NASA Contractor Report 4010

Space Station Group Activities Habitability Module Study

David Nixon

COOPERATIVE AGREEMENT NCC2-356
NOVEMBER 1986

NASA

NASA Contractor Report 4010

Space Station Group Activities Habitability Module Study

David Nixon
Institute for Future Studies (SCI-ARC)
Southern California Institute of Architecture
Santa Monica, California

Prepared for
Ames Research Center
under Cooperative Agreement NCC2-356

NASA
National Aeronautics
and Space Administration

Scientific and Technical Information Branch

1986

CONTENTS

EXECUTIVE SUMMARY

This report documents a study carried out during 1985 by a faculty and student team at The Institute for Future Studies at Southern California Institute of Architecture for the Space Human Factors Office at NASA-Ames Research Center. The Technical Monitor for NASA was Marc M. Cohen.

The purpose of the study was to explore and analyse architectural design approaches which are applicable to the Group Activities Habitability Module specified for the Space Station, and identified by NASA as Habitability Module 1 in the Space Station Reference Configuration Description, Systems Engineering and Integration, Space Station Program Office, Johnson Space Center, JSC-19989, August 1984. This Reference Configuration specified 2 Habitability Modules, 2 Laboratory Modules and 1 Logistics Module.

Principal crew accommodation which is scheduled by NASA for provision in Habitability Module 1 includes a Galley, a Wardroom and an Exercise facility, of which the Wardroom is the most significant in terms of size and function.

The study was divided into a Research Phase, during which architectural program material was identified and habitability design guidelines were developed, and a Schematic Design Phase, during which a range of alternative individual design concepts for the internal architectural configuration of the Module were developed, analysed and evaluated.

The following points summarize the results of the study in terms of seven key conclusions drawn both from the Research Phase and the Schematic Design Phase which specifically relate to Habitability Module 1 on the Space Station.

- ## A SEMI-PRIVATE LIBRARY/STUDY FACILITY IN THE GROUP HABITABILITY MODULE IS DESIRABLE.

  - An enclosed Library and Study facility for two or three crewmembers to use occasionally will be an essential ingredient on the Space Station. It will help to alleviate any social tensions or polarizations which may arise if the only-off duty choice for crewmembers is between the Wardroom and its communal activity, or a Sleeping Compartment and its private seclusion.

  - Because of internal volume limitations, this facility can be configured as an intermittent function at Space Station I.O.C. stage in the form of an internally adaptable or deployable enclosure. This function would subsequently be relocated as a permanent feature following the addition of further Modules during Space Station growth.

- **INTERNAL CONFIGURATIONS MUST ABSORB CREW SHIFT AND SCHEDULE VARIATIONS.**

  - The selection of Module interior architecture will define the feasibility of a 2-shift or 3-shift daily crew cycle or a convertible 2/3 shift daily crew cycle, with each requiring a capability for continuous modification of crew complements and schedules.

  - In view of the difficulty and undesirability of preplanning all Space Station crew operations, all potential crew routine options need to be cross-checked with the proposed Module internal architecture at all design and development stages, to avoid conflicts or incompatibilities.

- **RESEARCH INTO CREW TRANSLATION AND ORIENTATION ON POST-I.O.C. SPACE STATION IS REQUIRED.**

  - Research studies need to be undertaken to examine the implications of Space Station post-I.O.C. growth and change on crew orientation and translation throughout Module clustering options in order to ensure that optimum conditions of operational safety, security and efficency can always be maintained.

- **HIGHLY-ADAPTABLE INTERIORS WILL PERFORM BEST IN SPACE STATION OPERATIONAL SCENARIOS**

  - Highly-adaptable and modifiable Module internal architectural configurations which can adjust kinetically to changing Space Station functional requirements will be able to maintain higher Space Station life-cycle operational efficiency than dedicated or fixed configurations.

  - This capability for kinetic change will also provide an environmental feature and stimulus by allowing crews to initiate and experience configuration changes as and when they occur.

- **PERCEPTION AND TRANSLATION ARE ENHANCED BY HORIZONTAL RATHER THAN VERTICAL CONFIGURATIONS.**

  - A horizontal interior architectural configuration is more effective than a vertical configuration at accentuating and stimulating crew perception of internal spaciousness and perspective due to the absence of visually-restrictive intermediate floors present in a vertical configuration.

- A horizontal interior architectural configuration will provide unhindered intra-Module crew translation and freedom of movement, whereas intermediate transverse floors present in a vertical configuration will tend to obstruct efficent crew passage.

• KEY DESIGN ISSUES OF ON-ORBIT COMPLETION, LIFE-CYCLE MODIFICATION AND HULL INSPECTION INVOLVE SIMILAR PERFORMANCE OBJECTIVES.

- Module performance capabilities for on-orbit outfitting completion and life-cycle interior modification are essential if Space Station operational efficiency and crew habitability standards are to be gradually upgraded, or even maintained. Since the two issues involve a very similar set and sequence of crew performance activities and tasks, they can be considered as a combination.

- The manipulation of internal architectural elements and equipment for purposes of Module on-orbit completion or life-cycle modification will similarly be required for Module pressure-hull inspection, suggesting that all three can be integrated into a unified design development objective.

• INNOVATIVE INDUSTRIAL DESIGN APPLICATIONS FOR MODULE INTERIORS ARE NEEDED.

- During the Space Station detailed design stages, special attention needs to be given to the development of innovative industrial design solutions for elements, assemblies, components, equipment and accessories which together comprise the interior architectural configuration of the Group Habitability Module, for the purpose of achieving optimum operational efficiency, compactness and enhanced environmental habitability.

1 INTRODUCTION

1.1 PROJECT OBJECTIVES

This report entitled "Space Station Group Habitability Module Study" documents a project carried out by a faculty and student team during 1985 at The Institute for Future Studies, Southern California Institute of Architecture, Santa Monica, California for the Space Station Human Factors Office at NASA-Ames Research Center, Moffett Field, California. The Technical Monitor was Marc M. Cohen.

The purpose of the project has been to explore and analyse architectural design concepts for the Group Activities Habitability Module identified in the NASA Space Station Reference Configuration Description [ref. 1] as Habitability Module 1, and hereinafter referred to as HM1.

The principal features of HM1 are the Space Station Wardroom, Galley and Health Maintenance [Exercise] facilities, of which the Wardroom is the most significant in terms of both physical size and social function.

The project objectives have been to develop a series of Design Concepts for the interior architectural configuration of HM1 in scale-model and drawing form, using background research in the form of programmatic checklists and design guidelines. The Design Concepts have been subsequently analysed and evaluated with results documented as project conclusions.

The aim of the project has not been to select a "best" solution, but rather to identify and explore alternative design approaches which lead to generically diverse solutions for the interior architectural configuration of HM1.

1.2 PROJECT ORGANIZATION

The Project is divided into a RESEARCH PHASE and a SCHEMATIC DESIGN PHASE. The RESEARCH PHASE in Section 2 (commenced in June 1985 and completed in August 1985) identifies a set of Architectural Design Program criteria described in 2.1, and a series of Preliminary Habitability Design Guidelines described in Section 2.2.

The SCHEMATIC DESIGN PHASE in Section 3 (commenced in September 1985 and completed in December 1985) comprises the schematic design investigation of nine Design Concepts for the internal architectural configuration of HM1. The nine Design Concepts are presented and illustrated individually in Sections 3.2 through 3.10 by means of drawings, photographs, descriptions and analysis sheets.

Individual analysis sheets are used to evaluate the Design Concepts in 3.11, and using material drawn from both the RESEARCH PHASE and the SCHEMATIC DESIGN PHASE, various concluding comments are made and key points highlighted in CONCLUSIONS, Section 4.

2 RESEARCH PHASE

2.1 ARCHITECTURAL DESIGN PROGRAM

The Architectural Design Program contained in Section 2.1 is a preliminary program and checklist for a range of accommodation and facilities required within HM1.

The information encompasses outline design requirements which, together with design guidelines contained in Preliminary Habitability Design Guidelines, Section 2.2, have been developed to support the Schematic Design Phase of the project.

Each programmatic element of HM1 is described in this section as an "activity" rather than a "room" or "compartment". This is necessary for two reasons. First, the program sought to avoid pre-empting or prejudicing the independent creative development of different internal configurations during the Schematic Design Phase [which might otherwise have been intimidated by early references to activity grouping or compartmentalization]. Second, the physical interrelationships between activity volumes and Module dimensional and geometrical constraints had not been determined prior to any design work.

The following ten key activity types are defined by this program. These activities have been identified during the research phase as key crew activities which are likely to occur within HM1.

- Meetings and Teleconferences
- Planning and Training
- Relaxation and Entertainment
- Eating and Drinking
- Food Preparation and Cooking
- Exercises and Games
- Housekeeping and Hygiene
- Space Station Operations (generic)
- Library and Study
- Shift and Crew Handovers

2.1.1 ACTIVITY : MEETINGS AND TELECONFERENCES

2.1.1.1 DESIGN CHARACTERISTICS

The Meeting and Teleconference function supports one of the most important socially-interactive activities on the Space Station. It provides accommodation for group meetings and Station-to-ground teleconferences for up to eight crewmembers on a regular basis. Crew positions and interpersonal distances are critical for good eye-to-eye contact, conversations, and teleconference monitoring and viewing angles. This function is likely to require the largest single volume in HM1 and possibly on the Space Station. A viewing window with comfortable viewing conditions for two persons close to this function is required by the Reference Configuration. Adequate circulation volume allowances around any permanent meeting table/appliance must be provided for ingress/egress.

2.1.1.2 DESIGN REQUIREMENTS

Extendable meeting table/ appliance for up to 8 persons	-	design of table geometry and size based on variable crew group numbers and zero-g body postures
Writing/worksurfaces	-	adjustable individual writing and worksurfaces for each crewmember
Information display panel	-	deployable/retractable visual display of general/ specific meeting-related information
Body [foot and thigh] restraints	-	adjustable positions associated with meeting arrangements/numbers
Tabletop object restraints	-	techniques for surface retention of papers/documents/writing implements/snacks/refreshments
Lighting systems	-	background/indirect lighting and task/surface lighting design
A/V teleconference system	-	integrally designed to serve group meeting area with camera/monitor/microphone positions based on best viewing/recording arrangement
Implement storage	-	local storage for writing implements/paper/ checklists etc

2.1.2 ACTIVITY : PLANNING AND TRAINING

2.1.2.1 DESIGN CHARACTERISTICS

The Planning and Training function provides accommodation for on-board training, planning, scheduling and work preparation for individual crewmembers, or for two crewmembers to use together. Visual privacy, aural privacy and physical independence from other Module activities are desirable though not essential features. It is basically a quiet location for working and training activities requiring concentration, and for private conversations. Training activities are likely to occur intermittently in HM1 since highly-specialized or technical mission training will probably occur in the Laboratory Modules.

2.1.2.2 DESIGN REQUIREMENTS

Workstations for 2 persons	- dedicated/ergonomic design based on specific technical requirements
Body [foot and thigh] restraints	- adjustable for side-to-side or face-to-face conversational positions
Printed material storage	- storage close to or integrated with workstations with compartmental security for manuals/videotapes/documents/print-outs etc
A/V tapedeck system	- integral with workstations including videotape panel and associated equipment for on-board training reviews and operations
Desktop object restraints	- techniques for surface retention of papers/documents/small objects/writing implements/refreshments
Information display panel	- permanent visual display of general/specific information and training material layout
Visually private enclosure	- permanent or occasional operable partition system to provide visual privacy
Aurally private enclosure	- permanent or occasional operable partition system with acoustic separation from group activity noise
Lighting systems	- background/indirect lighting and task/surface lighting design
Instrumentation	- capability for integral digital/analog type instrumentation display
Writing surface	- adjustable height/angle writing surface

2.1.3 ACTIVITY : RELAXATION AND ENTERTAINMENT

2.1.3.1 DESIGN CHARACTERISTICS

Group Relaxation and Entertainment will occur intermittently in the common locations in HM1. Capability for group entertainment should be included in the design of the meeting, teleconference and eating/drinking functions. Comfortable group viewing of a projection screen is an essential requirement. The shared environment and surroundings in which group relaxation occurs should have the potential for being both comfortable and stimulating. The ability of a specific crew or mission to determine their visual decor/ image preferences during their tour may be a desirable feature.

2.1.3.2 DESIGN REQUIREMENTS

A/V entertainment system	-	design for group viewing with screen position based on best group audience arrangement assuming 3-crew shift viewing together
Body [foot and thigh] restraints	-	adjustable positions/postures for relaxed group viewing and window observation for 2 persons
Surrounding surfaces/finishes	-	adjacent partitions/linings with surface materials/ finishes designed for physical/tactile comfort
Lighting system	-	background/indirect lighting and task/surface lighting design
Recreational equipment storage	-	storage for miscellaneous group recreational equipment [e.g. games/hobbies/musical instruments]
Large decor display	-	visual display of crew-selected decor/photos/ images/artwork and associated material storage
Window	-	window required for exterior observation for 2 persons to use simultaneously with 360° viewing orientation

2.1.4 ACTIVITY : EATING AND DRINKING

2.1.4.1 DESIGN CHARACTERISTICS

Eating and Drinking [Group Meals] is another extremely important social function on the Space Station. A dining table/appliance for up to eight persons is required, possibly in the form of four permanent [single-shift] and four occasional places. Crewmember positions and distances are critical for good eye-to-eye contact and conversation during meals. The group entertainment viewing facilities described in section 2.1.3.2 should be capable of being operated during mealtimes. Good circulation access behind any fixed table equipment is necessary for ingress/egress.The evening single-shift dinner is probably the most important social event of the day and may well be connected with informal meetings or teleconferences.

2.1.4.2 DESIGN REQUIREMENTS

Dining table appliance for 4 persons	- design of dining table/surface geometry based on body posture and group conversation considerations
Expanded table for 6-8 persons	- dining table/surface may be designed to extend to provide accommodation for up to 6-8 persons during full crew meals/meetings
Lighting systems	- background/indirect lighting and task/surface lighting design
Receptacle and utensil restraint	- techniques for surface retention of eating utensils and food and drink items
Utensil and napkin storage	- local storage of eating utensils and napkins
Body [foot and thigh] restraints	- adjustable positions/postures for eating and drinking in a group context
A/V entertainment system	- same as in section 2.1.3.2 with system suitable for mealtime viewing
Window	- same as in section 2.1.3.2 but location appropriate for more remote viewing

2.1.5 ACTIVITY : FOOD PREPARATION AND COOKING

2.1.5.1 DESIGN CHARACTERISTICS

A Food Preparation and Cooking function is required for up to three crewmembers to use simultaneously. This assumes that all crewmembers will share cooking and clean-up tasks. A comprehensive, purpose-designed range of cooking, food preparation and clean-up facilities will be included. Flexibility of operation is highly desirable where one crewmember may prepare for the shift, or each crewmember may prepare individually. Likewise, menu selection or preference may range from fully pre-packaged options to "cookbook" options. The location should be capable of being separated from other group activities either on a permanent or temporary basis.

2.1.5.2 DESIGN REQUIREMENTS

Kitchen facilities for 2-3 persons	- dedicated/ergonomic design based on cooking/food facilities for 2 to 3 persons simultaneously
Refrigerated food/liquid storage	- 14-day compartmentalized storage by refrigeration/deep-freeze for frozen/perishable/fresh food and unsealed containers

Ambient food/liquid storage	-	14-day compartmentalized storage for processed/ dehydrated/pre-sealed and packaged food and drink
Cooking and eating utensils	-	easy-access storage and restraint of food preparation and cooking utensils/equipment/eating containers/eating utensils
Cleaning materials	-	easy-access storage and dispersal of dry/damp/wet cleaning wipes/towels/sponges
Preparation work-surfaces	-	ergonomically designed worksurfaces for food preparation and simple subsequent clean-up
Worksurface object restraint	-	techniques for surface retention of food/drink preparation equipment/containers/utensils while in use
Ovens	-	zero-g programmable microwave and/or convective ovens for sealed/fresh food cooking
Hotplates	-	innovative zero-g ceramic hotplates for aero-dynamic surface cooking
Water supply	-	hot/room temperature/chilled water supply
Dishwasher and handwasher	-	zero-g dishwasher and separate handwasher
Wet trash/waste disposal	-	waste liquid and wet trash disposal dump and drainage system
Dry trash disposal	-	dry trash disposal receptacle/compactor system
Meal record display	-	provision for storage/display of menus for selection and consumed food/drink nutrition monitoring log
Local ventilation system	-	localized ventilation extracts close to appliances
Lighting system	-	background/indirect lighting and appliance/ worksurface lighting
Body [foot and thigh] restraints	-	adjustable for food preparation tasks

2.1.6 ACTIVITY : EXERCISES AND GAMES

2.1.6.1 DESIGN CHARACTERISTICS

A separate, dedicated Exercise function is required for regular physical exercise and health maintenance. Demountable/stowable exercise equipment will be included as well as portable/stowable exercise and games gear. Regular exercise equipment might be located close to a window for crew observation while in use. The location should be physically, visually and aurally separated from all other Module activity locations. Innovative zero-g Games are likely to be developed for occasional group participation. This suggests that an extendable/deployable games volume envelope is included for this purpose.

2.1.6.2 DESIGN REQUIREMENTS

Large exercise equipment	- mountable/demountable exercise equipment [e.g. rowing machine/bicycle/treadmill] for 2 persons
Small exercise equipment	- storage of small exercise equipment.[e.g. chest expander/grip exerciser]
Exercise log display	- integral equipment ergometer systems and storage/ display of related logbooks/checklists
A/V entertainment system	- associated A/V entertainment system designed for viewing during exercise [may be designed to show simulated terrestrial routes synchronized with equipment operation]
Zero-g games equipment storage	- innovative group-participation zero-g games designed in stowable/deployable equipment form
Local ventilation system	- ventilation fans/diffusers/outlets located close to exercise equipment with manual controls
Window	- window preferably located close to large exercise equipment for exterior viewing while in use

2.1.7 ACTIVITY : HOUSEKEEPING AND HYGIENE

2.1.7.1 DESIGN CHARACTERISTICS

Housekeeping and Hygiene are intermittent activities which will occur throughout the Space Station and which do not require specially allocated locations [an exception to this is the Personal Hygiene Compartment which is not a significant design feature in this study]. Meal and snack clearing-up, miscellaneous trash removal, food/drink restocking, regular environmental cleaning/vacuuming and general tidying-up are activities that will be shared by all crewmembers. Simplicity of operation is a key requirement for all housekeeping operations. Some activities such as trash compaction, restocking or vacuuming may be designed as "creative exercise" tasks.

2.1.7.2 DESIGN REQUIREMENTS

Trash collectors and containers	- purpose-designed trash collectors and containers to serve trash generated by diverse module activities
Vacuum cleaner system	- manually-operated vacuum cleaner system for use throughout modules
Trash compactor	- manually and/or automatically operated trash compaction equipment located close to kitchen location
Personal hygiene compartment	- anthropometrically-designed private personal hygiene compartment with toilet/wash facilities [detailed design of compartment not included in study]
Food/drink restock system	- zero-g "carts" for 14-day restocking of galley with food and drink selections from Logistics Module

2.1.8 ACTIVITY : SPACE STATION OPERATIONS [GENERIC]

2.1.8.1 DESIGN CHARACTERISTICS

Space Station operations and control will be capable of being carried out from both Habitability Modules via distributed command and control as recommended by Cohen (ref. 7). A purpose-designed workstation for this activity is likely to be generic or repetitive in concept. It should be capable of being periodically physically, visually and aurally isolated from all other Module activities. Occasionally, two crewmembers may occupy the workstation together.

2.1.8.2 DESIGN REQUIREMENTS

Generic space station control	- dedicated/ergonomic workstation for 1 person based on specific technical requirements with allowance for a second person on occasional visit
Body [foot and thigh] restraints	- adjustable for optimum ergonomic positions
Printed material storage	- storage close to and/or integrated with workstation with compartment security formanuals/handbooks documents/print-outs etc
A/V communications system	- integral with workstation including cameras/ monitors/videotape panel and associated equipment or IV/EV/ground communications

Desktop object restraints	-	techniques for surface retention of papers/ documents/small objects/writing implements/ refreshments
Information display panel	-	permanent visual display of general/specific information and space station operation data
Visually private enclosure	-	permanent or operable partition system to provide visual privacy
Aurally private enclosure	-	permanent or operable partition system with acoustic separation of inside conversation from group noise
Lighting systems	-	self-illuminated panels with non-glare back-ground lighting
Instrumentation	-	capability for integral digital/analog type instrumentation display
Writing and keyboard surface	-	adjustable height/angle surface for keyboard operation and writing

2.1.9 ACTIVITY : LIBRARY AND STUDY

2.1.9.1 DESIGN CHARACTERISTICS

A Library and Study function accommodates the quietest activities that will occur in HM1. This is a shared, quiet facility which is considered important during the 90-day crew tours in helping to reduce any social polarization or psychological/physiological discomfort which may arise if the only off-duty choice is between a private sleeping compartment and a communal Wardroom. This location can also be used for private conversations or gatherings for two or three crewmembers. A desirable requirement is a window for private observation by individual crewmembers. The Library facility will contain storage of books, video and audio tapes where individuals can go to read, listen or observe in peace and quiet. The environment and surroundings must be designed for maximum comfort and relaxation. Complete physical, visual and aural isolation is required from all other Module activities.

2.1.9.2 DESIGN REQUIREMENTS

Semi-private library for 2-3 persons	-	dedicated library/quiet location with visual privacy from group activities provided by permanent or operable partition system
Aurally quiet enclosure	-	permanent or operable partition system with acoustic insulation from group noise

Reading material/tape storage	-	integral storage of books/magazines/videotapes/ compact discs etc
A/V entertainment system	-	associated integral A/V entertainment system designed for individual use
Surrounding surfaces/finishes	-	enclosing partitions/linings with surface materials/finishes designed for physical/tactile comfort
Lighting systems	-	background/indirect lighting and reading task lighting design
Body [foot and thigh] restraints	-	adjustable positions/postures for individual relaxation and window observation
Window	-	window is a desirable feature for individual exterior viewing during Library occupation

2.1.10 ACTIVITY : SHIFT AND CREW HANDOVERS

2.1.10.1 DESIGN CHARACTERISTICS

Shift and Crew Handovers are periodic activities occurring throughout the Space Station and for which no permanent locations are required. Shift Handovers will occur 2-3 times every 24 hours involving up to 8 persons, and Crew Handovers every 45 or 90 days involving up to 16 persons (ref.7). Sufficient circulation volume and non-conflicting routing are key design considerations throughout the Group Habitability Module during crew or shift handovers when many crewmembers may be simultaneously moving about. This is particularly important during STS crew exchanges when baggage, supplies and equipment are being exchanged. The Meeting location should be capable of expanding to accommodate an optimum number of crewmembers for short crew exchange meetings.

2.1.10.2 DESIGN REQUIREMENTS

Extendable meeting table/appliance	-	meeting table/appliance designed to temporarily extend to 12 person capacity during crew handovers [assumes additional persons will use stowable body restraints]
Travel kitbags	-	provision of purpose-designed kitbags for stowage and transfer of group documents/objects/equipment during crew exchange
Temporary restraints	-	stowable temporary body restraints for additional crewmembers during exchange meetings

2.2 PRELIMINARY HABITABILITY DESIGN GUIDELINES

The Preliminary Habitability Design Guidelines contained in Section 2.2 comprise an outline set of design guidelines for the range of accommodation and facilities required within HM1.

The information encompasses background guidelines which, together with design requirements contained in Architectural Design Program, Section 2.1, have been developed to support the Schematic Design Phase of the project.

Section 2.2.1 on Activity Routines provides a necessary reference framework for establishing the types and sequence of crew activities likely to occur in HM1.

Section 2.2.2 on Activity Proximities summarizes activity spatial and organizational interrelationships and key activity area adjacency criteria.

Sections 2.2.3 and 2.2.4 deal respectively with individual Wardroom activity envelopes and ergonomic interfaces, and how those envelopes can be assembled into Wardroom group activity volumes. These two sections are *not* intended to be read as design options but strictly as guidance illustrations of key design issues.

2.2.1 ACTIVITY ROUTINE GUIDELINES

2.2.1.1 CREW ROUTINE REFERENCES

Information on crew make-up and crew routine activities has been extracted from Space Station Definition and Preliminary Design, Request for Proposal, issued on September 15 1984 with subsequent revisions as advised by NASA.

Later revisions include the addition of Payload Specialist as a new crew-member category; increase of exercise and recreation periods from 1/2 hour to 1 hour each; incorporation of exercise periods into on-duty periods; reduction of daily work periods for all crewmembers to 8 hours; crew complement increase of up to 8 persons.

2.2.1.2 OUTLINE CREW ROUTINE CRITERIA

Provisional Space Station IOC requirement is for a 6-8 person crew comprising 2 Station Specialists, 2-3 Mission Specialists and 2-3 Payload Specialists. 2 alternating crew shifts will each be of 12 hours duration with crews working 6-day weeks. Each 3-4 person shift is likely to comprise a Station Specialist, 1-2 Mission Specialists and 1-2 Payload Specialists. Crew tours will be partly rotated every 45 days or fully rotated every 90 days. On-board operations will be carried out 24 hours a day, 7 days a week.

2.2.1.3 OUTLINE CREW ROUTINE SCHEDULE

Mission or Payload Specialist : on-duty	7 hrs	-	Customer Operations
	1 hr	-	Lunch
	1 hr	-	Training
	1 hr	-	Planning
	1 hr	-	Exercise
	1 hr	-	Station Maintenance
	12 HRS	-	TOTAL
Station Specialist : on-duty	7 hrs	-	Space Station Systems Management/Ops.
	1 hr	-	Lunch
	1 hr	-	Training
	1 hr	-	Planning
	1 hr	-	Exercise
	1 hr	-	Station Maintenance
	12 HRS	-	TOTAL
All Specialists : off-duty	8 hrs	-	Sleep
	1 hr	-	Personal Hygiene
	1 hr	-	Recreation
	1 hr	-	Dinner
	1/2 hr	-	Breakfast
	1/2 hr	-	Shift Handover
	12 HRS	-	TOTAL

2.2.1.4 FIGURE 1 - DAILY GROUP AND INDIVIDUAL ROUTINES

FIGURE 1, PAGE 15 lists the range of daily crew routines based on criteria outlined in 2.2.1.2 and 2.2.1.3. These are arranged on a 24 hour time scale. FIGURE 1 also indicates which routines are individual or group activities and the number of crewmembers in the group.

2.2.1.5 FIGURE 2 - DAILY ROUTINES AND ALTERNATING SHIFTS

FIGURE 2, PAGE 16 lists the daily crew routines in two columns representing alternating crew shifts on a 24 hour time scale. Solid arrows indicate extent of on-duty periods and hollow indicate extent of off-duty periods.

2.2.1.6 FIGURE 3 - GROUP MODULE ACTIVITY FLOW SEQUENCE

FIGURE 3, PAGE 17 describes a flow sequence on a 24 hour time scale of those activities which occur within HM1. The sequence differentiates between those activities which occur in HM1 [ringed in solid lines down the center], and those activities which occur in other Space Station Modules [ringed in dotted lines down the edges]. Parallel activities [which occur simultaneously in time] and serial activities [which occur sequentially in time] are also indicated.

