Space Station

WORK PACKAGE 2
ADVANCED DEVELOPMENT

SSS87-0071

HUMAN FACTORS REPORT (FINAL)

PROJECT 30 MANNED SPACE SYSTEMS HABITABILITY

JANUARY 16, 1987

Prepared by: Project Engineering-Advanced Development/
Rockwell/Grumman
For NASA Lyndon B. Johnson Space Center

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This document is submitted by the Rockwell Space Station Systems Division Advanced Development Project Office in compliance with the Advanced Development Plan (DR-05), Rockwell document No. SSS 85-0011, Revision 4, dated November 10, 1986.

The data contained in this document was generated as part of the project identified in the Space Station Advanced Development Plan as Project 30, Manned Space System Habitability. This corresponds to Grumman IR&D Project S143-301 under the direction of G. Harms. This data was identified and released to the Space Station Systems Division as Grumman document SS005-ATD-08.

ABSTRACT

The objective of Grumman's Manned Space Systems Habitability IR&D project is to develop guidelines and design criteria for Space Station habitat modules by focusing on three related functional disciplines: human factors, interior architecture, and crew support. Specific objectives for the human factors study are to: establish a data base of human performance criteria and requirements, define human factors guidelines and design criteria for habitation module interior architecture, and establish the methodology for evaluating the man-machine interfaces involved in habitation module interior design.

This report includes an update of a study previously reported in the last Interim Report concerning the estimation of crew productivity on the Space Station. It's main thrust is to determine the amount of crew on-duty overhead time required to operate and maintain the Space Station. The amount of on-duty time remaining represents the available time to perform productive customer operations. This is the single most critical criteria for determining the cost-effectiveness of the Space Station.

Remaining portions of this report describes crew task and time analyses for the Galley and the Wardroom, the Personal Hygiene and Waste Collection Accommodations, and the Exercise Facility.

The final section describes the way in which the full size Habitation Module mock-up was used in initial evaluations of the Galley/Wardroom baseline and alternative design concepts.

Previous Manned Space Stations Habitability Human Factors reports provided initial human performance criteria, and requirements and guidelines for Habitation Module interior architectural design.

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1 - INTRODUCTION

This is the final report of the Human Factors study conducted as part of Grumman's Manned Space Systems Habitability IR&D project described in the Advanced Development Plan, WP-2 Space Station Definition and Preliminary Design Phase, 751B/GR05-01 Grumman Aerospace Corporation, dated 1 May 1985. The overall objective of this Grumman IR&D project is to develop guidelines and design criteria for Space Station habitat modules by focusing on three related functional disciplines: human factors, interior architecture and crew support. The human factors contribution to this project includes the following tasks:

- Establishing a data base of human productivity criteria/requirements
- Defining human factors guidelines and design criteria for habitation module interior architecture
- Establishing the methodology for evaluation of habitation module interior designs for conducting human factors evaluation of habitation module mockups.

The initial data base of human factors guidelines and requirements was completed and is contained in the Interim Report. The initial productivity study described in the Interim Report has been updated and is included herein. Also included are detailed task and time analyses for the Galley/Wardroom, the Personal Hygiene and Waste Collection; and Exercise Facilities. In addition, a preliminary methodology was developed for evaluating the Habitation Module interior design. The mockup evaluation methodology was applied to examining Galley/Wardroom design for both the Grumman Space Station Division (GSSD) baseline and alternative concepts.

2 - SUMMARY

Section 3 presents an update of the initial study to develop and analyze representative crew tasks and performance times, and which are used as a basis from which productivity assessments can be made. Originally identified as Trade 26, Human Productivity, this effort evolved to be an evaluation criterion for system design. In the conduct of the study, eleven major on-duty crew task categories were generated, their task times estimated and appropriately assigned to each crew skill type comprising the crew complement. The categories included:

- Logistics Resupply and Crew Changeout
- OMV Berthing/Unberthing
- Station Maintenance Intravehicular Activities (IVA) and Extravehicular Activities (EVA)
- Facility Cleandown
- Training
- Station Management
- Planning
- EVA Support
- Lunch
- Shift Handover
- Unscheduled Slack Time.

On-duty overhead time estimates per crew specialty area (i.e., Station Operator, Mission Specialist and Payload Specialist) were determined along with total crew time. Results indicated that 45.8% of the crew's time was required to be devoted to these custodial activities to maintain the core station in an operational condition; and to serve as a base for performing on-orbit productive customer activities.

The principal contributors to this high level of overhead were EVA Station Maintenance and Station Management, including the pre- and post-activities required for conducting EVA activities. As crew time is a measurably expensive resource, the primary objective of system design is to achieve and maintain high levels of human productivity by:

- Integrating advanced technology options
- Applying sound human factors design principles to the man-machine interface
- Designing habitation for motivation and user acceptance.

Sections 4, 5, and 6 report on the results of task and time analyses for the Galley/Wardroom, Personal Hygiene and Waste Collection, and Exercise Facilities. The results indicate the basic design approach satisfies the operational requirements for achieving the functional purposes of the specific accommodations and the time requirements for crew performance.

Section 7 describes the use of the Habitation Module mock-up as a design tool and ways for improving the design of the Galley/ Wardroom. The results showed that major improvements are needed in Galley work surface area, food selection techniques, design of doors and drawers, Wardroom table design, and in loose item retention techniques. However, the overall arrangement of the Galley, with respect to the work flow associated with meal set-up, food retrieval and preparation, food cooking and dispensing, and serving and clean-up, appears to satisfy the needs for efficiency, safety and traffic flow for a crew of eight.

3 - HUMAN PRODUCTIVITY

3.1 OBJECTIVES

Human Productivity is considered an evaluation criteria to be used in assessing the economic feasibility of alternate approaches to Space Station design, rather than as a trade study in itself. Principal elements are:

- The cost of resources provided to the crew to enable them to generate usable output
- The amount of time required by the crew to perform the tasks needed to generate usable output.

To date, the major thrust of GSSD's Human Productivity effort has been on determining the tasks and task times for that portion of on-duty crew time associated with overhead, i.e., those tasks needed to maintain and operate the core facility. Subtracting the estimated on-duty overhead time from the total 12 hours allocated daily work time yields the amount of time available for supporting customer payload operations. The latter represents on-duty productive time.

The distinction between the activities and time spent by operational personnel in tending the core facility, versus supporting and implementing customer activities, is one of the central issues in Space Station human productivity.

3.2 SCOPE

This report begins by describing the results of an initial study presented in Section 4 of GSSD's Manned Space Systems Habitability Human Factors Interim Report SS005/ATD-06, dated 3 April 1986, entitled "Crew Task Allocations and Time Estimates." The purpose of that study was to initiate development of representative Space Station crew tasks and to estimate their performance times as a basis from which productivity assessments could be made. This effort focused on the on-duty crew overhead activities required to operate and maintain core Space Station facilities with a crew of six.

The crew activities investigated and described were concerned with both IVA and EVA on-duty overhead tasks that, in general, included:

- Proximity operations
- Station maintenance and shift handover
- Logistics and housekeeping
- Station management
- Planning
- Training
- Eating.

Task definition was, in most cases, at a top level of description. The methods of task definition and time determination varied and included:

- Rationale assessment
- Use of available analogs
- Use of expert opinion, i.e., flight personnel and engineering designers
- Simple task analysis
- Use of existing studies
- Consideration of NASA guidelines.

The results of this initial study are described in Subsection 3.3, and its method formed the basis for examining the task and time allocations for a crew complement of eight. The results of this follow on study are described in Subsection 3.4 of this report.

3.3 RESULTS OF INITIAL STUDY FOR A CREW COMPLEMENT OF SIX

3.3.1 Groundrules & Assumptions

1. Space Station configured as follows:
   - Two Habitability Modules
   - Two Laboratory Modules
   - One Logistics Module.

2. The mix of crew skills on each 12 hour shift included:
   - One Station Specialist (in charge of the Station and whose principal activities are in systems management and in the support of science and payload operations)
   - Two Mission Specialists (subordinate to S/S Commander and whose main purpose is to perform EVA, Remote Manipulation Systems (RMS), Orbit Maneuvering Vehicle/Orbit Transfer Vehicle (OMV/OTV) and customer operations).

3. Overhead was considered any activity concerned with operating or maintaining the core station.

4. Productive time was considered any activity concerned with performing customer operations.

5. As most major activities have some element of "Housekeeping" or "Logistics" inherent in them, there was no separate breakdown for these categories. Hence, they are included in their respective overhead or productive categories.

6. EVA and IVA Scheduled and Corrective (Unscheduled) maintenance manhours were derived from Rockwell International's (RI) "top down" analysis as per their DR-07 Operations Planning, Appendix C, On-Orbit Maintenance Plan, SSS85-0208, dated 20 December 1985.

7. The analog for Space Station Facility Cleandown was the final Foreign Object Debris (FOD) for Grumman's E-2C aircraft as performed by its manufacturing department.

8. The main assumptions for logistics resupply/crew changeout included:
   - The Space Station RMS berths and releases the orbiter
   - The orbiter RMS removes and replaces the logistics module
   - All 12 crewmembers eat during this period but not necessarily at the same time
   - All Space Station disconnect/closeout and reconnect/start-up activities occur and are chargeable to this period as overhead
   - Low g-sensitive payload and/or experimental operations occurring during this period are suspended
   - The orbiter commander stays in the orbiter
   - This event will occur approximately six times per year and will involve every member of the crew during its eight hour duration.

9. The arrival and departure flight control operations associated with the OMV begin and end at a range of 12,000 feet, respectively.

10. A 15 minute/day/crewmember budget was established for training.

11. It was generally assumed that, for Station Management, decision-making would be augmented by expert systems and executive (supervisory) control systems such that systems status and control could be made in a rapid and efficient manner. Subsystems affected would include:
    - ECLSS
    - Propulsion

- *Communications and Tracking*
- EPS
- GN&C
- DMS
- Thermal Control
- Habitability.

12. Specific assumptions concerning Station Management included the following:
    - Critical functions would probably be automated, but would also be supervised full time by a crewmember during real-time operations, and probably also observed by Mission Control Center (MCC). These included dynamic activities such as:
        - OMV/Space Transportation System (STS) proximity operations
        - Station-keeping reboost
    - Other functions would be carried out without 100% human monitoring, but would signal crewmembers and/or MCC with alarms if system or consumable red lines were violated
    - Manual override must be provided for critical functions.

13. Assumptions in the area of Planning included the following:
    - Planning will include task/operations sequencing, manpower/skills allocation, timeline generation, master plan preparation and printout of updated checklists for insertion into/replacement of both IVA and EVA checklist books/cards and CRT formats
    - Planning would be done at appropriate levels of detail, e.g.,:
        - Per speciality area
        - Per shift
        - Per day
        - Per week or biweekly
        - Per core station/payload mission activity

- Continuous planning by the crew, ground and NSTS is a fairly subtle process. However, it is expected that there would be a planning freeze once per shift which is always subject to revision based upon changing requirements. An executive planner (expert system problem-solver/conflict resolver) would accept inputs from Data Management Systems (DMS), and update plans and schedules including insertion of unscheduled/contingency events in real-time, i.e., as events unfold
- Based on NASA's Space Station Flight Operations Plan of 15 July 1985, one hour of planning per crewmember/ day is assumed for this activity category.

