THE ROLE OF MAN IN FLIGHT EXPERIMENT PAYLOAD MISSIONS

Volume I : Results

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EXECUTIVE SUMMARY

A controversy exists today concerning the required Role of Man, and his attendant skills and levels of skill, for Sortie Lab operations. Some portion of this controversy can be laid to the existing scheme for classifying crew skills. This scheme lists 23 discipline titles at varying levels of specificity. The primary objective of this study then was to generate a taxonomy of candidate crew roles which would 1) be applicable across all experiments 2) be useable for Sortie scientists and engineers in determination of level of skill as well as type of skill.

The role classification scheme developed in this study depended on the definition of the term "role" used in the study. A Role of Man was defined as a responsibility for performance of a set of related function and tasks, which performance requires specified levels of skills and knowledges. A Role of Man does not imply a type of man, nor does it connote that a single individual would fill each role, as with a position or billet. A role, or responsibility for a set of functions, may be shared by several individuals, or conversely several roles may be assigned to a single individual.

The joining recommendation formulated in this study is that Sortie Lab engineers and Payload experiment scientists begin to use the Role of Man classification as described in this study. This action would serve to standardize the terminology for describing required crew roles and skills; it would enable differentiation of levels of skill; and it would facilitate the allocation of roles to available Sortie Lab personnel in multi-experiment missions.

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I. INTRODUCTION

In the development of the Sortie Lab and the flight experiment payloads to be flown in the Sortie Lab one of the key concerns involves crew requirements. Question of crew size, crewman skills and skill levels, crew composition, on board vs. ground personnel responsibilities, etc., are important considerations for the planning and definition of Sortie missions. As part of the rationale for the Shuttle, NASA had determined that the personnel within the Sortie Lab crew can be the scientists or experimenters who developed the experiment to be flown. Thus, on some Sortie missions, personnel will be involved who are different than the highly trained astronauts who have flown manned space flights from Mercury through Skylab.

The initial problem to be resolved in the development of Sortie Lab crew requirements is the specification of the most effective and efficient Role of Man in experiment missions to be flown in the Sortie. This study was directed toward establishing guidelines for Role of Man determination and alternate role description.

The first problem encountered in attempting to develop Role of Man guidelines is that fact that Shuttle Payloads, experiments, and even the Shuttle itself are still in the early stages of development. Even though this is true, questions of crew skills and roles cannot be postponed until the design approach for the systems has been frozen. Actually, the requirements and constraints associated with human performance of experiment activities should serve as an input to the design of experiment hardware. Therefore, the conceptual design of an experiment cannot be completed until information is available concerning the roles, responsibilities and requirements of the man in experiment operations. The criteria for establishing roles of man then become an important item for Sortie Lab experiment development, and for the design of the Sortie Lab itself. Within the Sortie Lab program at MSFC, the factor of crew skills has already been identified as one of the significant resources to be considered and established during Phase B Lab conceptual development.

A second serious problem for determination of the Role of Man involves the rationale underlying the Sortie Lab as an orbital experiment facility which can be manned by the users, the scientists or experimenters. The Skylab program, as well as the manned space programs of the past, involve crewmen who have undergone years of intensive training in every aspect of the operational, engineering, and scientific requirements of the specific missions. The Sortie Lab, on the other hand, will accommodate scientists who have spent their careers in earth based laboratories, who will have only a basic knowledge of Shuttle and Sortie Lab systems, and who will have undergone training and conditioning for space flight for only a few months (certainly less than a year). The significant advantage of putting the scientist in space is to maximize the validity and relevance of the data return, in terms of how the acquired data relates to the general body of knowledge contained in the respective discipline. The approach is, therefore, consistent with the overall philosophy of the Sortie Lab program: to maximize data return at minimum cost. The difficulty that this approach causes for the present study is that the homogeneous population of potential crewmen available for space flights of the past, from Mercury through Skylab, will give way in the Shuttle era to two different populations: the astronaut population (Orbiter crew) and the highly variable (in terms of skills, skill levels, physical capabilities, etc.) population of scientists and experimenters to be involved in the conduct of experiments in the Sortie Lab.

The third problem encountered in establishing criteria for roles of man in the Sortie Lab program is the situation that on board scientists will need to be involved in the operation of other experiments (other than their own specific experiment), or at least with a range of different experiments to be conducted on a Sortie Lab mission. This will probably be a more frequently encountered requirement for 30-day missions as opposed to seven-day flights. No consideration is being given to the approach of flying different personnel for each individual experiment to be conducted in the lab. Therefore, when the number of experiments to be flown exceeds the number of available crew positions, some sharing of crew time on different experiments must be accomplished.

The fourth and final problem associated with this study concerned the usage and the connotations of the phrase "Role of Man". For some, the role of man implies the justification for the use of man in the experiment system. Thus man's role is that he be aboard and available for any activities which may be assigned to him. For others, the phrase

"Role of Man" connotes the skills which the man must possess and the time he is required to interact with experiment apparatus. For the purposes of this investigation, a role is defined as a responsibility for the conduct of specific activities or functional sequences. A role is described in terms of the functions to be performed and the skills, knowledges, and levels of skill and knowledge required to ensure successful completion of the assigned functions. A role does <u>not</u> imply an individual or type of individual. A specific role may be filled by several individuals either concurrently or sequentially, or, conversly, a single individual may serve several roles.