FIGURE 1 - DAILY GROUP AND INDIVIDUAL ROUTINES

TIME	TYPICAL CREW ROUTINE	DUTY	IND. OR GRP. ACTIVITY	NUMBER IN GRP.
00.00–07.00	SLEEP	OFF-DUTY	INDIVIDUAL [HAB. MODULE 2 ONLY]	1
07.00	PERSONAL HYGIENE	OFF-DUTY	INDIVIDUAL	1
07.00–07.30	BREAKFAST	OFF-DUTY	GROUP	3-4
07.30–11.30	STATION/MISSION/PAYLOAD OPERATIONS [INC. STATION MAINTENANCE]; EXERCISE (10.00)	ON-DUTY	INDIVIDUAL OR GROUP [HAB. + LAB. MODULES]	1-3 [MISSION/PAYLOAD SPECIALISTS] + 1-2 [STATION SPECIALIST]
11.30–12.30	PLANNING OR TRAINING	ON-DUTY	INDIVIDUAL OR GROUP	1-4
12.30–13.30	LUNCH	ON-DUTY	GROUP	3-4
13.30–18.30	STATION/MISSION/PAYLOAD OPERATIONS [INC. STATION MAINTENANCE]; EXERCISE (15.30)	ON-DUTY	INDIVIDUAL OR GROUP [HAB. + LAB. MODULES]	1-3 [MISSION/PAYLOAD SPECIALISTS] + 1-2 [STATION SPECIALIST]
18.30–19.30	PLANNING OR TRAINING	ON-DUTY	INDIVIDUAL OR GROUP	1-4
19.30–20.00	SHIFT HANDOVER	OFF-DUTY	GROUP	6-8 [BOTH CREWS]
20.00–21.00	DINNER	OFF-DUTY	GROUP	3-4
21.00–22.00	RECREATION	OFF-DUTY	INDIVIDUAL	1
22.00–22.30	PERSONAL HYGIENE	OFF-DUTY	INDIVIDUAL	1
22.30–24.00	SLEEP	OFF-DUTY	INDIVIDUAL	1

FIGURE 2 - DAILY ROUTINES AND ALTERNATING SHIFTS

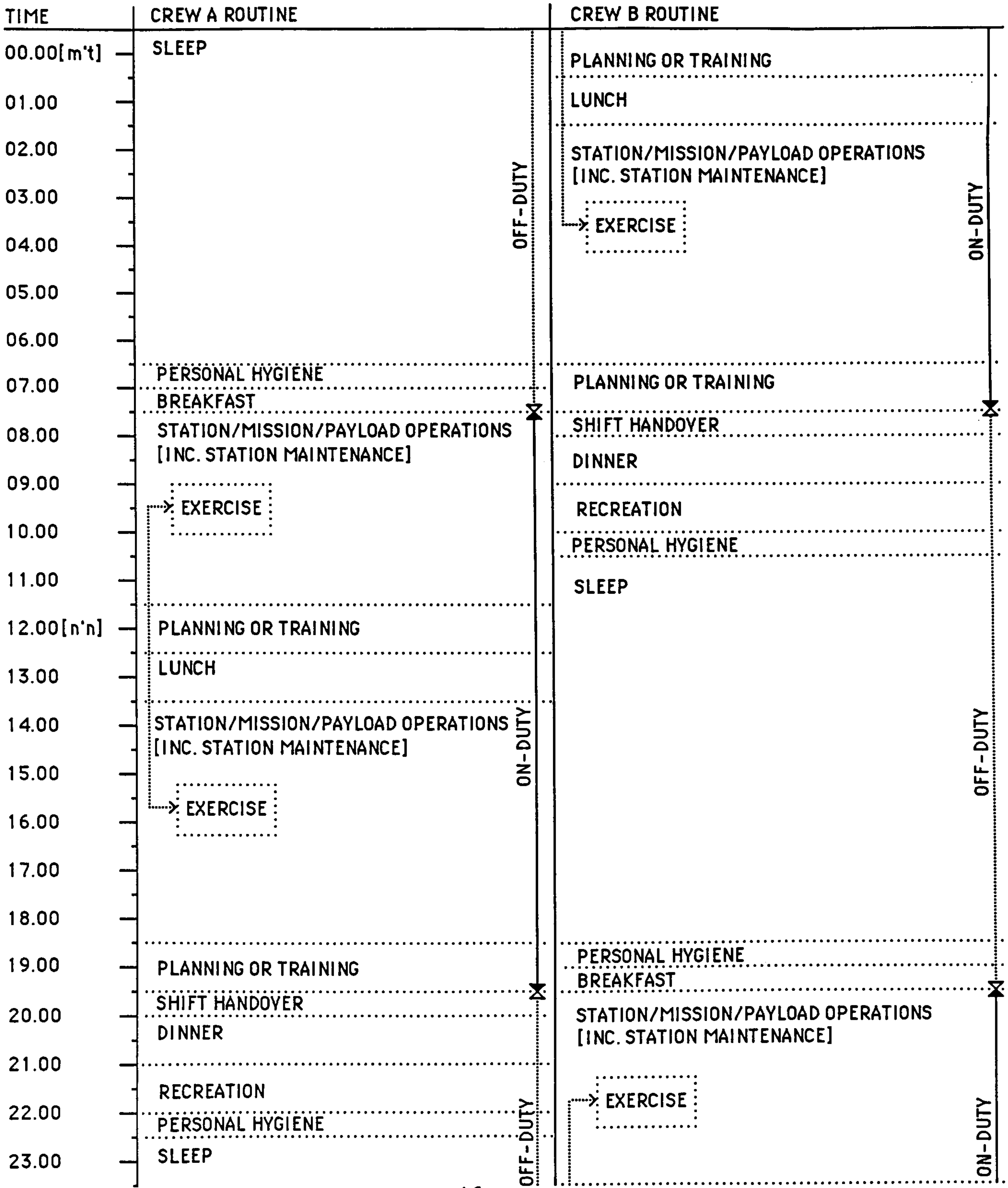
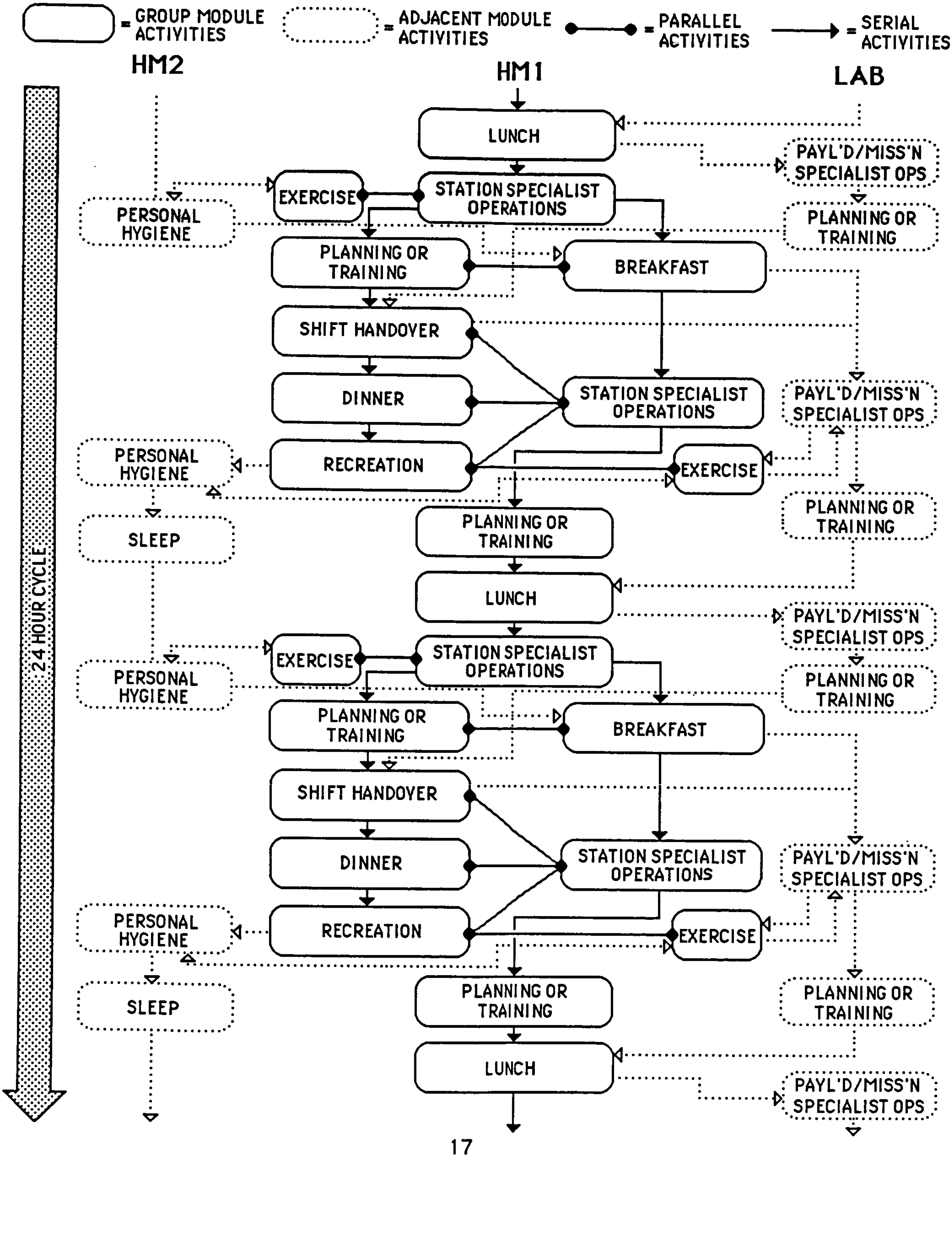


FIGURE 3 - GROUP MODULE ACTIVITY FLOW SEQUENCE



2.2.2 ACTIVITY PROXIMITY GUIDELINES

2.2.2.1 REFERENCES FOR DETERMINING ACTIVITY TYPES AND LOCATIONS

In order to proceed with a representative paradigm of HM1 activity types and their proximities to each other, it is necessary to identify certain assumptions about which activities occur in HM1, together with their individual characteristics. These assumptions have been derived from several reference sources, including Space Station Reference Configuration Description and Space Station Definition and Preliminary Design, Request for Proposal. Certain habitability references were drawn from a Space Station habitability analogy study by Stuster [ref. 2].

2.2.2.2 HABITABILITY MODULE 1 OPERATIONS

IVA Station Specialist Operations will be carried out throughout the Space Station and within HM1 on an intermittent basis. IVA Mission and Payload Specialist Operations will generally be carried out in the Laboratory Modules except for proximity-operations and earth-observation functions which will occur in HM1.

2.2.2.3 HABITABILITY MODULE 2 ACTIVITIES

Sleep activities will occur exclusively in HM2 [Sleep Module]. Specified daily Personal Hygiene periods just before and after sleep will involve crew showers and/or sponge baths which will occur exclusively in HM2. Occasional restroom visits during the day will require a restroom to be located in HM1 to avoid disturbing those crewmembers asleep in HM2.

2.2.2.4 MEALTIMES

Breakfast may be arranged as a group activity or on an individual/informal basis. Lunch may be arranged as a group activity or on an individual/informal basis if the latter works better with individual crewmember work operation scheduling where, for example, a continuous 1 hour absence may not be realistic or feasible. Dinner should always be arranged as a group activity and should be prepared and enjoyed together by each shift in as relaxed a manner as possible. Under normal routine conditions, alternating shift mealtimes should not be scheduled in parallel as this could cause significant Food Preparation and Cooking "bottlenecks" in the kitchen area. Large impromptu meals for an entire crew, which may occur on special occasions such as crew handovers, should be possible with careful Food Preparation organization.

2.2.2.5 OPERATIONS SUPPORT ACTIVITIES

Crew Handover, which will occur at Shuttle visit times, is too complex and indeterminate to predict at this time other than assuming that HM1 may host from 12 to 16 persons for handover meetings. Station Maintenance time may include Housekeeping duties, such as accommodation and equipment cleaning, laundry, tidying up and kitchen or laboratory maintenance tasks. Housekeeping would be carried out on a shared or individual basis.

Planning and Training activities may occur on an intermittent basis in HM1 although Mission and Payload Specialists may carry out most of their Training activities in the Laboratory Modules. Planning activities might suitably be scheduled directly before Shift Handover. This would facilitate a combined Planning and Shift Handover session, as the shift going off-duty may need to check or revise planning schedules to handover the the shift about to go on-duty.

2.2.2.6 FIGURE 4 - ACTIVITY ADJACENCY COMPATIBILITY MATRIX

FIGURE 4 , PAGE 21 is a matrix diagram which interrelates each activity type in HM1 according to a graduated 5-point scale of spatial compatibility. The matrix diagram indicates which activity areas can be combined, which can be adjacent, which need partial or complete separation, and which are non-related.

2.2.2.7 FIGURE 5 - ACTIVITY PROXIMITY BUBBLE DIAGRAM

FIGURE 5, PAGE 22 is a matrix diagram which summarizes the key significant activity proximities and separations in simple bubble form.

2.2.2.8 KEY ACTIVITY PROXIMITY DESIGN CRITERIA

FIGURES 4 and 5 provide key information on activity area proximity relationships and movement patterns in HM1. These relationships and patterns, together with the activity assumptions summarized above, generate a list of key design criteria summarized below.

- KITCHEN/GALLEY

  A Kitchen/Galley for Food Preparation and Cooking should be close to the Lounge/Dining/Wardroom but physically separate from it. If the Lounge/Dining/Wardroom is subdivided, the Kitchen/Galley should be closest to that part of it allocated to group meals. The Kitchen/Galley should have the capability of being physically, visually and aurally separate from other areas, though occasional group participation in, or observation of, Food Preparation activities may be desirable.

- LOUNGE/DINING/WARDROOM

  A Lounge/Dining/Wardroom should accommodate Meetings, Teleconferences, Group Meals, Group Planning, Group Relaxation and Entertainment activities. It may be configured as a single volume accommodating all these activities, or as adjacent volumes, each of which accommodates one or two activities [e.g. Meetings/Teleconferences/Group Planning as one combination and Group Meals/Relaxation/Entertainment as another].

  The design should enable Meeting/Planning activities and Meal/Relaxation/Entertainment activities to occur simultaneously without mutual conflict. The Lounge/Dining/Wardroom is the most important area on the Space Station for crew social interaction.

- LIBRARY/STUDY

  A Library/Study should accommodate Training, Study, Individual Planning, Meditation and Observation activities. It may be configured as a single volume accommodating all these activities, or as adjacent volumes, each accommodating one or two activities [e.g. Training/Individual Planning as one combination and Meditation/Observation/ Study as another].

  The design should preferably enable Training/Planning activities and Meditation/ Observation/Study activities to occur simultaneously without mutual conflict. The Library/Study is a "quiet" facility for 2-3 person use. It should be physically, visually and aurally separate from all other areas.

- GYMNASIUM/EXERCISE FACILITY

  The Gymnasium/Exercise facility should be visually,physically, and aurally separate from all other areas. The Group Games function may be considered as a flexible function which occasionally extends or deploys into other group activity accommodation during group games, but never into the Library/Study or Kitchen/Galley.

FIGURE 4 - ACTIVITY ADJACENCY COMPATIBILITY MATRIX

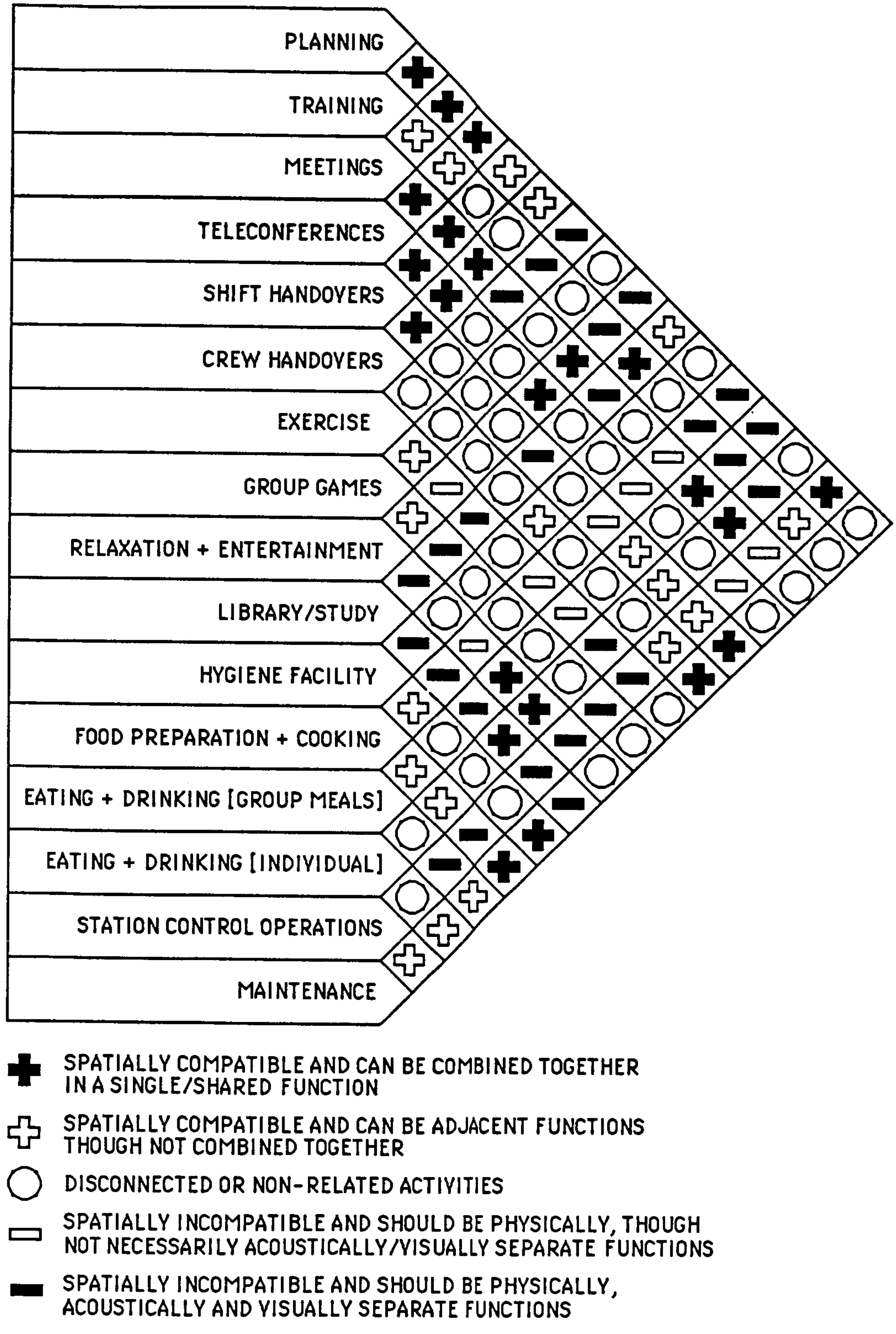
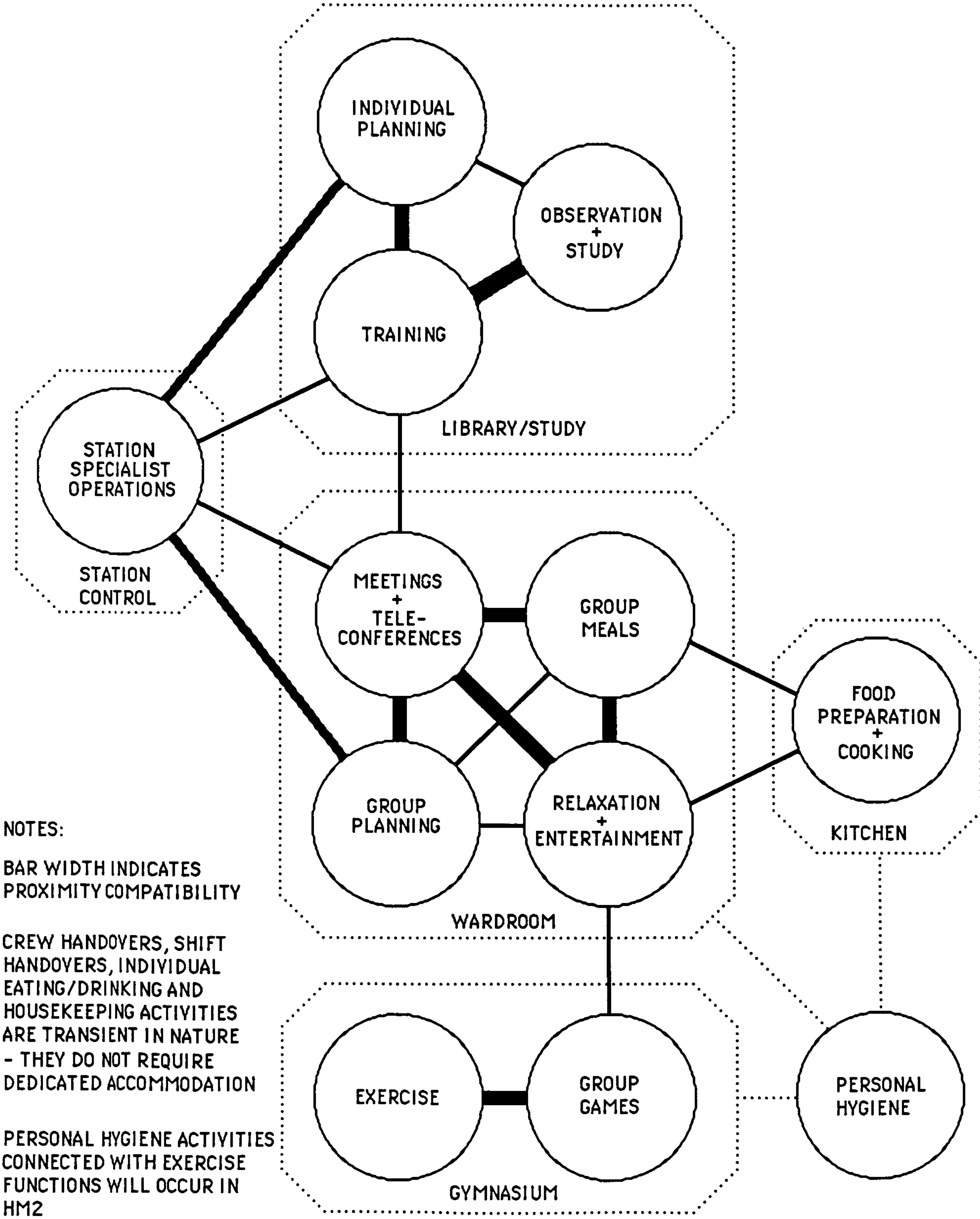


FIGURE 5 - ACTIVITY PROXIMITY BUBBLE DIAGRAM



NOTES:

BAR WIDTH INDICATES PROXIMITY COMPATIBILITY

CREW HANDOVERS, SHIFT HANDOVERS, INDIVIDUAL EATING/DRINKING AND HOUSEKEEPING ACTIVITIES ARE TRANSIENT IN NATURE - THEY DO NOT REQUIRE DEDICATED ACCOMMODATION

PERSONAL HYGIENE ACTIVITIES CONNECTED WITH EXERCISE FUNCTIONS WILL OCCUR IN HM2

2.2.3 ACTIVITY ERGONOMIC GUIDELINES

2.2.3.1 WARDROOM ACTIVITY ERGONOMIC ENVELOPES

Taking 95% male and 5% female anthropometric neutral body posture angular relationships and reach envelopes, a set of scale diagrams has been developed which explores a preliminary range of geometries for three key Wardroom activity categories -Meetings and Teleconferences; Eating and Drinking; Planning and Training.

The diagrams illustrate the interfaces between a single figure and the different ergonomic envelopes in top, front and side view positions.

Each type of activity is illustrated in the form of different geometries describing a minimum, a maximum and a median approach to the ergonomic envelope involved.

The minimum approach compares the 5% female neutral body posture with the shape and size of a minimum feasible ergonomic activity interface. The maximum approach compares the 95% male neutral body posture with the shape and size of a maximum feasible ergonomic activity interface. These figures have been derived from diagrams included in Zero-G Workstation Design by NASA-Johnson Space Center [ref. 3], and The Influence of Zero-G and Acceleration on The Human Factors of Spacecraft Design by Brand Griffin [ref. 4] also summarized in Proceedings from the Seminar on Space Station Human Productivity [ref. 5]. The median approach overlays both 5% female and 95% male neutral body postures and compares them with the shape and size of a median ergonomic activity interface which represents the optimum or preferred interface design for that particular activity.