14. EVA Don/Doff/Servicing was based on the following:
    - Two crewmembers/EVA
    - One hour pre-EVA and two hours post-EVA support time
    - The monitoring by an IVA crewmember of the EVA crewmembers one-third of the EVA time
    - The use of Option 4 hardsuit, which eliminates the need for prebreathing
    - Eighty hours/PLSS of maintenance support time to obtain the maximum on-orbit life of each unit.

15. The on-duty meal period was considered to be lunch. Lunch occurs in the middle of the on-duty period and, contrary to NASA guidelines, is considered the short, or 1/2 hour meal period, of the day.

16. A meal involving six crewmembers eating simultaneously would require, for efficiency purposes, one crewmember to retrieve and prepare the food for cooking, and one crewmember to cook and serve. One other crewmember would assist in setting up the wardroom table.

17. A goal of 15 minutes/day was established for shift handover for each shift, i.e., 15 minutes for the on-duty crewmembers, and 15 minutes for the off-duty crew coming on duty.

18. NASAs estimate of one hour/day/crewmember was used for unscheduled slack time. Included in this estimate is time required for personal hygiene needs.

19. The manner in which the on-duty, off-duty and days-off hours/year/crewmember were determined was as follows:

    Available Hours/Crewmember/Year Based On:

313	Working Days/Year
52	Days Off/Year
365	Days/Year (8760 Hours)

    Therefore:

3756	On-Duty Hours/Year	(313 Workdays x 12 Hour Shift)
3756	Off-Duty Hours/Year	(313 Workdays x 12 Hour Off)
1248	Days-Off Hours/Year	(52 Days x 24 Hours)
8760	Hours/Year	

3.3.2 Conclusions

3.3.2.1 Task Categories - Eleven major on-duty overhead task categories emerged from the study. These are shown in Table 3-1 along with the overhead hours/year/crewmember.

Both IVA and EVA activities are indicated. The majority of the time is devoted to station maintenance including EVA Station maintenance and the time required to support EVA activities. Considerable time is allocated to Station Management where, in spite of the degree of automation anticipated to be onboard, considerable crew attention is expected to be required to monitor and check the performance of automated systems in order to gain confidence in their reliability.

Table 3-2 consolidates study results into a distribution of hours/year/crewmember which results from estimating the on-duty overhead task times.

Table 3-1 Task Categories & Estimated Times for On-Duty Overhead Hours/Year/Crewmember

	IVA	EVA	TOTAL
1. SPACE STATION/ORBITER BERTHING/CREW CHANGEOUT/LOGISTICS RESUPPLY	48.0	-	48.0
2. OMV BERTHING/UNBERTHING	11.7	-	11.7
3. STATION MAINTENANCE	209.7	314.6	524.3
4. FACILITY CLEANDOWN	27.5	-	27.5
5. TRAINING	78.3	26.1	104.4
6. STATION MANAGEMENT	406.9	-	406.9
7. PLANNING	313.0	-	313.0
8. EVA DON/DOFF/SERVICING	211.3	-	211.3
9. LUNCH	156.5	-	156.5
10. SHIFT HANDOVER	78.3	-	78.3
11. UNSCHEDULED SLACK TIME	313.0	--	313.0
TOTAL	1854.2	340.7	2194.9

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Table 3-2 Distribution of Hours/Year/Crewmember Resulting From Estimating On-Duty Overhead Task Times

	ON-DUTY	OFF-DUTY	TOTAL
PRODUCTIVE	1561.1 (41.6%)	N/A	1561.1
OVERHEAD	2194.9 (58.4%)	3756 MANDATED	5950.9
OFF-DAYS	N/A	1248 MANDATED	1248
TOTAL	3756 MANDATED (100%)	5004 MANDATED	8760 HOURS/YR

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It shows that 2195 hours/year/crewmember out of 3756 hours/year/crewmember of available time are estimated to be devoted to on-duty overhead. This is 58.4% of the total on-duty work time available, and leaves 1561 hours/year/crewmember, representing 41.6% of the mandated 3756 hours/year crewmember, in which to support customer payload activities.

3.3.2.2 Evaluation of Results - It should be understood that, at present, there are no criteria for determining if these percentages are acceptable. However, it was possible to compare the results of this study to the amount of on-duty time suggested as a guideline for crew activity planning that appeared in NASA's Space Station Definition and Preliminary Design RFP, dated 15 September 1984, Table C-3-II. The allocation of on-duty time for each skill category indicated by NASA was:

Mission Specialist	Station Specialist
9 hrs for customer productive operations	4 hrs for support of customer productive operations
3 hrs for overhead operations	8 hrs for overhead operations
12 hrs total on-duty time/day	12 hrs total on-duty time/day

For the six crewmember complement, one Station Specialist and two Mission Specialists were assigned to each shift. Using the work allocation percentages shown above for a single 12 hour on-duty work shift, a comparison between the results of the analysis presented in this report and NASA's guidelines was made as shown in Table 3-3. The results indicate only a 2.7% difference, where NASA's guidelines show less on-duty overhead time than Grumman's analysis. This 2.7% difference is equivalent to 101.4 hours/year/crewmember.

Table 3-3 Comparison of Grumman Analysis vs NASA Guidelines with Respect to Estimating On-Duty Productive & Overhead Crew Task Time

	PERCENT ALLOCATION FOR TASK CATEGORIES FOR A SINGLE ON-DUTY WORK SHIFT PER NASA GUIDELINES			NASA GUIDELINE	VS	GRUMMAN ANALYSIS
TYPE OF ON-DUTY ACTIVITY	STATION SPECIALIST	MISSION SPECIALIST NO. 1	MISSION SPECIALIST NO. 2			
CUSTOMER (PRODUCTIVE) ACTIVITIES	33.3% +	75.% +	75.0% = 183.3 ÷ 3 =	61.1%	VS	58.4%
OVERHEAD ACTIVITIES	66.7% + 100.0%	25.0% + 100.0%	25.0% = 116.7 ÷ 3 = 100.0%	38.9% 100.0%	VS	41.6% 100.0%

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3.4 RESULTS OF FOLLOW-UP ESTIMATES FOR A CREW COMPLEMENT OF EIGHT

The initial study was evaluated by cognizant GSS Space Station personnel. The method used in its derivation was judged to be a reasonable approach to the problem. Consequently when NASA, later in Phase B, mandated an increase in crew size, it was decided to use this approach for a crew complement of eight. The results of this follow-up study are described below. In addition, certain modifications were made in the bookkeeping associated with the charging of overhead versus productive time between major task categories and among crew skill specialty areas.

3.4.1 Groundrules & Assumptions

Refinements to the groundrules and assumptions included the following:

1. Space Station configured as follows:
   - One Habitability/Station Operation Module
   - One Multi-Purpose Module
   - One ESA Module
   - One JEM Module
   - One Logistics Module.

2. Skill specialty assignments as follows:
   - Two Station Operators whose main responsibilities are:
     - Station systems management (command)
     - IVA station systems maintenance
     - Operation of the MRMS with respect to routine station operations; and support of EVA, station and customer operations
     - On-orbit training support to customer systems operations
   - Four Mission Specialists responsible for:
     - Operation and servicing of customer systems
     - Operation of station-provided customer support systems such as:
       - o MRMS with respect to IVA/EVA support
       - o EVA which only the Mission Specialist can perform
     - Operation and servicing of customer systems
     - Operation of station-provided customer support systems such as:
       - o MRMS with respect to IVA/EVA support
       - o EVA which only the Mission Specialist can perform
     - Station systems maintenance such as:
       - o EVA which only the Mission Specialist can perform
       - o IVA, as required, to support the station operator
   - Two Payload Specialists dedicated to IVA operations and the servicing of customer systems.

3. The on-duty overhead time allocated to OMV Berthing/Unberthing is split on a 80% vs 20% basis between Station Operators and the Mission Specialists, with greater time involvement assigned to the Station Operators.

4. All EVA station maintenance (on-duty overhead) and EVA Don/Doff/Servicing activities are assigned to Mission Specialists.

5. Eighty-five percent of Station Management time is assigned to Station Operators, and the remaining 15% is to be accomplished by Mission Specialists.

6. A food/drink system is provided within the spacesuit to enable Mission Specialists to gain nourishments during a full duration EVA of e.g., 7 hours. One-half hour is allocated for this activity.

7. The IVA/EVA maintenance manhours provided by RI for the initial study are considered conservative estimates for the modified Space Station configuration with a crew complement of eight.

8. The use of Grumman's E-2C as an analog for Facility Cleandown activities remains a valid, and perhaps conservative, estimate of the time required for its accomplishment.

9. Payload Specialist time allocation considerations included the following:
   - During the 8 hours of logistics resupply and crew changeout, only 4 hours are charged to on-duty overhead. The remaining 4 hours are considered customer related
   - All laboratory maintenance and cleandown are charged to customer time
   - Some training is required on core station operations and is charged to on-duty overhead
   - All planning and on-duty shift handover activities are charged to the customer
   - One half-hour of unscheduled slack time is charged to on-duty overhead for interfacing with the core station equipment. The remaining unscheduled slack time is charged to the customer.

3.4.2 Results

Merging the groundrules and assumptions established in the initial study for a crew of six with those refinements indicated in the previous section, task times were re-estimated for each of the eight crewmembers as shown in Table 3-4. The addition of two crewmember including the dedication of the Payload Specialists to customer activities, resulted in the reduction of overall on-duty overhead from 58.4% to 45.8% of the total on-duty time available. Table 3-4 shows the time allocations per major task category for each skill specialty area. Table 3-5 shows an IVA vs EVA breakout for appropriate major task categories. Table 3-6 is a summary of the percent of on-duty overhead vs productive time resulting from the analysis for each skill specialty. Table 3-7 shows the estimated, derived and mandated hours and percent of time on-duty and off-duty vs the overhead, productive and off-day categories. The data in Table 3-7 is for a calendar year, where 70,080 is the total hours available for a crew of eight. Included is a breakout of IVA vs EVA on-duty overhead time (in-hours) and percent of time. The key to high productivity is the reduction of IVA, and in particular, EVA maintenance and the accompanying EVA support activities Also, as confidence is gained in allowing automated Station Management to proceed without the redundant parallel monitoring activities of the crew, this task category will experience a reduction in time requirements.

