREENING RESULTS

Model Number	Screening Criteria: Practicality	Differences	Decision Making	Program Requirements	Acceptable
1	X		X		
2					Yes
3			X		
4	X		X		
5	X		X		
6	X				
7					Yes
8	X		X		
9					Yes
10	X		X	X	
11	X		X	X	
12	X				
13	X				
14					Yes
15	X		X	X	
16	X		X		
17					Yes
18	X		X		
19	X	X	X		
20	X		X		
21	X	X			
22					Yes
23	X		X		
24					Yes
25	X	X	X	X	
26	X	X	X	X	
27	X	X			
28	X	X			
29					Yes
30	X	X	X	X	
Total	22	7	16	6	8

were rejected, an eventual final "ultimate" authority did not exist. Models lacking this authority were those where authority was shared at all remaining levels simultaneously, or was assigned at the lowest level only. Under these circumstances there would be no leadership or decisive action, and the most likely result would be chaos. Examples were models one, three, four and five.

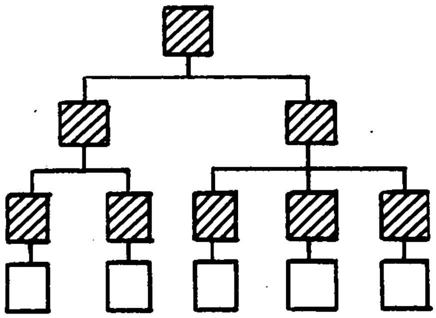
The last criterion was used to reject six models which did not satisfy general Space Base program requirements and assumptions. Models rejected were those which could not possibly accommodate a 50-100 member crew of technologists involved in multidisciplinary R&A activities in space for extended periods of time. Included were models ten, eleven, and fifteen.

Models were not considered acceptable if they were rejected by one or more screening criteria. As a result of this screening process by the researcher, only eight of the original thirty models remained for further analysis. These remaining models are shown in Figure 12 (classical models) and Figure 13 (matrix models), along with names assigned to each and major features. These features are a summary of the descriptions presented next.

Descriptions of Feasible Models

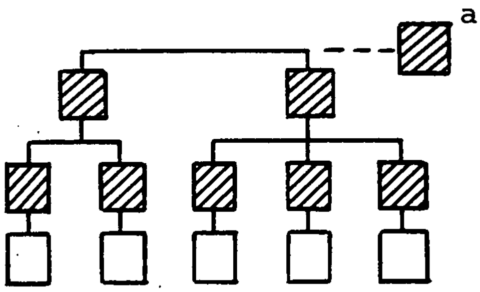
The eight models identified in Figures 12 and 13 were important to the study because they served as a feasible set of Space Base models for later analysis and evaluation. These models were called traditional, dual command, line, round table, total matrix, dual matrix, Organizational Structural Model — Model Name and Major Features

Traditional



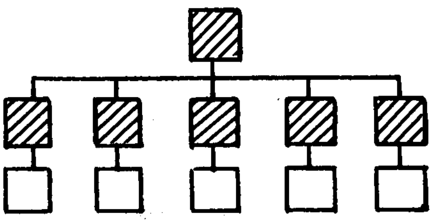
- Four-level model
  - Space Base Director, R&A and Support Operations Directors, functional managers, and technologists
- Traditional line organization with delegated authority and responsibility

Dual Command



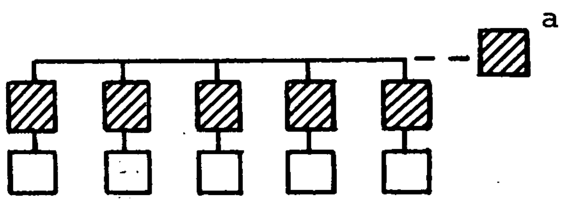
- Three-level model
  - R&A and Support Operations Directors, functional managers, and technologists
- Each Director with authority and responsibility for respective areas
- Mission Director resolves impasses

Line



- Three-level model
  - Space Base Director, functional managers, and technologists
- A simple line organization with delegated authority and responsibility

Round Table

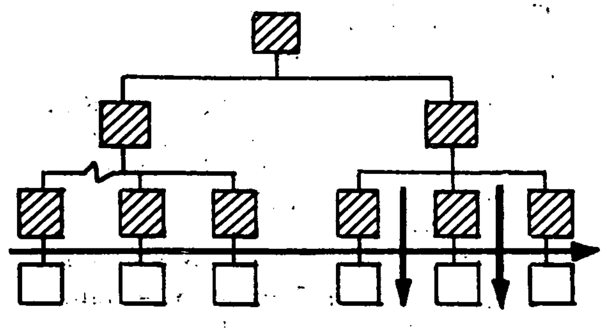


- Two-level model
  - Functional managers and technologists
- Decision committee of functional managers with rotating chairmanship
- Mission Director resolves impasses

[a]Mission Director located on earth

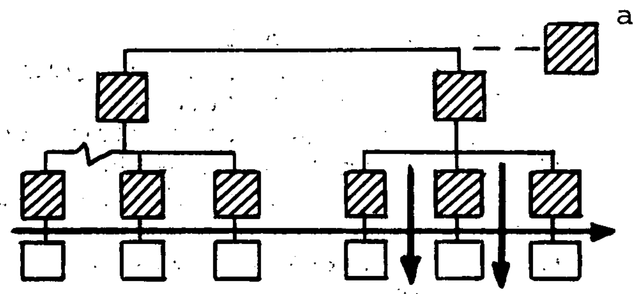
Fig. 12.--Classical organizational structural models to be evaluated and their major features.

Organizational Structural Model	Model Name and Major Features



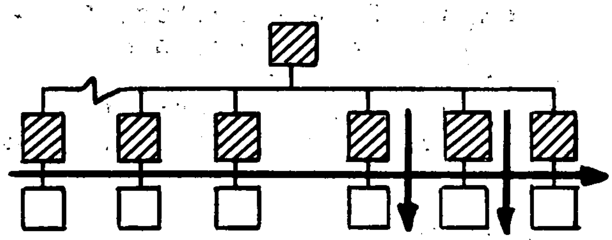
Total Matrix

- Four-level model
  - Space Base Director, R&A and Support Operations Directors, project/functional managers, and technologists
- Project/functional authority and responsibility
- Technologists assigned to projects as needed



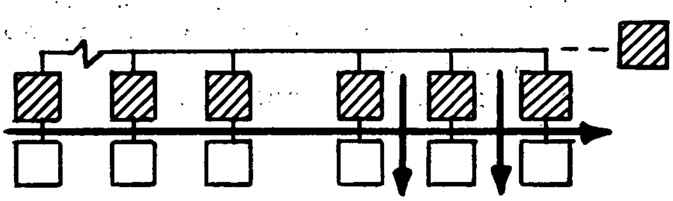
Dual Matrix

- Three-level model
  - R&A and Support Operations Directors, project/functional managers, and technologists
- Project/functional authority and responsibility
- Technologists assigned to projects as needed



Standard Matrix

- Three-level model
  - Space Base Director, project/functional managers, and technologists
- Project/functional authority and responsibility
- Technologists assigned to projects as needed



Shared Matrix

- Two-level model
  - Project/functional managers and technologists
- Decision committee of project and functional managers with rotating chairmanship
- Technologists assigned to projects as needed
- Mission Director resolves impasses

[a]Mission Director located on earth

Fig. 13.--Matrix organizational structural models to be evaluated and their major features.

standard matrix, and shared matrix. Each has different characteristics and complexities, and for that reason, a description of each was needed to ensure that evaluation team members had the same general understanding. The following descriptions identify the nature and scope of the eight remaining models.

Traditional

This four-tiered model consists of three management and one task levels. The three are the Space Base Director level, the R&A and Support Operations Directors level, and the level of the functional managers. The task level is comprised of groups of technologists assigned to various functions. The Space Base Director has ultimate authority and responsibility for overall in-orbit Space Base activities, operations, and crew safety required for goal accomplishment. The Director makes all significant operational decisions and resolves conflicts between lower level directors.

The R&A and Support Operations Directors have delegated authority and responsibility within their respective areas. Part of this responsibility is to resolve conflicts between the functional managers who report directly to them. The various functional managers have delegated authority and responsibility to ensure that resources under their control are effectively and efficiently utilized. The groups of technologists assigned to the various functions are responsible for Space Base task accomplishment only within their assigned work areas and capabilities.

Dual command

This model is a three-level structure consisting of two management and one task levels. The R&A and Support Operations Directors occupy the highest level, the various functional managers are next, and finally, groups of technologists are assigned to various functions at the lowest level. In this simple but somewhat unique structure, the R&A and Support Operations Directors share overall in-orbit Space Base authority and responsibility. The R&A Director is responsible for all R&A activities, while the Support Operations Director provides for all Space Base operations and for the comprehensive support required for R&A activities. The latter is solely responsible for personnel safety and welfare. In the event of an impasse between these directors on issues of common interest, an earth-based Mission Director serves as the final arbiter.

The various functional managers have delegated authority and responsibility to ensure that resources under their control are effectively and efficiently utilized. The groups of technologists assigned to the various functions are responsible for Space Base task accomplishment only within their assigned work areas and capabilities.

Line

This three-tiered model consists of two management and one task levels. They are the Space Base Directors level, the level of the various functional managers, and the technologist task level. In this simplified line organization, the Space Base Director has total authority and responsibility for in-orbit Space Base activities, operations, and crew safety. The resolution of conflicts between the functional managers occurs at this level.

The functional managers have delegated authority for the activities within their functional responsibility. These managers ensure that resources under their control are effectively and efficiently used. The groups of technologists assigned to the various functions are responsible for Space Base task accomplishment only within their assigned functional areas and capabilities.

Round table

This is a two-level model consisting of one management and one task levels. These levels are the level of the various functional managers, and the technologist task level. Overall in-orbit Space Base authority and responsibility is vested in a "decision committee" comprised of the functional managers. Pro tem chairmanship of the committee is in accordance with a prearranged sequence and plan. Each functional manager serves for an equal period of time on a rotating basis.

All significant decisions relating to R&A and support operations functions are made by consensus action of the decision committee. If significant disagreement results, the earth-based Mission Director acts as final arbiter. The functional managers, serving in a dual role, possess delegated authority and responsibility within their respective areas to ensure that resources under their control are effectively and efficiently used. Groups of technologists assigned to the various functions are responsible for Space Base task accomplishment only within their assigned functional areas and capabilities.

Total matrix

This four-tiered model consists of three management and one task levels. The three are the Space Base Director level, the R&A and Support Operations Directors level, and the level of project and functional managers. The task level is comprised of groups of technologists assigned to various projects and functions. The Space Base Director has ultimate authority and responsibility for overall in-orbit Space Base activities, operations, and crew safety required for goal accomplishment. The Director makes all significant operational decisions and resolves conflicts between lower-level directors.

The R&A and Support Operations Directors have delegated authority and responsibility for goal accomplishment within their respective areas. Part of this responsibility is to resolve conflicts between the project/functional managers who report directly to them. These project/functional managers have delegated authority and responsibility to ensure that resources under their control are effectively and efficiently utilized. The authority and responsibility of the project managers are horizontal in nature, while those of the functional managers are vertical. Technologists are assigned to various projects on an as-needed basis through mutual consent of the managers involved or by the assignment from earth because of special skill needs.

Dual matrix

This model is a three-level structure consisting of two management and one task levels. The R&A and Support Operations Directors occupy the highest level, the various project/functional managers are next, and finally, groups of technologists are assigned at the lowest level. In this simple but somewhat unique structure, the R&A and Support Operations Directors share overall in-orbit Space Base authority and responsibility. The R&A Director is responsible for all R&A project activities, while the Support Operations Director provides for all Space Base operations and for the comprehensive support required for the R&A projects. The latter is solely responsible for personnel safety and welfare. In the event of an impasse between these directors on issues of common interest, an earth-based Mission Director serves as the final arbiter.

The various project/functional managers have delegated authority and responsibility to ensure that resources under their control are effectively and efficiently utilized. This delegated authority and responsibility for the project managers is horizontal in nature, while that of the functional managers is vertical. Technologists are assigned to various projects on an as-needed basis through mutual consent of the managers involved, or by the direct assignment from earth because of special skill needs.

Standard matrix

This three-tiered model consists of two management levels and one task level. They are the Space Base Director level, the level of the various projects/functional managers, and the technologists task level. The Space Base Director has total authority and responsibility for in-orbit Space Base activities, operations, and crew safety. The resolution of conflicts between the project and functional managers occurs at this level.

The project and functional managers have delegated authority for the activities within their responsibility. They are primarily responsible for ensuring that resources under their control are effectively and efficiently used. The authority and responsibility of the project managers are horizontal in nature, while those of the functional managers are vertical. The groups of crew member technologists are assigned to the various projects on an as-needed basis through mutual consent of the managers involved, or by the direct assignment from earth because of special skill needs.

Shared matrix

This is a two-level model consisting of one management and one task levels. These levels are the level of the various project and functional managers and the technologists task level. Overall in-orbit Space Base authority and responsibility is vested in a "decision committee" comprised of the project and functional managers. Pro tem chairmanship of the committee is in accordance with a prearranged sequence and plan. Each project and functional manager serves for an equal period of time on a rotating basis.

All significant decisions relating to project and functional activities are made by consensus action of the decision committee. If significant disagreement results, the earth-based Mission Director acts as arbiter. The project and functional managers, serving in a dual role, possess delegated authority and responsibility within their respective areas to ensure that resources under their control are effectively and efficiently utilized. The authority and responsibility of the project manager are horizontal in nature while those of the functional managers are vertical.

Technologists are assigned to the various projects on an as-needed basis through mutual consent of the managers involved or by the direct assignment from earth because of special skill needs.

The Evaluation Process

The development of forty-six criteria which could serve as standards on which judgments could be made and the narrowing of feasible organizational structural models to eight, using the rationale discussed previously in this section, required a method to evaluate these models against the criteria. The remaining portion of this section describes that method.

Evaluation Team Membership

Two pilot and one final evaluation, using five man teams, were accomplished to obtain data for this study. Pilot and primary evaluators were selected based on the requirement that each was knowledgeable in one or more of the areas of investigation previously identified and discussed, namely: (1) program requirements and assumptions, (2) management concepts and practices, and (3) applicable analog data. To provide a wide but knowledgeable range of views, a diversified team was selected. While it would have been possible for the researcher to make this evaluation, it was felt that better results could be achieved if a knowledgeable team performed this task. The researcher, however, did serve as a member of all teams.

Separate and independent pilot teams (except for the researcher) were composed of knowledgeable John F. Kennedy Space Center, Florida, NASA employees of various disciplines.

The primary evaluation team was composed of three NASA, one contractor, and one academic representative. The NASA personnel were from two NASA centers - the John F. Kennedy Space Center, Florida, and the Marshall Space Flight Center, Huntsville, Alabama. The contractor member was from the Grumman Corporation, Bethpage, New York, and was the manager for the Grumman Space Station study extensively referenced. The academic representative was the department head of the general business department at East Texas University's School of Business and was a former NASA employee. The areas of specialized capabilities and interests, related experience, employer and location, and formal education of each evaluation team member are included in Table 7.

Evaluation Scores

Evaluation scores developed by the researcher, as shown in Table 8, provided a means for members of the pilot

TABLE 7

EVALUATION TEAM MEMBERSHIP

	Hugh E. McCoy	James M. Ragusa	Chester B. May	Samuel C. Campbell	Dr. Edgar J. Manton
Education/ discipline(s)	Management/ engineering	Management/ engineering	Engineering science/ physiology/human relations	Experimental psychology/mathematics	Management/ engineering
Experience related to study	Former NASA-KSC Mgr. for Advanced Mission Studies--including Space Station and Space Base--has knowledge of space environments, management practices and principles.	Former member of NASA-KSC Advanced Missions Planning Group--knowledgeable of analogs, space activities, operations, and related behavioral science studies.	One of six crewmen on Ben Franklin Gulf Stream Drift Mission--responsible for crew habitability, human behavior, environment and microbiology studies during mission.	Study manager for Grumman Space Station Command Structure Study--knowledgeable of analogs and psychological/physiological considerations of space environments.	Knowledgeable of space operations/management practices and principles and behavioral science studies related to the study.
Employer/location	NASA-Kennedy Space Center, Florida	NASA-Kennedy Space Center, Florida	NASA-Marshall Space Flight Center, Alabama	Grumman Aircraft Corporation, Bethpage, New York	East Texas University Commerce, Texas
Formal education	Clemson University Stanford University (Sloan Fellow)	University of Illinois Florida State University	Marshall University University of Oklahoma	Manhattan College Fordham University	U.S. Naval Academy Florida State University

and primary evaluation teams to quantify their feelings by scoring each model on its criteria satisfying ability. Interval scale values with a range from four to zero were used. A significant advantage in using these scales was that arithmetic calculations can be made. Descriptions for these five scores represent an all-inclusive range from criterion "completely satisfied" to "not at all satisfied." These descriptions and scores were found during two pilot runs to be adequate to identify all possibilities of satisfaction of criterion by the models considered. It was felt by the researcher, and later verified by various evaluators, that scores beyond a range from four to zero would be in excess of the perceptual ability of evaluators to distinguish criteria satisfaction.

TABLE 8

EVALUATION SCORES

Descriptions of Criterion Satisfaction	Scores
Completely satisfied	4
Substantially satisfied	3
Partially satisfied	2
Poorly satisfied	1
Not at all satisfied	0

Evaluation Activities and Instructions

The purpose of the pilot activities was to test and refine the evaluation technique. In each of these runs, a group session lasting approximately one-and-one-half hours was used to review, explain, and answer questions concerning instructions and evaluation material provided. These group sessions ensured that each team member had a common understanding of the models, the criteria, and what was expected of them during the evaluation activities. Several minor difficulties identified during the first run were corrected and factored into the instructions and evaluation material used for the second run. Corrections included several criteria which were deleted or revised, and rearrangement of models to aid in understanding. Pilot team results were obtained in early September 1972.

The results of these pilot evaluations provided encouragement to mail revised final evaluator instructions and evaluation material to the primary evaluation team members in late September 1972. Appendix E identifies these instructions and material, and includes supplement material which was not included elsewhere in this study. Conference and individual telephone calls followed to ensure that a common baseline of understanding existed. Results were received from the primary evaluators during October 1972. These data were used by the researcher to verify that the evaluators generally understood the nature and scope of the models and the criteria. If a reasonable doubt existed, as indicated by significant variation in scores when compared to the consensus of other evaluator scores, the evaluator was contacted and clarification was provided if needed. In several cases, revisions to scores and satisfaction rationale resulted.

Each evaluator was instructed to work independently and proceed as follows: The eight models were to be evaluated in turn against the first criterion. An evaluation score from four to zero was to be assigned to each model, based on the evaluator's judgment as to how well the criterion was satisfied. After each model had been scored, the models were to be compared against the second criterion and assigned a score. This process was to be continued until the eight models were evaluated against the forty-six criteria. Each model thus received five scores (one from each evaluator) against each criterion. When a model did not completely satisfy a criterion (i.e., a value of four was not assigned), the evaluator was asked to identify reasons on forms provided.