2.2.3.2 FIGURE 6 - MEETINGS AND TELECONFERENCES : MINIMUM ERGONOMIC ENVELOPE

See PAGE 25

2.2.3.3 FIGURE 7 - MEETINGS AND TELECONFERENCES : MAXIMUM ERGONOMIC ENVELOPE

See PAGE 26

2.2.3.4 FIGURE 8 - MEETINGS AND TELECONFERENCES : MEDIAN EQUIPMENT ENVELOPE

See PAGE 27

2.2.3.5 FIGURE 9 - EATING AND DRINKING : MINIMUM ERGONOMIC ENVELOPE

See PAGE 28

2.2.3.6 FIGURE 10 - EATING AND DRINKING : MAXIMUM ERGONOMIC ENVELOPE

See PAGE 29

2.2.3.7 FIGURE 11 - EATING AND DRINKING : MEDIAN EQUIPMENT ENVELOPE

See PAGE 30

2.2.3.8 FIGURE 12 - PLANNING AND TRAINING : MINIMUM ERGONOMIC ENVELOPE
See PAGE 31

2.2.3.9 FIGURE 13 - PLANNING AND TRAINING : MAXIMUM ERGONOMIC ENVELOPE
See PAGE 32

2.2.3.10 FIGURE 14 - PLANNING AND TRAINING : MEDIAN EQUIPMENT ENVELOPE
See PAGE 33

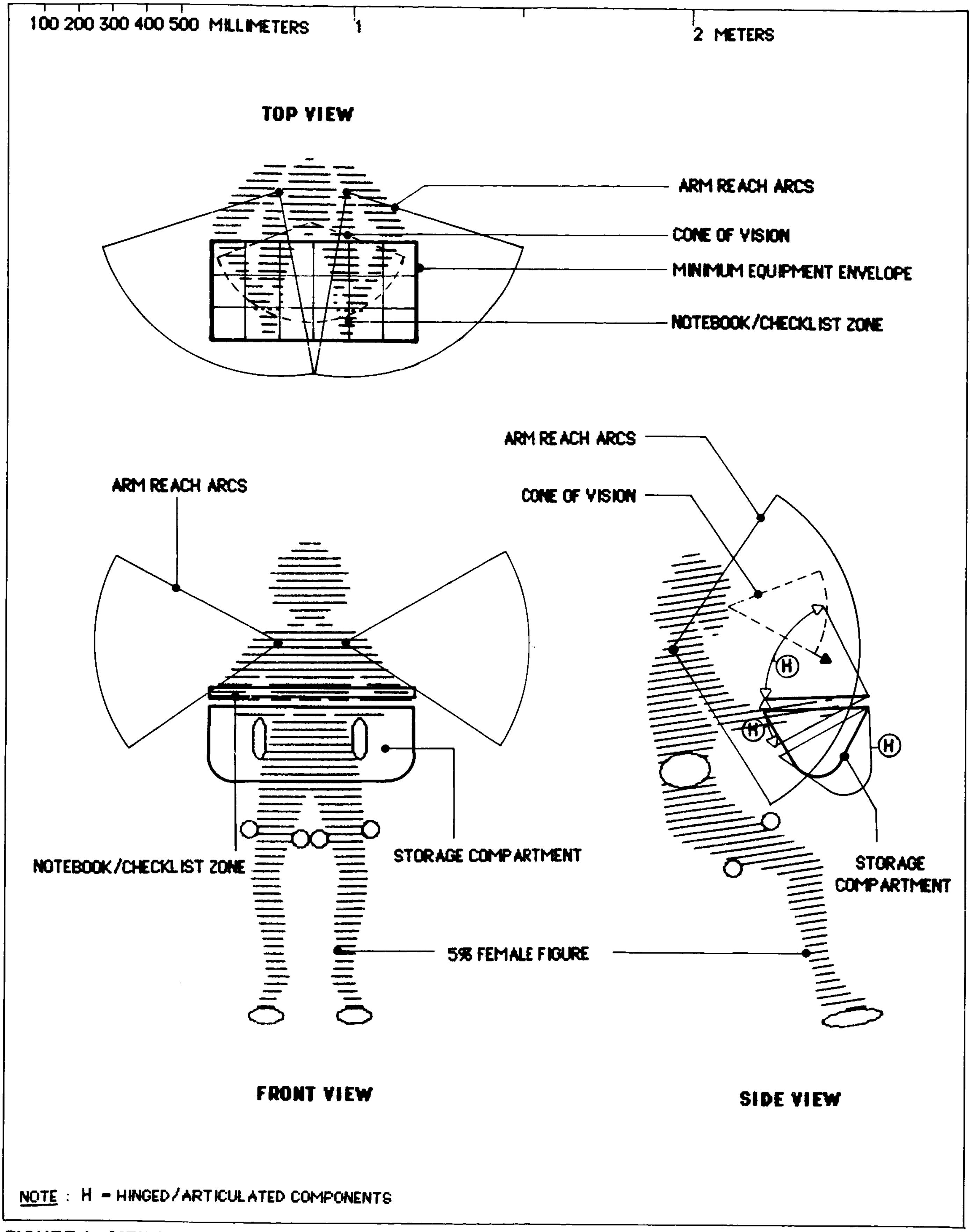


FIGURE 6 - MEETINGS AND TELECONFERENCES : MINIMUM ERGONOMIC ENVELOPE

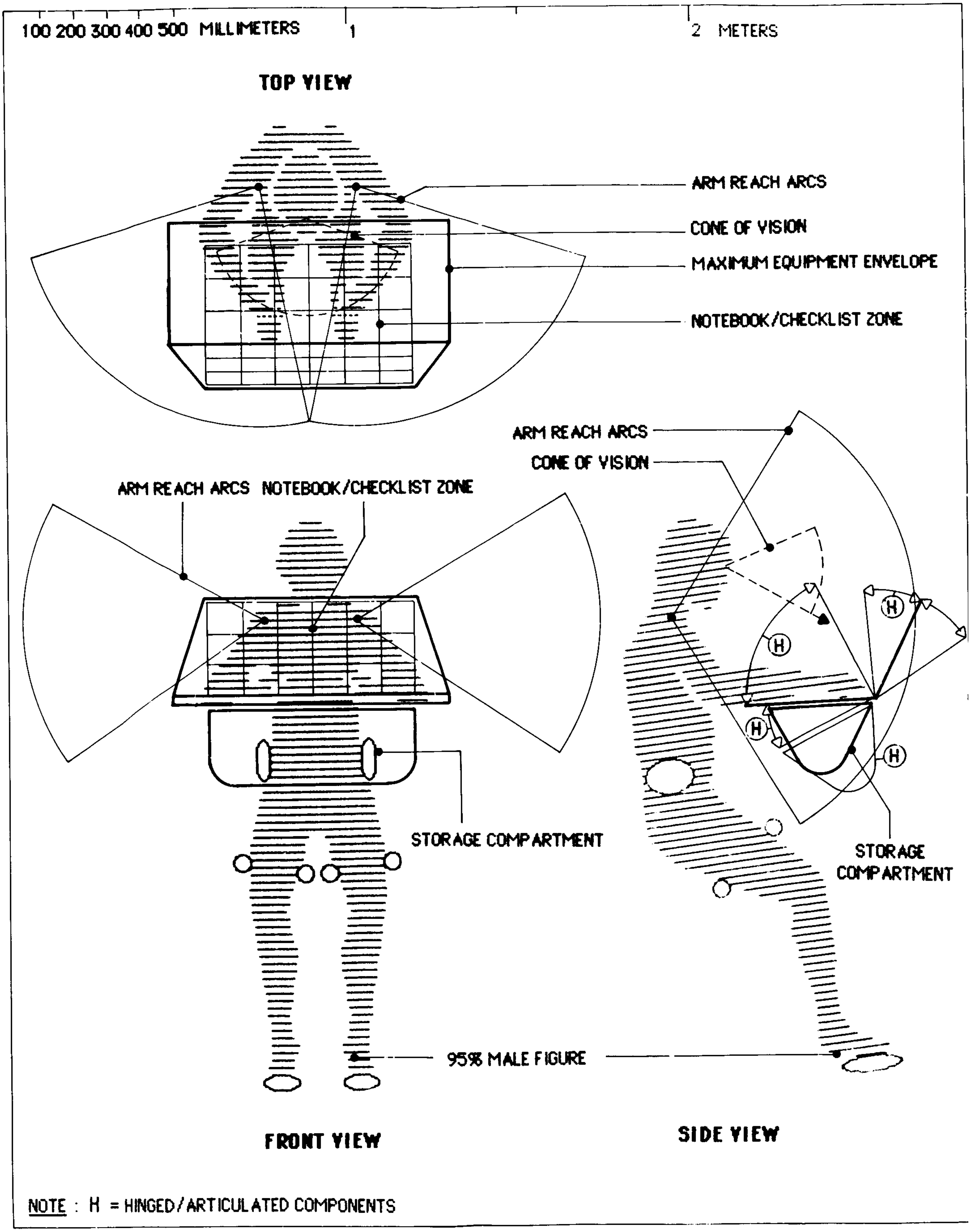


FIGURE 7 - MEETINGS AND TELECONFERENCES : MAXIMUM ERGONOMIC ENVELOPE

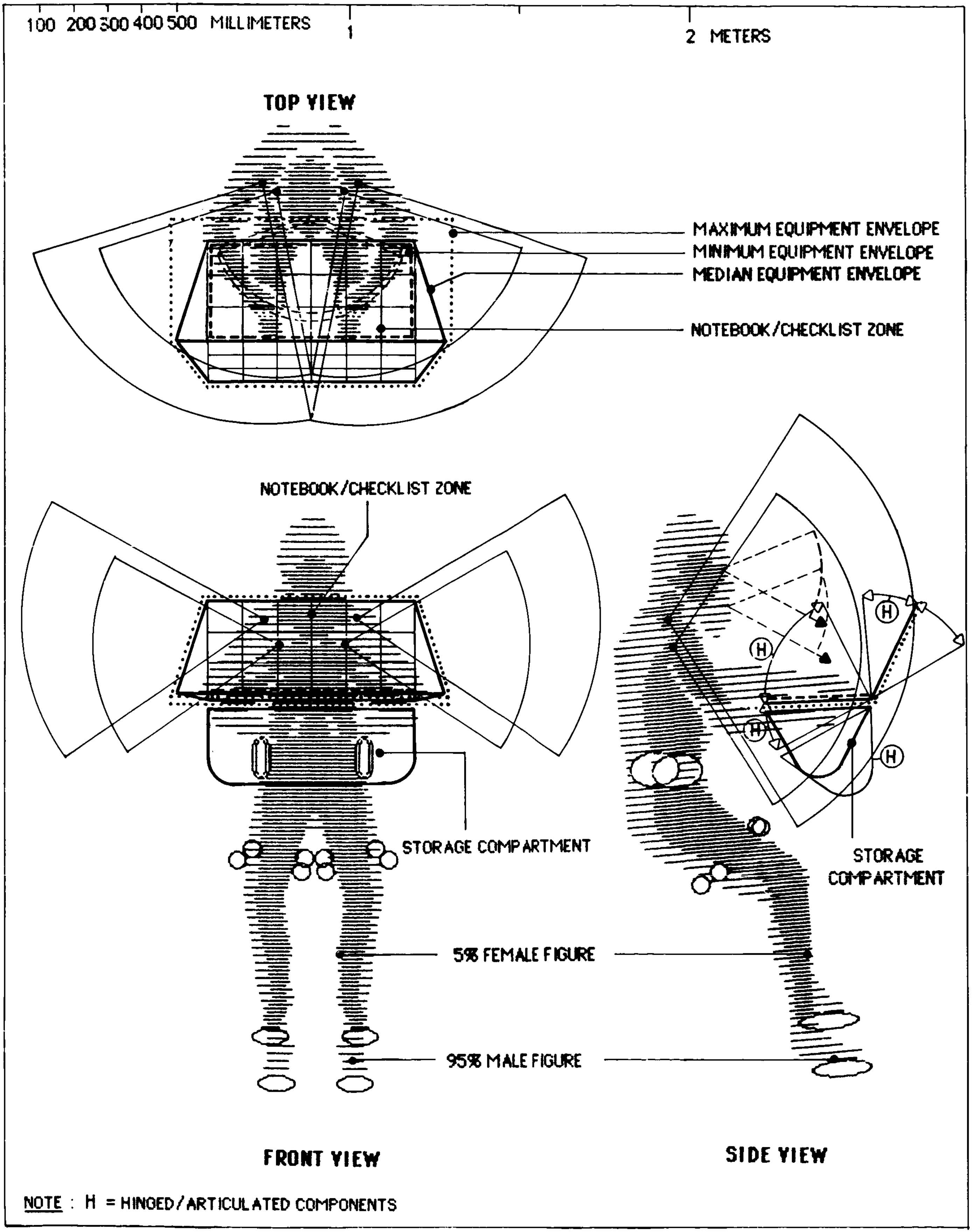


FIGURE 8 - MEETINGS AND TELECONFERENCES : MEDIAN EQUIPMENT ENVELOPE

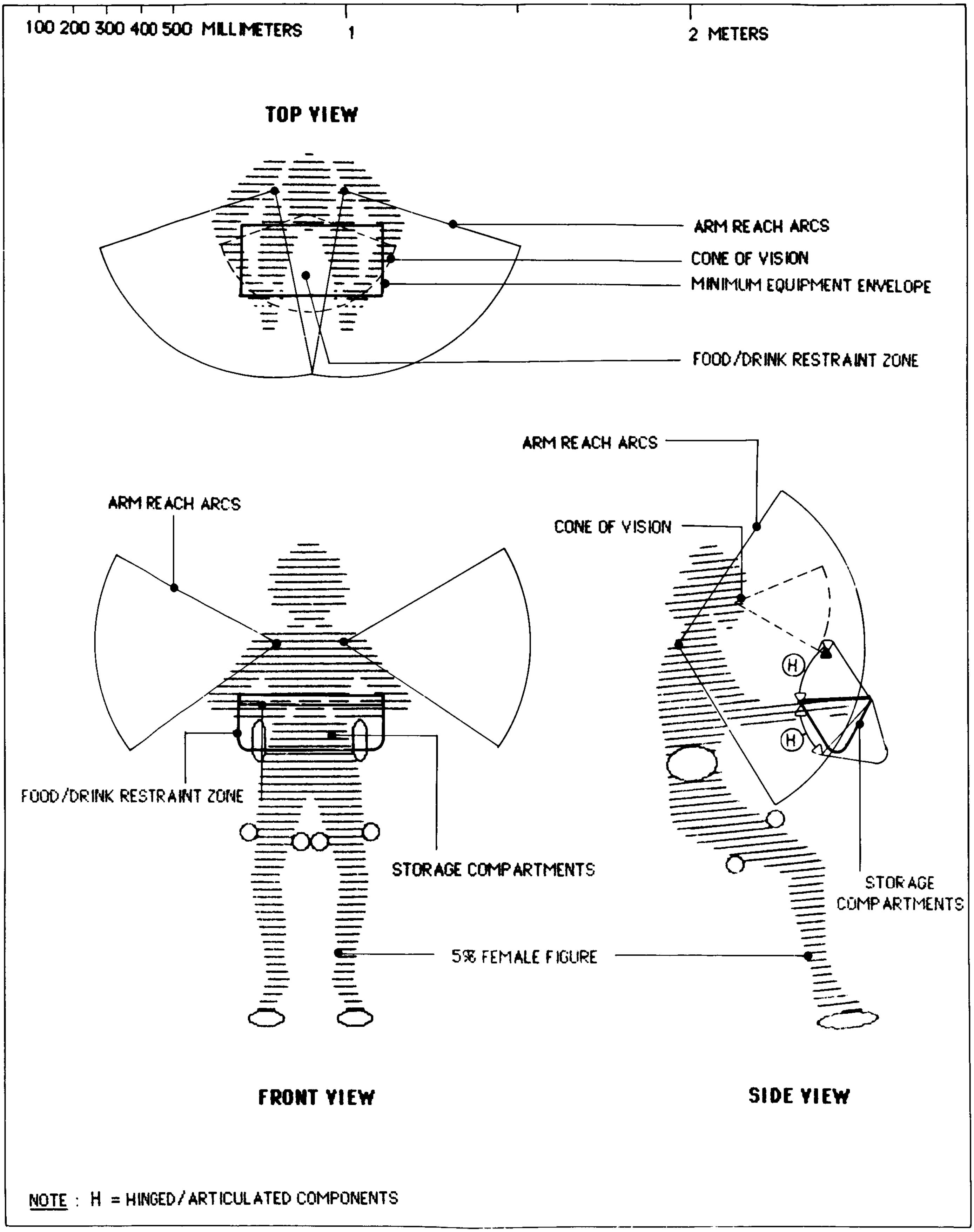


FIGURE 9 - EATING AND DRINKING : MINIMUM ERGONOMIC ENVELOPE

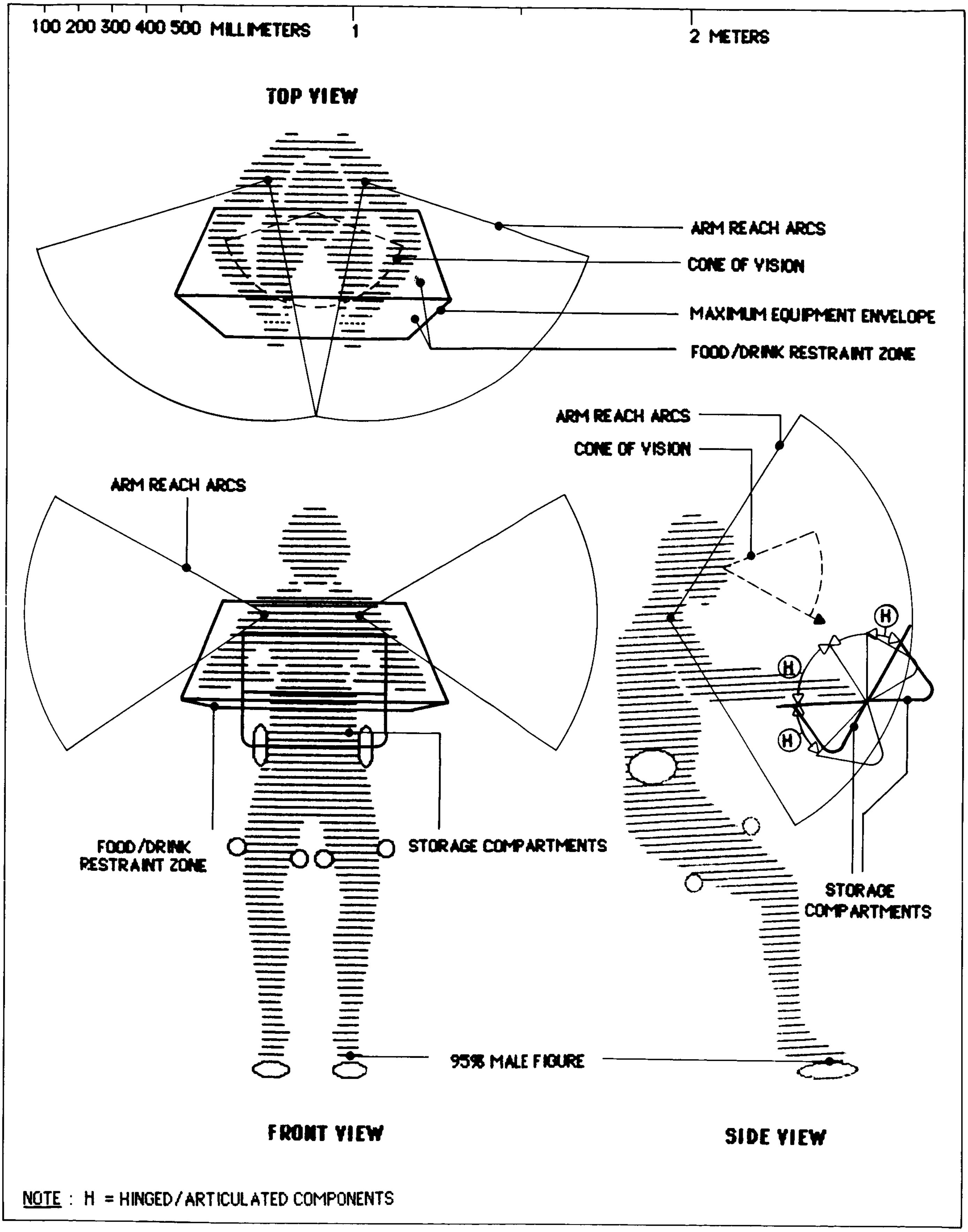


FIGURE 10 - EATING AND DRINKING : MAXIMUM ERGONOMIC ENVELOPE

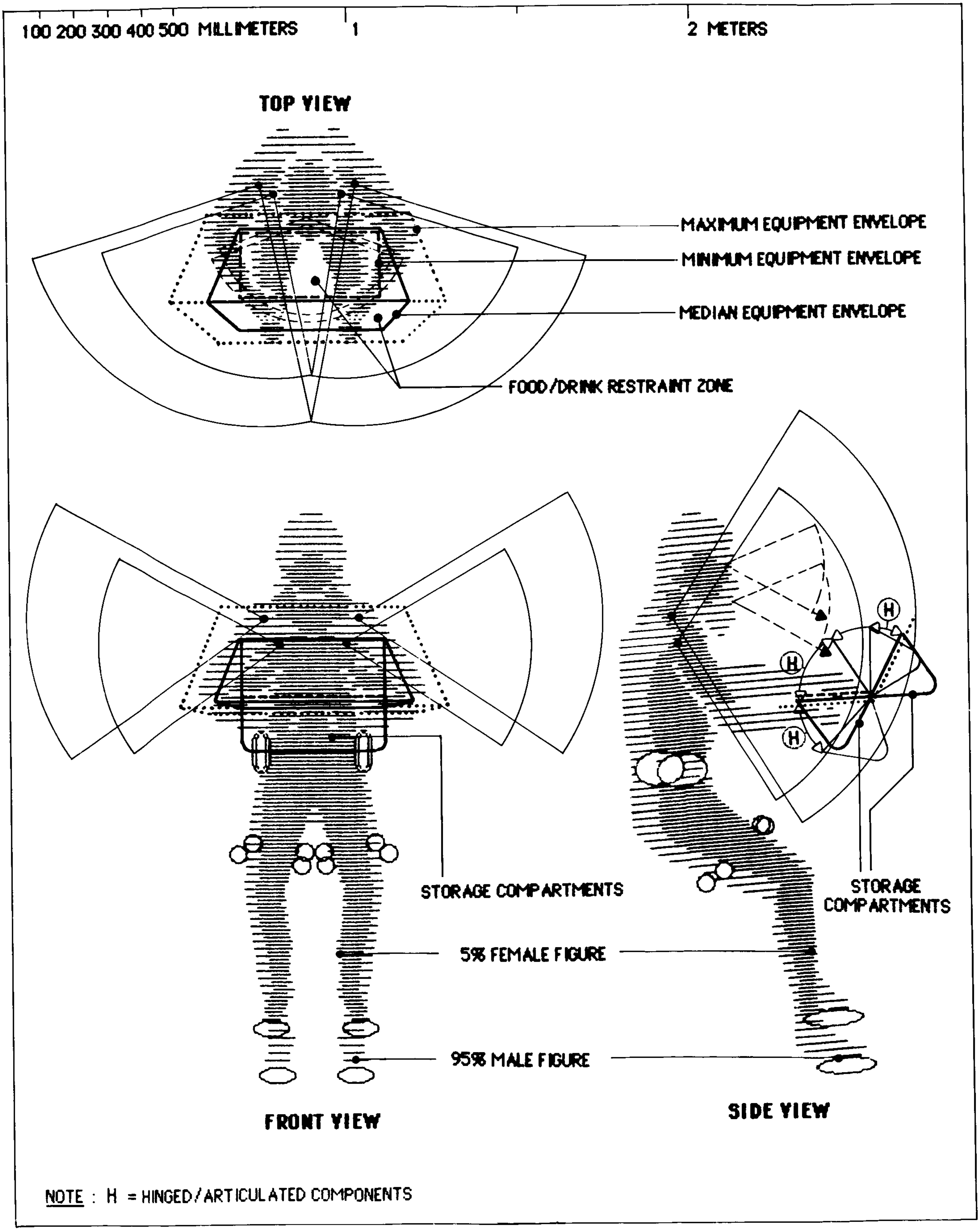


FIGURE 11 - EATING AND DRINKING : MEDIAN EQUIPMENT ENVELOPE

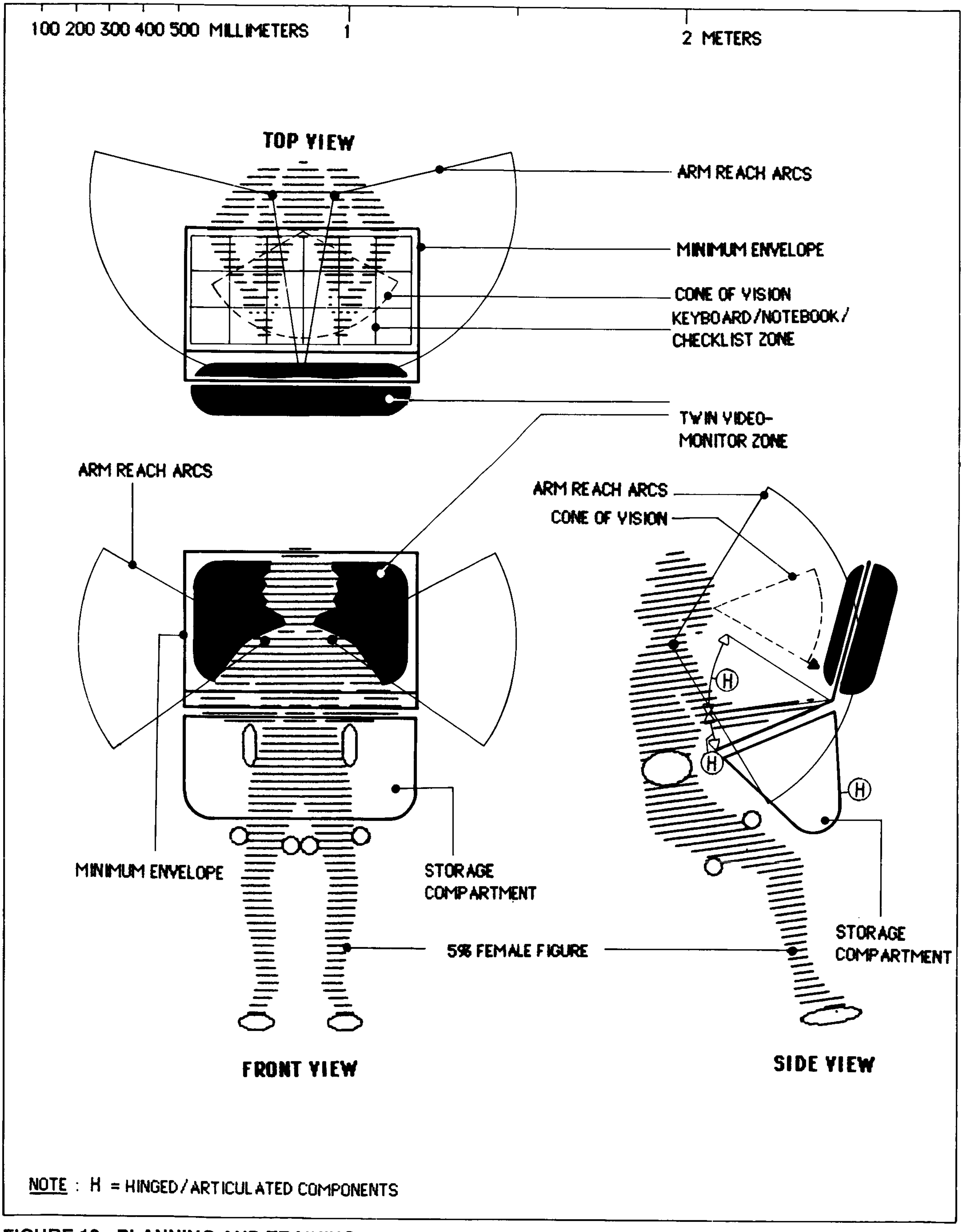


FIGURE 12 - PLANNING AND TRAINING : MINIMUM ERGONOMIC ENVELOPE

ORIGINAL PAGE IS
OF POOR QUALITY

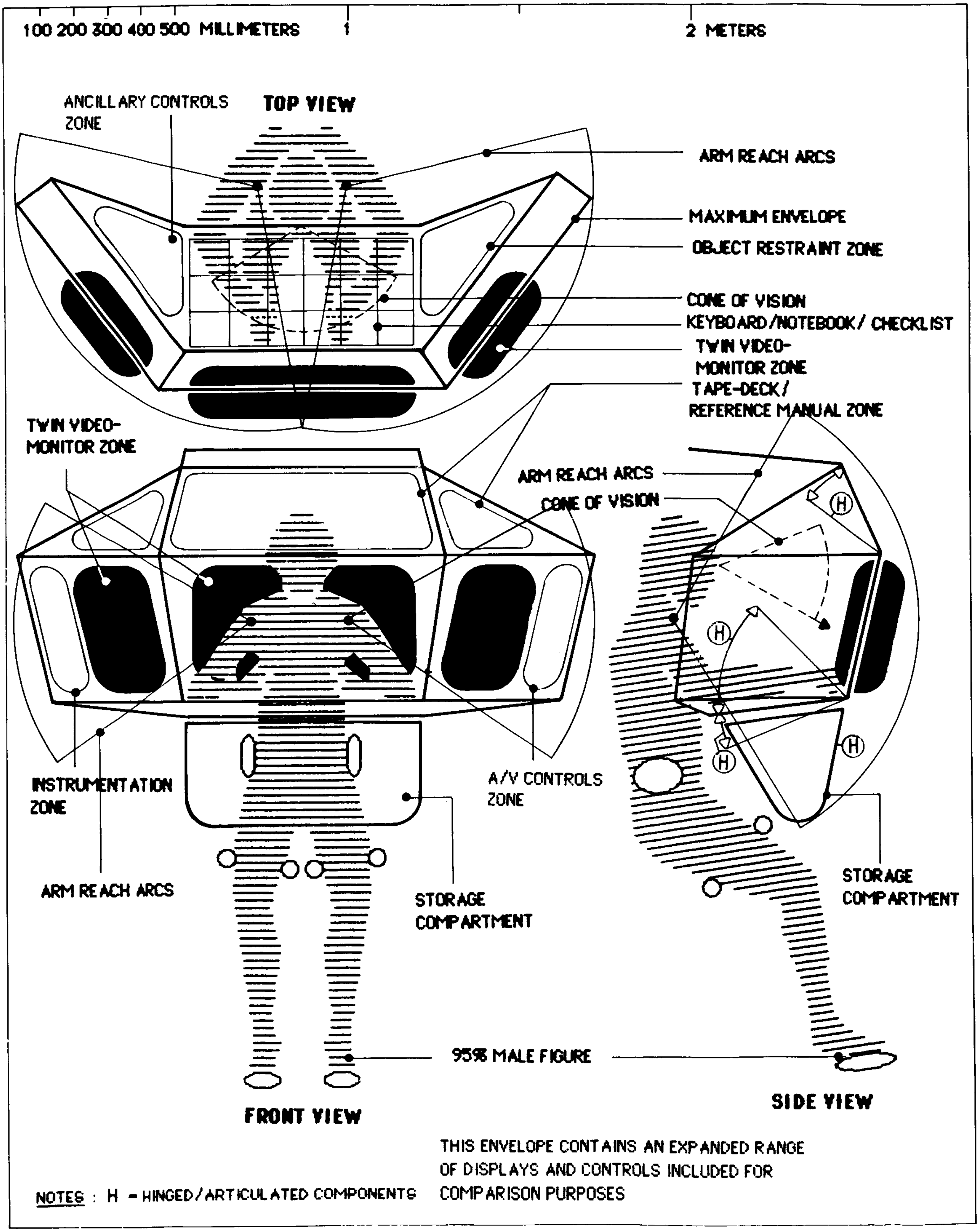


FIGURE 13 - PLANNING AND TRAINING : MAXIMUM ERGONOMIC ENVELOPE

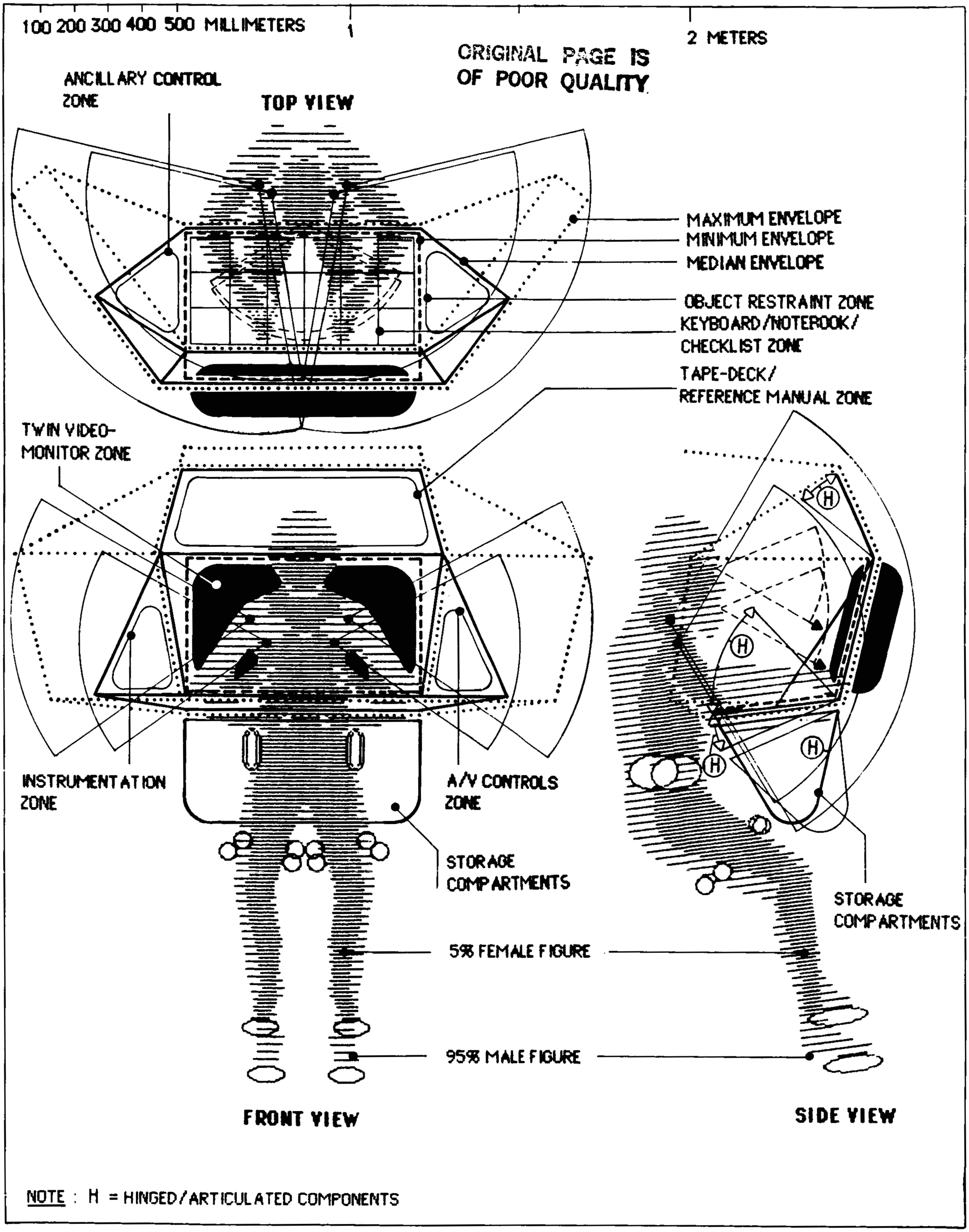


FIGURE 14 - PLANNING AND TRAINING : MEDIAN EQUIPMENT ENVELOPE

2.2.4 ACTIVITY VOLUMETRIC GUIDELINES

2.2.4.1 WARDROOM ACTIVITY VOLUMETRIC ENVELOPES

Taking the set of individual Wardroom activity ergonomic envelopes developed in Section 2.2.3, a series of outline volumetric envelope diagrams has been developed which illustrate alternative group spatial arrangements for each key Wardroom group activity.

