MARTIN
MARIETTA

Human Factors
9/21/66

ATM/Skylab

MARTIN COMPANY

7/21/6

ENCLOSURE #1

STATEMENT OF WORK

MAN/MACHINE ACTIVITIES - ATM

I SCOPE

This Statement of Work encompasses the man/machine effort required to optimize the crew role and the systems design for the Apollo Telescope Mount (ATM) experiment.

II OBJECTIVES

The objectives of the program are:

1. To identify the tasks required to actuate, control and monitor the ATM, to retrieve data cassettes by EVA, and to stow the cassettes aboard the ATM carrier.
2. To define and establish specifications for the equipment required to support the crew during EVA translation, data retrieval, handling and stowage.
3. To apply human engineering criteria thru design support of those systems interfacing the orbital crew member.
4. To confirm the feasibility of human performance on those tasks identified by analysis (including simulation) of crew variables and constraints, equipment limitations, and mission requirements.
5. To develop a training program, including course outlines, equipment description, personnel requirements, and facility utilization, to implement indoctrination of the crew to the ATM.

III ASSUMPTIONS

The following assumptions will be included among those to be used in the performance of this program.

1. The Apollo Block II suit shall be utilized by the astronauts.
2. Attitude stabilization, pointing and control shall be conducted by the astronaut(s) within the ATM carrier.
3. The carrier configuration and flight profile shall be consistent with the currently designated AAP configurations.

IV PROGRAM OUTLINE

1. General

a. Maximum utilization will be made of results obtained from the Gemini and Apollo programs.

b. Maximum use shall be made of hardware components and systems which are either available commercially or have been developed under other related programs.

c. The Human Factors Engineering Section shall develop a detailed program plan categorizing the effort into a logical sequence of anticipated tasks. Each task will contain objectives, the expected product, allocated man-hours, relation to other tasks, data required from Government sources; the plan shall also provide for milestone event reviews.

d. Conventional equipment, procedures, and techniques will be utilized whenever possible.

2. Crew/System Integration

a. The Human Factors Engineering Section shall identify critical system parameters for both the ATM and its carrier. Such factors as pointing and tracking accuracies, mounting characteristics, target acquisition modes, environmental limitations, monitoring requirements, data retrieval requirements (removal and/or replacement, frequency, masses), accessibility and interfaces will be evaluated for compatibility with the human operator.

b. Those system requirements which constitute a constraint directly or indirectly on an interfacing system and which affect adversely the crew performance will be identified. Where possible alternate systems or procedures will be recommended which will alleviate the constraint or improve system effectiveness.

c. Identification will be made of the variables and constraints imposed by the crew member plus all candidate crew support (IVA and EVA) equipment, and incorporate this data into the task analyses and new equipment design specifications.

d. All equipment with which the crew will interface shall be analyzed and the operating and stowage requirements determined. This equipment will include.

1) ATM display and control equipment
2) Guidance and navigation equipment
3) ATM data cassettes
4) Data handling equipment (tools)
5) Data stowage equipment
6) Life support equipment
7) Airlocks and accessories (hatches and controls)
8) Crew stabilization and translation equipment (IVA and EVA)

e. A detailed task analysis including timeline shall be conducted based on the following major activities:

1) Target acquisition,
2) ATM stabilization and control,
3) Data recording,
4) Data retrieval,
5) Data stowage,
6) Equipment assembly,
7) Crew movement to and from the ATM work area.

The analysis shall be updated based on simulation results.

f. Design specifications will be created for special crew equipment and tools requiring development and where necessary, modifications will be recommended for existing equipment. Applicable human engineering criteria will be referenced for both new design and modifications.

3. Design Support

The principles of human factors engineering shall be applied to all related ATM equipment to ensure the efficient integration of man into the design of the system.

a. The HFE inputs shall comply with system analysis requirements as well as other appropriate inputs. Standard MSFC-STD-267 shall be the basic reference document for the human engineering design features.

b. Human factors criteria and recommendations shall be applied to system and subsystem preliminary layouts and related drawings. The approval of layout drawings by the HFE group shall verify that the configuration and arrangement of equipment satisfy man/equipment performance requirements, and that the design complies with applicable criteria specified in Standard MSFC-STD-267.

c. Human factors principles and procedures shall be applied, during detail design, to equipment drawings, such as panel layouts, workspace layouts, controls, crew equipment and other drawings depicting equipment necessary for operation by the ATM carrier crew.

d. HFE personnel shall participate in design reviews to ensure consideration of crew operations and crew/equipment interactions.

4. Simulation

a. Upon completion of the preliminary task analysis, a simulation plan will be written and implemented covering the following factors:

    1) Critical tasks to be simulated,
    2) Recommended mode of simulation - mechanical, KC-135, part task, etc.,
    3) Sketches of mockups required,
    4) Facilities required,
    5) Simulation schedule.

b. The Human Factors Engineering Section shall write the detailed test procedures and submit mockup design requirements for the approved tasks to the appropriate design groups.

c. HFE personnel shall monitor the operation of all simulation testing and participate in the design evaluations conducted on component mockups which interface the human operator.

d. Procedural changes and time measurements produced by simulation testing shall be incorporated into the detailed task analysis. Recommended design changes resulting from simulation and/or mockup design evaluation shall be submitted by the Human Factors Engineering Section to the appropriate design groups.

5. Training

a. The ATM task requirements shall be evaluated and those skill levels required to fulfill the orbital functions shall be presented.

b. From the detailed task analysis, HFE personnel shall identify those tasks where training is necessary and the degree of training required to ensure their desired performance.

c. The Human Factors Engineering Section shall identify necessary training support personnel by specialty, training level and certification.

d. Training equipment and facilities shall be identified by quantity, configuration, state of development, location (if existing), and need date.

e. A training program outline shall be developed. This will include:

1) Proficiency development program for flight crew.
2) Training aids - classroom material and equipment.
3) Trainers - task simulators.
4) Training briefings for NASA personnel and experiment contractors.

Course outlines, frequency and duration, as well as equipment descriptions, including sketches, will be provided with the training plan.

V EXPECTED RESULTS

The following documentation will be submitted by the Human Factors Engineering Section:

1. A listing of the systems and/or procedures related to ATM which are incompatible with human performance criteria and over which the contractor has no direct control.

2. Related mission constraints, ATM and carrier design constraints, personal equipment constraints, and crew imposed constraints.

3. A detailed task analysis and timeline commencing with the preparation for ATM target acquisition and ending with the stowage of the data cassettes within the ATM carrier after the final EVA.

4. Design specifications for both newly developed crew support equipment and modification to existing equipment.

5. The simulation plan and detailed simulation results, conclusions and recommendations.

6. Design evaluation inputs on related ATM subsystems requiring crew/equipment interactions.

7. A training plan including course description, material and equipment requirements, skill levels and facility recommendations.

8. A training implementation plan containing a schedule of overall training events proposed for ATM.

9. An outline and content description of an ATM flight crew training and familiarization manual.

9/21/66

ENCLOSURE #2

ATM PROBLEM AREAS

1. The general cost of EVA in expendables, crew man hours, safety, and crew fatigue. (See attachments 1 and 2).

2. The impact of EVA where vehicle configurations involve crew transfers by EVA. (See attachment 3).

3. Other EVA considerations. (See attachment 4).

4. The basic overload of the crew in respect to man hours available for experiments versus the man hours required by present experiment definitions. On 211/212 this shows 502 man hours available versus 859 man hours required. (See attachment 5).

5. The problem of developing and getting implemented into experiment designs, basic principles of human factor engineering and mission operation requirements. This is an extremely time-sensitive function. (See attachment 6 for a very preliminary set of the types of data that must get factored into the experiment and carrier equipment designs).

6. Stabilization and Control requirements for ATM are the most stringent ever attempted in manned space flight. Considerable study and simulation above that already undertaken is probably required. (See attachment 7 for some of the basic items requiring work in this area).

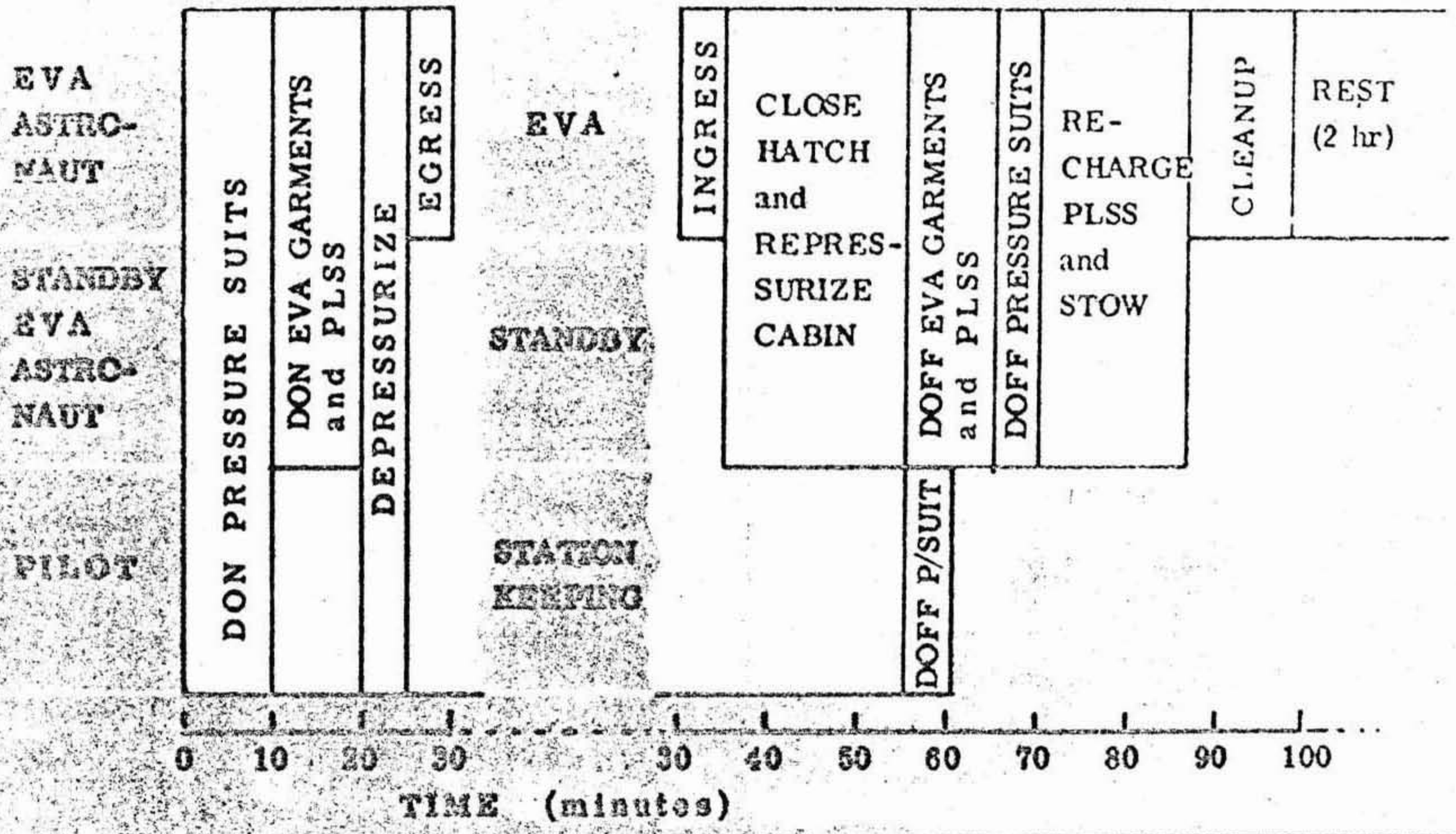
7. The LEM is an extremely poor vehicle for extended habitation. Much human factor effort must be expended to provide reasonable comfort to the crew. (See attachment 8 for some considerations on this item. Also, refer to the section on crew habitability in attachment 5).

8. See attachment 9 for other ATM Man/Machine Considerations.

ATTACHMENT 1 & 2

EVA CREW TIME COST

MARTIN COMPANY



TOTAL MANHOURS = 6+ (3 × Period of Actual EVA)

Attachment #1

OTHER EVA COSTS

MARTIN COMPANY

CONSUMABLES per EVA

		lb
Oxygen		
	Cabin Loss	7.0+
	Consumed by Astronauts (PLSS)	3.0+
	Umbilical	6 lb/hr
Water		14.66
LiOH (Contaminant Control Cartridge)		7.2
Fuel (Stabilize and Station Keeping)		?

ADDITIONAL REQUIREMENTS

		Wt (lb)	Vol (ft^3)	Quantity
PLSS		64	3	2
Protective Garments	Thermal	50	.5	2
	Meteoroid	15	1	2
Safety Tethers		10	.5	2
EVA Astronaut Maneuvering System		10-140	<1-9	2
PLSS Replaceables				
	Battery	5	.05	1 per 4 EVA's
	Contaminant Control Cartridge	3.6	.04	1 per EVA
Rescue Kit (est)		10	.5	1
TOTAL		167-297	6.6-15.6	

SAFETY FACTORS

Radiation Exposure
Meteoroid Exposure
Astronaut Fatigue
Low System Safety

Attachment #2

ATTACHMENT #3

THE EVA COMMUTING PROBLEM

Perhaps the most significant difference between the candidate configurations is a requirement for regular commuting to work by EVA for both the Dr. Mueller and the Alternate #1 configuration. Present Gemini experiment has shown that while EVA can be accomplished it is extremely difficult and laborious to the crew. Any design that requires deliberate and periodic EVA should be carefully analyzed and the consequences fully understood. Due to the safety factors and workloads involved, every effort should be made to minimize the quantity of EVA's required.

Chart #1 shows a typical time line for a crew shift involving the Dr. Mueller configuration. The time line is for the crew member about to go to work in the LEM/ATM. He would don and check out his EVA suit in the S-IVB workshop, enter the AL, secure the hatches and connect a long umbilical. He would then depressurize the AL and open the EVA hatch. While he was doing these activities the astronaut who had been on experiment duty would be going through a similar set of activities in the LEM. Once both astronauts were prepared, the first astronaut would then make a traverse across to the LEM, enter the LEM and hook up one of the standard LEM short umbilicals to his suit. He would then transfer his long umbilical to the second astronaut who would hook it up and disconnect the short LEM umbilical. The second astronaut would then traverse back to the AL while the first astronaut monitored his progress from the open hatch of the LEM. Following this, the first astronaut would secure the LEM hatch, repressurize the LEM, doff his suit and store it. As shown by the chart, after about 90 minutes he would be ready for work.

This approach is based on the development of a 150-ft long umbilical on the basis that the use of an umbilical is generally preferable to the PLSS for short term tasks. However, the PLSS could be utilized although the time would be longer. It is also based on the development of a clothesline-type rig for the purpose of traversing between the AL and the LEM. Several techniques could be used in this area. The chart also indicates the total quantity of oxygen consumed during the course of swapping the two crew members.

In the case of the Alternate #1 configuration a similar EVA would be required. Due to vehicle configuration the use of an umbilical would be undesirable and the PLSS would be required. The time for EVA in this configuration would be perhaps 10-15 minutes longer. Additionally, a walkway, probably consisting of handholds and rails, would have to be developed across the entire length of the configuration.

Due to the aforementioned problems, plus the inherent safety problems of EVA, it will be necessary to minimize this type of activity in order to make either the Dr. Mueller or the Alternate #1 configurations practical. The most obvious method of doing this is to lengthen the experiment duty cycle in the LEM. We have examined the possibility of using an 18-hour work cycle as shown in Figure 2. Using this cycle it is possible to perform all the necessary watch requirements and personnel hygiene, eating, exercise

EVA FOR SHIFT-CHANGE/MUELLER CONFIGURATION

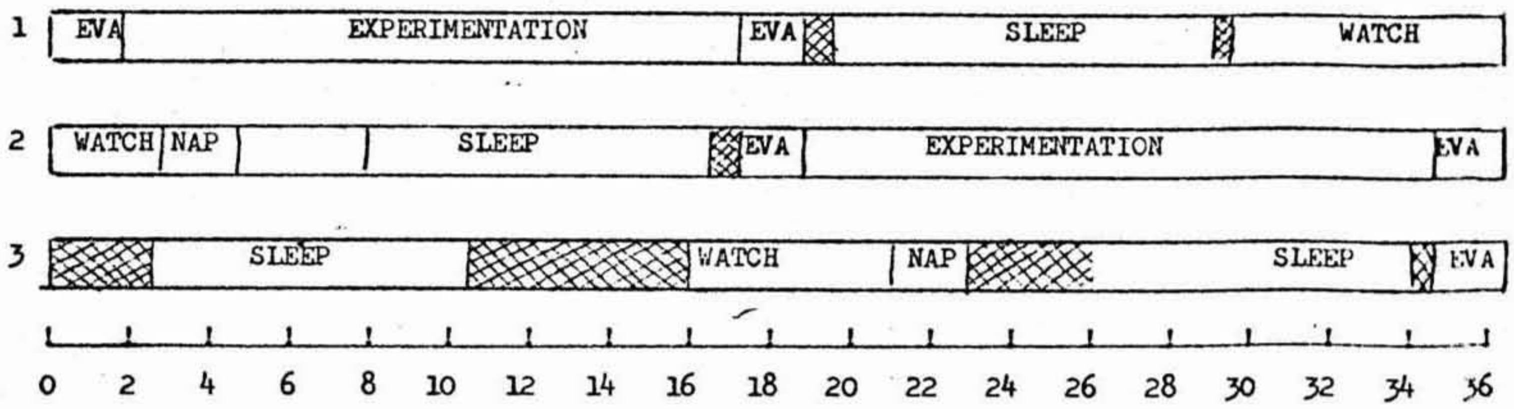
Activity	Minimum Time Costs	O_2 Costs
Don and Check Out Suit	20	
Enter and Secure AL, Connect Long Umbilical	10	
Depressurize AL	2	3.5 lbs
Open EVA Hatch	2	
Traverse to LM	10	
Enter LM, Switch to LM Umbilical	5	12 lbs (Umbilical System Loss)
Monitor #3 Traverse to AL	10	
Secure LM Hatch	2	
Repressurize LM	15	6.9 lbs
Doff Suit and Stow	15	
	91 minutes	22.4 lbs

Development Requirements:

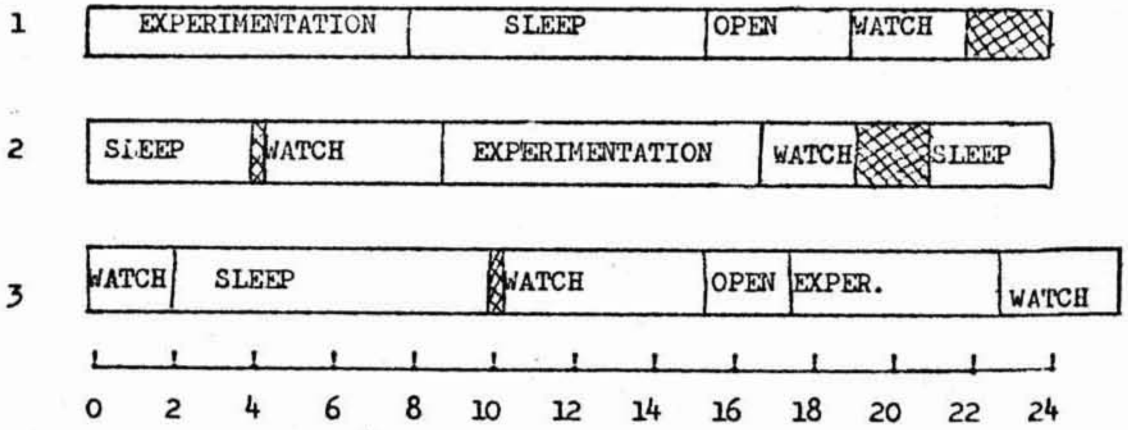
- 150 foot Umbilical
- "Clothesline" Traverse Rig
- LM Hatches for Multiple Usage
- External Lighting

CHART #1

CREW SCHEDULE



Mueller Configuration and Alternative 1 (54 hour cycle) - 18 Hour Experimental Shift



Alternative 2 (24 Hour Cycle) - 6-8 Hour Experimental Shift

CHART #2

and similar activities. In any 3-day period the individual will obtain 24 hours of sleep although it would not be distributed on an 8-hour per 24-hour basis. This cycle may very well not be practical from a crew point of view. On the other hand, some consideration such as this must be made in order to make either of the first two configurations practical. The second part of Chart #2 merely indicates that in the shirt-sleeve environment of Alternate #2 configuration, it is possible to work a normal 8-hour day; 8-hour sleep cycle.

Chart #3 provides a summary of operational differences between the three configurations for a 7-day mission. In order to make the Mueller configuration and the Alternate #1 competitive, they are both based on an 18-hour experiment work schedule as compared to an 8-hour work schedule for Alternate #2. Based on this premise, there is no serious penalty in time available for experiments between various configurations. However, there is a major difference in the number of EVA's and pressurization cycles required by the Alternate #2 and the other two configurations. If the work schedule is changed to a 12-hour experiment duty cycle the number of EVA's involved in the first two configurations changes from 18 to 28, and the number of pressurization cycles changes from 10 to 15. At the same time, the amount of time available for experiments drops to about 90 hours. Although the time available for ATM experiments is not greatly different for Alternate #2.