Table 3-4 Task Categories & On-Duty Overhead Manhours Per Year Per Crewmember

	MAJOR TASK CATEGORY	BASIS OF MANHOURS PER YEAR	STATION OPERATORS RED 1 IVA	STATION OPERATORS BLUE 2 IVA	MISSION SPECIALISTS RED 1 IVA	MISSION SPECIALISTS RED 1 EVA	MISSION SPECIALISTS RED 2 IVA	MISSION SPECIALISTS RED 2 EVA	MISSION SPECIALISTS BLUE 3 IVA	MISSION SPECIALISTS BLUE 3 EVA	MISSION SPECIALISTS BLUE 4 IVA	MISSION SPECIALISTS BLUE 4 EVA	PAYLOAD SPECIALISTS RED 1 IVA	PAYLOAD SPECIALISTS BLUE 2 IVA	TOTAL
1	SPACE STATION/ORBITER BERTHING/CREW CHANGEOUT LOGISTICS RESUPPLY	6 EVENTS PER YEAR 8 HRS/EVENT/ CREWMEMBER	48.0	48.0	48.0	-	48.0	-	48.0	-	48.0	-	24.0	24.0	336.0
2	OMV BERTHING/UNBERTHING	12 EVENTS PER YEAR 5.87 HRS/EVENT	28.1	28.1	3.5	-	3.5	-	3.5	-	3.5	-	-	-	70.2
3	STATION MAINTENANCE (CORE STATION ONLY)	TOTAL HRS PER YEAR (HI ESTIMATE)	209.7	209.7	209.7	471.9	209.7	471.9	209.7	471.9	209.4	471.9	LAB ONLY PRODUCTIVE	LAB ONLY PRODUCTIVE	3145.8
4	FACILITY CLEANDOWN (CORE STATION ONLY)	TOTAL HRS. PER YEAR E-2C ANALOG	27.5	27.5	27.5	-	27.5	-	27.5	-	27.5	-	LAB ONLY PRODUCTIVE	LAB ONLY PRODUCTIVE	165.0
5	TRAINING	DAILY BUDGET	78.3	78.3	78.3	6.1	78.3	6.1	78.3	6.1	78.3	6.1	20.0	20.0	534.2
6	STATION MANAGEMENT	DAILY ESTIMATE	1046.3	1046.3	87.2	-	87.2	-	87.2	-	87.2	-	-	-	2441.4
7	PLANNING	NASA DAILY BUDGET	313.0	313.0	313.0	-	313.0	-	313.0	-	313.0	-	PRODUCTIVE	PRODUCTIVE	1878.0
8	EVA DON/DOFF/ SERVICING	146 EVA EVENTS, 2 CREWMEMBERS 7 HRS EVA, 1/3 IVA MONIT.	-	-	317.0	-	317.0	-	317.0	-	317.0	-	-	-	1268.0
9	LUNCH	DAILY GOAL	156.5	156.5	83.5	73.0	83.5	73.0	83.5	73.0	83.5	73.0	156.5	156.5	1252.0
10	SHIFT HANDOVER	DAILY BUDGET	78.3	78.3	78.3	-	78.3	-	78.3	-	78.3	-	PRODUCTIVE	PRODUCTIVE	469.8
11	UNSCHEDULED SLACK TIME	NASA DAILY GUIDELINE	313.0	313.0	313.0	-	313.0	-	313.0	-	313.0	-	156.5	156.5	2191.0
	NOTE: 3756 ON-DUTY HOURS/MAN/YEAR		2298.7	2298.7	1559.0	551.0	1559.0	551.0	1559.0	551.0	1559.0	551.0	357.0	357.0	13,751.4
	X 8 CREWMEMBERS				2110		2110		2110		2110				
	30,048 TOTAL ON-DUTY CREW HOURS/YEAR		61%	61%	56%		56%		56%		56%		10%	10%	45.8%

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Table 3-5 Task Categories & Estimated Times For On-Duty Overhead Hours/Year For a Crew Complement of Eight

MAJOR TASK CATEGORY	ON-DUTY OVERHEAD TIME ALLOCATIONS		
	TOTAL	IVA	EVA
1 SPACE STATION/ORBITER BERTHING/CREW CHANGEOUT LOGISTICS RESUPPLY	336.0	336.0	-
2 OMV BERTHING/UNBERTHING	70.2	70.2	-
3 STATION MAINTENANCE (CORE STATION ONLY)	3145.8	1258.2	1887.6
4 FACILITY CLEANDOWN (CORE STATION ONLY)	165.0	165.0	-
5 TRAINING	534.2	509.8	24.4
6 STATION MANAGEMENT	2441.4	2441.4	-
7 PLANNING	1878.0	1878.0	-
8 EVA DON/DOFF/ SERVICING	1268.0	1268.0	-
9 LUNCH	1252.0	960.0	292.0
10 SHIFT HANDOVER	469.8	469.8	-
11 UNSCHEDULED SLACK TIME	2191.0	2191.0	-
TOTAL ON-DUTY OVERHEAD TIME	13,751.4	11,547.4	2204.0
PERCENT OF TOTAL ON-DUTY TIME	45.8%	38.4%	7.3%

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Table 3-6 Allocation of On-Duty Time by Space Station Skill Speciality

	PERCENT TIME		
SKILL SPECIALTY	OVERHEAD	PRODUCTIVE	TOTAL ON-DUTY
STATION OPERATOR	61%	39%	100%
MISSION SPECIALIST	56%	44%	100%
PAYLOAD SPECIALIST	10%	90%	100%

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Table 3-7 Allocation of Hours/Year For an Eight Person Crew Complement

ACTIVITY TYPE \ SHIFT TYPE	ON-DUTY SHIFT	OFF-DUTY SHIFT	TOTALS
PRODUCTIVE ACTIVITY	16,297 (23.3%)	N/A	16,297 (23.3%)
OVERHEAD ACTIVITY	13,751** (19.6%)	30,048* (42.9%)	43,799 (62.5%)
OFF-DAY ACTIVITY	N/A	9,984* (14.2%)	9,984 (14.2%)
TOTALS	30,048* (42.9%)	40,032* (57.1%)	70,080 (100%)

*Mandated Time

**Breakout of IVA and EVA Activity:

ACTIVITY TYPE \ SHIFT TYPE	ON-DUTY SHIFT
OVERHEAD ACTIVITY	IVA + EVA = TOTAL 11,547 + 2,204 = 13,751 (16.5%) + (3.1%) = (19.6%)

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3.5 SHIFT PROFILES

Using the eleven major on-duty categories as blocks of events, along with identifying top level categories of generic on-duty productive and off-duty activities, it is possible to construct profiles of several types of work shifts. These are shown below. It is then possible to combine these shift types into two-shift mission profile timelines as shown in Fig. 3-1.

3.5.1 Type 1 Logistics Resupply Work Shift

3.5.1.1 On-Duty Overhead Tasks

- Space Station/orbiter berthing/crew changeout/logistics resupply
- Facility cleandown
- Station management
- Planning

- Eating
- Shift handover
- Unscheduled slack time.

3.5.1.2 <u>On-Duty Productive Tasks</u>
- None

3.5.1.3 <u>Off-Duty Tasks</u>
- Personal hygiene
- Health maintenance
- Eating
- Unscheduled slack time
- Shift handover
- Sleep.

3.5.2 <u>Type 2, EVA Maintenance On Core Station Shift</u>

3.5.2.1 <u>On-Duty Overhead Tasks</u>
- EVA/don/doff/servicing
- EVA training
- EVA station maintenance
- Station management
- Planning
- Eating
- Shift handover
- Unscheduled slack time.

3.5.2.2 <u>On-Duty Productive Tasks</u>
- IVA mission payload

3.5.2.3 <u>Off-Duty Tasks</u>
- Personal hygiene
- Health Maintenance
- Eating
- Unscheduled slack time

- Shift handover
- Sleep.

3.5.3 Type 3, IVA Maintenance On Core Station Shift

3.5.3.1 On-Duty Overhead Tasks

- IVA Station maintenance
- Station management
- Planning
- Eating
- Shift handover
- Unscheduled slack time.

3.5.3.2 On-Duty Productive Tasks

- IVA mission payload.

3.5.3.3 Off-Duty Tasks

- Personal hygiene
- Health maintenance
- Eating
- Unscheduled slack time
- Shift handover
- Sleep.

3.5.4 Type 4, EVA Maintenance On OMV Shift

3.5.4.1 On-Duty Overhead Tasks

- OMV berthing (unberthing done during some subsequent shift)
- EVA don/doff/servicing
- EVA station maintenance - OMV
- Station management
- Planning
- Eating

- Shift handover
- Unscheduled slack time.

3.5.4.2 <u>On-Duty Productive Tasks</u>
- IVA mission payload.

3.5.4.3 <u>Off-Duty Tasks</u>
- Personal hygiene
- Health maintenance
- Eating
- Unscheduled slack time
- Shift handover
- Sleep.

3.5.5 <u>Type 5, EVA Mission Payload Shift</u>

3.5.5.1 <u>On-Duty Overhead Tasks</u>
- EVA don/doff/servicing
- Station management
- Planning
- Eating
- Shift handover
- Unscheduled slack time.

3.5.5.2 <u>On-Duty Productive Tasks</u>
- EVA mission payload.

3.5.5.3 <u>Off-Duty Tasks</u>
- Personal hygiene
- Health maintenance
- Eating
- Unscheduled slack time
- Shift handover
- Sleep.

3.5.6 Type 6, IVA Mission Payload Shift

3.5.6.1 On-Duty Overhead Tasks

- Station management
- Planning
- Eating
- Shift handover
- Unscheduled slack time.

3.5.6.2 On-Duty Productive Tasks

- IVA mission payload.

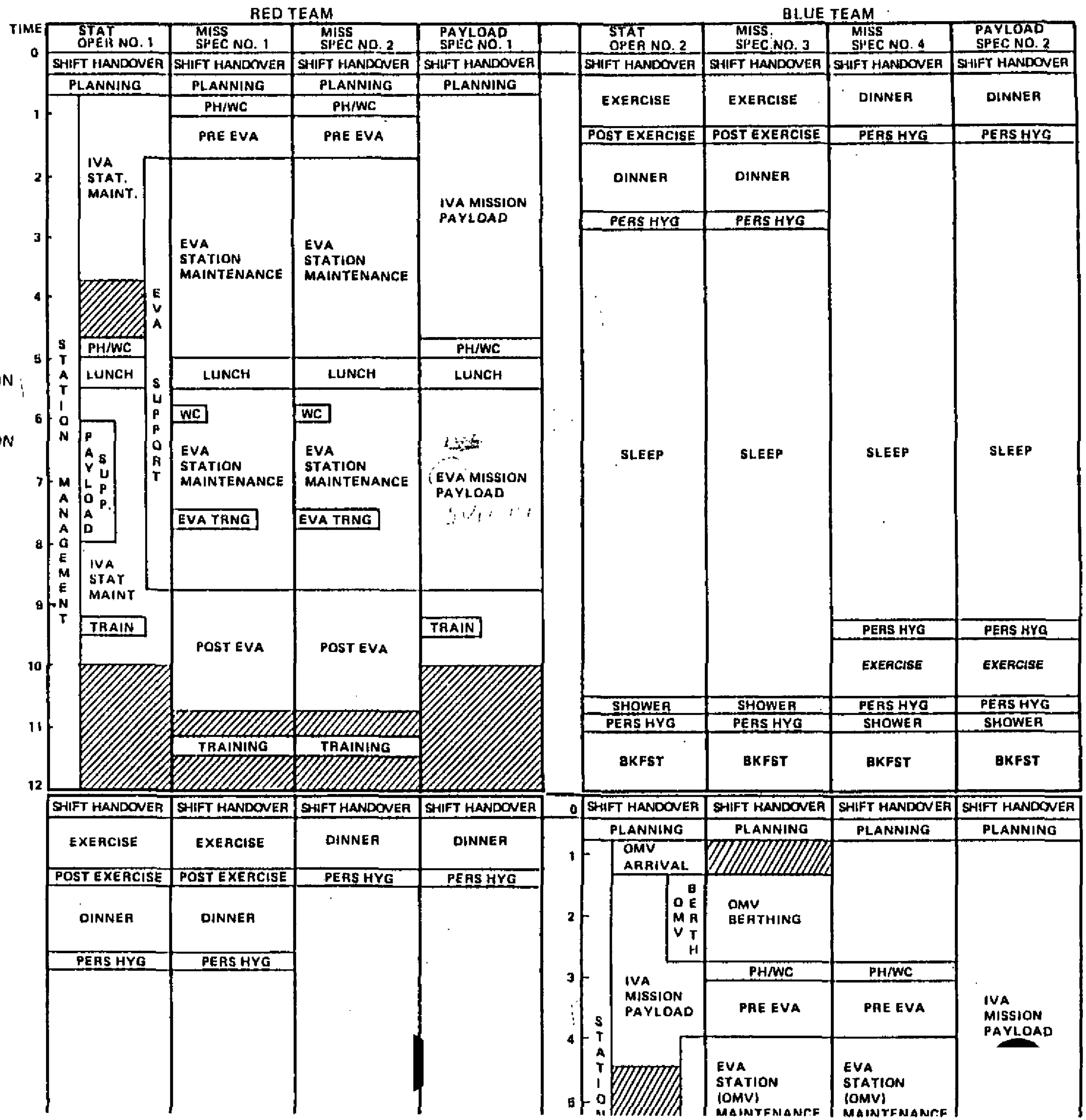
3.5.6.3 Off-Duty Tasks

- Personal hygiene
- Health maintenance
- Eating
- Unscheduled slack time
- Shift handover
- Sleep.