The diagrams illustrate the characteristics of volume geometries generated by typical crew groups involved in each activity, as determined by their combined stationary envelopes, associated physical movement patterns and sightline requirements. Alternative overall geometrical arrangements are indicated for each activity.

2.2.4.2 FIGURES 15 AND 16 - GROUP MEETINGS : VOLUMETRIC ENVELOPES

See PAGES 35 and 36 respectively

2.2.4.3 FIGURES 17 AND 18 - TELECONFERENCES : VOLUMETRIC ENVELOPES

See PAGES 37 and 38 respectively

2.2.4.4 FIGURES 19 AND 20 - EATING AND DRINKING : VOLUMETRIC ENVELOPES

See PAGES 39 and 40 respectively

2.2.4.5 FIGURE 21 - PLANNING AND TRAINING : VOLUMETRIC ENVELOPES

See PAGE 41

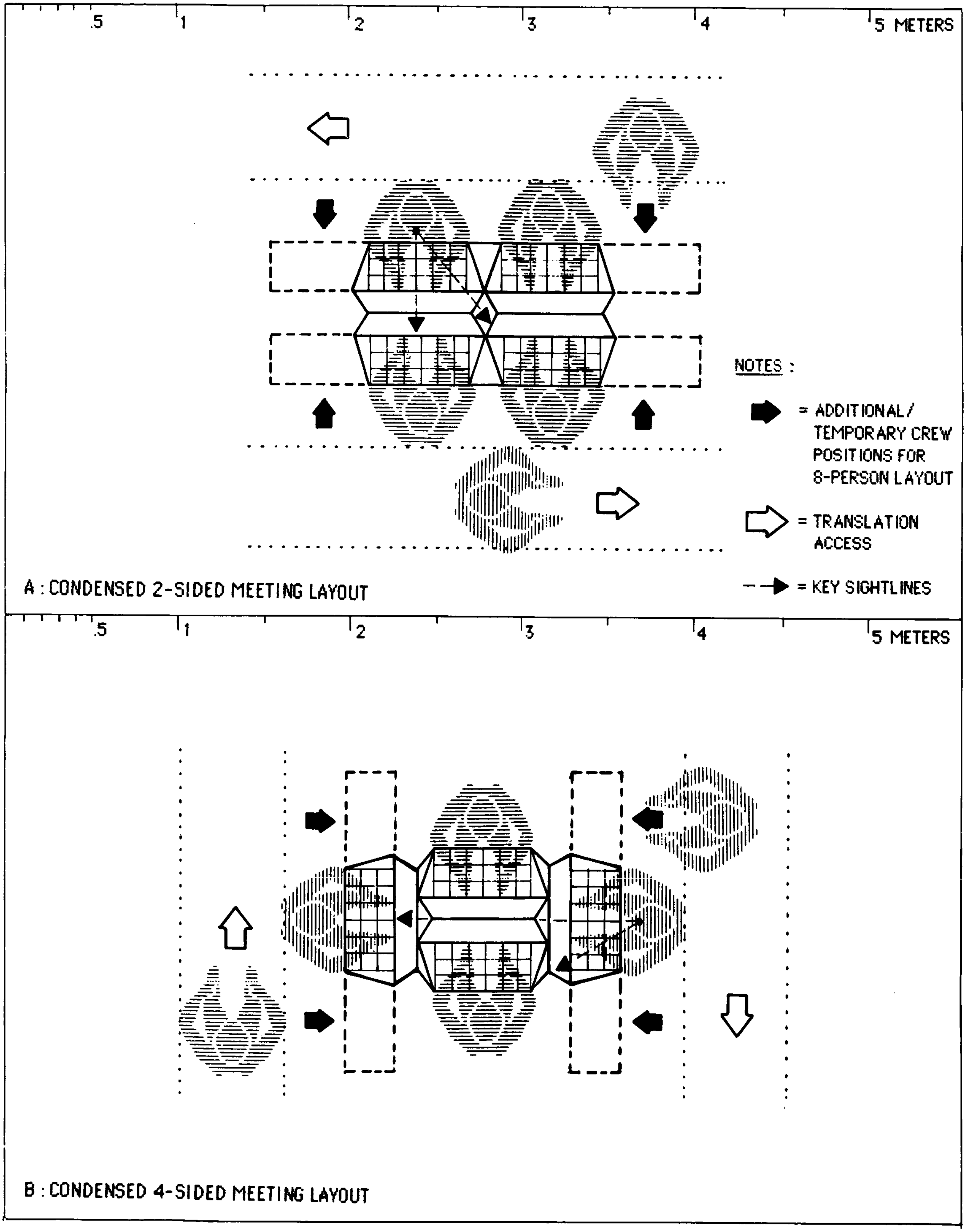


FIGURE 15 - GROUP MEETINGS : VOLUMETRIC ENVELOPES

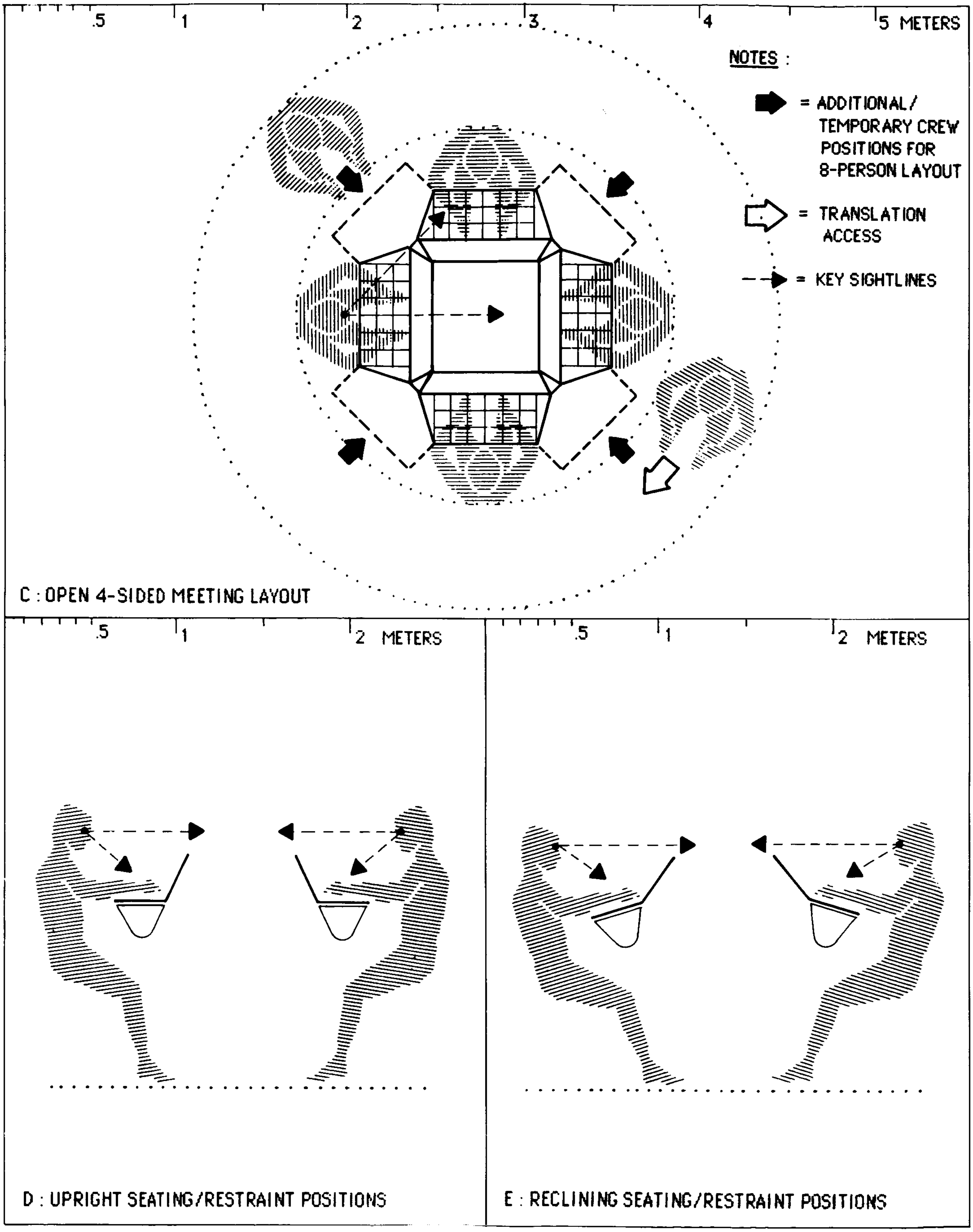


FIGURE 16 - GROUP MEETINGS : VOLUMETRIC ENVELOPES

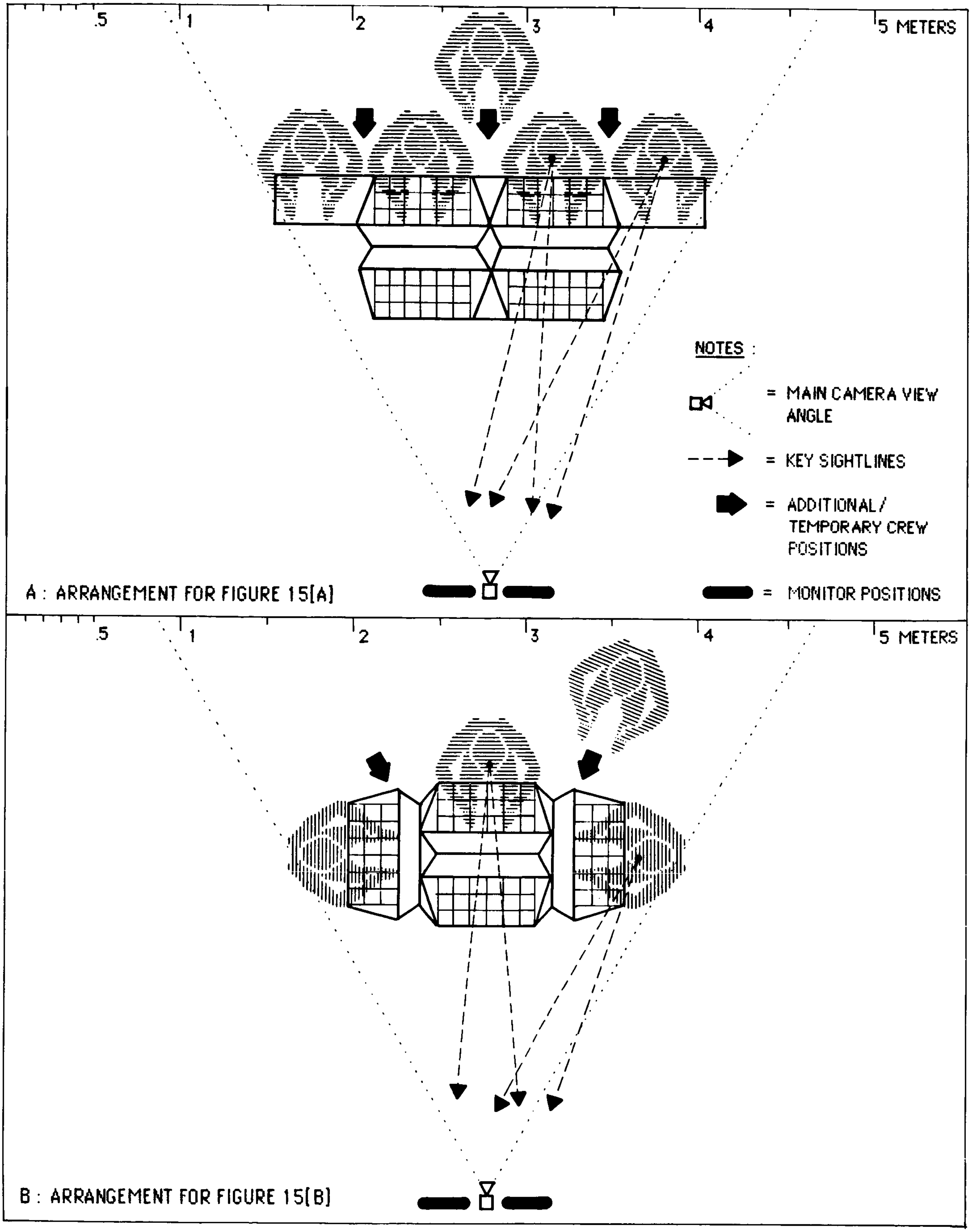
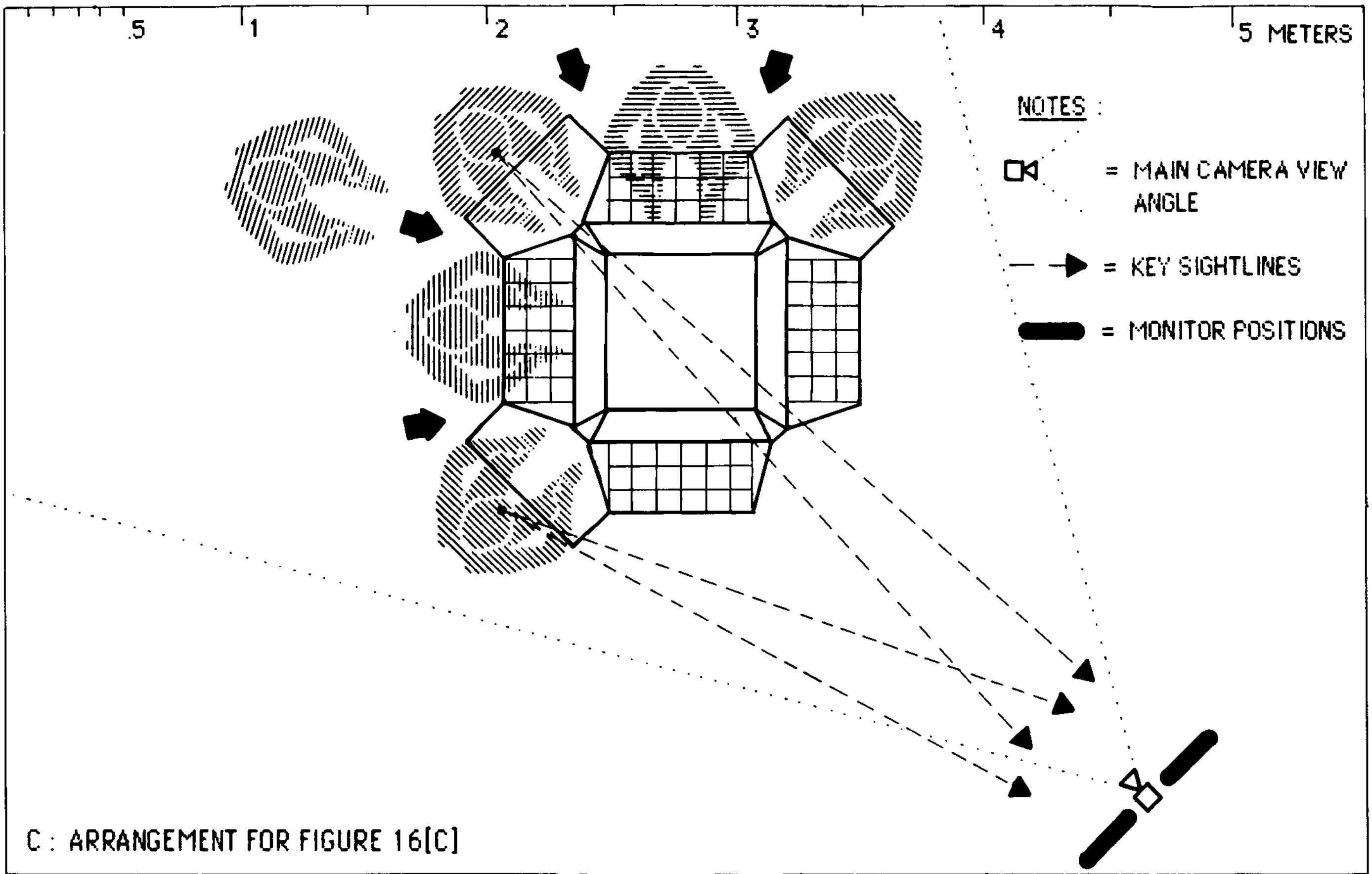


