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SKYLAB EXPERIENCE BULLETIN NO. 26

THE METHODS AND IMPORTANCE OF MAN-MACHINE ENGINEERING EVALUATIONS IN ZERO-G

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MAN-MACHINE ENGINEERING DATA APPLICATIONS
OF
SKYLAB EXPERIMENTS M487/M516

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THE METHODS AND IMPORTANCE OF MAN-MACHINE ENGINEERING EVALUATIONS IN ZERO-G

This document is the twenty-sixth in a series of releases which are intended to make available to NASA and contractor personnel those results from the Skylab Man-Machine Engineering Experiments which have design and requirements relevance to current and future projects and programs.

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MAN-MACHINE ENGINEERING EVALUATIONS IN ZERO-G

SUMMARY

This report is intended to serve as a summary document for the series of Skylab Bulletins published over the last two years. This bulletin will summarize the total array and address the importance of continuing to recognize the man-machine engineering discipline as a viable element in manned spaceflight. As such, man-machine engineering investigations, evaluations, and verifications should be an integral part of every manned mission. These activities should be implemented through sound preflight planning, efficient inflight execution, detailed postflight analysis and reporting, and continuing application of resulting designs, techniques, and principles which enhance human efficiency in zero-g.

PRESKYLAB EXPERIENCE

Through the completion of the three manned programs preceding Skylab, the man-machine engineering discipline had been relegated to a very subordinate position with respect to acquiring inflight data and making application of results. The operational aspects of each mission were sufficiently demanding in and of themselves to leave little time for crew evaluations of what was sometimes considered to be "creature comfort" items. However, the standard human factors requirements were levied on each program, and the individual spacecraft and their associated operational and experimental equipment were submitted to thorough man-machine engineering scrutiny. Nevertheless, no dedicated inflight evaluations or experiments in the human factors area were implemented during these programs, and the state-of-the-art of man-machine interfaces in zero-g advanced very slowly. Even though numerous postmission reports were written, no specific records were kept of human engineering "finds" during the various missions. Thus, most of the information on this subject offered by returning crewmen was screened for cost and schedule impact and then implemented or rejected accordingly. Skylab opened a new vista in this area.

SKYLAB DESIGN

Two experiments that were under the control of the Man-Machine Engineering Section of the Spacecraft Design Division were incorporated into the Skylab Program. These investigations were oriented toward determining how crewmen function in zero-g with respect to carrying out assigned tasks and self-maintenance chores.

This section of the report will define the manner in which the man-machine engineering data to be obtained during Skylab were identified and how the data collection techniques were chosen and implemented. No attempt will be made to describe the hardware aboard Skylab which was subject to evaluation since these descriptions and evaluations have been thoroughly documented in other bulletins in this series (see Appendix 1).

Skylab Experiment M487, Habitability/Crew Quarters

The objective of Experiment M487 was "...to measure, evaluate, and report habitability features of the crew quarters and work areas of the Skylab Orbital Assembly (OA) in engineering terms useful to the design of future manned spacecraft" (see reference 1). The process of defining and acquiring data that would allow the objective to be met was a major chore. As a first step, the broad term "habitability" was broken down into component parts so that individual elements could be dealt with in the overall data definition process. Nine elements of habitability were defined and are listed in Table I. Next, specific methods of acquiring information concerning each element of habitability had to be devised.

Several methods of data collection were defined and some of the techniques were implemented during the Skylab Medical Experiments Altitude Test (SMEAT) project conducted at JSC in 1972. As a result of the SMEAT findings, several of the data acquisition formats were changed, even though the basic concepts and techniques were retained as valid methods for retrieving inflight information (see reference 2). The SMEAT project solidified the M487 protocols, and a positive definition of inflight procedures grew out of the experience gained.

ELEMENTS OF HABITABILITY

Element	Characteristics
Internal Environment	Composition, temperature, and movement of the respirable atmosphere. Acoustic and lighting levels.
Spacecraft Architecture	Geometric arrangements of compartments, interior appointments, and stowage provisions.
Mobility and Restraint of Crewmembers	Locomotion and restraint modes and mechanical aids.
Food and Drink	The fare, its stowage, preparation, serving, and consumption.
Clothing	IVA garments.
Personal Hygiene	Facilities and provisions for waste collection, personal cleanliness, and grooming.
Housekeeping	Vehicle cleanliness; refuse collection and disposal.
Communication	IVA person-to-person.
Off-Duty Activity	Leisure and entertainment provisions.

TABLE I

Several different avenues of inflight data collection were finally chosen for implementation aboard Skylab. These included the following:

- Filming specific activities to observe man-machine interfaces.
- Periodically providing subjective stimulus materials to elicit crew evaluations and comments concerning the design adequacy of various habitability features.
- Constantly monitoring inflight "air-to-ground" conversations and unsolicited "onboard recorded" comments to retrieve relevant ad hoc remarks which would either apply directly to the investigation or stimulate clarifying questions to the crew during or after the mission.
- Providing various instruments with which quantitative environmental measurements could be made.
- Observing scheduled and unscheduled TV transmissions for potentially applicable scenes.

Each method will be covered briefly to indicate the manner in which it was to be implemented.

Candidate activities for photography (16mm) were selected following several observations of various crew activities in the one-g trainers. Judicious expenditure of the meager film budget allowed on each mission necessitated closely controlled conditions to insure that appropriate scenes were captured while retaining sufficient film for subsequent activities. This constraint tended to force M487 investigators to try to acquire at least some footage on as many different activities and demonstrations of man-machine interfaces as possible, even though repititious filming of a single activity across time would have provided better comparative data for trend analysis. The activities chosen to be photographed by M487 are included as Appendix 2.

The subjective data retrieval techniques proposed for Skylab were new to manned missions. Never before had investigators designed a checklist to be used in flight which contained direct questions about and opportunities for evaluating human engineering adequacy of equipment, provisions, and functions aboard the spacecraft. As mentioned previously, the concept was evaluated during the SMEAT project and extremely valuable data was acquired concerning the format for presenting the material to the crew. In addition to the format, timing of presentation was considered essential: accomplishing the evaluations while in flight was necessary to overcome memory fading during long duration missions. Also, receipt of data during the mission would allow the investigators on the ground to pursue pertinent points with the crew while still aboard the spacecraft and in a position to further evaluate any given item of concern or interest. This data exchange was possible because of the onboard voice recording system which had been designed for ground command retrieval at various ground stations of any onboard recorded comments. The stimulus material designed to initiate this series of events is included as Appendix 3 and contains direct questions to be answered, specific items of hardware to be evaluated, various environmental ratings, and general opportunities for commenting on any of the man-machine engineering aspects of the vehicles or equipment.

Unsolicited crew comments were considered an excellent potential source of data since they would probably be the result of some onboard discovery rather than a response to a direct inquiry by the investigators. Daily scanning of the transcribed "air-to-ground" conversations was planned as the technique to find and extract pertinent data.