Summary

This chapter indicated how the study was conducted. Major consideration was given to (1) the development of organizational structural evaluation criteria, (2) development of classical and modern organizational structural models and their reduction to a much smaller, feasible set for evaluation purposes, and (3) a description of the evaluation process.

Forty-six criteria with rationale were developed and synthesized from data which were presented in sections I and II. Major sources of these data were found in (1) program requirements and assumptions, (2) management concepts and practices, and (3) applicable analog data. The specific source of these data and rationale for each were provided. Sixteen criteria came from the first source, nineteen from the second, and eleven from the third.

Thirty models were identified by considering various combination of authority assigned to various levels of classical and modern matrix organizational hierarchical pyramids. These levels were identified as command, discipline, function/project, and task. The hypothetical Space Base organizational structural models served to help in the understanding of the variations which were considered. After screening, a much smaller feasible set of eight models resulted. This screening was accomplished by using criteria of practicality, difference, decision-making, and program requirements and assumptions. The eight models were described and major features identified. These models were called traditional, dual command, line, round table, total matrix, dual matrix, standard matrix, and shared matrix. The first four were classical in nature while the last four were modern matrix variations.

Last, the evaluation process was described. It included an identification of pilot and primary evaluation team members, evaluation scores, and evaluation activities and instructions. A primary evaluation team consisted of five knowledgeable NASA, contractor, and academic members. These evaluators, after pilot runs by two other teams, independently scored the eight models by determining how well they felt each model satisfied each of the forty-six criteria. To do this, a four to zero interval scale scoring system was used independently by each of the evaluators. Data derived from this process served as the basis for section IV--Presentation and Analysis of Data.

IV. PRESENTATION AND ANALYSIS OF DATA

The purpose in conducting this study was to identify an optimum hypothetical organizational structure which would assure the orderly, effective, and efficient management of a mixed Space Base crew in pursuit of mission goals. Conduct of this study and the resulting data obtained helped to realize this purpose. Findings which result from the evaluation team data and subsequent analyses were used by the researcher to identify the most feasible organizational structure model from a group of eight models which were considered. These findings and analyses constitute the final phase of the study methodology.

Findings and Preliminary Analysis

The raw score data presented in Table 9 are the tabulated evaluation team relative scorings of the eight models. The scores of the five evaluators (A thru E) were totaled for each model and criterion and represent each model's score (T). The column totals for each model are obtained by summing the evaluator totals (T) for each criterion. From these column totals, a ranking of models was obtained. When ranked, the descending order was (1)

TABLE 9

EVALUATION TEAM RELATIVE SCORING OF ORGANIZATIONAL STRUCTURAL MODELS
(RAW DATA)

Evaluation Criteria	Criteria Level	Organizational Structural Models															
		Traditional		Dual Command		Line		Round Table		Total Matrix		Dual Matrix		Standard Matrix		Shared Matrix	
		ABCDE	T	ABCDE	T	ABCDE	T	ABCDE	T	ABCDE	T	ABCDE	T	ABCDE	T	ABCDE	T
<u>Objectives and Plans</u>																	
1. Multi. R&A Activities																	
1.1 Variety of R&A	I	34243	16	34143	15	32342	14	31141	10	44444	20	44344	19	42343	16	41142	12
1.2 Undefined activities	I	34232	14	33132	12	32233	13	31131	9	44444	20	44343	18	42343	16	41142	12
1.3 Assigned priority	II	44243	17	34143	15	43343	17	31142	11	44444	20	34243	16	43344	18	32142	12
1.4 Situat. requirements	II	42333	15	22132	10	34433	17	22131	9	43444	19	23143	13	34344	18	22142	11
2. Crew Size																	
2.1 Large crew	I	44334	18	44334	18	32333	14	31332	12	44444	20	44444	20	42344	17	41243	14
2.2 Crew growth	I	44243	17	44243	17	33142	13	32142	12	43444	19	42244	16	32343	15	31243	13
2.3 Many technologists	I	33243	15	23243	14	33343	16	23343	15	44344	19	44243	17	44344	19	44243	17
<u>Capability of Personnel</u>																	
3. Crew composition																	
3.1 Mixed crew	I	44344	19	44234	17	44344	19	44234	17	44444	20	44334	18	44344	19	44234	17
3.2 Multination crew	I	44333	17	34233	15	43333	16	23232	12	44444	20	34343	17	43244	17	23142	12
3.3 Diverse backgrounds	II	34343	17	24243	15	33343	16	23242	13	44444	20	34343	17	43244	17	33142	13
3.4 Task leader	II	42322	13	42122	11	32122	10	22121	8	44444	20	44344	19	34343	17	24142	13
3.5 P.I. participation	II	32342	14	32142	12	33342	15	23341	13	44444	20	44344	19	44344	19	44443	19
3.6 Varying crew size	II	22332	12	22132	10	22132	10	23232	12	44444	20	44344	19	44444	20	44344	19
4. Crew Selection and Training																	
4.1 Min. astro training	I	44444	20	44344	19	34244	17	34244	17	44444	20	44344	19	44344	19	44244	18
4.2 Dual selection	II	44344	19	44344	19	44244	18	44344	19	44344	19	44344	19	44344	19	44344	19

TABLE 9--Continued.

Evaluation Criteria	Criteria Level	Organizational Structural Models: Traditional		Dual Command		Line		Round Table		Total Matrix		Dual Matrix		Standard Matrix		Shared Matrix	
		ABCDE	T	ABCDE	T	ABCDE	T	ABCDE	T	ABCDE	T	ABCDE	T	ABCDE	T	ABCDE	T
4.3 Crew selection	II	43243	16	43243	16	44143	16	44344	19	44344	19	44344	19	43244	17	43344	18
4.4 Train./indoctrin.	I	44344	19	43244	17	32243	14	30142	10	42334	16	42134	14	41233	13	41132	11
Environment																	
5. Mission Duration																	
5.1 Ten-year life	I	44333	17	43233	15	32333	14	21232	10	44444	20	43244	17	32344	16	20143	10
5.2 Varying tours	I	34344	18	34244	17	23343	15	21242	11	44444	20	44244	18	43343	17	40142	11
5.3 Multishift work	I	34343	17	32243	14	32343	15	21242	11	44444	20	44244	18	34344	18	34243	16
5.4 Replacement	I	23344	16	12243	12	22342	13	11241	9	44444	20	44244	18	43344	18	42142	13
6. Environmental Factors																	
6.1 Rewards vs. costs	II	32343	15	33242	14	23343	15	23242	13	43444	19	44343	18	34344	18	34242	15
6.2 Cohesive group	II	32343	15	22232	11	42343	16	22232	11	33434	17	23123	11	32333	14	22222	10
6.3 Work schedule	II	23343	15	23243	14	33342	15	33242	14	43444	19	43344	18	43343	17	43243	16
6.4 Prof. satisfaction	II	42342	15	42242	14	33342	15	23241	12	43444	19	44344	19	44344	19	44243	17
6.5 Human capabilities	II	22342	13	22242	12	33343	16	12243	12	33444	18	23143	13	44344	19	34243	16
6.6 Full employment	II	24333	15	24233	14	33333	15	12232	10	34443	18	34343	17	43344	18	21242	11
6.7 Various construct.	I	34333	16	14233	13	24333	15	14232	12	44444	20	24143	14	34344	18	24243	15
7. Autonomy of Operations																	
7.1 Autonomous operations	I	33344	17	12122	8	33244	16	12122	8	43443	18	12222	9	43343	17	12122	8
7.2 Planning/scheduling	I	44344	19	33233	14	33244	16	21132	9	43444	19	23233	13	42344	17	21133	10
7.3 Nonduty work	II	34344	18	34244	17	34244	17	24244	16	44444	20	44344	19	44344	19	44244	18

TABLE 9--Continued.

Evaluation Criteria	Criteria Level	Organizational Structural Models															
		Traditional		Dual Command		Line		Round Table		Total Matrix		Dual Matrix		Standard Matrix		Shared Matrix	
		ABCDE	T	ABCDE	T	ABCDE	T	ABCDE	T	ABCDE	T	ABCDE	T	ABCDE	T	ABCDE	T
Authority																	
8. Authority and Responsibility																	
8.1 General definition	II	44344	19	14343	15	33244	16	11341	10	43244	17	13342	13	43243	16	11341	10
8.2 Various managers	II	44344	19	24344	17	33344	17	12331	10	44344	19	23244	15	22344	15	11231	8
8.3 Unity of command	II	44444	20	24233	14	43444	19	11132	8	43444	19	23133	12	42444	18	11132	8
8.4 Span of control	II	24233	14	34232	14	43233	15	11232	9	24343	16	34344	18	42344	17	11343	12
8.5 Work flexibility	II	22243	13	12343	13	33243	15	14342	14	33444	18	33244	16	44344	19	24243	15
8.6 Personal freedom	II	42224	14	42324	15	43234	16	24344	17	42223	13	42423	15	43233	15	34443	18
9. Comm., Coord., and Integ.																	
9.1 Group decision making	II	32243	14	33343	16	43244	17	24443	17	32244	15	33344	17	44244	18	24443	17
9.2 Quality and speed	II	44344	19	33223	13	43444	19	20122	7	43344	18	32223	12	42443	17	20122	7
9.3 Line of commun.	II	44444	20	43243	16	32343	15	21141	9	33444	18	32243	14	22342	13	11141	8
9.4 Bidirectional comm.	II	44343	18	33343	16	43243	16	32443	16	33243	15	32343	15	22143	12	21443	14
9.5 Tech. profes. comm.	II	34343	17	34343	17	42243	15	42443	17	33344	17	33344	17	42244	16	42443	17
9.6 Two-way audio/video	II	44344	19	44344	19	44244	18	44444	20	44344	19	44344	19	44244	18	44444	20
9.7 Min. interfaces	II	33423	15	33223	13	44334	18	22142	11	32423	14	32223	12	42334	16	21142	10
9.8 Feedback	II	42334	16	42333	15	33234	15	34432	16	43344	18	43343	17	34244	17	34443	18
9.9 Creative climate	II	42343	16	43343	17	43243	16	44443	19	44344	19	44344	19	44244	18	44444	20
	Total	757		671		715		576		853		752		786		638	
	Rank	3		6		5		8		1		4		2		7	

total matrix, (2) standard matrix, (3) traditional, (4) dual matrix, (5) line, (6) dual command, (7) shared matrix, and (8) round table.

Up to this point all criteria have been equally weighted. It should be obvious that those criteria which fall into the program requirements and assumptions category are generally of more importance to NASA than are those of management concepts and practices and applicable analog data. Even the assumptions identified by the researcher will probably be program requirements in time. Space Base program requirements and assumptions criteria were, therefore, considered mandatory and assigned a weighting factor of one and were called level I criteria. A second category of criteria for weighting purposes was management concepts and practices and applicable analog data. These criteria were assigned a weighting factor of one-half, and were identified as level II criteria. Table 9 indicates which criteria are contained in each category.

Tables 10 and 11 are tabulations of scores abstracted from Table 9 for level I and II criteria, respectively. Revised model column totals and ranks by criteria level are shown. A tabulation of weighted level I and II criteria scores, as well as ranks, are included at the end of Table 11. Because of the wide variation in model column scores, it was decided by the researcher to consider only the four highest ranking models for subsequent

TABLE 10

TABULATION OF SCORES FROM EVALUATION ANALYSIS: LEVEL I CRITERIA

Level I Criteria	Organizational Structural Models								Range of Scores[a]
	Traditional	Dual Command	Line	Round Table	Total Matrix	Dual Matrix	Standard Matrix	Shared Matrix	
1.1	16	15	14	10	20	19	16	12	4
1.2	14	12	13	9	20	18	16	12	6
2.1	18	18	14	12	20	20	17	14	3
2.2	17	17	13	12	19	16	15	13	4
2.3	15	14	16	15	19	17	19	17	4
3.1	19	17	19	17	20	18	19	17	2
3.2	17	15	16	12	20	17	17	12	3
4.1	20	19	17	17	20	19	19	18	1
4.4	19	17	14	10	16	14	13	11	6
5.1	17	15	14	10	20	17	16	10	4
5.2	18	17	15	11	20	18	17	11	3
5.3	17	14	15	11	20	18	18	16	3
5.4	16	12	13	9	20	18	18	13	4
6.7	16	13	15	12	20	14	18	15	6
7.1	17	8	16	8	18	9	17	8	9
7.2	19	14	16	9	19	13	17	10	6
Total 16	275	237	240	184	311	265	272	209	. .
Rank . .	2	6	5	8	1	4	3	7	. .

[a]The dual command, line, round table, and shared matrix models are not included.

TABLE 11

TABULATION OF SCORES FROM EVALUATION ANALYSIS:
LEVEL II CRITERIA

Level II Criteria	Organizational Structural Models								Range of Scores[a]
	Traditional	Dual Command	Line	Round Table	Total Matrix	Dual Matrix	Standard Matrix	Shared Matrix	
1.3	17	15	17	11	20	16	18	12	4
1.4	15	10	17	9	19	13	18	11	6
3.3	17	15	16	13	20	17	17	13	3
3.4	13	11	10	8	20	19	17	13	7
3.5	14	12	15	13	20	19	19	19	6
3.6	12	10	10	12	20	19	20	19	8
4.2	19	19	18	19	19	19	19	19	0
4.3	16	16	16	19	19	19	17	18	3
6.1	15	14	15	13	19	18	18	15	4
6.2	15	11	16	11	17	11	14	10	6
6.3	15	14	15	14	19	18	17	16	4
6.4	15	14	15	12	19	19	19	17	4
6.5	13	12	16	12	18	13	19	16	6
6.6	15	14	15	10	18	17	18	11	3
7.3	18	17	17	16	20	19	19	18	2
8.1	19	15	16	10	17	13	16	10	6
8.2	19	17	17	10	19	15	15	8	4
8.3	20	14	19	8	19	12	18	8	8
8.4	14	14	15	9	16	18	17	12	4
8.5	13	13	15	14	18	16	19	15	6
8.6	14	15	16	17	13	15	15	18	2

TABLE 11.--Continued.

Level II Criteria	Organizational Structural Models: Traditional	Dual Command	Line	Round Table	Total Matrix	Dual Matrix	Standard Matrix	Shared Matrix	Range of Scores[a]
9.1	14	16	17	17	15	17	18	17	4
9.2	19	13	19	7	18	12	17	7	7
9.3	20	16	15	9	18	14	13	8	7
9.4	18	16	16	16	15	15	12	14	6
9.5	17	17	15	17	17	17	16	17	1
9.6	19	19	18	20	19	19	18	20	1
9.7	15	13	18	11	14	12	16	10	4
9.8	16	15	15	16	18	17	17	18	2
9.9	16	17	16	19	19	19	18	20	3
Total 30	482	434	475	392	542	487	514	429	. .
Rank . .	4	6	5	8	1	3	2	7	. .
Level I Criteria	275	237	240	184	311	265	272	209	
½ Level II Criteria	241	217	237.5	196	271	243.5	257	214.5	
Total	516	454	477.5	380	582	508.5	529	423.5	
Rank	3	6	5	8	1	4	2	7	

[a]The dual command, line, round table, and shared matrix models are not included.

analysis. The main reason was that a major discontinuity in scores consistently occurred between the fourth and fifth ranked models. Elimination of additional models within the top four models was considered by the researcher to be premature, since the reasons for variations between scores and ranks were not evident. The highest ranked classical and matrix models as well as two other matrix models are, therefore, assessed.

Tables 10 and 11 also include a range of scores column for the four finalist candidate models. Values are seen to range from nine to zero, and only a relatively few of the criteria show high ranges. These criteria were considered to be discriminating, since they vary significantly between the candidate models. They were important to this study because they were used in the final analysis to select the best model.

Table 12 lists ten discriminating level I and II criteria. The five level I criteria were identified because of the break in range of scores between six or greater and four or less. A different rationale for selecting level II discriminating criteria was used, however. After careful consideration by the researcher, it was realized that because of previous weighting factor considerations, level II criteria could and should only have a limited influence on final selection of a recommended model. For that reason, only the five level II criteria with ranges of

TABLE 12

DISCRIMINATING CRITERIA ANALYSIS

Discriminating Criteria	Organizational Structural Models				Range of Scores
	Traditional	Total Matrix	Dual Matrix	Standard Matrix	
Level I[a]					
1.2 Undefined activities	14	20	18	16	6
4.4 Training and indoctrination	19	16	14	13	6
6.7 Various construction	16	20	14	18	6
7.1 Autonomous operations	17	18	9	17	9
7.2 Planning and scheduling	19	19	13	17	6
Total	85	93	68	81	. .
Rank	2	1	4	3	. .
Level II[b]					
3.4 Task leader	13	20	19	17	7
3.6 Varying crew size	12	20	19	20	8
8.3 Unity of command	20	19	12	18	8
9.2 Quality and speed	19	18	12	17	7
9.3 Line of communications	20	18	14	13	7
Total	84	95	76	85	. .
Rank	3	1	4	2	. .
Weighted[c]					
Level I Criteria	85	93	68	81	
½ Level II Criteria	42	47.5	38	42.5	
Total	127	140.5	106	123.5	
Rank	2	1	4	3	

[a]Level I criteria with range of scores six or greater from Table 10.
[b]Level II criteria with range of scores seven or greater from Table 11.
[c]A weighting factor of one-half was assigned to the Level II criteria.

scores of seven or higher were considered. They were intended to serve either to validate or refute the conclusions of the level I analysis.

Final Analysis

The final and most important portion of this study methodology consists of a two-part analysis to select a preferred optimum model from the finalist models. The first part was concerned with how well these models scored and ranked in relation to each other, and was quantitative in nature. The second part, a qualitative analysis, consisted of evaluation and reassessment of differences between the finalist models with respect to how well the ten level I and II discriminating criteria identified in Table 12 were satisfied.

This two-part analysis provided a rationale for the selection of the total matrix model as the preferred Space Base organizational structural model. The quantitative and qualitative superiority of the model is assessed in the discussion and tables which follow.

Quantitative Analysis

Table 13 is important because it indicates variation (if any) in ranking. Significantly, the total matrix model consistently maintained the highest rank throughout various criteria analyses. This was also true during the

TABLE 13

RANKING CORRELATION OF ORGANIZATIONAL STRUCTURAL MODELS FROM SCORING DATA

Model Name	All Criteria				Discriminating Criteria[a]		
	Total	Level I	Level II	Weighted	Level I	Level II	Weighted
Traditional	3	2	4	3	2	3	2
Dual command	6	6	6	6	. .	. .	. .
Line	5	5	5	5	. .	. .	. .
Round table	8	8	8	8	. .	. .	. .
Total matrix	1	1	1	1	1	1	1
Dual matrix	4	4	3	4	4	4	4
Standard matrix	2	3	2	2	3	2	3
Shared matrix	7	7	7	7	. .	. .	. .