Another feature shown on the summary chart is the fact that the time required for the crew to reassemble into the CSM for emergency abort is considerably less for the Alternate #2 configuration. Likewise, the chart shows an order of ranking due to the hazard of EVA. Because of the great number of EVA's required for the first two configurations, there is a considerable spread between the number one rating of Alternate #2 and the second and third ratings of the other configurations. Another factor in this rating is the fact that the EVA at the end of the work shift will be accomplished by an astronaut who may already be highly fatigued and more prone to accidents.

One place on the chart represents the relative crew workload for assembling the basic configuration. The configuration #2 would be accomplished by a relative normal Apollo docking maneuver. In both the Dr. Mueller and Alternate #1 relatively complicated space erection techniques would be involved. Here again there is a wide spread between the #1 rating and the comparative evaluation of the second and third ratings.

In summary, from a crew operation point of view, there is a major balance in favor of Alternate #2 configuration. Between the Dr. Mueller configuration and the Alternate #1 there is little choice. It would appear that the commuting problem is easier for the Dr. Mueller configuration, but the problem of the original structural build-up would be somewhat more difficult.

SUMMARY OF DIFFERENCES IN CONFIGURATION FOR 7 DAYS

	Mueller Conf.	Alternative Conf. 1	Alternative Conf. 2
Time Available for Experiments (18-Hour Schedule)	100 Hrs	100 Hrs	108 Hrs
Number of EVA's	18 Umbilical	18 PLSS	1 Umbilical
Number of Depressurization	AIM 10 LM 9	AIM 10 LM 9	AIM 1 LM 0
Crew Time for Emergency Evacuation of the LM to the AIM	> 25 Min	> 30 Min	< 5 Min
Crew Safety for EVA (Least hazard to greatest)	2nd	3rd	1st
Crew Workload for Configuration Set-Up (Least to greatest)	3rd	2nd	1st

CHART #3

ATTACHMENT #4

OTHER EVA CONSIDERATIONS

EVA

1. Minimize EVA cycles and duration

   To -

   Reduce crew workload to **realistic level**

   Insure compatibility with support equipment, i.e., life support system, maneuvering unit, A.L. hatch seal

   Reduce oxygen required

   By -

   Optimizing EVA procedures

   Eliminating tasks not demanding direct human input

   Simplifying required EVA tasks for minimum crew exertion

   Insuring compatible hardware design, i.e., cassette fasteners, handles, tethers, controls

   Insuring optimum equipment location for crew accessibility

2. Determine EVA support hardware requirements

   Including -

   Stabilization hardware

   Maneuvering equipment

   Illumination requirements

   Data cassette/crew tethering hardware

   Data cassette protective equipment

   Cassette attachment/detachment tools

   Airlock hatch actuation tools

   By -

   Identifying mobility, dexterity, and visual acuity requirements for each task

   Simulating critical tasks to develop optimum procedure and establish support requirements

   Analyzing available support hardware for application and compatibility

   Identifying ATM interfaces for crew tethering

   Determining ATM data cassette environmental limitations.

3. Insure crew/system compatibility during EVA

   By -

   Evaluating ATM/carrier attitude stability modes

   Analyzing crew equipment failure modes

   Determining compliance of ATM system with applicable human engineering criteria and available Gemini/Apollo data

   Simulation of critical tasks to insure reasonable metabolic loads

   Establishing safety procedures to be undertaken in the event of an emergency

   Determining ACS constraints on crewman

4. Insure crew/mission compatibility during EVA

   By -

   Scheduling EVA for maximum operation during orbital light side

   Scheduling EVA during orbital periods possessing minimum hazard, i.e., meteoroid shower activity, South Atlantic anomaly, solar radiation

   Scheduling EVA during periods of minimum mission operation

ATTACHMENT #5

ANALYSIS OF CREW CONSIDERATIONS

MISSION 211/212

SEP 14 1966

TABLE OF CONTENTS

Summary

The analysis of mission objectives, flight profiles, spacecraft operations, experiment considerations and operations, and carrier comparisons for mission 211/212 is presented with conclusions and recommendations as related to crew considerations and operations. The CSM/RCM/ATM offers crew advantages not available within the CSM/LEM/ATM configuration. All experiments can be accomplished with a reduction in the quantity but not the quality of desired information. The mission will be trying and difficult for even the most highly motivated astronauts.

Introduction

The purpose of this study is to ascertain, in preliminary form, the operational constraints and potential problems associated with crew participation during the mission. Factors considered are mission objective, flight profiles, spacecraft operations, experiments operations and carrier consideration. Conclusions and recommendations are included for use by technical personnel.

There are many factors that can have an influence on crew operations during orbital or lunar missions. Some are very real, and can be evaluated, while many are quite nebulous and are a function of an individual crew member on a specific flight. Many in this category can only be evaluated at this time by intuition and opinion, with little or no firm facts to substantiate the conclusion. Many of the opinionated items must await actual Apollo flight experience before real answers are available.

Therefore, this study will be revised and upgraded as more and better information becomes available.

Basic crew considerations must be evaluated for two categories, i.e., Intra-Vehicular Activities including all spacecraft operations, housekeeping, personal hygiene, and experiment operations; Extra-Vehicular activities, including all preparations for external spacecraft and experiment operations, crew and cargo transfer, external maintenance and repairs, and emergency operations including astronaut rescue and retrieval.

The crew represents the most flexible system contained in the spacecraft. It has a demonstrated capability of rapidly adjusting to the situation without severely effecting adjacent systems. Dual or triple redundancy is incorporated depending upon the number of astronauts present. Adaptation to limited and restricted operating environments has been repeatedly accomplished with selected personnel in test flights for years. However, flights have been a relatively short duration limited to a few hours, or a few days, in the most extreme cases. Since the main objective of AAP is the extension of manned space flight function, every effort must be exerted to increase the comfort and working conditions of the astronaut.

MISSION OBJECTIVES

CREW CONSIDERATIONS

Mission Objective

The objective of Mission 211/212, as specified by NASA, is as follows:

1. Conduct solar astronomy observations using ATM mounted experiment sensors.

2. Store carrier-ATM in orbit for subsequent rendezvous and reuse (see Mission 213 - Launch CSM into rendezvous orbit, coplaner with carrier ATM from Mission 211/212).

*3. Conduct rendezvous experiments between CSM and carrier vehicle for lunar rendezvous problem analysis early in flight program.

*4. Observation and measurement of extended duration space flight effects on crew members.

*5. Conduct synoptic weather and mapping photography experiment using CSM as experiment carrier.

* Objectives not supplied by NASA.

MISSION FLIGHT PROFILE & OPERATIONS

CREW CONSIDERATIONS

A. MISSION 211/212 - MISSION PROFILE ANALYSIS

The mission description for 211/212 as described in C-2-211/212-2, 9 August 1966, forms the basis for these comments as to the relative desirability of various possible mission profiles for Flights 211/212.

TABLE I

Mission Descriptions - 212 First Launch

Method I

212-LEM (ATM)-Dir. inj. 200 n.mi. circular
211-CSM-Dir. inj. 120 n.mi. phasing orbit
211-CSM dock with 212 LEM
Conduct all experiments in 200 n.mi. circular orbit

Comments: All experiments would be conducted at 200 n.mi. Altitude for mapping higher than desired. It may be necessary to separate LEM and CSM during ATM experiment so that more than one experiment can be conducted simultaneously. This method is rated #4 for crew consideration.

Method II

212-LEM (ATM)-Dir. inj. 200 n.mi. circular
211-CSM (Rack)-Dir. inj. 120 n.mi. circular phasing orbit
211-Conduct mapping experiments
211-Transfer, rendezvous and dock with 212 LEM at 200 n.mi.
Conduct ATM experiments

Comments: This launch and orbital sequence is rated #2 and permits maximum utilization of the manned vehicle at both the 120 n.mi. and 200 n.mi. orbits. Furthermore, if the LEM must be separated from the CSM during the ATM experiment, separation time and distance can be minimum (5 miles or less). This is required in the event the LEM must be abandoned or an orbit abort is required. It should be realized that the manned LEM, when separated from the CSM, has no orbital abort capability and rendezvous and crew transfer must be accomplished by the CM prior to aborting the orbit. Therefore, a manned LEM separated from the CM is not a desirable configuration and should be avoided. In the event this configuration is required, the LEM crew is placed in a very high risk situation.

Method III

212-LEM (ATM)-Dir.inj. 200 n.mi. circular
211-CSM (Rack)-Dir. inj. 100 x 200 n.mi.
211-CSM transpose and dock to rack
211-CSM (Rack)-Rendezvous with 212 LEM in 200 n.mi. circular orbit
211-CSM undock rack
211-CSM dock to 212 LEM and transfer two (2) crewmen
211-CSM undock 212-LEM
211-CSM dock to rack
211-CSM (Rack)-Transfer to 120 n.mi. circular
Conduct mapping experiments
211-CSM (Rack)-Transfer and rendezvous with 212 LEM
212-LEM crew (EVA) recover rack data
211-CSM undock rack
211-CSM dock to 212 LEM

Comments: This sequence is much too complicated and places an unnecessary risk on the 2-man crew of the LEM at 200 n.mi. and the CM at 120 n.mi. This sequence is highly unacceptable for crew safety in the event of a LEM failure or orbital abort.

Method IV

212-LEM (ATM and Mapping)-Dir.inj. to 120 n.mi. circular
211-CSM-Dir.inj. 120 x 200 n.mi. phasing orbit
211-Circularize, rendezvous and dock with 212 LEM At 120 n.mi.
Conduct all experiments
CSM/LEM transfer to 200 n.mi. for LEM (ATM) storage

Comments: This method required unnecessary orbital changes by the manned vehicle. Suggest 211 CSM direct inject into 120 n.mi. phasing orbit with LEM.

Method V

212-LEM (ATM)-Dir. inj. to 200 n.mi. circular
211-CSM (Rack)-Dir. inj. to 100 x 200 n.mi. phasing orbit
211-CSM transpose and dock to rack
211-CSM (Rack)-Rendezvous with 212 LEM in 200 n.mi. circular orbit
Transfer two (2) crewmen by EVA from 211 CSM to 212 LEM
Conduct ATM and mapping experiments
211-CSM undock rack dock to LEM

Comments: This method requires transfer of the crew by EVA and undocking from the rack by the CM prior to docking with the LEM. Again, it would appear that more time than is necessary would be spent by the two crewmen in the LEM with separation from the CSM. Not a desirable condition.

Method VI

212-LEM (ATM)-Dir. inj. 200 n.mi. circular
211-CSM (Rack)-Dir. inj. 100 x 200 n.mi.
211-CSM-Transpose and dock to rack
211-CSM rendezvous with 212 LEM at 200 n.mi.
Transfer two (2) crewmen to LEM by EVA
211-CSM (Rack)-Transfer to 120 n.mi. circular
Conduct mapping experiment
211-CSM (Rack)-Transfer to 200 n.mi. and rendezvous with 212 LEM
LEM crew recover data (EVA) from rack
211-CSM undock from rack
211-CSM dock to 212 LEM

Comments: This sequence prevents rapid recovery of the two crewmen in the LEM by the CSM, i.e., LEM at 200 n.mi., CSM at 120 n.mi. This method is not acceptable for safety reasons.

Mission Descriptions - 211 First Launch

Method I

211-CSM-Dir. inj. 120 n.mi. phasing orbit
212-LEM (ATM)-Dir. inj. 200 n.mi. circular orbit
211-CSM-Transfer to 200 n.mi. and rendezvous with 212 LEM
211-CSM-Dock with 212 LEM
Conduct all experiments in 200 n.mi. circular orbit

Comments: This sequence is acceptable for crew safety. However, the 200 n.mi. mapping orbit is not desirable when 120 n.mi. is preferred. This method is rated #3.

Method II

211-CSM (Rack)-Dir. inj. 120 n.mi. circular phasing orbit
211-CSM (Rack)-Conduct mapping and weather experiments
212-LEM (ATM)-Dir. inj. 200 n.mi. circular orbit
211-CSM-Transfer, rendezvous and dock with 212 LEM at 200 n.mi.
Conduct ATM experiments

Comments: This sequence is preferred from crew consideration and offers better utilization of equipment than Method II - Table I. This sequence is rated #1 from crew consideration.

Method III

211-CSM (Rack)-Dir. inj. 100 x 200 n.mi. phasing orbit
211-CSM-Transpose and dock to rack
212-LEM (ATM)-Dir. inj. 200 n.mi. circular orbit
211-CSM-Undock rack
211-CSM-Dock to 212 LEM and transfer two (2) crewmen to LEM and conduct ATM experiments
211-CSM-Undock 212 LEM
211-CSM-Dock to rack
211-CSM (Rack)-Transfer to 120 n.mi. circular orbit
211-CSM-(Rack)-Conduct mapping experiments
211-CSM-(Rack)-Transfer and rendezvous 212 LEM
212-LEM Crew-Recover rack data by EVA
211-CSM-Undock rack
211-CSM-Dock to 212 LEM

Comments: This method is too complicated and prevents rapid recovery of the LEM crew by the CSM, i.e., LEM at 200 n.mi. CSM at 120 n.mi. Totally unacceptable for crew safety.

Method IV

211-CSM-Dir. inj. 120 x 200 n.mi. phasing orbit
212-LEM (ATM and Mapping)-Dir. inj. to 120 n.mi. circular orbit
211-CSM-Circularize, rendezvous and dock with 212 LEM at 120 n.mi.
Conduct all experiments
CSM-LEM transfer to 200 n.mi. circular orbit for LEM storage

Comments: This sequence requires unnecessary orbit changes by the CM in order to rendezvous with the LEM, i.e., CSM 120 x 200 n.mi. LEM 120 n.mi. This method is more complicated than necessary.

Method V

211-CSM (Rack)-Dir. inj. to 100 x 200 n.mi. phasing orbit
212-LEM (ATM)-Dir. inj. 200 n.mi. circular orbit
211-CSM-Transpose and dock to rack
211-CSM (Rack)-Rendezvous with 212 LEM in 200 n.mi. orbit
Transfer two (2) crewmen by EVA from CSM to LEM
Conduct ATM and mapping, and weather experiments
211-CSM-Undock rack and dock to LEM

Comments: This method requires EVA transfer of the crew from CSM to LEM, and undocking from rack prior to docking with LEM. Appears to be unnecessary, complicated and time consuming if abort of the LEM is required. Not a desirable sequence.

Method VI

211-CSM (Rack)-Dir. inj. 100 x 200 n.mi. phasing orbit
211-CSM-Transpose and dock to rack
212-LEM (ATM)-Dir. inj. 200 n.mi. circular orbit
211-CSM (Rack)-Rendezvous with 212 LEM at 200 n.mi. orbit
Transfer two (2) crewmen to 212 LEM by EVA and start ATM experiments
211-CSM (Rack)-Transfer to 120 n.mi. circular orbit
211-CSM (Rack)-Conduct mapping experiments
211-CSM (Rack)-Transfer to 200 n.mi. and rendezvous with 212 LEM
LEM crew recover data from rack by EVA
211-CSM-Undock from rack
211-CSM-Dock to 212 LEM

Comments: Totally unacceptable due to complexity and orbital separation of manned LEM and CSM, i.e., LEM at 200 n.mi., CSM at 120 n.mi. Not a desirable condition.

CONCLUSION

	Table 1	Table II
Method I	#4	#3
Method II	#2	#1
Method III	Not acceptable	Not acceptable
Method IV	Requires extra orbital changes	Requires extra orbital changes
Method V	Requires EVA and complicates emergency	Requires EVA and complicates emergency
Method VI	Not acceptable	Not acceptable

Table I lists the 212 launch first followed by 211 (manned). Table II lists 211 launch first followed by 212 (unmanned). At this time, we can state that it is preferable to accomplish all rendezvous with unmanned vehicles having a passive rather than an active role. Therefore, the unmanned 212 should be placed in orbit prior to launch of the manned 211 so that all maneuvering is performed and controlled by the crew vehicle (during its powered phase). This is preferable from safety and physiological reasons in that the crew is actually initiating and terminating all powered maneuvers and can take abort action in the event of a collision. Furthermore, the pilot has the physiological advantage of assuring that he has complete control of the powered vehicle and can utilize his judgment as required. Therefore, where the choice exists, it is always preferable to place the unmanned vehicle in orbit prior to the launch of the manned vehicle or in the event the manned vehicle is in orbit, to place the unmanned vehicle in a deeper orbit and permit the manned vehicle to initiate a powered phase to accomplish the rendezvous. Based on these assumptions, the first choice from an operational point of view, is Method II of Table II as described below:

211-CSM (Rack)-Dir. inj. 120 n.mi. circular phasing orbit
211-CSM (Rack)-Conduct mapping and weather experiments
212-LEM (ATM)-Dir. inj. 200 n.mi. circular orbit
211-CSM-Transfer, rendezvous and dock with 212 LEM at 200 n.mi.
Conduct ATM experiments

B. OPERATIONAL MANEUVER REQUIREMENTS (MISSION 211/212)

Based on the foregoing mission profile, the following is an analysis of the basic vehicle maneuvers required to perform the mission without regard to experiment considerations.

Flight 211

1. Assume velocity trimming and maneuvering is performed by S-IVB until separation. This includes orientation for transposition and docking.

2. Transposition and docking (start with +X axis forward and approximately in the trajectory plane, +Z axis up) - 40 minutes.

   a. Add 2 FPS forward velocity to CSM.
   b. Perform 180° pitch maneuver.
   c. Roll - 63°.
   d. Subtract 2 FPS forward velocity.
   e. For final docking, assume 15 minimum pulse cycles of each RCS control axes.
   f. Rotate mated vehicle 180° (place +X axis forward).
   g. Jettison S-IVB using S-IVB RCS.

3. During the rack experiments operational phase of the mission at 120 n.mi., the following maneuvers are performed on a daily basis:

   a. IMU alignment once per day. (X axis unchanged, rotate +Z axis to +30° above horizon, maintain fine mode stability 20 minutes).

b. Navigational sightings twice per day. (X axis unchanged, rotate +Z axis to local vertical and pointed toward earth. Maintain fine mode stability for 36 minutes).

c. Assume the start up and stopping of six barbecue maneuvers per day. Assume a 90° yaw or pitch realignment from normal flight alignment to the barbecue attitude which orients the Y-Z plane toward the sun (±20°). Establish a roll rate of 1 to 2.5 revolutions per hour about the X axis. Assume drifting mode once roll rate is obtained. On stopping, return vehicle to original attitude.

4. In preparing for the orbit change, the +X axis is forward and approximately parallel to the local horizontal. The -Z axis is down and approximately parallel to local vertical. Obtain required ΔV using SM main engine.

5. During orbit transfer perform the following:

   a. One IMU alignment (See 3a).
   b. One navigational sighting (See 3b).
   c. One midcourse correction: Assume correction of 10 fps.

6. Circularize orbit using main SM engine. Adjust X axis about 10° in pitch.

7. Drop RACK.

8. Rendezvous with Flight 212. Use CM-RCS for following maneuvers:

   a. Adjust velocity total of 60 fps. (40 fps in coarse increments, 20 fps in fine increments).

   b. Lateral translation of 3 miles.

   c. Vertical translation of 10 miles.

   d. Assume 30 minimum impulse cycles of each control axis.

9. On a <u>daily</u> basis, the following maneuvers are required. (Same as item 3).

10. If the LEM/ATM is undocked for experiment purposes:

    a. Flight 211 will be the target vehicle for subsequent dockings. Assume fine mode stability in normal flight attitude for 20 minutes for each docking.

b. Flight 211 will station keep on Flight 212, i.e., maintain a position about 1/2 mile below and within 1 to 3 miles aft. (Continue requirements of Item 9 while stationkeeping). For each undocking, subtract 2 fps and then adjust to achieve station position.

11. At completion of flight, rotate combined vehicle so +X axis is forward and slow CSM (Flight 211) 4 fps and translate down 1/2 mile to achieve separation from the LEM (Flight 212).

12. During the 8 hours prior to re-entry, cool the forward heat shield by rotating the -X axis toward the sun.

13. For CM/SM separation, the +X axis is rotated 60-70° above the direction flight and in the trajectory plane. The +Z axis is oriented to upward local vertical.

14. Entry starts with the -X axis in the trajectory plane and rotated approximately 26° earthward from local horizontal and with the +Z axis pointed away from earth.
Note: Minimum RCS propellant at start of re-entry will be ______ pounds.

Flight 212

1. Assume velocity trimming and maneuvering is performed by S-IVB until separation. This includes orientation for transposition and docking.

2. If the LEM remains docked there will be no maneuvering requirements (the CSM of Flight 211 will also provide maneuvering for CMG unloading).