2.0 CLASSIFICATION OF THE ROLE OF MAN IN FLIGHT EXPERIMENT PAYLOAD MISSIONS

The first step to reduce the existing confusion today concerning the Role of Man in space was to clearly identify terms or designators used to describe types of men. The definitions resulted from a classification of the personnel types or skill classes required to perform the functions identified for a flight experiment mission (Appendix A).

The approach used to develop the Role of Man classification scheme was to identify the dimensions along which personnel types must be differentiated. Based on the functions and associated requirements identified in Appendix A, as well as opinions and comments made by various payload scientists, and the classifications used in the shuttle payload planning activity (scientist, engineer, technician), it was resolved that the dimensions should represent level of scientific skills and knowledges; and level of technical skills and knowledges. Since skill requirements will vary as a function of the discipline involved, the third dimension of the classification was scientific or technical specialty or discipline.

Figure 1 presents the resultant classification scheme in pictorial form. The front square of the cube represents the personnel types or roles for a single experiment while those along the third dimension represent specific disciplines. Until experiment scheduling is further advanced, little can be said about the skill mixes needed for the multi-experiment situation. The approach followed in this study was to limit the scope to the single experiment situation for the present and then to identify at a later time how that situation changes as other experiments are included.

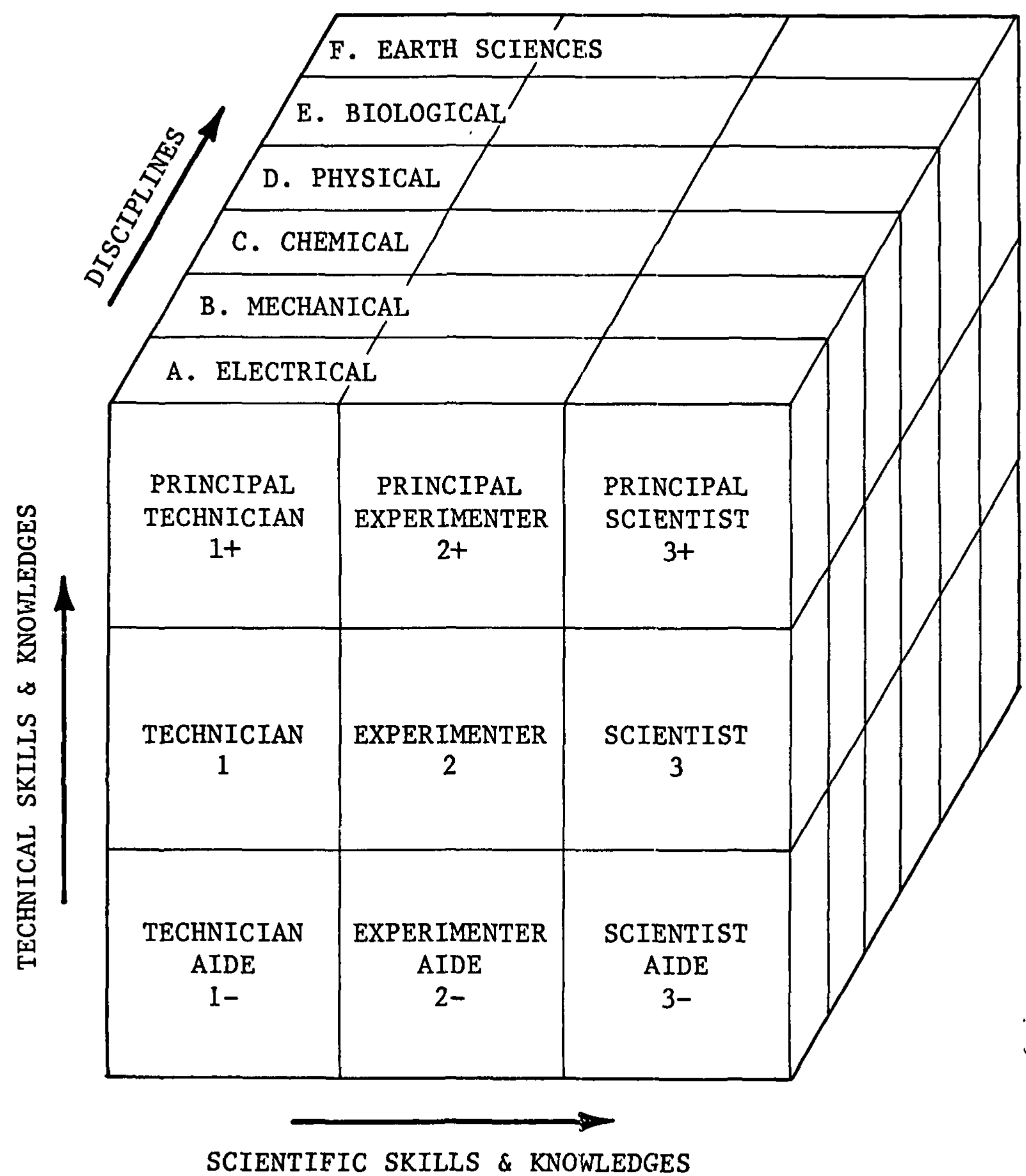
The three basic role types are illustrated by the columns of the single experiment matrix (technician, experimenter, and scientist). Reading left to right, the columns represent an ascending continuum of scientific skills and knowledge, which are minimal for the technician level and maximal for the scientist level. The rows of the matrix indicate ascending order of technical skills and knowledge, reading from bottom to top, for each of the three basic role types. Thus, at the technician level, there is the technician aide with little facility in the engineering or scientific aspects of the experiment; then the technician level, concerned primarily with the engineering aspects of the experiment; to the principal technician level with full facility for experiment hardware and software checkout, setup, and maintenance.