SHIFT
EMPHASIS
USING MAJOR
TASK CATEGORIES

SHIFT TYPE 2 EVA MAINT
ON
CORE STATION

SHIFT TYPE 3 IVA MAINT
ON
CORE STATION



SHIFT TYPE 4 EVA MAINT

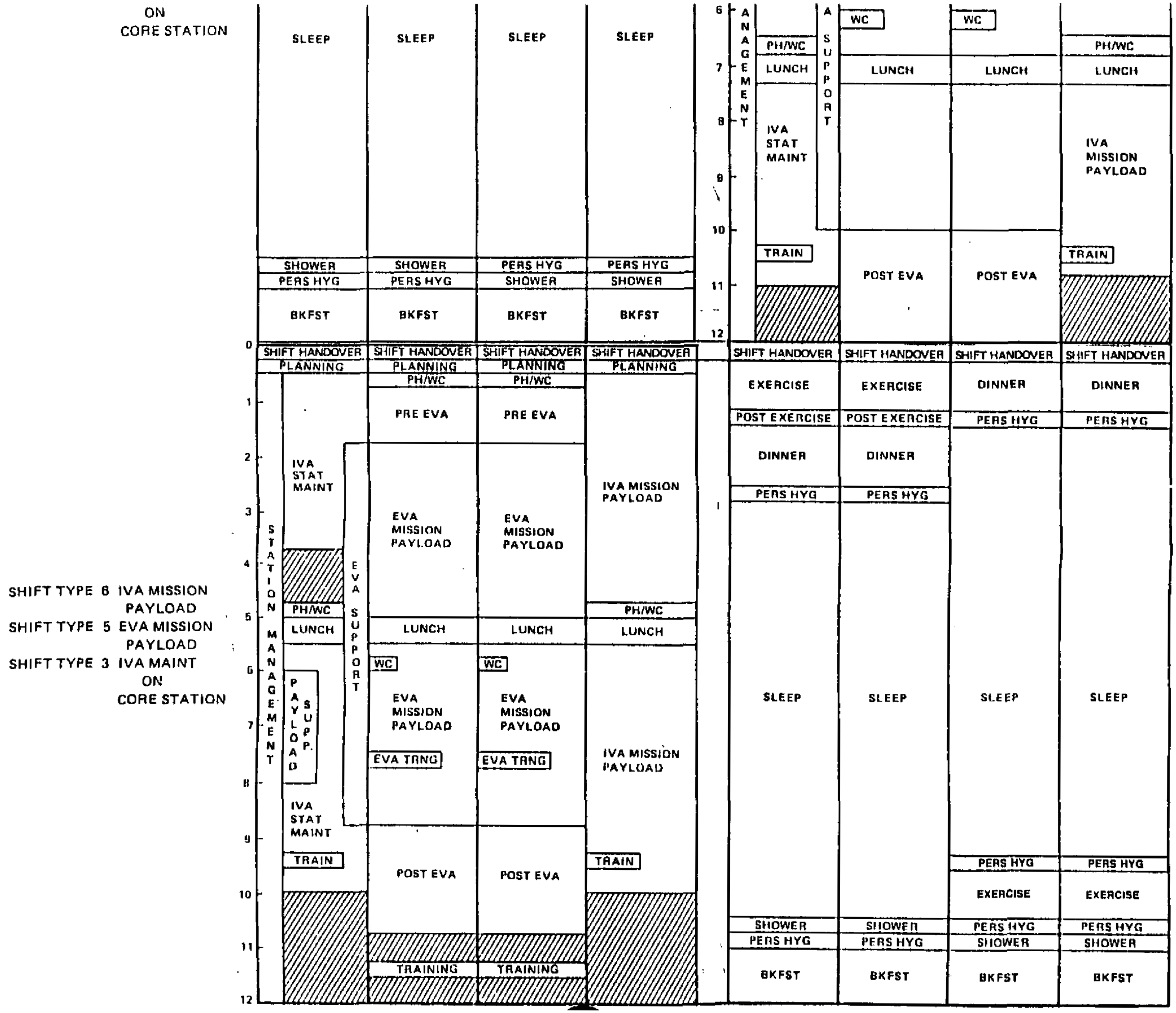


Fig. 3-1 Preliminary Operations Timeline for a Crew Size of 8 ISS Derived from Combining Shift Types

4 - PERSONAL HYGIENE/WASTE COLLECTION TASK TIMELINE & FACILITY LOADING ANALYSIS

4.1 OBJECTIVE

Paragraph 2.2.10.3.8 of JSC 30000, Section 3, Revision A indicates that "a minimum of two independent waste collection systems (for both fecal and urine collection) shall be provided." In addition Paragraph 2.2.10.3.7 indicates that "personal hygiene facilities shall be provided which include the separate capability for whole body cleaning, handwashing and oral hygiene." At the time the task timeline and facility loading analysis was performed, the accommodations provided for the accomplishment of bodily functions, in line with these requirements, were as follows:

- Facilities provided in the Habitation/Station Operations Module:
  - Personal Hygiene Facility provisions
    - Urine collection
    - Whole body shower
    - Handwasher (also used for oral hygiene)
  - Waste Collection Facility provisions
    - Fecal collection
    - Urine collection
    - Handwasher (also used for oral hygiene)
  - Galley/Wardroom provisions
    - Handwasher also used for oral hygiene, if needed, and integrated into the galley arrangement
- Facilities provided in the Multi-Purpose Lab Module
  - Personal Hygiene Facility provisions
    - Urine collection
    - Whole body shower

- o Handwasher (also used for oral hygiene)
- Waste Collection Facility provisions
  - o Fecal collector
  - o Urine collector
  - o Handwasher (also used for oral hygiene)
- Laboratory provisions
  - o Handwasher/emergency eyewash (also used for oral hygiene, if needed).

The important issues in evaluating the design were (1) to determine if the number of personal hygiene and waste collection capabilities provided enable the eight member crew to perform the necessary body functions on a timely basis, and (2) to determine the pattern of facility use and the resulting traffic flow.

4.2 METHOD

The first step in this process was to determine the details of personal hygiene and waste collection tasks, the times required for their performance and to uncover specific equipment and procedural requirements. These task and time details are shown in Tables 4-1 and 4-2.

Table 4-1 Personal Hygiene/Waste Collection Activities

DAILY	MALE	FEMALE	PLANNING*
URINATION (DETAILS IN TABLE 2)	3:55	4:30	5:00
DEFECATION (DETAILS IN TABLE 2)	11:55	12:10	15:00
SHOWERING (DETAILS IN TABLE 2)	24:45	29:30	30:00
CLOTHING CHANGE	2:00	2:00	5:00
TEETH BRUSHING	3:00	3:00	5:00
TEETH FLOSSING	5:00	5:00	5:00
HAIR COMB/BRUSH	2:00	5:00	5:00
HAIR GROOMING (DONE IN PRIVATEQUARTERS AFTER SHOWERING)	5:00	10:00	—
SHAVING	5:00	—	5:00
HANDS/FACE WASHING & DRYING	3:00	3:00	5:00

*Task times used in developing Analysis Schedule (Table 4-3) and represented in the Activity Timeline (Fig. 4-1).

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Table 4-2 Some Personal Hygiene/Waste Collection Activity Details

URINATION	MALE	FEMALE
DOFF CLOTHES, STOW & ENTER, ATTACH RESTRAINTS	:45	1:00
APPLY URINE COLLECTION DEVICE	:30	:30
URINATE	1:00	1:00
REMOVE DEVICE, CLEAN DEVICE & SELF	:30	:30
WASH & DRY HANDS	:10	:30
TOTAL	3:55	4:30
PLANNING TIME	5:00	
ASSUMPTION – TWO PIECE GARMENT		

DEFECATION	MALE	FEMALE
DOFF CLOTHES, STOW & ENTER/ATTACH RESTRAINTS	:45	1:00
PREPARE DEVICE	:30	:30
APPLY URINE COLLECTION DEVICE	:30	:30
DEFECATE (URINATE)	5:00	5:00
RELEASE RESTRAINTS	:10	:10
REMOVE DEVICE, CLEAN DEVICE & SELF	3:00	3:00
WASH & DRY HANDS	1:00	1:00
DON CLOTHES	1:00	1:00
TOTAL	11:55	12:10
PLANNING TIME	15:00	
ASSUMPTIONS – MUST INCLUDE PREPARATION FOR URINATION – TWO PIECE GARMENT		

SHOWERING	MALE	FEMALE
DOFF CLOTHES & STOW	:45	1:00
ENTER SHOWER & RESTRAINTS	1:00	1:00
WASH BODY & HAIR INCLUDING USE OF HANDHELD SPRAY	10:00	12:00
CLEAN SHOWER	2:00	2:00
DRY BODY & GROOM SELF	10:00	12:00
DON CLOTHES	1:00	1:30
TOTAL	24:45	29:30
PLANNING TIME	30:00	
ASSUMPTIONS – TWO PIECE GARMENT – WATER TEMPERATURE QUICKLY ADJUSTED – HAIR DRYING COMPLETED IN PRIVATE QUARTERS		

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The next step was to develop a reasonable personal hygiene/waste collection scenario in which a fairly heavy load would be placed on the use of the facilities provided, but not necessarily one in which all eight crewmembers are involved. The following assumptions were made:

- Four off-duty crewmembers awake and are in need of using the facilities in a fairly representative way. Additionally, two on-duty crewmembers also are in need of using the facilities. (The remaining two on-duty crewmembers were not considered in the scenario.) Of the crewmembers considered, there is one off-duty and one on-duty female
- Use of the fecal collector, whether by a male or female, must always require attaching the urine collection device
- Most, but not all, people use the handwasher as part of their routine in this type of situation
- Some, but not all, will shower as part of their post-sleep routine
- Most, but not all, people will floss their teeth but some will brush their teeth post-sleep
- All of the male crewmembers are clean-shaven and will shave as part of their normal wake-up routine
- Final drying of the hair, with or without a hair blower, will take place in the crewmember's private quarters, including detailed grooming. This provides an element of cooperation in freeing up the facility for the next person's use
- The handwashers in the galley and lab can be used if needed
- A detailed schedule of facility use is shown in Table 4-3. Using this schedule, a timeline scenario was constructed that sequences the four off-duty and two on-duty crewmembers through the facilities so as to accomplish their bodily functions and personal hygiene needs. This is depicted in Fig. 4-1

Table 4-3 Daily Personal Hygiene/Waste Collection Analysis Schedule

CREWMEMBER											
OFF-DUTY								ON-DUTY			
1		2		3		4		5		6	
MALE		FEMALE		MALE		FEMALE		MALE		FEMALE	
ACTIVITY	DURATION IN MINUTES	ACTIVITY	DURATION IN MINUTES	ACTIVITY	DURATION IN MINUTES	ACTIVITY	DURATION IN MINUTES	ACTIVITY	DURATION IN MINUTES	ACTIVITY	DURATION IN MINUTES
D	15	D	15	U	5	U	5	U	5	HW	5
CC	5	CC	5	CC	5	CC	5	HFW	5	D	15
TB	5	TB/F	10	TB	5	TB/F	10			HFW	5
SHV	30	SHO	30	SHV	5	SHV	5				
SHV	5	(HG)	10	HC/B	5	HC/B	5				
(HG)	5			D	15	D	15				
				HFW	5	HFW	5				

NOTE: ONLY 6 OF 8 CREWMEMBERS INVOLVED IN SCENARIO

ACTIVITY KEY:

D – Defecation
U – Urination
CC – Clothing Change
TB/F – Teeth Brushing/Flossing
SHO – Showering
HC/B – Hair Combing/Brushing
(HG) – Hair Grooming (in Personal Quarters)
HFW – Hand/Face Washing & Drying
SHV – Shaving

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- Scenario analysis considered activities that are considered to occur on a frequent, daily basis. Infrequent activities performed by both male and female crewmembers, (e.g., nailclipping) were not included in the analysis. Also, infrequent personal hygiene activities performed only by female crewmembers were not included. However, requirements and timelines related to menstrual care, douching and other feminine functions are presented in Table 4-4.