3. If LEM operates undocked:

   a. Assume one daily IMU alignment (See 3a).
   b. Assume one daily navigational sighting (See 3b).
   c. There will be no barbecue requirement.
   d. For redocking the LEM will be the active vehicle.

      1) Assume lateral translation of one mile, vertical of one mile, and longitudinal of three miles.

      2) For final docking, assume 15 minimum pulse cycles of each RCS control axis.

C. CONCLUSIONS CONCERNING THE OPERATIONAL ASPECTS OF MISSION 211/212

This mission provides several optimal mission profiles. A recommended profile has been given in paragraph A. Basic mission maneuvers are all similar to Apollo requirements and will entail no new training or equipment revisions. This is an alternate AAP mission and the mission as described, will complement the development of the basic Apollo mission. The possible separation of the LEM for extended periods of experiment operations is undesirable and will be discussed later in this report.

EXPERIMENT OPERATIONS

CREW CONSIDERATIONS

Experiment Operations

Prior to Mission 211/212 analysis, the following assumptions were made:

a. A CSM/Rack (211) in a 120 n.mi. circular orbit for a total of 13 days.

b. The 14th day spent with the CSM transferring to a 200 n.mi. orbit and rendezvousing and docking with the carrier (212).

c. The carrier (212) injected directly into a 200 n.mi. circular orbit after the launching of 211.

d. The carrier spends 13 days in a 200 n.mi. orbit.

e. The 28th day spent in CSM-carrier separation and CM re-entry maneuvers.

f. Six manhours of experimental time available on the first day of the 211/212 mission.

g. Eight hours/day/man are available for experiments (24 manhours per day).

h. The one astronaut in the CSM during CSM-carrier separation, will not be expected to perform experiments.

The preceding assumptions indicate that there are 294 manhours free for experiment time during Flight 211 (low orbit) and 208 manhours available for carrier (based on 2 men) experimentation. This totals 502 manhours.

A thorough analysis of the candidate experiments reveals a requirement for 859 manhours, including such experiment-related tasks as alignment, spacecraft attitude holds, unstowing and setting up equipment, EVA preparation, etc. It is obvious that all these experiments cannot be operated for the desired time because of the deficit of available time (859 desired experiment time minus 502 available experiment time = -357 manhours).

The 859 experiment times can be broken down as follows in Table I.

Table I

All 3 crewmen needed	Two crewmen needed	One crewman needed
450 manminutes - 13th day	616 manminutes - daily 1st - 13th day	367' - daily, 1st - 13th day
720 manminutes - 16th day	26 manminutes - 1st, 7th & 13th day	180' - 2nd - 8th day
900 manminutes - 27th day	1394 manminutes - daily, 15th - 27th day	170' - 3rd - 13th day
	600 manminutes - 15th & 16th day	903' - daily, 15th - 27th day
	232 manminutes - 17th - 25th day	10' - 17th - 25th day
		120' - 15th, 17th, 19th, 21st, 23rd day
		60' - 28th day

Inasmuch as three men are available for a maximum of 880 manminutes on any given day (of flight 211), there appears to be no unusual problem in performing any of the experiments requiring three men. The heavy requirements for all three crewmen on the 13th, 16th and 27th days of the mission sharply curtail additional experimentation on those days. The remaining time allocation on these three days for the remaining crew members is as follows. Two men available for a maximum of 520 manminutes.

During carrier operation where only two men are available for experiments, it is estimated that there will be 924 manminutes available for two men and 200 minutes available for one man. It can be seen that the 1394 manminute, daily (15th - 27th day) requirements for two men, cannot be met. Moreover, the daily requirements of one man for 903' per day (15th - 27th day) cannot be satisfied.

It should be pointed out that experiments M011, M022 and M044 have no in-flight requirements. M005 and M007 were combined for purposes of our time study. M012 was combined, in part, with M017. M019 is also combined with M012. The EVA requirements of S005 and S006 were combined. EVA requirements for S016, S017, S018, S019, S020, S052, S053, S054, and S056 were also combined.

A total of 16 EVA's, requiring 97.2 manhours were presently required. Experiment S018 takes 54 of the manhours for EVA's related to micrometeoroid collections. All these EVA hours include the pre and post-EVA activities as well as the actual EVA time. The longest period of EVA outside the spacecraft is three hours.

Experiments S005 and S006 will be flown on Flight 211 and will require a 150 minute EVA with an astronaut spending 30 minutes outside the craft collecting film cannisters from the rack. This activity makes it necessary to carry one PLSS for the EVA worker and one PLSS for the standby in the event it is necessary for him to rescue the EVA worker. There is serious doubt if the C/M can stow two PLSS's. It may be necessary to provide the standby an umbilical, hooked into the C/M ECS, long enough to allow rescue operations. Another desirable approach is to do the basic EVA by means of an umbilical, For EVA excursions in the carrier, it is assumed that two PLSS's will be available and that the carrier will have sufficient resupply commodities.

The final EVA wherein all the ATM experiment packages are to be retrieved (27th mission day) should not be undertaken until the CSM has docked with the carrier, thus utilizing a full crew of three astronauts.

The following experiments impose the greatest time demands on the Apollo crewmen:

M012 - 504 Manminutes per day - days 2-13
M020 - 270 Manminutes per day - days 2-13
*S005 - 180 Manminutes per day - days 2-8 } Flight 211
*S006 - 170 Manminutes per day - days 2-12

*S018 - 270 Manminutes per day - days 15-27 (EVA)
**S019 - 538 Manminutes per day - days 15-27
*S053 - 198 Manminutes per day - days 15-27
*S055 - 354 Manminutes per day - days 15-27 } Flight 212
*S056 - 516 Manminutes per day - days 15-27

An additional factor which has a serious impact on the accomplishment of experiments is the night and daytime experiment operating requirements. The experiments above, marked with "*" can be done in daylight only; those marked "**" can be performed only during the nighttime.

A glance at the established mission timeline shows 90 manminutes allotted of exercise time. Inasmuch as M012 requires exercising on the ergometer, these allocated 90 manminutes could be utilized for performance of experiment M012. Moreover, the set up time required for M012 is 60 manminutes per day. If the ergometer can be left in an assembled position, this would save an additional hour of time.

General Conclusions and Recommendations

A "typical" day of Mission 211 was timelined in terms of experimental operations and from this timeline the following conclusions and recommendations were evolved:

1. Periods of Watch must be utilized to accomplish the experiments. The duration of watch periods wherein the crewman can be away from his watch station must be extended from 15 to 20 minutes.* Otherwise, experiments requiring 17 and 18 minute continuous operations will have to be re-evaluated.

2. Astronauts must give up portions of their sleep, naps, personal hygiene and lunch hours in order to schedule the experiments.

3. Daily experiment participation by crewmen will be as follows:

   Pilot - 319 minutes
   Navigator - 395 minutes
   Engineer - 361 minutes

4. Experiments requiring 30 continuous minutes of experiment operation can be performed <u>only</u> during an astronaut's standby period. This means that any experiment requiring 30 successive minutes can be performed only once per day per man <u>unless</u> it is all right to repeat the same experiment within a man's 3 hour standby period. Experimenters should try to arrange experiments so that they can be performed in 15-20 minute increments.

5. Because of the great demand on crewmen's time, it will be necessary to set up apparatus for experiment "X" and do part of that experiment; while this apparatus is still set up, it will be necessary to set up apparatus for experiment "Y" and then perform some of that experiemnt. A complete analysis of space problems need to be undertaken in connection with the experiment timelines. (In other words, available crew time alone does not give us a realistic picture of what can be optimally accomplished within the C/M.) The value of simulation cannot be over-stressed.

6. Though the mission-assigned experiments can be performed during Flight 211 within the allocated time, the C/M will be a busy and crowded laboratory. The addition of a RCM to carry some of the experimental apparatus would significantly relieve this congestion problem while saving a sizeable amount of time. The inclusion of a RCM on Flight 211 would allow the experimental apparatus to be initially set up and then left in an assembled position. If experiment apparatus for No. M004, M009, M012, M018 and M020 could remain assembled, the astronauts would face a more realistic time schedule.

* 15 minute watch period was recommended by Martin Company in "Crew Operations Requirements" dated 10 August 1966.

7. It is interesting to note that once the typical mission timeline of events was completed for Flight 211, there were a minimum of six hours for the three crewmen per day on an individual basis. (Only one man free) This suggests that experimenters should look very closely at the experiments to determine ways in which experiments could be conducted by one person, rather than on a pair (subject-experimenter) basis.

Detailed experiment operations data for Mission 211/212 can be found in Table I. The following comments apply to the individual experiments which present problems:

1. M004 - This experiment requires 17 minute time increments. Recommend 17 minute away-from-work allowance during astronaut's watch periods.

2. M012 - Though the analysts have requested this experiment to be repeated three times a day, it is recommended that it be done only twice a day. The only means of scheduling it three times a day is to leave the apparatus set up permanently - an improbability within the C/M.

3. M020 - Requirements for this 30 minute experiment include its execution twice per day on all astronauts. It is recommended that it be performed only once per day. Otherwise, it imposes serious scheduling problems.

4. S018 - At this time, this experiment requires one 135' EVA per day for the orientation of micrometeorite detector plates for a total of twelve days. Recommend that:

   a. The number of EVA's be halved, or

   b. Means of remotely reorienting the plates be devised, or

   c. Detector plates be positioned so that visual inspection can be made from within the LEM, thus possibly eliminating the need for 12 EVA's.

5. S019 - Completely unrealistic requirement for constant surveillance by an astronaut during all dark-side orbits. Recommend that this time demand be reduced by 75%. Or develop an automatic device capable of meeting experiment objectives.

6. S055 - Requires two astronauts for a total of 546 minutes a day. Recommend that this requirement be halved.

7. S056 - This experiment requires 120 hours of Flight 212 time, including spacecraft orientation. On a 12 day flight, this means ten hours a day are to be devoted to this one experiment. Recommend that the experiment be seriously analyzed to determine if it is worth this much time. Reduce experiment time by at least 75%.

FIG. 1 AAP MISSION TIMELINE OF EVENTS
MISSION

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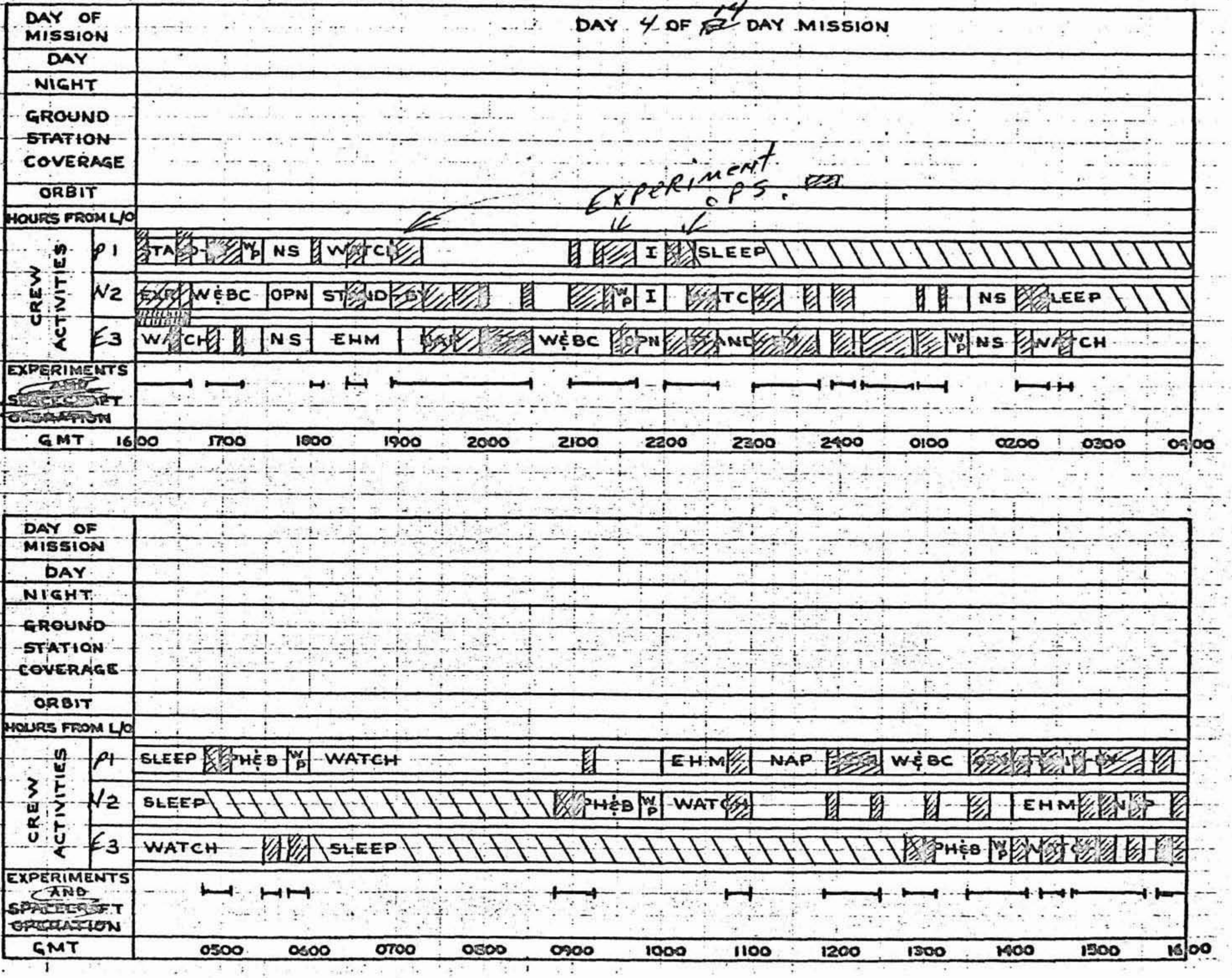

MISSION 211/212

MAJOR EQUIPMENT AND ASSOCIATED TASKS

EXPERIMENT	No In-Flight Equipment Req.	Electrocardiogram	Phonocardiogram	Biomedical Tape Recorder	Urine Volume Meas. System	Electroencephalogram	Ergometer	Proportional Counter	Voice Tape Recorder or Data	Impedance Pneumograph	Thoracic Blood Flow Assembly	Gas Meter Analyser	Nephelometer	TV Camera	TV Monitor	PLSS	Movie Camera	Film Cassette Retrieval	EVA - Equipment	Metric Camera	Panoramic Camera	Radar Altimeter	Lens Cover System	Image Orthicon Camera System	Dielectric Tape Camera	Spectrometer	Stellar Camera	Emulsion Package	X-Ray Detector	70mm Camera	Space Tools	35mm Movie Camera	16mm Movie Camera	X-Ray Telescope	H Viewing System	Coronagraph	Spectroheliograph	UV Spectrograph	Photomultipliers
In-Flight Phonocardiogram		x	x	x																																			
Bio-Assays Body Fluids					x																																		
Calcium Balance Study					x																																		
In-Flight Sleep Analysis				x		x																																	
Human Otolith Function																																							
Cytogenic Study	x																																						
Exercise Ergometer		x		x			x	x	x																														
Thoracic Blood Flow		x		x			x			x	x																												
Vector Cardiogram		x		x																																			
Metabolic Rate Measurement				x			x			x		x																											
Pulmonary Function				x					x	x		x																											
Red Blood Cell Survival																																							
Microbiological Assay																																							
Anti-G Elastic Garment																																							
In-Flight Nephelometer													x																										
Space Suits + Lunar Exp. Hardware									x					x	x	x	x																						
Synoptic Terrain Photography									x									x	x	x	x	x	x																
Synoptic Weather Photography									x									x	x	x			x	x	x	x	x												
Trapped Particles Assymetry																												x											
X-Ray Astronomy									x									x	x				x				x		x	x									
Micrometeorite Collection									x										x												x								
UV Stellar Astronomy									x									x	x													x	x						
UV X-Ray Solar Photography									x																							x	x						
Apollo Telescope Mount																																x			x				
White Light Coronagraph																		x	x				x									x			x	x			
High Resolution Photography of Solar Atmosphere																		x	x				x									x						x	
X-Ray Telescope (214/215/216)																	x	x	x															x					
Ultraviolet Spectrometer									x														x												x			x	
Intensity of Solar Flares									x																										x		x		x
Spectroheliography in the EUV								x	x									x	x				x						x	x				x	x		x	x	

* C[illegible]
[illegible] – Experimenter
E/S – Exp & Subject
S – Subject
A – Assistant

EXPERIMEMT OPERATIONS DATA — MISSION - 211/212

Crew Ops. Analyst - R.W. Walker
Date - 9/12/66

Experiment Number	Experiment Title	Flight Number 211	212	Carrier	Crew Use* Commander	Navigator	Sys Eng	Experiment Session Time Line (min, hrs, etc, as specified) Time Per Crewman	Continuous elapsed time	Total Session Time (minimum ets)	Desired Frequency	Desired Tolerance	Total Experiment Time – this mission	Pointing & Tracking Constraints	Remarks
M004	IN-FLIGHT PHONOCARDIOGRAM	X		CM	S			17'	51 MIN	152 MIN	1/DAY	+24 HRS ±2.4 HRS	1224 MIN	NONE	
						E/S		17' 17'							
							E/S	17' 17' 17'							
M005	BIOASSAYS BODY FLUIDS	X		CM	E/S			7'	21 MIN	21 MIN	EACH URINE VOIDING	NONE	1008 MIN (EST)	NONE	ANALYST EST. ZERO EXP. TIME - SAID INCLUDE IN PERSONAL HYGIENE PERIOD - ADD TIME TO P.H. FOR EXP. PERFORMANCE
						E/S		7'							
							E/S	7'							
M007	CALCIUM BALANCE STUDY	X		CM	E/S	E/S	E/S	← SEE REMARK →						NONE	TIME IS INCLUDED IN M005
M008	IN-FLIGHT SLEEP ANALYSIS	X		CM	S			6' 6'	6 MIN	72 MIN	EACH SLEEP PERIOD	NONE	864 MIN	NONE	SIX MIN SET-UP & TEAR DOWN TIME BEFORE AND AFTER EACH SLEEP PERIOD
						E/S		6' 6' 6' 6'							
							E/S	6' 6' 6' 6' 6' 6'							
M009	HUMAN OTOLITH FUNCTION	X		CM	S			6'	18 MIN	36 MIN	1/DAY	NOT CRITICAL	432 MIN	NONE	
						E/S		6' 6'							
							E/S	6' 6' 6'							
M011	CYTOGENIC STUDY	X		CM	← SEE REMARK →										NO EFFORT DURING Flight
M012	EXERCISE ERGOMETER	X		CM	S			38'	114 MIN	168 MIN	3/DAY	O.A. + 24 HRS ± 10% OF 8 HRS	6048 MIN	NONE	THIS EXP MAY REQUIRE EXCESSIVE SPACE AND REQUIRE AN EXCESSIVE AMOUNT OF EXERCISE OF THE CREWMEN. CANNOT BE DONE 3 TIMES/DAY - TWICE only.
						E/S		9' 9' 38'							
							E/S	38' 9' 9' 9' 9'							
M017	THORACIC BLOOD FLOW	X		CM	S			6'	6 MIN	36 MIN	1/6 DAYS	O.A. + 12 HRS ± 10%	108 MIN		CONDUCTED IMMEDIATELY AFTER EXERCISE PERIOD
						E/S		6' 6'							
							E/S	6' 6' 6'							

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O.A. - ORBIT ATTAINMENT

Sheet 1 of 4

* Crew Use:
E - experimenter
E/S - Exp & Subject
S - Subject
A - Assistant

EXPERIMENT OPERATIONS DATA — MISSION- 211/212

Crew Ops. Analyst - R W WALKER
Date - 9/12/66

Experiment Number	Experiment Title	Flight Number		Carrier	Crew Use *			Experiment Session Time Line (min, hrs, etc, as specified)							
		211	212		Commander	Navigator	Sr. Eng	Time Per Crewman	Continuous Elapsed Time	Total Session Time (min-min etc)	Desired Frequency	Desired Tolerance	Total Experiment Time - this mission	Pointing & Tracking Constraints	Remarks
M018	VECTORCARDIOGRAM	X		CM	S	E/S	E/S	17' 17' 17' 17' 17' 17'	51 MIN	102 MIN	1/DAY	NOT CRITICAL	1224 MIN	NONE	
M019	METABOLIC RATE MEASUREMENT	X		CM	← SEE NOTE →									NONE	CONDUCTED AS A PART OF M012 - NO ADDITIONAL TIME REQUIRED
M020	PULMONARY FUNCTION	X		CM	S	E/S	E/S	30' 30' 10' 5' 10' 5' 10' 5' 30'	90 MIN	135 MIN	2/DAY	NOT CRITICAL	3240 MIN	NONE	
M022	RED BLOOD CELL SURVIVAL	← SEE REMARK →													PRE- & POST FLIGHT EFFORT ONLY
M044	MICROBIOLOGICAL ASSAY	← SAME AS M022 →													
M048	ANTI-G ELASTIC GARMENT	X		CM			E/S	60'	60 MIN	60 MIN	1/FLT	NONE	60 MIN	NONE	GARMENT IS DONNED BEFORE REENTRY
T003	IN-FLIGHT NEPHELOMETER	X		CM			E	5'	5 MIN	5 MIN	1/10 HRS	O.A. + 5 URS ± 20%	145 MIN	NONE	THE EXPERIMENT IS PERFORMED TWICE IN 5 MINUTES.
M466	SPACE SUITS AND LUNAR EXPERIMENT HARDWARE	X	X	CM & LEM	A	A	E	300' 300' 240' 300' 300' 240' 240' TEST 1 TEST 2 TEST 3 (EVA)	300/240	11920 MIN	TESTS 1 & 2 1/FLT TEST 3 1/FLT	NOT CRITICAL	1920 MIN	NONE	TEST # 3 TO BE PERFORMED IN DAYLIGHT
S005	SYNOPTIC TERRAIN PHOTOGRAPHY	X		CM & RACK	A	A	E	30' 30' 30' 30' 30' 150' 150' 6' 6' 6' 6' 6' 150' PHOTOGRAPHY EVA	36/150	1636 MIN	EVA 1/FLT PHOTO- 1/DAY (ON 7 DAYS)	SEE REMARKS	1710 MIN.	REQUIRED	START ON SECOND DAY, FIFTH ORBIT AND PERFORM WHEN DESIRED TARGETS ARE VISIBLE AND ILLUMINATED BY SUNLIGHT. EVA TO RETRIEVE FILM ON THIRTEENTH DAY. DURING DAYLIGHT.
S006	SYNOPTIC WEATHER PHOTOGRAPHY	X		CM & RACK	E			34' 34' 34' 34' 34'	34 MIN.	170 MIN	1/DAY (10½ DAYS)	DEPENDENT ON CONDITIONS	1800 MIN	REQUIRED	EVA COMBINED WITH S005 - PHOTOGRAPHS TO BE TAKEN OF PREDETERMINED WEATHER TARGETS. EACH 34 MINUTES INCLUDES 30 MIN TO POINT S/C.