The engineering level proceeds from an experimenter aide level (data manager-communicator); to the experimenter level (laboratory assistant); to the principal experimenter. The scientist level begins with the scientist aides who are not experimenters nor PI's; to the scientific level, to the principal scientist or principal investigator level, who has maximum skills and knowledges both along the scientific continuum and the engineering continuum. The PI level when applied over several experiments becomes the scientist astronaut designation currently being used in Skylab.

The term "role" was defined in this study as a specific combination of tasks, skills, and knowledges. The tasks associated with each of the nine basic roles were developed from a functional description of a generalized in-flight experiment. This functional analysis was constructed to indicate the types of function to be required for an experiment based on an assessment of

ROLE OF MAN CLASSIFICATION SCHEME

FIGURE 1



experiment operations in an earth-based laboratory as well as a review of experiment requirements for Skylab, Apollo, and Gemini. Each function described in the analysis was subjected to a further analysis of requirements to complete the function, such as performance requirements (tasks and required levels of performance), information requirements or dependencies on mission elements external to the experiment system. This functional analysis comprised the baseline for establishment of crew roles, since roles were defined as combinations of tasks and associated skills and knowledges (derived from requirements).

In the development of the Role classification scheme, each of the functions and tasks identified in the flight experiment payload mission requirements analysis (Appendix A) were allocated to each of the 9 role types along a four step scale. The ratings and descriptions of ratings used in the scale were as follows:

Rating	
-	Task does not apply to the role
1	Task may be performed in a backup mode or under supervision
2	Task is a secondary responsibility for the role
3	Task is a prime responsibility for the role

The results of the allocations are presented in Appendix B. A summary of the results is depicted in Table 2. Based as the clustering of tasks to roles, a profile was generated for each role which incorporates role responsibilities and requirements. Requirements are listed in terms of required knowledges and skills to fill the role described by the position. The role profiles are presented in Appendix C. A summary of the profiles is presented in Table 3. Based on these analyses, the following descriptions of roles was formulated:

Principal Scientist	- Intimate knowledge of the experiment: plans, objectives, variables, conditions, data requirements, methods, procedures, techniques, hardware operation, software, and data management requirements; by virtue of involvement in setting up the experiment, overseeing the engineering design, and performing similar experiments on earth.
	- Possess all intellectual skills and abilities required for decision making, information integration, data interpretation, etc.
	- Perceptual and motor skills may vary with age and physical condition which could constrain the position to earth based facilities rather than on-orbit during the conduct of the experiment.
Scientist	- High level of scientific skills and knowledge in the discipline area of the experiment. Probably less experiment engineering skills and knowledge than the PI due to less involvement in the experiment design and development.
	- Responsible to the PI for experiment decisions.
	- Possesses all capabilities to adapt the experiment to changing conditions, analyze and interpret data, check data quantity and quality.
	- Needs assistance for checkout, calibration, setup, fault isolation, and maintenance and repair.
Scientific Aide	- Scientific personnel involved in the experiment who are not at the PI or scientist level. Should usually refer to scientists of the experiment discipline concerned about data resulting from the experiment who have actual involvement in the conduct of the experiment, and who will use the data.
Principal Experimenter	- High level of competence in understanding of the experiment itself (procedures, objectives, uses to be made of the data, etc.)
	- All required capability for operating free flying experiments or experiments where the orientation is on complex operations rather than interpretation of scientific data (e.g., pointing an earth observation sensor to a designated land mass).

	- All required capability for setup, preparation, monitoring of the status of hardware and software, performing static and dynamic checkouts, and modifying experiment hardware and software.
	- Facility for checking data quality, making decision to acquire additional data, assessing the effects of changing conditions on data, etc.
Experimenter	- Operation of experiment apparatus and equipment in accordance with instructions and supervision of scientist level personnel.
	- Capability in laboratory techniques; specimen preparation, colony maintenance, equipment setup, preparation, operation, and monitoring.
	- Engineering capability as regards laboratory apparatus alone.
	- Capable of data checks but not of scientific interpretation of data.
Experimenter Aide	- Concerned with formatting, reducing, processing, storing, communicating data without regard to the specific content of the data.
	- Capability in all data management areas except data acquisition and recording. Capability of maintaining data recording equipment and hardware/software associated with all other data management functions.
	- Facility with computer programming and processor operation.
	- Capable of packaging data for communication to earth.
	- Beyond the data system, involvement with experiment systems or with experiment objections, procedures, and methods, under supervision of experimenters or scientists.
Principal Technician	- Full knowledge of the design and performance of systems. Capabilities for setup, preparation, calibration, alignment, adjustment, static check, dynamic check, fault isolation, and maintenance and repair.
	- Little knowledge or skill in scientific discipline, including experiment objectives, procedures, techniques, data acquisition requirements.
	- May be specialized, as electromechanical technician, bio-technician, optics technician, etc.