4.3 RESULTS

Figure 4-1 shows that all four off-duty crewmembers plus two on-duty crewmembers can be accommodated by the facilities provided in about one hour. This scenario is considered to place a reasonable load on the facilities in terms of their availability for use. However a small amount of waiting time, i.e., 5 minutes, occurs in a number of cases until a needed facility becomes available. This sort of situation requires cooperation on the part of the crew and consideration of the needs of other crewmember in order for it to succeed.

Consequently, based on this initial analysis, the present number of facilities provided are sufficient to meet the needs of daily bodily functions and personal hygiene for an eight person crew.

Table 4-4 Female Personal Hygiene (Sheet 1 of 2)

LOCATION: PERSONAL HYGIENE AREA ***FUNCTION: MENSTRUAL CARE***
COLLATERAL FUNCTIONS: - TAMPON REMOVAL MAY PRECEDE OR FOLLOW URINATION OR DEFECTION
FREQUENCY: VARIES - SANITARY NAPKINS ARE NOT VIABLE AS PRIMARY COLLECTION METHOD IN ZERO-G. NAPKINS MAY BE USED TO PROTECT CLOTHING RATHER THAN ABSORB BLOOD, AND MAY BE WORN ALL DAY. - TAMPONS SHOULD BE CHANGED AT LEAST EVERY FOUR HOURS IN ORDER TO AVOID TOXIC SHOCK SYNDROME. WITH HEAVY MENSTRUAL FLOW, THESE MAY BE CHANGED EVERY TWO HOURS.
ISSUES: - SYNCHRONICITY OF PERIODS IN WOMEN LIVING IN CLOSE QUARTERS. WOMEN'S PERIODS MAY SYNCHRONIZE, SO THAT ALL FEMALES IN SPACE STATION COULD BE MENSTRUATING SIMULTANEOUSLY. - TAMPONS ARE SOMETIMES REMOVED IN CONJUNCTION WITH URINATION OR DEFECATION - TAMPONS OR SANITARY NAPKINS SHOULD BE READILY AVAILABLE. THERE SHOULD BE A CLOSET IN THE PH AREA FOR PERSONAL ITEMS. - MENSTRAL FLOW ON TO NAPKIN IN ZERO-G. - TAMPON APPLICATION OR REMOVAL CAN BE DONE IN CABIN, AS WELL AS PH AREA
REQUIREMENTS: - MUST BE ABLE TO DISPOSE OF TAMPON OR NAPKIN, APPLICATORS AND WRAPPINGS.   - WRAPPINGS OF TAMPONS ARE MADE EITHER OF A SARAN-TYPE WRAPPING, THIN PAPER OR PLASTIC - SHOULD BE ABLE TO DISPOSE OF TAMPONS OR NAPKINS IN THE PH AREA USED FOR DEFECATION. - SHOULD ALSO GIVE CONSIDERATION TO DISPOSAL OF TAMPONS OR NAPKINS IN PH AREA USED FOR URINATION.
CONCEPTS: - STANDARD COMMERCIALLY AVAILABLE TAMPONS OR NAPKINS SHOULD SUFFICE.
RECOMMENDATIONS: - *DESIGN FOR SIX TAMPONS PER DAY FOR A PERIOD OF FIVE DAYS FOR EACH WOMAN* (TOTAL OF 30 TAMPONS PER WOMAN PER MENSTRUAL CYCLE). DESIGN FOR 10 MINI-PADS PER WOMAN PER MENSTRUAL CYCLE. - TAMPONS SHOULD BE AVAILABLE ON PH AREA. HAVE BAG FOR TAMPON DISPOSAL AVAILABLE IN PH AREA AND IN CABIN.

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Table 4-4 Female Personal Hygiene (Sheet 2 of 2)

PERSONAL HYGIENE FUNCTIONS WHCH MAY DIFFER FOR WOMEN:		
TASK	**DURATION**	**REQUIREMENTS**
HAIR DRYING	10 MINS	BLOW DRYER
HAIR GROOMING	10 MINS	WOMEN CAN BRING ANY OF THE FOLLOWING IN HER PERSONAL KIT: CURLING IRON, ROUND BRUSH, COMB, HOT ROLLERS, NON-HEATING CURLERS, CLOTH-COATED RUBBER BANDS, BARRETTES, HAIR SCISSORS
COSMETIC APPLICATION	10 MINS	WOMEN CAN BRING ANY OF THE FOLLOWING IN HER PERSONAL KIT: MOISTURIZER, FACIAL FOUNDATION, FACIAL CREAM, EYE MAKEUP, LIPSTICK. NO POWDERS PERMITTED.
UNDERARM SHAVING	3 MINS	FREQUENCY VARIES FROM ONCE PER DAY TO NEVER. CAN USE WHATEVER PRODUCT IS USED FOR MALE FACIAL SHAVING.
LEG SHAVING	5 MINS	FREQUENCY VARIES FROM ONCE PER DAY TO NEVER. CAN USE WHATEVER PRODUCT IS USED FOR MALE FACIAL SHAVING.
NAIL CARE	5 MINS	WOMEN TYPICALLY FILE FINGER NAILS, NOT CLIP THEM.

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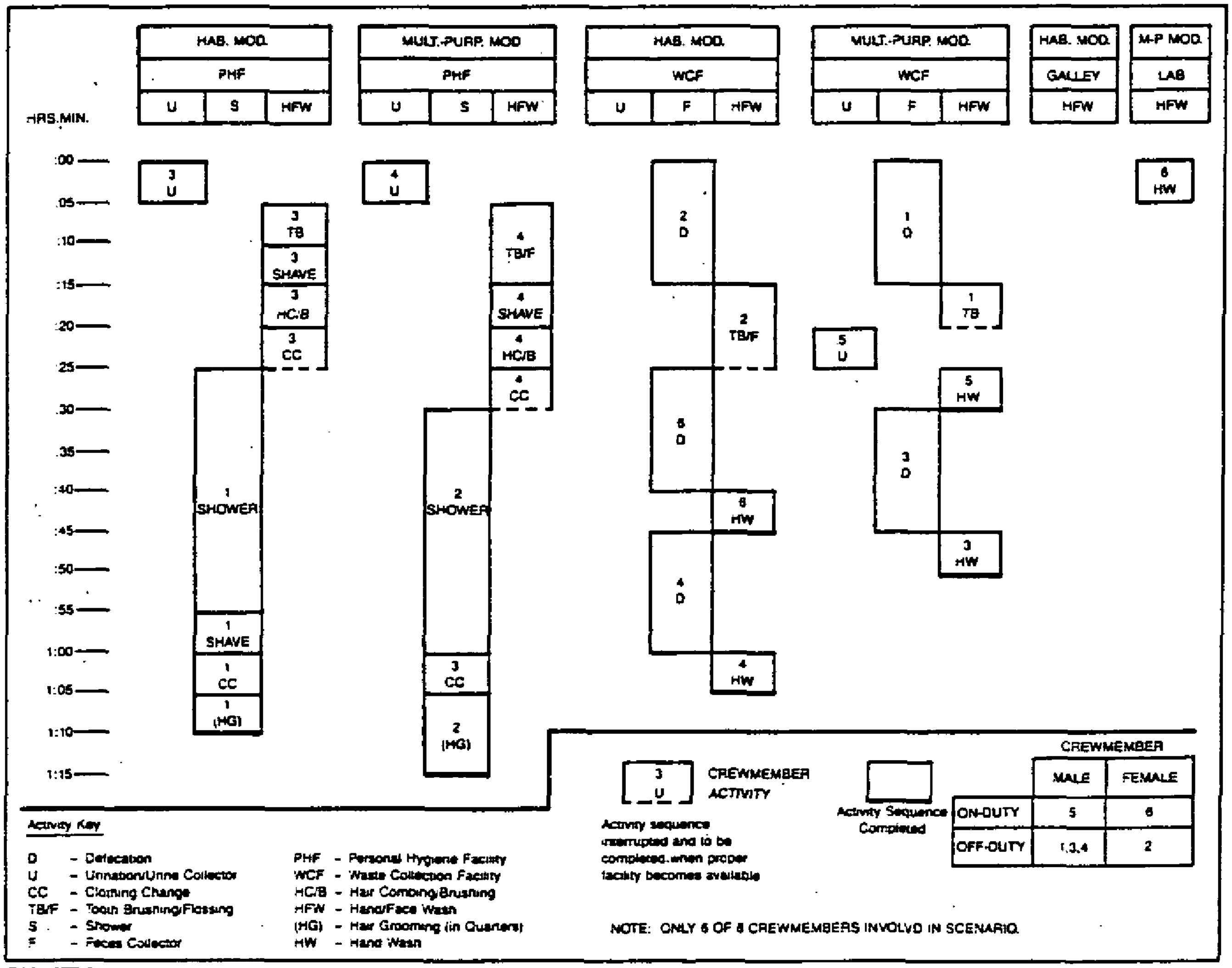

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Fig. 4-1 Daily Personal Hygiene & Waste Collection Facility Loading Timeline

5 - GALLEY WORK & TRAFFIC FLOW ANALYSIS

5.1 OBJECTIVE

As is the case with any kitchen, the key to efficient use of the Space Station galley is as much dependent upon the type of equipment provided as it is on how and in what sequence that equipment is utilized. To this end, a task/timeline/link analysis was performed to determine if a particular functional arrangement would be considered efficient in terms of the resulting work flow pattern and time requirements for food preparation, cooking and serving; and subsequent clean-up and trash disposal.

It should be noted that, at the time the analysis was performed, the requirement for six crewmembers existing. Upon examining the results of this analysis, the addition of two crewmembers to the meal preparation scenario should have minimal, if any, impact on the time required for meal preparation. Subsequent analyses will be performed to verify this assertion.