[a]The dual command, line, round table, and shared matrix models are not considered in this analysis.

two pilot evaluations when all criteria were considered.[1] The other highest ranking models showed rank variation, while the lowest four did not. It is difficult to determine from Table 13 why the traditional, dual matrix, and standard matrix varied in rank. It can only be observed that changes did occur. Considering all forty-six criteria, it is seen that the traditional model had the most rank variation, due primarily to the effect of the thirty level II criteria. Only small changes were observed between the traditional and standard matrix models when only discriminating criteria are considered.

Tables 14 and 15 look at the same data differently, and consider how well the total matrix and the next best model satisfy criteria on an absolute and percentage basis by criteria groupings. Table 14 shows that the total matrix model has a higher criteria satisfaction capability than does the next best model based on scoring data. When all criteria are considered, the total matrix model is seen to have percentage satisfaction variation which ranges from a high of 97 to a low of 90 per cent. This model also seems to satisfy level II markedly better than level I criteria. The percentage superiority between the total matrix and the next best model is shown to vary between 11 and 4 per cent.

Only slightly different conclusions are reached when

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[1]While the primary purpose of the pilot evaluations was to improve the evaluation team process, some preliminary assessment was made of comparable data obtained.

TABLE 14

SCORING ANALYSIS OF CRITERIA SATISFACTION AND DIFFERENCES FOR THE TOTAL MATRIX MODEL VS. THE NEXT BEST MODEL

Model Comparison	All Criteria							
	Total		Level I		Level II		Weighted	
	Number	Per Cent	Number	Per Cent	Number	Per Cent	Number	Per Cent
Total matrix model	853	93	311	97	542	90	582	94
Next best model	786	85	275	86	514	86	529	85
Total possible	920	. .	320	. .	600	. .	620	. .
Per cent superior	. .	8		11		4		9

Model Comparison	Discriminating Criteria					
	Level I		Level II		Weighted	
	Number	Per Cent	Number	Per Cent	Number	Per Cent
Total matrix model	93	93	95	95	140.5	94
Next best model	85	85	85	85	127	85
Total possible	100	. .	100	. .	150	. .
Per cent superior	. .	8	. .	10	. .	9

TABLE 15

RELATIVE ANALYSIS OF CRITERIA SATISFACTION FOR THE TOTAL MATRIX MODEL VS. THE NEXT BEST MODEL

Total Matrix Criteria Satisfaction	All Criteria					
	Level I		Level II		Total/Weighted	
	Number	Per Cent	Number	Per Cent	Number	Per Cent
Better	13	87	20	67	33	72
Less than	1	7	6	20	7	15
Same as	2	12	4	13	6	13
Total	16	100	30	100	46	100

Total Matrix Criteria Satisfaction	Discriminating Criteria					
	Level I		Level II		Total/Weighted	
	Number	Per Cent	Number	Per Cent	Number	Per Cent
Better	3	60	4	80	7	70
Less than	1	20	0	0	1	10
Same as	1	20	1	20	2	20
Total	5	100	5	100	10	100

discriminating criteria data are analyzed. Total matrix percentage satisfaction was high in all cases, but variation was small ranging from 95 to 93 per cent. Level II criteria are satisfied slightly better than are the level I and weighted criteria categories. Percentage superiority over the next best model varies only slightly between 10 and 8 per cent. While some of the percentage differences appear relatively small, especially the 4 per cent difference in the all criteria, level II category, it should be realized that this analysis is only part of several which indicate that in the overall consideration, the total matrix model is the most feasible Space Base organizational structure.

Table 15 is a slightly different approach and indicates the number and percentage of criteria which the total matrix model satisfied better than, less than, or the same, as the next best model. As indicated, percentage satisfaction varies between 81 and 67 per cent for all criteria, and 80 to 60 per cent for the discriminating criteria. Greater relative satisfaction occurred for the level I criteria when considering all criteria, but the converse was true when considering discriminating criteria only.

The analysis of criteria satisfaction indicated in Tables 14 and 15 showed that the total matrix model consistently scored higher than the next best model (and all others). The reasons for this superior performance were not obvious. More insight into these reasons, however, is provided by the qualitative analysis which follows.

Qualitative Analysis

The second part of the final analysis, which confirmed the selection of the total matrix model, was concerned with a qualitative assessment of how well the finalist models satisfy the level I and level II discriminating criteria. The paramount objective during this analysis was to select the model which would permit the most effective and productive R&A and support operations. Productive objective accomplishment was, therefore, the most important standard which was used to judge the discriminating criteria satisfaction by the finalist models.

Also of importance during the assessment was what was called "reality testing" in the Grumman study.[1] Scoring differences noted between the models were reassessed and their importance was judged in relation to the conditions anticipated for the Space Base. Consideration was given during this analysis to such questions as which of the discriminating criteria are more important for model selection? How real are these differences between models when tested against the Space Base? Are the differences important? If the differences are real and important, are they as large as or smaller than the magnitude of their scores? And finally, how compatible are the models to the

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[1] *Ibid.*, pp. G-9-G-10.

assumed Space Base manning levels included in Appendix E?

Many of the judgments and assessments made by the researcher were supported by information and insights contained in the brief written rationale provided by each evaluator when criteria were less than fully satisfied by the models. The following discussion of discriminating criteria was arranged in the order considered by the researcher to be in descending order of importance with level I criteria discussed first. This order permitted a logical development upon which the total matrix model recommendation was based. Model scores utilized in the discussion have been abstracted from Table 12, and criterion numbers are provided for reference purposes.

Level I discriminating criteria

Undefined activities (1.2)

This criterion required that the organizational structure have the flexibility to support R&A activities and interplanetary missions which are not defined in detail at present. Rationale was that the probability of long range Space Base program success will be increased if the organizational structure is flexible enough to accommodate change. These factors allude to the fact that there are many unknowns associated with the program which will become a reality in the Space Base era. Included are new technology, techniques, hardware, and man's future needs.

Evaluators scored the models as follows: total matrix--twenty, dual matrix--eighteen, standard matrix--sixteen, and traditional--fourteen. From these results, it was seen that the three project-type models scored highest, with the total matrix model receiving a perfect score indicating complete satisfaction. The reason for the matrix models scoring well was clearly that the evaluators considered the flexibility of project organizations as being compatible with the need for the in-orbit organization to be able to adapt to the ever-changing requirements during the ten-year operating life of the program.

Clearly, the total matrix model satisfies these criteria better than do the other two matrix models. For one thing, as new R&A activities and interplanetary missions are identified, the R&A and Operations Support Directors can ensure that project and functional authority and responsibility are established. While the dual matrix model also requires discipline directors, part of their time would be devoted to the total operation of the Space Base because of their shared dual command responsibilities. The standard matrix does not have benefit of these directors, and requires that the various project/functional managers ensure that change is accommodated, perhaps with limited results.

Various construction (6.7)

This criterion specified that the organizational structure shall be appropriate for either a modularly constructed or centralized Space Base design. The rationale for this criterion was that since Space Base design has not been finalized, the structure identified should be compatible with either a modular or centralized design. This criterion was the only one considered which attempted to assess the effect of structural design on organizational structure selection.

The evaluator scores varied widely for this criterion. They were total matrix--twenty, standard matrix--eighteen, traditional--sixteen, and dual matrix--fourteen. This scoring indicated that models without a Mission Director located on earth scored highest. It was, however, evidence from evaluator comments that matrix models, because of their smaller project team sizes, were more compatible to modular laboratories such as the one shown in Appendix A. For that reason, the traditional model did not score as well as the total and standard matrix models. The evaluators dislike for the dual matix model, however, apparently outweighed its project orientation advantages. Regardless, the total matrix model, with its perfect criterion satisfaction, was considered superior to the other models and was judged to be totally compatible with either a modular or centralized Space Base design.

Autonomous operations (7.1)

This criterion emphasized the ability of the organization structure to allow for autonomous Space Base R&A

activities and support operations. The rationale was that cost effectiveness dictates that the operation of the ten-year life Space Base should be as independent from earth control and support as possible.

Evaluator scores were total matrix--eighteen, traditional--seventeen; standard matrix--seventeen; and dual matrix--nine. It should be noted that this criterion had a higher score range than did any of the forty-six criteria listed in Tables 10 and 11. The reason for this difference, as indicated by the evaluators, was that the three top models did not require a Mission Director on earth as did the dual matrix model. The requirement for authority and responsibility external to the Space Base was considered to be a serious limitation, since conflict resolution from earth can only result in lack of confidence by crew members in leadership and the dual command arrangement.

The three highest scoring models utilize the Space Base Director to serve as a single authority to ensure as autonomous activities and operations as possible from earth. The reason these models did not score higher, however, was that there is a limitation to how autonomous and self-sufficient the Space Base can remain. The Space Shuttle is still mandatory to sustain life and support all activities and operations because of its crew rotation, resupply, and rescue capability.

The total matrix model scored slightly higher in satisfying this criterion. The reasons given by the evaluators were that projects allow for more autonomy in R&A activities than do the traditional R&A arrangement, and the discipline directors assist in ensuring autonomy when compared to their absence in the standard matrix model. In reality, this criterion was not as helpful in discriminating between the highest scoring models because all three models would adequately provide for an autonomous Space Base except for necessary Space Shuttle support.

Planning and scheduling (7.2)

This criterion was related to autonomy of operations. It required that the structure shall allow, to the maximum extent possible, in-orbit mission planning activities and support operation priority definition and work scheduling. The rationale used was that the crew of the Space Base needs a capability for mission planning, priority definition, and activity scheduling. Consideration must also be given to work/rest-cycle variations, equipment sharing, number of crewmen available for duty, crew skill proficiency, scheduling conflicts, and requirements for team tasks.

Evaluation scores for the model were total matrix--nineteen, traditional--nineteen, standard matrix--seventeen, and dual matrix--thirteen. From these scores and evaluator rationale, it was evident that those models which do not require an earthbound Mission Director scored highest. The reason was obvious since in-orbit capability for planning and scheduling would be overshadowed by the Mission Director. The reason for equal superiority between the total matrix and traditional models was not as obvious. Both models, however, do have a three-level hierarchy with authority and responsibility for planning and scheduling.

The real difference between these models was within the R&A area, where planning and scheduling are either accomplished by the Project Managers or the R&A Managers. In the first case, fewer crew members are involved for each project manager to be concerned with, but multiple projects require more coordination by the R&A Director. In the second case, the R&A Managers have a more difficult task to be concerned with because of much larger teams, but the R&A Director has a reduced coordination responsibility. Thus, the total matrix model does not have a clearcut advantage over the traditional model. Both, however, almost totally satisfy the criterion.

Training and
indoctrination (4.4)

The criterion was identified to ensure that the training and indoctrination of long and short duration crew members could be accommodated. The rationale used was based on the belief that some in-orbit training and indoctrination will be required within the Space Base because of the possibility that some personnel may be involved in R&A activities for extended periods. Indoctrination was considered to be a recurring requirement.

The models scored as follows: traditional--nineteen, total matrix--sixteen, dual matrix--fourteen, and standard matrix--thirteen. The traditional model was clearly superior to all other models in satisfaction of this criterion. The main reason identified by the evaluators was that because of the semipermanency of the R&A crew teams, there would be less turnover and training/indoctrination requirements. The opposite was, of course, true with the matrix organizations, since they frequently must accommodate new project teams.

While the total matrix model was outscored by the traditional model, it was the highest scoring of the matrix models. The problem here was that other criteria require viable and adaptable provisions which inherently require some transiency, in R&A crew members. In addition, full and cross utilization of support personnel requires that on occasion some training will be needed. Matrix models satisfy these requirements best and, in reality, should be considered to be more important to overall Space Base activities and operations than the training/indoctrination difficulties created. What was signigicant, however, was that the hierarchical authority and responsibility relationships which exist for the total matrix model can accommodate the training/indoctrination needs of transient and more permanent crew members better than the other matrix models.

<u>Level II discriminating criteria</u>

Task leader (3.4)

This criterion established the need for a task leader assigned and responsible for each major R&A activity. Rationale was provided from a management concepts and practices source, which indicated that the likelihood of timely and efficient task accomplishment was increased if an individual was identified as being responsible for its success.

Evaluator scores for the models were total matrix--twenty, dual matrix--nineteen, standard matrix--seventeen, and traditional--thirteen. The top scoring matrix models have an inherent advantage in satisfying this criterion because of the requirement that task leaders (project managers) be identified for each project. Each of these R&A project managers directs the activities of a relatively small number of technologists (approximately six) regardless of Space Base crew size, as the Appendix E assumed manning levels for the matrix models shows. Conversely, the traditional model has no task leaders identified per se.

The R&A managers only partially serve as task leaders when R&A crew sizes are small (i.e., approximately nine team members). As was seen from the assumed manning levels for classical organizational structural models located in Appendix E, this was true when total Space Base crew size is 50. When Space Base growth reaches 100, however, the assumed size of the R&A groups is 23. These groups were not intended to have any task leaders below the R&A manager level because only a four-tier level of authority model was utilized for this study. The traditional model, therefore, cannot satisfy this criterion as well as the matrix models, and specifically the total matrix model which received a perfect score.

Varying crew size (3.6)

This criterion, closely related to the task leader criterion, indicated that structure shall allow for R&A activity teams consisting of four to fourteen technologists. Rationale, from applicable analog data, considered that efficient and effective R&A team size has been found to vary between four to fourteen individuals including the team leader, participating technologists, and the principal R&A investigator.

Criterion evaluation scores ranged widely as follows: total matrix--twenty, standard matrix--twenty, dual matrix--nineteen, and traditional--twelve. The closely grouped matrix models obviously scored highly, and the traditional model did not. The reason simply was that only the matrix models provided for R&A teams of the desired size. Average team size of six technologists was shown in the assumed manning levels for matrix organizational structural models for a Space Base crew size of 50 to 100. The traditional model, conversely, falls outside the desired team size when total Space Base size is 100. The assumed team size of nine for Space Base size of fifty is, however, within the desired range.

Evaluators collectively were unable to distinguish between the total and standard matrix models, giving each a perfect score. Only a small reduction in score was noted for the dual matrix model. Clearly, when the assumed manning levels were used, the matrix models satisfied the criterion. The classical, traditional model did not do so for a 100 crew member Space Base population.

Unity of command (8.3)

This criterion states that the structure selected will utilize the unity of command principle when possible. Rationale from management concepts and practices indicates that coordination of work efforts and the utilization of resources can be achieved best by a single authority. In addition, the decision-making process may involve many people, but final authority must be vested in a single individual.

The four candidate models scored as follows: traditional--twenty, total matrix--nineteen, standard matrix --eighteen, and dual matrix--twelve. While a wide range of scores existed for this criterion, the top three indicated a high satisfaction level. The top scoring model completely satisfied this criterion because of its classical nature (i.e., every individual within the organization has only a single superior, from the technologists at the task level to the R&A and Support Operations Directors).

The other two high scoring models are of the matrix type and inherently violate the unity of command principle. Violation occurs when technologists who are normally part of the support operations crew are assigned to a project because of skill capability or lack of full employment. Loyalties then become divided between functional and project managers. In the case of the low scoring dual matrix model, no provision was provided for total in-orbit unity of command. Not only do the functional technologists have split command loyalties, but so do the R&A and Support Operations Directors: sharing command authority and responsibility except in the case of conflict which requires resolution by the Mission Director.

The strength of the total matrix model was indicated by the fact that in spite of its inherent design which violates the unity of command principle, it scored well. The evaluation team members thus felt that the model could be used by management without serious unity of command problems.

Quality and speed (9.2)

This criterion was intended to ensure that the structure selected had provision for quality and speed in decision making. Rationale from management concepts and practices dictated that managers need a structure which assists them in rendering sound decisions. This requires good information inputs and an analytical process that yields unambiguous, unbiased judgments. In addition, these decisions must be appropriate to the situation and arrived at and acted on within time constraints.

Model scoring was as follows: traditional--nineteen, total matrix--eighteen, standard matrix--seventeen, and dual matrix--twelve. From these scores, it was seen that three models substantially satisfied the criterion about equally well, but the dual matrix model did not. The reason the latter was unable to score well was that the evaluators considered that the requirement for a Mission Director on earth would restrict speed and perhaps quality of decision making when impasses were reached.

While the total matrix model was not the highest scoring model, it did score well considering that the project teams are more numerous than are the R&A functional groups of the traditional model. What the total matrix model lacks in speed because of width is compensated for by the upward flow of quality information by knowledgeable project managers, hopefully resulting in better decisions by directors.

It was interesting to note that the inherent shorter lines of communication of the three-level standard matrix model were not considered by the evaluators to significantly improve quality and speed of communications.

The reason given was that the R&A and Support Operations Directors would do much to improve decision making because of their intermediate position serving as a filter, translator and reinforcer of upward and downward communications.

Line of communications (9.3)

This criterion specified that the structure shall allow for lines of communication between groups for all critical and safety-associated tasks. Rationale identified in applicable analog data indicated that open lines of communications would ensure uniform, efficient response to dangerous situations.

Model scoring was traditional--twenty, total matrix--eighteen, dual matrix--fourteen, and standard matrix --thirteen. Clearly the traditional model scored best, followed closely by the total matrix model. The remaining models did not score well. The reason for the superior performance of the top model was that it has the most direct path and fewest interfaces from the Space Base Director, with total safety responsibility, to others within the organization who may need timely information.

The total matrix model has as direct a path, but it also has more projects and interfaces for a communicator to contend with. The dual matrix has limited lines of communications even though the Support Operations Manager was assumed to have safety responsibility for the total Space Base crew. Like the standard matrix model, expanded downward communication interfaces reduce the effectiveness and efficiency of lines of communications.

Even though the total matrix model scored second to the traditional model and the other models did not score well, this criterion was not considered by the researcher to be as important as the other discriminating criteria. The primary reason was that the speed and effectiveness of critical safety communications will be improved by newer audio and visual systems. Even with today's warning equipment, emergency procedures, and periodic training requirements, this criterion was not considered by the researcher to be as sensitive to organizational structure as the scores indicated.

Summary

This section was concerned with the presentation and analysis of data provided by subjective determination of how well eight organizational structural models satisfied forty-six criteria. Analysis of this data resulted in the selection by the researcher of the modern, project-type total matrix organizational structural model as the optimum Space Base structure. The methodology used for this analysis was to tabulate first the data obtained and conduct a preliminary analysis to reduce the eight models considered to a smaller set of finalist models. The second step was the performance by the researcher of a final in-depth analysis to identify the desired model.

The tabulation of data and preliminary analysis contained in this section accomplished several things. First, it allowed the ranking of the eight models by the use of model scores provided by the team of five evaluators. This resulted in the elimination of the four lowest-ranking models, leaving one classical model and three matrix models for further assessment. They were the traditional, total matrix, dual matrix, and standard matrix models. The division of all criteria into two differently weighted categories helped in this analysis. Determination of range of scores for the four finalist models for all weighted criteria provided a means of identifying those level I and II criteria which significantly discriminated between the models. Ten discriminating criteria were identified, five for each criteria level.

