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

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ABSTRACT

The purpose of this exploratory study was to identify an optimum hypothetical organizational structure for a large earth-orbiting multidisciplinary research and applications (R&A) Space Base manned by a mixed crew of technologists. Since 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 the empirical testing of it. 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.

INTRODUCTION

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 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, as Figure 1 illustrates. 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, direct, and coordinate the concerted efforts of the organization toward its goals in an orderly manner.

METHODOLOGY

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

The first phase, concerned with data research, relied heavily on data obtained from the 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: Space Base program requirements and assumptions, related studies, general and specific organizational structural variables, the nature of professional organizations and technical professionals, and 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. Several models were identified by considering combinations 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. Screening of the models was accomplished by using criteria of practicality, difference, decision making, and program requirements and assumptions with the result being a smaller, more feasible set of models.

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, 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 discriminating criteria were satisfied by the models. These criteria discriminated because of their wide variation of summed evaluator scores between models. The final quantitative and qualitative analysis resulted in an answer to the primary study question.

PRIMARY QUESTION

While the broad purpose of the study was to expand on the body of knowledge concerned with the role of organizational structure on human endeavor, the primary question of this study was: what is the preferred organizational structure for optimizing the mission accomplishment of the various technologists who will work and live in a large multidisciplinary earth-orbiting Space Base? 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, illustrated in Figure 2. This four-level hierarchical 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 a project/functional level, as are project/functional groups of technologists at the task level. The lines with arrows on this matrix model are included to indicate horizontal project and vertical functional authority and responsibility. The broken line on the project side of the structure indicates that a number of small project teams are possible and would be used depending on mission needs.

This structure was found to possess the greatest capability for orderly, efficient, and effective management of the crew through its adaptability to 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 all discriminating criteria best.

ELEMENTAL QUESTIONS

The answer to the primary question was arrived at through research and the development of answers to eight elemental questions by the use of the study methodology.

Questions one through five were answered during the first phase of the study methodology, questions six and seven in the second phase, and question eight in the third phase.

Question one: What known program requirements are important to organizational structure selection, and what assumptions must be made? A review of Space Base literature identified twelve program requirements considered by NASA to be necessary to insure program success. These requirements are listed in Table 1. In addition to these requirements, nine assumptions relevant to organizational structural considerations and relating to R&A activities and operations were made by the researcher to simplify, clarify, and restrict variables. These assumptions are listed in Table 2.

Question two: What related studies provide insight into Space Base organizational structure selection? An extensive and intensive review of primary and secondary literature revealed that there have been no studies whose sole purpose was to determine a preferred Space Base 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 (2) identified basic Space Base program objectives and developed a Statement of Work for follow-on contractor study efforts (3,4). While neither contractor studied organizational structure per se, both indicated that crew members could be assigned to two organizational groups, namely: R&A activities and operations. Two other studies were investigated because they were important to the study methodology. The first was the Grumman Aircraft Engineering Corporation study (1) which served as the model for the phased methodology used in the present study. The second was a study by Sells (5) 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. Using a three-point scale, each of eleven comparison systems were scored, using fifty-six system characteristics listed under seven descriptive categories.

Question three: What variables are important to the selection of an organizational structure for a Space Base? 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 appropriate to this study. These variables are objectives and plans, capability of personnel, environment, and authority (6). In addition to these general variables, nine specific variables were used. These variables are 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 first seven of these variables were derived (and modifed) from those used in the Grumman study. The latter two were added by the researcher to broaden the list.

Question four: What type of organizational structure best serves the needs of technical professionals? A review of literature relating to professional organizations, characteristics of technical professionals, and the relationship 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 a more modern and 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.

Question five: 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 organizational structural selection? 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 in descending order of similarity to Space Base were:

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

After these applicable analogs were identified, they were analyzed 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. Results are shown in Table 3. Investigation in these areas revealed a variety of data invaluable for subsequent analyses. It should be noted, however, that more than one-half of the correlations (indicated by the cross-hatched areas) were not considered to be relevant even though the analogs were judged to be applicable.

Question six: What evaluation criteria should be used to select the preferred organizational structure? A multitude of criteria and rationale for their use were identified. After careful screening a total of forty-six criteria were grouped in four general and nine specific variable categories. These criteria by categories are listed in Table 4. The sources of these criteria were program requirements and assumptions, management concepts and practices, and applicable analog data. Sixteen, nineteen, and eleven criteria were identified from these sources, respectively.

Question seven: What variation to basic classical and modern organizational structural models should be considered for Space Base use, and why? From an analysis of program requirements and assumptions, management concepts and practices, and applicable analogs, thirty variations of classical and matrix models were identified. These models, reduced to a feasible set of eight by the researcher, were equally divided between classical and matrix model variations. The remaining eight models were judged feasible because they were found to be practical and sufficiently different, and because they provided for decision making and satisfied program requirements and assumptions. Models with descriptive names and major features are shown in Figures 3 and 4. Cross-hatched areas indicate authority (supervisory) responsibility.