Television transmissions were planned to be made on a scheduled basis during each mission, and the habitability experiment certainly stood to profit from any such data that could be obtained in addition to the planned photography. Background activity by a second or third party is often as valuable to someone looking for data as the primary focus of a scene is to the party who scheduled the transmission.

Finally, a set of environmental measurement instruments was included as onboard experiment hardware. The purpose of these instruments was to provide the crewmen with quantitative measuring devices with which to supplement their subjective impressions of the environment in which they had to function daily. Table II lists the experiment equipment and the function of each item.

EXPERIMENT EQUIPMENT LIST

	Experiment Equipment	Function
a.	Velometer (Portable)	Provides the means for measuring air movement velocity within the OA.
b.	Measuring Tape (Portable)	Provides the means for measuring distances to evaluate pertinent sizes and locations.
c.	Sound Level Meter (Portable)	Provides the means for measuring sound pressure levels in the OA.
d.	Frequency Analyzer (Portable)	Provides the means for analyzing the sound spectrum within the OA.
e.	Ambient Thermometers (Portable)	Provide the means for measuring ambient OA air temperatures.
f.	Digital Thermometer (Portable)	Provides the means for measuring wall temperatures and temperatures of solids and surfaces within the OA.
g.	Force Gauge	Provides the.means for measuring forces required to open or close locker drawers and panels.
h.	Spare Batteries	Required for Velometer and Sound Level Meter.

TABLE II

Preflight simulations demonstrated that one additional item was necessary to properly conduct the investigation. Since intrusive demands were to be made on the crewmen's time while in flight to accomplish specific portions of the M487 protocol, it was determined that a full-time representative would be required in the Mission Control Center (MCC) to insure that daily flight planning included those requirements or activities deemed necessary for M487 on any given day. Also, an MCC representative would be in a position to respond rapidly to crew inquiries about the experiment, to view all TV transmissions, and to intercept crew comments that merited follow-up responses from the ground. Thus, a position was established in the MCC for a man-machine engineering monitor.

Skylab Experiment M516, Crew Activities/Maintenance Study

The objective of Experiment M516 was "...to evaluate Skylab man-machine relationships by gathering data concerning the crew's capability to perform work in the zero-g environment on long duration missions" (see reference 3). As with M487, the M516 investigators had to define the scope of the problem to be dealt with and then identify the parameters which could be isolated for data acquisition. Four specific areas of investigation were chosen: (1) manual dexterity (the ability to accomplish manipulative tasks), (2) locomotion (moving one's self from point to point), (3) mass handling and transfer (moving cargo from point to point), and (4) inflight maintenance (on-orbit repair of inoperative items). The design of an inflight protocol for acquiring data in these defined areas was very similar to that used for M487. The same sources of data were available, the same team of investigators would oversee the data acquisition, and the same methods of inflight data retrieval applied. Consequently, only those items which differed from M487 will be addressed here.

Similar film quantity constraints were placed on M516 as were imposed on M487, thus the same rigorous method was used of viewing tasks in training sessions prior to selecting them as suitable inflight subjects. Appendix 4 contains the list of subjects selected for each mission.

The subjective questionnaires and evaluation forms were integrated into a single checklist with M487 items as a convenience to procedures writers and a slight consolidation of an already over-abundant supply of different books and individual checklists required for on-orbit operations. Even though certain questions and evaluations were easily integrated with M487 items, some of the M516 material was sufficiently experiment peculiar to merit a separate page in the checklist. These M516 peculiar items are included as Appendix 5.

A routine similar to that followed for M487 was adopted for M516 retrieval of unsolicited crew remarks, viewing of TV transmissions, scanning of daily transcripts, responding to crew inquiries, and cataloging items for postmission debriefings.

One area of investigation set M516 apart from M487: the challenge of acquiring sufficient data to evaluate the capability for conducting inflight maintenance (IFM), and drawing conclusions concerning the future of IFM in upcoming programs. There was some concern about whether or not there would be a sufficient test of the various crew's IFM capabilities during the course of trouble-free missions to draw firm conclusions about the discipline. This concern led the M516 investigators to propose a mock-IFM task. The task selected was an interchange of two of the control moment gryos contained in the M509 astronaut maneuvering unit. The exchange was to be conducted toward the end of the SL-4 mission, following the completion of all M509 experiment objectives. The full cooperation of the M509 Principal Investigator was obtained and the task was developed, training hardware identified, and procedures written. To futher create a situation as similar as possible to an unexpected inflight failure of some item of equipment with which crewmen might not be totally familiar, the plan called for training only one crewman to perform the task. His training sessions would be used to refine the procedures and develop as explicit a checklist as possible. However, another crewman would actually perform the task inflight with the trained crewman available to assist, if necessary. It was felt that this would present as realistic a set of circumstances as possible. Useful data would be acquired on both IFM capability in zero-g and procedures development ability to accommodate such happenings.

One additional element of the IFM discipline drew particular attention from M516 during the planning phase. Sufficient emphasis was placed on the need for IFM data that experiment investigators attended most preflight IFM crew training exercises to become thoroughly familiar with the procedures required to perform any given task. This familiarity would allow the man-machine engineering representative in the MCC to determine whether or not to ask for onboard filming or TV of unscheduled IFM tasks as they occurred. Also, other data mediums, such as crew commentary on the "do-ability" of the task, could be initiated as IFM tasks showed up in the course of the missions.

SKYLAB EXPERIENCE

As stated previously, this report will not attempt to duplicate the engineering analyses and evaluations contained in the other Skylab Experience Bulletins. The purpose of this document is to evaluate the effectiveness of the techniques used to acquire man-machine engineering data from Skylab and to establish a firm requirement for the continued incorporation of such endeavors on all future manned missions. The presentation in this section of the report will concentrate on the lessons learned from the Skylab experience.

Skylab Data Retrieval Techniques

The methods described in preceding sections for acquiring data during the Skylab missions turned out to be acceptable, but numerous refinements were developed as the missions progressed and opportunities were always available to improve both the quantity and quality of the data retrieved. One example will serve to make the point. The subjective stimulus material was intended to serve two separate pruposes: (1) to elicit individual impressions of the design adequacy of the various man-machine interfaces aboard the spacecraft, and (2) to stimulate group discussion about specific items and operations in order to take advantage of the "three heads are better than one" theory of acquiring more data from an interchange of ideas among crewmen than from a single crewman depending upon his recall to produce a thorough set of thoughts on any given subject. To meet this end, the rating forms used to evaluate various equipment items were intended to be accomplished privately, while a set of questions had been carefully prepared to serve as source material for the group discussions. The crewmen soon determined that their schedule was such that gathering a quorum for a discussion session was nearly impossible. Further, when they did attempt to conduct a group discussion, one crewmember always ended up serving as the spokesman for the group, and the communications process required to allow any of the three to record comments while also allowing each to hear the other turned out to be more trouble than seemed justified. Consequently, the crewmen asked to change the format to eliminate the group discussions and allow all subjective data takes to be conducted individually. The change was approved by the investigators and everyone profited. The crewmen were no longer constrained by communications techniques, the flight planners could much more easily schedule the data takes on an individual basis, and the investigators received approximately three times as much data as expected for these particular sessions.