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* Crew use:
E - experimenter
E/S - Exp & Subject
S - Subject
A - assistant

EXPERIMEMT OPERATIONS DATA — MISSION - 211/212

Crew Ops. Analyst - R. W. Walker
Date - 9/12/66

Experiment Number	Experiment Title	Flight Number 211	Flight Number 212	Carrier	Crew Use * Commander	Crew Use * Navigator	Crew Use * Sys. Eng.	Experiment Session Time Line (min, hrs, etc, as specified) Time Per Crewman	Continuous Elapsed Time	Total Session Time (min-min, etc)	Desired Frequency	Desired Tolerance	Total Experiment Time - this mission	Pointing & Tracking Constraints	Remarks
S016	TRAPPED PARTICLE ASSYMETRY	X		LEM	A			EVA / RADIATION STUDY	260 MIN	604 MIN	EVA 2/FLT OTHER 1/DAY	SEE REMARK	2048 MIN	REQ'D	PERFORM EVA ON SECOND DAY AFTER 200 MI. ORBIT. ~~START EMISSION PARTICLE MEASUREMENTS AFTER~~ EVA TO PLACE EXP PACKAGE IN POSITION, AFTER MEASUREMENTS ARE COMPLETE, RETRACT PACKAGE BY EVA
						E		260' 12' 12' 12' 12' 12' 12' 12'							
							A	260'							
S017	X-RAY ASTRONOMY	X		LEM	A			EVA 300'	300'/126 MIN	1/EVA 242/DAY	9 ORBITS	NOT CRITICAL	3078 MIN	REQ'D	EVA REQUIRED ON 27TH DAY OF MISSION
						A		300' [illegible]							
							E	300' 116'							
S018	MICROMETEORITE COLLECTION	X		LEM		A		10'	30 MIN	30 MIN	1/DAY	NOT CRITICAL	360 MIN	REQUIRED	EVA TO BE COMBINED WITH S016 - FOR SETUP & TEAR DOWN
							E	20'							
						A/E		135'	135 MIN	270 MIN	1/DAY	DAYTIME	3240 MIN		DAILY EVA TO CHANGE DETECTORS - EVA MAY BE ELIMINATED BY MECHANICAL DEVICE
							A/S	135' EVA							
S019	U.V. STELLAR ASTRONOMY	X		LEM		E		50'	50 MIN	70 MIN	100 TIMES	NIGHT	7000 MIN	REQUIRED	EVA COMBINED WITH S016
							A	20'							
S020	SPECTROGTAPHY IN THE UV	X		LEM			E	90'	90 MIN	90 MIN	1/DAY	IN SUNLIGHT	1080 MIN	REQ.	EVA COMBINED
ATMA	ATM	X		LEM	← SEE REMARK									→	THE ATM PROVIDES A STABILIZED PLATFORM FOR EXPERIMENTS.
S052	WHITE LIGHT CORONAGRAPH	X		LEM			E	90'	90 MIN	90 MIN	1/DAY	IN SUNLIGHT	1080 MIN.	REQ.	EVA REQUIRED BUT IS COMBINED WITH S016
S053	HIGH RESOLUTION PHOTOGRAPHY OF THE SOLAR ATMOSPHERE	X		LEM		E		114'	114 MIN	198 MIN	1/DAY	SUN VISIBLE	2376 MIN	REQ	EVA COMBINED
							A	84'							
S054	X-RAY TELESCOPE	X		LEM			E	120'	120 MIN	120 MIN	5 TIMES	IN DAYLIGHT	600 MIN	NONE	
S055	UV SPECTROMETER	X		LEM		E		192'	192 MIN	354 MIN	1/DAY	IN DAYLIGHT	4248 MIN	REQ	
							A	162'							

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75.40

* Crew Use:
E - Experimenter
E/S - Exp & Subject
S - Subject
A - Assistant

EXPERIMENT OPERATIONS DATA — MISSION - 211-212

Crew Ops. Analyst - R.W. Walker
Date - 9/12/66

Experiment Number	Experiment Title	Flight Number 211	Flight Number 212					Carrier	Crew Use * Commander	Crew Use * Navigator	Crew Use * Sys Eng	Experiment Session Time Line (min, hrs, etc, as specified) Time Per Crewman	Experiment Session Time Line (min, hrs, etc, as specified) Continuous Elapsed Time	Total Session Time (min-min etc)	Desired Frequency	Desired Tolerance	Total Experiment Time - this mission	Pointing & Tracking Constraints	Remarks
S056	INTENSITY OF SOLAR FLARES		X					LEM		A E		30 HRS 90 HRS	NOT KNOWN	NOT KNOWN	N/A	N/A	7200		TO BE PERFORMED WHEN SUN IS VISIBLE EVA TO BE COMBINED SOLAR FLARES WILL BE OBSERVED
																	7200		

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Sheet 4 of 4

EVA EQUIPMENT REQUIREMENTS

For experiments M466, S005 and M006, the following EVA equipment is needed (In C/M-Flight 211):

Lunar Space Suit Assembly	(3)	Based on 14-Day Mission
TMA	(2)	
LCA	(2)	
CWG	(42)	
*PLSS (2) and spares		
AMU (1) and spares		
AMU Fuel Support		
20' Tether (2)		
EVA Visor (2)		

*If only one PLSS can be stowed in the C/M, the standby crewman will need a twenty foot umbilical (hooked into the spacecraft ECS) to perform rescue missions if necessary. It may also be possible to substitute 75 foot umbilicals for the PLSS's.

For experiments S016 and S018, all the following EVA equipment would be transferred into the carrier (Flight 212):

TMA	(2)	Based on 14-Day Mission
LCA	(2)	
*CWG	(14)	
PLSS (2) and spares		
AMU (1) and spares		
AMU Fuel Support		
20' Tethers (2)		
EVA Visors (2)		
*Block II Pressure Suits (2)		
Portable Light		

*19 additional CWG's will be needed to be carried into orbit by the carrier. (2) Block II suits also to be carried by carrier.

It should be noted that a handhold system must be developed for crewman stability at the work locations. Moreover, if an AMU is not used, a handhold system will have to be developed for crewman transfer.

CREW CONSIDERATIONS

CARRIER RECOMMENDATIONS

Crew Considerations - Mission 211/212

The selection of a carrier based solely on crew considerations is an extremely difficult task. For example, the ability to maintain on station for a period of two weeks in the Gemini has been demonstrated in a single flight by highly motivated astronauts. In this particular case, the accomplishment was a challenge of a singular feat rather than a routine occurrence. The trend today is to increase the workload and the mission duration several fold in a spacecraft that is severly restricted and limited for a 14-day mission. We must accept the results of the Gemini and the initial three man Apollo missions as minimum standards for crew habitability and comfort and attempt to improve these standards for the AAP missions.

Habitability

Environmental parameters are not a consideration for carrier tradeoff studies in that the cabin atmosphere will be maintained at 5 ± .2 psi normal, $3\frac{1}{2}$ psi emergency and prior to EVA egress, 100% oxygen, relative humidity from 40 to 70%, cabin temperature 75 ± 5°F and cabin dioxide not to exceed 5 millimeters of mercury for normal operation and 7.6 mm. Hg maximum.

Crew Comfort

The LEM and ATM represents a total pressurized volume of 260 ft^3 with a working space of 122 ft^3 for two men. Waste disposal and storage, food and sleeping facilities are minimum and sized for a 24-hour mission with a reserve time of 24 hours. Normal crew operation requires suited astronauts that may or may not be pressurized. Fecal collection with two suited crewmen in the LEM would be very difficult. The RCM on the other hand, with 366 ft^3 of pressurized volume with separate waste facilities, offers more privacy for waste collection. The opportunity to break the routine can be taken advantage of by utilizing the movements and tasks associated with the food storage and preparation areas. In addition, the necessity for the astronauts to move around within the LEM is very limiting. The actual operation of the vehicle is accomplished from the crew stations. The RCM could be designed to permit more movement of the crew which is certainly desirable on missions of 24 hours or longer.

The ability to remove the pressure suit for shirtsleeve operation and for personal hygiene, is highly desirable for all Apollo Applications flights. Equipment and space for shaving and cleansing should be provided for daily use. The LEM can be modified to provide this capability for a two-man crew. Pressure suit operations, including EVA, will require suit storage, and ability for crew to inspect, clean, and dry each suit prior to storage and use. Any suited operation will require both crew members to be in pressure suits so that the dressing and donning of the suit, removal and drying, will probably require the utilization of all available free pressurized space. No other tasks, experiments, or procedures normally will be accomplished until the suits are stored.

Internal arrangements, including proturberances or sharp edges, must be compatible with the movements and motions required for two astronauts to adequately accomplish all operations required with the suits.

Modifications are required for missions that require separation of the LEM from the Command Module for periods in excess of 24 hours. A seven day manned LEM separated from the Command Module with a two-man crew, requires fecal collection and storage, urine collection and storage/dump. It is recommended that existing food storage and preparation be enlarged to include a preparation area. Personal hygiene facilities should be modified to include provisions for body and dental cleansing and shaving. Shirtsleeve should be normal operating mode. Change of clothing every other day, or three changes for the seven day mission are minimal requirements.

The LEM has no provision for sleeping other than napping on stations during the normal 24 hour mission. When away from the Command Module during a basic Apollo mission, the crew is expected to remain fairly active for the 24 hour period. However, on a seven day mission with the existing crew station restraints, napping on stations cannot be expected to suffice for sleeping facilities. Provisions for uninterrupted sleep for a minimum of seven hours for each crew member must be provided.

Similarly, this feature must be retained in its existing form in the RCM, or suitable facilities provided.

The Command Module normally provides the minimum crew comfort requirements including a "galley" for food preparation, and separated waste collection and storage facilities. It would appear at this time that the RCM could have at least the same capability as the CM. In fact, depending upon the mission, the available facilities could be expanded to provide additional crew comfort.

Crew Safety

The separation of the experiment carrier, i.e., either the LEM and ATM or the RCM and ATM from the Command Module, represents an extremely high risk situation in that the ability to abort from orbit is delayed until the crew is aboard the Command Module.

The ability to egress from the LEM through the hatches in the event two men are conducting experiments, is difficult and trying under normal conditions. Emergency egress of two astronauts and transfer by EVA to the Command Module, may be preferred to rendezvousing and docking, providing the CM is standing by. The RCM equipped with the airlock, appears to offer an easier egress than through the tunnel system on the LEM. The airlock can accommodate only one astronaut at a time; however, the opening dimensions are considerably larger and more accommodating to the suited astronaut. Emergency egress should be quicker and less hazardous to the astronaut.

Similarly, the ability to provide assistance to a distressed astronaut during EVA or crew transfer appears to be easier and quicker from the RCM airlock in preference to the LEM hatches.

Retrieval of the disabled astronaut through the airlock probably can be accomplished with less difficulty and expenditure of energy than through the hatch on the LEM derivatives.

Conclusions

On the basis of the LEM configuration for the normal 24 hour mission, and the ability to incorporate additional crew habitability, comfort, and safety required for a seven day mission, a revised LEM can be designed to accomplish the mission. On the other hand, the features already available in the Command Module, modified and expanded in the RCM, combined with the addition of an airlock, certainly provides a safer, more habitability and comfortable configuration for a two-man crew on a seven day mission.

Carrier Chice - 1st, RCM;   2nd, LEM

CONCLUSIONS AND RECOMMENDATIONS

CREW CONSIDERATIONS

Conclusions and Recommendations

The analysis of mission objectives, spacecraft operations, experiment considerations, and carrier comparisons for Mission 211/212, is presented as related to crew considerations and operations.

The mission can be performed with the CSM/RCM/ATM or with the CSM/LEM/ATM configuration. All experiments as presently defined cannot be accomplished within the mission time. However, if experiment operating times and repeatability are reduced for the extremely long experiments, the mission could produce valuable scientific information on all experiments. Quantity of experimental data would be reduced at no expense to quality.

The analysis of experiment operations has been performed independent of carriers. As a result, considerable crew time is necessary for preparation, set up, and stowage of experiments that must be repeated during flight. In this respect, any additional free space for experimentation can result in a more efficient crew operation. This factor can become very important in a two man operation in the LEM or the RCM.

Carrier comparisons of the LEM and RCM indicate a more favorable and desirable configuration for crew comfort and habitability can be obtained with the RCM.

Separation of the CM from the experiment carrier for seven days presents a very high risk situation for the two crew members. In the event of an emergency involving orbital abort, the two crewmen in the experiment carrier must somehow transfer as quickly as possible to the Command Module before re-entry procedures can be initiated.

Waste disposal, expanded food preparation, and provisions for crew sleeping at least seven hours without interruption must be incorporated into the LEM and are assumed part of the RCM.

Preliminary evaluation of the experiments does not indicate any serious operational or training requirements beyond the normal pointing, tracking and EVA required for the Apollo program. Simulated crew operations of each experiment and selected spacecraft operation will be required to demonstrate and confirm crew competence.

The mission can be accomplished, but at best will be trying and difficult for the crew in the RCM/ATM/Airlock configuration. The LEM/ATM presents a more difficult living quarter for two men over a seven day period and is definitely a second choice. Highly motivated astronauts "may" be able to complete the mission in the LEM, but accomplishment of all requirements and objectives will be a major task for any crew.

ATTACHMENT #6

CREW OPERATIONS REQUIREMENTS

PRELIMINARY

30 AUGUST 1966

Approved ______________________
G. A. Rodney
Crew Operations, AAP

CREW OPERATIONS REQUIREMENTS

TABLE OF CONTENTS

References

a. Mission AS-204A, SC-012 Spacecraft Operation Rules 1-10-66, NAA.

b. Assumptions.

c. Experiment Pallet Operational Constraint, 65-1/NAA; MH01-22018-414.

d. NASA letter, POM/0131/L-18, dated 31 January 1966.

e. NAA internal letter, 692-804-050-66-017, dated 2 February 1966.

f. NAA internal letter, 692-804-050-66-020, dated 4 February 1966.

g. Design Reference Mission, LED-540-12, GAEC, dated 30 October 1964.

h. Apollo Extension Systems - LEM Phase B Final Report, Vol. IV, dated 8 December 1965.

i. Apollo Extension Systems - LEM Phase B Final Report, Vol. III, dated 8 December 1965.

j. Design Criteria and Reference Data Handbook for Lunar Exploration Systems, Vol. II, NASA, Huntsville.

k. System Analysis Summary, Part II, NAA SID-65-1534-2, dated 29 December 1965.

NOTE: Where appropriate, the letter designation of the source reference is placed by the paragraph number.

1.0 HUMAN FACTOR REQUIREMENTS

1.1 Scope

These requirements apply to equipment and work places which directly affect the flight crew during Intravehicular Activities (IVA) and Extravehicular Activities (EVA).

1.2 Purpose

The primary purpose is to establish specifications for the equipment supplier and AAP design and mission planning groups. It is an objective to maintain standardization with the existing Apollo system hardware.

1.3 General Requirements

1.3.1 Implementation

Implementation will be accomplished through design reviews, interface documentation, and configuration control.

1.3.2 Equipment Standardization

Equipment configuration should be similar to existing Apollo flight equipment so the crew will require minimal special training.

1.3.3 Equipment Designation

Equipment will be named for ease of identification by the crew rather than to conform with scientific custom or academic precision.

1.3.4 Exceptions to Specific Requirements

Exception to specific requirements will be made by reference to the general requirements.

1.3.5 Supplements to Specific Requirements

When a design requirement is not specified, typical Human Engineering practices will be followed. The following documents are recognized as authoritative in stating good Human Engineering design:

a. MIL-STD-130B, 24 April 1962, (MIL-STD Identification Marking of U.S. Military, Property.

b. MIL-STD-803A-1.

c. MIL-STD-803A-2 (USAF), 1 December 1964, Part 2.

d. MIL-STD-12B, 18 May 1959, (Abbreviations for use on drawings and technical type publications).

e. NPC-500-1, 18 May 1964, and MSC Supplement #1, Rev. B, 26 April 1965, (Apollo Configuration Manual).

f. MC-999-0007, 15 September 1962, NAA, (General Specification Human Engineering Design Criteria for Spacecraft Systems).

1.4 ASSESSIBILITY AND PHYSICAL DESIGN REQUIREMENTS

1.4.1 General Criteria

1.4.1.1 Crewman Size Criteria

(j) The size of the crewman shall be within the range from 5% to 95% percentile population as given below

ASTRONAUT SIZE CRITERIA

Measurements*	Range	Mean
HEIGHT FROM FLOOR		
Stature	66.30--70.90	69.25
Eye Height, Standing	62.17--67.05	64.48
Cervicale	56.42--61.26	59.19
Crotch	30.31--35.79	32.92
Foot Length	10.00--11.25	10.56
Foot Breadth	3.70-- 4.52	4.07
Upper Arm Length	11.85--15.59	13.57
Forearm-Hand Length	17.12--20.39	18.49
Hand Length	7.20-- 7.83	7.47
Chest Breadth	11.34--12.80	12.33
Waist Breadth	10.55--12.48	12.36
Hip Breadth	12.76--14.33	13.88
Wrist Breadth	2.24-- 2.48	2.35
Forearm to Grip Length	13.10--14.56	13.87
Functional Reach	29.10--34.44	31.12
Elbow-Wrist Length	10.85--11.96	11.46
Elbow-Rest Height	7.55--11.02	8.99
DEPTHS		
Chest Depth	8.37--10.47	8.95
Waist Depth	7.44-- 9.92	8.46
Buttock Depth	8.42--10.55	9.27
SEATED MEASUREMENTS		
Sitting Height	35.00--37.67	36.11
Eye Height, Sitting	29.21--33.54	31.36
Head Height	4.88-- 5.67	5.29
Knee Height	20.31--22.83	21.85
Elbow-Elbow	16.97--20.20	18.90
Knee-Knee	13.31--15.51	14.89
Shoulder Breadth	17.51--19.40	18.91
Hip Breadth	13.40--15.30	14.58
Buttock-Knee Length	22.03--25.68	23.99

Measurements*	Range	Mean
HEAD		
Length	7.56—8.35	7.98
Breadth	5.71—6.14	6.26
Circumference	22.08—23.70	22.74
CIRCUMFERENCE		
Chest	36.34—41.53	38.54
Waist	28.86—35.43	31.93
Hip	36.26—38.46	38.49
Upper Thigh	21.06—24.41	22.50
Lower Thigh	15.23—18.07	16.26
Calf	13.94—16.77	15.16
Ankle	8.38—10.04	9.08
Biceps (Flexed)	12.09—13.27	13.10
Forearm	10.75—11.81	11.39
Wrist	6.57—7.32	7.03
Hand	8.46—9.13	8.77
Waist Front	12.09—13.54	12-65
Waist Back	14.57—16.06	15.45
LYING		
Vertex to Seat	34.80—39.01	37.74

*All measurements in inches

1.4.1.2 (j) Display and Control Location

Control panels and displays shall be so located in respect to the crewman's restrained operating station that they are within the normal reach distance of a 5th to 95th percentile man. This functional arm reach distance is defined in the following table.