Question eight: What analyses can be used to assess feasible classical and modern organizational structures and select the preferred one? During the preliminary portion of this final assessment, scores for each model by criterion resulted from team evaluations. Table 5 ranks models by summed evaluator scores and indicates wide score discontinuities. While the total matrix model clearly scored higher than the others, the top four models were retained for further in-depth analysis. Table 6 shows these finalist models and indicates criteria with summed evaluator scores which varied significantly between models as indicated by their range of scores. These ten level I and II criteria were considered to be discriminating because of this variation. 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 facility 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 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.

CONCLUSIONS

The review of appropriate literature, visitations, interviews, evaluation team results, and findings of this research allowed the researcher to reach three major conclusions.

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 resources to satisfy program objectives and plans, when compared to a variety of alternate models. This conclusion was considered by the researcher to be retrospectively sound because only an organic-adaptive project organization has the inherent flexibility of satisfying Space Base program objectives presently envisioned and those which are still undefined.

The second conclusion was that while a number of criteria relating to 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 organization structure. For example, discriminating criteria were found in each specific 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, multi-national 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. This conclusion was not intended to belittle the importance of these criteria to overall organizational structural activities. It does mean, however, that when the highest ranking models identified in this study were analyzed, these criteria were not found to be important in selecting one model over the others, i.e., they did not discriminate.

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 shows that relevancy to Space Base was found lacking. This leads to an ultimate conclusion that Space Base, as envisioned, will be an environment somewhat unique to itself.

REFERENCES

(1) National Aeronautics and Space Administration, Crew Operations Study of Command Structure, May 14, 1971, by Samuel C. Campbell, Perry L. Gardner, and Robert H. Schaefer (Bethpage, New York: Grumman Aerospace Corporation, 1971).

(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).

(3) National Aeronautics and Space Administration, Space Base Concept Data (Phase A Definition): Volume 1, June, 1970 (Huntington Beach, Calif: McDonnell Douglas Astronautics Co., 1970).

(4) National Aeronautics and Space Administration, Space Base Definition: Volume 1, July 24, 1970 (Downey, California: North American Rockwell Corp., 1970).

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

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

Figure 1. Space Base Initial Assembly and the Space Shuttle

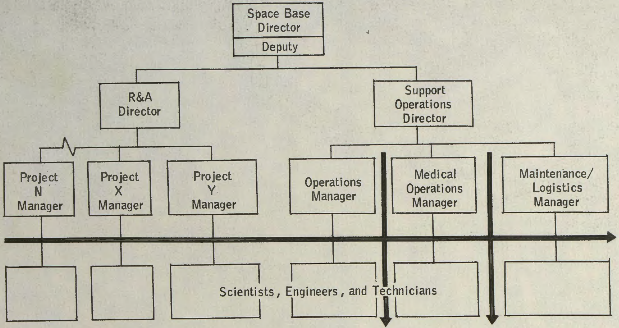
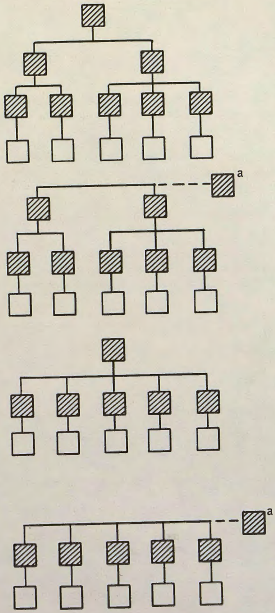


Figure 2. Total Matrix Organizational Structural Model

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

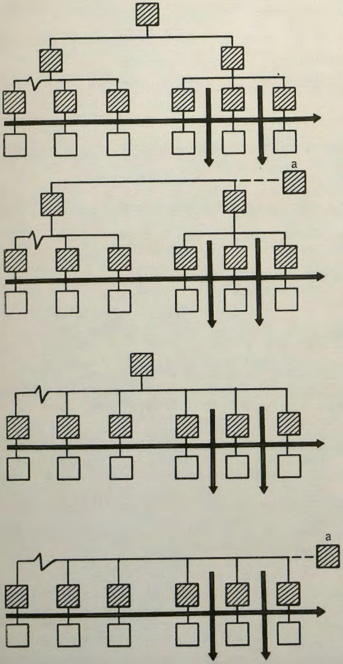
Round Table

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

[a]Mission Director located on earth

Figure 3. Classical Organizational Structural Models 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 function managers with rotating chairmanship
- Technologists assigned to projects as needed
- Mission Director resolves impasses

[a]Mission Director located on earth

Figure 4. Matrix Organizational Structural Models Evaluated and Their Major Features

Table 1. Space Base Program Requirements

1. The Space Base will be operational by 1985.
2. The Space Base crew size is expected to be maintained between 50 to 100 technologists of various skills.
3. Initial crew size will be 50 members. As the Space Base facility size grows, crew size will increase to 100 technologists.
4. 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.
5. A variety of multidisciplinary R&A activities will be accomplished concurrently within the Space Base.
6. International as well as domestic technologists will participate as Space Base R&A crew members.
7. The Space Base will support R&A activities and interplanetary missions which are not defined in detail at present.
8. The Space Base will be a semipermanent facility with a minimum operational life of ten years with resupply.
9. Female, as well as male, technologists will comprise the Space Base crew.
10. The Space Base will be as autonomous from earth control and support as possible.
11. Support operations personnel will function to satisfy the needs of the R&A technologists who use but do not operate the Space Base.
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 any overly restrictive physical or mental requirements.