A two-part final analysis provided a more detailed rationale for optimum model determination. The first part of this analysis was concerned with how well the four finalist models scored and ranked in relation to each other. A ranking correlation of models, and scoring and relative analysis of criteria satisfaction for the total matrix versus the next best model was accomplished. These results indicated that in all cases, the total matrix model consistently ranked first and satisfied various criteria groupings better than all other models considered.

The second part of this final analysis provided more insight into the strength of the total matrix model's ability to satisfy level I and II discriminating criteria. Analysis of the five level I criteria determined that in all cases except one, the model selected scored better than or equal to the other models for valid reasons. Even in the case of the exception, a rationale was provided for downgrading the importance of the criterion because of other more significant considerations such as more effective and productive R&A and support operations accomplishments. Analysis of level II discriminating criteria were used to validate the level I results. Again, the total matrix model was found to satisfy these criteria more consistently, for valid reasons.

The findings and analysis of this section strongly support the conclusion reached by the researcher that the total matrix model was the best structure to assure the orderly, effective, and efficient management of Space Base technologists. The summary and conclusions, with implications and recommendations resulting from the research conducted, are discussed in the section V.

V. SUMMARY AND CONCLUSIONS

The Study Problem and Methodology

This study was concerned with the determination of an optimum hypothetical organizational structure for a large earth-orbiting multidisciplinary R&A Space Base manned by a mixed crew of 50 to 100 domestic and international technologists. The facility would be designed for a useful ten-year operating life. Supplied with equipment, personnel, and food by a reusable Space Shuttle, Space Base would serve to greatly expand advancements in the sciences, exploration, public and private services, and foreign relations.

For discussion and analysis purposes, Space Base organizational structure was defined to be the established pattern or deliberate grouping of relationships among the components or parts of a formal organization to achieve specific goals. It was characterized by planned division of activities, leadership, and communications responsibilities. Another salient feature was the presence of a hierarchy of authority needed to plan, control, direct, and coordinate the concerted efforts of the organization effectively and efficiently toward its goals.

While the broad purpose of the study was to expand the body of knowledge concerned with the role of organizational structure on human endeavor, the primary question answered by the research conducted during this study was what is the preferred organizational structure for optimizing the mission accomplishments of the various technologists who will work and live in a large multidisciplinary earth-orbiting Space Base? The answer to this question was reached through research and the development of answers to the following elemental questions:

1. What known Space Base program requirements are important to organizational structure selection and what assumptions must be made?

2. What related studies provide insight into Space Base organizational structure selection?

3. What variables are important to the selection of an organizational structure for a Space Base?

4. What type of organizational structure best serves the needs of technical professionals?

5. How appropriate to Space Base are the multitude of social systems and environmental situations involving isolation, confinement, and situational danger; and what can be learned from the most applicable analogs with regard to Space Base organizational structural selection?

6. What evaluation criteria should be used to select the preferred Space Base organizational structure?

7. What variation to basic classical and modern organizational structural models should be considered for Space Base use and why?

8. What analyses can be used to assess feasible classical and modern organizational structures and select the preferred one?

The research accomplished during the study was a modified operational replication of a NASA-funded Grumman Corporation analysis which identified a preferred organizational structure for a twelve-man Space Station. Data collection and analysis activities, like those of the Grumman study, had the following phases: (1) data research, (2) development of organizational structural evaluation criteria and a set of feasible models, and (3) evaluation of feasible models and selection of the optimum one.

The first phase, concerned with data research, relied heavily on data obtained from review of primary and secondary literature, visitations and examinations of certain Space Base analogs where appropriate and practical, and interviews with knowledgeable persons. Specific topics investigated using these sources of data were (1) program requirements and assumptions, (2) related studies, (3) general and specific organizational structural variables, (4) the nature of professional organizations and technical professionals, and (5) applicable analogs. The purpose of reviewing these topics was to obtain data which were useful for subsequent phases of the methodology.

The second phase used first-phase data to develop evaluation criteria and a feasible set of organizational models. Criteria with rationale were identified from program requirements and assumptions, management concepts and practices, and applicable analog data. These criteria were then grouped into a number of general and specific categories for organizational purposes.

A four-level Grumman "level-of-authority" model was used to generate a variety of organizational structural models from parent classical line-functional and modern matrix models. These levels were called command, discipline, function/project, and task. From the parent models, others were developed by varying the level and number of authority assignments. The resulting models were then screened by the researcher to determine if they were reasonable and practical, possessed sufficient difference from the other models, provided for decision making, and satisfied program requirements and assumptions.

The third and final phase used the data and analyses of the first two phases and provided a means for evaluating the set of models and selecting the preferred one. This was accomplished partially by an evaluation team considered to be a panel of experts who individually scored the criterion-satisfying ability of each model using a five-point scoring system. This technique allowed each evaluator to quantify subjective judgments. After two pilot teams confirmed the feasibility of this type of evaluation analysis, a final five-man evaluation team scored the models. This team consisted of the researcher and two other NASA employees, the manager of the Grumman study, and a member of the academic community.

Remaining analysis for this phase of the methodology was accomplished by the researcher. This independent analysis, using final evaluation team data, consisted of quantitative and qualitative segments. Quantitative analysis determined how well the evaluated models scored and ranked in relation to each other, while qualitative analysis determined how well certain discriminating criteria were satisfied by the models. These criteria discriminated because of their wide variation of summed evaluator scores between models. This final quantitative and qualitative analysis resulted in an answer to the primary study question.

Summary of Findings

The primary question

The essential finding of the research conducted during this study was that the hypothetical organizational structure which optimizes the mission accomplishment of Space Base technologists was the total matrix model. This structure was found to possess the greatest capability for orderly, efficient, and effective management of the crew through its adaptability of anticipated objectives, R&A activities, and support operations. More specifically, this model was selected for two fundamental reasons. The first was that it consistently scored and ranked highest in relation to the other candidate models evaluated during the study. Second, analysis showed that, overall, the model satisfied the discriminating criteria best.

The four-level hierarchical total matrix model requires staffing by a Space Base Director and Deputy at the command level, and R&A and Support Operations Directors at the discipline level. In addition, various Project and Operations, Medical Operations, and Maintenance/Logistics Managers are needed at the project/functional level, as are project/functional groups of technologists at the task level.

The elemental questions

The first elemental question was concerned with the identification of established Space Base program requirements and the development of assumptions which were needed to make the study possible. A review of literature identified twelve program requirements considered by NASA to be necessary to ensure program success:

1. The Space Base will be operational by 1985.

2. The Space Base crew is expected to be maintained between 50 to 100 technologists of various skills.

3. The Space Shuttle will be used to provide Space Base logistics in the form of supplies, crew rotation, and exchange of scientific instruments and data.

4. A variety of multidisciplinary R&A activities will be accomplished concurrently within the Space Base.

5. International as well as domestic technologists will participate as Space Base R&A crew members.

6. The Space Base will support R&A activities and interplanetary missions which are not defined in detail at present.

7. The Space Base will be a semipermanent facility with a minimum operational life of ten years with resupply.

8. Female, as well as male, technologists will comprise the Space Base crew.

9. The Space Base will be as autonomous from earth control and support as possible.

10. Support operations personnel will function to satisfy the needs of the R&A technologists who use but do not operate the Space Base.

11. Initial crew size will be 50 members. As the Space Base facility grows in size, the crew will increase to 100 technologists.

12. The vast majority of crew members, especially those involved with R&A activities, will be nonastronaut trained and will have been selected using criteria without any overly restrictive physical or mental requirements.

In addition to these program requirements, nine assumptions relevant to organizational structural considerations and related to Space Base R&A activities and operations were made by the researcher to simplify, clarify, and restrict variables:

1. The great majority of Space Base personnel will be technical professionals, i.e., scientists and engineers, while a much smaller group will be technicians and semiskilled personnel. The technicians of the Space Base era will, however, be as capable as today's technical professionals because of rapid advances in the state-of-technology and knowledge requirements.

2. Some in-orbit training and indoctrination will be required because some R&A technologists may participate for extended periods and new crew member indoctrination will be a recurring requirement.

3. R&A technologists and support operations personnel will participate in Space Base duty for varying (yet unspecified) lengths of time.

4. Nonroutine and around-the-clock activities and support operations will be accomplished within the Space Base when required. This will allow R&A technologists the flexibility to perform activities during "nonstandard" hours for various technical reasons. Support operations personnel, in addition to supporting nonroutine activities, will be required to operate and maintain the Space Base on an around-the-clock basis.

5. Personnel changes will be made within the Space Base as required to replace technologists because their work is complete or to reassign them to higher priority work.

6. The Space Base will either be of a modular design as envisioned by the Space Task Group with major components sized to fit into the Space Shuttle cargo bay, or it will be a more centralized design placed in orbit by another vehicle--with the former being more likely.

7. In-orbit Space Base managers will be technically trained in either a scientific or engineering discipline and will be NASA employees. This assumption, therefore, restricts discussion of whether nontechnical personnel can manage technologists--especially within the Space Base.

8. Permanent party and transient technologists will comprise the Space Base crew at any point in its operational life. The permanent members will be NASA employees assigned to the program on a full time basis. The transient members would be international and domestic technologists usually involved in one-time-only R&A activities.

9. Crew members will be approximately divided between R&A and support operations. This ensures that adequate supporting personnel are available to assist those involved in accomplishing Space Base objectives.

The second elemental question pertained to related studies which would provide insight into Space Base organizational structure selection. An extensive and intensive review of primary and secondary literature revealed that there have been no Space Base studies the sole purpose of which was to determine a preferred organizational structure. However, there were some related studies which were found to be important to the present study.

In 1969, an in-house NASA study identified basic Space Base program objectives and developed a Statement of Work for follow-on contractor study efforts. Studies by the McDonnell Douglas Astronautics Company and the North American Rockwell Corporation resulted from the NASA Statement of Work. While neither contractor studied organizational structure per se, both indicated that all Space Base crew members could be assigned to two organizational groups: R&A activities and operations.

Concurrent with the contractor efforts, independent studies by two NASA employees at different NASA centers were accomplished. These exploratory studies were conducted by von Tiesenhausen of NASA's Marshall Space Flight Center, and Gundersen at NASA's Manned Spacecraft Center. In the first study, von Tiesenhausen, concluded that a mixed military-type and a scientifically-oriented organization structure was needed for Space Base. The author then established a hypothetical line-functional organization and showed how requirements and activities of personnel organized in this fashion affect Space Base layout. This functional organization divided all Space Base personnel into three groups: Base Command and Management, Base Operations, and Scientific Faculty.

In the second study, Gundersen proposed a military line organization similar to that of a nuclear submarine to be used for Space Base. Personnel were to be divided into two major functional groups: Operations and Technical Projects, with a Space Base commander and his deputy considered as part of Operations. The author also concluded that cross skills were important to crew selection.

Two other studies were investigated because they were important to the study methodology. The first was the Grumman Aircraft Engineering Corporation study on Space Station command structure. This study served as the model for the present studies phased methodology which has previously been described. The Grumman study also identified seven specific Space Station organizational structural variables. They were multidisciplinary scientific operations, crew size, Space Station with users on board, mission duration, duty cycle, arrangement of space, and Space Station autonomy.

The second was a study by Sells of a 500-day manned space flight to Mars and back. This study provided a technique to determine the appropriateness of a number of social systems to the Mars mission system under analysis. Using a three-point scale, each of eleven comparison systems was scored, using fifty-six system characteristics listed under seven descriptive categories. These descriptive categories used were objectives and goals, value systems, personnel composition, organization, technology, physical environment, and temporaral characteristics. Sells' analysis indicated that submarines, exploration parties, and bomber crews are most similar to the Mars extended-duration space ship, while industrial work groups and shipwreck and disaster situations are the most dissimilar.

The third elemental question related to the identification of variables important to the selection of Space Base organizational structure. After an extensive review of the literature relevant to organizational design and selection, it was determined by the researcher that four general variables identified by Koontz and O'Donnell were most appropriate to this study. They were objectives and plans, capability of personnel, environment, and authority.

In addition to these general variables, nine specific variables were used. They were multidisciplinary R&A activities; crew size; crew composition; crew selection and training; mission duration; environmental factors; autonomy of operations; authority and responsibility; and communications, coordination, and integration. Seven of these variables were derived (and modified) from those identified in the Grumman study. The latter two were added by the researcher to broaden the list.

The fourth elemental question involved the requirement to identify the organizational structure which best serves the needs of technical professionals. During the review of literature relating to professional organizations, characteristics of technical professionals, and the relationships of technical professionals to the organization, revealed a variety of data important to this and subsequent considerations. These data indicated that professional organizations (defined as those where knowledge is produced, applied, preserved, or communicated) required more modern, flexible, even temporary, organic-adaptive organizational structures if objectives were to be optimized. This organizational form contrasts to more classical mechanistic structures which adequately serve other more routine organizational endeavors.

The fifth elemental question relates to the appropriateness of the multitude of social systems and environmental situations to Space Base and what can be learned from them. The first part of this question was answered by the use of the social system comparison analysis developed by Sells, which provided a means of ranking twenty-two systems and situations by degree of similarity. Ten analogous systems and situations were identified and used for the present study. The ten highest ranking analogs of Space Base in descending order of similarity were

1. Space Station
2. Various oceanographic research ships
3. Antarctic stations
4. Earthbound R&D laboratories
5. Ben Franklin research submarine
6. Tektite II laboratory
7. Ninety-Day Space Station simulation
8. Nuclear submarines
9. Sealab II
10. Skylab

After these applicable analogs were identified, they were analyzed in depth using data derived from appropriate literature, visitations to several analogs, and interviews with knowledgeable people. A correlation analysis between these analogs and the general and specific variables previously described, identified the areas where in-depth analysis was justified. Investigation in these areas revealed a variety of data invaluable for subsequent analyses.

The sixth elemental question pertained to evaluation criteria identification and use. A multitude of criteria and rationale for their use were identified, and, after careful screening, a total of forty-six criteria were grouped in four general and nine specific variable categories. The source of these criteria were Space Base program requirements and assumptions--sixteen, management concepts and practices--nineteen, and analog data--eleven. A rationale for each criterion was also provided from these sources.

The seventh elemental question concerned the identification of classical and modern organizational structural models for use in Space Base and the rationale. From an analysis of program requirements, management concepts and practices, and applicable analogs, thirty variations of classical and matrix models were identified, using the Grumman "level-of-authority" method of model generation.

These models, reduced to a feasible set of eight by the researcher, were equally divided between classical and matrix model variations. The eight remaining models were judged feasible because they were found to be practical, sufficiently different, provided for decision making, and satisfied program requirements and assumptions. The models were called traditional, dual command, line, round table, total matrix, dual matrix, standard matrix, and shared matrix.

Finally, the eighth elemental question addresses itself to the analyses which would provide a rationale for the selection of an optimum model of those considered. A two-part methodology and several techniques were required and used. During the first part data were collected from an evaluation team. This allowed the eight feasible models to be reduced to one classical and three matrix models. Those remaining were the traditional, total matrix, dual matrix, and standard matrix models.

Also significant from the evaluation data were the identification of discriminating criteria that have values which varied significantly between the final four models. Five level I criteria associated with Space Base program requirements, and five level II criteria of lesser importance coming from the other sources were identified. They were level I --undefined activities, training and indoctrination, various Space Base construction, autonomous operations, and planning and scheduling; and level II--task leader accommodation, varying crew size, unity of command, quality and speed in decision making, and line of communications availability.

During the secondary portion of this assessment, quantitative and qualitative analyses performed by the researcher supported the identification of the total matrix model as the optimum Space Base model. Quantitative analysis showed that in all cases the total matrix model consistently ranked first when a rank correlation and scoring of total, level I, level II, and weighted criteria were performed. Likewise, the total matrix model was determined to be superior overall to the other three finalist models during an in-depth qualitative analysis which evaluated the extent and completeness of discriminating criteria satisfaction.

Summary of the Conclusions

The review of appropriate literature, visitations, interviews, evaluation team results, and findings of this research permitted the researcher to reach a number of conclusions that are listed and briefly discussed in the following paragraphs. These conclusions were derived primarily from analysis presented in section IV; however, the last conclusion resulted from the analysis of applicable analogs discussed earlier.

The total matrix model

The first conclusion was that the project-type organizational structural model called total matrix should be used for the Space Base program. This model offers the greatest probability of optimizing the utilization of Space Base resources to satisfy program objectives and plans, when compared to a variety of alternate models considered. In retrospect, this conclusion was considered by the researcher to be sound, because only an organic-adaptive project organization has the inherent flexibility of satisfying Space Base program needs presently envisioned and those which are still undefined at this time. It should be realized, however, that while the total matrix model was selected, both the standard matrix and traditional models scored and ranked fairly well in comparison. The validity and usefulness of these models should not be overlooked in future studies and applications.

<u>Discriminating criteria</u>

The second conclusion was that while a number of criteria relating to Space Base program requirements and assumptions, management concepts and practices, and applicable analog data are available, only a relatively few were found to be important to the selection of Space Base organizational structure. For example, discriminating criteria were found in each criteria category except crew size and mission duration. These variables, usually discussed extensively in the literature, were not found to discriminate for the models identified in this research.

Several seemingly important and interesting criteria for organizational structural selection which also did not discriminate were mixed crew of males and females, multinational crew, technical professional communications, and creative climate. The former two criteria have been the subject of much speculation and little research, while the latter two have been the subject of extensive research and discussion in a variety of literature. The conclusion was not intended to belittle the importance of these criteria to overall organizational structural activities. It did mean, however, that when the highest ranked models identified in this study were analyzed, these criteria were not found to be important in selecting one model over the other (i.e., they were not discriminating).

Applicable analogs

The third conclusion was that while a multitude of environmental situations involving isolation, confinement, and situational danger exists, only a limited amount of data relevant to Space Base organizational structure can be obtained. Certain social system similarities were found and several organizational structural criteria were identified from the more similar analogs. However, analysis of data showed that relevancy to Space Base was found lacking. This led to an ultimate conclusion that Space Base as envisioned would be an environment somewhat unique in itself.

Implications of the Study

A number of implications are advanced and presented as a result of this research study. Hopefully, this discussion will be of value to practitioners and theoreticians who are concerned with organizational structure design and selection for complex organizations, as well as to those who will be involved in Space Base program management. Important to this latter group will be the need for orderly, effective, and efficient Space Base R&A activities and support operations.

Implications for Space Base Program Management

The study was justified primarily because of the need to reduce high program costs, to maintain a productive crew, and to accommodate a mixed crew of technologists in an unusual environment. As a result of this study, it was determined that an organic-adaptive total matrix model would best serve these needs. The rationale provided was that this model, overall, satisfied level I and level II discriminating criteria and all criteria considered better than the other models.