FIGURE 17 - TELECONFERENCES : VOLUMETRIC ENVELOPES



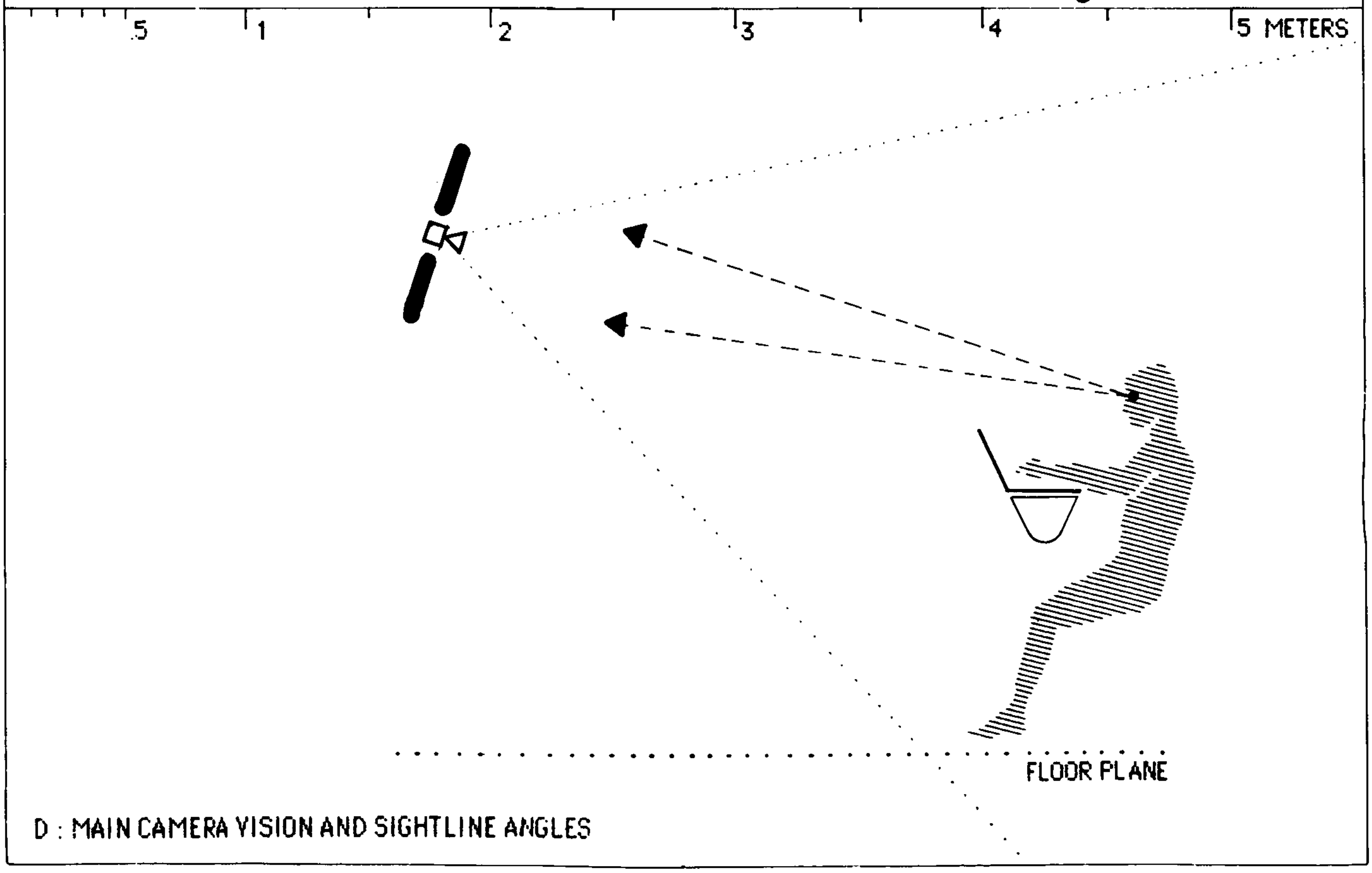


FIGURE 18 - TELECONFERENCES : VOLUMETRIC ENVELOPES

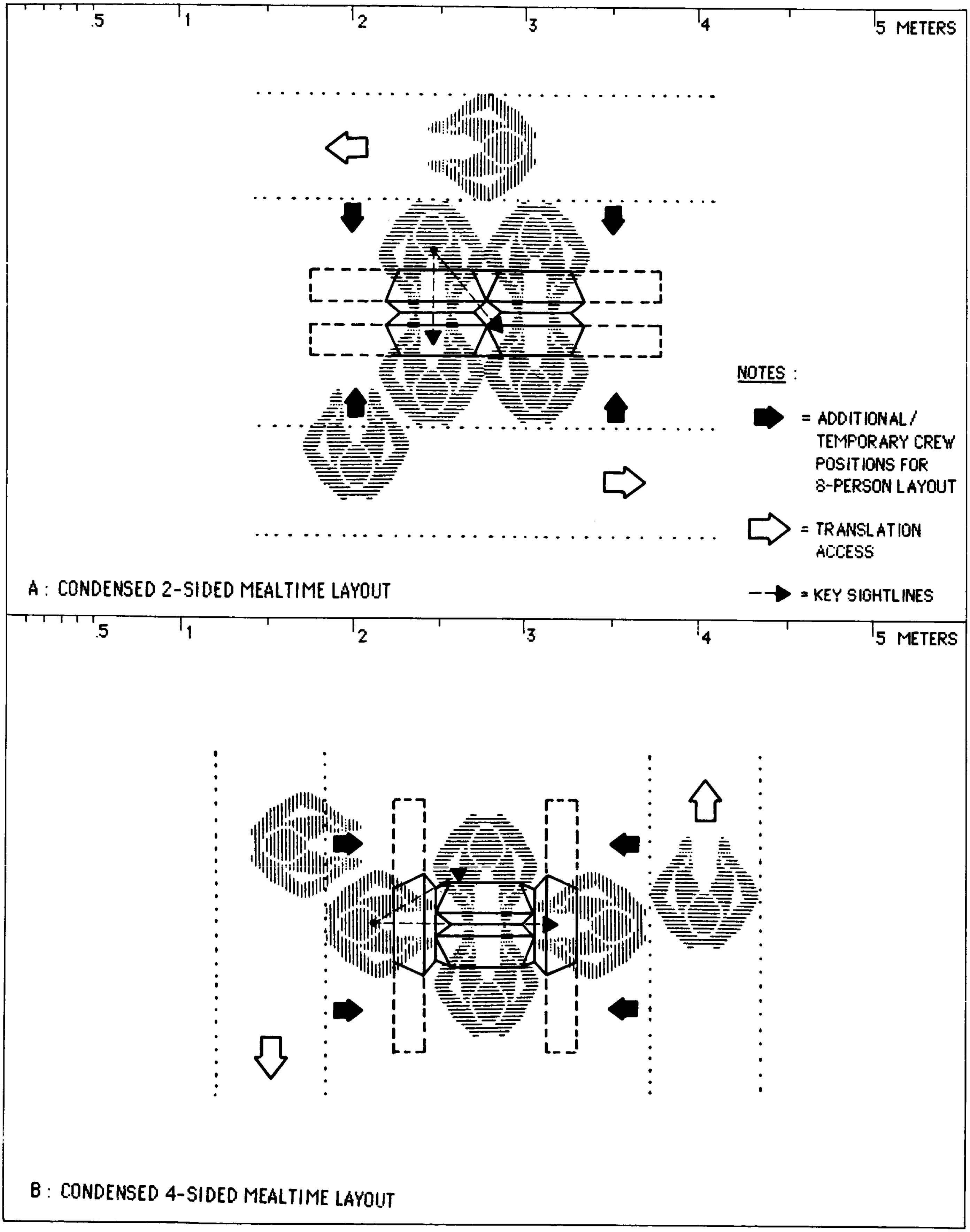


FIGURE 19 - EATING AND DRINKING : VOLUMETRIC ENVELOPES

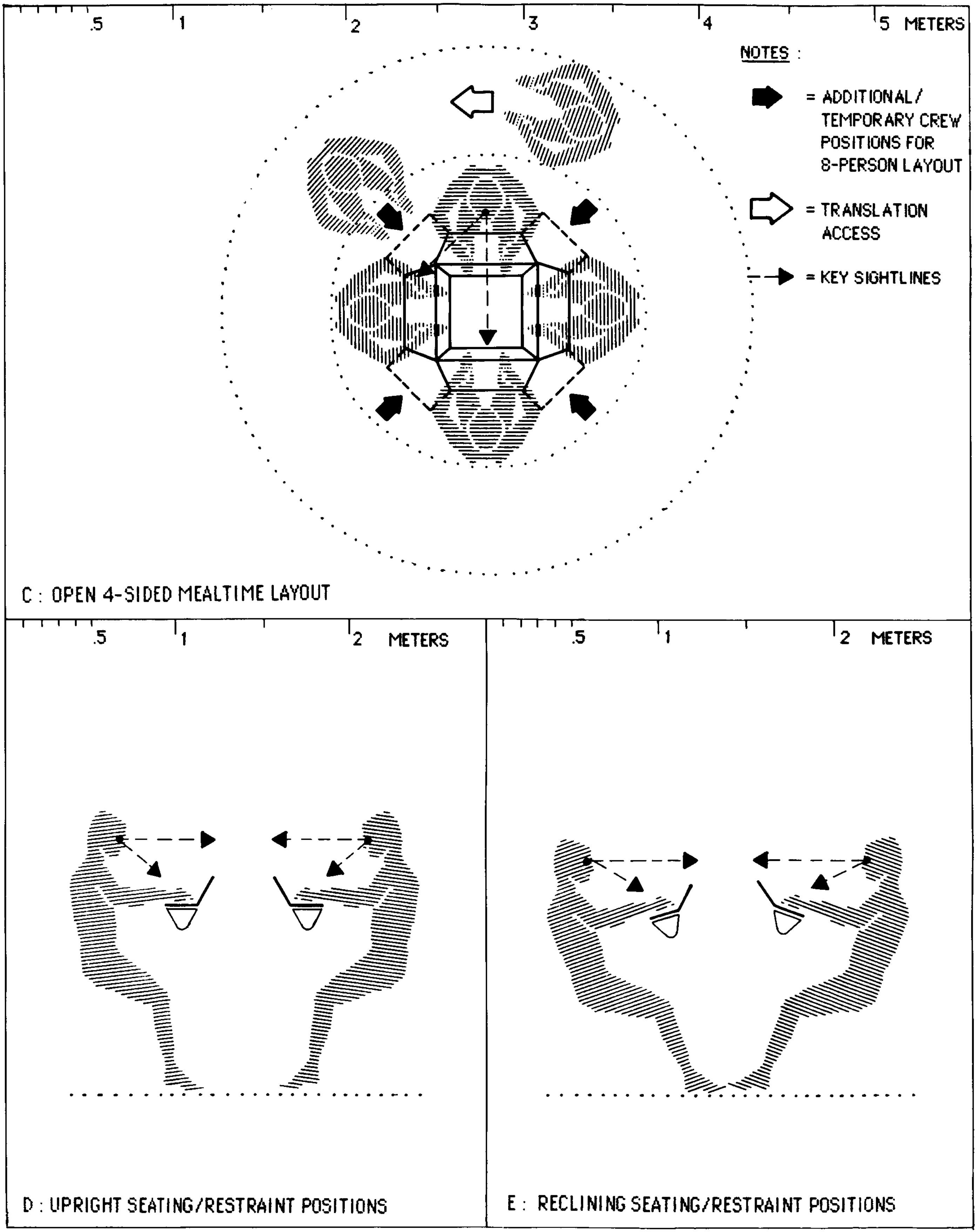


FIGURE 20 - EATING AND DRINKING : VOLUMETRIC ENVELOPES

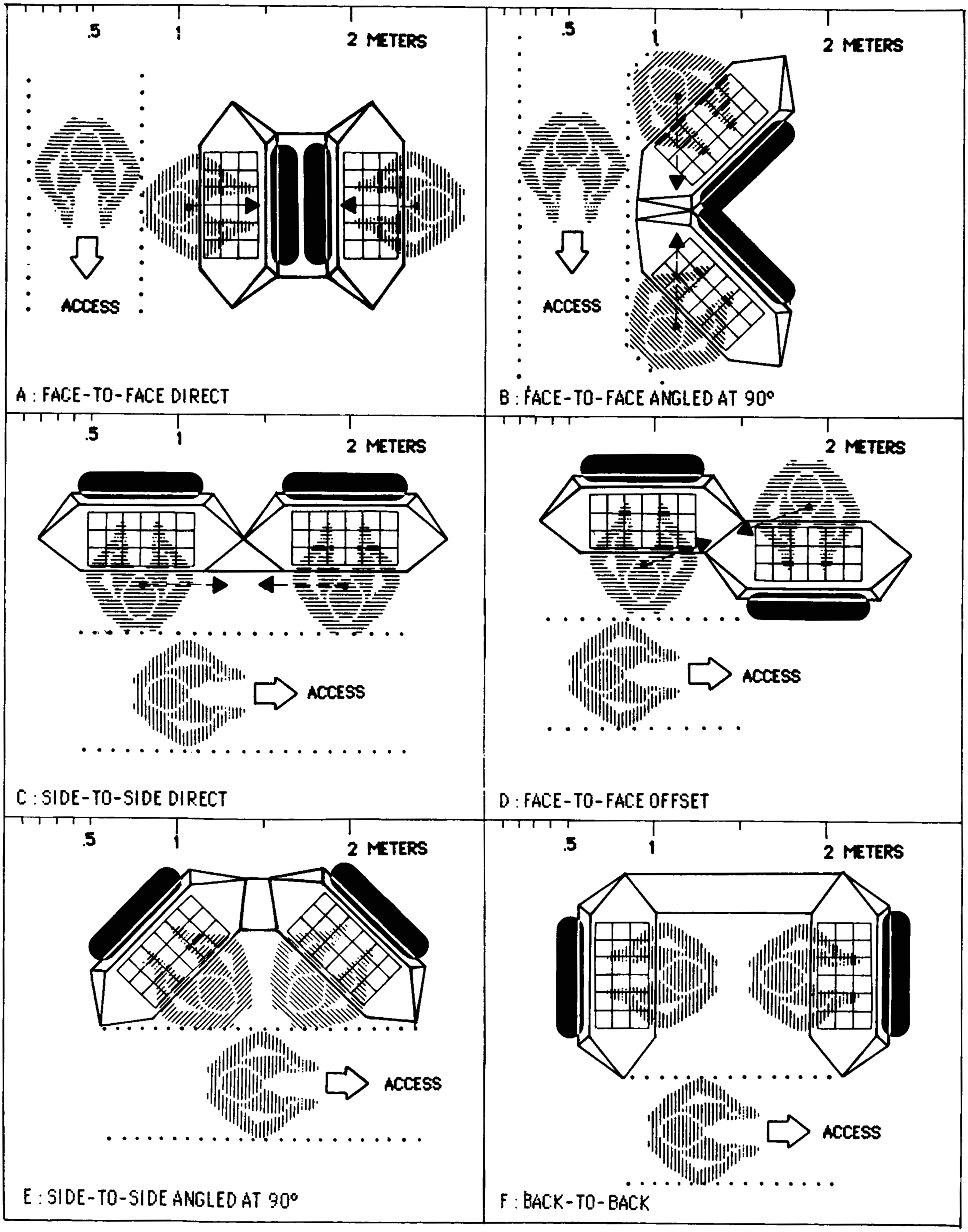


FIGURE 21 - PLANNING AND TRAINING : VOLUMETRIC ENVELOPES

3 SCHEMATIC DESIGN PHASE

3.1 DESIGN PHASE METHODOLOGY

3.1.1 BASIC OBJECTIVES

The SCHEMATIC DESIGN PHASE comprises the second part of the project "Space Station Group Habitability Module Study". This phase involves the preliminary investigation of a series of outline Design Concepts for the interior configuration of HM1 in sufficient depth and fidelity to enable a comparative analysis and evaluation of the design characteristics of the concepts to be made.

Nine individual Design Concepts have been developed.

Each concept has been selected with the objective of postulating and testing an alternative design approach based on individual design interpretation of the program requirements related to the volumetric constraints of the Common Module. The Design Concepts range substantially in character from conventional dedicated and fixed interior configurations to experimental multi-purpose and adaptable interior configurations.

At a schematic design level, the purpose of identifying and investigating substantially different design approaches is twofold

- Wide-ranging interpretations of a common design problem at an early stage can sometimes herald and highlight innovatory design ideas which may develop optimum performance potential compared to more conventional counterparts.
- The process of developing and analysing innovatory design ideas at a schematic level broadly defines their field of feasibility and gives an early indication of the nature and extent of their realistic application before commitment to design development.

3.1.2 OUTPUT VISUAL MATERIAL

Each of the nine Design Concepts has been developed over a period lasting approximately eight weeks from design inception to scale-model completion.

The Design Concepts are expressed as preliminary scale models showing the Common Module shell cut away to expose the interior configuration treatment. The models are constructed at 1/2" = 1'0" scale.

The Design Concepts are illustrated in explanatory drawing form showing four views of the interior of the Module - a longitudinal plan/section from above, a longitudinal section/elevation from the side and two cross-sections. Key activity areas and features are noted. The original drawings are at 1:25 metric scale.

The Design Concepts are illustrated in DESIGN CONCEPTS 1-9, Sections 3.2 to 3.10.

3.1.3 ANALYSIS PROCEDURE

The main characteristics of each Design Concept are analysed on a SCHEMATIC DESIGN ANALYSIS SHEET which accompanies DESIGN CONCEPTS 1-9, Sections 3.2 to 3.10.

The design characteristics are analysed in terms of ten selected Design Factors.

Each Design Factor addresses a key issue essential for consideration within the context of resolving the interior design configuration of HM1. Together, the Design Factors comprise a relevant and appropriate set of criteria against which the individual Design Concepts can be analysed and evaluated. The Design Factors are not intended to represent an exhaustive list of such factors which concern HM1, but do include those factors which are predominant ingredients in the determination of designs at an initial schematic level.

The ten Design Factors are

- COMMUNAL ORGANIZATION
- SPATIAL PERCEPTION
- INTERNAL CIRCULATION
- COMPARTMENT ADAPTATION
- ON-ORBIT COMPLETION
- LIFE-CYCLE MODIFICATION
- ERGONOMIC UTILIZATION
- EXTERIOR OBSERVATION
- EQUIPMENT RATIONALIZATION
- STRUCTURAL INSPECTION

The analysis of each Design Concept in terms of the ten Design Factors yields varying levels and qualities of design response.

On the SCHEMATIC DESIGN ANALYSIS SHEETS, these levels of design response are represented in terms of their benefit and resolution qualities. These are indicated in two vertical columns on the right-hand side of each sheet.

The first column indicates whether the design response to a particular Design Factor constitutes a significant 'advantage', a 'disadvantage', or neither. The second column indicates the resolution of the design response in terms of a five-point rating scale ranging from 'optimum' with a value of 1, to 'minimal' with a value of 5.

For the purposes of the analysis, each of the ten Design Factors is given equal weighting.

This equal weighting is necessary for three reasons. First, all the Design Factors are considered to be equally essential considerations in determining optimum interior configurations for HM1 and therefore must be addressed as a group from a schematic design level onwards. Second, an attempt to prioritize the Design Factors at an early design stage may tend to prejudice the subsequent consideration and accommodation of those factors rated less important than others. Third, there appears to be no formal or advisory information generally available at this time which attempts to prioritize the range of design criteria associated with the interior configurations of the Space Station Modules.

The analysis procedure broadly seeks to determine the effectiveness of the design response of each schematic Design Concept to each Design Factor, and to weigh the benefit and resolution of each response.

The depth of the analysis procedure adopted has been tailored to the depth of design investigation of each Design Concept, where both address design issues which have not proceeded beyond a broad outline or schematic level of investigation.

3.2 DESIGN CONCEPT 1

3.2.1 OUTLINE DESCRIPTION

Horizontal configuration with dedicated compartment organization based on a sequence of activity areas ranging from communal [noisy] to semi-private [quiet]. The Wardroom is located centrally. Extendable individual Training/Library compartments are located towards one end, either side of a central core-wall. An Exercise area is located at the other end, next to the Galley area.

3.2.2 PRINCIPAL FEATURES

Manually extendable partition screens forming semi-private Training/Library Compartments which vary in size. Use of a color sequence [against a neutral background] to generate interior visual interest and enhanced perspective by means of a warm-to-cool color gradient related to the communal-to-private activity sequence.

3.2.3 DESIGNER

Polly Osborne [U.S.A.]

3.2.4 SCHEMATIC DRAWINGS

See FIGURE 22, PAGE 46

3.2.5 MODEL PHOTOGRAPH

See FIGURE 23, PAGE 47

3.2.6 SCHEMATIC DESIGN ANALYSIS

See TABLE 1, PAGE 48

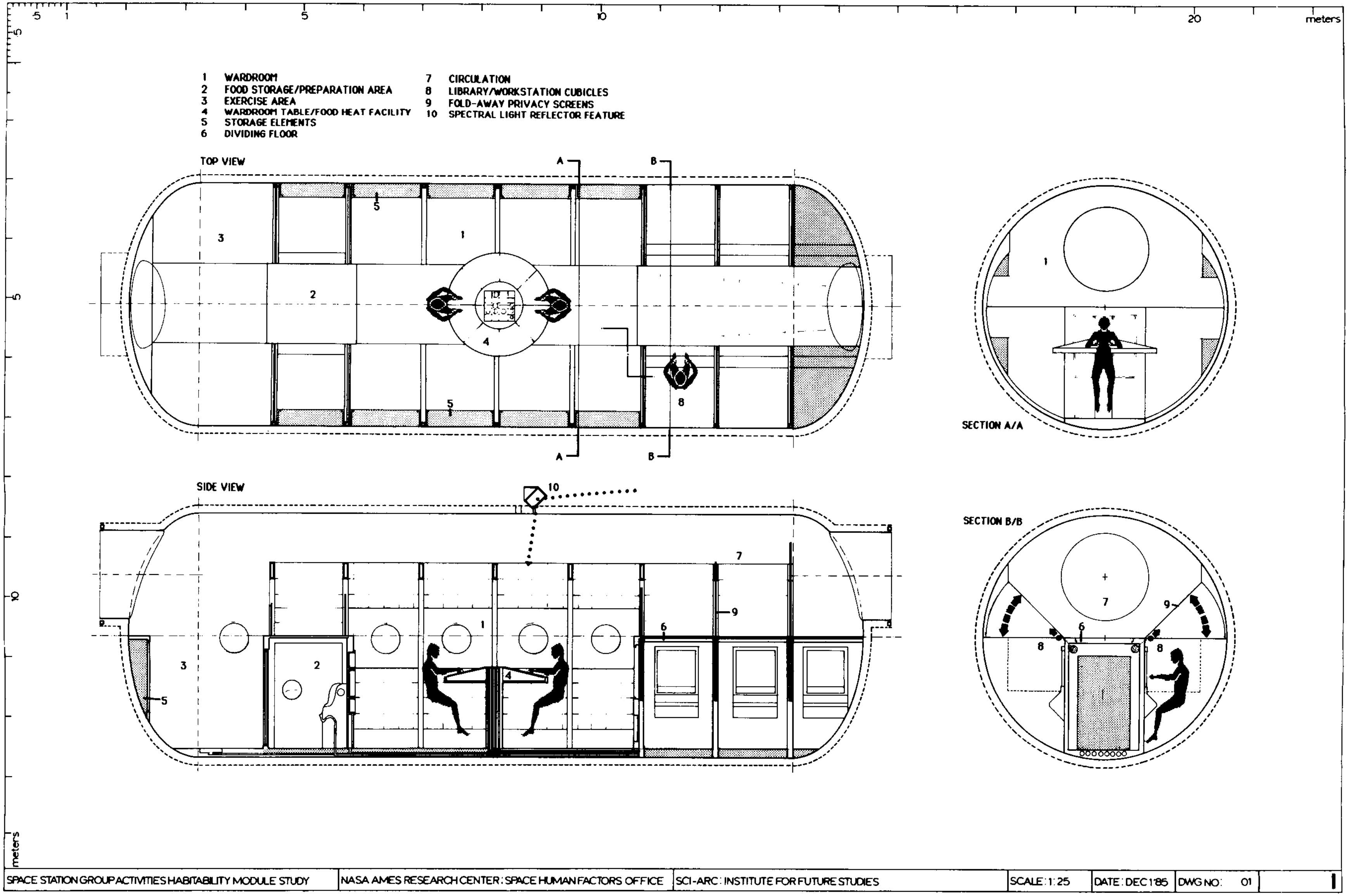


FIGURE 22 - DESIGN CONCEPT 1 SCHEMATIC DRAWINGS

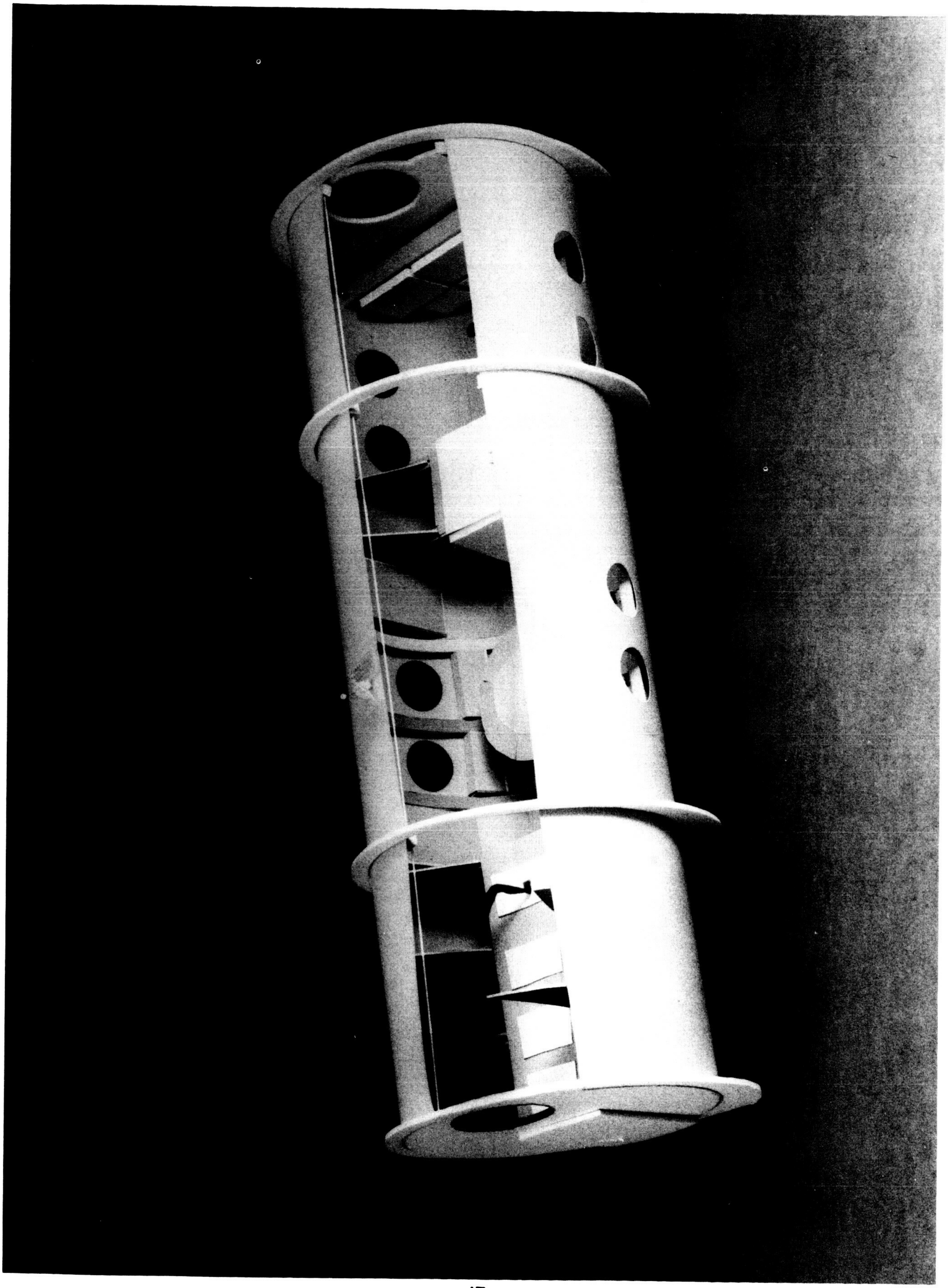


FIGURE 23 - DESIGN CONCEPT 1 MODEL PHOTOGRAPH

TABLE 1 - SCHEMATIC DESIGN ANALYSIS SHEET 1 | **SCHEME : 1**

DESIGNER[S] : POLLY OSBORNE

CONFIGURATION : HORIZONTAL

BENEFIT: A = Advantage, D = Disadvantage

RESOLUTION: 1= optimum, 2= acceptable, 3= average, 4= deficient, 5= minimal

FACTOR TYPE :	ANALYSIS NOTES :	BENEFIT	1	2	3	4	5
COMMUNAL ORGANIZATION	LARGE CENTRAL WARDROOM. ON ONE SIDE, EXERCISE AND FOOD STORAGE/PREPARATION FACILITIES [ADJ. LAB. MODULE]. ON OTHER SIDE, LIBRARY AND PRIVATE STUDY CUBICLES [ADJ. SLEEP MODULE]	A	■				
SPATIAL PERCEPTION	ENHANCED PERSPECTIVE ACHIEVED BY USE OF COLOR ON BULKHEADS AND SPATIAL PROGRESSION. ENHANCEMENT AND ENRICHMENT OF INTERIOR SURFACES AND COLORS BY NATURAL LIGHT APPLICATION	A	■				
INTERNAL CIRCULATION	CLEAR, UNOBSTRUCTED CIRCULATION PATH WITH OFFSET AT EACH END TO HATCHES	-		■			
COMPARTMENT ADAPTATION	ADAPTABILITY IS LIMITED. LIBRARY CONTAINS INDIVIDUAL STUDY COMPARTMENTS WHICH EXPAND OR RETRACT BY MEANS OF SLIDING SCREENS. ELSEWHERE, FACILITIES ARE FIXED	D					■
ON-ORBIT COMPLETION	INTERNAL ARCHITECTURE WOULD REQUIRE RATIONALIZATION INTO ELEMENT/EQUIPMENT PACKAGES FOR ON-ORBIT COMPLETION	-				■	
LIFE-CYCLE MODIFICATION	GENEROUS WARDROOM VOLUME AND DETACHABILITY OF ELEMENTS AND EQUIPMENT WOULD FACILITATE LIFE-CYCLE MODIFICATION FROM PRESENT INTERIOR CONFIGURATION	-		■			
ERGONOMIC UTILIZATION	POTENTIAL FOR ERGONOMIC UTILIZATION NOT FULLY EXPLORED. LIBRARY COMPARTMENTS, WARDROOM TABLE AND FOOD STORAGE/ PREPARATION AREA REQUIRE EXTENSIVE DEVELOPMENT	-				■	
EXTERIOR OBSERVATION	WINDOWS LOCATED IN MAIN WARDROOM VOLUME WITH GOOD GENERAL ACCESS. CLOSE VIEWING AND 360° ANTHROPOMETRIC ROTATION REQUIRE MODIFIED REVEAL DESIGN	-		■			
EQUIPMENT RATIONAL-IZATION	DEDICATED ARCHITECTURAL DESIGN OF INTERIOR WITH INDIVIDUALLY DESIGNED ELEMENTS AND EQUIPMENT. RATIONALIZATION IS POSSIBLE IN CERTAIN AREAS, BUT NOT UNIVERSAL	-			■		
STRUCTURAL INSPECTION	SATISFACTORY ACCESSIBILITY IN CENTRAL WARDROOM AND EXERCISE AREA. ACCESSIBILITY MORE COMPLEX IN THE LIBRARY AND END CONSOLE AREAS	-			■		

3.3 DESIGN CONCEPT 2

3.3.1 OUTLINE DESCRIPTION

Horizontal configuration with dedicated compartment organization and separation of Training/Entertainment/ Conference areas from Galley/Exercise/Dining areas by a modular "greenhouse" wall. Galley/Exercise areas utilize a central core-wall. Proximity Operations and Personal Hygiene areas are located at opposite ends of Module.

3.3.2 PRINCIPAL FEATURES

Central modular "greenhouse" wall for growth of fresh fruit or vegetables for crew consumption. The concept comprises individual plug-in transparent glovebox modules supported by a structural framework which also functions as the nutrient delivery system. Greenhouse provides a feature within the large communal crew area.

3.3.3 DESIGNER

Chris Miller [U.S.A.]

3.3.4 SCHEMATIC DRAWINGS

See FIGURE 24, PAGE 50

3.3.5 MODEL PHOTOGRAPH

See FIGURE 25, PAGE 51

3.3.6 SCHEMATIC DESIGN ANALYSIS

See TABLE 2, PAGE 52

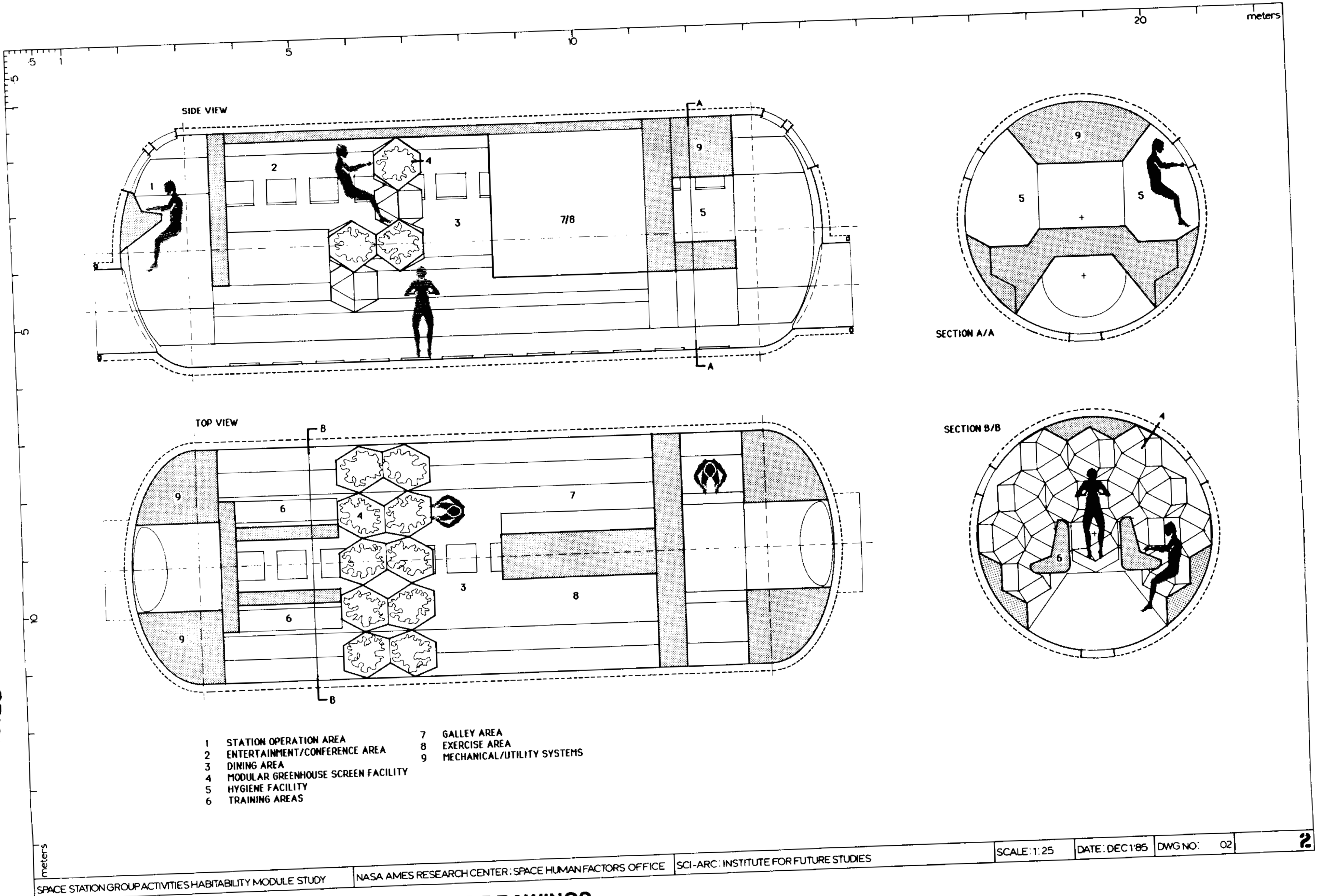


FIGURE 24 - DESIGN CONCEPT 2 SCHEMATIC DRAWINGS

FIGURE 25 - DESIGN CONCEPT 2 MODEL PHOTOGRAPH

TABLE 2 - SCHEMATIC DESIGN ANALYSIS SHEET 2

SCHEME : 2

DESIGNER[S] : CHRIS MILLER

CONFIGURATION : HORIZONTAL

BENEFIT: A = Advantage, D = Disadvantage

RESOLUTION: 1 = optimum, 2 = acceptable, 3 = average, 4 = deficient, 5 = minimal

FACTOR TYPE :	ANALYSIS NOTES :	BENEFIT	1	2	3	4	5
COMMUNAL ORGANIZATION	SERIES OF DEDICATED ACTIVITY AREAS INTERCONNECTED IN A LINEAR SEQUENCE. CENTRAL COMMUNAL AREA DIVIDED INTO 2 SECTIONS BY PARTIALLY TRANSPARENT 'GREENHOUSE' WALL	-			■		
SPATIAL PERCEPTION	RELATIVELY SPACIOUS COMMUNAL AREAS. A CENTRALLY LOCATED TRANSPARENT PARTITION IS A MODULAR 'GREENHOUSE' WALL WHICH WOULD ACT AS MAJOR VISUAL FEATURE AND SOURCE OF INTEREST	A	■				
INTERNAL CIRCULATION	DIRECT PERIPHERAL CIRCULATION PATH FROM MODULE END-TO-END	A	■				
COMPARTMENT ADAPTATION	REGULAR COMPARTMENTAL ADAPTABILITY NOT ESPECIALLY FEATURED OR OPTIMIZED EXCEPT FOR MODULAR ADAPTABILITY OF THE 'GREENHOUSE' WALL	D					■
ON-ORBIT COMPLETION	CERTAIN ELEMENTS AND EQUIPMENT COULD BE FITTED IN ORBIT. 'GREENHOUSE' MODULE WALL MAY BE ASSEMBLED IN ORBIT	-		■			
LIFE-CYCLE MODIFICATION	LOCATION OF ECLSS SYSTEMS IN END-CAPS AND LINEAR UTILITY RUNS WOULD FACILITATE LIFE-CYCLE MODIFICATION. 'GREENHOUSE' WALL MODULES AND SOME ELEMENTS WOULD BE REPLACEABLE	-		■			
ERGONOMIC UTILIZATION	INDIVIDUAL ACTIVITY AREAS DESIGNED FOR ERGONOMIC OPERATION. DEVELOPMENT REQUIRED TO IMPROVE ERGONOMIC UTILIZATION OF OTHER AREAS	-				■	
EXTERIOR OBSERVATION	LARGE COMMUNAL AREAS AND LACK OF PERIMETER ELEMENT AND EQUIPMENT ATTACHMENTS ENSURES GOOD CHOICE OF WINDOW LOCATIONS AND UNOBSTRUCTED 360° ANTHROPOMETRIC ROTATION	A	■				
EQUIPMENT RATIONAL-IZATION	DEDICATED ARCHITECTURAL DESIGN OF INTERIOR WITH INDIVIDUAL ELEMENTS AND EQUIPMENT. RATIONALIZATION IS POSSIBLE IN CERTAIN AREAS, BUT NOT UNIVERSAL	-			■		
STRUCTURAL INSPECTION	LARGE COMMUNAL AREAS AND MINIMUM PERIMETER ELEMENT AND EQUIPMENT ATTACHMENTS FACILITATE STRUCTURAL INSPECTION. LESS EASY TOWARDS MODULE ENDS WITH BUILT-IN FACILITIES	-			■		

3.4 DESIGN CONCEPT 3

3.4.1 OUTLINE DESCRIPTION

Adaptable and asymmetrical sequence of activity areas utilizing modular, interlocking storage elements to generate activity enclosures. Activity areas are interconnected with a centrally located Wardroom. Galley/Exercise areas and Library/Training areas are respectively located towards each end of the Module.