5.2 METHOD

The first step in the analysis was the recognition of a simple assembly-line type functional arrangement as follows:

- Disposal/supply end
  - Trash disposal and compaction
  - Water supply
  - Utensil supply and storage
- Preparation/cooking end
  - Food storage
  - Food retrieval and preparation for cooking
  - Cooking, serving and residue disposal.

A representative menu for six crewmembers eating simultaneously was prepared and is shown in Table 5-1. To facilitate the meal process, crewmembers were assigned specific responsibilities, as shown below in Table 5-2.

Detailed tasks were then defined for every aspect of the meal process along with estimates of the time required for their performance. As each of the task descriptions were generated, link diagrams were developed that depicted the work and traffic flow of crewmembers in the meal process. A total of 15 link diagrams were developed for each of the task groupings.

A representative task and accompanying link analysis are shown in Table 5-3 and Fig. 5-1, respectively. The task elements are identified for Crewmember No. 1 including the task times. Each "step" was then placed on the functional arrangement link diagram for the galley and wardroom table. All link diagrams were then combined into a summary diagram.

Table 5-1 Representative Crewmember Food Selections

APPETIZER	MAIN COURSE	BREAK/SNACK
- JUICE - GRAPEFRUIT CHUNKS	- SCRAMBLED EGGS WITH BACON OR HAM - COLD CEREAL WITH SLICE OF AMERICAN CHEESE - FRANKS WITH MUSTARD - ROAST BEEF SANDWICH WITH LETTUCE AND MUSTARD - BROILED SIRLOIN WITH MASHED POTATOES AND GRAVY, & GREENBEANS	- TOAST WITH BUTTER - TOAST WITH JAM - TWINKIES - POTATOE CHIPS - BREAD WITH BUTTER
SALAD	**DESSERT**	**BEVERAGE**
- LETTUCE & TOMATO	- CAKE - BAKLAVA	- COFFEE - WATER - MILK - TAB - TEA

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Table 5-2 Summary of Crewmember Meal Task Assignments

TASK ASSIGNMENT	TASK
ONE CREWMEMBER	RESUPPLY BULK FOOD (LOGISTICS TASK)
ALL OTHER CREWMEMBERS	1 PLAN MEAL 2 WASH HANDS
CREWMEMBER NO. 1 SETS UP WARDROOM TABLE	3 UNSTOW EATING UTENSILS/UNLOAD DISHWASHER, DINNERWARE, NAPKINS, TRAYS. DISPOSE OF TRASH
CREWMEMBER NO. 2 PREPARES FOOD	4 UNSTOW FOOD FROM FREEZER, REFRIGERATOR, & AMBIENT STORAGE. UNPACKAGE AND DISPOSE OF TRASH 5 UNSTOW COOKING UTENSILS 6 PREPARE FOOD/REHYDRATE/HOLD; DISPOSE OF TRASH
CREWMEMBER NO. 3 COOKS FOOD	7 COOK/HEAT FOOD. DISPOSE OF TRASH/HOLD 8 SERVE FOOD
ALL OTHER CREWMEMBERS	9 EAT 10 CLEAN-UP, DISPOSE OF TRASH/SORT/RESTOW 11 USE DISHWASHER 12 CONSOLIDATE/COMPACT TRASH (ONE CREWMEMBER ONLY FOR COMPACTION)
ONE CREWMEMBER	STOW COMPACTED TRASH DETERMINE RESUPPLY OF BULK FOOD (LOGISTICS TASK)

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Table 5-3 Dining Preparation Task/Times Crewmember No. 1 – *Wardroom Table Setup*

STEPS	ESTIMATED TIME (MINUTES)	TASK ELEMENTS
1.	1.5	WASH HANDS
2.	2.0	PLAN MEAL
3.	1.5	UNLOAD UTENSILS FROM DISHWASHER
4.	1.5	SET THE WARDROOM TABLE
5 & 6	2.0	RETURN CLEAN UTENSILS NOT NEEDED FOR THIS MEAL TO STOWAGE
7 - 10	5.0	UNSTOW OTHER UTENSILS (TRAYS, ETC.) FOR TABLE AND FOR FOOD PREPARATION & COOKING
11	0.5	TAKE PLACE AT WARDROOM TABLE
	14.0	

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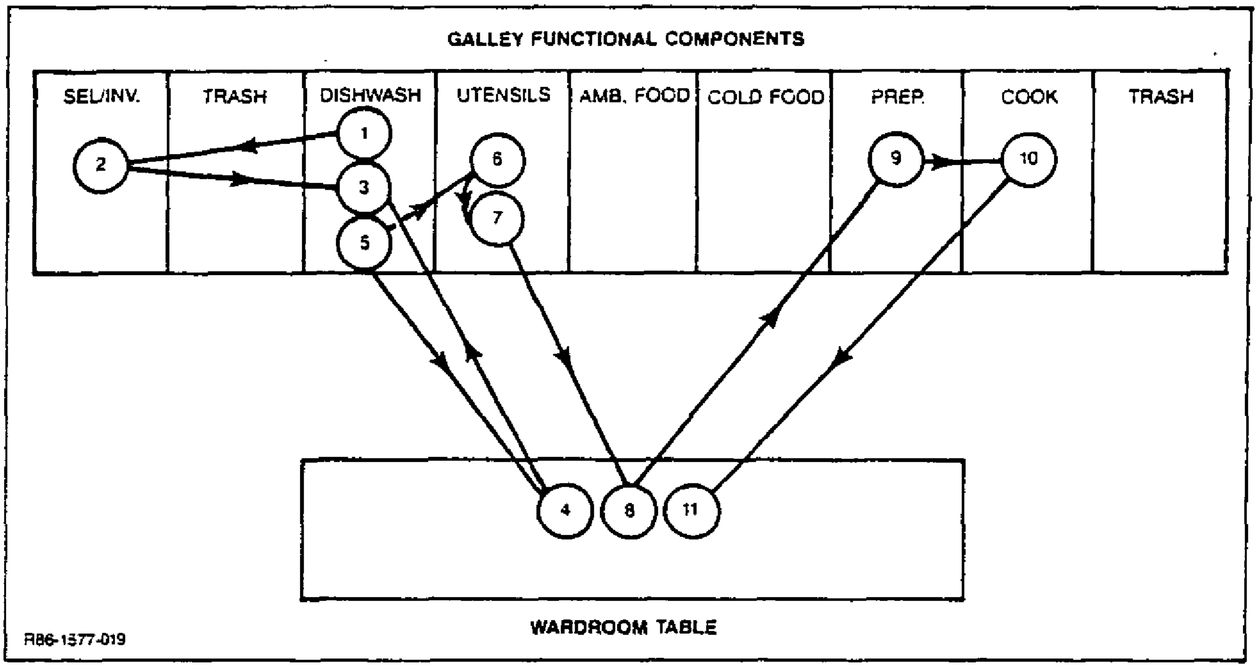

Fig. 5-1 Phase I, Dining Preparation, Crewmember No. 1, Wardroom Table Set-Up Link Analysis

5.3 RESULTS

The consolidated link analyses support the "assembly line" functional arrangement concept and; thus, provide the rationale for the present recommended galley equipment arrangement shown in GSS drawing No. 751B-1110, Sheet 2, dated June 20, 1986. In this drawing, a left to right meal sequence arrangement is shown (A right to left arrangement would be just as satisfactory). This configuration maintains an efficient work flow pattern and retains the "disposal/supply end" and the "preparation/cooking end" concept described earlier.

Finally, based on the preliminary estimates of task time, all six crewmembers can complete the meal sequence in about one hour as shown in Fig. 5-2. The addition of two more crewmembers, as stated earlier, should have minimal, if any, impact on meal preparation, consumption and clean-up.

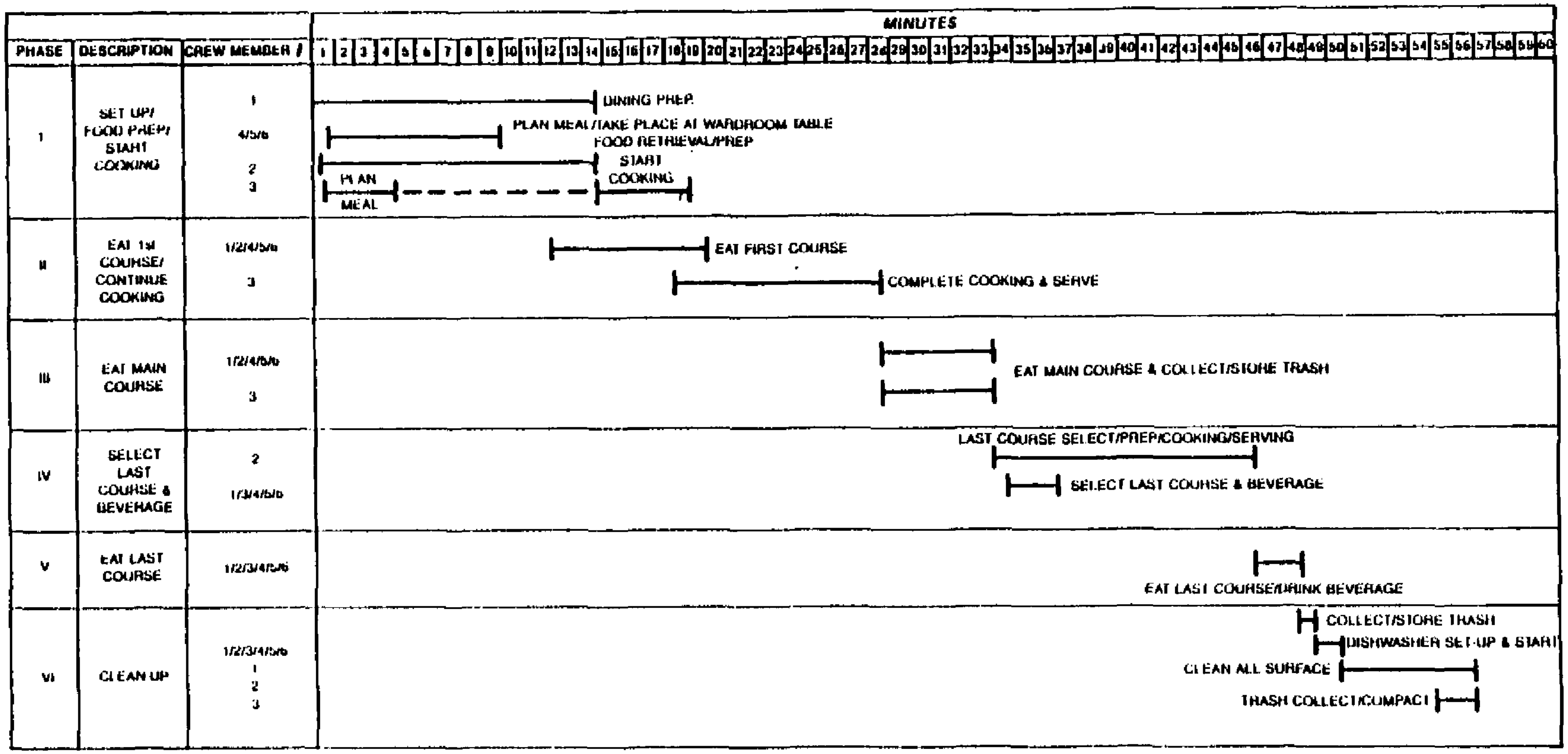

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Fig. 5-2 Meal Sequence Timeline

6 - EXERCISE TASK TIMELINE

6.1 RATIONALE

In the microgravity environment, several physiological changes take place which adversely affect astronaut productivity. Various exercise protocols can ameliorate, to some extent, some of these changes; specifically, (1) cardiovascular deconditioning, (2) skeletal muscle atrophy, and (3) bone demineralization as evidenced by a loss of calcium from the long bones of the lower extremities. Therefore exercise will be required of each crewmember.