The unsolicited comments offered by the crewmen, both on the air-to-ground and onboard recorded communications channels, proved to be valuable supplemental data and were no doubt often prompted by the presence of the M487 and M516 stimulus material. Thus, data fallouts are often accrued simply from the impression made upon crewmembers by periodic reminders in the form of required responses, whether they are verbal evaluations or quantitative measurements made with onboard instruments.

The procedures for acquiring film and TV data were adequate in terms of acquisition of planned targets, but the ability of the "system" to accept real-time updates or short-notice targets was extremely limited. This limitation appeared to the investigators to be more traditional than actual, and in future missions more flexibility in this area would certainly enhance opportunities to acquire man-machine engineering data. In most cases, the discovery inflight of a problem worth documenting is not a predictable situation.

Investigator Involvement

Enough cannot be said about the importance and value of investigator involvement in the design, development, implementation, conduct, analysis, and reporting. on man-machine engineering evaluations during manned missions. Developing an early rapport with the assigned crewmembers is extremely important in establishing a clear line of communication between them and the investigator. In most scientific experiments the crewmember functions as an operator and/or interpreter to manipulate the data gathering hardware and sometimes assess the quantity or quality of data and decide upon alternate courses of action in cases of unsatisfactory results. In the case of man-machine engineering evaluations, the crewmember often serves as the actual sensor from which the data is obtained. Thus, understanding the requirements for the data, the various methods for acquisition and evaluation, and the intended use of the results allows the crewmember to function as an integral link in the system, and unquestionably enhances the result.

The time spent in the one-g trainers by investigators during the preflight crew training schedule proved to be well worthwhile as familiarity with the spacecraft and experiment hardware came into play repeatedly during the course of the missions. Such knowledge was also very important in being able to interpret the data acquired during a mission and in conducting an effective post-mission debriefing with the crew. The time spent in the trainers defining camera look-angles for photographic data takes, for instance, resulted in a complete familiarity with that data system and the operational environment in which it would be used. The knowledge acquired during such sessions also led to the capability for visiting the trainers during the mission in response to "short-fuse" data take opportunities and determining the best method for implementing a data take in that situation.

The presence of a man-machine engineer in the control center during the missions was found to be essential also, in terms of being an advocate for the conduct of the specified inflight activities, responding to real-time or "short-fuse" data take opportunities, evaluating real-time or near real-time data for quality and quantity and asking for supplements if necessary, and in being available to respond to crew inquiries pertaining to the man-machine interfaces aboard the vehicle.

- Man-machine engineering investigators must continue to be actively involved in manned missions if a continuing flow of inflight data is to be maintained that will contribute to the advancement of the state-of-the-art of the discipline and the enhancement of future manned operations.

Data Returns

Since this report will not duplicate any of the technical results documented in the other Skylab Experience Bulletins, the one data contribution that can be made here is to make potential users aware of the methods of data cataloging that were instituted and the resulting systems.

The types of data acquired from the Skylab Program have already been defined, but they may be summarized here as verbal (crew comments, responses to subjective stimulus items, debriefings, etc.), visual (TV, 16mm, 35mm), and measured (instrument readings). The instrument readings were usually recorded verbally onboard the spacecraft and, hence, show up among the verbal data just as a matter of convenience.

All the verbal data, including air-to-ground transcripts, onboard recorded transcripts, and postflight debriefings, were examined to extract pertinent man-machine engineering information. An indexing system was developed to topically isolate these data, and a cataloging technique was implemented which logged all comments pertinent to a given subject under that heading. Each transcript comment is indexed so that it may be traced to the mission, day, and crewmember who made it. A total of 20 major topics and 188 subheadings were identified during this exercise, and the individual comments were cataloged appropriately. The system exists in both typed form and on microfiche. A typical page is shown in Figure 1. This cataloging technique allowed the non-applicable remarks to be removed and, in the case of the microfiche, reduced a 5-drawer file cabinet of paper to a single small envelope of pertinent data.

Multiple miles of 16mm motion picture film and TV tapes were acquired as Skylab data. A cataloging activity similar to that undertaken for the verbal data was instituted to reduce the visual data to some manageable quantity of topically indexed footage. The same basic index system was used as for the verbal data. In some instances, a new subheading was deemed necessary to properly identify a film sequence, thus the basic 188 topics covered by the verbal data catalog were expanded to 195 for the film catalog. However, film was not found that covered each topic contained within the verbal data catalog so only 112 topics were supported by film data. Table III lists the complete range of topics covered by both the verbal and visual data catalogs, with the topics covered by film or TV noted by an asterisk. A typical page from the film catalog (see Figure 2) shows the manner in which a specific scene can be traced to the subjects, their activities, and when in which mission it took place. The scenes have been spliced together into convenient topical groupings and stored on 400-foot 16mm reels.

The significance of the man-machine engineering data acquired during Skylab will only be known as future missions and programs reflect improved habitability

SKYLAB MAN-MACHINE DATA FROM MISSION SL-IV
FOR: A. ARCHITECTURE
16. Storage Volume/Access

MISSION DAY: 41 DAY OF YEAR: 360 (CONTINUED)
MISSION TIME: (361)04:18:35 GMT

NOTE: M487-3B Wardroom Compartment

SPT: modules. Just everything has ended up in here, instead of - just a haven of anything they can't fit elsewhere. And I don't think that's right. We ought to put things in here which are directly used for the food. You ought to have to have the pantry right down here.

NOTE: M487-3B Waste Management Compartment

SPT: Stowage volume and access: that's no good - pretty poor. I think it would be much easier if we had more - make the thing larger and put some more lockers around here where we could store more towels, more washclothes, urine disposal bags. Each guy have his own cupboard for - for his own personal belonging. I think that's way under - under supplied and ... related to personal items, your Dopp kit and else you'd like to keep in there

NOTE: M487-3B Sleep Compartment

SPT: I intend to take and restow lots of things, take the trash bags out of there, which have no place in the sleep compartment, a whole host of other things and try to make a little more provision for some of the things I'd like to have immediately accessible to me. Stowage volume and access: I've just discussed again that is poor, in that stowage volume for personal items is negligible. Access to them: I would just as soon use a few more walls for that.

NOTE: M487-3B Airlock Compartment

SPT: Stowage volume and access. I think we need a little more stowage volume for EVA. And that fits in with the whole - Well, the question of volume.