Panel layouts should be constrained between these limits but normally closer to that defined by the 5th percentile crewman. All controls will be adaptable to efficient operation in either class of pressure of suit. Preliminary Martin experimental data indicates a maximum forward reach of a 5th percentile man in a space suit is less than 17.0 inches.

DISPLAY AND CONTROL LOCATION

DEGREES

5th Percentile (In.)

HEIGHT ABOVE SEAT IN INCHES	0	15	30	45	60	75	90	105	120	
-6										
0				16.0	17.9	17.4	18.5	19.2	19.2	
6	17.0			22.4	23.8	23.9	25.6	25.8	25.3	
12	19.4	21.5	23.5	24.9	27.0	27.6	28.0	28.8	29.1	
18	21.3	22.9	25.4	26.9	28.1	29.3	30.0	30.8	30.7	
24	21.6	23.4	24.9	26.4	28.0	28.9	30.0	31.1	31.2	
30	20.1	22.0	23.7	26.4	27.4	28.3	29.3	30.0	29.1	
36	17.4	18.7	20.2	22.4	23.9	25.1	25.9	26.9	25.7	[illegible]
42	12.7	13.2	13.6	16.0	19.2	20.3	21.1	22.2	20.4	[illegible]
48										

50th Percentile (In.)

HEIGHT ABOVE SEAT IN INCHES	0	15	30	45	60	75	90	105	120	
-6										
0			17.5	19.0	20.0	21.0	21.0	22.0	22.0	[illegible]
6	19.5		23.0	24.5	26.0	26.5	27.0	28.0	27.5	[illegible]
12	22.5	23.5	26.0	27.5	28.5	29.5	30.0	31.0	30.5	[illegible]
18	24.0	25.8	27.0	29.0	30.1	31.1	32.0	32.7	[illegible]	[illegible]
24	24.5	26.0	27.5	29.5	30.5	31.5	32.5	33.0	33.0	[illegible]
30	23.6	25.2	26.9	28.4	29.5	30.6	31.6	32.2	32.4	[illegible]
36	21.0	23.0	24.5	25.5	27.0	29.0	29.0	30.0	30.0	[illegible]
42	17.0	19.0	19.5	22.0	23.0	24.5	25.5	26.5	26.0	[illegible]
48	11.0	12.3	13.5	15.0	16.0	16.8	18.0	19.5	19.0	[illegible]

95th Percentile (In.)

HEIGHT ABOVE SEAT IN INCHES	0	15	30	45	60	75	90	105	120	
-6						12.0	11.9	15.0	15.1	[illegible]
0			21.2	22.4	23.5	24.5	24.8	25.5	25.2	[illegible]
6	22.7	21.6	25.5	27.3	28.6	29.6	30.3	30.5	30.6	[illegible]
12	25.1	27.2	28.7	29.7	31.1	32.1	33.2	33.1	33.5	[illegible]
18	26.6	28.7	29.8	31.2	32.5	34.1	34.6	35.0	35.1	[illegible]
24	26.3	28.7	30.1	31.1	33.0	34.0	35.0	35.1	35.6	[illegible]
30	25.9	28.1	29.4	30.6	31.9	33.5	34.4	34.6	35.2	[illegible]
36	24.5	25.7	28.1	28.1	29.6	31.1	32.0	32.7	33.1	[illegible]
42	20.8	23.5	24.6	24.5	26.5	27.3	29.0	29.7	30.0	[illegible]
48	15.4	16.8	18.3	18.2	20.1	21.7	21.9	24.6	23.5	[illegible]

1.4.1.3 (j) Pressure Suit Mobility

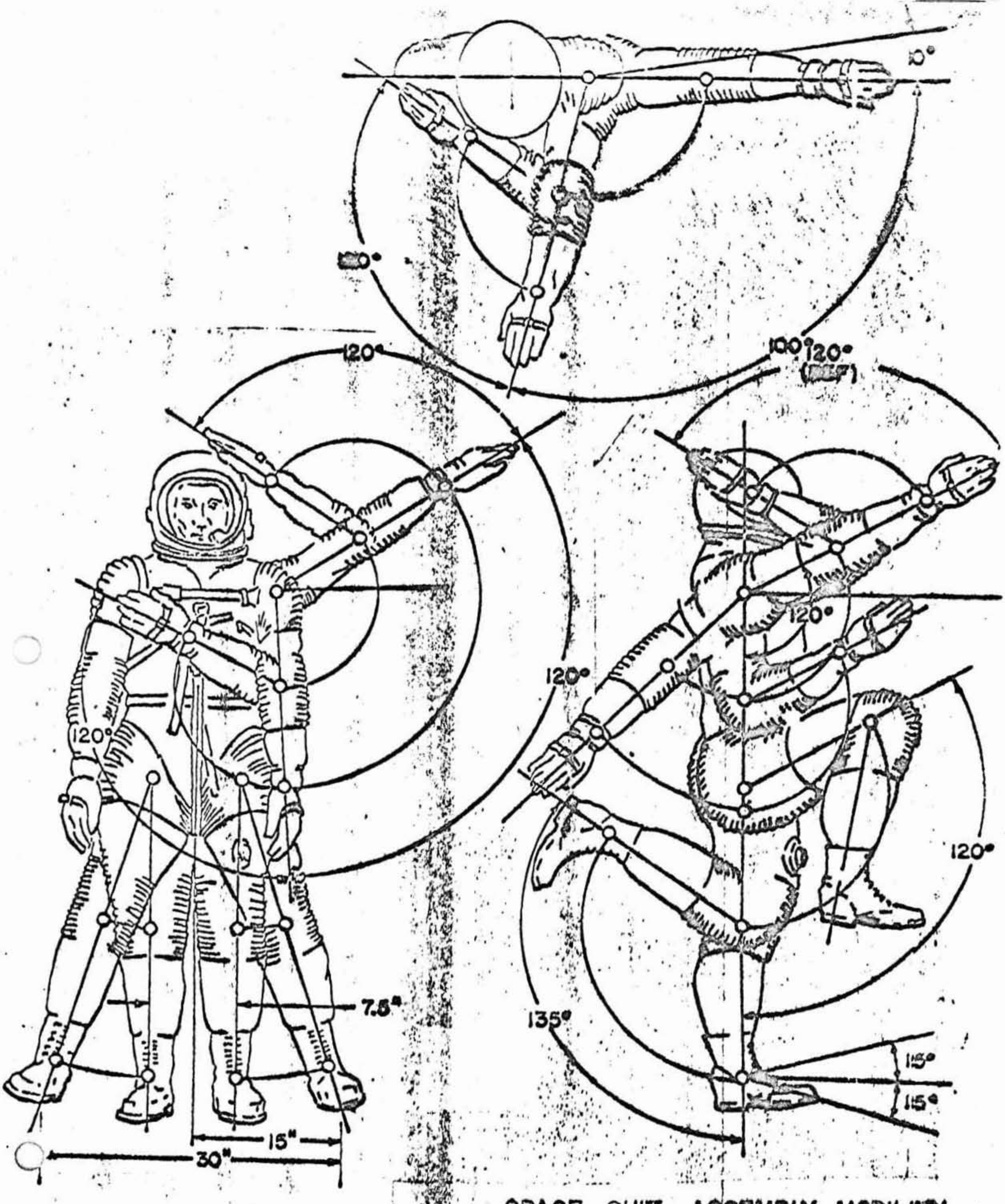
The equipment will be designed to operate with the pressure suit schematic presented in Figure 2-1. The mobility of this suit (Apollo Block II, A6L) does not provide freedom of movement in all axes. The range of movement is summarized in Table 2-3 and Figure 2-1.

MAXIMUM PERFORMANCE REQUIREMENTS FOR THE ELEMENTARY BODY MOVEMENTS INTRAVEHICULAR AND EXTRAVEHICULAR WEAR, AT 3.7 PSIG

MOVEMENTS	RANGE OF MOVEMENTS (IN DEGREES)
A. NECK MOBILITY	
Flexion (forward-backward)	120
Flexion (left-right)	30
Rotation (Abduction)	45
B. SHOULDER MOBILITY	
Adduction	45
Adbuction	125
Lateral - Medial	150
Flexion	170
Extension	50
Down-up	150
Lateral Rotation	35
Medial Rotation	110
C. ELBOW MOBILITY	
Flexion - Extension	155
D. FOREARM MOBILITY	
Supination (palms up)	130
Pronation (palms down)	75
E. WRIST MOBILITY	
Flexion (Adduction)	85
Extension (Abduction)	65
Flexion (Backward)	35
Extension (Forward)	50

BODY MOBILITY (CONT'D)

MOVEMENTS	RANGE OF MOVEMENTS (IN DEGREES)
F. TRUNK - TORSO MOBILITY	
Trunk Rotation (Adbuction-Adduction)	70
Torso Flexion (Lateral - Medial)	50
Torso Flexion (Forward)	80
Torso Flexion (Backward)	25
G. HIP MOBILITY	
Adbuction (leg straight)	45
Adduction (knee bent)	30
Abduction (knee bent)	35
Rotation (Sitting)	
Lateral	30
Rotation (Sitting)	
Medial	30
Flexion	115
Extension	35
H. KNEE MOBILITY	
Flexion (standing)	120
Rotation (medial)	35
Rotation (lateral)	35
Flexion (kneeling)	160
J. ANKLE MOBILITY	
Extension	40
Flexion	50
Abduction	30
Adduction	30



SPACE SUIT ASSEMBLY MOBILITY
PRESSURIZED TO 3.5 PSIG

1.4.2 Crew Station Restraint Requirements

1.4.2.1 General

Any area requiring any manipulation and/or visual readout of an instrument by a crew member will be provided with positive means of crew restraint that will control both translational and rotational movement.

1.4.2.2 Restraining Devices

Restraining devices will be provided at EVA work areas and in areas requiring crew translational movement. Acceptable devices include:

a. EVCT - The NAA developed EVCT handhold. (Diagram to be added).

b. Velcro Pads - Conditions to be added.

c. Handholds - Criteria to be added.

d. Rails - Preliminary Martin data indicate that rigid rails utilized for longitudinal translational should have a rectangular cross-section 7/8" wide x 1-1/8" deep and be elevated 3" above the adjacent surface.

e. Tethers - Conditions to be added.

1.4.3 Assessibility

1.4.3.1 Panel Openings - (Preliminary Martin Data)

The size of any opening requiring the suited astronaut to reach in with one hand must be at least 6½" x 6½"; with two hands, at least 6½" high x 23" wide, and if visual viewing is necessary, the opening must be 8" wide x 11" high for one arm and 23" wide x 11" high for two arms. Since the suited astronaut has little feel capability, visual capability will generally be required at any access panel. All edges and projections near the opening must be rounded so as not to puncture the space suit.

1.4.3.2 Type of Doors or Panels

A door or panel opening outward should have a method for securing in the open position. Inward opening doors must not trap the arm or equipment during removal. Free type panels must be provided with a positive means of stowage adjacent to the area and located so as not to intefore with subsequent work activity.

1.4.3.3 EVA Hatch Sizes

(To be added).

1.4.4 Moveable Units

1.4.4.1 General

Units which must be moved shall be provided with lift points in line with the center of mass. The weight of the unit shall be marked on the unit and the center of mass shall be identified if it is not coincident with the geometrical center. Units shall be designed to permit removal and replacement with one hand under limited visibility conditions. Units shall slide into position and be constructed so that misalignment is impossible. Units shall slide out of position to stop limits and shall be removed from the supporting panel or rack by a change in the direction of removal at the stop. Units shall be provided with stands or rests for use when out of the panel or rack. The unit will have no projections, cables or other incumberances which must be removed while the unit is held. The system must not present sharp edges or protrude beyond the surface of the panel or rack when the unit is not in the operating position.

1.4.4.2 Unit Covers

Unit covers shall be designed so that they can be opened or removed without instruction or tools and shall be provided with a method of storage.

1.4.4.3 Identification

To prevent confusion, components to be removed should be color coded or otherwise clearly identified differently from the components used as replacements.

1.4.4.4 Equipment Size and Weight

Maximum size for moveable equipment is as follows:

	Size	Weight
Orbital IVA	(TO BE ADDED)	
Orbital EVA		
Lunar IVA		
Lunar EVA		

1.4.5 Fasteners

1.4.5.1 General

Mounting fasteners shall require no tools and shall be operated with either hand. When a fastener is not secured, this will should be obvious on inspection. Fasteners to be latched or unlatched during EVA should not require an open-loop reaction force. Dzus type fasteners are unsatisfactory since they require inward and rotational pressure which must be reacted by tethers.

1.4.5.2 Fastener Devices

To be completed later.

1.5 ILLUMINATION

The external ambient light conditions for the AAP mission will vary from approximately zero to 12,240 foot candles. Because of the collimated nature of the light, extreme contrast between directly lighted areas and those in shadow must be expected.

1.5.1 (j) Internal Ambient Illumination - (Including areas accessible by EVA in which data recovery, equipment changes, adjustments, etc., are contemplated)

a. Ambient illumination levels in all areas requiring any visual reference by the astronaut shall be adjustable within the range of 25 to 50 foot candles.

b. Where cabin windows are provided the internal brightness ratio shall be controllable to ratios less than 10:1.

c. Light sources shall be of a diffuse type.

d. All indicators and panel areas shall have uniform ambient light coverage.

e. Light sources shall be arranged so that the viewing angle of the visual work area is not equal to the angle of incidence from the source.

1.5.2 (j) Work Station Illumination

The general requirements for the illumination of work stations are:

a. No light sources visible to the operator (in normal working positions).

b. Anti-glare coated instrument covers.

c. Bulb replacement from the front of display panel; no special tools required.

d. Sharply defined transilluminated markings readable when viewed at any angle up to 60° from normal of the display panel.

1.5.3 (j) Brightness Levels and Adjustments

a. For map and chart reading: a diffuse source continuously adjustable to produce a brightness level of 15 to 50 foot lamberts.

b. For instrument panels: brightness level adjustable from 0 to 100 foot-lamberts, whether illuminated from external or internal sources.

c. Controls: allowance of adjustment for separate panel light sources to achieve apparent equal brightness.

d. EVA work areas: (To be added)

1.5.4 Brightness Ratios
(j)

Wherever feasible, the maximum brightness ratios should be controlled to within:

a. 5:1 between the task area and immediate surroundings.

b. 7:1 between the dimmest and brightest instruments.

c. 20:1 between the task area and remote surfaces.

d. 40:1 between a light source and the survace adjacent to it.

1.6 COLOR CODING
(j)

The color coding of AAP equipment should be compatible with LEM/Apollo Standards. The applicable Tables 2-1 and 2-2 documented in LEM Specification LSP 340-001A of 2/17/64, as changed on 6/8/64, are shown in the following tables:

COLOR CODING (COMPONENTS)

Item	Color	Fed. Std. 595
Walls, Ceiling, Internal Structure	Tan	30227
Internal Movable Structure (hatches, access panels)	Lt. Brown	30140
Floor, Steps, Work Surface	Brown	20099
Restraint Straps	Blue Gray	35189
Restraint Structure	Blue Gray	35189
Restraint Upholstry	Blue Gray	35189
PLSS (Backpack)	White	37875
Harness Straps PLSS	White	37875
Cabling, Ducts, Internal	Same as Background	
Controls, Emergency	Orange-Yellow & Black Striped	23538 27038
Docking Ring Tunnel	White	27875
Glare Shield	Black	37038
Hand Grips	Yellow	23793
Hand and Foot Levers, Knobs, Control Handles, Non Illum. Push Buttons	Lt. Gray	26440
Handles, Assist Latch	Satin Chrome	None
Hardware, Instrument Panel	Gray	36231
Instrument, Indicator Bezels and Cases	Gray	36231
Instrument and Indicator Faces	White or Black	37875-37038

1.6 CONTINUED

Item	Color	Fed. Std. 595
Instrument Panels	Gray	36231
Lettering	White	37875
Switch, Levers, Toggle	Satin Chrome	None
Telescope and IMU	Lt. Green	24410

COLOR COMPONENTS (SYSTEMS)

Item	Color	Fed. Std. 595
Crew Provisions	Lt. Blue	25414
Communications	Dk. Gray	26132
EPS (Electrical Power System)	Orange	22246
N & G (Navigation & Guidance)	Lt. Green	24410
Operational Instrumentation	Blue Green	25193
S & C (Stabilization & Control)	Yellow	23793
Experiment Hardware		

1.7 CONTROLS

Optimum panel surface areas should be used for priority subsystem controls and displays. With that exception, controls should be located for:

1) Ease of Operation
2) Sequence of Operation
3) Frequency of Operation
4) Control/Display Relationships
5) Minimal Hand/Eye Excursion

Automatic systems with functions critical to crew safety shall have audible and visual warning signals and manual overrides.

Controls shall be designed to prevent:

1) Inadvertent Operation
2) Crewman Injury
3) Damage to System

All controls other than standard Apollo equipment shall be tested to demonstrate freedom from control reversal errors and shall meet the system precision requirements with no more than one overshoot error and two undershoot errors.

1.7.1 General Rules for Controls

(k)

The direction of movement of the control will be consistent with the movement of the controlled object or moving portion of display. Controls must be easily identifiable by both visual and tactile senses. Because visual cues are primary, however, the control markings are the most important coding method for control identification.

All controls will have two types of information located proximate to the control -- identification of the control function and method of control operation, where required. Combined hand controls, such as two controls on concentric shafts for gross and fine adjustment, may be used only when space limitations prohibit the use of individual controls and accidental movement of the controls will not create a hazardous condition.

When manual performance requirements are such that the controlled object can be adjusted in a limited number of discrete steps, detent controls will be used. When high-precision manual settings are required over a wide range, multirotational controls should be used.

All controls will be distributed so that no one limb will be overburdened. All controls will be designed, oriented, and located so that they are in accordance with normal work habit patterns, customary reactions, and human reflexes. It is desirable to recognize the generalized sources of human error in the operation of controls in order that the design may preclude them. The potential for human error exists in the following examples:

a. Similarity of control devices, causing the wrong control to be actuated because of confusing it with another.

b. Location of controls too closely together, causing inadvertent operation of adjacent control and interfering with ease of operation.

c. Improper sequencing, rate adjustment, and overly complicated adjustments causing mistakes in control operation.

d. Long and involved procedures difficult to commit to memory.

e. Operation of controls in a direction contrary to normal movement of the operator (particularly subject to human error during times of stress or emergency).

f. Location of controls in such positions that the operator can brush or knock against them, causing inadvertent operation.

g. Arrangement of the instrument panel in such a way that it is impossible or very difficult to reach for one control while operating another.

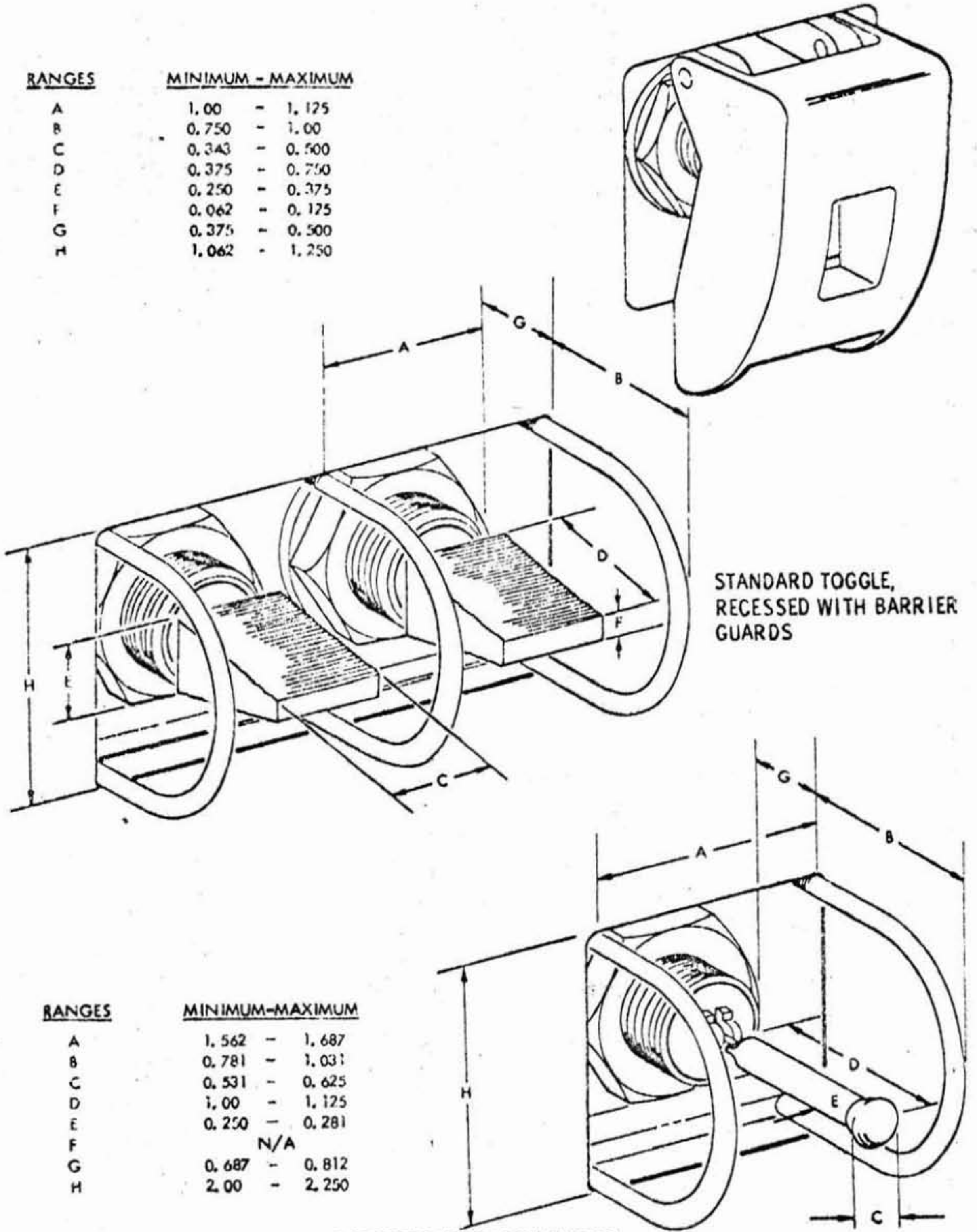
1.7.2 (k) General Safeguard Criteria

Because of the confined quarters and the difficulty of controlled movement by the astronauts in zero gravity environment, safeguards must be adhered to in the design of controls and layout of the console to preclude inadvertnet actuation of controls. Recesses will be used for toggle switches if it appears that the control might be actuated inadvertently. Guarded pushbuttons, toggle switches, or lever-lock-type switches are required for functions that are irreversible. They will have recess installation depending the position on the main display console previously stipulated.