In general, it was seen that the total matrix model was optimum because it provided for R&A activities which are undefined at present, either a modularly constructed or centralized Space Base design, autonomous operations from earth except for Shuttle visits, in-orbit planning and scheduling, and effective training and indoctrination of crew members. In addition, this model accommodated task leaders, had flexibility for varying crew size, provided for the unity of command principle, encouraged quality and speed of decision-making, and ensured a line of communications in the event of emergency.

As with any study of this nature, it is necessary to discuss implications for those practitioners concerned with Space Base program management--program planners, the Program Manager, in-orbit Space Base Directors, as well as the remainder of the crew. Important considerations for these personnel because of the selection of the total matrix are facility design crew selection training plans, crew scheduling, motivation, and morale.

Facility design

Facility design must have provisions for crew accommodation, commonly used facilities, and work areas required to support the mission. While the total matrix model does not possess unique features requiring special designs, considerations must be made for living and working matters, work team audio and visual communications, equipment layout, and health and recreational equipment, among other things. Certain special needs for female and international crew members and occasional VIPs who may be visitors must also be considered.

Crew selection

The identification of a four-level model consisting of three management and one task level dictates general crew selection requirements. For example, selection of the various level managers will require different selection criteria than those required for the technologist task members. Selection criteria will be based on general and specific administrative and technical skills required.

The Space Base Director and the R&A Director should be selected on the basis of related background and experience in managing large, multidisciplinary activities. The Support Operations Director should have an operations background. Project and functional managers who may have a lesser scope of responsibility must be people who can work cooperatively with each other and others without excess detrimental competition. Technologists should be selected based on specialized skills, cross skills, knowledge, and experience. They should be people who are motivated to learn from others. The sources of these personnel will be from NASA, and domestic/international universities, and industries.

Training plans

While it is planned that all crew members will have a minimum of astronaut-type training and physical conditioning, certain training will be required after crew members have been selected. Three general types of training will be needed to ensure mission success. They are specialized, familiarization, and team training.

Specialized training would prepare skilled technicians to use equipment peculiar to Space Base and necessary for performing their specialized tasks. This training would be necessary even though the individuals were highly trained and experienced in a discipline. Familiarization training would be required by all personnel prior to their first mission assignment. Included in this category would be communications, safety, and emergency procedures, and facility familiarization. Finally, team training would focus on the activities and tasks that require group interaction and cooperation. This training would promote the development of cohesive work units and flexibility of group assignment by encouraging group members to learn and appreciate the skills of other members.

The literature on group performance is rich with conclusion on the efficiency of this latter type of training. When groups train as teams, cohesiveness results, even when they are operating under less than ideal working conditions. Cohesive groups are usually less vulnerable to reduction in performance over long periods of time. Even more important, these groups have been found to act and react more favorably during critical and emergency conditions.

Crew scheduling

Certain aspects of crew scheduling must be evaluated by program planners as a function of organizational structure selection. Crew scheduling can be considered as consisting of two primary areas: tour of duty and duty cycle. Both areas are important to program management.

An assumption made during this study was that crew members will remain in the Space Base for varying tours of duty. This likely situation will result in the condition where certain crew members and task teams will be returned to earth when their activities are complete. New task members joining established task groups and the formation of entirely new groups are, therefore, a reality. As a result, task groups and individuals must be rotated without causing a restructuring of communication links or channels of influence. Members and teams must fit into the existing structure working under a task leader without disruption. The total matrix model is, however, well suited to this type of transient activity.

Duty cycles for members and teams will be determined largely by the nature of tasks which must be performed. Frequently, work will be accomplished by R&A members on a variety of shifts throughout a period depending on the nature of the experiments and observations to be made. On-board planning and scheduling, thus, becomes more acute, as does the need for communications, coordination, and integration. In addition, varying maintenance repair and housekeeping functions by Support Operations personnel must be accomplished when they will not conflict with R&A activities.

Crew motivation and morale

A significant factor affecting crew motivation and morale and relating to organizational structure is the degree of crew participation and involvement in the decision-making process. This consideration appears repeatedly in management literature. While the total matrix model is dependent at all levels and designed for participation in the decision making process, leadership style is also important. An authoritarian leader, except in emergency situations, will do much to stifle the creative environment needed. Conversely, a participative leadership style over extended periods of time will develop a superior level of performance and achievement using the total matrix model.

Another function affecting crew motivation and morale is the degree to which the reality of the Space Base environment, in terms of duty assumptions and responsibilities, matched each crew member's expectations. Important to this consideration are crew training activities which would define, in general terms, what would be expected of each member so that little misinformation existed. If this understanding at least approximates reality, crew members at all levels will not be confronted with unanticipated situations and expectations. Deterioration of morale would not result from inaccurate or incomplete representation of their roles.

In the past, NASA has not selected organizational structure first and then considered facility design, crew selection, training, scheduling, and motivation and morale for its manned space programs. While there are several reasons for the approach taken, the main one was that only a few astronauts (one-to-three) were usually required. Those concerned with Space Base program management need to be conscious of this difference and the implications of the selection of an in-orbit matrix structure. They also need to be aware of the requirements and advantages of this model over the more conventional line-functional structures used in the past.

Implications for Those Concerned With Management Theory

The primary purpose of this investigation was to identify the optimum organizational structure for a crew of technical professionals involved in multidisciplinary activities in an unusual environment. It was found that an organic-adaptive type of project organization will best fit Space Base program objectives, type of personnel involved, and situational conditions. Important to management theoreticians obviously would be the method and rationale which were used to develop and answer the primary study question. Consequently, in a theoretical sense, the methodology was important, if not more important, than the answer derived because of its possibilities. For that reason, both the implications of the methodology, and the selection of a matrix structure are discussed.

The methodology

A significant study implication is that the methodology used is not confined to Space Base analysis only. By its very nature, it is applicable to all management studies involving organizational structure design and selection. The methodology is therefore valuable to government, corporation, and academic planners, since it is not sensitive to any particular set of organizational objectives and plans, capability of personnel, environment, or authority needs.

Initial or periodic organizational structure assessment to determine a superior model is possible. Initially, a preferred model can be identified using the study methodology. Once functioning, the organizational structure can be modified to satisfy changing needs. As new criteria and model variations are identified, a team or several teams of experts can be used to evaluate criteria satisfaction by the operating model and other candidates. Overall ranking and range of scores analyses to determine if a new criterion discriminates will provide valuable insight into the suitability of the models.

More specifically, the Sells technique used early in the study, has several obvious advantages to other comparison schemes. First, it is a quantitative method by which comparison between a number of social systems can be made. Not only can these systems be ranked, but a similarity analysis can be made by system description categories, namely, objectives and goals, value systems, personnel composition, organization, technology, physical environment, and temporal characteristics. Second, a large variety of systems can be assessed simultaneously. As a result, a variety of organizational types (e.g., profit, nonprofit, diversified, and centralized) can be scored and ranked as part of the same analysis.

The Grumman methodology, as modified by the present study, also has universal applications. This three-phase approach allows any analyst to identify the optimum structure of those considered based on the best information available. As new criteria, models, and teams are identified, revised data can be used to update, modify slightly, or totally change results.

Data research, development of organizational structural evaluation criteria and a set of feasible models, and evaluation of feasible models and selection of the one which is optimum are a relatively simple sequence. As with any other technique of this nature, the quality of results achieved is a function of the quality of the input data, effort expended, and competency of the evaluation personnel. In spite of the simplicity of the three phases involved and the synergistic results, each phase has certain implications that should be indicated.

Data research, the first phase, used reviews of literature, visitations and examination of certain analogs, and interviews as sources of data. Most management studies would not use all three of these sources in such a concurrent and complementary fashion. The reason is simply that it is usually difficult to integrate the variety of data obtained. In addition, without the Sells technique, it would be difficult to properly determine which potential analogs to investigate. Even after this analysis, if applicable analogs are found not to exist, valuable information has been obtained.

Development of evaluation criteria and a set of feasible models, the second phase, evolves from data research. These developments are the result of the integration of data obtained. The taxonomy used and the collation of these data do much to limit and direct these developments. Since this phase requires criteria which could be used for evaluation and possible organizational structural model identification, care must be taken to ensure that only the most applicable are used. Otherwise the evaluation becomes too cumbersome and results in wasted effort.

Evaluation of feasible models and selection of a final model, the third phase, can be accomplished by an individual or many, depending on resource availability and quality of results desired. This phase of activities is particularly suited to the iterative Delphi technique which has been found useful for consensus forecasting. Using Delphi for consensus evaluation would not only be a new application of the technique, but it would enhance the evaluation process by providing added confidence in the results achieved. Computerized scoring and quantitative analysis of results obtained would be an obvious advantage if the evaluation group were large or recurring results were needed.

An important consideration, however, is that while all criteria used in the evaluation process are important and can be weighted accordingly, the attention of the final evaluators should be focused on the discriminating criteria as well. The identification of these criteria separate the wheat from the chaff and allow in-depth analysis of criteria which discriminate between models. Incremental analysis of these criteria provides a great deal of insight into the strengths and weaknesses of models under analysis.

In summary, the flexibility and usefulness of the methodology (including the Sells technique) has a number of advantages over other evaluation techniques. Usually, other schemes are based on the intuition of a few, or consideration of only a limited number of important variables required to insure proper organizational structural selection. This methodology has no such weaknesses.

<u>The selection of a matrix structure</u>

The resultant selection of a total matrix project organization for Space Base has several obvious advantages over other models considered. These advantages have already been discussed extensively. However, there are several supplemental considerations for those concerned with management theory.

The first, as this study points out, is that organic-adaptive organizational structures will probably have a significant and increasing function in the future. The need for mechanistic (bureaucratic) structures, while having certain application for more routine functions, cannot meet the needs and demands of complex organizations of the future. The second is that the needs of creative technologists, with respect to professional organizations, situational factors, authority relationships, and potentials of conflict, must be continually evaluated and studied. Research on research will have increased importance in the future.

The rate of growth of technology due to advancements made by technical professionals in professional organizations has been ever increasing. However, many organizations have become even more complex as seemingly insurmountable problems are identified and solved. As demonstrated by the Apollo program and other large undertakings, multidisciplinary approaches are needed to find these solutions. Once solutions are found, members of the teams formed are reassigned to use their skills and talents for other applications. This trend will probably continue in the future because of the productivity of this approach. Results will be obtained which would be impossible using the classical organizational structures and traditional personnel assignments.

Limitations of the Study

Research studies are not without limitations, and this one is no exception. Several limitations are recognized and are identified below. Basically, they can be classified into three general categories: evaluator limitations, instrument limitations, and analysis limitations.

Evaluator limitations

This limitation refers to the general unwillingness and/or inability of an evaluator to accurately respond in scoring social systems or models. In this case, both the researcher and other members of the evaluation team are affected, since evaluation activities occurred using the Sells technique and the Grumman methodology. In reality, the only problem encountered in the present study might have been the difficulty for evaluators to accurately assess their personal perceptions of the systems or models being considered. The tedious and time consuming requirements of these evaluations do not help.

It was found by the researcher during the Sells evaluation that on occasion there was some difficulty in accurately assessing personal perceptions. For that reason, the total evaluation was repeated three times, each time updating prior results. A similar technique was used by several of the evaluators during the model versus criteria comparisons. Several evaluators reported that they had a much stronger feeling of confidence in their scoring responses after the second or third iteration. To further increase this confidence, after data were received, the researcher asked each evaluator to review his scoring of models for a particular criterion if results were significantly different from the consensus.

As a result of these procedural steps, reasonable assurance exists that evaluators were able to accurately quantify their personal perceptions. While an inherent evaluator limitation in this kind of research may exist, a lot was done to reduce or totally alleviate the problem procedurally.

Instrument limitations

This limitation refers to deficiencies in the evaluation material and instructions used in this research. Several possible limitations are recognized:

1. The data gathered were not adequate to provide answers to the primary and elemental questions.
2. The evaluators may not have understood the instructions asked, the evaluation material, or what was expected of them.
3. The evaluators may not have followed the instructions.
4. The labeling of organizational structural models may have biased the evaluators.

The first limitation cited above was not a problem because the data obtained did answer the elemental questions which provided an answer to the primary study question. The second limitation also did not materialize because of conference and individual telephone calls which followed the mailed evaluation packages. Even though two pilot evaluations were conducted, there was some evidence that several evaluators did not fully understand a few of the criteria and distinctions between some of the models. Minimum effort was required to correct this problem, however, and usually a single contact was all that was required.

The third limitation was concerned with evaluators not following instructions. There is little evidence to believe that this occurred, since each evaluator was instructed to score model variations for the first criterion, then proceed to the second, and so on. Results received and conversations with the evaluators indicate that this procedure was closely followed without difficulty. In addition, since one of the evaluators developed the Grumman evaluation scheme used, it is doubtful that difficulty was experienced in understanding or following instructions on his part.

The fourth limitation, related to possible model labeling bias, was not considered to be a serious problem by the researcher. The reason was that names were assigned to the eight feasible models based on their predominant features. These model features were carefully described to each evaluator. However, since no attempt was made in this study to measure variations in evaluation scores due to labeling bias, it is suggested that descriptive names not be used in future replications of this evaluation process. Numbers or letters assigned to each model would be a recommended substitute.

Analysis limitations

This limitation is concerned with those aspects of the study methodology which involves the analysis of data accomplished in section IV. Since several types of analyses identified and verified the selection of a single model as being optimum, limitation of any one analysis technique was not considered significant and would not invalidate the primary study conclusion. In addition, scoring and ranking techniques used in the present study are widely used, primarily because of their simplicity and ease of understanding.

Two possible analysis limitations during the final quantitative and qualitative portion of section IV were overcome by the rationale provided. The first was that during quantitative analysis comparing percentage superiority of the total matrix model and the next best model, in some cases, only small superiority was indicated--perhaps due to chance variation. The occurrence of these small differences was not considered to be important because what must be realized was that the next best model was being contrasted. If comparisons were made to each of the individual models, percentage superiority of the total matrix model would be considerably higher.

The second possible limitation was that too much subjectiveness would be introduced into the qualitative portion of the analysis. Care was exercised, however, because rationale for analysis was provided by written evaluator comments when models did not fully satisfy the criteria. Also, in proper perspective, it should be realized that the qualitative analysis was intended to be supportive and somewhat redundant to the quantitative analysis.

Although the above evaluator, instrument, and analysis limitations were noted, it was not felt that any were so severe as to reduce the validity or usefulness of the study results. These limitations are not unique to this study since they occur in most behavioral science research studies. Importantly, more significant limitations were eliminated by the study design used, and as a result many potential errors which could have materialized did not.

Other Areas for Research

This study has resulted in findings, conclusions, and implications. The researcher, therefore, feels that it is appropriate to identify a number of areas which would be useful for further analysis of this subject. This research is suggested because of the large financial investment Space Base will require, the program's potential significance, and, hopefully, the part that this study will play in Space Base planning and organizational considerations.

First, an exact replication of the model evaluation process should be accomplished by teams of different mixes and sizes. Further replication should also include the results of additional studies of evaluation criteria, organizational structural models, and weighting factors. These criteria and models should be investigated for additions, deletions, or modifications. Even the Space Base program requirements which resulted in level I criteria should be reevaluated for validity and usefulness now that a period of time has elapsed since their inception. A computer software program would be useful for data analysis purposes, if team size increases. This replication would serve to validate the model selected, even though the total matrix model was identified as the preferred model from data obtained from pilot and primary evaluation team results. These teams should include heterogeneous members of diverse backgrounds and interests including those from scientific, industrial, military, and academic organizations.

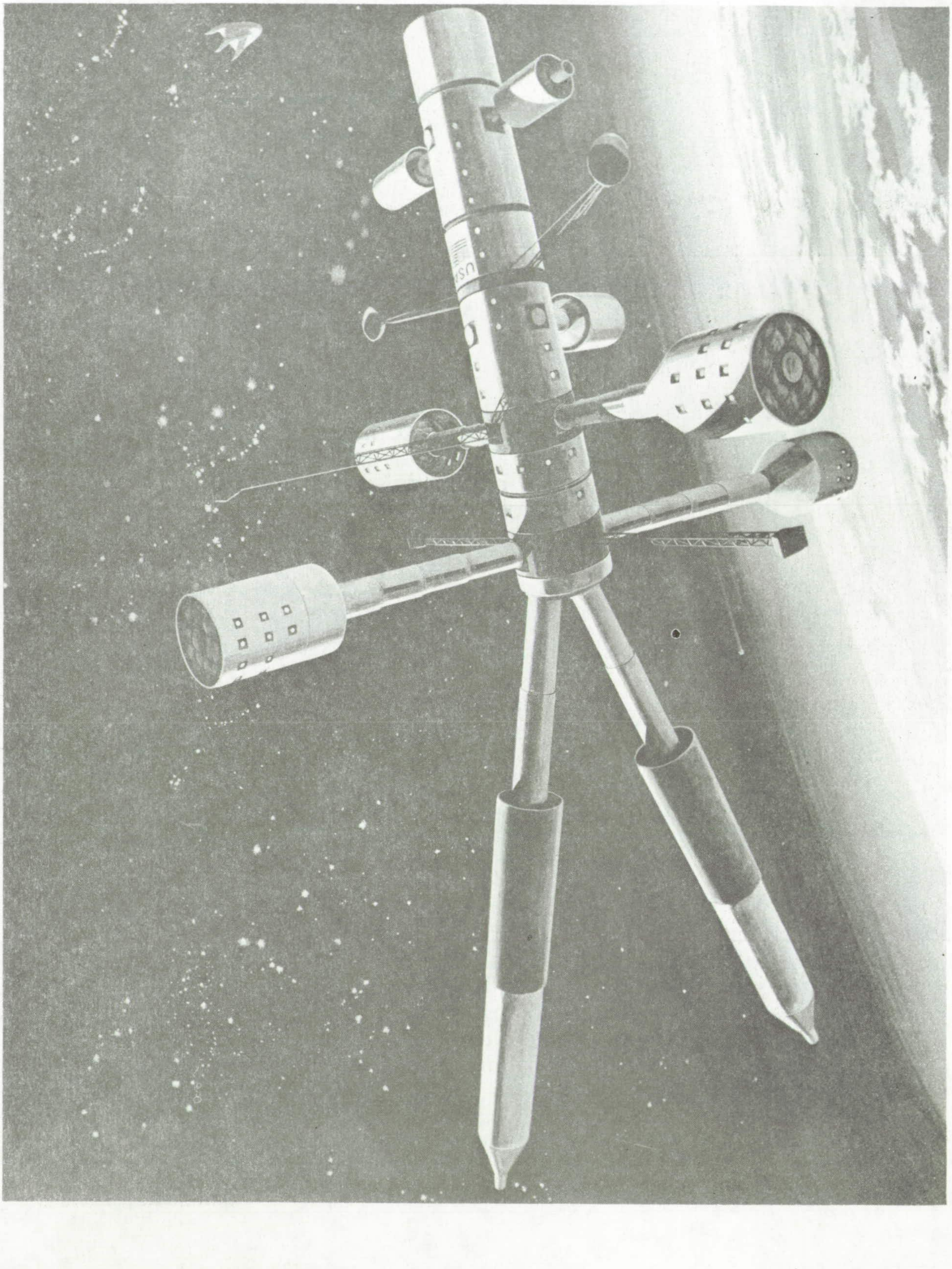
Second, the top two organizational structural models should be tested <u>in situ</u> in the most analogous environments possible. That is, test the total matrix and traditional models in either oceanographic research ship or antarctic situations. Testing in these environments, in conjunction with worthwhile R&A activities and support operations, would allow removal of large-sized heterogeneous crews from their natural and customary social and work environments, and would provide confinement and stress conditions. This testing would serve to validate fundamental premises regarding large groups involved in and supporting R&A activities and small groups involved in project/function assignments, the organizational structural findings drawn, and recommendations made in this study.