6.2 ASSUMPTIONS

The following assumptions are made:

- Crew of eight
- Two teams of four astronauts each, and 12 hr off-duty/on-duty cycles
- Six day work week
- A minimum of two astronauts can exercise simultaneously; so there will be at least two exercise devices provided
- Each exercise device will be multifunctional, i.e, both aerobic and anaerobic exercise will be performed, and an appropriate form of exercise, while meeting the aerobic or anaerobic requirement, will also be appropriate to reducing the rate of bone demineralization
- A minimum of 1 hr/24 hr period will be devoted to exercising.

6.3 ISSUES

1. Number and configuration of exercise devices (Refer to Subsection 6.2).

- Exercise must include periods of aerobic and anaerobic activity
- In order to counteract calcium loss from bone, an exercise device that provides a high inertial loading of the leg bones is necessary.

Recommendation: Develop exercise machines that are multi-functional; that is, can provide at least two of the types of exercise.

2. Minimum Time for Exercise in a 24 Hour Period.
   - There is little data regarding the optimum time necessary for exercise in order to optimize the prevention of cardiovascular deconditioning, muscle atrophy, and bone demineralization.

   Recommendation: Exercise period should be for a minimum of 1 hr of actual exercise per 24 hr period.

3. Optimum Schedule for exercising during a 24 Hour Period.

The scheduling of a 1 hr exercise period per 24 hr (1 1/2 hr for preparation, exercise and cleanup) during 12 hr duty cycles is problematic. Several factors need to be considered when scheduling exercise:

- Exercise right after a meal should be avoided
- To minimize EVA overhead time, the on-duty cycle for mission specialists should not be interrupted with an exercise period
- After a 12 hr work period, an astronaut may not want to exercise or may be too tired to exercise at sufficient intensity to counteract deconditioning
- Two exercise periods per 24 hr may be more effective than a single, 1 hr exercise period
- Under normal conditions (i.e., nonemergency), exercise has a higher priority than work. Thus, exercise periods

should be completed each day, even if work periods need to be reduced.

Recommendation: Explore several possible schedules for exercise during a 24 hr period.

6.4 EXERCISE SCHEDULE & TIMELINES

Two exercise periods are possible - one during off-duty hours and one during on-duty hours. Tables 6-1 and 6-2 give the timelines for these two periods.

Table 6-1 Off-Duty Exercise Task/Timeline

	TASK	TIME
1	DOFF AND STOW BASIC IVA GARMENTS	2:30
2	DON EXERCISE CLOTHES (IN CREW QUARTERS)	2:30
3	TRANSLATE TO EXERCISE AREA AND STOW TOWEL	1:00
4	ATTACH BIOMEDICAL MONITORS TO SELF	1:00
5	DEPLOY AND GET ON EXERCISE DEVICE/ATTACH RESTRAINTS	0:30
6	PUT ON HEADSET HOOK UP HEADSET LEAD TO AUDIO/VIDEO SYSTEM TURN ON CASSETTE PLAYER INSERT AUDIO/VIDEO CASSETTE TAPE INTO PLAYER	0:30
7	HOOK UP CHEST HARNESS LEAD TO BIOMEDICAL MONITOR TURN ON BIOMEDICAL MONITOR ELECTRONICS ENTER INFORMATION (PERSONAL IDENTIFICATION AND EXERCISE DEVICE TO BE USED) INTO BIOMEDICAL DATA RECORDER START PLAYER, SELECT PREFERRED CHANNEL AND ADJUST CONTROLS (AUDIO AND VIDEO) START BIOMEDICAL DATA RECORDER SET COUNTDOWN TIMER TO 20 MIN AND START TIMER	1:00
8	PERFORM EXERCISE PROTOCOL	20:00
9	TURN OFF BIOMEDICAL DATA RECORDER, BIOMEDICAL MONITOR ELECTRONICS AND DETACH LEADS UNPLUG HEADSET LEAD FROM AUDIO/VIDEO SYSTEM EJECT CASSETTE TAPE FROM PLAYER TURN OFF POWER TO CASSETTE PLAYER DETACH RESTRAINTS UNSTOW AND USE TOWEL TO DRY OFF RE-STOW TOWEL CLEAN PERSPIRATION FROM EXERCISE DEVICE	2:00
10	CHANGE EXERCISE DEVICE	0:30
11	ATTACH RESTRAINTS TO SELF AND REPEAT STEPS 7 THROUGH 9 ABOVE	23:00
12	UNSTOW TOWEL AND EGRESS EXERCISE AREA	:30
	TOTAL ESTIMATED TIME:	55:00

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Table 6-2 On-Duty Exercise Task/Timeline

	TASK	TIME
1	DOFF AND STOW BASIC IVA GARMENTS	2:30
2	DON EXERCISE CLOTHERS (IN CREW QUARTERS)	2:30
3	TRANSLATE TO EXERCISE AREA AND STOW TOWEL	1:00
4	ATTACH BIOMEDICAL MONITORS TO SELF	1:00
5	DEPLOY AND GET ON EXERCISE DEVICE ATTACH RESTRAINTS PUT ON HEADSET HOOK UP HEADSET LEAD TO AUDIO/VIDEO SYSTEM TURN ON CASSETTE PLAYER INSERT AUDIO/VIDEO CASSETTE TAPE INTO PLAYER	0:30
6	TURN ON BIOMEDICAL MONITOR ELECTRONICS HOOK UP CHEST HARNESS LEAD TO BIOMEDICAL MONITOR ENTER INFORMATION (PERSONAL IDENTIFICATION AND EXERCISE DEVICE TO BE USED) INTO BIOMEDICAL DATA RECORDER START PLAYER, SELECT PREFERRED CHANNEL AND ADJUST CONTROLS (AUDIO AND VIDEO) START BIOMEDICAL DATA RECORDER SET COUNTDOWN TIMER TO 20 MIN AND START TIMER	1:00
7	PERFORM EXERCISE PROTOCOL	20:00
8	TURN OFF BIOMEDICAL DATA RECORDER, BIOMEDICAL MONITOR ELECTRONICS AND DETACH LEADS UNPLUG HEADSET LEAD FROM AUDIO/VIDEO SYSTEM EJECT CASSETTE TAPE FROM PLAYER DETACH RESTRAINTS UNSTOW AND USE TOWEL TO DRY OFF CLEAN PERSPIRATION FROM EXERCISE DEVICE	2:00
9	STOW EXERCISE DEVICE	0:30
10	EGRESS EXERCISE AREA	:30
	TOTAL ESTIMATED TIME:	31:30

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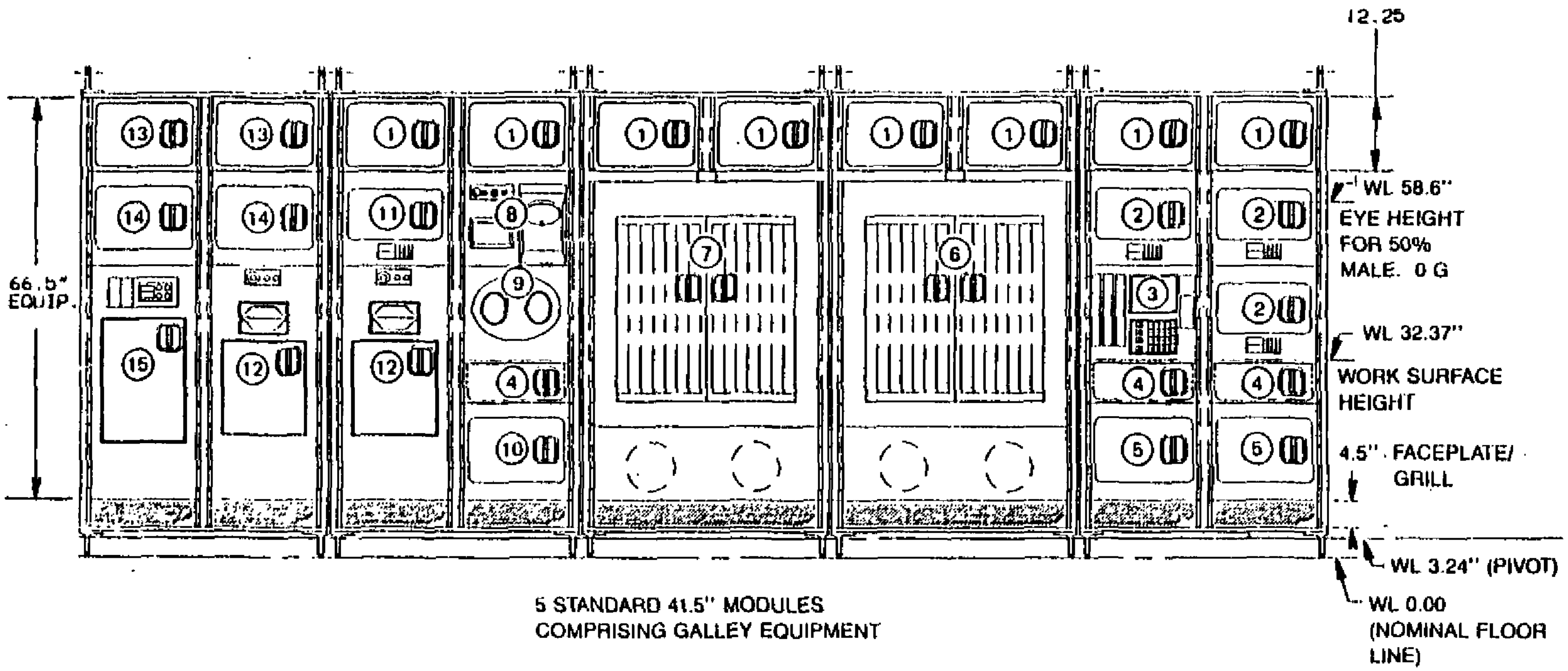
7 - INITIAL MOCK-UP EVALUATION EXERCISES

7.1 MOCK-UP DESCRIPTIONS

GSS's initial mock-up activities of Space Station interior design began by focusing on the Galley/Wardroom. Two mock-ups were used. One was a full-scale representation containing all of the visible interior architecture and functional sites of the Habitation Module and is located at its Bethpage facility. In addition to the Galley/Wardroom it included the Command and Control Station, the Health Maintenance and Exercise areas, the Personal Hygiene/Waste Collection and Laundry Facilities, Crew Quarters, and Window Work Stations. The Galley/Wardroom in this mock-up contained only static (nonfunctioning) pictorial representations of its component parts. However, it was possible to pull down a 42 in. standard Galley rack to demonstrate maintenance and accessibility to the interior skin of the module.

The Galley/Wardroom portion of the mock-up was first configured to represent the GSS baseline design as shown in Fig. 7-1. Following the scenario exercise and video taping of the baseline concept that included a round table, the mock-up was reconfigured to depict an alternative arrangement with a T-shaped table.