*****

TYPICAL PAGE FROM VERBAL DATA CATALOG

FIGURE 1

CATALOGING TITLES FOR SKYLAB MAN-MACHINE DATA

(Reference: Contract NAS 9-14210)

A. ARCHITECTURE

* 1. Compartment Arrangement
* 2. Compartment Orientation
* 3. Compartment Volume
* 4. Ceiling/Floor Proximity
* 5. Controls & Displays
  6. Color Scheme
  7. Compartment Multi-use
* 8. Floor Design
* 9. Hatches/Doors
  10. IVA Coordinate System
*11. Light Baffles
*12. Locker Doors/Fasteners
  13. Nomenclature
*14. Passageways
  15. Protective Padding/Guards
*16. Storage Volume/Access
*17. Trash Airlock
  18. Ventilation System
*19. Windows
*20. Food Table/Non-eating Uses
*21. Temporary Storage Provisions
*22. Work Area
  23. Privacy Curtains
*24. Drying Stations
  25. Standardization

B. COMMUNICATIONS

  1. Verbal Comm. (IVA)
* 2. Intercomm. (IVA)
* 3. SIA Locations
* 4. Comm. Equipment

C. CREW ACTIVITIES

* 1. Data Package/Checklist/Cue Card Use
* 2. Experiment Operations
* 3. Physical Exercise
* 4. Pre EVA
* 5. Post EVA
* 6. Pre Sleep
* 7. Post Sleep
  8. Schedule Adaptation
  9. Sleep Period
*10. Training
*11. Zero G Adaptability
*12. Equipment Use
  13. Unanticipated Problems
*14. Improvisations
  15. Future Considerations

D. ENVIRONMENT

  1. Temperature
* 2. Airflow
  3. Noise
  4. Illumination
  5. Humidity
  6. Task Interference
  7. Sleep Interference
* 8. Instruments/Use
* 9. Portable Fan
  10. Odor

E. EVA-SUITED ACTIVITIES

* 1. EVA Maintenance
* 2. Tool Use
* 3. Restraint Use
* 4. Mobility

F. FOOD MANAGEMENT

* 1. Accommodations

* film data available

TABLE III

F. FOOD MANAGEMENT (CONTD)

* 2. Beverage Dispensers
* 3. Eating Utensils
* 4. Food Adherence
* 5. Food Reconstitution Dispenser
* 6. Food Cans
* 7. Food Trays
* 8. Seasoning Dispensers
* 9. Tray/Mouth Proximity
*10. Wardroom Table
*11. Water Gun
12. Food Bags
*13. Food Preparation

G. GARMENTS

* 1. Outer Garments
2. Under Garments
3. Gloves
4. Shoes
* 5. Head Gear
6. Comfort/Fit
7. Warmth
* 8. Don/Doff Ease
9. Tear Resistance
10. Abrasion Resistance
11. Snag Resistance
12. Improvement Recommendations
13. Use Rates

H. HOUSEKEEPING

1. Biocide Wipes
2. Cleanup Procedures/ Hardware
3. Design Inadequacies
* 4. Filter Screens/Cleaning
* 5. General Utility Wipes
6. Provision Inadequacies
7. Preflight Preparations

H. HOUSEKEEPING (CONTD)

8. Sanitation Problems
9. Timeline Impositions
*10. Trash Collection Provisions
*11. Trash Airlock Use
12. Unanticipated Problems
*13. Utensil Wipes
*14. Vacuum Cleaner/Use

I. LOCOMOTION

* 1. Translation/Within Compartment
* 2. Translation/Intercompartment
3. Translation/Times
* 4. Zero G Adaptability

J. LOGISTICS MANAGEMENT

* 1. Mass Handling
* 2. Mass Transfer
* 3. Paper Management

K. MAINTENANCE/SCHEDULED

1. Solid Traps
2. Mol Sieve Char. Canister
3. $PPCO_2$ Inlet/Outlet Cartridges
4. PPO_2 Cartridges
5. EVA/IVA Cool/Gas Sep.
6. WMC Vent Filter
7. WMC Charcoal Canister
* 8. Fecal Collector Filter
9. Urine Separator
*10. Film Handling
*11. Equipment Cleaning

* film data available

TABLE III (Continued)

L. MAINTENANCE/UNSCHEDULED

1. Problem Recognition
* 2. Inspection
3. Troubleshooting
* 4. Repair/Replacement

M. MANUAL DEXTERITY

1. Design Recommendations
2. Muscle Group Use
* 3. Postural Adjustments
* 4. Reactive Force Removal

N. MOBILITY/RESTRAINT

* 1. ATM Chair Restraint
2. Conical Shoe Cleats/Grid
* 3. Equipment Restraints
* 4. Fecal/Urine Collector Lap Strap & Handholds
* 5. Fireman's Pole/Strap
* 6. Foot Platforms
* 7. Handholds
* 8. Handrails
* 9. Light Duty Foot Restraints
*10. Mobility Aids
*11. Portable PGA Foot Restraint
*12. Restraint Device Assistance
13. Restraint Device Improvement
*14. Sleep Restraint
*15. Triangular Shoe Cleats/Grid
*16. Universal Mount
*17. Restraint Problems
*18. Thigh Restraints

O. OFF-DUTY ACTIVITY

1. Exercise Equipment Use
2. Future Mission Considerations
3. News Briefings
* 4. New ODA Devised
* 5. ODAE Kit & Use
6. Recommendations for Improvements
7. Reading
8. Tape Recordings
* 9. Window Viewing

P. PERSONAL HYGIENE

* 1. Dental Care
* 2. Face Cloths
* 3. Hand Washer
4. Most Disconcerting Problem
* 5. Personal Hygiene Kit
* 6. Shower
7. Shampoo
8. Soap
9. Sponge Baths
*10. Towels
11. Tissues
12. Wet Wipes
*13. Washcloth Squeezer
*14. Shaving/Razor
15. Fecal/Urine Cleanup
*16. Hair Trim

Q. PERSONAL EQUIPMENT

* 1. Flashlight
* 2. Pocket Knife
* 3. Scissors
4. Sunglasses

R. PHYSIOLOGICAL DATA

1. Body Heights
2. Water Consumption

* film data available

TABLE III (Continued)

S. TOOL INVENTORY

1. EMU Maintenance Kit
2. M512 Tools
3. Repair Kit
4. S190 Maintenance Kit
* 5. Tool Kit No. 1
6. Tool Kit No. 2
7. Tool Effectiveness
8. Tool Needs
9. Tool Improvisations
*10. Tool Use
*11. Tool Caddy

T. WASTE MANAGEMENT

* 1. Fecal Collection Equipment
* 2. Plenum Bags
* 3. Trash Airlock
* 4. Trash Bags
* 5. Trash Handling
* 6. Urine Collection Equipment
7. Collection Cycles

* film data available

TABLE III (Continued)

SKYLAB MAN-MACHINE DATA FILM CATALOG INDEX
FOR: A. ARCHITECTURE
16. Storage Volume/Access

MISSION NO.	REEL NO.	SCENE INDEX/DESCRIPTION					
		NO.	FOOTAGE		FRAME COUNT		FILM REF.
			FEET	FR	START	END	
SL-II	5	4	16	14	02883	03536	TV SL2-037
			MD 4 DOY 148 SPEED: 24 fps Crewman obtains document out of Flight Data Stowage locker on far side of WDRM table and below window.				
		5	13	14	03557	04090	TV SL2-027
			MD 6 DOY 150 SPEED: 24 fps Crewman places eating utensils in stowage locker behind his table position in WDRM.				
		6	18	13	04111	04843	MAG CI-03
			MD 15 DOY 159 SPEED: 6 fps Crewman opens experiment camera stowage container that is on FWD Compartment floor grid.				
		7	9	24	04864	05247	MAG CI-07
			MD 18 DOY 162 SPEED: 6 fps Crewman opens/closes film vault door in the FWD Compartment.				
		8	45	14	05268	07081	TV SL2-114
			MD 22 DOY 166 SPEED: 24 fps SPT transfers ED31 containers to a holding device which he inserts into an IMSS locker located in WDRM.				