1.7.3 (k) Toggle Switches

Toggle or lever-type switches may be two- or three-position, tab handle, or lever-lock handle, and momentary or maintaining in their switching action. Total throw distances of toggle and lever-lock switches should be 34 ± 8 degrees. The force required to change position should be 10-100 ounces. An axial pull of 40 ± 20 ounces is recommended to release the lever-lock switch from a locked position.

The minimum allowable spacing between toggle switches grouped in horizontal rows should be one inch on centers. When used in locations where the handle could pose a hazard to crew members or be subjected to inadvertent actuation, the switch should be semirecessed and provided with barrier guards as shown in Figure 1-3. Maximum distance between barrier guards should not be more than one inch. Emergency switches or switches whose inadvertent actuation would create a hazardous condition must have a lever-lock handle or be protected by a guard.



RANGES	MINIMUM - MAXIMUM
A	1.00 - 1.125
B	0.750 - 1.00
C	0.343 - 0.500
D	0.375 - 0.750
E	0.250 - 0.375
F	0.062 - 0.125
G	0.375 - 0.500
H	1.062 - 1.250

STANDARD TOGGLE, RECESSED WITH BARRIER GUARDS

RANGES	MINIMUM-MAXIMUM
A	1.562 - 1.687
B	0.781 - 1.031
C	0.531 - 0.625
D	1.00 - 1.125
E	0.250 - 0.281
F	N/A
G	0.687 - 0.812
H	2.00 - 2.250

RECESSED LEVERLOCK TOGGLE

Figure 1-3 Toggle Switches

The preferred direction of toggle-switch operation is vertical in reference to the operator.

Position pairs should be in accordance with the following criteria:

UP	:	ON	OPEN	ACTIVATE	INCREASE
DOWN	:	OFF	CLOSE	DEACTIVATE	DECREASE

PRIMARY	DEPLOY	AUTO
BACKUP	STOW OR BLANK	MANUAL

Where a third position is added for OFF, the OFF should be in the center position except where this would compromise equipment performance, in which case OFF should be in the bottom position.

1.7.4 Rotary Switches

(k)

Rotary switches (with not more than 12 selectable positions) may be equipped with knobs as shown in Figure 1-4. All rotary switches with selectable positions should be detented. Each switch should employ a detent cam to hold the activating shaft in each of the individual switch positions. A stop will be provided at the extremes of the actuating shaft's rotation except in cases requiring 360-degree rotation.

Rotary switch throw distances between positions should be 30 degrees with a torque required to change positions of 12 - 100 inch-ounces.

The order of positions will be such that clockwise movement is "on", "ascending order", "increased performance", etc.

1.7.5 Rheostats

(k)

When the rheostat is viewed from its knob side, the maximum resistance should be in the OFF direction with decreasing resistance in the full ON direction. The control should rotate through an arc of 300 degrees plus or minus 5 degrees. A snap-action OFF position is recommended to open the rheostat circuit and should occur just as the contact passes beyond the maximum resistance point.

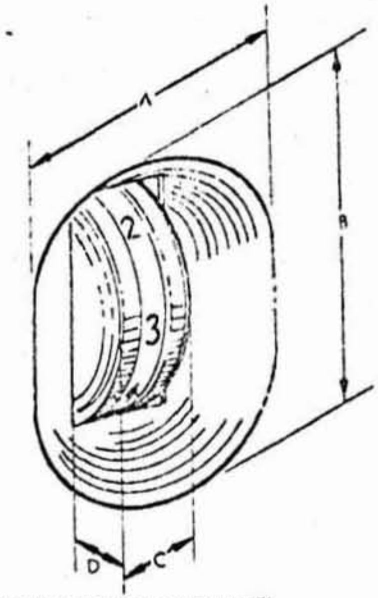
Depending on the installation required, all rheostats should conform to the rotary knob design as shown in Figure 1-4.

1.7.6 Thumbwheels - Potentiometers

(k)

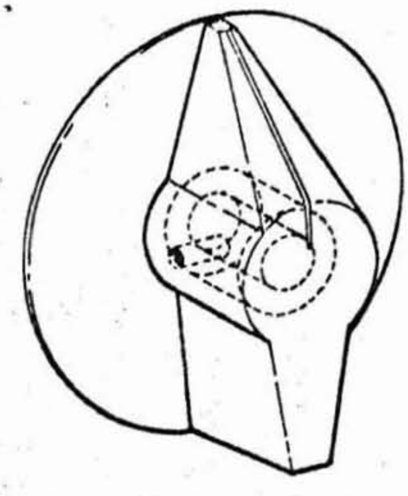
The operating shaft and contact arm should rotate through an arc of 300 degrees plus or minus 10 degrees.

If the potentiometer is to be mounted flush on the control panel, a thumbwheel knob is to be employed. The standard thumbwheel knob and recess are shown in Figure 1-4. A clockwise or upward movement of the thumbwheel should result in increased output.



RECESSED THUMBWHEEL

RANGES	MINIMUM	MAXIMUM
A	0.937	1.062
B	1.375	1.500
C	0.343	0.406
D	0.218	0.781



ROTARY KNOBS AND RHEOSTATS

RANGES	MINIMUM	MAXIMUM
A	1.90	2.125
B	0.687	0.812
C	0.500	0.625
D	0.312	0.437
E	0.437	0.562
F	0.093	0.156
G	0.093	0.156
H	1.05	1.20

Figure 1-5 Thumbwheel and Rotary-Knob Switches

1.7.7 (k) Pushbutton Switches

The standard pushbutton switch (Figure 1-5) will be a minimum of 0. 750 square inches and may be background-illuminated or nonilluminated.

Pushbutton switches will have a total travel distance of 0. 125 to 0. 06 inch. Switch actuation will occur at a depression of 5/32 ± 1/32 inch and will provide a tactile feedback to the operator. Mechanical resistance to actuation of pushbutton switches will be 10 - 75 ounces throughout the depression range.

Pushbutton switches may be stacked vertically or horizontally on one-inch centers. Pushbuttons are to be mounted flush with the panel and have a minimum spacing of 0. 125 inch. Stacked pushbuttons should incorporate guards (Figure 1-5) to prevent inadvertent actuation.

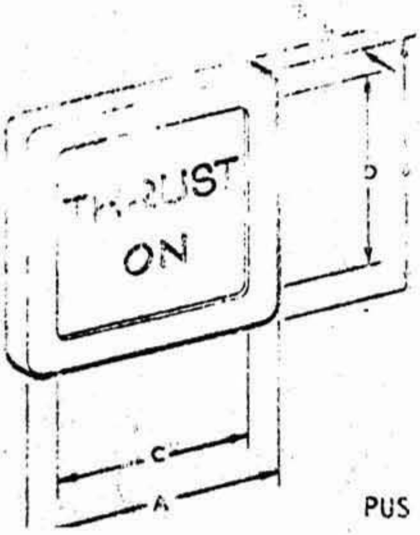
The color of the illuminated pushbutton surface, depending on application, will be aviation white, yellow, red, or green in accordance with specification MIL-C-25050A. When not illuminated, the pushbutton face or cap cover will be a nonspecular white with a 1:7 or greater contrast ratio (face to legend) and free of tint upon visual inspection.

1.7.8 (k) Circuit Breakers

Circuit breaker design should conform to details of Figure 1-6. Circuit breakers generally are of the pop-out release, push-to-reset-type. Circuit breakers will be nondefeating (i.e., manually holding the knob in the reset position will not override the circuit-breaking function).

The tripped condition of the plunger-type circuit breaker is indicated by a white band which is a minimum of 0. 156-inch wide. The circuit breaker body and head will be black. Coding, if required, shall be limited to the top surface of the circuit breaker head. The force required to reset a plunger-type circuit breaker will not exceed 12 pounds, and the force required to trip a circuit breaker manually will not exceed 8 pounds.

The minimum allowable space between circuit breakers grouped in horizontal rows will be 0. 8 inch on center and the distances between rows a minimum of one inch.



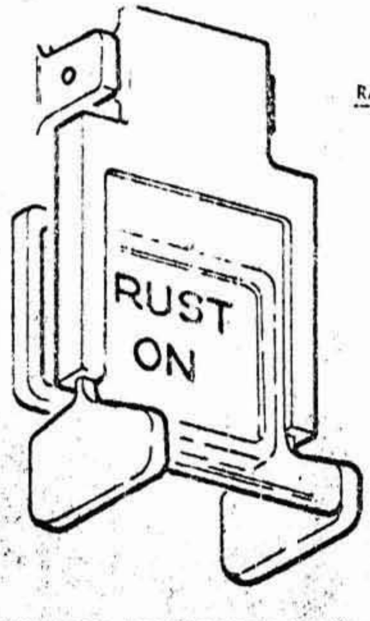
STA[illegible] [illegible]

RANGES	[illegible]	[illegible] - MAX[illegible]
A ILLUM. ON[illegible]	[illegible]	- 0.875
B ILLUM [illegible]	[illegible]	- 0.875
C	[illegible]	1.06
D	[illegible]	[illegible]
E	[illegible]9	[illegible]

MAST[illegible] ONLY

RANGES	MIN[illegible]	[illegible] - MAXIMUM
A	0[illegible]	[illegible]
B	[illegible]	0.687
C	[illegible]	- 1.125
D	0.[illegible]	- 0.843
E	0.[illegible]	- 0.156

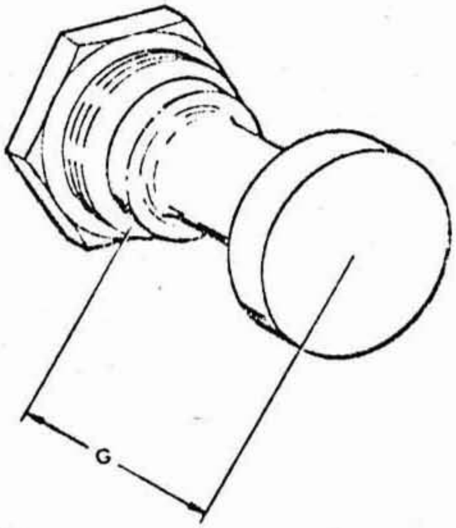
PUSHBUTTON SWITCH



RANGES	MINIMUM - MAXIMUM
A	0.937 - 1.062
B	1.375 - 1.500
C	0.343 - 0.406
D	0.218 - 0.281

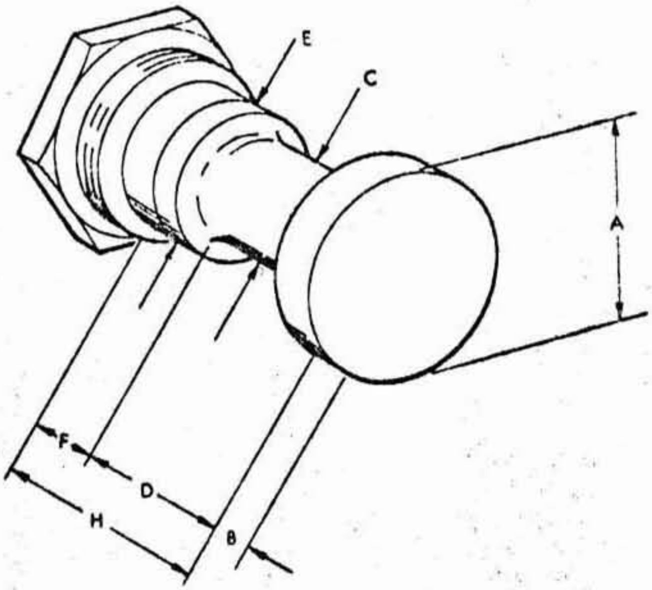
PUSHBUTTON COVER GUARD (TYPICAL)

Figure 1-5 Pushbutton Switches



RESET CONDITION

RANGES	MINIMUM - MAXIMUM	
A	0.375	0.437
B	0.093	0.156
C	0.187	0.250
D	0.375	0.437
E	0.281	0.343
F	0.156	0.375
G	0.531	0.593
H	0.750	1.031



TRIPPED CONDITION

Figure 1-6 Circuit Breaker

1.8 DISPLAYS
(k)

In the design of any item that involves operators, one of the primary considerations is the method by which pertinent information will be presented. Its importance stems from the fact that almost all of the operator's decisions and actions are based on the information presented to him. Information displayed to operators should conform generally to the following general rules:

1. Displays will be restricted to types of information essential for adequate job performance.

2. Display information will be limited to the degree of accuracy actually required for the decisions and control actions necessary to accomplish assigned tasks.

3. Data will be presented in the most direct, simple, understandable, and usable form possible.

4. Displays will be located and identified so as to obviate undue searching.

5. Displays will be functionally or sequentially grouped so as to simplify the operator's activities.

6. Information will be presented in such a manner that any failure or malfunction in the display or display circuitry will become apparent immediately.

7. All displays will be properly illuminated, coded, and labeled as to function.

1.8.1 Meters
(k)

The specification of meters, including pointer location, movement display scale, and general form factor characteristics, will apply to the following types (Figures 1-7 and 1-8):

1. Single horizontal moving pointer displays.

2. Single vertical moving pointer displays.

3. Dual vertical moving pointer displays.

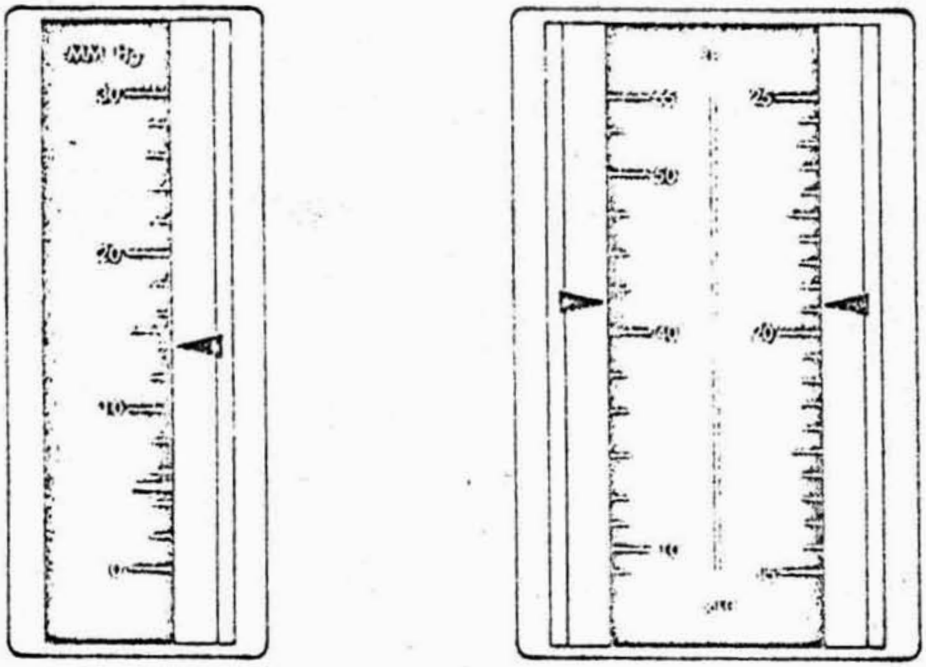
4. Four vertical moving pointer displays.

5. Single circular displays.

6. Dual circular displays.

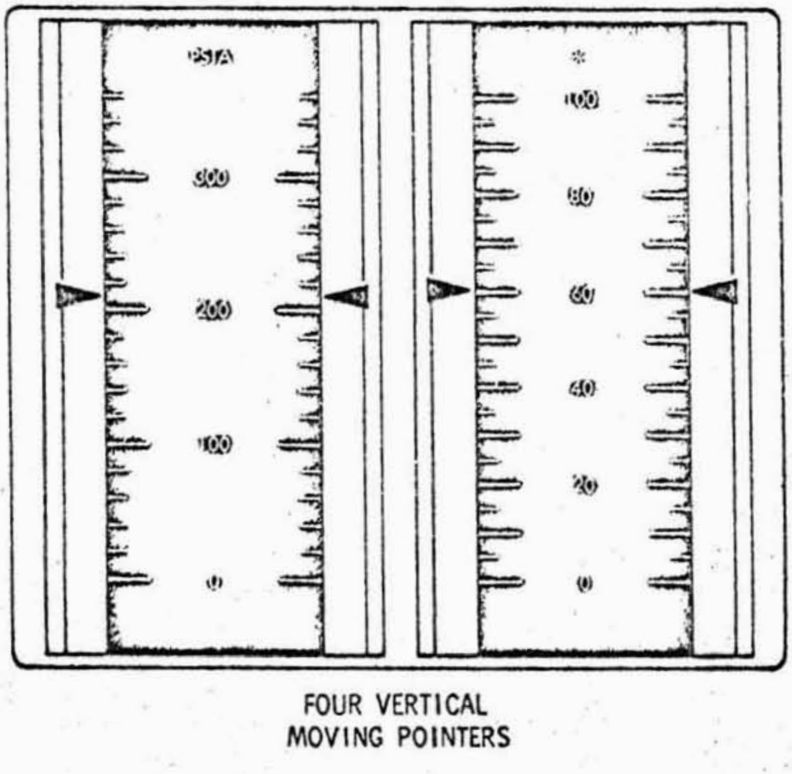
1.8.2 Meter Scale
(k)

Linear scales are generally preferred. When accuracy requirements exceed those that can be attained using a linear scale, however, the operating range can be expanded to acquire the needed accuracy. Expanded scales result in the compressed portion of the scale being nonlinear. Nonlinear scales also can be used when the meter is required to be operated from a nonlinear signal.