3.4.2 PRINCIPAL FEATURES

Modular element system comprising interchangeable, radially-segmented elements. The elements are mounted against the curved Module internal surface. Elements fulfill supplies storage, equipment, utilities and workstation functions. Major visual interest generated by varied interplay between solid elements and open volumes.

3.4.3 DESIGNER

Regis Fauquet [France]

3.4.4 SCHEMATIC DRAWINGS

See FIGURE 26, PAGE 54

3.4.5 MODEL PHOTOGRAPH

See FIGURE 27, PAGE 55

3.4.6 SCHEMATIC DESIGN ANALYSIS

See TABLE 3, PAGE 56

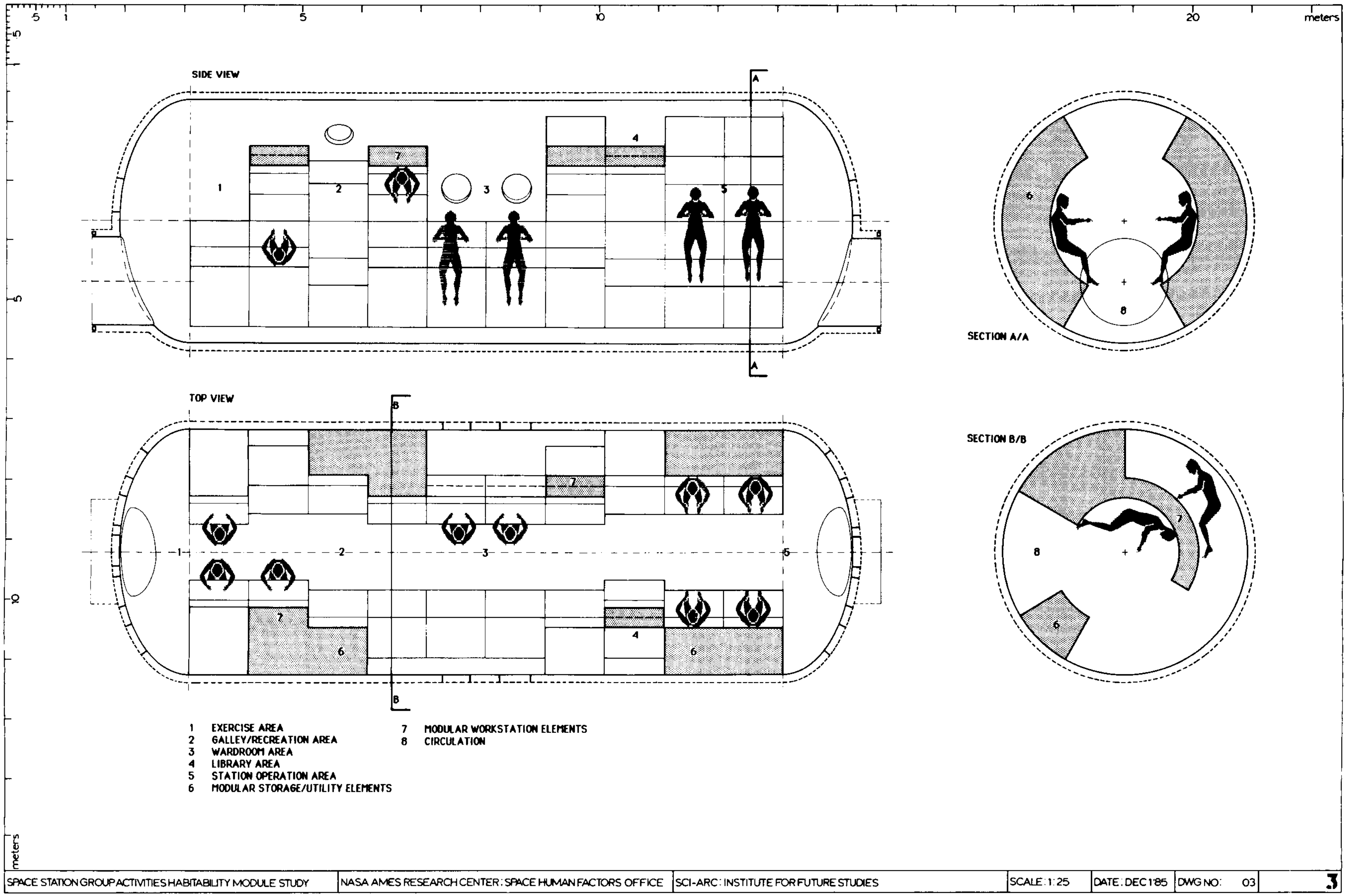


FIGURE 26 - DESIGN CONCEPT 3 SCHEMATIC DRAWINGS

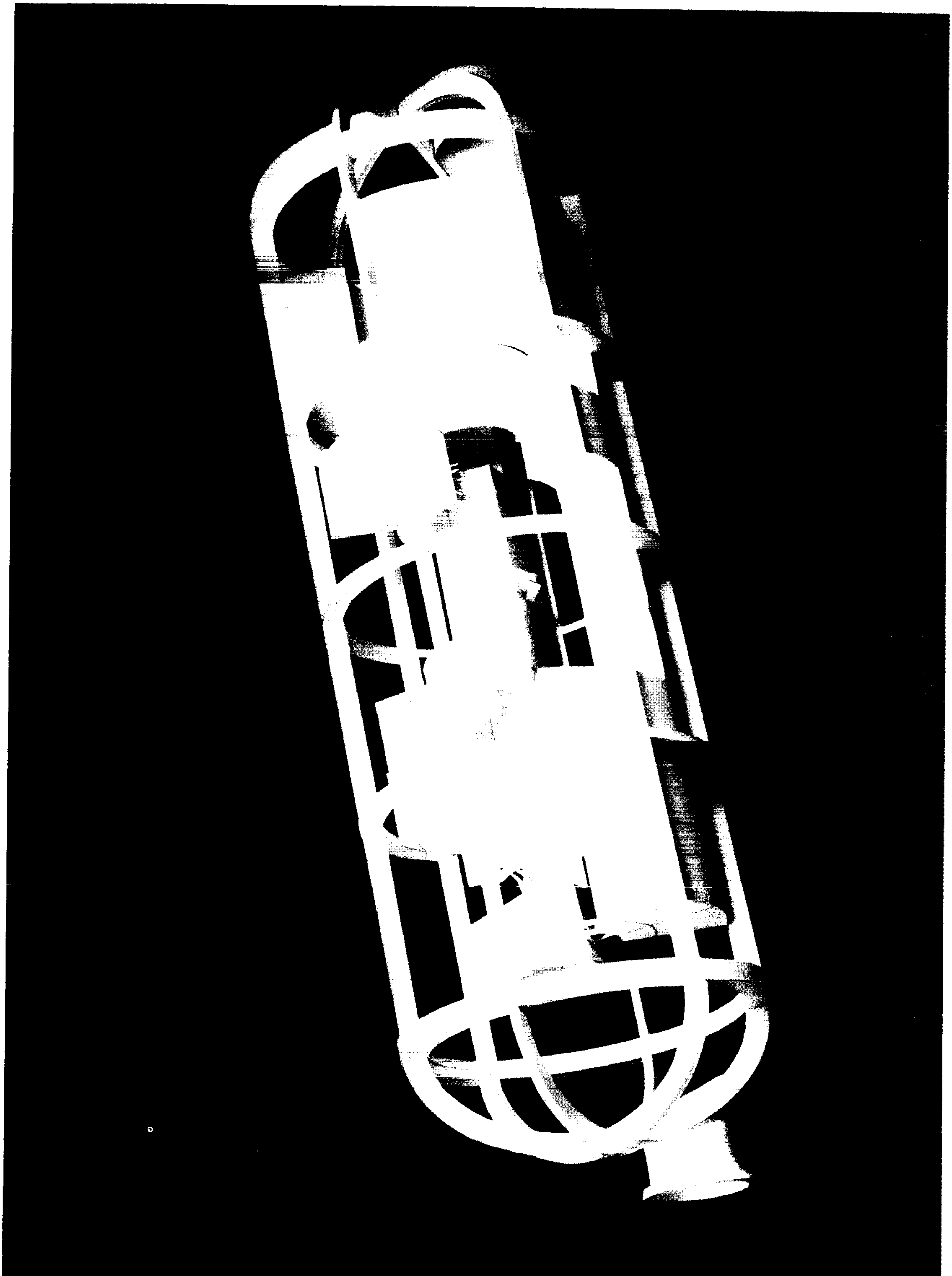


FIGURE 27 - DESIGN CONCEPT 3 MODEL PHOTOGRAPH

TABLE 3 - SCHEMATIC DESIGN ANALYSIS SHEET 3		SCHEME : 3					
DESIGNER[S] : REGIS FAUQUET **CONFIGURATION :** HORIZONTAL [POTENTIAL FOR VERTICAL]		**BENEFIT** A = Ad-vantage D = Disad-vantage	**RESOLUTION** 1= optimum 2= acceptable 3= average 4= deficient 5= minimal				
FACTOR TYPE :	**ANALYSIS NOTES :**		1	2	3	4	5
COMMUNAL ORGANIZATION	SERIES OF DEDICATED ACTIVITY AREAS INTERCONNECTED IN A LINEAR SEQUENCE WITH CENTRALIZED WARDROOM. MODULAR ELEMENTS/EQUIPMENT USED TO DEFINE ACTIVITY AREA BOUNDARIES	-			■		
SPATIAL PERCEPTION	MODULAR NATURE OF INTERNAL ELEMENTS AND EQUIPMENT AND THEIR ASYMMETRICAL LOCATION ALONG MODULE WOULD GENERATE SUBSTANTIAL VISUAL INTEREST AND VARIETY	A	■				
INTERNAL CIRCULATION	CENTRAL AND DIRECT CIRCULATION PATH FROM MODULE END-TO-END	A	■				
COMPARTMENT ADAPTATION	OCCASIONAL ADAPTABILITY POSSIBLE BY DETACHMENT AND RELOCATION OF MODULAR ELEMENTS, BUT NOT ON A REGULAR BASIS	-			■		
ON-ORBIT COMPLETION	MODULAR ELEMENTS AND EQUIPMENT DESIGNED TO PASS THROUGH END HATCHES AND ATTACH TO SHELL AND EACH OTHER WITH SIMPLE FASTENINGS. ON-ORBIT COMPLETION WOULD BE STRAIGHTFORWARD	-		■			
LIFE-CYCLE MODIFICATION	INTERNAL CONFIGURATIONS CAN BE REPLANNED AND MODULAR ELEMENTS AND EQUIPMENT REPLACED, ENSURING GOOD LIFE-CYCLE MODIFICATION POTENTIAL	A	■				
ERGONOMIC UTILIZATION	ERGONOMIC UTILIZATION MAY BE IMPACTED BY CONSTRAINTS OF MODULAR SIZES AND SHAPES. IT MAY NOT BE POSSIBLE TO FULLY COORDINATE THESE WITH ANTHROPOMETRIC CONSIDERATIONS	D					■
EXTERIOR OBSERVATION	WINDOWS LOCATIONS ARE UNCONSTRAINED BECAUSE OF MODULAR GRID CHOICE. WINDOW PROXIMITY TO INTERNAL PROJECTING MODULAR ELEMENTS MAY AFFECT 360° ANTHROPOMETRIC ROTATION	-			■		
EQUIPMENT RATIONAL-IZATION	OPTIMUM EQUIPMENT RATIONALIZATION POSSIBLE THROUGH USE OF MODULAR APPROACH TO DESIGN OF RANGE OF INTERNAL ELEMENTS AND EQUIPMENT	A	■				
STRUCTURAL INSPECTION	DETACHABILITY OF INTERNAL MODULES FROM INTERNAL SHELL AND FROM EACH OTHER WOULD AID STRUCTURAL INSPECTION, THOUGH MANAGEMENT OF DETACHED ELEMENTS WOULD REQUIRE CARE	-			■		

3.5 DESIGN CONCEPT 4

3.5.1 OUTLINE DESCRIPTION

Large Wardroom containing a multi-purpose, variable-size table element. Adaptable Library/Training compartments for individual use are adjacent to the Wardroom . The Galley is located adjacent to the Wardroom in one end-cap. The Exercise and Personal Hygiene areas are located at the other end, separated from the Wardroom by a storage bulkhead.

3.5.2 PRINCIPAL FEATURES

Pivoted revolving storage screens function as individual Library/Training compartment dividers. A nested and gimballed Wardroom table responds to alternative crew group sizes. Galley occupies domed end of Module facing the main Wardroom area.

3.5.3 DESIGNER

Dan Varnum [U.S.A.]

3.5.4 SCHEMATIC DRAWINGS

See FIGURE 28, PAGE 58

3.5.5 MODEL PHOTOGRAPH

See FIGURE 29, PAGE 59

3.5.6 SCHEMATIC DESIGN ANALYSIS

See TABLE 4, PAGE 60

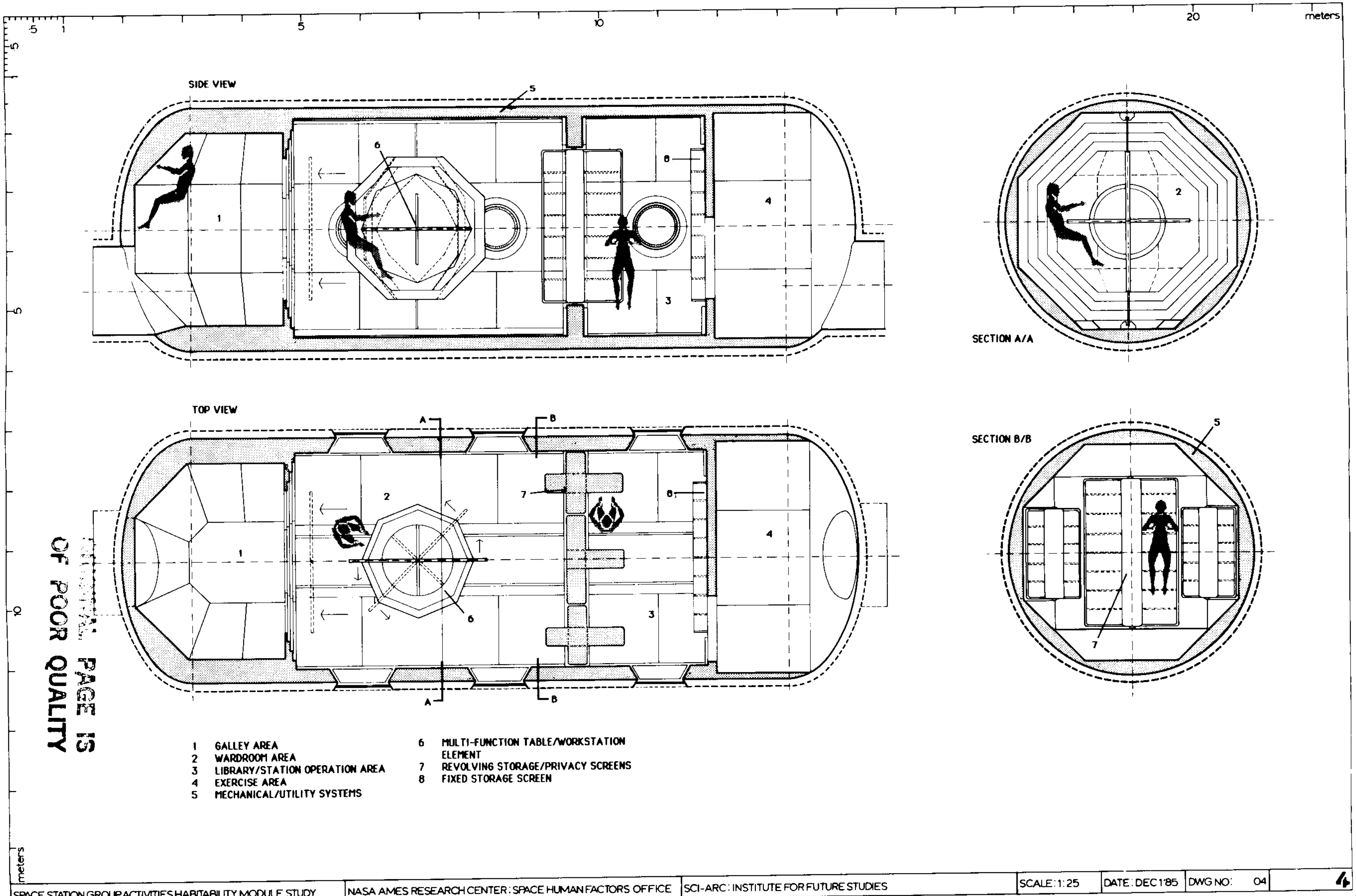


FIGURE 28 - DESIGN CONCEPT 4 SCHEMATIC DRAWINGS

FIGURE 29 - DESIGN CONCEPT 4 MODEL PHOTOGRAPH

TABLE 4 - SCHEMATIC DESIGN ANALYSIS SHEET 4		SCHEME : 4	
DESIGNER[S] : DAN VARNUM CONFIGURATION : HORIZONTAL		BENEFIT A = Ad-vantage D = Disad-vantage	RESOLUTION 1= optimum 2= acceptable 3= average 4= deficient 5= minimal
FACTOR TYPE :	**ANALYSIS NOTES :**		
COMMUNAL ORGANIZATION	LARGE MULTI-PURPOSE WARDOOM LOCATED NEXT TO FOOD STORAGE/ PREP AREA IN END-CAP. ADAPTABLE LIBRARY COMPARTMENTS NEXT TO WARDROOM. EXERCISE AREA IN OTHER END-CAP	-	3
SPATIAL PERCEPTION	WARDROOM AND GALLEY ACTIVITY AREAS CONFIGURED AS GENEROUS INTERNAL VOLUME FOR MAXIMUM SPACIOUSNESS. WARDROOM TABLE AND GALLEY LAYOUT PROVIDE VISUALLY INTERESTING FEATURES	-	2
INTERNAL CIRCULATION	FREE CIRCULATION IN WARDROOM AREA. CIRCULATION THROUGH LIBRARY COMPARTMENTS WILL REQUIRE CARE DEPENDING ON PARTITION CONFIGURATION	-	3
COMPARTMENT ADAPTATION	HIGHLY ADAPTABLE WARDROOM TABLE DESIGNED TO ACCOMMODATE DIFFERENT CREW GROUPS. LIBRARY COMPARTMENTS RECONFIGURE TO DIFFERENT CREW USES BY PANEL ROTATION	A	1
ON-ORBIT COMPLETION	INTERNAL ARCHITECTURE WOULD REQUIRE RATIONALIZATION INTO ELEMENT/EQUIPMENT PACKAGES FOR FEASIBLE ON-ORBIT COMPLETION	D	5
LIFE-CYCLE MODIFICATION	GENEROUS WARDROOM VOLUME WOULD AID LIFE-CYCLE MODIF-ICATION. ADAPTABLE/MOVABLE ELEMENTS AND EQUIPMENT BEST CANDIDATES FOR UPGRADING AND REPLACEMENT	-	3
ERGONOMIC UTILIZATION	ERGONOMIC UTILIZATION REQUIRES FURTHER DEVELOPMENT. WARDROOM TABLE DESIGN AND GALLEY ARE POTENTIALLY HIGHLY EFFICIENT ERGONOMICALLY	-	3
EXTERIOR OBSERVATION	WINDOWS LOCATED IN MAIN WARDROOM VOLUME WITH GOOD GENERAL ACCESS AND SUFFICIENT FREEDOM FOR 360° ANTHRO-POMETRIC ROTATION	A	1
EQUIPMENT RATIONAL-IZATION	THE DEDICATED AND OCCASIONALLY COMPLEX NATURE OF INTERNAL ELEMENTS AND EQUIPMENT, TOGETHER WITH LACK OF MODULARITY, WOULD REDUCE POTENTIAL FOR RATIONALIZATION	D	5
STRUCTURAL INSPECTION	SATISFACTORY ACCESSIBILITY IN WARDROOM AND EXERCISE AREA. ACCESSIBILITY MORE COMPLEX IN LIBRARY AND GALLEY AREAS	-	3

3.6 DESIGN CONCEPT 5

3.6.1 OUTLINE DESCRIPTION

Vertical configuration with organization based on a range of communal and semi-private needs using a combination of fixed and adaptable elements and equipment. The Wardroom is located centrally and can be expanded by a sliding bulkhead. Proximity Operations areas are located in each end-cap. Adaptable workstation consoles respond to variably- sized Meetings/Planning/Training activities.

3.6.2 PRINCIPAL FEATURES

Sliding and interlocking workstation consoles integrated within the sliding bulkhead. The consoles respond to alternative crew group sizes while the sliding bulkhead generates a large communal Wardroom volume.

3.6.3 DESIGNERS

Keith Andersen [U.S.A.] and Dan Bernstein [U.S.A.]