TYPICAL PAGE FROM VISUAL DATA CATALOG

Figure 2

and working conditions aboard manned spacecraft as a result of these data. However, the impact of the Skylab results is already being seen in the Shuttle design, and continuing applications of the lessons learned is the goal of the investigators who collected, analyzed, and reported on the Skylab data.

Importance of Timing

Only one of the nine Skylab crewmen voiced any objection to the inflight collection of the man-machine engineering data. He felt that the time used could have been better spent on other scientific investigations and that the human engineering data could be related by the crewmembers during postmission debriefings. However, the experience of the investigating team overwhelmingly points toward the need for collecting the data while the crew is aboard the spacecraft. Several factors lead toward this conclusion.

First, recall begins to dim after a very short time, and depending upon that medium to gather detailed information proves totally unsatisfactory after a mission the length of any of those flown during the Skylab Program. Even a mission of approximately a week, as currently planned by the Shuttle, may prove to be too long to depend totally on recall for man-machine engineering data.

Another aspect of the data retrieval which results in the same effect on data as recall is the dimming of priorities once the mission is complete. This simply means that some item or event that is terribly important to a crewmember at some critical juncture during a mission may become relatively insignificant in retrospect when the total priorities and accomplishments of the mission are reveiwed postflight. Nevertheless, that same item or event will create the same irritant in an upcoming mission unless it is reported, evaluated, and, if necessary, improved or corrected. Personal interviews with several crewmen have revealed that reflections upon personal notes made during flight or review of transcript comments sometimes surprises them in terms of what was important to them at that moment versus what is important to them later in terms of new and demanding requirements for ongoing or upcoming responsibilities. These inputs, acquired as closely as possible to the event that stimulated the response, are a big part of what man-machine engineers need to conduct meaningful evaluations of man-machine interfaces under actual operational conditions.

An element of timing in data retrieval that had never been available to or exploited by man-machine engineers prior to Skylab was the opportunity to see or hear something relayed from the spacecraft that stimulated thought on the ground about alternative methods of operation, additional data takes under like or varying circumstances, and the request for clarification. Without real-time or near real-time feedback from the crewmembers aboard the spacecraft, this valuable tool of investigation is lost. No one is in a better position to evaluate the adequacy of design of some item than the crewmember actually using it in a flight situation.

Finally, there are quantitative measurements to be made that cannot be accomplished anywhere other than in the operational environment. This point needs much amplification in future missions as the man-machine engineering discipline seeks to move toward the quantitative end of the data scale and away from over-dependence upon qualitative or subjective impressions as a primary means of evaluation.

POSTSCRIPT

The list of Skylab Experience Bulletins in Appendix 1 needs further explanation. The list shown was an intended total of all bulletins to be published. Due to time and workload constraints, some will not be completed under the cover of bulletins, but it is intended that the subject matter of those yet unpublished be addressed in some form and transmitted to anyone needing to be aware of Skylab results in that area. Unfortunately this will leave gaps in the numbering system of the bulletins, since those already published and those in preparation at this time were assigned a number when the total inventory was developed. However, whatever form of report the information takes when it is documented will be forwarded to the standard bulletin distribution list to insure continuity of information flow.

CONCLUSIONS AND RECOMMENDATIONS

1. Man-machine engineering investigations such as those conducted during the Skylab missions are essential to the manned spaceflight business and should be continued and expanded in future programs.

2. Collecting data inflight is essential rather than relying completely on crew recall in postmission debriefings.

3. The techniques and methods of data collection employed during Skylab missions were satisfactory and acceptable to crewmembers. These should become a baseline to build upon in future programs.

4. Man-machine engineering evaluations need to move in the direction of becoming more quantifiable and less subjective.

5. Investigator involvement is an essential ingredient in man-machine engineering evaluations and should be encouraged and supported at all levels of technical and managerial organization.

6. Dedicated man-machine engineering participation is required in the control center during manned missions.

7. Maintaining a core of experienced personnel, who are temporarily free of other responsibilities, to document man-machine engineering results of manned missions is essential to insure that useful information is continually fed back into the manned spaceflight business.

8. Official program recognition and status must be afforded man-machine engineering evaluations on all manned missions to insure assignment of priorities and recognition of requirements for the discipline.

9. The format and techniques employed in publishing the Skylab Experience Bulletins have proven to be acceptable and expiditious for distribution of information to a wide range of users. These methods should be viewed favorably as convenient means of reporting results in similar future situations.

10. Cataloging future man-machine engineering data to be compatible with the system generated following the Skylab Program would enhance the continuity of the system and would place the data in a format familiar to potential users.

REFERENCES

1. NASA, George C. Marshall Spaceflight Center, Experiment Requirements Document for Habitability/Crew Quarters (Experiment M487), SE-010-049-2H, May 5, 1972.

2. NASA, Lyndon B. Johnson Space Center, Skylab Medical Experiments Altitude Test (SMEAT), TMX-58115, October 1973.

3. NASA, Manned Spacecraft Center, Experiment Requirements Document for Crew Activities/Maintenance Study (Experiment M516), MSC-03057, May 31, 1972.

LIST OF APPENDICIES

APPENDIX 1

LIST OF PLANNED AND PUBLISHED SKYLAB EXPERIENCE BULLETINS

Appendix 1

Planned and Published Skylab Experience Bulletins

1. JSC-09535, Skylab Experience Bulletin No. 1, Translation Modes and Bump Protection, June 1974.
2. JSC-09536, Skylab Experience Bulletin No. 2, Architectural Evaluation for Airlock, June 1974.
3. JSC-09537, Skylab Experience Bulletin No. 3, Architectural Evaluation for Sleeping Quarters, July 1974.
4. JSC-09538, Skylab Experience Bulletin No. 4, Design Characteristics of the Sleep Restraint, July 1974.
5. JSC-09539, Skylab Experience Bulletin No. 5, Inflight Maintenance as a Viable Program Element, September 1974.
6. JSC-09540, Skylab Experience Bulletin No. 6, Space Garments for IVA Wear, August 1974.
7. JSC-09541, Skylab Experience Bulletin No. 7, An Overview of IVA Personal Restraint Systems, October 1974.
8. JSC-09542, Skylab Experience Bulletin No. 8, Cleansing Provisions Within the Waste Management Compartment, October 1974.
9. JSC-09543, Skylab Experience Bulletin No. 9, Foot Restraint Systems, December 1974.
10. JSC-09544, Skylab Experience Bulletin No. 10, Body Restraint Systems, December 1974.
11. JSC-09545, Skylab Experience Bulletin No. 11, Personal Mobility Aids (IVA), January 1975.
12. JSC-09546, Skylab Experience Bulletin No. 12, Temporary Equipment Restraints, February 1975.
13. JSC-09547, Skylab Experience Bulletin No. 13, Tools, Test Equipment, and Consumables Required to Support Inflight Maintenance, November 1974.
14. JSC-09548, Skylab Experience Bulletin No. 14, Personal Hygiene Equipment, January 1975.
15. JSC-09549, Skylab Experience Bulletin No. 15, Cable Management in Zero-G, September 1975.