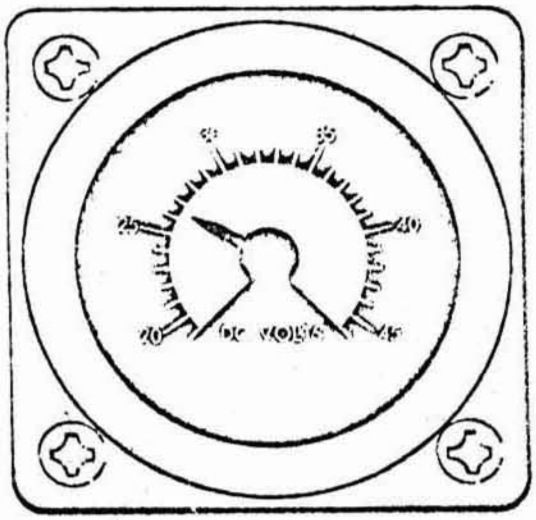
SINGLE VERTICAL MOVING POINTER

DUAL VERTICAL MOVING POINTERS

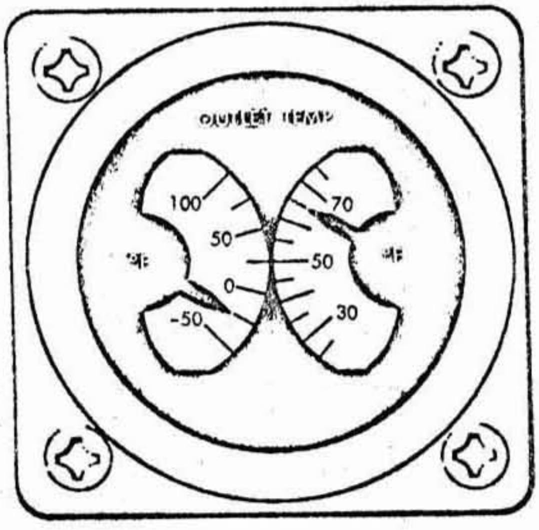


FOUR VERTICAL MOVING POINTERS

Figure 4-7 Vertical Meters



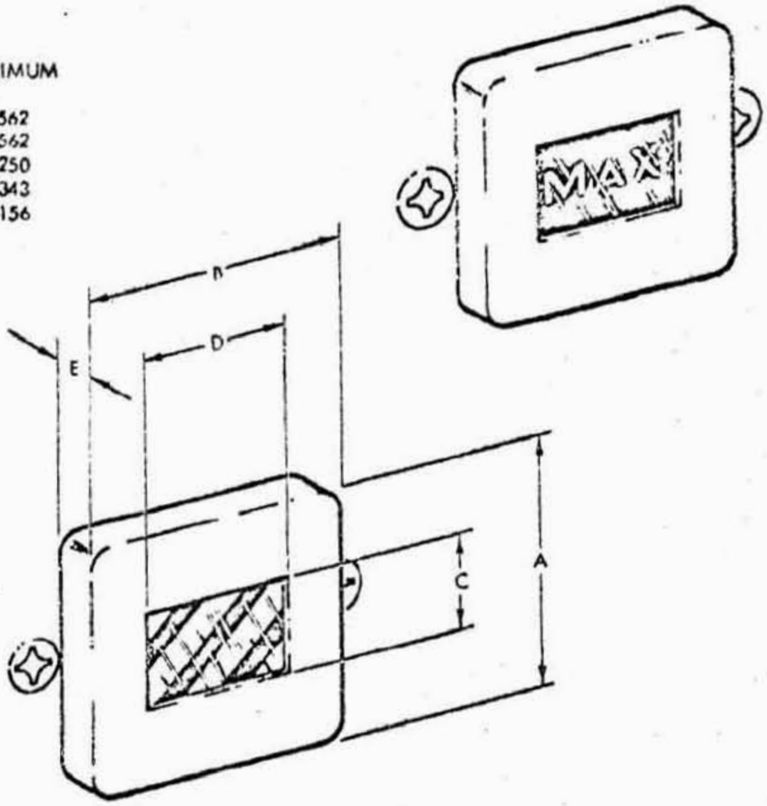
SINGLE CIRCULAR
MOVING POINTER



DUAL CIRCULAR
MOVING POINTER

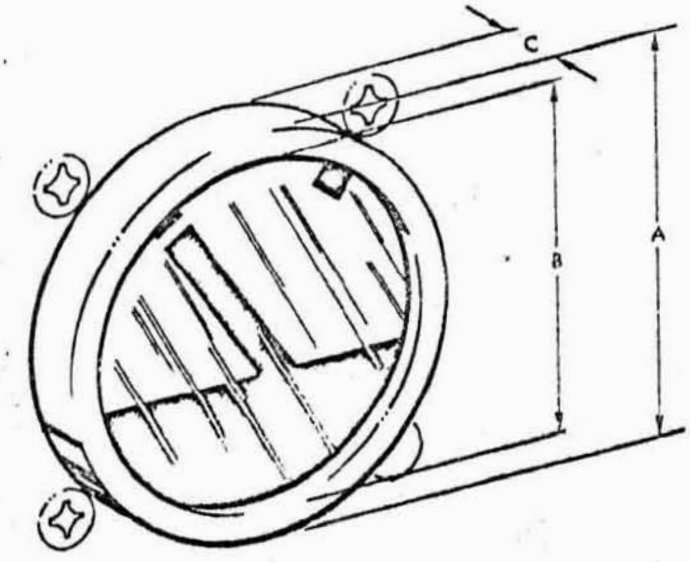
Figure 11-8 Circular Meters

RANGES	MINIMUM	-	MAXIMUM
A	.500	-	.562
B	.500	-	.562
C	.187	-	.250
D	.281	-	.343
E	.093	-	.156



DRUM INDICATORS

RANGES	MINIMUM	-	MAXIMUM
A	.718	-	.781
B	.625	-	.656
C	.093	-	.156



DISC INDICATOR

Figure 1-8 Electromechanical Event Indicators

1.8.3 (k) Display Form and Arrangement

Numeric quantity readouts, digital or analog, should be normalized to read in percentage of maximum usable fluid by volume or weight as sensed. Vertical scale indicator groups for subsystem condition monitoring should be arranged first by system function, then by displayed parameter, then by alphabetic or numeric sequence, in descending order of subgroups. For typical fluid systems, the preferred order of display arrangement, reading from left to right or from top to bottom in pilot axes, is as follows:

1. System function:

   Pressurizing agent, fuel, oxidizer

   N_2 H_2 O_2

2. Displayed parameters:

   Flow, temperature, pressure, quantity, volts, amperes.

3. Alphabetic or numeric sequence:

   System A - System B

   or

   Tank 1 Tank 2

1.8.4 (k) Display Pointer Location and Movement

The pointer in vertical single-pointer displays will be located to the right of the scale. Pointer movement in an up direction indicates increased values.

The pointer in horizontal single-pointer displays should be located above the scale (there may be legitimate exceptions). Pointer movement to the right indicates increased values. The individual pointers on dual-pointer indicators should be located outboard of their respective scales (i.e., bezel, pointer 1, scale 1, scale 2, pointer 2, bezel). Pointer movement upward indicates increased values.

The individual pointers on four-pointer indicators will be as shown in Figure 1-7 (i.e., bezel, pointer 1, scale 1, pointer 2, pointer 3, pointer 4, bezel).

The pointers in dual circular indicators should pivot about the extremities of the horizontal axis. The left scale commences at the 135-degree point from the top center point and concludes counterclockwise at the 45-degree point. The right scale commences at the 225-degree point from the top center point and concludes clockwise at the 315-degree point. Pointers for both circular and vertical dial faces should be close to the dial face and scale to reduce parallax to a minimum. Except for approved special cases, the pointer head will be triangular and the sides of the pointer shaft, where required, will be parallel (Figures 1-7 and 1-8).

1.8.5 Display Markings

(k)

When operationally useful, colored range markings must be used on vertical, horizontal, and circular displays to indicate operating ranges. Three operating range markings are recommended to indicate the following conditions:

1. Normal

2. Marginal

3. Prohibited or limit mark

Range markings should be 0. 05-inch wide and extend to the limits of the scale factor represented. Range markings will be imposed over the scale index markings to enhance readability and visual cue response. Limit marking should be 0. 07-inch wide and equal in length to the long graduation of the scale in question.

Display cover faces will be coated with an antireflective transparent material.

1.8.6 Alphanumeric Readouts

(k)

Alphanumeric readouts should be composed of electroluminescent seven-line characters that have the following design details:

Slant - 14-1/2 degrees ± 1/2 degree to the right from the vertical

Height - 0. 500 inch ± 0. 005 inch

Width - 0. 375 inch ± 0. 005 inch

Stroke Width - 0. 625 inch ± 0. 005 inch

Spacing between numerals - 0. 100 inch ± 0. 005 inch minimum (measured at the base of the numeral

1.8.7 Electromechanical Event Indicators

(k)

Electromechanical event indicators are recommended for use when highly reliable go-no-go (or two-position) indications are required and when electrical power availability is severly restricted. These indicators are recommended for use as go-no-go (operational/nonoperational) status indicators and for two-position positioning indicators, e.g., normal-maximum and normal-minimum positions.

1.8.8 Two-Position Drum Indicators

(k)

Two-position, electromechanical drum indicators will be used for status indicators (Figure 1-8). The blank (gray) position of the drum will infer that the connected system element is in an operational mode or is not inhibited from operation. The barber pole (alternate black and white) position of the drum indicators will infer that the connected system element is inhibited from operation or indicates an out-of-tolerance condition.

A pair of two-position electromechanical drum indicators will be used as positioning indicators for some system devices. One will indicate the normal and maximum positions of the device. The second will indicate the normal and minimum position of the device.

The pair of drum indicators will be referenced to a switch position.

The display face of the two-position event indicators should be rectangular with a display size no less than 0. 187 by 0. 281 inch and the long axis mounted horizontally.

Electromechanical status indicators usually will be located above the associated control switches. Electromechanical position indicators will be located with reference to switch positions.

1.8.9 Disc Indicators
(k)

Electromechanical disc event indicators may be used to disply changes analogous to a system device position. These indicators are used in automatic systems and are not directly associated with a switch operation. They may be used for system device operational position status. The indicator will display the position of the system device from one extreme to the other using a rotatable black pointer. There should be two black indices on a white background to indicate the extremees (Figure 1-8).

The display face of the electromechanical disc event indicators will be circular having a display diameter no less than 0. 625 inches. The indices must be fixed having a length of 0. 090 and width of 0. 093 inches. The pointer length should be 0. 31 and width of 0. 093 inch. The pointer spacing from an index should be no greater than 0. 016 inch (Figure 1-8).

1.8.10 Alarm System

Any experiment that has any operating characteristic which can produce a time-critical hazardous condition requiring immediate corrective action will be designed with an interface instrumentation output compatible with the CM Master Alarm System.

(Additional criteria to be added)

1.8.11 Validation Testing

Nonstandard or integrated displays which combine related information in a single display unit, shall be subjected to human engineering tests to determine the effect of the integration on system performance. Units which produce performance equal to or better than single purpose indicators are acceptable.

1.9 PHYSIOLOGICAL REQUIREMENTS & LIMITATIONS

1.9.1 Crew Operational Consumable Requirements

(See Table   for Summary)

1. Food
(i)

Food quantity will be based on an individual calorie intake of 3000K calories per man per day. One-man days' food requires 179 cu. inches stored volume at 2.3 pounds weight.

2. Water
(i)

Water consumption is as follows:

2.6 lb/man-day, drinking and food preparation
5.0 lb/man-day, sanitation and hygiene

3. Constant Wear Garments

Each crew member requires a new constant wear garment (CWG) every two days. Number of suits required = (number of crew) x $\frac{(n-2)}{2}$ where n is mission duration in days. Where n is an odd number use the next smaller number. Stored volume is .13 cu. ft. and   pounds per suit.

4. Personal Hygiene

(To be added)

5. EVA Operational Consumption

a. One PLSS LiOH cartridge per usage; dimension 5½"D x 11".
(h) weight 4.5 lbs. Store 5 internally, the remainder may be stored externally.

b. The PLSS uses a rechargeable battery that must be re-
(h) charged for 10 hours per usage. Allow 4 usages per battery. Dimension 3½" x 4-3/4" x 6½", weight 5 lbs., store internally.

c. A full PLSS oxygen charge is   pounds. Oxygen consumption will average   pounds per hour.

d. During EVA the standby EVA astronaut will operate from the
(i) suit loop of the ECS, requiring operation of the suit loop fan at 152 watts per hour power consumption.

e. An additional Constant Wear Garment (CWG) will be included for each crewman on EVA or EVA standby duty. (This is in addition to the callout of paragraph 1.2.5.1 (3)).

TABLE

CREW OPERATIONAL CONSUMABLE REQUIREMENTS (SUMMARY)

Commodity	Wts. #	Volume Cu. In.	Power Watts
A. Per Man Per Day			
1. Food	2.3	179	
2. Water	7.6	211	
3. Oxygen	2		
4. Constant Wear Garment (based on 1 every other day)	(-)	11	
5. Personnel Hygiene - chewing gum tooth cleaner, deodorant, etc.	(-)	(-)	
6.			
B. Per Man Per EVA			
1. PLSS LiOH cartridge	3.6	69	
2. Battery			
a. Recharge after usage			(-)
b. Replace after 4th usage	5	119	
3. Constant Wear Garment		225	
4. Oxygen (per hour)	0.25		
5. Cooling Water	1.85		

1.9.2 Crew Waste Production

1. Untreated biological wastes shall not be allowed to become free residue in space.

2. Man's Waste Production
(i)

Commodity	Wt.	Vol.
1. Urine	3.2	(-)
2. Feces	0.3	(-)
3. Water Vapor	5.3	(-)
4. Carbon Dioxide	2.3	(-)

There are additional minor items of human waste that can be ignored from a weight standpoint as total production for a 3-man crew for 30 days is about 1.25 pounds. These items include flatus, hair, nails, microorganisms, skin cells, and mucus.

1.9.3 Radiation Limitations

(To be added)

2.0 FLIGHT OPERATIONAL REQUIREMENTS

2.01 Scope

These requirements define those requirements and constraints that effect the in-flight mission operations of AAP.

2.02 Purpose

The primary purpose is to define those requirements and criteria either peculiar to AAP or defined by the Apollo mission configuration that are necessary for mission planning or effect equipment design. It is an objective to maintain the same functional in-flight mission procedures, techniques, and planning that characterize the standard Apollo mission.

2.1 CREW ASSIGNMENTS AND DUTY STATIONS

2.1.1 Crew Assignments

It is anticipated that all crew members will receive a degree of training that permits total interchangeability of crew duties on an emergency basis. The order of priority of crew utilization is:

a. Maintenance of flight safety

b. Conduct of basic flight operations

c. Exploration of natural phenomena

d. Scheduled measurements and observations of natural pehnomena

e. Repair, calibration and modification of mission-specific equipment.

For the purposes of crew skill selection, training plans, and normal mission planning, the following ground rules shall apply:

a. Commander - The command astronaut will perform all major spacecraft maneuvers from the left hand position of either the CM or LEM. He will also be the backup navigator on the CM.

b. Navigator - Is responsible for CM navigation and operation of the CM including docking when the LEM is separated.

c. Systems Engineer - Is primarily responsible for all experiment activities plus backup operation and navigation of the LEM.

d. Assignment Priorities - The following table lists assignment priorities for the various crew members. For purposes of mission planning no normal assignements will be made where the crew member is listed as type 4. In the case of CM type experiments the commander is listed as both type 3 and 4 - type 3 for repetitive experiments or those obviously requiring all crew members such as most bio-med, and type 4 for highly specialized type of experiments such as a telescope program.

Crew Member	Launch & Recovery	CM or CM Docked to LEM or Experiment Carrier Operations			LEM Operations		
		Maneuvers	Navigation	Experiments	Maneuvers	Nav.	Exp
Commander	1	1	2	3 & 4	1	1	2
Navigator	2	2	1	2	3	3	4
System Engr.	3	4	4	1	2	2	1

Where: 1. Prime Responsibility - Full training and capability

2. Secondary Responsibility - Full training and capability

3. Operating Capability - Sufficient training to demonstrate capability of normal operation

4. Emergency Capability - Indoctrination and limited pra

2.1.2 <u>Duty Stations</u>

(To be added)

6. Allow 24 hours between EVA's for each crewman.

7. Maximum planned outside time for one EVA operation is three hours.

8. Provisions will be made to permit EVA during darkness.

2.2.3 LEM and Lunar Surface Constraints

Hard suit EVA on lunar surface will be limited to six continuous hours per day.

(This requires a PLSS change)

2.3 COMMUNICATIONS - REQUIREMENTS

1. All three astronauts will have continuous inter-communications capability at all times.

2. An astronaut controlled down-link voice communication capability shall be available from all major work stations of each carrier or vehicle.

3. For EVA positive two-way voice communication between the EVA astronaut and the standby astronaut is mandatory at all times, i.e., no antenna blind spots are permissible. Where the crew is split between vehicles the standby astronaut and the third astronaut will have two-way communications capability.

4. (a) T/M and voice coverage between spacecraft and MSFN is required as follows:

   a. All SPS burns.

   b. Once per orbit or not more than 2-hour intervals.

   c. Deorbit maneuver.

5. (a) T/M, voice, radar, and command coverage between spacecraft and MSFN is required as follows:

   a. Launch.

   b. Major SPS burns (≥ 15 seconds) - desire two minutes contact prior to and following completion of burn (exception is deorbit maneuver).

   c. Any significant maneuver.

2.4 GENERAL CONSTRAINTS ON EXPERIMENT OPERATIONS

1. Maximum utilization of the crew for redundancy monitoring and failure mode corrections/operations of experiments will be used.

2. Experiment data set-up, pre- or post-calibration and operation will be on-board controlled and will not require any ground uplink support capabilities.

3. The data record, dump or redump requirements will be a crew responsibility and will not require any ground uplink control.

4. It is desirable not to have experiment activities during major flight maneuvers -- launch, translation and docking, major SPS burns, deorbit, lunar landing and ascent, and re-entry. If required, it will not utilize more than one crew member performing from his regular duty station.

5. Experiment activities will be complete at least eight hours prior to deorbit and as noted in section 3.

2.5 BASIC DUTY CYCLE AND GROSS TIME LINE

2.5.1 General Ground Rules

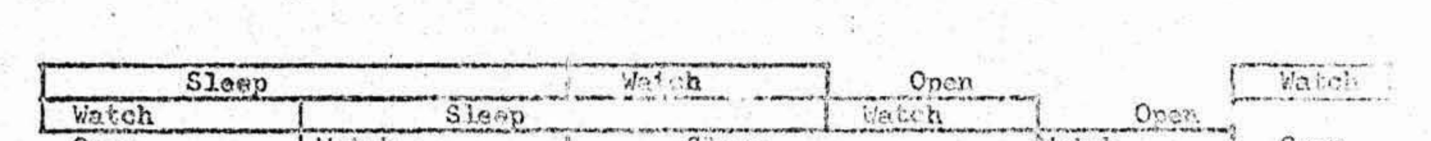
The question of a proper work/rest duty cycle is a highly opinionated variable. A final answer will not result in all probability until after several long period Apollo flights have been completed. In the meantime, a reasonable cycle must be selected to permit mission analysis of selected experiment groupings. This cycle will be used to analyze the basic acceptability of various experiment groupings with the understanding that where it becomes a limiting factor, a specific analysis of alternate solutions will be made. The cycle selected is based on the following general premises:

1. One crewman will always be awake and in charge of mission integrity, i.e., watch duty.
2. The work/rest cycle will be oriented to maintain a normal living routine phased to coincide with the eastern U.S. time zone.
3. Each astronaut will have one sleep period of approximately seven hours augmented, when possible, by a nap of not more than one hour.
4. Personnel Tasks - eating, hygiene, exercise will not be rigidly scheduled, and for mission planning purposes time allocations for these tasks will be made by duty period.
5. Routine mission housekeeping tasks - status checks, LiOH changes, mission log maintenance, etc., will not be rigidly scheduled, and for mission planning purposes time allocations for these tasks will be made by duty period.
6. For preliminary AAP mission analysis it will be assumed that eight (8) hours per day per man, or a total of 24 manhours per day is available for experiment activity.

2.5.2 Standard Planning Crew Duty Cycle and Time Available

1. Three-man operation with CM or CM docked to other vehicle.

   a. Duty Cycle



*All times are Eastern Standard Times and the start of first sleep period may be established for any given mission from 1600 to 2000.

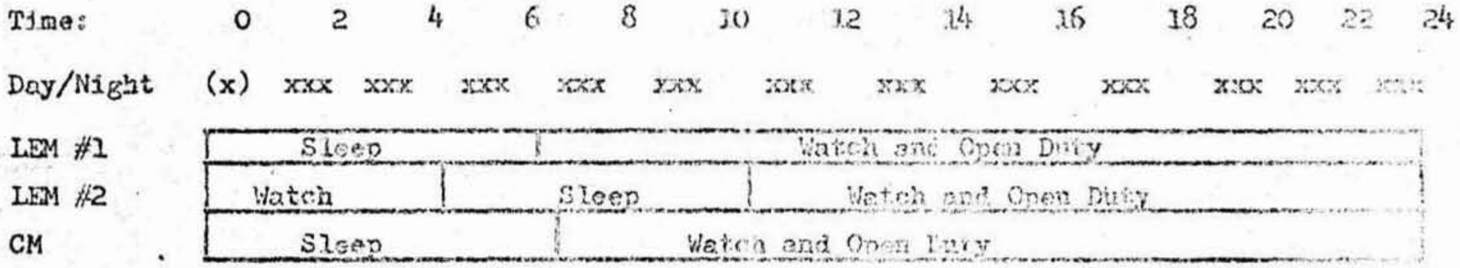
b. Crew Time Availability for Experiment Operations

(See sections 1.3.3, 1.3.4 and 1.3.5 for derivation of times).

Number of Crew Available	Span Time	Manhours Available for Experiments
3	8	11:40 - 14:40
2	8	7:10 - 8:40
1	8	2:40
		21:30 - 26:00 (hrs.)

2. Three-man Operation - one in CM. Two in undocked LEM

a. Duty Cycle



This duty cycle is based on the following premises:

1) Minimizing the time all three crew members are asleep, simultaneously. In this case, it is only for about 2 hours since the last hour of the sleep period is actually involved in personnel hygiene and eating.

2) Minimizing the number of day periods made unavailable for operations due to the LEM crew being asleep. In this case only one such day period is lost.

3) This cycle is based on a 2-hour orbit period for ground scheduling purposes. The actual cycle should be adjusted to the true orbit period that will be closer to 1.9 hours for 40-mile and 2.1 hours for 8-mile lunar orbits. This will result in minor variations to the time allotments available.