- Active during setup, checkout, fault isolation, and maintenance and repair.
- May be time shared among several experiments.
- Knowledge of Sortie and Shuttle interfaces with the experiment. Capability in the operation and maintenance of support systems, including life support, lighting, control/display, power, etc.
- Knowledge of experiment system hardware and software, to the level necessary to perform maintenance, repair, alignment, calibration, etc.

Technician Aide - Little familiarity with scientific or engineering aspects of specific experiments. Concerned with providing technical assistance under direct supervision.

The nine roles of man developed in this study indicate only that these are the types of roles or positions required to meet the functional requirements of a generalized experiment. *The roles do not imply that a different man* occupies each role. Obviously, the best approach to Sortie manning is to assign as many roles as possible to individual crew members.

The roles do indicate the number of personnel required or time requirements for each. They only indicate what skill groupings are needed to perform an experiment mission. In the development of the Sortie Lab, crew skill is considered an available resource, similar to power, data communication capacity, free volume, etc. The importance of crew skill definition becomes apparent when considering the relationship of this resource to the dual overall goals of the Sortie Lab, maximum data return at lowest cost. The consideration which directly relate to crew skills which influence system costs and quantity and quality of data return include the following:

Engineering Factors

- Degree to which equipment design is common or specific across experiments within a mission, and across missions
- Extent of automation versus man performance
- Communications availability and capacity between ground and Sortie Lab

Support Factors

- Degree of computer support required
- Degree of in-flight maintenance and repair
- Special support requirements imposed on the Sortie by individual experiments

Operational Factors

- Time allocated to the experiment per mission
- Number of different experiments per mission
- Capability for quick reaction unscheduled data collection
- On-board data rescheduling and experiment modification
- Degree of involvement of the shuttle crew in experiment operations
- Degree of commonality of on-orbit experiment apparatus and procedures with on-ground apparatus and procedures for the same experiment

Personnel Factors

- Number of flight personnel
- Skill mix of flight personnel
- Number of ground personnel
- Skill mix of ground personnel
- Crew duty cycles
- Crew time allocations per experiment
- Extent of required training and conditioning
- Degree of workload imposed on individual crew members
- Degree of task sharing across roles and positions

The satisfaction of requirements associated with these factors will usually involve compromises between costs of systems and operations on the one hand, and data return on the other. An approach emphasizing maximum design commonality will result in lower costs but may adversely affect the capability to obtain required data. The effort directed toward developing crew skill requirements or roles of man in this study is actually directed toward establishing the crew skill inputs to the overall cost-data return equation.

In developing the crew skill requirements as they influence cost and data factors, one primary source of information is the scientific and engineering

TABLE 2

FUNCTION ALLOCATION TO ROLES

	ROLE								
Function	Prin. Tech.	Tech.	Tech. Aide	Prin. Expmtr.	Expmtr.	Expmtr. Aide	Prin. Sci.	Scien.	Scien. Aide
Planning							Prime	Sec.	Backup
Expmt. Mgt.							Prime	Sec.	
Modify									
Plans							Prime	Sec.	
Proced.							Prime	Sec.	
Systems	Prime	Prime		Sec.	Sec.	Sec.	Prime	Sec.	
Supp.Sys.	Prime	Prime							
Data						Sec.	Prime	Prime	
Data Use							Prime	Sec.	Sec.
Personnel							Prime	Sec.	
Select Modes							Prime	Prime	
Setup-Prepare	Prime	Prime		Sec.	Sec.		Sec.	Sec.	
Static Check	Prime	Prime		Prime	Prime		Prime	Prime	
Actuate-Initiate	Sec.	Sec.		Prime	Prime		Prime	Prime	
Dynam. Check	Sec.	Sec.		Prime	Prime		Sec.	Sec.	
Detect Probs.	Sec.	Sec.		Prime	Prime		Sec.	Sec.	
Isolate Probs.	Prime	Prime		Sec.	Sec.		Sec.	Sec.	
Repair Decision	Prime	Prime	Backup	Sec.	Sec.	Sec.	Sec.	Sec.	
Operate Expmt.				Prime	Prime		Sec.	Sec.	
Monitor Expmt.				Prime	Prime		Prime	Prime	
Acquire Data				Prime	Prime		Sec.	Sec.	
Record Data				Prime	Prime		Sec.	Sec.	
Id. Changes				Sec.	Sec.		Prime	Prime	
Assess Oper.				Sec.	Sec.		Prime	Prime	
Isolate Probs.	Prime	Prime		Sec.	Sec.		Sec.	Sec.	