3.6.4 SCHEMATIC DRAWINGS

See FIGURE 30, PAGE 62

3.6.5 MODEL PHOTOGRAPH

See FIGURE 31, PAGE 63

3.6.6 SCHEMATIC DESIGN ANALYSIS

See TABLE 5, PAGE 64

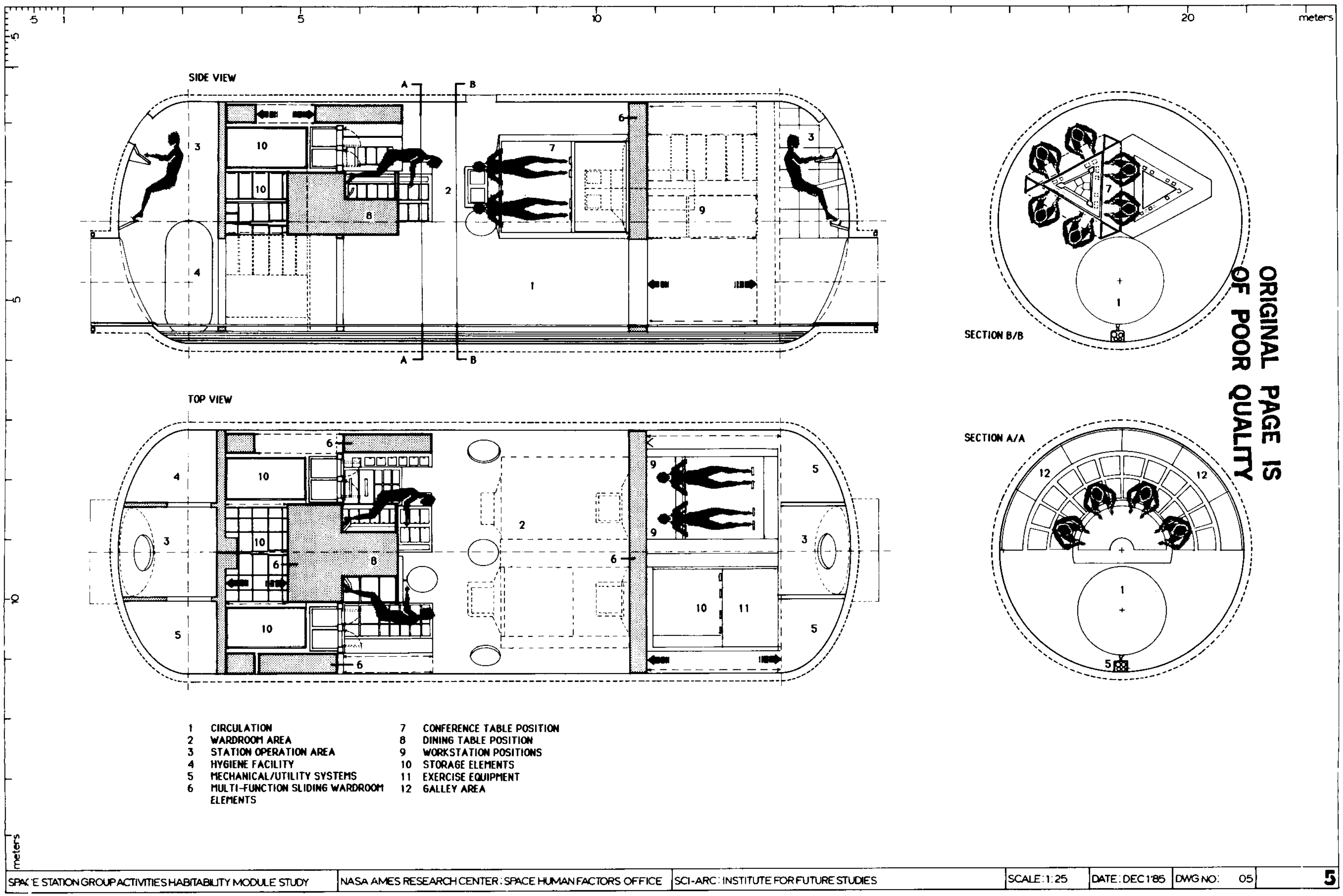


FIGURE 30 - DESIGN CONCEPT 5 SCHEMATIC DRAWINGS

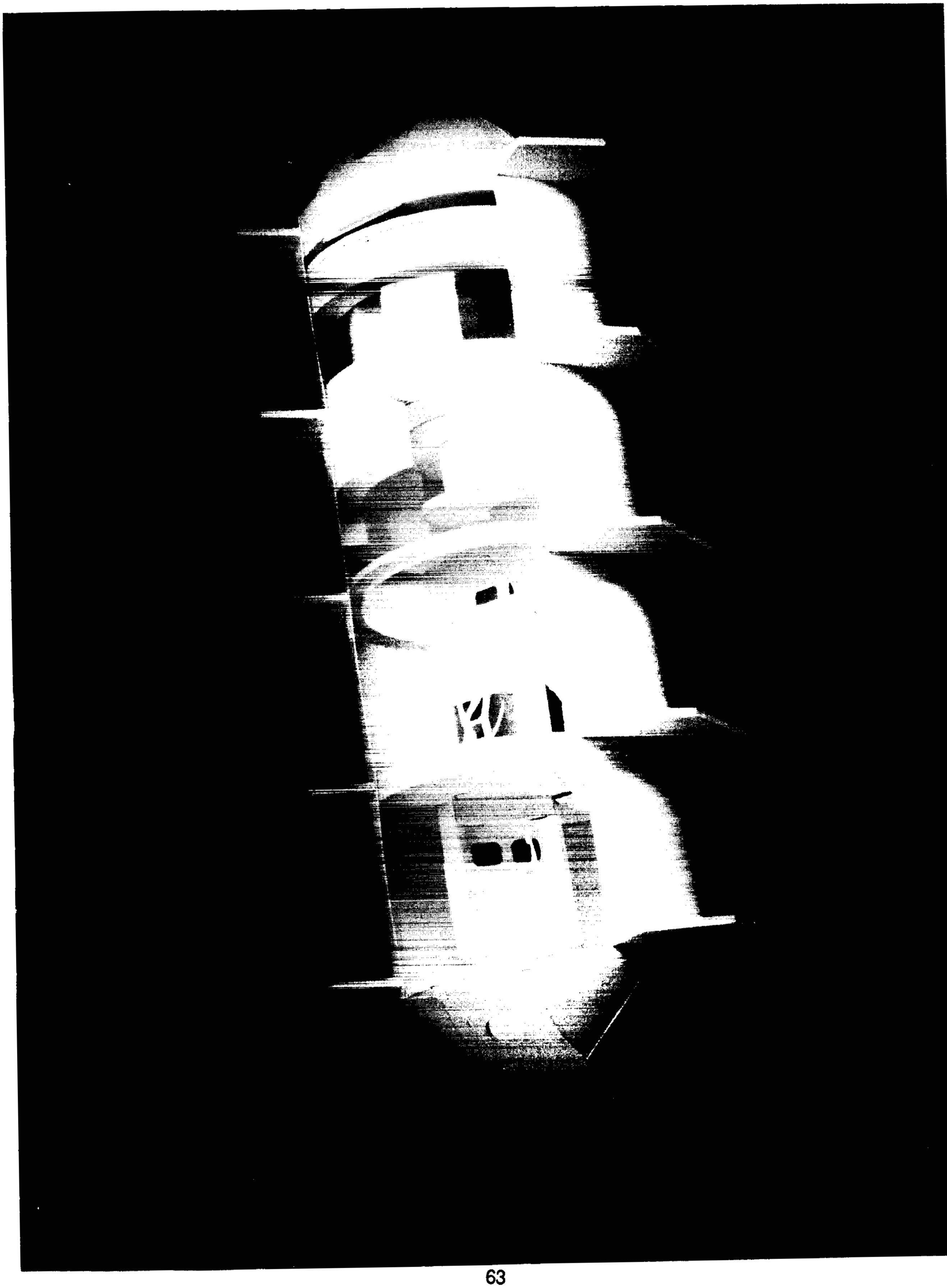


FIGURE 31 - DESIGN CONCEPT 5 MODEL PHOTOGRAPH

TABLE 5 - SCHEMATIC DESIGN ANALYSIS SHEET 5		SCHEME : 5					
DESIGNER[S] : KEITH ANDERSEN AND DAN BERNSTEIN **CONFIGURATION :** VERTICAL CONFIGURATION		**BENEFIT** A = Ad-vantage D = Disad-vantage	**RESOLUTION** 1= optimum 2= acceptable 3= average 4= deficient 5= minimal				
FACTOR TYPE :	**ANALYSIS NOTES :**		1	2	3	4	5
COMMUNAL ORGANIZATION	SEPARATION INTO 3 MAIN ACTIVITY GROUPS SEPARATED BY BULK-HEADS. CENTRAL COMMUNAL AREA CAN OCCASIONALLY EXPAND VIA SLIDING BULKHEAD	-		■			
SPATIAL PERCEPTION	SLIDING BULKHEAD AND RETRACTABLE EQUIPMENT MUST BE OPERATED TO ACHIEVE SPACIOUSNESS. OPPOSED VERTICAL POSITIONS OF TABLE/WORKSTATIONS MAY DIS-ORIENT AND DISCOMFORT CREW	D					■
INTERNAL CIRCULATION	STRAIGHTFORWARD PASSAGE THROUGH TRANSVERSE BULKHEADS AND VERTICALLY-CONFIGURED ACTIVITY COMPARTMENTS	-		■			
COMPARTMENT ADAPTATION	SEVERAL APPROACHES TO COMPARTMENT ADAPTABILITY INCLUDING EXPANDABLE CONFERENCE TABLE, RETRACTABLE DINING TABLE, DEPLOYABLE STORAGE AND SLIDING COMPARTMENT BULKHEAD	A	■				
ON-ORBIT COMPLETION	LIMITED POTENTIAL FOR SIMPLE ON-ORBIT COMPLETION DUE TO DEDICATED VERTICAL CONFIGURATION AND COMPLEXITY OF INTERNAL ELEMENTS AND EQUIPMENT	D					■
LIFE-CYCLE MODIFICATION	POTENTIAL DIFFICULTY OF LIFE-CYCLE MODIFICATION DUE TO DEDICATED VERTICAL CONFIGURATION AND COMPLEXITY OF INTERNAL ELEMENTS AND EQUIPMENT	-				■	
ERGONOMIC UTILIZATION	ERGONOMIC UTILIZATION GOOD ,PARTICULARLY DESIGN AND OPERATION OF DINING TABLE, CONFERENCE WORKSTATIONS AND STORAGE FACILITIES THROUGHOUT	A	■				
EXTERIOR OBSERVATION	PROXIMITY OPERATIONS WINDOWS LOCATED AT EACH END OF MODULE. WINDOWS LOCATED IN CENTRAL WARDROOM AREA AND LIBRARY AREA	-			■		
EQUIPMENT RATIONAL-IZATION	THE DEDICATED AND COMPLEX NATURE OF INTERNAL ELEMENTS AND EQUIPMENT, TOGETHER WITH LACK OF MODULARITY WOULD REDUCE POTENTIAL FOR EQUIPMENT RATIONALIZATION	D					■
STRUCTURAL INSPECTION	ELEMENTS AND EQUIPMENT COULD BE DESIGNED TO BE DETACHABLE FROM MODULE SHELL. FREE INTERNAL ACTIVITY AREAS WOULD AID ACCESSIBILITY - BULKHEADS AND BUILT-IN STORAGE MAY REDUCE IT	-			■		

3.7 DESIGN CONCEPT 6

3.7.1 OUTLINE DESCRIPTION

Horizontal configuration with capability for highly adaptable compartment modification. Changes can be made readily on a daily routine or a life-cycle basis by means of movable, pivoted perimeter panels which extend outwards. This multi-purpose design configuration occupies the center of the Module while fixed Personal Hygiene and storage/utility facilities are located at Module ends.

3.7.2 PRINCIPAL FEATURES

Modular articulated panels in a 5-standoff arrangement swing outwards to form crew activity enclosures based on requirements ranging from daily timelines to the long-term life-cycle. Panels accommodate supplies storage, workstations, utilities, equipment and screen enclosure functions.

3.7.3 DESIGNERS

Robert Kleis [W. Germany] and Karl Ulle [U.S.A.]

3.7.4 SCHEMATIC DRAWINGS

See FIGURE 32, PAGE 66

3.7.5 MODEL PHOTOGRAPH

See FIGURE 33, PAGE 67

3.7.6 SCHEMATIC DESIGN ANALYSIS

See TABLE 6, PAGE 68

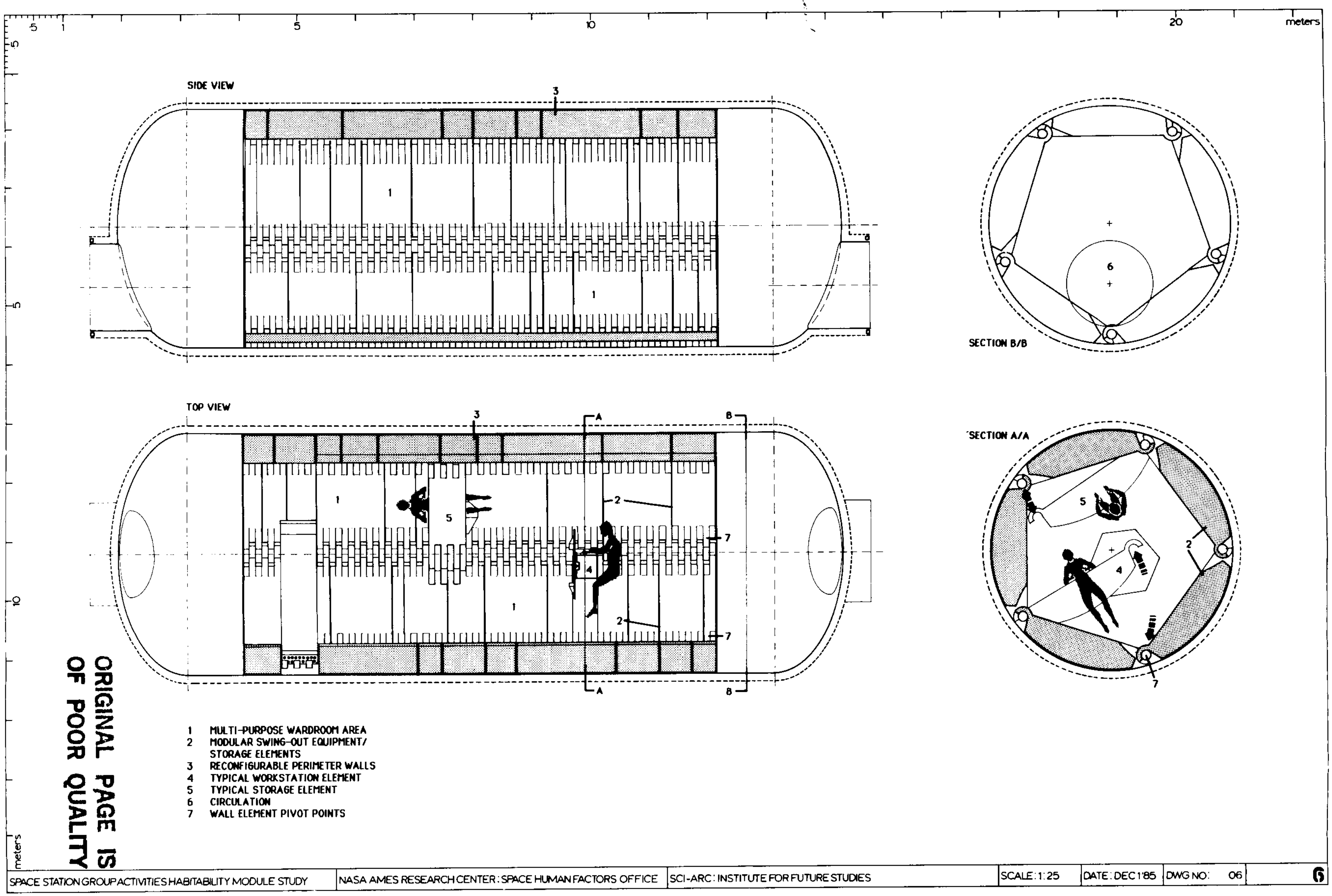


FIGURE 32 - DESIGN CONCEPT 6 SCHEMATIC DRAWINGS

ORIGINAL PAGE IS
OF POOR QUALITY

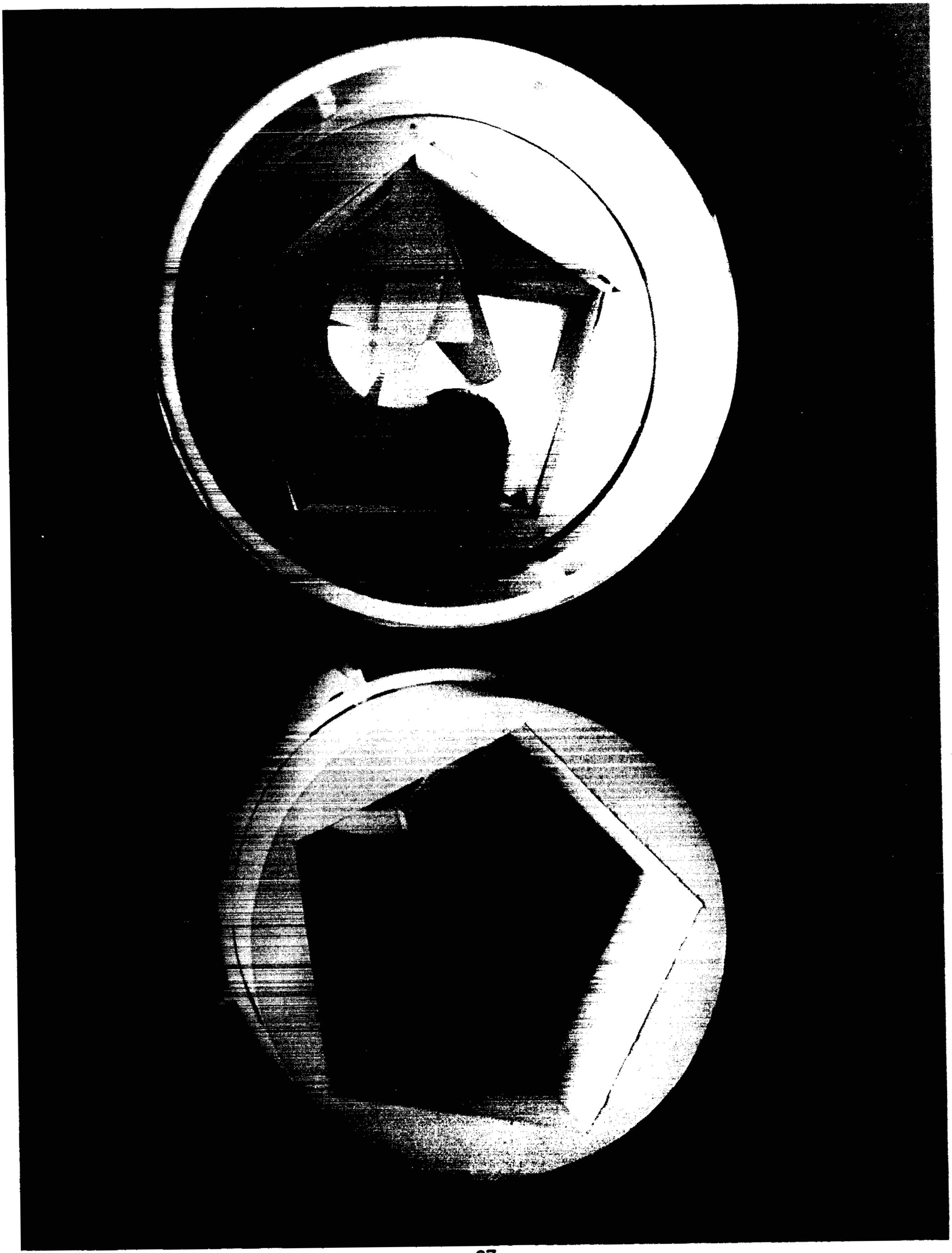


FIGURE 33 - DESIGN CONCEPT 6 MODEL PHOTOGRAPH

TABLE 6 - SCHEMATIC DESIGN ANALYSIS SHEET 6 | **SCHEME : 6**

DESIGNER[S] : ROBERT KLEIS AND KARL ULLE

CONFIGURATION : HORIZONTAL [POTENTIAL FOR VERTICAL]

BENEFIT: A = Advantage, D = Disadvantage

RESOLUTION: 1 = optimum, 2 = acceptable, 3 = average, 4 = deficient, 5 = minimal

FACTOR TYPE :	ANALYSIS NOTES :	BENEFIT	1	2	3	4	5
COMMUNAL ORGANIZATION	CENTRAL MODULE VOLUME IS FULLY MULTI-PURPOSE IN CONCEPT. ORGANIZATION DEPENDENT UPON FUNCTION AND ALIGNMENT OF PERIMETER PANELS BASED ON TIMELINE REQUIREMENTS	-		■			
SPATIAL PERCEPTION	CONTINUALLY CHANGING NATURE OF INTERIOR ACHIEVED BY CYCLIC SELECTION AND ALIGNMENT OF PANELS WOULD GENERATE AND MAINTAIN VISUAL INTEREST AND SPATIAL VARIETY	-		■			
INTERNAL CIRCULATION	MULTI-PURPOSE COMMUNAL VOLUME AND USE OF PANELS TO FORM PARTIAL ENCLOSURES WOULD ENSURE RELATIVELY FREE LINEAR CIRCULATION THROUGH THE MODULE	-			■		
COMPARTMENT ADAPTATION	POTENTIALLY HIGH LEVEL OF COMPARTMENTAL ADAPTABILITY ACHIEVED BY FOLD/SWING-OUT PERIMETER PANEL SYSTEM WHICH RESPONDS TO CYCLICAL DAILY ACTIVITY OPERATIONS AND NEEDS	A	■				
ON-ORBIT COMPLETION	ARTICULATED ATTACHMENT OF PERIMETER PANELS TO MODULE INTERIOR WOULD FACILITATE ON-ORBIT COMPLETION PROCESS	A	■				
LIFE-CYCLE MODIFICATION	ARTICULATED ATTACHMENT OF PERIMETER PANELS TO MODULE INTERIOR, AND RATIONALIZATION OF PANEL/EQUIPMENT FUNCTIONS ENSURES PROGRESSIVE LIFE-CYCLE MODIFICATION POTENTIAL	-		■			
ERGONOMIC UTILIZATION	POTENTIAL FOR ERGONOMIC UTILIZATION NOT FULLY EXPLORED, THOUGH OPTIMUM ERGONOMIC DESIGN LIKELY DUE TO WIDE RANGE OF PANEL ALIGNMENTS/GEOMETRIES/INTEGRAL EQUIPMENT ROLES	-			■		
EXTERIOR OBSERVATION	DIFFICULTY OF INTRODUCING WINDOWS IN CENTRAL MULTI-PURPOSE AREA DUE TO CONFLICT WITH PERIMETER PANEL PERFORMANCE REQUIREMENTS	D					■
EQUIPMENT RATIONAL-IZATION	POTENTIAL FOR EQUIPMENT RATIONALIZATION IS VERY GOOD, ONCE MAJOR PANEL ELEMENT AND INTEGRAL EQUIPMENT DESIGN RANGE IS CLARIFIED	A	■				
STRUCTURAL INSPECTION	FOLD/SWING-OUT CAPABILITY OF PERIMETER PANELS ENSURES OPTIMUM ACCESSIBILITY FOR STRUCTURAL INSPECTION	A	■				

3.8 DESIGN CONCEPT 7

3.8.1 OUTLINE DESCRIPTION

Horizontal configuration with large curvilinear elements bisecting the Module cross- section. Curvilinear elements create open communal areas above for Meetings/Tele-conferences/Exercise/Entertainment, and enclosed spaces below for individual activities including Planning and Training. One large element can occasionally rotate and interlock with fixed elements to create a large, free activity volume.

3.8.2 PRINCIPAL FEATURES

Unique profile and geometry of curvilinear elements generate visually and spatially interesting group activity areas, as well as ergonomically efficient and comfortable semi-private or individual areas within a common cross-section area. Flexibility of overall spatial composition is a key asset.

3.8.3 DESIGNER

Uri Sally [Israel]

3.8.4 SCHEMATIC DRAWINGS

See FIGURE 34, PAGE 70

3.8.5 MODEL PHOTOGRAPHS

See FIGURES 35, 36 AND 37, PAGES 71, 72 AND 73

3.8.6 SCHEMATIC DESIGN ANALYSIS

See TABLE 7, PAGE 74

ORIGINAL PAGE IS OF POOR QUALITY

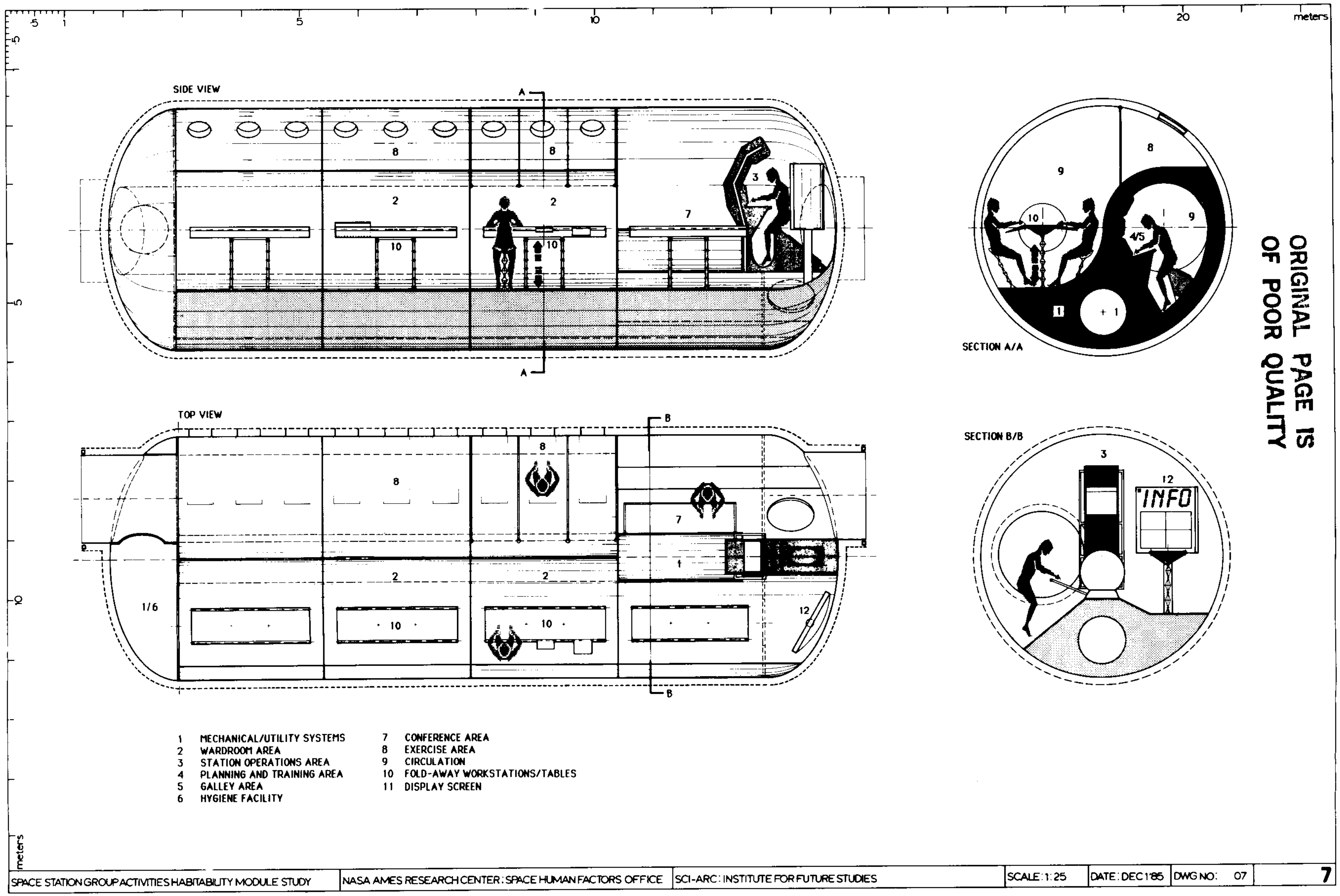


FIGURE 34 - DESIGN CONCEPT 7 SCHEMATIC DRAWINGS

FIGURE 35 - DESIGN CONCEPT 7 MODEL PHOTOGRAPH

ORIGINAL PAGE IS
OF POOR QUALITY

FIGURE 36 - DESIGN CONCEPT 7 MODEL PHOTOGRAPH

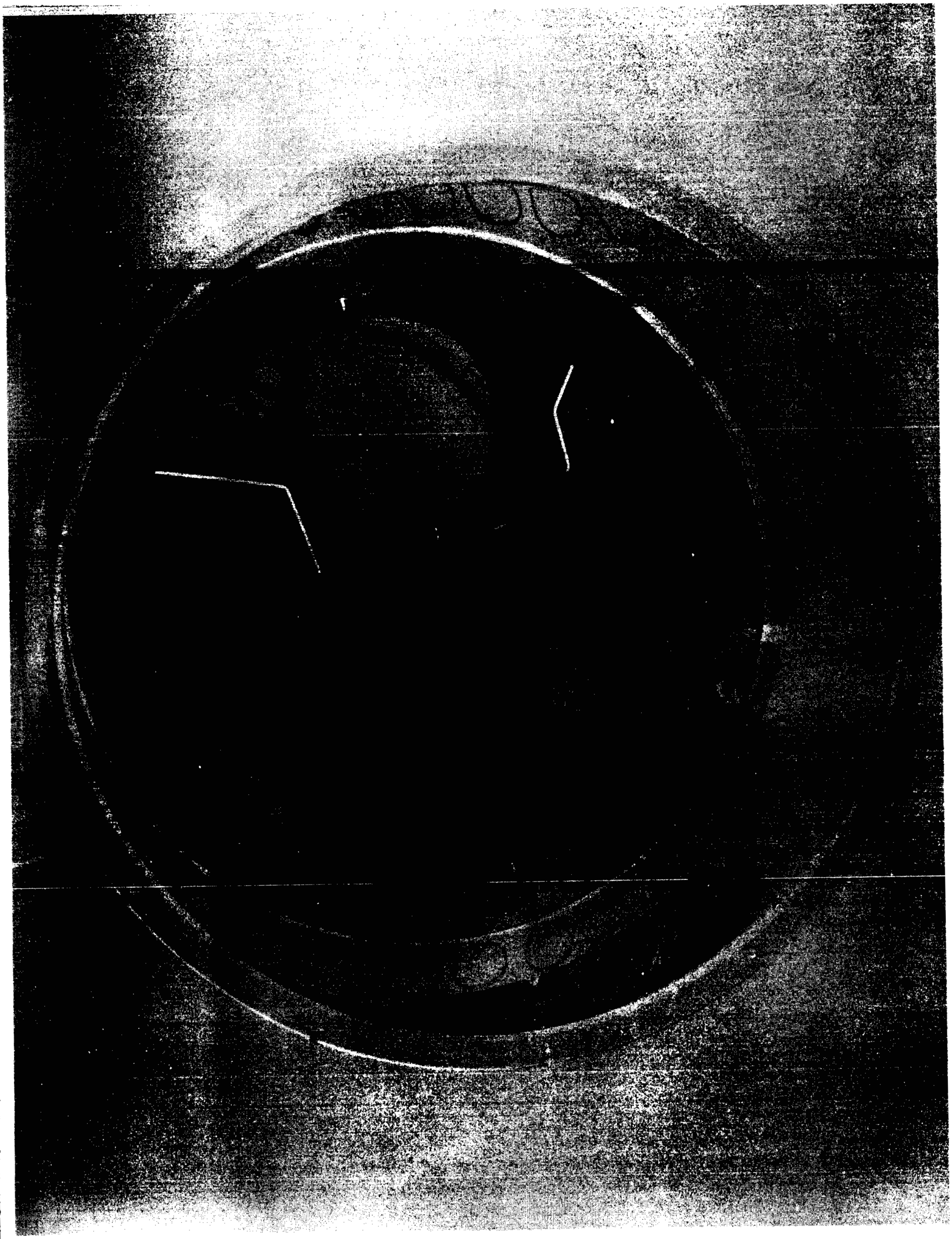


FIGURE 37 - DESIGN CONCEPT 7 MODEL PHOTOGRAPH

TABLE 7 - SCHEMATIC DESIGN ANALYSIS SHEET 7

SCHEME : 7

DESIGNER[S] : URI SALLY

CONFIGURATION : HORIZONTAL

BENEFIT: A = Ad-vantage; D = Disad-vantage

RESOLUTION: 1 = optimum; 2 = acceptable; 3 = average; 4 = deficient; 5 = minimal

FACTOR TYPE :	ANALYSIS NOTES :	BENEFIT	1	2	3	4	5
COMMUNAL ORGANIZATION	LARGE, CURVILINEAR ELEMENTS ORGANIZE FACILITIES INTO COMMUNAL [WARDROOM/EXERCISE] ON OUTSIDE, AND INDIVIDUAL [TRAINING/GALLEY/HYGIENE] ON INSIDE WITH GOOD SEPARATION	A	■				
SPATIAL PERCEPTION	INTERLOCKING AND ALTERNATING NATURE OF CURVILINEAR ELEMENTS GENERATES INTERESTING AND EXCITING INTERNAL VIEWS THROUGH MODULE	A	■				
INTERNAL CIRCULATION	CIRCULATION EITHER THROUGH COMMUNAL ZONE OUTSIDE ELEMENTS OR THROUGH INDIVIDUAL ZONE WITHIN ELEMENTS	-		■			
COMPARTMENT ADAPTATION	MAIN ELEMENTS NORMALLY LEFT IN ALIGNED SEQUENCE. OCCASIONAL ROTATION AND INTERLOCKING OF ELEMENTS TO ACHIEVE FREE INTERIOR VOLUME IS POSSIBLE BUT TECHNICALLY COMPLEX	-			■		
ON-ORBIT COMPLETION	LARGE SIZE AND COMPLEXITY OF MAJOR CURVILINEAR ELEMENTS AND ASSOCIATED RECESSED EQUIPMENT WOULD MAKE ON-ORBIT COMPLETION DIFFICULT	-				■	
LIFE-CYCLE MODIFICATION	LARGE SIZE AND COMPLEXITY OF MAJOR CURVILINEAR ELEMENTS AND ASSOCIATED RECESSED EQUIPMENT WOULD MAKE LIFE-CYCLE MODIFICATION DIFFICULT	D					■
ERGONOMIC UTILIZATION	DESIGN OF EXTENDING/RECESSED EQUIPMENT ON ELEMENT EXTERIOR AS WELL AS WORKSTATIONS, STORAGE BANKS AND UTILITIES ACCESS ON ELEMENT INTERIOR ARE BASED ON OPTIMUM ERGONOMICS	A	■				
EXTERIOR OBSERVATION	WINDOWS AND WINDOW REVEALS FREE OF OBSTRUCTIONS. 360° ANTHROPOMETRIC ROTATION REQUIRES WINDOWS WELL CLEAR OF ELEMENT PERIMETERS	-		■			
EQUIPMENT RATIONAL-IZATION	POTENTIAL FOR EQUIPMENT RATIONALIZATION GOOD, ONCE THE MAJOR ELEMENT AND INTEGRAL EQUIPMENT DESIGN RANGE IS CLARIFIED	-		■			
STRUCTURAL INSPECTION	ACCESS FOR INSPECTION VERY GOOD IN OPEN COMMUNAL AREAS BUT DIFFICULT AND COMPLICATED IN ENCLOSED ELEMENT AREAS WHERE SIMPLE DETACHMENT TECHNIQUES WOULD BE NEEDED	-			■		

3.9 DESIGN CONCEPT 8

3.9.1 OUTLINE DESCRIPTION

Horizontal configuration comprising a sequence of activity areas separated by bulkheads and floors enclosed by flexible, freeform envelopes. The envelopes respond to cyclical or fluctuating crew activity changes by manual adaptation on a daily routine or long-term life-cycle basis, and would generate continuous crew visual interest and involvement through the capability for self-determination of the interior. Wardroom, Exercise and Entertainment areas are centrally located with Personal Hygiene, Library and Galley areas towards Module ends.