Third, the selection of the total matrix organizational structural model suggests that other program elements such as Space Base design, crew selection, training, scheduling, and motivation and morale will be affected. Other related studies should be begun at an early date to investigate the effects of the selected structure on these considerations. A fully successful Space Base program will be dependent on the compatibility of these follow-on considerations to the total matrix model.

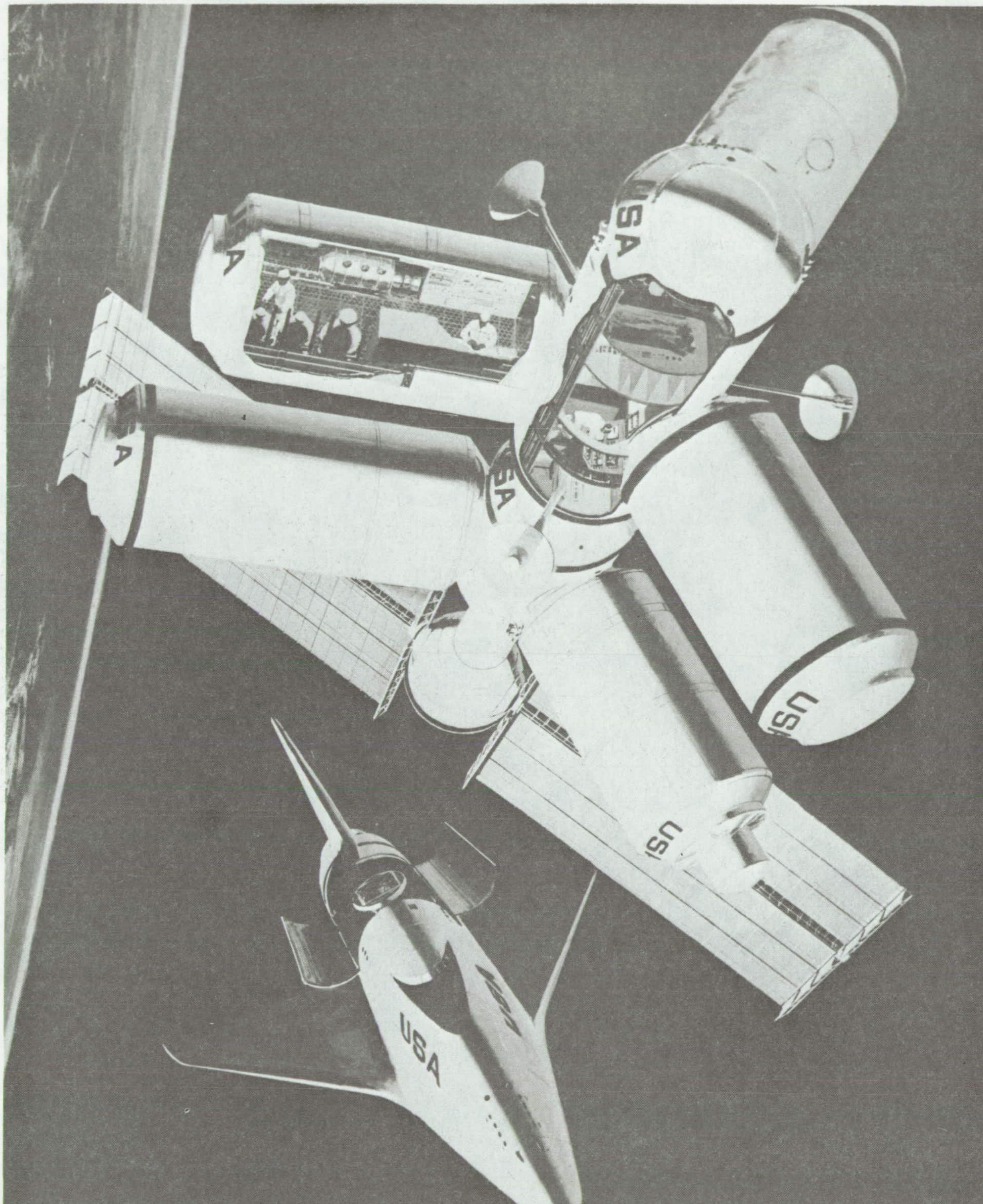
Finally, the methodology should be tested in a wide variety of environments where optimum results are at a premium. These environments should include the gamut from large to small, highly skilled to unskilled, diversified to centralized, and profit to nonprofit organizations. If after several years of testing and structuring of a variety of groups the methodology is validated, a valuable contribution will have been made to general organization theory and practice.

APPENDIX A

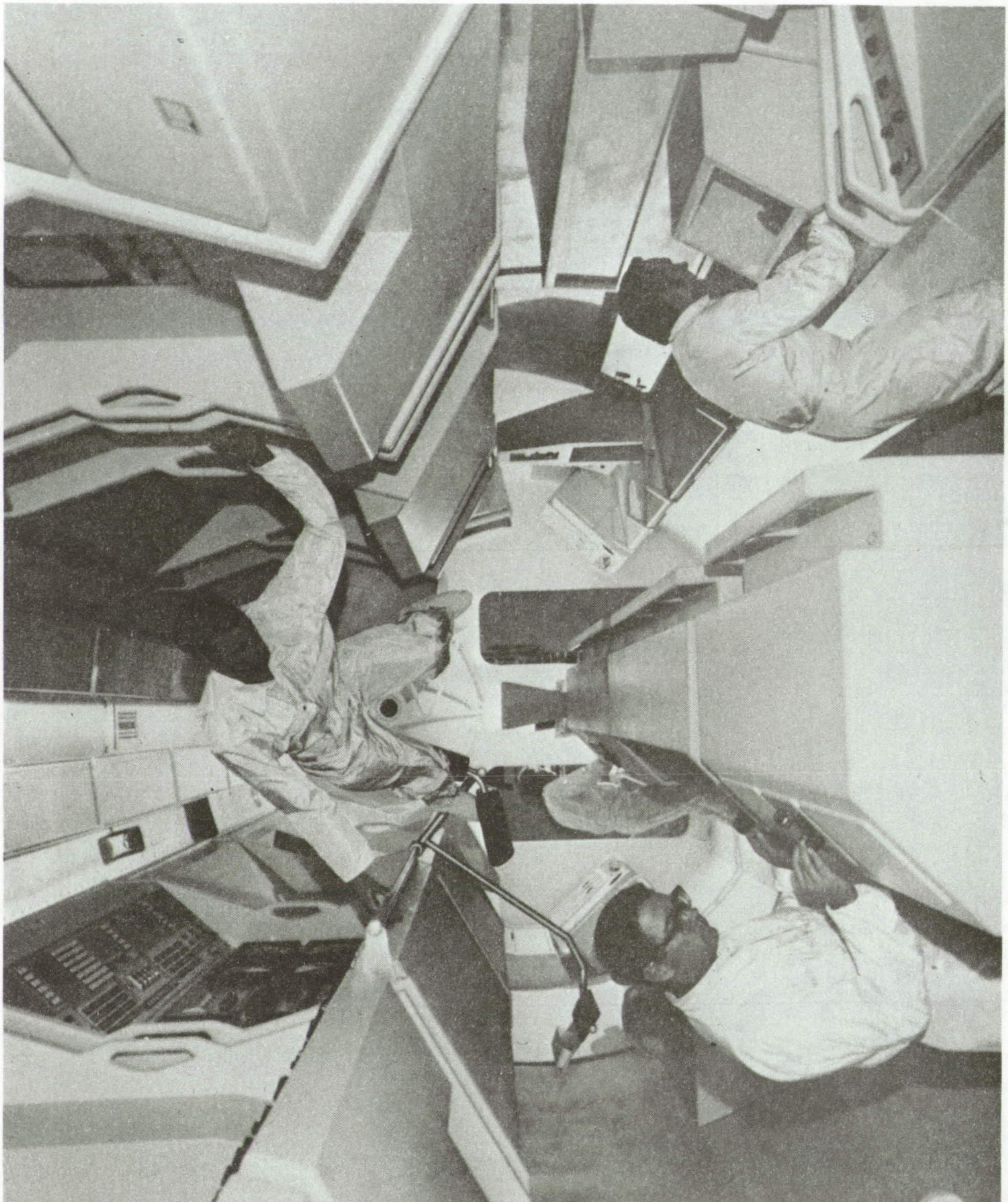
SPACE BASE CONCEPTS AND MODULAR LABORATORY MOCKUP



Centralized Space Base Configuration



Modular Space Base Assembly Using the Space Shuttle



Modular Laboratory Mockup

APPENDIX B

DEFINITIONS OF TERMS USED IN THE STUDY

DEFINITIONS OF TERMS USED IN THE STUDY

The nature of this subject requires that certain terms used should be defined to aid in understanding. The definitions provided are intended to be traditional in nature, although some may not be. The terms included in this Appendix are defined by the researcher in the following way:

Analog.--an environment or facility which has similar, appropriate, and related characteristics to the situation being evaluated.

Applications.--the direct use of a space facility to conduct periodic and continuous earth and space survey, study, service, and development activities.

Applied Research.--investigation which is directed toward practical or commercial application of scientific knowledge.

Authority.--the right connected with a position or rank to make a decision in fulfillment of a responsibility and to act, command, or require action by others.

Basic Research.--original investigation or inquiry which is directed toward increasing the knowledge of science rather than practical application.

Confinement.--physical and temporal limitation on the activities and translational motions of an individual or group, occasioned by enclosure within a restrictive barrier, and sometimes associated with elements of perceptual and social isolation.

Criterion.--a standard on which a judgment or decision may be based.

Delegation.--the granting or conferring of both responsibility and authority from one organization to another.

Development.--systematic use of scientific knowledge directed toward the production of useful materials, devices, systems, or methods including design and origination of prototypes and processes.

Discipline.--a branch of learning or field of study.

Discriminating Criteria.--judgment standards which have evaluation scores which vary significantly between tested organizational structural models.

Effectiveness.--the degree to which an individual or group of individuals realize goals and objectives.

Efficiency.--a measure of the amount of resources used to produce a unit of output.

Engineer.--a college-trained person having expert knowledge in the design, operation, or production of either mechanical, electrical, chemical, aeronautical, or similar discipline mechanisms and processes.

Formal Organization.--a system of coordinated activities of a group of people working cooperatively toward a common goal under authority and leadership.

Hierarchy.--the vertical division of authority and responsibility and the assignment of duties to organizational units.

Homeostasis.--a stable state or balance.

Informal Organization.--those aspects of an organizational system which are not formally planned, but arise spontaneously from activities of participants.

Interface.--a region common to two or more elements, systems, projects, or programs and characterized by mutual physical, functional, environmental, operations, and/or procedural properties.

Integration.--the process of achieving unit of effort among the various subsystems in the accomplishment of the organization's task.

Isolation.--separation from the whole and set apart.

Laboratory.--a facility or area equipped for scientific experimentation, research, development, or testing.

Manager.--an individual engaged in decision-making, that affects technical professionals and others, the one who implements these decisions through command.

Mission.--the purpose for which the organization exists; it is the sum of all the more detailed goal formulations--the objectives.

Multidisciplinary.--participating in work activity of two or more technical professionals trained in various disciplines.

Organic-Adaptive Organizational Structure.--a temporary organizational system of diverse specialists solving problems, linked together by coordination and task evaluation.

Organizational Structure.--the established pattern or deliberate grouping of relationships among the components or parts of a formal organization to achieve specific goals; characterized by planned division of activities, leadership, and communications responsibilities, and the presence of a hierarchy of authority needed to control, direct, and coordinate the concerted efforts of the organization towards its goal.

Power.--the ability to secure desired behavior from individuals or to affect a situation in a predetermined manner.

Principal Investigator (P.I.).--a member of the scientific, academic, or medical community responsible for a research or applications activity.

Process.--a series of actions that leads to the accomplishment of objectives; e.g., management processes include planning, organizing, controlling, directing and coordinating.

Program.--a related series of undertakings which continue over a period of time (normally years) and which are designed to accomplish a broad scientific or technical goal.

Project.--an undertaking with a scheduled beginning and end, such as the operation of a new launch vehicle (and associated ground support equipment) during its R&D phase.

Project Manager.--an individual responsibile for the planning, organizing, directing and controlling of a project.

Research.--investigation or inquiry which is either of the basic or applied variety.

Research and Applications (R&A) Facility.--an in-orbit operational Skylab, Space Station, or Space Base.

Responsibility.--the obligation of an individual to perform the duties assigned to him to the best of his abilities. In another sense, a responsibility may be regarded as a duty.

Scientist.--a college-trained person having expert knowledge in either chemistry, mathematics, physics, astronomy, psychology, or similar disciplines or areas of study.

Situational Stress.--the set of environmental circumstances which tend to disturb homeostasis or internal stability.

Span of Control.--the number of subordinates reporting to a superior.

Stress.--the set of circumstances which tend to disturb homeostasis, or internal stability.

Structure.--see organizational structure.

Synergistic.--cooperative action such that the total effect is greater than the sum of the parts taken separately.

Technical Professional.--a scientist or engineer who is experienced and working in the same or related field as his discipline of study.

Technician.--a noncollege-trained person having skills in one or more areas of scientific or engineering areas of study.

Technologist.--a scientist, engineer, or technician.

Work Unit.--a task which contributes to the accomplishment of functions, and which a single individual is required to perform.

SPACE BASE ANALOG EVALUATION

A study of this nature requires, as part of the analytical process, consideration of appropriate analogous situations. The basic problem then was to determine what situations are most similar to the Space Base environment under consideration. The methodology which makes this comparison possible is contained in this appendix.

Sells has developed a comparison method for evaluating the appropriateness of eleven well-known social systems to a subject system.[1] The systems considered all had elements of isolation, confinement, situational danger and substantial information in the literature associated with them. These variables and data availability make each identified system important for consideration purposes. The objective of the Sells study was to develop a ranking for eleven systems, and to determine categorical areas of similarity and difference. The subject system was a hypothetical 500-day mission to Mars and return by a crew

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[1] S. B. Sells, "A Model for the Social System for the Multiman Extended Duration Space Ship," Aerospace Medicine, XXXVII (November, 1966), 1105-135; and S. B. Sells, "General Theoretical Problems Related to Organizational Taxonomy: A Model Solution and Its Assumptions," Paper presented to the Symposium on People, Groups, and Organizations: An Effective Integration of Knowledge, New Brunswick, New Jersey, September 30, 1966.

of six.[1]

The following list contains the eleven system patterns identified by Sells[2] and eleven additional systems identified by the writer. Two of the additional systems identified are for programs which have not been accomplished yet, but will be prior to the initiation of an operational Space Base. The two futuristic systems identified, and also discussed in other parts of this study, are the Skylab and Space Station programs. The comparative systems used for this analysis are:

1. Apollo spacecraft
2. Nuclear submarines
3. Ben Franklin research submarine
4. Tektite II laboratory
5. Sealab II
6. Oceanographic research ships
7. Antarctic stations
8. Exploration parties and expeditions
9. Transoceanic aircraft flights
10. Prison societies
11. Mental hospital wards
12. Off-Shore/Remote drilling rigs
13. Bomber crews
14. Remote AC&W stations
15. Professional athletic teams
16. Industrial work groups
17. Shipwrecks and disaster situations
18. Prisoner of war groups
19. Earthbound R&D labs
20. Ninety-day Space Station simulation
21. Skylab
22. Space Station

Table 1 is a comparison of social system profiles for the identified twenty-two system patterns with that of Space

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[1]Sells, "A Model for the Social System," p. 1130.

[2]*Ibid.*, p. 1134.

TABLE 1

COMPARISON OF SOCIAL SYSTEM PROFILES OF TWENTY-TWO SYSTEM PATTERNS WITH THAT OF SPACE BASE

System Structure Characteristics	COMPARISON SYSTEMS																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
I. OBJECTIVES AND GOALS																						
1. Formally Prescribed	1	1	2	2	2	2	2	1	1	0	0	0	1	1	1	1	1	0	1	1	2	2
2. Mandatory	2	2	2	2	2	2	2	2	2	1	1	1	2	2	1	1	1	1	2	2	2	2
3. Formal Authority	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2
4. Polarization	1	1	2	2	2	2	2	1	1	0	0	1	1	1	1	1	1	1	2	2	2	2
5. Remoteness of Goals	0	1	0	1	1	2	2	1	0	0	0	0	1	0	1	2	0	0	2	1	1	2
6. Success Criteria	1	1	2	2	2	2	2	1	0	0	0	1	0	0	1	1	0	0	2	2	1	2
7. Success Uncertainty (Risk)	2	1	1	0	2	1	2	2	0	0	0	1	2	1	0	0	2	1	1	0	2	2
8. Unitary Goals	1	0	1	1	1	2	2	1	0	0	0	0	0	0	0	1	0	0	2	2	2	2
9. Competition	2	1	0	1	1	2	1	1	0	0	0	1	1	0	1	1	0	0	1	1	2	2
10. Emphasis on Growth	0	0	0	1	1	2	2	1	0	0	0	1	0	0	0	2	0	0	2	1	1	2
II. VALUE SYSTEMS																						
11. Obedience To Command	1	0	2	1	1	2	2	1	1	0	0	1	0	0	0	1	0	0	2	2	1	2
12. Mission Emphasis	0	1	2	2	1	2	2	0	1	0	0	1	0	1	1	1	0	0	2	1	1	1
13. Respect for Indiv. Lives	1	1	1	1	1	1	1	2	1	0	0	1	1	1	2	1	1	0	1	2	2	2
14. National Priority	2	2	1	1	1	0	1	2	0	0	0	0	2	2	2	1	1	2	1	1	2	2
15. Military Trad. in Pers. Attits.	0	0	1	2	1	2	1	1	0	0	1	1	0	1	0	1	0	0	2	2	1	2
16. Accept. of Amer. Way of Life	1	1	1	2	1	2	2	1	1	0	0	1	1	1	2	2	0	1	2	1	1	2
III. PERSONNEL COMPOSITION																						
17. Intellectual Level	2	1	2	2	1	2	1	1	0	0	0	0	1	1	1	1	1	1	2	2	2	2
18. Educational Level	2	1	2	2	1	2	1	1	1	0	0	0	1	1	1	1	1	1	2	2	2	2

TABLE 1.--Continued.