TABLE 3

ROLE PROFILE SUMMARY

	+1 Prin. Tech.	1 Tech.	-1 Tech. Aide	+2 Prin. Expmtr.	2 Expmtr.	-2 Expmt. Aide	+3 Prin. Scien.	3 Scien.	-3 Scien. Aide
Knowledges									
Science	0	0	0	1	2	0	3	3	3
Experiment	0	0	0	2	2	0	3	3	2
Expmt. Sys.	3	1	1	3	2	2	3	2	1
Engineering	3	2	2	3	2	2	2	1	0
Supp. Sys.	3	2	1	2	2	2	2	1	0
Skills									
Experimentation	0	0	0	2	2	1	3	3	3
Data Interpre.	2	0	0	2	2	1	3	3	3
Data Analysis	0	0	0	2	2	1	3	3	3
Data Mgr.	0	0	0	3	3	3	2	2	2
Exp.Sys.Control	1	0	0	3	3	1	3	3	2
Sys. Maintenance	3	3	2	2	2	1	2	1	0
Mission Integ.	1	1	0	1	1	0	2	1	0
Setup-Prep.	3	3	2	2	2	2	3	2	1
Oper.-Monitor	1	1	0	3	3	2	3	2	2
Assess Changing Conditions	0	0	0	2	2	0	3	3	2
Supp. Sys. Control	3	2	1	2	2	1	2	1	0

CODE
0 - No Requirement 1 - Minimum-Needs Supervision 2 - Good Familiarity-Competence 3 - Full Knowledge - Capability

community concerned with eventually flying actual experiments on board the Sorties. For this reason it was decided that additional effort, to be conducted after termination of this study, would require a checklist to be used in obtaining required information from the payload scientists and engineers. It may be argued that, due to current mission schedules which indicate the first Sortie Lab mission to be flown in early 1980, and due to the early development stage of shuttle payloads and Sortie Lab experiments, it is too early to begin to define crew skill requirements. However, the Sortie Lab program is presently in Phase B and lab design configuration and layout concepts are being currently developed. It is imperative that crew skill factors receive equal consideration with engineering design parameters in the development of lab concepts. Therefore, definitive guidelines concerning required crew skills as they relate to candidate Sortie Lab experiments are needed today.

The information required of payload personnel to enable the development of crew skill guidelines and criteria must include the following items for individual experiments:

- Required assignment of experiment tasks to different roles (keeping in mind that roles involve only a short hand notation for a cluster of skills and do not imply different crewmen for each different role)
- Limitation on role sharing by individual crew member
- Boundaries on number of personnel required, by type (technician level, engineer level, scientist level)
- Projected duration and duty cycle for each crewman for each experiment period
- On-orbit versus on-ground responsibilities and duties
- Estimated training and conditioning time
- Degree of reliance on ground to orbit communications
- Extent of computer support required for:
  - data processing and management

- experiment scheduling and control
- generation of displays

- Extent of in-flight maintenance and repair
- Extent of on-orbit versus on-ground checkout
- Special support requirements to be imposed on the sortie lab
- Other experiments in the discipline which can be time shared
- Requirements for quick reaction unscheduled data collection
- Requirements for on-board data analysis and interpretation
- Requirements for on-board rescheduling and modification
- Degree to which on-orbit experiment apparatus and procedures differs from on-ground apparatus and procedures
  - effects of weightlessness
  - effects of confinement
  - effects of communication limitation
  - effects of thermal, vacuum, contamination environment

The checklist to be used to acquire this information must serve two separate although related objectives. Basically, it must enable the acquisition of requirements, insights and opinions of payload scientists and engineers. Secondly, it should serve to sensitize these personnel to the crew skill factors which must be considered in planning the experiment. While achieving these goals, the checklist must also be as terse and concise as possible, imposing a minimum workload on a respondent while obtaining from him all needed information.

3.0 CURRENT STATUS OF SORTIE LAB CREW SKILL DESCRIPTIONS

The list of crew skills currently used in the Sortie Lab Progarm are presented in Table 4. The difficulties with this list are:

- It assumes a universal understanding of the skills involved.
- It does not treat level of skill other than to indicate that a level is implied which is commensurate with the label.
- The list of specialists does not correspond to the ten discipline areas used by Sortie Lab planning personnel.
- The list is heavily weighted in some discipline areas (e.g., six of the 23 skill designators relate directly and only to the Life Sciences discipline).
- The list is minimally weighted in other discipline areas (no designators relating directly to Space Technology, Space Processing Applications, and Communication/Navigation).

An additional difficulty with the list is the inclusion of the skills "general" (20) and "crewman" (23). The list includes 14 scientific designators, four types of technician, two types of engineer, medical doctor, and the two ambiguous classifications (general and crewman).

The selection of crew skills from this list as they apply to payload experiments currently being contemplated for the Sortie Lab are presented in Appendix D. A summary of the data in this appendix indicates the following number of experiments assigned to each crew skill:

Skill	Number of Experiments
Science:	
Astronomer	5
Physics/Chemistry	5
Geologist	1
Optical Scientist	1
Meteorologist	2
Medical Doctor	3
Biologist	2

Non-Science:	
Electro-Mechanical Technician	59
Optical Technician	7
Biological Technician	4
Medical Technician	2
Electronics Engineer	3
Photo Technician	2
Crewman	7