2.5.3 Watch Duty Period

2.5.3.1 Three-Man Operation with CM or CM Docked to Other Vehicle

One crewman will be awake and on watch duty assignment at all times. During these periods he will be responsible for the maintenance of spacecraft systems, communications, position and flight records or logs, and general operational activities

In case of emergency he will alert the vehicle commander. Each crew member will work two four-hour watch duty assignments per day, one immediately following the sleep cycle and one immediately preceding the sleep cycle. During each four-hour watch the following activities will be performed:

1. Sixteen (16) minutes out of every hour will be used for vehicle monitoring and maintenance.

    a. Status check of EPS hourly (6 min.) recharge batteries as required.

    b. Status check of ECS hourly (1 min.).

    c. Voice contact with MSFN every 2 hours or once per orbit (5 min.).

    d. Purge fuel cells - alternate H_2 and O_2 purges every 3.5 hours (12 min.).

    e. SM-RCS status check preferably within T/M range of MSFN every 4 hours (3 min.).

    f. Status check of SPS every 4 hours (2 min.).

    g. Battery check every 7 hours (1 min.).

    h. Status check of CM-RCS in unpressurized state every 12 hours (1 min.).

    i. Alternate replacing the CM LiOH filter elements every 12 hours (5 min.).

    j. Status check of pyro batteries every 24 hours (1 min.).

    k. Data dump to MSFN on each orbit, as required. (2 min. crew time).

2. Twenty-five (25) minutes for maintenance of position logs and basic mission records. The watch crewman will be expected to maintain sufficient spacecraft position orientation to be able to initiate abort procedures at any time.

3. Twenty (20) minutes for eating (generally snacks) during each watch. This is an average value that will be worked on an "as available" basis by the crew.

4. Fifteen (15) minutes for exercise. This provides one-half hour of exercise during watch duty which will be added to one-half hour additional during the open duty period. This will be worked on an "as available" basis by the crew. No exercise will be performed on the day that a crewman makes an Extra Vehicular operation.

5. Twenty (20) minutes for personnel hygiene. This is an average value to be used on an "as required" basis by the astronaut.

6. Eighty (80) minutes per watch is available for secondary experimental duties. These should primarily fall into the category of assisting in bio-med experiments or initiating and/or monitoring cockpit controlled experiments. Generally speaking, no more than 15 minutes continuous concentration at one time period on experimental duties should be scheduled for the watch duty crewman. During EVA the watch duty crewman will operate from the commander's (LH) couch.

7. This leaves sixteen (16) minutes unassigned per watch which will generally be utilized for navigational fixes or additional experiment time.

2.5.3.2 Three-Man Operation -- one man in CM, two men in LEM

1. Watch Duties of One Man in CM

   a. The single man in the CM will perform all the functions called out in sections 2.5.3.1 (1) and 2.5.3.1 (2). Additionally, he will check in with the LEM on a minimum of once per hour (1 min.).

   b. The one-half (½) hour immediately prior to and immediately following the sleep period will be utilized to perform the accumulated monitoring and maintenance functions of sections 2.5.3.1 (1) and 2.5.3.1 (2) that were not accomplished due to the sleep period.

   c. These primary watch functions will average about 40 minutes per hour.

   d. The remaining activities noted in sections 2.5.3.1 (3) through 2.5.3.1 (7) will be listed under Open Duty section 2.5.4.

2. Watch Duties of Two Men in LEM

   a. (   ) minutes out of every hour will be used for vehicle monitoring and maintenance.

      1) Status check of EPS hourly (6 min.), recharge batteries, as required, if capability exists.

      2) Status check of ECS hourly (1 min.).

      3) Voice contact with CM a minimum of once hourly (1 min.).

      4) Voice contact with MSFN every two hours or once per orbit (5 min.).

5) Purge fuel cells if applicable - alternate H_2 and O_2 purges every hours (12 min.).

6) Replace LEM LiOH filter elements every hours (5 min.).

2.5.4 Open Duty Period

2.5.4.1 Three-Man Operation With CM or CM Docked to LEM

During any 24-hour period each man will have one continuous 8-hour open duty period. During this period certain housekeeping activities must be performed but the remainder of the time is available for experiment activity and required navigational fixes or spacecraft maneuvers. The following activities are included during this period:

1. Take nap (1 hour). This can be scheduled by the crew on "as available" basis and can be eliminated occasionally.
2. Eat one hot meal (1 hour). This is scheduled for one hour to allow some time for relaxation or recreation.
3. Perform exercise for 1/2 hour. This would normally be broken into three ten- (10) minute periods and can be eliminated occasionally. No exercise is required on the day a crewman performs an extra vehicular operation.
4. Perform waste elimination and body cleaning (1 hour).
5. The remaining time is available for other activities (4½ to 6 hours).
   a. Flight operations - see section 3.0 for required flight operation functions.
   b. Experiment activities - to be determined.

2.5.4.2 Three-Man Operation - one in CM, two in LEM.

(To be added).

2.5.5 Sleep Period

2.5.5.1 Three-Man Operation With CM or CM Docked to LEM

The sleep period for each man will be eight (8) hours. It is anticipated that about seven (7) hours of this time will be effective sleep. The remaining time will be utilized to prepare the sleep station and, on rising, cleaning up the sleep station, performing personnel hygiene, and eating breakfast. The individuals eighth hour of sleep will be in the form of a nap during the open duty period. (See 1.5.3.1.1).

2.5.5.2 Three-Man Operation - One in CM, Two in LEM

The sleep period for each man will be seven (7) hours. It is anticipated that about six (6) hours of this time will be effective sleep. The remaining time will be utilized to prepare the sleep station and, on rising, cleaning up the sleep station, performing personnel hygiene, and eating breakfast. Depending on the length of this type of operation a nap of one to two hours duration should be scheduled during the open period.

2.6 OPERATIONAL CONSTRAINTS BY MISSION SEGMENT

2.6.1 Launch Operations to Liftoff

1. (a) Launch cut-off time is 1500 hours local time because of recovery requirements.

2. (b) No experiment activity will require crew participation more than 90 minutes, or less than 1 minute prior to liftoff.

3. (b) Experiment activities during the countdown are limited to those that can be performed by the systems engineer from his couch position.

2.6.2 Post Launch and Earth Orbit

1. (b) From liftoff to confirmation of orbit experiment activity is undesirable. If required, it should be limited to the capability of the systems engineer from his couch position.

2. (g) A status check of all systems will be performed after insertion. Assume 45 minutes with all crew members occupied except as noted above.

3. (a) Batteries will be recharged after insertion. Nominal span is 100 minutes but crew loading is 2 minutes for systems engineer.

4. (a) There shall be a minimum of one orbit prior to S-IVB/CSM separation.

5. (c) The S-IVB G&C and PCS shall be used for all maneuvers prior to S-IVB/CSM separation.

6. (c) IMU fine alignment will be required once per day for normal spacecraft requirements (20 minuts).

7. (c) IMU aligament requires having the +X axis approximately in the local horizontal, pointed in the direction of flight and maintained within ± 30° of the plane of the orbit. The +Z axis must remain at least 30° above the local horizon.

8. (b) During near earth orbit operations navigational sightings will be taken no less than twice per day (36 minutes per set of three sightings).

9. (c) Oribtal navigational sightings require having the +X axis in the direction of flight and the +Z axis near local vertical and pointed toward earth.

2.6.3 Translunar Injection

1. (c) The S-IVB provides G&C and thrust for the translunar injection. The +X axis is forward and approximately parallel to local horizontal. The -Z axis is down and approximately parallel to local vertical.

2. Recharge batteries 20 minutes prior to deorbit burn (20 minutes).
(b)

3. Preparation time for translunar injection includes systems checks
(g) crew tie down, IMU coarse and fine alignment -- 32 minutes involving all crew members.

2.6.4 Transposition and Docking - S-IVB Separation

1. The CSM is the active vehicle during transposition and docking.
(c) The S-IVB is in the attitude hold mode.

2. The transposition maneuver starts with the +X axis forward and
(c) within ± 30° of the trajectory plane, +Z axis up. After separation from the S-IVB the CSM performs a +180° pitch maneuver followed by a -63° roll in order to align for docking.

3. Time for transposition and docking including preparation, jettison
(g) of SLA, and performance of hard docking procedures is 40 minutes involving all crewmen.

4. Time for S-IVB separation including preparatory procedures is
(g) 5 minutes.

2.6.5 Translunar Coast

1. The coast period includes a maximum of nine midcourse navigational
(c) sightings, four IMU alignments and three delta V corrections.

2. Passive Thermal Control (PTC) is required during coast periods
(d) except as interrupted by the requirements of item 1 above. During PTC the CSM Y-Z phase is pointed toward the sun (±20°) and a roll rate of 1 to 2.5 revolutions per hour is established about the X axis. This rolling action combines with vehicle residual drift rates causing the X axis to precess about its initial orientation, precession creating rotations of approximately ±20° about the Y and Z axes. Periods of non PTC operation are limited to 3 hours and must be followed by 15 hours of continuous PTC. The "rule-of-thumb" is that for a long attitude hold time, the ratio of roll to hold is 5 to 1. For short attitude hold times (less than 15 minutes), the ratio is 7 to 1.

Attitude Hold	Required Roll Time
5 min.	35 min.
15 min.	1.75 hours
30 min.	2.5 hours
3 hrs (max.)	15 hrs.

3. Time period for navigational sightings is 36 min. Involves one man.
(g)

4. Time period for mid-course correction involves all three crewmen,
(g) includes maneuver C/M to desired attitude, system set-up and checkout, firing of SM-RCS for ullage, SPS firing, verification of delta V obtained (requires contact with MSFN), post firing system checks, 25 min.

5. Time period for an IMU coarse alignment sequence is 11 minutes,
(g) 6 minutes additional for fine aligement, and 3 minutes for a fine alignment check.

2.6.6 Lunar Orbit Insertion

1. The X axis is approximately parallel to the lunar local horizontal
(c) with -X forward. No restriction is placed on the direction of the Y or Z axes.

2. Time for lunar orbit injection includes system checks. IMU coarse
(g) alignment, IMU fine aligement, maneuver C/M to desired alignment, set-up LOI navigation parameters, ullage firing, SPC firing, post fire system checks - 1 hr. 5 min.

2.6.7 Lunar Orbit

1. Orbital navigational sightings will be required during the first
(c) two orbits for orbit confirmation. During this period the general CSM attitude will be with the +X and +Z axes pointed below the local horizontal plane and the X axis will lie within 60° of the orbit plane.

2. A minimum of three orbital navigational sightings (utilizing IMU
(c) alignment of 40 minutes) will be required daily. See item above for attitudes.

3. Proper ECS operation in lunar orbit is dependent upon the orienta-
(d) tion of a plane which bisects the CSM +Z/-Y and -Z/+Y quadrants
(c) and which parallel the X axis. The edge of this plane must remain within 25° of the subpolar point (the point at which the sun-moon line intersects the lunar surface). Deviation from this requirement is allowed a maximum of 3 orbits every two days.

4. 4. IMU alignment necessitates placing the +X axis in the general
(c) direction of flight and maintaining it within 60° of the orbit plane. The +X axis must remain at least 30° above the local horizontal.

5. Time for initial entry into LEM-equalize CSM and lock pressure,
(g) remove and stow CM pressure and thermal hatches, perform CM system checks, disconnect and stow probe and drogue, check for LEM pressure equalization, open LEM hatch, transfer to LEM, transfer umbilical to LEM - 14 min.

6. Time for initial LEM checkout -- activate and checkout communica-
(g) tions, control and warning system, power system, ECS, ARS, suit fans, transfer of PLSS and other equipment to LEM, transfer second man, deploy landing gear, checkout propulsion systems, coarse and fine alignment of LEM IMU, set up navigation in LEM, close up LEM - 2 hrs. 17 min.

2.6.8 Lunar Transfer and Landing

1. The 1 hour prior to LEM separation from the CM, all three crew
(g) members will be totally occupied with navigation and other spacecraft preparatory activities.

2. From LEM separation to touchdown, no experiments will be performed
(h) either on-board LEM or CM.

3. The two LEM crewmen will have completed a sleep cycle no more than
(h) 6 hours prior to start of lunar transfer.

2.6.9 Lunar Surface

1. After landing, preliminary LEM securing and checkout time is 15 min.
(g)

2. Preparation time for initial lunar egress - examine surface,
(g) photograph, review exploration plans in light of actual conditions, check out and don suits and PLSS equipment, check out communications, get scientific equipment ready - 1 hr. 8 min.

3. Dump LEM pressure - 5 min.
(g)

4. Exit LEM, get scientific equipment and lower to ground, climb down
(g) ladder to lunar surface, check mobility and surface conditions - 12 min.

5. Conduct external inspection of LEM - 5 min.
(g)

6. Erect and align lunar surface S-band dish antenna - 20 min.
(g)

7. Climb ladder, transfer equipment into LEM, enter LEM - 2 min.
(g) 30 sec.

8. Repressurize LEM - 18 min. 30 sec. (single system)
(g) 1 min. 20 sec. (both systems)

9. No biological waste shall be disposed on the lunar surface without
(g) sterilization.

10. The LEM is designed so that it can be left unoccupied with the
(g) cabin unpressurized on the lunar surface. Experiment design should conform, or possible effects be properly defined.

11. Figure shows the maximum distance for EVA from the LEM as a function of the duration of the EV activity. This is based on the amount of oxygen available to provide purging of the EV suit in case of pressure suit revitalization system failure.

2.6.10 Lunar Return and Rendezvous

1. Preparation for launch - 1 hr. 1 min.
(g)

2. There will be no experiment activity during LEM lunar return,
(b) docking, and period through transearth injection.

3. The LEM will be considered the active docking member on the
(g) return rendezvous.

2.6.11 Transearth Injection

1. LEM jettison occurs prior to IMU alignment and is accomplished
(c) with the -X axis in the direction of flight and the +Z axis pointed towards the lunar surface.

2. IMU alignment is the same as lunar orbit (2.6.7).
(c)

3. Following IMU alignment the +X axis is directed approximately
(c) parallel to the local horizontal prior to initiating transearth injection.

4. Recharge batteries 20 minutes prior to deorbit burn - 20 min.
(b)

5. Preparation time for transearth injection will take approximately
(g) 3 hrs. prior to engine ignition.

2.6.12 Transearth Coast and CM/SM Separation

1. Same as Translunar Coast (2.6.5-1)
(b & c)

2. Same as Translunar Coast (2.6.5-2)
(c)

3. In addition to the PTC requirements of item 2 above, it is
(c) necessary to provide pre-re-entry cooling for the forward heat shield. This is accomplished by keeping the -X axis turned sunward within the limits specified for PTC.

4. No experimental or special operational activity requiring crew
(a, b & c) attention shall be scheduled during the final four hours of the Transearth Coast period due to the criticality of establishing a safe entry corridor. Equipment stowage will be completed during this period.

5. For CM/SM separation the +X axis is rotated 60-70° above the
(a & c) direction of flight and in the trajectory plane. The +Z axis has a positive projection on the upward local vertical.

6. The CM/SM separation and pre-entry maneuver must be initiated
(a) no less than 5 minutes prior to reaching 400,000 feet entry altitude.

7. Perform EPS status check prior to CM/SM separation (6 min.) and
(a) a main bus status check after separation and prior to re-entry
(3 min.).

8. Check pyro batteries prior to CM/SM separation (1 min.).
(a)

9. Disconnect fuel cells from CM busses prior to CM/SM separation
(a) (1 min.).

10. Perform status check of CM/RCS two hours prior to CM/SM separation
(a) (1 min.).

11. Preheat CM/RCS engine valves 10-13 minutes, to be complete 10 minutes
(a) prior to CM/SM separation.

2.6.13 Re-entry and Recovery

1. CM landing shall be planned no earlier than one hour prior to
(a) sunrise, or later than three hours prior to sunset.

2. The longitude of entry for both the CM and SM must be such that
(a) the SM does not endanger any land masses.

3. Entry starts with the -X axis in the trajectory plane and rotated
(c) approximately 26° earthward from local horizontal and with the
+Z axis pointed away from earth.

4. Experiments or data returned in the CM, must survive a maximum
(g) of two days after landing.

2.7 OPERATIONAL CONSTRAINTS BY VEHICLE SYSTEMS

2.7.1 ECS (CM) System Routine Operational Constraints

1. (a) The radiator inlet temperature must be maintained above 75°F to prevent freezing and below °F to prevent boiling. The following are operational "rule-of-thumb" constraints. Where experiment requirements require violation of these rules, a detailed thermal balance analysis should be made.

   a. (a) The radiator surface should not be exposed to solar radiation incidence angles of ±45° for more than 20 minutes per orbit on the average to prevent boiling. Maximum exposure of these angles for any one time is one orbit.

   b. (a) The spacecraft attitude should not be constrained in an inertial or earth relative orientation for longer than 3 hrs.

   c. (a) Electrical loads of less than 1680-1690 watts require periodic exposure of the radiator to the sun to prevent freezing.

2.7.2 Service Propulsion System (SPS) Routine Operational Constraints

1. (a) SPS propellant must be maintained above 40°F. Although no fixed rule is possible, attitude holds greater than 3 hours in duration without solar incidence on the SM aft end should be avoided. Where experiment activities exceed this time, a thermal analysis should be conducted to check propellant temperatures.

2.7.3 RCS (SM) Routine Operational Constraints

1. (a) Any one quad of the RCS (SM) shall not be pointed towards deep space for periods exceeding 6-10 hours.

2.7.4 S-IVB Routine Operational Constraints

1. (a) The S-IVB propellant tanks must be vented periodically, probably about every 4 hours on an average.

2. (a) The S-IVB stable platform in the IU has a middle gimbal restriction of ±45° about the X-axis vehicle yaw at launch, roll in flight.

2.7.5 Guidance and Navigation System Routine Operational Constraints

1. (a) The S-IVB stable platform in the IU has a middle gimbal restriction of ±45° about the X-axis vehicle yaw at launch, roll in flight.

2.8 ABORT REQUIREMENTS

2.8.1

1. SPS propellant shall be maintained above the combution
(a) instability level during any deorbit maneuver.

(OX ____________________ lbs; FUEL ____________________ lbs.).

2. Continuous SPS abort capability will be maintained.
(a)

3. The mission shall be aborted as soon as possible after
(a). uncontrolled loss of cabin pressurization.

4. SM-RCS deorbit capability shall be provided during any portion
(a) of near-earth orbital flight.

5. In-flight contingency actions shall be initiated primarily by
(g) manual means unless emergency condition requirements are such
that manual ope ation is inconsistent with crew safety.

ATTACH. 7,8 &.9

ATM Stabilization and Control

1. Insure ATM operator requirements are within tolerances of human capability

   By -

   Analyzing crew capability to acquire target within 10 minutes

   Determining crew inputs for automatic operation of the ATM

   Evaluating sequence for experiment commands (maximum 100 commands)

   Selecting control modes compatible with operator capabilities

   Analyzing available ATM target and status presentation hardware

   Selecting display and control combination which places least demand on operator skill and endurance

   Insuring that ATM CMG and LEM ACS provide near synchronous response to operator input

2. Determine training requirements to ensure maximum crew proficiency with selected ATM display and control hardware

   By -

   Specifying critical tasks required for performance of ATM mission

   Providing course and briefing outlines for crew familiarization and training

   Insuring direct correlation between trainer and operational equipment

Attachment 7

ATM Carrier Habitability and Profile

1. Evaluate carrier habitability

   By -

   Analyzing overall usable volume availability

   Insuring ATM peculiar and crew support equipment complies with human engineering and flight safety criteria

   Insuring adequacy of illumination for ATM display and control systems

   Establishing work cycle compatible with overall mission requirements and Gemini/Apollo data

2. Evaluate carrier profile for compatibility with ATM systems

   By -

   Checking ATM retrievable (EVA) cassette size against hatch sizes

   Evaluating data cassette masses to ensure crew translation capability

   Confirming compatibility between cassettes and carrier stowage provisions

   Evaluating ATM D&C for compliance with human engineering work station criteria

   Confirming volume allocation and stowage configuration for special EVA gear, i.e., maneuvering system, tools, lights, life support

Attachment 8

OTHER ATM MAN/MACHINE CONSIDERATIONS

Crew Requirements From ATM

IVA

Ground checkout of ATM
Orbital checkout of ATM
Spacecraft pointing and tracking prior and during experiment
Crew motion restrictions during tracking
ATM pointing and tracking design and techniques
ATM experiment sequencing and control
Targets of opportunity (in-flight reprogramming)
ATM orbital reactivation (potential maintenance)
Control/display compatibility with LEM/ATM C&D
Orbital/MCC-H communications and flight planning

EVA

ATM film data retrieval (cassette management)
EVA crew equipment for frequent EVA's (mod's)
Crew locomotion and tethering (hardware)
Crew metabolic load (work schedule)
Illumination during EVA
Crew compartment pre- during and post- EVA procedures
Crew compartment EVA compatibility (hatches, O_2 supply)
ATM reactivation and refurbishment (batteries, CMG's, etc.)
Crew force and moment impacts on ATM installation design
Special tools and test equipment.

Attachment 9