*16. JSC-09550, Skylab Experience Bulletin No. 16, Off-Duty Activity.

17. JSC-09551, Skylab Experience Bulletin No. 17, Neutral Body Posture in Zero-G, July 1975.

18. JSC-09552, Skylab Experience Bulletin No. 18, Evaluation of Skylab IVA Architecture, December 1975.

19. JSC-09553, Skylab Experience Bulletin No. 19, Food System, February 1976.

**20. JSC-09554, Skylab Experience Bulletin No. 20, Designing for Inflight Maintenance Accessibility.

*21. JSC-09555, Skylab Experience Bulletin No. 21, IVA Environment.

*22. JSC-09556, Skylab Experience Bulletin No. 22, Evaluation of Requirements and Provisions for Housekeeping.

*23. JSC-09557, Skylab Experience Bulletin No. 23, IVA Communications.

**24. JSC-09558, Skylab Experience Bulletin No. 24, Evaluation of Zero-G Shower.

*25. JSC-09559, Skylab Experience Bulletin No. 25, Waste Management Systems.

***26. JSC-09560, Skylab Experience Bulletin No. 26, Stowage Accommodations.

27. JSC-09561, Skylab Experience Bulletin No. 27, Personal and Equipment Restraint and Mobility Aids (EVA), May 1975.

**28. JSC-09562, Skylab Experience Bulletin No. 28, Mass Handling and Transfer.

**29. JSC-09563, Skylab Experience Bulletin No. 29, Man-Machine Interface Influence on Timelines (IVA).

***30. JSC-09564, Skylab Experience Bulletin No. 30, Architectural Evaluation of Wardroom.

***31. JSC-09565, Skylab Experience Bulletin No. 31, Architectural Evaluation of Waste Management Compartment.

***32. JSC-09566, Skylab Experience Bulletin No. 32, Architectural Evaluation of Experiment Compartment.

* Still to be published.

** Cancelled.

*** Originally planned bulletin incorporated into Bulletin #18.

***33. JSC-09567, Skylab Experience Bulletin No. 33, Architectural Evaluation of Forward Dome Compartment.

***34. JSC-09568, Skylab Experience Bulletin No. 34, Architectural Evaluation of MDA/STS.

35. JSC-09569, Skylab Experience Bulletin No. 26, The Methods and Importance of Man-Machine Engineering Evaluations in Zero-G, May 1976.

*** Originally planned bulletin incorporated into Bulletin #18.

APPENDIX 2

EXPERIMENT M487 FILM SUBJECT TABLES

SL-2 M487 Photographic Requirements

Subject	Mission Time	Frame Rate (fps)	Running Time (Minutes)
Eating of Meal (Evening)	Early	6	10
Eating of Meal (Evening)	Late	6	10
Doff Clothing and Ingress Sleep Restraint	Early	6	2
Doff Clothing and Ingress Sleep Restraint	Late	6	2
Egress Sleep Restraint and Donn Clothing	Early	6	2
Egress Sleep Restraint and Donn Clothing	Late	6	2
Clean Mixing Chamber Screens in Dome	Early	2	10
Clean Mixing Chamber Screens in Dome	Late	2	10
Trash Airlock Operation	Mid	2	3
Trash Airlock Operation	Late	2	3
Demo of Activity in WMC	Mid	2	5
Crew Choice Various Off-Duty and Hygiene Activities	As Available	Crew Option	Crew Option

SL-3 M487 Photographic Requirements

Subject	Mission Time	Frame Rate (fps)	Running Time (Minutes)
Eating of Meal (Any)	Early	6	5
Eating of Meal (Any)	Mid	6	5
Eating of Meal (Any)	Late	6	5
Cleaning of Mixing Chamber Screens in Dome	Early	2	10
Cleaning of Mixing Chamber Screens in Dome	Mid	2	10
Cleaning of Mixing Chamber Screens in Dome	Late	2	10
Trash Airlock Operation	Early	2	5
Trash Airlock Operation	Mid	2	5
Trash Airlock Operation	Late	2	5
Restocking Pantry	Mid	6	15

SL-4 M487 Photographic Requirements

Subject	Mission Time	Frame Rate (fps)	Running Time (Minutes)
Eating of Meal (Any)	Early	6	5
Eating of Meal (Any)	Mid	6	5
Eating of Meal (Any)	Late	6	5
Cleaning of Mixing Chamber Screens in Dome	Early	2	10
Cleaning of Mixing Chamber Screens in Dome	Late	2	10
WMC Activity/Personal Hygiene	Early	6	4
WMC Activity/Personal Hygiene	Late	6	5
Restocking Pantry	Mid	6	14
Checklist Updating	Late	6	20

APPENDIX 3

SUBJECTIVE DATA FORMATS FOR EXPERIMENT M487

SL-2 M487-2A CREW DEBREIFING (ROUNDTABLE DISCUSSION)

1. What particular aspects of the O/A seem well designed and arranged for living and working in zero-g? What aspects are deficient and how?

2. Which restraint device offered the most assistance in performing tasks; which the least? What recommendations do you have for improvements?

3. How effective is non-equipment-assisted verbal communication throughout the O/A? How satisfactory have the intercom boxes been for IVA comm, voice recording, and ground comm? Are their locations in each compartment satisfactory?

4. How satisfactory are the food management and dining accommodations? How well does the food adhere to the utensils when eating? Would a closer tray-to-mouth proximity have improved eating ease?

5. What safety problems have arisen that are directly related to habitability?

6. How satisfactory have the various environmental elements of habitability been in providing a suitable habitat (lighting, noise, temperature, humidity, air flow)?

SL-2 M487-2B CREW DEBRIEFING (ROUNDTABLE DISCUSSION)

1. How adaptable are the various compartments to multi-uses beyond their prime design function (e.g., does the sleep compartment double for off-duty reading, etc.)?

2. How adequate has the sleep restraint been for sleeping? Has it been useful for anything other than sleeping? If so, what?

3. What non-eating uses have been found for the wardroom table? Would a design modification of the table and its associated restraint be desirable for any or all uses?

4. What sanitation problems have developed and how have you dealt with them?

5. What is the most disconcerting personal hygiene problem you have encountered?

6. How effective and efficient are the cleanup procedures and hardware? How much of a timeline imposition are cleanup chores?