Shuttle Payload Planning Information

In order to coordinate and organize the planning of space shuttle scientific and technological activities, NASA developed the Shuttle Payload Planning working groups. These groups, each dedicated to an individual discipline area, first met in August 1972 at the Goddard Space Flight Center. Since that time the working groups have met to update the plans and recommendations generated at the original meeting. The reports of each working group were published in May of 1973. While the report for each discipline is primarily concerned with describing the scientific or technical program to be implemented in the Shuttle Sortie Laboratory, most of the documents do address the problems associated with specifying the roles, responsibilities, and requirements of man in the program. The roles of man cited in these reports generally refer to the man on orbit as opposed to the role of man in the experiment program, either on the ground or in orbit. A capsulation of the requirements and recommendations for the role of man developed in each working group is presented below:

1) Life Sciences: The Life Science area is unique among the Shuttle Payload disciplines in that man is required to serve not only as an observer and experimenter, but also as an experimental subject, primarily in biomedical and behavioral investigation. The "roles" and numbers of personnel required in orbit for the Life Science

TABLE 4

CREW SKILL CLASSIFICATION SCHEME
CURRENTLY USED IN SORTIE LAB PROGRAM

1. Biological Technician
2. Biochemist
3. Medical Doctor
4. Behavioral Scientist
5. Astronomer/Astrophysicist
6. Optical Scientist
7. Electromechanical/Optical Technician
8. Photo Technician/Cartographer
9. Geologist
10. Meteorologist
11. Oceanographer
12. Agronomist
13. Geographer
14. Electronics Engineer
15. Mechanical Engineer
16. Thermodynamicist
17. Metallurgist
18. Chemist
19. Physicist
20. General
21. Biologist
22. Biomedical Technician
23. Crewman

program are: in the 1979-81 time period, one Life Sciences Mission Specialist and one dedicated scientist; in the 1982-88 period, one LS Mission Specialist and three dedicated scientists; and in the period 1989 and beyond, two LS Mission Specialists and six dedicated scientists.

2) Solar Physics: In directly addressing the role of man for both Sortie and free-flying payload missions, the working group noted in an orbiting observatory, man can contribute in three ways: as an observer; as an instrument operator; and as a technician. The working group report states that an important and challenging aspect of solar space observations is the opportunity for man to significantly increase the selectivity (and worth) of data by using his judgment. Decisions will be required as to where to point, what instrument modes to use, and when to acquire data. While many of the decisions can be made prior to the flight, and even on the ground during the mission, a significant portion will be best made by the man on orbit, monitoring the unpredicted variations in solar phenomena.

The working group went on to note that, at this time it is difficult to ascertain which role of man would be most important (observer, operator, or technician). If only one crewman can be accommodated, he should represent all three capabilities. Many astronomers are excellent technicians and it should not prove difficult to find an orbiting astronomer who is his own best technician and operator. If only two crewmen can fly, at least one should be a scientist while the other may be a technician.

In terms of skill requirements, the working group stated that the observer position should be filled by a person having a firm background in solar physics. This observer should also be trained as a competent instrument operator. In his function as technician, he should have in-depth knowledge of the physical details of each instrument. In this capacity he should be trained in such activities as assembly, setup, maintenance, component replacement, and instrument diagnosis and repair.

3) Astronomy: The working group indicated that, in addition to two pilots and one mission specialist, the Shuttle will provide facilities for from one to seven other crew members. The group stated that it is essential that these other crew members be scientists, with professional competence to make value judgments pertaining to the scientific goals of the mission and with an intimate familiarity with the instrumentation. Special training should be provided to enable them to evaluate the intervention of spacecraft systems and mission requirements with scientific objectives, and to effect changes to optimize the Shuttle-telescope interfaces. They may or may not be "principle investigators" in the sense that they exercise final command over the program. However, they should be drawn from the scientific community and have a direct personal interest in the analysis and dissemination of results. This approach does not obviate the need for adequate communication with the ground. Requirements for changing the program, based on quick look and on-orbit analyses, should be resolved through consultation with scientists on the ground. The group also recommended that the mission specialist be

scientifically oriented, pregerably in astronomy. He could be a scientist astronaut.

4) Communications and Navigation. One of the conclusions reported by this working group was that the most useful application of the Sortie Lab to communications and navigation will be by performing experiments which involve man in a necessary and relevant manner to increase the useful data output and decrease instrument complexity and cost.

5) Materials Processing and Space Manufacturing. The working group stated that, at the level of detail available at this time, it seems unrealistic to specity duty cycles of preference for single or multi-shift operations.

The Space Processing Program's early experiments are expected to consist mainly of the application of prescribed procedures to samples of materials. As in the case in the program's Skylab experiments (M551 through M566) process condition during most experimental runs will be under automatic programmed control, with handling of apparatus and samples performed with a simple industrial manipulator. Full automation of the early experiments is an option, however, it was considered cheaper to design the apparatus to be set-up and reconfigured by the Shuttle crew, since only simple mechanical skills would be required.

Requirements for manned involvement are likely to increase as the experiments increase in sophistication and the experimenters learn to use the crew's services. Two-man experiment support crews will probably suffice for most missions, but some extremely diversified dedicated payloads may require up to four men to exercise all equipment fully.

As presently viewed, the role of payload specialist in space processing experiments will be to act as skilled laboratory technicians than as primary investigators.