System Structure Characteristics	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	COMPARISON SYSTEMS																					
19. Extent of Relevant Training	0	1	2	1	1	2	2	1	1	0	0	1	1	1	1	1	0	0	2	1	0	2
20. Extent of Relevant Experience	1	1	1	2	2	2	1	1	0	0	0	1	1	1	0	1	0	0	1	0	2	2
21. Personality Selectivity	0	2	1	2	1	2	1	0	0	0	0	1	1	0	0	1	0	0	1	1	0	1
22. Moral Traits	2	1	2	2	1	1	1	2	1	0	0	1	1	1	1	1	0	0	1	2	2	2
23. Physical Selectivity	0	2	2	1	1	2	2	0	1	0	0	1	1	2	0	1	0	0	1	0	0	2
24. Possession of Requisite Skills	1	1	1	1	1	2	1	1	2	0	0	2	1	2	1	2	0	0	2	1	1	2
25. Motivation to Participate	1	2	2	2	2	2	2	1	1	0	0	0	1	1	1	1	0	0	2	1	1	2
26. Sex of Participants	0	0	0	1	0	0	1	1	2	0	1	0	0	0	0	2	1	0	2	0	0	2
27. Age Range	1	2	1	1	1	1	2	1	2	0	0	1	1	1	1	1	0	1	1	1	1	2
28. Presence of Non-Crew Pers.	0	0	0	0	0	2	2	0	0	1	1	1	0	1	1	1	0	0	1	0	0	2
29. Rank Distribution (All "Officers")	0	1	0	0	1	2	2	0	1	1	0	1	1	2	1	2	0	1	1	0	D	1
IV. ORGANIZATION																						
30. Formal Structure	0	2	0	0	1	2	2	1	2	2	2	1	2	2	2	2	1	1	2	2	0	2
31. Prescribed Roles	0	2	1	2	2	2	2	0	0	0	0	1	0	1	1	2	0	0	2	1	0	2
32. Command Structure	2	1	1	1	1	1	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2
33. Centralized Authority	1	1	1	1	1	2	2	2	2	1	2	1	2	2	2	1	2	1	1	1	1	2
34. Chain of Command with Provisions for Succession	0	2	1	1	1	2	2	2	2	0	0	1	2	2	2	2	1	1	2	2	0	2
35. Extensive Backup Organization	0	1	2	1	1	1	1	1	1	0	0	1	1	1	0	1	0	0	1	0	0	2
36. Autonomy Re Goals	1	1	1	1	1	2	2	2	1	0	0	1	2	1	1	0	1	0	1	1	1	2
37. Group Size	0	2	1	0	1	2	2	1	1	0	0	1	0	2	1	1	0	1	2	0	0	1
38. Prescribed Discipline	1	1	2	2	1	2	2	1	1	0	0	1	0	1	1	1	0	0	1	1	1	2
39. Social Distance Among Crew	0	2	0	0	1	2	2	1	2	1	1	1	1	2	1	2	0	1	1	0	0	1
40. Congruency of Rank and Status	1	1	2	2	1	2	2	1	0	0	0	1	1	1	1	1	0	0	1	1	1	2

TABLE 1.--Continued.

System Structure Characteristics	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	COMPARISON SYSTEMS																					
V. TECHNOLOGY																						
41. Technologic Complexity	1	2	2	1	2	2	1	1	2	0	0	1	2	2	0	1	0	0	2	2	1	2
42. Relation to Aviation Tradit.	2	1	1	1	1	1	1	1	2	0	0	1	2	1	0	0	1	0	0	2	2	2
43. Use of Simulators and Other Technical Train. Devices	1	1	1	1	1	2	1	1	0	0	0	1	1	1	1	1	0	0	1	2	1	2
44. Preparation for Missions	0	0	2	1	0	2	2	0	0	1	1	1	0	0	0	1	1	0	2	1	0	2
45. Use of Technical Language in Execution	2	2	2	2	2	1	1	1	2	0	0	1	2	2	2	1	0	0	2	2	2	2
46. Physical Preconditioning	0	1	1	1	1	1	1	1	1	1	0	0	0	2	1	1	1	0	0	2	1	2
47. Scientific Principles Involved	2	1	2	2	2	2	1	1	2	0	0	1	1	1	0	0	0	0	2	2	2	2
VI. PHYSICAL ENVIRONMENT																						
48. Required Physiol. Protection and Life Support	2	2	2	2	2	1	2	2	2	0	0	1	2	1	1	1	0	0	1	2	2	2
49. Remoteness From Base	2	2	1	1	2	2	2	2	1	0	0	1	2	1	0	0	2	2	0	1	2	2
50. Presence of Unknown Environmental Hazards	2	2	2	2	2	1	1	2	1	0	0	1	2	1	0	0	2	1	0	1	2	2
51. Confinement in Environment	1	2	2	2	1	2	2	1	1	2	1	1	1	0	0	0	1	1	0	2	2	2
52. Endurance Demands	1	2	2	1	1	2	1	1	2	0	0	1	1	2	0	0	0	0	0	2	2	2
53. Reduced Communications	2	0	1	1	1	0	0	0	1	0	0	0	0	1	0	1	0	0	1	2	2	2
54. Maneuvering Situation	1	2	2	2	1	2	2	2	2	1	0	2	1	0	0	0	1	1	0	2	2	2
55. Embedded Environmental Stresses	1	2	2	1	1	2	2	1	2	0	0	2	1	1	0	1	1	0	1	1	2	2

TABLE 1.--Continued.

System Structure Characteristics	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	COMPARISON SYSTEMS																					
VII. TEMPORAL CHARACTERISTICS																						
56. Duration of Participation	1	1	2	2	2	2	1	1	1	0	0	2	1	1	0	0	1	0	1	1	1	2
57. Daily Participation Required	1	2	2	1	1	2	2	1	1	0	0	2	1	2	0	2	1	0	2	2	1	2
58. Remoteness of Goals	0	1	0	1	1	2	2	1	0	0	0	0	1	0	1	2	0	0	2	1	1	2

Note: The numbers 2, 1, and 0 are used here to indicate the degree of similarity to the Space Base on a three-point scale: 2 (highly similar), 1 (moderately similar), and 0 (dissimilar).

Base. Sells has developed a standard set of system structure characteristics that can be applied generally as a means of ordering various microsocieties according to their similarity to each other. The set consists of seven categories and fifty-eight elements (slightly modified by the writer). These elements can be ordered on a continuum conducive to comparative analysis.[1] The numbered comparison systems are those identified above.

The twenty-two comparison systems have been sequentially evaluated against each system element. The numbers shown indicate the relative degree of similarity between the comparison systems and the Space Base system. A three point scale - two (highly similar), one (moderately similar), and zero (dissimilar or unrelated) - developed by Sells[2] was used. The comparative relative values shown, representing a separate decision in each case, were made by the writer based on extensive studies of the known characteristics of the comparison systems. A maximum similarity score for the fifty-eight elements would be 116 (2 x 58), with scores ranging from 116 to 0.

Table 2 is a tabulation of the similarity scores for each comparison system. The systems are then ranked starting with the highest scoring system (Space Station), and ending with the lowest (mental hospital wards).

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[1] _Ibid._, pp. 1132-134. [2] _Ibid._, p. 1134.

TABLE 2

COMPARISON SYSTEMS SIMILARITY RANK AND SCORE

Comparison Systems	Similarity Rank	Similarity Score
22. Space Station	1	111
6. Oceanographic research ships	2	99
7. Antarctic stations	3	93
19. Earthbound R&D labs	4	78
3. Ben Franklin research submarine	5	77
4. Tektite II lab	6	76
20. Ninety-day Space Station simulation	7	74
2. Nuclear submarines	8	72
5. Sealab II	9	71
21. Skylab	10	70
8. Exploration parties and expeditions	11	64
14. Remote AC&W stations	12	62
16. Industrial work groups	13	61
9. Transoceanic aircraft flights	14	59
13. Bomber crews	15	58
1. Apollo program	16	55
12. Off-Shore/remote drilling rigs	17	53
15. Professional athletic teams	18	43
17. Shipwrecks and disaster situations	19	29
18. Prisoner of war groups	20	23
10. Prison societies	21	16
11. Mental hospital wards	22	15

Several conclusions have been drawn by the writer based on the analysis of the ranking provided in Table 2. The first is that the first three systems are the most analogous to Space Base, and the last four rank least analogous. In both cases definite break points are shown in the similarity scores. The second conclusion is that because of the discernible break between the scores of the tenth (Skylab) and the eleventh (Exploration parties and expeditions) systems, that the first ten comparison systems should be considered the most analogous and relevant systems for purposes of this study.

Table 3 is an analysis of system similarities by descriptive categories. This method of comparative analysis, also developed by Sells,[1] uses numbers to indicate similarity on the following bases: two for matching over 70 per cent of the items in each category from Table 1, one for matching 31 to 70 per cent, and zero for matching less than 30 per cent.

The table is interesting because of the similarities and dissimilarities shown. In this analysis it is seen that there is close similarity to Space Base by the four top ranking systems. The notable exception is in the physical environment category for earthbound R&D Labs, and this result is not totally unexpected. The bottom four categories indicate the extent of dissimilarity which exists between

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[1]*Ibid.*, p. 1135.

TABLE 3

ANALYSIS OF SYSTEM SIMILARITIES BY DESCRIPTIVE CATEGORY

Comparison Systems	System Description Category						
	Object. and Goals	Value Systems	Pers. Comp.	Organiz.	Technol.	Phys. Envir.	Temporal Chars.
22. Space Station	2	2	2	2	2	2	2
6. Oceanographic research ships	2	2	2	2	2	2	2
7. Antarctic stations	2	2	2	2	1	2	2
19. Earthbound R&D labs	2	2	2	1	1	0	2
3. Ben Franklin research submarine	1	1	1	1	2	2	1
4. Tektite II lab	1	2	1	1	1	2	1
20. Ninety-day Space Stat. simulation	1	2	1	1	2	2	1
2. Nuclear submarines	1	1	1	2	1	2	1
5. Sealab II	2	1	1	1	1	1	1
21. Skylab	2	1	1	0	1	2	1
8. Exploration parties and expeditions	1	1	1	1	1	1	1
14. Remote AC&W stations	1	1	1	2	1	1	1
16. Industrial work groups	1	1	1	1	1	0	1
9. Transoceanic aircraft flights	0	1	1	1	1	2	1
13. Bomber crews	1	1	1	1	1	1	1
1. Apollo program	1	1	1	0	1	2	1
12. Off-shore/remote drilling rigs	1	1	1	1	1	1	1

TABLE 3.--Continued.

Comparison Systems	System Description Category						
	Object. and Goals	Value Systems	Pers. Comp.	Organiz.	Technol.	Phys. Envir.	Temporal Chars.
15. Professional athletic teams	1	1	1	1	0	0	0
17. Shipwrecks and disaster situations	0	0	0	0	0	1	1
18. Prisoner of war groups	0	0	0	0	0	1	0
10. Prison societies	0	0	0	0	0	0	0
11. Mental hospital wards	0	0	0	1	0	0	0

Note: The numbers 2, 1, and 0 are used here to indicate similarity on the following basis: 2, for matching over 70 per cent of items in the category (Table 1); 1, for matching 31 to 70 per cent; and 0, for matching less than 30 per cent.

these systems and Space Base in almost all categories. Only a few scattered, moderate similarities exist.

It is important and necessary to indicate that some limitations of this comparative analysis exist. First, weights are not assigned, nor is relative importance given to the particular elements of system structure characteristics shown in Table 1. Second, the list of elements may not be mutually exclusive or all inclusive. Lastly, this comparison was made by a knowledgeable individual (the researcher in this study) and not by a group of knowledeable individuals.

While these limitations at first seem to be a condemnation of the methodology, there are several reasons why the method should be considered valid and necessary for this study. First, while it may be desirable to weigh and give relative importance to each element, an adequate method does not exist to do so. A method might be for a knowledgeable individual or group to assign subjective weighing factors for each element, but here again this method has its limitations. In addition, there is probably little reason to believe that any one element is important enough to warrant a factor which would change the results significantly.

Second, while the list may not be mutually exclusive or all inclusive, it is the best available for this study. The methodology was found to be flexible enough to accommodate additions or deletions without significant impact.

Third, the methodology should not be condemned because an individual was the only one who assigned point values rather than a group. Realistically, it would be difficult, if not impossible, to assemble a group knowledgeable enough to individually or collectively make the point assessments for the spectrum of system structure characteristics and comparison systems considered.

In conclusion, the methodology and results presented in this appendix represent a necessary and accepted way of identifying and ranking the appropriateness of a multitude of analogous social systems. This analysis will serve as an important stepping stone for the total study methodology. The identified limitations of the Sells methodology are not considered by the researcher to be of sufficient magnitude to eliminate its use.

APPLICABLE ANALOG DESCRIPTION

This appendix provides a brief description of the salient aspects of the most applicable analogs identified in Appendix C and used in this study. These ten analogs, listed in descending order of similarity to Space Base are Space Station, oceanographic research ships, Antarctic stations, earthbound R&D labs, the Ben Franklin research submarine, the Tektite II lab, the ninety-day Space Station simulation, nuclear submarines, Sealab II, and Skylab.

Categories used for this discussion are objectives and goals, physical configuration, physical environments, personnel composition, organization, and technology. These categories are closely correlated to those used in the social system analysis of Appendix C, which was developed by Sells. In addition, these categories are similar to the organizational structural variables identified in Table 1 of section II. Much of the descriptive information of this appendix is summarized in Table 4 of that section. Any additional descriptive information of these analogs required by the reader, can be found in one of the appropriate references contained in the Bibliography.

Space Station

Objectives and Goals

To provide a centralized and general purpose laboratory in earth orbit for the conduct and support of scientific and technological experiments, for beneficial applications, and for the future development of space exploration capability for mission lasting three months in duration and longer

Physical Configuration

Either a modular design compatible with the Space Shuttle cargo bay (fourteen-foot diameter), or a more centralized design (thirty-three-foot diameter) launched by a modified Saturn vehicle

Physical Environment

- Circular earth orbit 242 miles high
- Semiconfinement and isolation
- Zero and/or partial gravity
- Autonomous operations planned

Personnel Composition

- Crew of six to twenty technologists
- One-sixth of crew involved in administrations and operations
- Male/female/international members
- Moderate crew selection and mission training

Organization

- Undefined and still in study stage
- Traditional line organizations recommended in several studies
- Moderate communications, coordination, and integration will be required

Technology

- Equipment automation where possible
- State-of-the-technology R&A activities
- Scientific principles involved

Oceanographic Research Ships

Objectives and Goals

- To conduct scientific studies and explorations of various durations of the oceans and seas in all their aspects, including the sediments and rocks beneath the seas; the interaction of sea and atmosphere; the behavior of the living content of the seas and sea floors; the chemical composition of the water; and the formation and interaction of beaches, shores, and estuaries

Physical Configuration

- Includes both conventional and special-purpose research ships and specialized research vehicles, such as deep submersibles

- Includes vessels of varying sizes, shapes, and operational limitations

Physical Environment

- Varies widely depending on oceanographic vessel configuration and mission objectives

- Semiconfinement and isolation

- A wide variety of geographical conditions

- Autonomous operations

Personnel Composition

- Crew size and skills vary widely

- Crew functions usually split between scientific activities and support operations

- Traditionally have an all male crew, but female and international crew members participating more

- Moderate crew selection and training

Organization

- Traditionally used Naval line (functional) organizations

- Now use more modern project structures for scientific activities with scientific responsibility for accomplishment resting with science leader and safety responsibilities belonging to the Captain

- Little communications, coordination, and integration is usually needed because of the specialization of each mission

Technology

- Some equipment automation
- Scientific principles involved
- State-of-technology varies widely

Antarctic Stations

Objectives and Goals

- To conduct a wide variety of scientific studies and explorations involving a number of research disciplines such as geology, physics, biology, medicine, glaciology, oceanography, astronomy, geophysics, paleontology, and psychology

- Studies conducted year-round

Physical Configuration

- Varies between large, well-equipped facilities to a small cluster of portable vans

- Many physical comforts and recreational facilities provided to personnel

Physical Environment

- Antarctica considered the most hostile environment on earth inhabited by man

- Temperatures recorded as low as $-126^{o}F$

- Austral winter (March through October) covers continent in complete and continuous darkness, while perpetual sunlight occurs during the summer

- Semiconfinement and isolation

- Total autonomy and isolation in winter

Personnel Composition

- Crew size varies at different stations between 8 and 340 people during "wintering in" period

- Crew functions usually split between scientific activities and support operations

- Civilian scientists and Navy officers and enlisted men staff stations

- Women excluded until recently

- Moderate crew selection and training

Organization

- Traditionally use Naval line (functional) organizational structure
- Navy officer is commander
- Various scientific leaders identified
- Little communications, coordination, and integration is usually needed

Technology

- Some equipment automated
- Scientific principles involved
- State-of-technology varies widely

Earthbound R&D Labs

Objectives and Goals

- To conduct a wide variety of R&D activities in the private and public sectors involving a number of disciplines such as physics, chemistry, biology, botany, and engineering

Physical Configuration

- Facilities vary widely with respect to size and location
- Usually located near universities or other desirable areas

Physical Environments

- Usually attempt to develop an atmosphere of creativity

- Technologist's equipment/funding needs normally accommodated

- Few if any physical hazards

- Moderate autonomy of operations

Personnel Composition

- Various staffing levels depending on funds and size of organization

- Fairly heterogeneous manning for administration, R&D activities, and support operations

- Male and female organization members

- Little physiological or psychological testing or training for a specific activity required

- Generally high education/skill levels

Organization

- Organizational structure varies depending on organization size and activities

- Matrix structure frequently used

- Moderate communications, coordination, and integration is usually needed

Technology

- Advanced and state-of-the-technology equipment required
- Scientific principles used extensively

<u>Ben Franklin</u>

Objectives and Goals

- To explore the Gulfstream from Florida to Nova Scotia using visual observations, bottom photography, and biological and acoustical surveys

- To provide data for NASA's man-in-space programs on crew reactions, the man-machine interface, habitability, and the effects of complete biological isolation during a long-term mission lasting thirty days

Physical Configuration

- A 147-ton displacement research submersible

- Length forty-eight feet, extreme beam twenty feet, and height twenty-one feet

- Four-knot maximum submerged speed

- Powered by four electric motors

- Marine observation through twenty-nine portholes

Physical Environment

- Semiconfinement and isolation
- Outside water temperature of 44.6^{o}F
- Strong eddy currents within the Gulfstream
- Some support provided by surface ships
- Moderate autonomy of operations

Personnel Composition

- A six-man crew

- Various scientific, engineering, and technician skills utilized

- Captain was a former Navy submariner

- Moderate crew selection and training

Organization

- Top-sided Mission Director had overall mission responsibility

- Small-scale on-board matrix organization

- Captain responsible for activities and operations within the submersible

- On-board Mission Scientific Leader identified

- Little communications, coordination, and integration was needed

Technology

- Some equipment automated
- State-of-the-technology equipment utilized
- Scientific principles involved

Tektite II

Objectives and Goals

- To determine if a small group of men could perform scientific tasks for extended time periods under hazardous conditions and in a nitrogen saturated environment

- To perform behavioral studies concurrently in the areas of individual and small group dynamics and human performance capability for use in NASA's man-in-space programs

Physical Configuration

- Two steel cylinders 12.5 feet in diameter and 18 feet high mounted vertically on a rectangular box-life base and connected by a tunnel

- An open hatch provided access to and from the sea.