7. How adequate is the ATM "Chair?" Is it readjusted for each crewman? Do you use the shoes/grid with it? Is the toebar useful? Do you use the chair anywhere other than at the ATM? Where? What design improvements do you recommend?

8. How comfortable are your garments in terms of fit, warmth, and don/doff ease? Were they sufficiently resistant to tearing and abrasion? Did they tend to snag as you moved about the O/A? What recommendations do you have for improving IVA garments?

9. What changes have you detected in the environmental elements discussed as the last question in the first debriefing? Have you used any of the M487 instruments to document these changes?

SL-2 M387-2C CREW DEBRIEFING (ROUNDTABLE DISCUSSION)

1. Which is preferable, the floor/ceiling orientation of the OWS, or the open cylindrical arrangement of the MDA/STS? How do the tasks to be performed influence your preference of orientation?

2. How adequate are the restraints and mobility aids throughout the O/A? Are more needed? Where? Are some unnecessary? Which ones?

3. How often have environmental factors (e.g., noise, temp, airflow, illumination) interfered with your ability to perform a task? Which tasks and where? Have any of these factors interfered with your ability to sleep?

4. What unique off-duty activities have you devised to supplement those provided in the ODAE kit? What recommendations do you have for improving recreational facilities and equipment for future programs? Are such items an important consideration for a mission the length of yours?

5. In terms of your zero-g living and working experiences during this mission, what specific habitability improvements would you recommend for the next Skylab crew; for future programs?

6. How satisfactory is the frequency of change of bedding and clothing?

SL-2 M487-3A SUBJECTIVE EVALUATION

INSTRUCTION:

Evaluate and voice record the overall adequacy of the equipment items. Descriptive comments are encouraged, especially concerning the following:

- o Functional performance
- o Convenience of use location and orientation
- o Comfort and ease of use

EVALUATION DEFINITIONS

RATING	DEFINITION
EXCELLENT	IMPROVEMENTS ARE NOT NEEDED AND WOULD ONLY BE A MATTER OF PERSONAL PREFERENCE
VERY GOOD	MINOR IMPROVEMENTS ARE POSSIBLE BUT NOT REALLY NECESSARY
ADEQUATE	SOME SHORTCOMINGS FOUND AND A FEW IMPROVEMENTS ARE DESIRABLE
POOR	NUMEROUS SHORTCOMINGS FOUND AND IMPROVEMENTS ARE NECESSARY
UNACCEPTABLE	GROSS SHORTCOMINGS FOUND AND IMPROVEMENTS ARE MANDATORY

EQUIPMENT ITEMS

WORK RESTRAINTS/MOBILITY AIDS

- o OWS fireman's pole
- o OWS dome and wall handrails
- o STS handrails
- o MDA handholds/handrails
- o Triangular shoes/grid
- o Water tank foot platform
- o ATM foot platform
- o Portable M512/M479/EREP foot platform
- o Portable PGA foot restraints
- o Portable handholds (specify where and how used)
- o Portable equipment restraints (tethers, bungees, universal mounts, etc)
- o ATM seat/backrest restraint
- o [illegible]nical shoe cleats/grid

WASTE MANAGEMENT/HYGIENE EQPT

- o Fecal collection equipment
- o Urine collection equipment
- o Urine flush water dispenser
- o Hand washer
- o Fecal/urine collector lap strap and handholds
- o WMC hand washer handrail
- o WMC lt-duty foot restraints
- o WMC ceiling handrail
- o Drying stations
- o Shower

SL-2 M487-3A SUBJECTIVE EVALUATION (Continued)

FOOD MANAGEMENT EQUIPMENT

- o WDRM table (eating sta)
- o Thigh restraints
- o WDRM lt-duty foot restraints
- o Food reconstitution dispenser
- o Water gun
- o Food tray
- o Food cans
- o Beverage dispensers
- o Seasoning dispensers
- o Eating utensils

MISCELLANEOUS

- o Sleep restraint
- o Trash airlock
- o Vacuum cleaner
- o Wardroom table (non-eating uses)

SL-2 M487-3B SUBJECTIVE EVALUATION

INSTRUCTIONS

Evaluate and voice record the design features and accommodations of each compartment (it is not required to be in the compartment being evaluated). Descriptive comments are encouraged, especially for items considered only adequate or less than adequate. Use the following terms:

EVALUATION DEFINITIONS

RATING	DEFINITION
EXCELLENT	IMPROVEMENTS ARE NOT NEEDED AND WOULD ONLY BE A MATTER OF PERSONAL PREFERENCE
VERY GOOD	MINOR IMPROVEMENTS ARE POSSIBLE BUT NOT REALLY NECESSARY
ADEQUATE	SOME SHORTCOMINGS FOUND AND A FEW IMPROVEMENTS ARE DESIRABLE
POOR	NUMEROUS SHORTCOMINGS FOUND AND IMPROVEMENTS ARE NECESSARY
UNACCEPTABLE	GROSS SHORTCOMINGS FOUND AND IMPROVEMENTS ARE MANDATORY

Evaluate each of the following compartments with the habitability parameters:

COMPARTMENTS	HABITABILITY PARAMETER TO BE EVALUATED
WDRM	o General arrangement and orientation of compartment o Volume of compartment
WMC	o Ceiling/Floor proximity o Ingress/Egress provisions
SLEEP	o Trash collection provision o Stowage volume & access
EXPMT	o Temporary equip restraints o Personnel mobility aids
FWD/DOME	o Personnel restraint devices o Thermal comfort
AIRLOCK	o Noise level o Illumination
MDA/STS	

SL-2 M487-3C SUBJECTIVE EVALUATION

INSTRUCTIONS

Evaluate and voice record the frequency of use of items in the following terms:

FREQUENCY EVALUATION TERMS

- Daily or every opportunity
- Every other day
- Once a week
- Every 2-3 weeks
- Never -

  If an item was seldom or never used, explain whether it was a function of poor design, malfunction, no requirement, etc. Though not specifically requested, the adequacy of any item may be independently evaluated by using the evaluation definitions.

ITEMS TO BE EVALUATED

- Jacket
- IV Boots
- IV Gloves
- Bump Hat
- Pillow
- Blankets
- Light Baffle
- Privacy Curtain
- Penlights
- Scissors
- Tool Caddy
- Portable Fan
- Tape Player
- Headset
- Microphone
- Playing Cards
- Books (pleasure)
- Hand Exerciser
- Hand Balls
- Dart Set
- Exer-Gym
- Binoculars
- Windows (off duty)

SL-3 M487-3 SUBJECTIVE EVALUATIONS (SL-2 DEVIATIONS)

M487-3A SUBJECTIVE EVALUATION GUIDE

WORK-RESTRAINTS/MOBILITY AIDS CATEGORY

Deletion	• Portable M512/M479/EREP Foot Platform

WASTE MANAGEMENT/HYGIENE EQUIPMENT CATEGORY

Addition	• Personal Hygiene Kit
Deletion	• Urine Flush Water Dispenser

MISCELLANEOUS CATEGORY

Additions	• Tool Caddy • Portable Fan • Off Duty Activity Equipment (ODAE) Kit Garments • Light Baffle • Privacy Curtain