The second mock-up was located in GSSs Houston facility. This depicted only the Galley/Wardroom area. (No other Habitation Module functional sites were represented.) In this mock-up, some of the Galley components possessed limited functional characteristics that were supplied by General Electric (GE). For instance, a number of ambient food storage compartments, a trash compactor, a refrigerator/freezer, and some microwave oven/dish cleaning units were capable of being opened and



KEY

-AMBIENT FOOD	1	-WATER DISPENSER	8
-OVEN:MICRO/CONVECT	2	-HAND WASHER	9
-INVENTORY UNIT	3	-UTENSILS/APPLIANCE	10
-TRASH COLLECTOR	4	-DISHWASHER	11
-HOUSEKEEPING	5	-TRASH COMPACTOR	12
-FREEZER/REFRIG.	6	-MISC. GALLEY STOW	13
-REFRIG/FREEZER	7	-MISC. GALLEY STOW	14
		-CLOTHES WASH/DRY	15

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Fig. 7-1 GSS Baseline Galley Arrangement

closed. Simulated food items, utensils and dishes could be put in or taken out to demonstrate interior volume and structural feature usage with respect to racks or operating parts. The handwash units could be deployed or restowed in their operational positions. Several air table work surfaces were deployable and functioned as designed. Trash collectors were capable of receiving discarded material. All of the semi-functioning units were provided for not only appearance sake but for fit and/or (limited) function. With the exception of the air tables, none were supplied with power, where it normally would have been appropriate.

At GSSs Houston facilities, the initial scenario exercise and video taping was done with this second mock-up arranged to represent the GSS baseline configuration. Following the exercise event, the baseline was reconfigured. A working keyboard and CRT display were added which enabled a test subject to enter his/her name, view a menu of food options and then select a particular meal. (In this concept the choices selected would be printed out and used as an aid in food retrieval. However, a working printer was not included.)

7.2 EXERCISE METHOD

During July and August of 1986, GSS used these mock-ups as a means of assessing fundamental aspects of Galley/Wardroom design and to develop insight into how future, more formal, mock-up evaluations should be conducted, particularly with regard to gaining useful, instructive information in situations where it is not possible to create 0 g conditions.

A variety of meal preparation and clean-up scenarios were generated. In general, the task sequences used were fairly constant from one session to another. In all cases, the sessions were directed by GSS personnel. Initial sessions began with a one-person meal sequence and, as experience was gained, additional test personnel were added to divide up the food preparation process between a meal set-up individual, a food retriever/server and a cook/server.

The exercise director held a pre-exercise training session with the participants, guided them through the exercises and conducted a post-exercise evaluation and summary session at the close of the proceedings, at which time the video tapes were reviewed.

As these events evolved there were some improvements made to the scenarios as experience was gained, and as the number of "crewmembers" participating increased from one, to four, to eight. Former astronaut, and technical consultant to GSS, Donald Peterson, participated in all events; and all exercises involved the participation of GSS and GE personnel, except those held in Houston, which were observed by cognizant RI an NASA personnel. The evaluation data generated from these exercises were in the form of comments recorded during their occurrence and from post exercise de-briefing sessions attended by both participating test team members and observers. The comments were documented in trip reports and in-house memos. A summary of these informal critiques and the conclusions and recommendations arising out of the exercises are referred to in Subsection 7.3.

7.3 RESULTS

The validity of information obtained from the use of mock-ups is directly related to their level of fidelity. The results reported in this section are, therefore, limited to the following:

- Galley/Wardroom general arrangement design factors such as the architectural concept, equipment functional arrangement, the meal process logistical sequence, Galley/Wardroom table functional relationship, and component orientation

- Food package handling and work surfaces
- Mobility and restraint
- Storage provisions accessibility
- Trash disposal provisions
- Accessibility to module walls
- Meal selection.

7.3.1 General Arrangement

The mock-up exercises conducted at this early stage of development have shown that GSS's basic Galley/Wardroom concept is in keeping with the primary objectives of the quad-truss interior architectural design philosophy. These include an open environment, unobstructured traffic flow and rapid egress, and an efficient work space arrangement. In addition, the functional arrangement of Galley equipment, containing integrated and stowable work surfaces, a contiguously situated but separable and stowable Wardroom table; is consistent with the logistical sequence required for meal preparation and clean-up. This sequence is essentially constant regardless of the number of crewmembers actively engaged (as table-setter, retriever, or cook) in the meal preparation process, i.e., one, two, to a maximum of three. In addition, the functional arrangement of food stowage provisions, cooking devices, trash disposal units, etc., are also consistently arranged with respect to this logistical sequence. It was expected, and clearly observed during the exercises, that as the number of active participants increased, the amount of physical movement would decrease. Under all conditions, however, the functional arrangement of Galley equipment was consistent with the work flow (meal preparation and clean-up) process.

One subtle advantage of GSSs Galley/Wardroom design is that, by locating all of the meal process provisions on one side of the Habitation Module, the potential exists for minimum interference with Station operations requiring the use of the Wardroom Table, if particular circumstances requiring such a situation should arise. This is, although the Wardroom table and Galley are functionally linked, as far as the meal process is concerned, the proposed design provides an efficient operational separation, if necessary.

GSSs Galley design provides for a forward-facing orientation of operating features. There are, at present, no provisions for overhead stowage for item retention as it is believed that forward-facing is a more effective way to configure Galley components with respect to safety, reach and visibility.

While the spacecraft designer is, in theory, free to utilize "ceilings" and "floors" as well as "walls" as work surfaces, fundamental questions arise as to how and under what conditions people successfully adapt to a multi-orientational field with respect to their psychological equilibrium, let alone work efficiency. These mock-up exercises provided no justification for altering GSSs baseline concept along these lines. Until such time as Galley operations can be evaluated in 0 g and its effects on meal preparation and comfort fully understood, overhead component placement must be considered a second-choice design option.

The GSS baseline concept shows two sets of refrigerator/freezers next to one another. This arrangement was preferred over an alternate configuration which separated these two sets of units. In addition, the T-shaped table seemed to take-up too much of the aisle space precluding easy translation back and forth across the module thus somewhat restricting the free flow of traffic. However, it's stowability was judged to be a valuable feature.

Another alternate configuration positioned the handwash closer to the food cooking area. It was conceived of as a sink for use during cooking, as well as a handwash, and may have offered some slight advantage if the food system is so designed as to require its use in that manner.

7.3.2 Food Package Handling & Work Surfaces

At the time these mock-up exercises were accomplished, little was known about the exact food packaging method to be used on the Space Station. The assumption was therefore made that food packaging would be similar to that used on the Shuttle, i.e., small individual portions to be used in conjunction with food trays. The exercises showed that this concept was compatible with the Galley stowage provisions but that considerably more work space was needed for interim retention on work surfaces and food trays during food retrieval and in preparation for cooking and serving. During eating, the food would be retained on trays at the Wardroom table which provides sufficient surface area and accommodations for eight crewmembers.

7.3.3 Mobility & Restraint

The Space Station meal process, as was demonstrated in these mock-up exercises, is a manually intensive activity involving the physical handling of a large number of small items. Unlike on earth, movement in 0 g is easy but remaining stationary to accomplish required tasks is difficult. In addition experience has shown that astronauts are very often content with simply floating in the general vicinity of their work. Neither of these effects or conditions were achievable in these exercises.

For purposes of expediency, it was assumed that foot loops would be the preferred method of restraint, on the grounds that they are the easiest to use. (Various other methods of IVA "anchoring" that have been tried by NASA to date have not proven to be altogether satisfactory.) However, use of such a system in a 0 g environment makes their implications for use in an "open-area" Galley design difficult to assess in one-g conditions. In addition, if facility design were to include work areas on ceilings and floors, (assuming that this multi-orientational field is deemed feasible) it would be necessary, as an example, to provide mobility and restraint aids to accommodate every body orientation necessary for performance.

It is imperative that special attention be given to defining the restraint and mobility system that is needed to perform the meal process tasks in an effective and comfortable manner. Once conceived, such a system must then be subjected to in-flight 0 g testing using a prescribed test scenario so as to verify its adequacy before a final assessment can be made.

7.3.4 Storage Provisions Accessibility

During the exercises, it was clearly observed that there was a considerable amount of storage area door and drawer opening and closing. This action not only caused the test subjects to have to step back (conceivably out of their foot restraints) but, in certain instances, wipes the food items/housekeeping supplies right off the air tables on which they had been previously positioned. A new concept of Galley door and drawer design is, therefore, needed which will minimize storage compartment interference with crewmember Galley activities and that will not disturb work surface items.

Several design approaches are possible that include recessing the doors such that they can be left open. (The extent to which this is possible with the refrigerator/freezer doors during the period of meal preparation should be investigated). In addition, the vertical area behind the work surfaces should not contain any components with doors or drawers, thus eliminating the problem.

7.3.5 Trash Disposal Provisions

Trash collectors at either end of the Galley proved to be a most useful adjunct to Galley design; particularly when a maximum of eight crewmembers were completing their meal and were involved in queing up to dispose of trash and debris. Likewise, the use of some trash collector located at the Wardroom Table would help to maintain the cleanliness of the area and was judged to be a desirable feature.

During these mock-up exercises there was no demonstration of the use of a vacuum device in the Galley/Wardroom area as part of the clean-up operation.

7.3.6 Accessibility to Module Walls

During the exercises, a 42 in. standard rack in the Galley was unpinned from its connecting point and rotated to expose the Module skin. This action was easily performed and it was evident that direct access to perform maintenance or cleaning could be easily accomplished.

7.3.7 Meal Selection

In these reviews, the location of the meal selection CRT and Keyboard at the cooking end of the Galley, adjacent to the ovens, was judged to be the functionally correct position because of its probable use in determining cooking time. However, the Meal Selection and Inventory Control System is very much unresolved at this point and needs more definition before a final judgement can be made.

7.4 CONCLUSIONS

The use of mock-ups is an integral part of the design process. Experience has shown that, in spite of the diligent application of a priori principles of design, much can be learned from such exercises that was not foreseen during earlier analysis and concept development, thus enabling subsequent optimization of design.

These informal Galley/Wardroom exercises have shown that GSSs concepts satisfy basic architecture and functional requirements for Space Station habitability. They provide an additional source of confidence in GSSs approach to Habitation Module interior design.

8 - REFERENCES

1. NASA, Space Station Definition and Preliminary Design, Request for Proposal, Solicitation No. 9-BF-10-4-01P, 15 September 1984.

2. NASA-JSC, Crew Interface Panel Space Station Habitability Requirements Document, JSC-19517, December 1983.

3. NASA-JSC, Skylab Evaluation Bulletin No. 3, Architectural Evaluation for Sleeping Quarters, JSC-09537, July 1974.

4. Stuster, J. (Anacapa Sciences, Inc.), Space Station Habitability Recommendations Based on a Systematic Comparative Analysis of Analogous Conditions, December 1984.

5. Lockheed Missiles & Space Company, Space Station Human Productivity Study Final Report (Volume III - Requirements), LMSC F060784/3, November 1985.

6. NASA, Man-Systems Integration Standards (Preliminary), 25 February 1986.

7. NASA-JSC, Skylab Evaluation Bulletin No. 19, Food System, JSC-09553, February 1976.

8. Rockwell International, Operations Plan: Orbital Operations Plan, Appendix B, RI SSS 85-0208, Fig. 2.2.2.2-1.

9. Grumman Corporation, Manned Space Systems Habitability Interior Architecture and Mockups, Interim Report, SS005-ATD-05, 27 March 1986.

10. Grumman Corporation, Manned Space Systems Habitability, Human Factors, Interim Report, SS005/ATD-06, 3 April 1986.

11. NASA-JSC, Space Station Program Definition and Requirements, JSC 30,000, October 1985.