- Located fifty feet deep in the Great Lameshur Bay off St. John's Island in the U.S. Virgin Islands

Physical Environment

- Danger from the bends
- Semiconfinement and isolation
- Habitat supported from shore
- Moderate autonomy of operations

Personnel Composition

- Ten - five diver teams

- Each crew consisted of scientists and one habitat engineer

- All-male and all-female crews

- High education/skill levels

- Stringent crew selection and training

Organization

- Team leaders selected before missions began

- Traditional line organization with main division between scientific and habitat engineering activities

- Small multishift operating test staff required during missions

- Little communications, coordination, and integration required

Technology

- Some equipment automated
- Advanced breathing and scientific equipment utilized
- Scientific principles used

Ninety-Day Space Station Simulation

Objectives and Goals

- To provide data in a closed ecology such as that of an orbiting Space Station for a period of ninety days

- To determine the performance of subsystems under continuous operating conditions

- To demonstrate the ability of the crew to operate and maintain the various subsystems

- To evaluate the requirements of the crew for maintenance of their physiological and psychological health to efficiently perform mission objectives

Physical Configuration

- Double-walled horizontal cylinder, twelve feet in diameter and forty feet in length

- An airlock located at one end

- Several small pass-through ports

- Simulator located at McDonnell Douglas Astronautics Company, Huntington Beach, California

Physical Environment

- Semiconfinement and isolation
- Moderate autonomy of operations

Personnel Composition

- One - four man crew
- Stringent crew selection and training
- Physical science graduate students
- Incentive pay program utilized for the crew

Organization

- Quasi-military line organization within simulator

- One crew member designated Crew Commander

- Deputy Commander selected by the Commander with approval of the Program Manager

- A relatively small multishift operating test staff and program management organization required during the simulation

- Little communications, coordination, and integration required

Technology

- Some automated equipment used
- An advanced regenerative life support system used

Nuclear Submarines

Objectives and Goals

- To serve as a strategic deterrent weapons system to prevent nuclear war

- To remain hidden, mobile, and ready to launch any or all sixteen nuclear-tipped Polaris or Poseidon missiles against an enemy

Physical Configuration

- Three classes of submarines ranging from 389 to 425 feet long, and 5,900 to 7,000 tons, respectively

- When on operational status, range the oceans of the world

Physical Environment

- Semiconfinement and isolation
- Operate without communicating
- Autonomy of operations
- Some fear of accident present because of earlier nuclear submarines losses

Personal Composition

- Crew size of approximately 125 Navy officers and enlisted personnel
- Varying education/skill levels
- Stringent crew selection and training

Organization

- Traditional Navy line (functional) organizational structure
- Captain has responsibility and authority for all vessel activities
- Stringent communications, coordination, and integration required

Technology

- Extensive equipment automation
- Many advanced systems used

<u>Sealab II</u>

Objectives and Goals

- To demonstrate that man can live in a hostile ocean environment at a depth of 205 feet, and perform useful work for extended periods without returning to the surface
- To increase man's knowledge of this environment for the purpose of making the millions of square miles of submerged

territory of the continental shelves off the coasts of the United States accessible for useful purposes

Physical Configuration

- A twelve foot diameter and fifty-seven foot long steel cylinder

- Eleven ports used for marine observation

- An open hatch provided access to and from the habitat

- Located one mile offshore in the Pacific Ocean, near the Scripps Institution of Oceanography, La Jolla, California

Physical Environment

- Three - ten man teams of divers

- Fifteen day mission duration with two men staying thirty days

- Mixture of male civilian and active duty Navy personnel: scientists, divers, and salvage specialists

- Ages varied from twenty-four to fifty years

- Education varied from less than ninth grade to the graduate level

- Stringent crew selection and training

Organization

- Traditional Navy line (functional) organization

- A relatively small multishift operating test staff required during the missions

- Little communications, coordination, and integration required

Technology

- Some equipment automation
- A diversity of technology utilized
- Some scientific principles involved

Skylab

Objectives and Goals

- Scientific investigations in earth orbit including astronomical, space physics, and biological experiments

- Applications in earth orbit including earth resources surveys to gather data for oceanography, water management, agriculture, forestry, geology, geography, and ecology

- Understanding man's capabilities in space for extended periods of time with one mission up to twenty-eight days duration and two others up to fifty-six days

Physical Configuration

- House trailer sized Orbital Workshop twenty-two feet in diameter and forty-eight feet long

- Other components such as an Airlock Module, Multiple Docking Adapter, Apollo Telescope Mount, and solar panels

Physical Environment

- Circular earth-orbit 270 nautical miles high
- Semiconfinement and isolation
- Zero gravity
- Limited autonomy of operations

Personnel Composition

- Three - astronaut crews of three men
- At least one crew member will be a scientist-astronaut
- Stringent crew selection and training

Organization

- Military-type line organization with a commander in orbit

- An extensive mission control and program management organization on earth

- Stringent communications, coordination, and integration required

Technology

- Some automated in-orbit equipment
- State-of-technology R&A activities
- Scientific principles involved
- Engineering skills required

APPENDIX E

EVALUATOR INSTRUCTIONS AND EVALUATOR MATERIAL

EVALUATOR INSTRUCTIONS AND EVALUATION MATERIAL

Study Purpose

The purpose of this study is to identify an optimum formal organizational structure which would assure the orderly and effective management of Space Base crew members and their resources.

Evaluator Instructions and Evaluation Material

1. Each evaluation team member should become familiar with the evaluation material included in the package provided.

   a. Artist's concept of centralized and modular earth-orbiting Space Bases, and a photo of a modular laboratory mockup.

   b. Space Base program requirements and assumptions.

   c. Figs. 4 and 5 (possible organizational structural models for a Space Base).

   d. Figs. 12 and 13--Classical and matrix organizational structural models to be evaluated and their major features.

   e. Descriptions of organizational structural models to be evaluated.

   f. Table 5--Criteria with sources and rationale for organizational structural model evaluation.

   g. Table 7--Evaluation team membership.

   h. Table 8--Evaluation scores.

   i. Individual relative scoring of organizational structural models forms (3).

   j. Classical and matrix assumed manning levels.

   k. Evaluation rationale forms (twenty-three).

2. Each evaluation team member is asked to formulate any questions, so that they can be discussed and answered when contacted. Unfamiliar words or terms used in the material provided should be noted. The purpose of this contact is to ensure that all team members have the same understanding of the organizational structural models, the criteria, and the study methodology.

3. On an individual basis, each team member will evaluate how well each of the criteria (listed in Table 5) are satisfied by the eight organizational structural models being evaluated (Figures 12 and 13). Some criteria are self-descriptive, while others require that the source/rationale column be read for better understanding. Once scores (from Table 8) are assigned to the models being evaluated (using the Individual Relative Scoring of Organizational Structural Models form), the process is repeated for the next criterion. If a model does not completely satisfy a criterion, the rater is to briefly indicate his reason on the evaluation rationale forms provided. These notes will be important should questions arise after preliminary evaluation of the data. If questions develop during the individual evaluation period, contact James Ragusa at (305)/867-2355. Results should be mailed to: James M. Ragusa, NASA-KSC-DY, Kennedy Space Center, Florida 32899.

4. Selected study evaluation team members may be asked to meet again after the data is received to critique results obtained.

Space Base Program Requirements and Assumptions

Initial operation 1980-2000 period

Minimum life of ten years

Autonomous activities and operations when possible

Modular or centralized configuration

Shuttle vehicle used for logistics

Multidisciplinary research and applications (R&A) activities

Interplanetary mission support

Crew size of 50 to 100

Initially 50 crew members - later 100

Male and female crew members

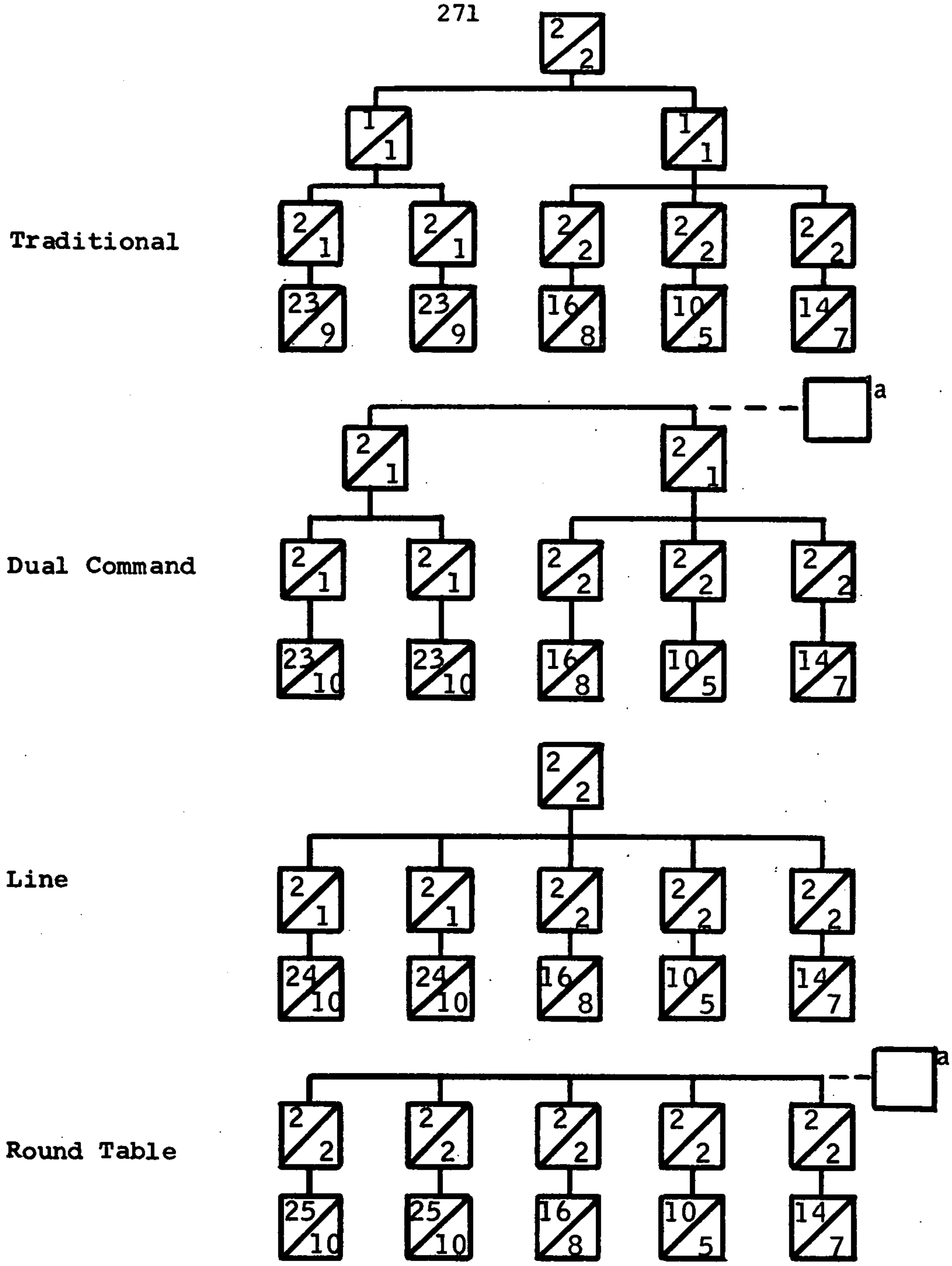
Domestic and international technologists

Permanent party and transient crew members

Minimum astronaut-type training and physical conditioning

NASA Directors and Managers

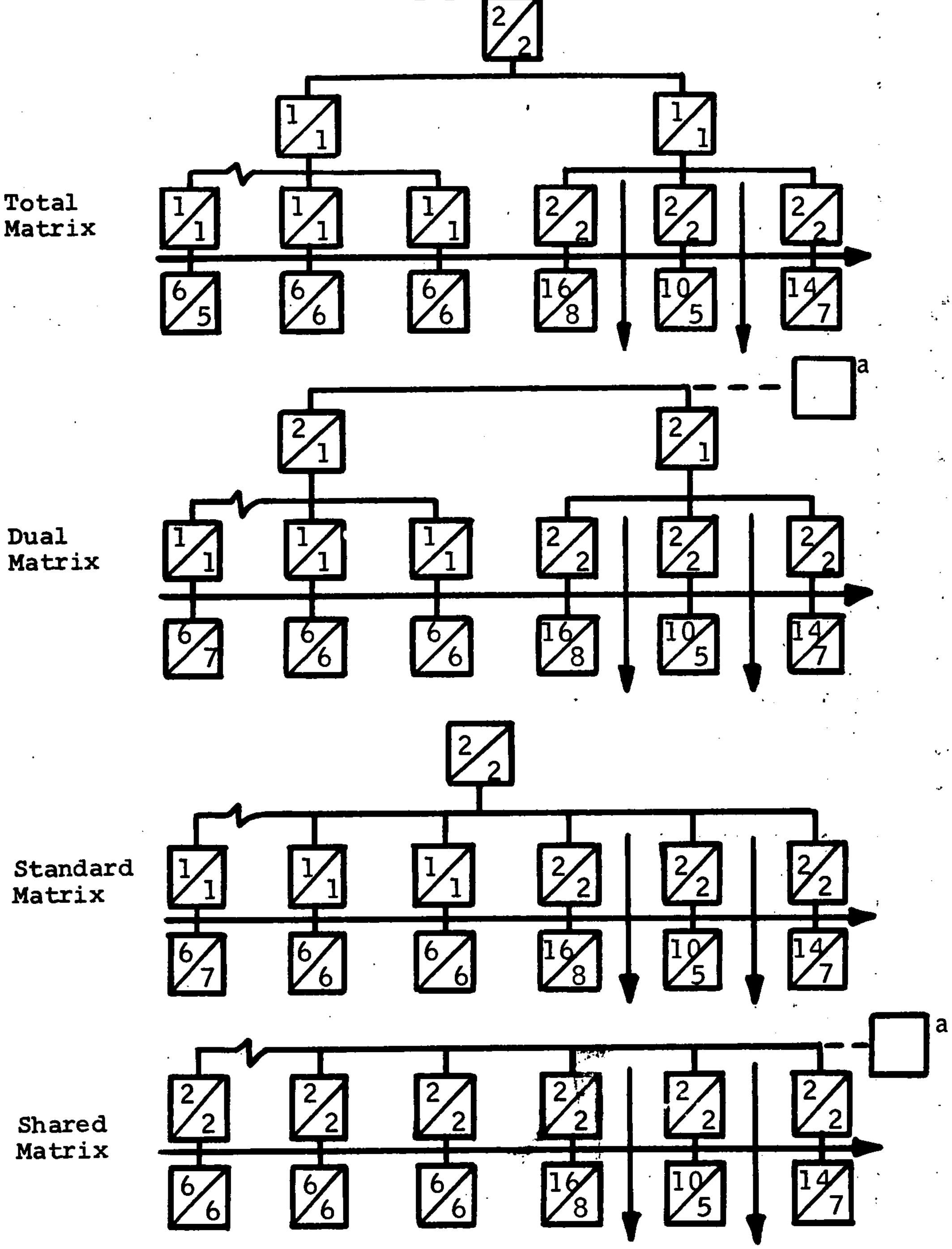
Around-the-clock and nonroutine activities and operations



Note: Numbers in the upper part of each box are manning levels for a crew size of 100, while the lower numbers are for a crew size of 50.

[a]Mission Director located on earth

Assumed manning levels for matrix organizational structural models



Note: Numbers in the upper part of each box are manning levels for a crew size of 100, while the lower numbers are for a crew size of 50.

[a]Mission Director located on earth

Assumed manning levels for matrix organizational structural models

INDIVIDUAL RELATIVE SCORING OF ORGANIZATIONAL STRUCTURAL MODELS

	Organizational Structural Models							
Evaluation Criteria	Traditional	Dual Command	Line	Round Table	Total Matrix	Dual Matrix	Standard Matrix	Shared Matrix
Objectives and Plans								
1. Multi-R&A Activities								
1.1 Variety of R&A								
1.2 Undefined activities								
1.3 Assigned priority								
1.4 Situat. requirements								
2. Crew Size								
2.1 Large crew								
2.2 Crew growth								
2.3 Many technologists								
Capability of Personnel								
3. Crew composition								
3.1 Mixed crew								
3.2 Multination crew								
3.3 Diverse backgrounds								
3.4 Task leader								
3.5 P.I. participation								
3.6 Varying crew size								

Evaluation Criteria	Organizational Structural Models							
	Traditional	Dual Command	Line	Round Table	Total Matrix	Dual Matrix	Standard Matrix	Shared Matrix
4. Crew Selection and Training								
4.1 Min. astro training								
4.2 Dual selection								
4.3 Crew selection								
4.4 Train./indoctrin.								
Environment								
5. Mission Duration								
5.1 Ten-year life								
5.2 Varying tours								
5.3 Multishift work								
5.4 Replacement								
6. Environmental Factors								
6.1 Rewards vs. costs								
6.2 Cohesive group								
6.3 Work schedule								
6.4 Prof. satisfaction								
6.5 Human capabilities								
6.6 Full employment								
6.7 Various construct.								

Evaluation Criteria	Organizational Structural Models							
	Traditional	Dual Command	Line	Round Table	Total Matrix	Dual Matrix	Standard Matrix	Shared Matrix
7. Autonomy of Operations								
7.1 Autonomous operations								
7.2 Planning/scheduling								
7.3 Nonduty work								
<u>Authority</u>								
8. Authority and Responsibility								
8.1 General definition								
8.2 Various managers								
8.3 Unity of command								
8.4 Span of control								
8.5 Work flexibility								
8.6 Personal freedom								
9. Comm., Coord., and Integ.								
9.1 Group decision making								
9.2 Quality and speed								
9.3 Line of commun.								
9.4 Bidirectional comm.								
9.5 Tech. profes. comm.								
9.6 Two-way audio/video								
9.7 Min. interfaces								
9.8 Feedback								
9.9 Creative climate								

Evaluation Team Member: ______________

Criterion	Traditional	Dual Command	Line	Round Table
	Total Matrix	Dual Matrix	Standard Matrix	Shared Matrix

Criterion	Traditional	Dual Command	Line	Round Table
	Total Matrix	Dual Matrix	Standard Matrix	Shared Matrix

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