Table 2. Space Base Assumptions

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 of 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 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. The former is the more likely design.
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. The Space Base crew will be comprised of both permanent and transient technologists 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 will be international and domestic technologists usually involved in one-time-only R&A activities.
9. Crew members will be divided, on an approximately equal basis, between R&A and support operations. This insures that adequate supporting personnel are available to assist those involved in accomplishing Space Base objectives.

Table 3. Correlation Matrix Between Applicable Analogs and Organizational Structural Variables

	Objectives and Plans		Capability of Personnel		Environment			Authority	
	Multiple R&A Activities	Crew Size (Number of People)	Crew Composition	Crew Selection and Training	Mission Duration (Months)	Environmental Factors	Autonomy of Operations	Authority and Responsibility	Communications, Coordination, 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

Table 4. Criteria and Sources for Organizational Structural Model Evaluation

Criteria	Source: Program Requirements and Assumptions	Source: Management Concepts and Practices	Source: Applicable Analog Data
	Level I	Level II	
1. Objectives and Plans			
A. Multidisciplinary R&A Activities			
(1) Variety of R&A	X		
(2) Undefined activities	X		
(3) Assigned priority			X
(4) Situational requirements		X	
B. Crew Size			
(1) Large crew	X		
(2) Crew growth	X		
(3) Many technologists	X		
2. Capability of Personnel			
A. Crew Composition			
(1) Mixed crew	X		
(2) Multination crew	X		
(3) Diverse backgrounds			X
(4) Task leader		X	
(5) P.I. participation			X
(6) Varying crew size			X
B. Crew Selection and Training			
(1) Minimum astronaut training	X		
(2) Dual selection			X
(3) Crew selection			X
(4) Training and indoctrination	X		
3. Environment			
A. Mission Duration			
(1) Ten-year life	X		
(2) Varying tours	X		
(3) Multishift work	X		
(4) Replacement	X		
B. Environmental Factors			
(1) Rewards vs. costs			X
(2) Cohesive group		X	
(3) Work schedule		X	
(4) Professional satisfaction		X	
(5) Human capabilities		X	
(6) Full employment		X	
(7) Various construction	X		
C. Autonomy of Operations			
(1) Autonomous operations	X		
(2) Planning and scheduling	X		
(3) Nonduty work		X	

Table 4. Criteria and Sources for Organizational Structural Model Evaluation (Continued)

Criteria	Source		
	Program Requirements and Assumptions	Management Concepts and Practices	Applicable Analog Data
	Level I	Level II	
4. Authority			
A. Authority and Responsibility			
(1) General definition		X	
(2) Various managers		X	
(3) Unity of command		X	
(4) Span of control		X	
(5) Work flexibility		X	
(6) Personal freedom			X
B. Communications, Coordination, and Integration			
(1) Group decision making		X	
(2) Quality and speed		X	
(3) Line of communications			X
(4) Bidirectional communications			X
(5) Technical professional communications		X	
(6) Two-way audio and video			X
(7) Minimum interfaces		X	
(8) Feedback		X	
(9) Creative climate		X	
TOTAL	16	19	11

Table 5. Evaluation Scores and Model Ranking

Rank	Model	Score
1	Total Matrix	853
2	Standard Matrix	786
3	Traditional	757
4	Dual Matrix	752
5	Line	715
6	Dual Command	671
7	Shared Matrix	638
8	Round Table	576

Table 6. Discriminating Analysis

Discriminating Criteria		Organizational Structural Models				Range of Scores
		Classical	Modern Matrix			
		Traditional	Total Matrix	Dual Matrix	Standard Matrix	
Level I[a]						
1A(2) Undefined activities		14	20	18	16	6
2B(4) Training and indoctrination		19	16	14	13	6
3B(7) Various construction		16	20	14	18	6
3C(1) Autonomous operations		17	18	9	17	9
3C(2) Planning and scheduling		19	19	13	17	6
	Total	85	93	68	81	
	Rank	2	1	4	3	
Level II[b]						
2A(4) Task leader		13	20	19	17	7
2A(6) Varying crew size		12	20	19	20	8
4A(3) Unity of command		20	19	12	18	8
4B(2) Quality and speed		19	18	12	17	7
4B(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	
1/2 Level II criteria		42	47.5	38	42.5	
	Total	127	140.5	106	123.5	
	Rank	2	1	4	3	

[a]Criteria identified from Space Base program requirements and assumptions source.

[b]Criteria identified from management concept and practices, and applicable analog data sources.

[c]Level II criteria were weighted using a factor of one-half.