6) Earth and Ocean Physics. The working group concluded that the advantages of using the shuttle include: using men to make equipment adjustments (gain) changes, frequency adjustments, etc.) to optimize matching sensor characteristics to the observables; using man as an observer to correlate with remote sensing; and using man's judgment to provide flexibility in the use of equipment and in programming experiments. The number and type of personnel required for experiments in this discipline was reported to be one experiment specialist.

7) High Energy Astrophysics: The working group proposed to achieve the safety objectives of Shuttle flights by minimizing the manned interface with the experiments. Investigations on the pallet would be automated to the degree possible. The mission specialist would be required for monitoring functions from the crew compartment or for EVA to perform simple alignments and repairs

8) Space Technology. The personnel requirements for each technology area were reported to include

- Advanced Technology Lab - No highly skilled specialists but broad crosstraining will be required in areas of electronics, meteorology, photography, optics, physics, microwave technology, and microbiology.
- Laser communicators - One or two persons in orbit to observe data, make experiment modifications and parameter changes, and perform diagnosis and troubleshooting.
- External contamination - No personnel required if data are returned by telemetry. If data are displayed on-board, the console must be monitored at appropriate times by one of the crew.
- Particulate matter - No personnel required other than for launch and recovery.

- Meteor Spectroscopy - Experiment can be highly automated. The role of man is to utilize control panels to initiate an experiment and to monitor instrument performance. Only one person in orbit is required.
- Microbiology - No personnel other than for launch and recovery.
- Exposure experiments - Same as above.
- Physics and Chemistry Lab - Requires laboratory-type physics and chemistry experiments which require many intricate operations. The experiments typically yield little data and require man to perform them. It is not clear that the experimenter himself need be present in the facility.

9) Atmosphere and Space Physics. A scientific crew of two to four personnel are required to perform such activities as:

   - Checkout and maintenance of equipment
   - Operation of remote sensing and active instruments
   - Communication with ground-based scientific personnel
   - Repair of malfunction
   - Perform on-board data reduction

10) Earth Observations. The committee stated that man's role in Shuttle operations for Earth observations will be as an inherent part of the overall Shuttle systems capability. The fact that men are aboard and available, allows Earth observation systems and mission designers to exploit this very versatile tool. Since men are available, they will be used whenever it is easier, cheaper, more reliable, and makes good sense to do so. The following are categories of things that the men may be required to do:

    - Scientific Experimenter or Observer
    - Skilled Sensor or Equipment Operator
    - Skilled Technician

It can be expected that scientists can function as experimenters and observers when they are supplied with appropriate controls and displays, permitting a great amount of flexibility in mode selection combinations, on the spot subjective evaluation, and reprogramming operations. In some cases, where actions are taking place on the ground or in aircraft simultaneously, the on-board scientist may coordinate with a team of ground-based scientists. The pointing of high-resolution, small field-of-view instruments will be done by the crew acting in the role of skilled sensor/equipment operators, although the continuous tracking might be done automatically. The technician functions will involve the manual replacement of equipment modules, erection and deployment operations, and miscellaneous trouble-shooting.

Manned functions are identical for both R&D and operational automated satellites. Checkout of automated satellites after launch will be accomplished by simple continuity-type checks before deployment from the Shuttle, followed by actual deployment and Shuttle station-keeping for a short time while the automated satellite is activated and checked out in initial operations. Failure or problems may be corrected by re-acquisition by the Shuttle and return to earth for repair. It is also possible that minor trouble-shooting and/or correctional actions may be accomplished in orbit, and the satellite then redeployed.

Man aboard the Shuttle will have a minimum potential role in the mission when the Shuttle is used to launch automated satellites, either R&D or operational. The Shuttle launch of these satellites provides an opportunity for activities such as check-out, alignment, power level adjustment, electrical activation etc. to be carried out after the accelerations and vibrations of launch have been experienced.

The rationale for conducting such activities in the Shuttle prior to deployment is based on the benefits to be realized from the ability to abort the automated satellite mission at this stage or the ability to make some kind of fix that can be performed aboard the Shuttle; but not after deployment. The type of fix that can be performed aboard the satellite would be the replacement of modular components whose probability of failure drops sharply after launch. The role of man would be in the remote manipulation from the crew station of the replacement mechanisms.

The major role in evaluating the results of these activities is assumed to be vested in the ground team. The satellite is remote from the crew. A significant role of a man aboard the Shuttle as a participant in these activities is not foreseen. He might control such functions as the initiation of such activities, provision of Shuttle power, relay of satellite telemetry to ground control, termination of activity, or disengagement of satellite to Shuttle circuitry.

A technician may have a post-deployment EV role such as erecting antennas, deploying arms or panels or constituting a manual backup for the automated accomplishment of these functions.

A role of the technician in refurbishment would be to manipulate the modular replacement equipment.

In summary, the role of the technician with respect to automated R&D and operational satellites appears in no case to be unique to Earth Observation Satellite missions.