M487-3C SUBJECTIVE EVALUATION GUIDE

Deletion	• The Entire Guide

SL-4 M487-3A SUBJECTIVE EVALUATIONS (SL-3 DEVIATIONS)

WORK RESTRAINT/MOBILITY AIDS CATEGORY

Addition	• WMC Hand Washer Handrail • Towels/Wash Cloths • General Utility Wipes • Wet Wipes • Biocide Wipes • Utensil Wipes • Trash and Plenum Bags • Urine/Fecal Bags

MISCELLANEOUS CATEGORY

Additions	• Air Diffusers • Air Vents (Sleep Compartments)

APPENDIX 4

EXPERIMENT M516 FILM SUBJECT TABLES

SL-2 M516 PHOTOGRAPHIC REQUIREMENTS

Subject	Mission Time	Frame Rate (fps)	Running Time (Minutes)
Relocation of Food Lockers F550 and F561	Early	2	15/Locker
M509 Unstowage from Launch Configuration	Concurrent W/M509	2	10
Transfer of Resupply Food Bundle to Pantry	Mid	2 2	5 5
Transfer to Resupply Food Bundle to Pantry	Late	2 2	5 5
Removal of Film Cassette From S054 Magazine	Post EVA-S054 Film Retrieval	6	10
Unscheduled Maintenance	As Required	Crew Option (2 pre-ferred)	33
Demonstration of ATM Chair Setup and Use	As Available	2	10

SL-3 M516 PHOTOGRAPHIC REQUIREMENTS

Subject	Mission Time	Frame Rate (fps)	Running Time (Minutes)
Reload Teleprinter Paper	Early	6	5
Reload Teleprinter Paper	Mid	6	5
S183 Unstow, Relocate, Mount	Mid	2	10
S183 Unstow, Relocate, Mount	Late	2	10
Mol Sieve Charcoal Canister Replacement	Mid	6	5
Unscheduled Maintenance Activities	As Required	2	23
Remove Film Cassette from S054 Magazine	Mid	6	15

SL-4 M516 PHOTOGRAPHIC REQUIREMENTS

Subject	Mission Time	Frame Rate (fps)	Running Time (Minutes)
M516 Push/Pull Force Measuring Task	As Scheduled	2	15
Demo of OWS Air Mixing Chamber Screens as a Maintenance Station	As Scheduled	6	10
Removal of Film Cassette from S054 Magazine	Following 1st EVA	6	10
MOL Sieve "A" Charcoal Canister Replacement	Concurrent with HK-28H	6	5
IMSS Demo	As Scheduled	2	5
IMSS Demo	As Scheduled	6	5
Unscheduled Maintenance Activities	As Required	2	23

APPENDIX 5

SUBJECTIVE DATA FORMATS FOR EXPERIMENT M516

M516 INFLIGHT DEBRIEFING QUESTIONS

1. How effective are the various tools used thus far; in particular which are poorly suited for use in zero-g? Did you find that you needed any tools other than those provided in the kits? (SL-2, 3 and 4)

2. What postural adjustments have you had to make in order to accommodate task performance in zero-g? What major muscle groups do you employ in zero-g as opposed to one-g? Would you offer any design recommendation for future vehicles based upon these considerations? (SL-3 and 4)

3. The previous Skylab crew observed that handling large masses was far less difficult than handling multiple items of relatively small mass. Has your experience been similar, and what logistic management techniques have you employed to cope with this problem? (SL-3 and 4)

4. Have you found that you could accomplish maintenance tasks reasonably well either on-line or at improvised work sites, or would these chores have been simplified by having a dedicated maintenance station? Would you recommend a dedicated maintenance station for future long term mission? (SL-3 and 4)

5. What is your prime method of removing reactive forces when you must exert linear push or pull forces during a task? Removing torques? (SL-3 and 4)

6. Have you noted a definite tendency to establish an IVA coordinate system as a frame of reference for locomoting and working within the various modules and compartments of Skylab? Discuss the application you feel this should have in the design of future vehicles. (SL-3 and 4)

7. What is your opinion concerning the advisability of exerting design influence to standardize (for future vehicles) the multiple types of snaps, latches, retainers, restraint, doors, etc. that you have been confronted with aboard Skylab. (SL-3 and 4)

8. What unanticipated problems have occurred in performing various activation, housekeeping or experiment activities to date? Are there any common difficulties that can be traced to inadequacies of design, onboard provisions, or preflight preparations? (SL-2, 3 and 4)

9. What individual work activities have required assistance from another crewman? What activities scheduled as two-man tasks have required only one man? (SL-2)

10. Discuss both the beneficial and the detrimental effects of zero-g on the following types of activities: (SL-2, 3 and 4)

    a) individual work activities while restrained at a specific work location
    b) handling and transferring various sized equipment items (small, medium, large)
    c) work activities requiring assistance from another crewman
    d) personal maintenance activities (personal hygiene, donning/doffing garments, etc)
    e) waste management and cleanup chores
    f) locomotion in and through the various OA compartments

M516 SUBJECTIVE EVALUATION GUIDE

INSTRUCTIONS

Using the following 5-point guidelines, evaluate the overall adequacy of the equipment provided to accomplish routine and unscheduled maintenance tasks and the design acceptability of the tasks themselves from the point of view of access, logistic management during disassembly/reassembly, tool and component/parts restraint, and overall ease of task accomplishment. (SL-2, 3 and 4)

EVALUATION DEFINITIONS

RATING	DEFINITION
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ADEQUATE	SOME SHORTCOMINGS FOUND AND A FEW IMPROVEMENTS ARE DESIRABLE
POOR	NUMEROUS SHORTCOMINGS FOUND AND IMPROVEMENTS ARE NECESSARY
UNACCEPTABLE	GROSS SHORTCOMINGS FOUND AND IMPROVEMENTS ARE MANDATORY

-TOOL INVENTORY-

* Tool Kit #1
* Tool Kit #2
* Repair Kit
* S190 Maint Kit
* M512 Tools
* EMU Maint Kit

-MISC. SUPPORT ITEMS-

* Adequacy of Work Sites
* Adequacy of Lighting
* Adequacy of On-Board Data Pkg
* Adequacy of Pre-Flt Prep for Maint Tasks

-MAINTENANCE TASKS-

Scheduled Replacement Items
  * Solids Traps
  * MOL Sieve Char Canisters
  * PPCO2 Inlet/Outlet Cartgs
  * PPO2 Cartgs
  * EVA/IVA Cool Gas Separator
  * WMC Vent Filter
  * WMC Char Canister
  * Fecal Collector Filter
  * Urine Separators

Scheduled Cleaning Items
  * OWS Air Mix Chmb Screens
  * WMC Vent Filter
  * AM/OWS Circ Filter Screens

Unscheduled Replacement Items
  * Fans
  * Valves
  * Seals
  * Lights
  * Other (define item)

Unscheduled Repair Items
  *Identify Task and Evaluate