Results of Symposia on Manned Function in Space

A series of seminars have been planned at the Lunar Science Institute, Houston Texas, to inquire into the requirements of man in space flight in the future. These seminars are jointly sponsored by NASA Johnson Space Center and the University of Houston, and involve participants of the scientific community. Two such seminars have been completed to date and a report of the findings of each is currently available. These include Astronomy and Plasmas, Particles, and Fields. In the report on Manned Functions in Space Observations: Plasmas, Particles, and Fields (May-June 1972) the participants concluded that the scientific team on orbit must include scientific skills for real time or short lead time decision making. The minimum capability experimental crew for particle injection experiments would involve a senior scientist and either a junior scientist with strong technician competence or a top grade technician. In defining crew skill requirements for Probes, Wakes, and Sheaths, the participants noted that man would be essential for deployment, alignment, observation, measurement, and module removal and replacement. For the seven day sortie mission the minimum crew would contain a scientist familiar with each experiment, or a scientist on the ground and a technician on board to handle routine measurements. The group concluded that often it is not apparent what must be done until the operations are attempted on the initial flight, so that there would be a premium on having on board scientists for any non-routine operation. In dealing with High Density Plasma and Releases the participants suggested that the principal investigator and an assistant (probably at the technician level) should fly with the experiments. The Mission Specialist should serve as coordinator for several experiments and between the experiments and the spacecraft. In the area of Wave-particle Interaction the seminar group concluded that sophisticated experiments can benefit from manned participation due to man's unique ability to adapt and modify the experiment protocol to suit existing conditions. The group did state, however, that if more man means less science, then the use of man should be discouraged. Experiments in this area would call for skilled professional scientists, as many as possible within constraints of the program objectives. The scientists should be supported by skilled technicians to perform routine data taking and instrument maintenance.

The astronomy panel considered man requirements in three specific areas: the Large Space Telescope (LST), Low Resolution Optical and UV Astronomy, and Radio and IR Astronomy. For the LST the primary functions of many would be maintenance, repair, and experiment update. These requirements indicate the need for a technician type astronaut on orbit. In most cases where the Shuttle is used for satellite placement, it is not necessary to require the principal investigator to be on board. The exact nature of the orbit-ground communication system would be important in deciding the level of scientific decision making required on board. For Low Resolution optical and UV Astronomy a need for an on board astronomer was formulated. For Radio and IR Astronomy, a need was identified for two man scientific teams per shift for high resolution interferometer observations. One man would be required to monitor and adjust the interferometer operation while the other would monitor telescope operation and data quality. For these experiments it was determined that a 24 hour duty cycle was highly desireable.

Perspective on the Role of Man in Space

A report entitled the "Role of Man in Space" was recently published by the NASA Apollo program office. The report notes that operations requiring repetitive in-flight operation of sensors, or the relay of data, are readily adaptable to automation. Man is useful in complex, multi-use vehicles and operations, or where a high degree of judgment, discrimination and selectivity are required, or where manual dexterity and analytical capabilities are required, such as response to unexpected events. Man can also serve effectively in augmenting tasks, providing an alternative to redundancy in hardware system, and improving data management systems.

The report cites some examples from Apollo experience on the contribution of human involvement to mission success. The types of examples include:

- Rapid response to emergencies
- Self-contained operation in absence of communication with ground
- Rapid sensing, reaction, and vehicle control
- Enhancement of instrumentation flexibility
- Reduction of automation complexity in multi-purpose missions
- Equipment repair and improvisation (also demonstrated on the Skylab II Mission)
- Investigation and Exploration, including sensory documentation and sample selection

While the Apollo Program Office report eloquently describes the rationale for manned space flight, it stops short of directly defining what the role, or range of roles of man should be in Shuttle payload missions based on Apollo experience. One possible problem here is the precise definition of what is encompassed in the phase, the "Role of Man." The Apollo report treats the phrase as meaning the presence of man in orbit. It is more concerned with the question, does man have a role in space, rather than defining what the role or limits of the role should be.

In the present study a role was viewed primarily as a responsibility. A role comprises basic related functions. Thus a role may be filled by several individual crewmen, simultaneously or at intervals, and alternately, several roles may be assigned to a single crew member.

A role of man is therefore described by the activities to be performed and by the skills and skill levels required to adequately perform the activities. The list of 23 crew skill designators currently being used in the Sortie Lab program are not really role designators, since they only indicate discipline area and general skill level (scientist or technician). They leave it up to the user to determine specific activities to be performed, and do not in any way address the problem of how to conduct multi-experiment missions. In dealing with roles rather than skill designators or discipline titles, it is possible to identify requirements for different roles for each experiment as well as for the mix of experiments carried on a single mission.

The approach of developing requirements for crew roles rather than for specific types of individuals is also more meaningful given the radical change in philosophy concerning personnel to be on board the Shuttle versus the crews of Mercury, Gemini, Apollo, and Skylab. All of these pre-Shuttle missions are characterized by their reliance on a highly selective, extremely skilled, and intensely trained population of astronauts and scientist astronauts. While such individuals will comprise the Shuttle operational crew (both pilots and possibly mission specialist), the Shuttle will also provide for personnel of lower overall mission related skills but of probably higher experiment related skill levels. It is for these payload specialist and experimenter personnel that the approach of defining requirements in terms of roles has its meaning. The approach taken in this study was to develop a framework for defining roles of experiment personnel and establishing guidelines for payload scientists and engineers to assign roles to personnel based on the significant functions to be performed and skills and skill levels associated with these functions.