3.9.2 PRINCIPAL FEATURES

Enclosing freeform envelopes are double-skin membranes extended between floors and bulkheads and activated and rigidized by pneumatic and/or vacuumatic operation. Membranes are configured as incremental and interconnected elements in a grid pattern which are individually attached to the Module interior. Individual elements contain supplies, equipment and workstations.

3.9.3 DESIGNER

Eyal Perchik [Israel]

3.9.4 SCHEMATIC DRAWINGS

See FIGURE 38, PAGE 76

3.9.5 MODEL PHOTOGRAPH

See FIGURE 39, PAGE 77

3.9.6 SCHEMATIC DESIGN ANALYSIS

See TABLE 8, PAGE 78

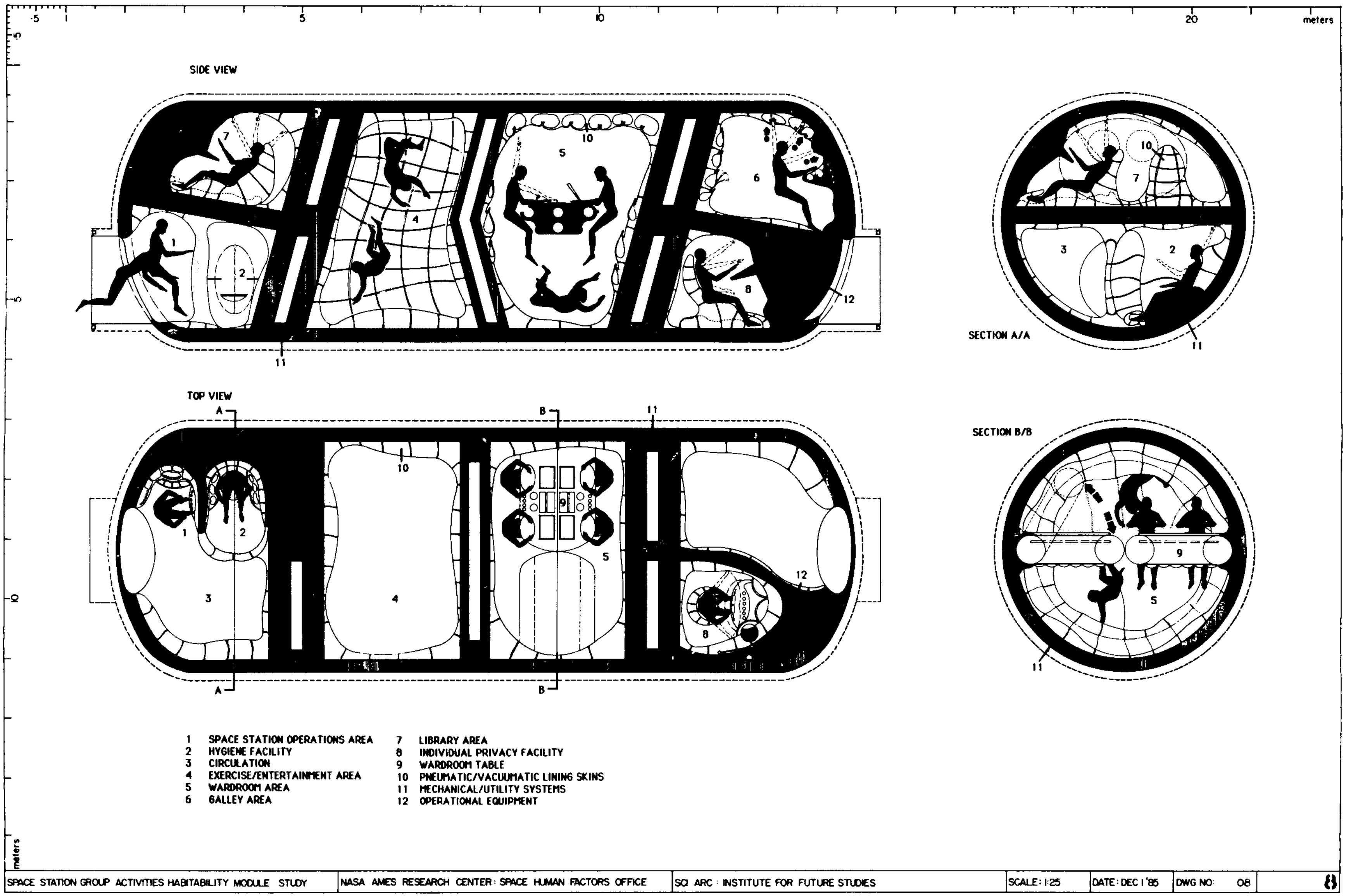


FIGURE 38 - DESIGN CONCEPT 8 SCHEMATIC DRAWINGS

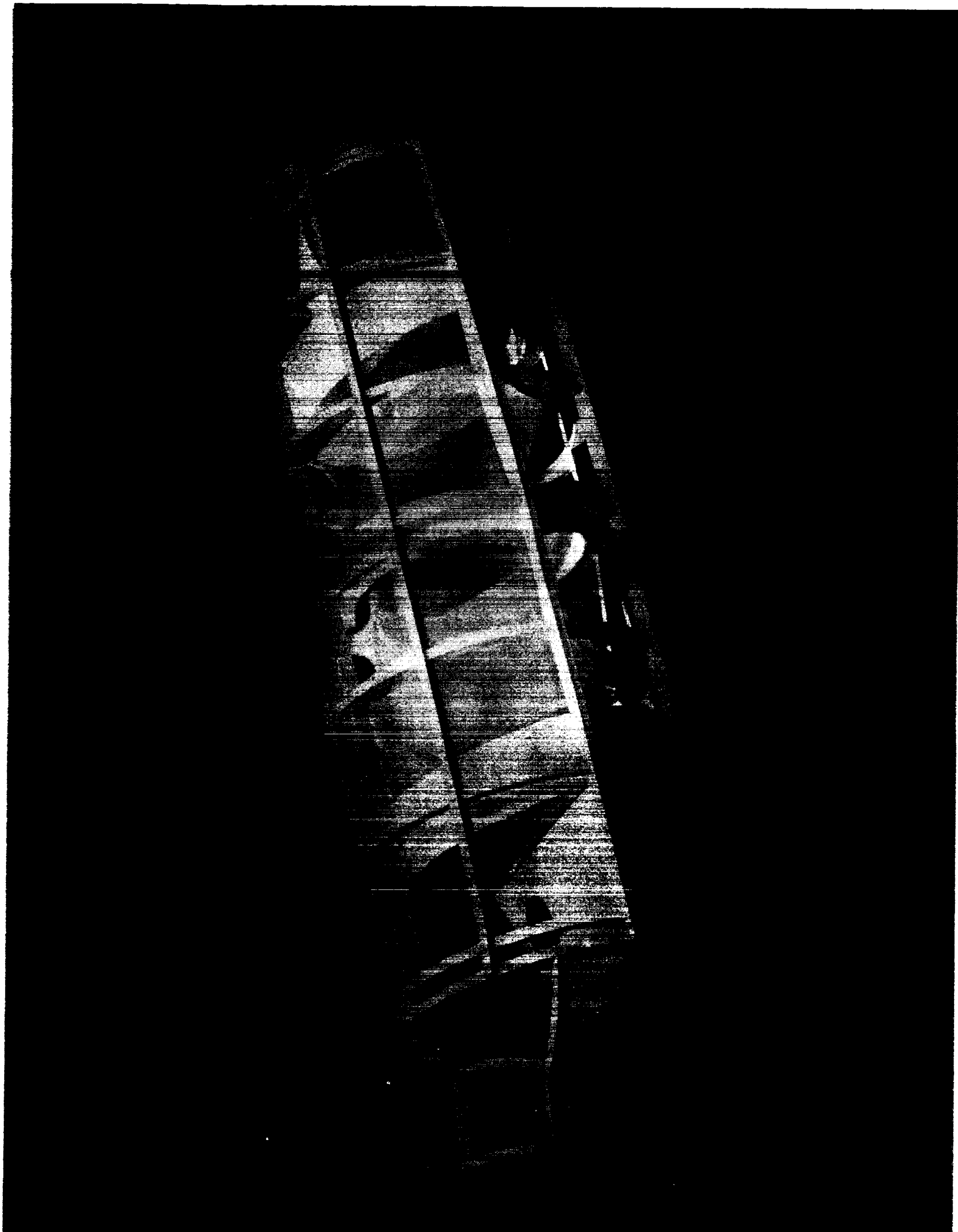


FIGURE 39 - DESIGN CONCEPT 8 MODEL PHOTOGRAPH

TABLE 8 - SCHEMATIC DESIGN ANALYSIS SHEET 8		SCHEME : 8						
DESIGNER[S] : EYAL PERCHIK CONFIGURATION : HORIZONTAL [POTENTIAL FOR VERTICAL]		BENEFIT A = Ad-vantage D = Disad-vantage	RESOLUTION 1= optimum 2= acceptable 3= average 4= deficient 5= minimal					
FACTOR TYPE :	ANALYSIS NOTES :		1	2	3	4	5	
COMMUNAL ORGANIZATION	A SERIES OF LINKED ACTIVITY VOLUMES SEPARATED BY BULKHEADS. ACTIVITIES ON TWO LEVELS AT EACH END SEPARATED BY FLOORS. MAIN COMMUNAL AREAS [WARDROOM/RECREATION] ARE CENTRAL	-		■				
SPATIAL PERCEPTION	ACTIVITY AREAS ARE INTERCONNECTED WITH CONTINUOUS VIEWS THROUGH MODULE. UNIQUE VISUAL INTEREST GENERATED BY FREE-FORM INTERIOR LININGS AND 3-DIMENSIONAL ORGANIC SHAPES	A	■					
INTERNAL CIRCULATION	INFORMAL CIRCULATION THROUGH THE INTERCONNECTED ACTIVITY VOLUMES. CIRCULATION AND MOVEMENT AIDED BY CURVILINEAR ENVELOPE GEOMETRIES	-			■			
COMPARTMENT ADAPTATION	USE OF PNEUMATIC [POSITIVE PRESSURE] AND VACUUMATIC [NEG-ATIVE PRESSURE] ENVELOPE LINING GRIDS ACHIEVES OPTIMUM COMPARTMENTAL ADAPTABILITY BY CREW ACTIVATION AS REQUIRED	A	■					
ON-ORBIT COMPLETION	INTERIOR LINING ENVELOPES AND INTEGRAL EQUIPMENT ATTACHED TO MODULE INTERIOR AT GRID NODE POINTS FROM INSIDE. DEFLATED FORM IN TRANSIT ENSURES EFFICIENT STOWABILITY	A	■					
LIFE-CYCLE MODIFICATION	INTERIOR LINING ENVELOPES AND INTEGRAL EQUIPMENT MAY BE MISSION-DEDICATED AND WOULD ACCOMPANY CREW TOURS DURING S.S. LIFE-CYCLE. REGULAR UPGRADING AND DEVELOPMENT POSSIBLE	A	■					
ERGONOMIC UTILIZATION	CONSIDERABLE POTENTIAL FOR ERGONOMIC UTILIZATION OF INTERIOR ENVELOPE LININGS AND INTEGRAL EQUIPMENT. REQUIRES FURTHER DEVELOPMENT	-			■			
EXTERIOR OBSERVATION	INTERIOR ENVELOPE LININGS OBSTRUCT EASE OF ACCESS TO WINDOWS FOR OBSERVATION. WINDOW LOCATION REQUIRES CAREFUL COORDINATION WITH LINING GRID TO AVOID REDUCING ADAPTABILITY	D					■	
EQUIPMENT RATIONAL-IZATION	POTENTIAL FOR EQUIPMENT RATIONALIZATION GOOD, ONCE MAJOR LINING ELEMENTS AND INTEGRAL EQUIPMENT DESIGN RANGE IS CLARIFIED	-		■				
STRUCTURAL INSPECTION	STRUCTURAL INSPECTION THROUGHOUT IS FACILITATED BY SIMPLE DETACHABILITY OF INTERNAL LINING SKINS AT GRID NODE POINTS	-		■				

3.10 DESIGN CONCEPT 9

3.10.1 OUTLINE DESCRIPTION

Horizontal configuration using zero-g neutral body posture anthropomorphic criteria as design generators for a series of linked cellular activity compartments. The Wardroom is centrally located with Exercise, Personal Hygiene areas and individual Library compartments located on either side. Proximity Operations areas are located at each end of the Module. The interior shapes created by the design approach would act as a major visual stimulus to the crew and create the potential for a long-term comfortable and efficent environment.

3.10.2 PRINCIPAL FEATURES

The use of zero-g neutral body posture anthropomorphic criteria to develop the interior configuration using stationary as well as mobile anthropometric shapes and geometries to develop the free space as well as ergonomic elements and equipment to determine the enclosing envelope.

3.10.3 DESIGNER

Jun Okushi [Japan]

3.10.4 SCHEMATIC DRAWINGS

See FIGURE 40, PAGE 80

3.10.5 MODEL PHOTOGRAPH

See FIGURE 41, PAGE 81

3.10.6 SCHEMATIC DESIGN ANALYSIS

See TABLE 9, PAGE 82

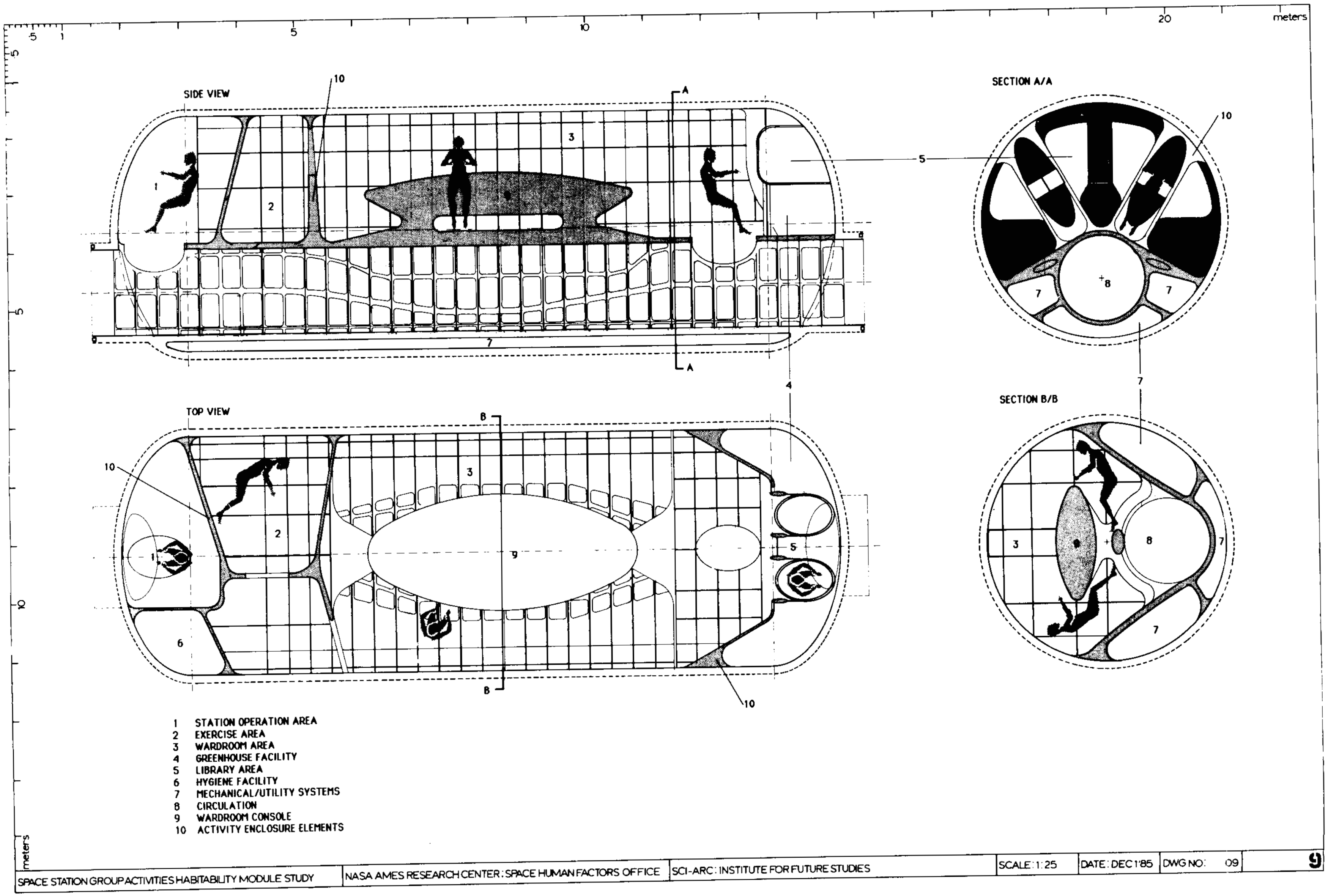


FIGURE 40 - DESIGN CONCEPT 9 SCHEMATIC DRAWINGS

ORIGINAL PAGE IS
OF POOR QUALITY

ORIGINAL PAGE IS
OF POOR QUALITY

FIGURE 41 - DESIGN CONCEPT 9 MODEL PHOTOGRAPH

TABLE 9 - SCHEMATIC DESIGN ANALYSIS SHEET 9		SCHEME : 9					
DESIGNER[S] : JUN OKUSHI **CONFIGURATION :** HORIZONTAL		**BENEFIT** A = Ad-vantage D = Disad-vantage	**RESOLUTION** 1= optimum 2= acceptable 3= average 4= deficient 5= minimal				
FACTOR TYPE :	**ANALYSIS NOTES :**		1	2	3	4	5
COMMUNAL ORGANIZATION	ACTIVITY AREAS CLUSTERED ALONG CIRCULATION SPINE. ACTIVITIES SEPARATED INTO COMMUNAL WARDROOM [ACTIVE] FUNCTIONS AND SEMI-PRIVATE LIBRARY/WORKSTATION [PASSIVE] FUNCTIONS	-		■			
SPATIAL PERCEPTION	DIRECT UTILIZATION OF ANTHROPOMETRIC GEOMETRIES AND MOVEMENT PATTERNS IN DEVELOPING ACTIVITY AREA CONFIGUR-ATIONS ACHIEVES INTERESTING AND EXCITING SPATIAL ENVIRONMENT	A	■				
INTERNAL CIRCULATION	DIRECT PERIMETER CIRCULATION PATH FROM MODULE END-TO-END	A	■				
COMPARTMENT ADAPTATION	COMPARTMENTAL ADAPTABILITY NOT CLEARLY DEFINED AND REQUIRES EXTENSIVE DEVELOPMENT. EXTENSIVE ADAPTABILITY UNLIKELY TO BE REALIZED DUE TO NATURE OF CONCEPT	D					■
ON-ORBIT COMPLETION	INTERNAL SKELETAL AND ENCLOSURE ELEMENTS CAPABLE OF ON-ORBIT COMPLETION. DIVISIBILITY AND ITEMIZATION OF INTERNAL CONFIGURATION REQUIRES EXAMINATION	-			■		
LIFE-CYCLE MODIFICATION	INTERNAL ENCLOSURE ELEMENTS AND EQUIPMENT MAY NOT BE CAPABLE OF LIFE-CYCLE MODIFICATION. NATURE OF LIFE-CYCLE CHANGES REQUIRES SUBSTANTIAL CLARIFICATION	-			■		
ERGONOMIC UTILIZATION	CONSIDERABLE POTENTIAL FOR EFFECTIVE ERGONOMIC UTILIZATION OF INTERIOR ENVELOPE ELEMENTS AND EQUIPMENT. REQUIRES FURTHER DEVELOPMENT	-			■		
EXTERIOR OBSERVATION	WINDOWS POTENTIALLY FREE OF OBSTRUCTIONS. CHOICE OF WINDOW LOCATION FAIRLY EXTENSIVE. 360° ANTHROPOMETRIC ROTATION REQUIRES WINDOWS CLEAR OF INTERNAL STRUCTURE	A	■				
EQUIPMENT RATIONAL-IZATION	THE UNIQUE NATURE OF INTERIOR CONFIGURATION COMBINED WITH SPECIALIZED APPROACH TO DESIGN OF STRUCTURE AND ENVELOPE LININGS SUBSTANTIALLY LIMITS POSSIBILITY FOR RATIONALIZATION	-			■		
STRUCTURAL INSPECTION	ELEMENTS AND EQUIPMENT COULD BE DESIGNED TO BE DETACHABLE FROM MODULE SHELL. FREE-FORM COMMUNAL AREA WOULD AID ACCESSIBILITY -STRUCTURAL MEMBERS MAY REDUCE IT	-			■		

3.11 DESIGN PHASE EVALUATION

3.11.1 BASIC OBJECTIVES

The main objective of the evaluation stage is to assimilate in outline the analysis results of the SCHEMATIC DESIGN ANALYSIS SHEETS in a manner which assists in the develop- ment of general conclusions to be drawn on the study.

The evaluation stage has two main themes

- To rate the level of effectiveness of design resolution of the ten Design Factors.
- To highlight the key advantages or disadvantages of the nine Design Concepts.

3.11.2 EVALUATION METHODS

The evaluation process is carried out by means of two matrix tables.

DESIGN FACTOR EVALUATION MATRIX 1 [TABLE 10, PAGE 85] combines the results of the ten Design Factor 5-point resolution ratings from each SCHEMATIC DESIGN ANALYSIS SHEET. This facilitates comparisons of the Design Factors in terms of the effectiveness of their resolution by the Design Concept group. The individual resolution ratings are added horizontally to give cumulative values in the right-hand vertical column. Low cumulative values indicate the most successfully resolved Design Factors and high cumulative values indicate the least successfully resolved Design Factors.

DESIGN CONCEPT EVALUATION MATRIX 2 [TABLE 11, PAGE 86] combines the results of the nine individual Design Concept benefit ratings from each SCHEMATIC DESIGN ANALYSIS SHEET. This facilitates comparisons of the Design Concepts in terms of key advantages or disadvantages [or neither]. Advantages and disadvantages are added vertically to give cumulative scores in the two lower horizontal columns. High ratios of advantages to disadvantages indicate the most successful Design Concepts and low ratios of advantages to disadvantages indicate the least successful Design Concepts.

3.11.3 EVALUATION RESULTS

- Design Factor SPATIAL PERCEPTION achieves 6 'optimum' ratings and 1 'minimal' rating in Matrix 1. This indicates that this Factor has been successfully interpreted by many of the Design Concepts. Comparison with evaluation result figures below indicates that this Design Factor is the most extensively and successfully resolved Design Factor of the group.
- Design Factor INTERNAL CIRCULATION achieves 3 'optimum' and 0 'minimal' ratings in Matrix 1. Design Factor COMMUNAL ORGANIZATION achieves 2 'optimum' and 0 'minimal' ratings in Matrix 1. These figures suggest that both Design Factors have only been partially resolved by the Design Concepts, although no 'minimal' ratings occur.

- Design Factor COMPARTMENT ADAPTATION achieves 4 'optimum' ratings and 3 'minimal' ratings in Matrix 1. Design Factor EXTERIOR OBSERVATION achieves 3 'optimum' and 2 'minimal' ratings in Matrix 1. Design Factors LIFE-CYCLE MODIFICATION and ERGONOMIC UTILIZATION each achieve 2 'optimum' ratings and 1 'minimal' rating in Matrix 1. These figures indicate that this group of Design Factors have been inconsistently resolved by the Design Concepts, although 'optimum' ratings slightly outweigh 'minimal' ratings.

- Design Factors ON-ORBIT COMPLETION and EQUIPMENT RATIONALIZATION each achieve 2 'optimum' and 2 'minimal' ratings in Matrix 1. This indicates that these two Design Factors have generally been inadequately resolved by the Design Concepts. Comparison with evaluation result figures above indicates that these are the least extensively or successfully resolved Design Factors of the group.

- Design Factor STRUCTURAL INSPECTION achieves 1 'optimum' rating and 0 'minimal' ratings in Matrix 1 indicating that this Design Factor has been insufficiently addressed by the majority of Design Concepts.

- DESIGN CONCEPTS 3, 6 and 8 each have the highest ratio of 'advantages' [4] to 'disadvantages' [1] in Matrix 2. These figures indicate that these 3 Design Concepts are the most successful at resolving the Design Factors taken as a group.

- DESIGN CONCEPTS 2, 7 and 9 are the next most successful Design Concepts in terms of ratio of 'advantages' [3] to 'disadvantages' [1] in Matrix 2.

- DESIGN CONCEPTS 1 and 4 are marginally successful at resolving the group of Design Factors with respective ratios of 'advantages' [2 and 2] to 'disadvantages' [1 and 2] in Matrix 2.

- DESIGN CONCEPT 5 has the lowest ratio of 'advantages' [2] to 'disadvantages' [3] in Matrix 2, indicating that it is the least successful Concept at resolving the Design Factor group.

- In Matrix 1, the spread of cumulative values of Design Factor resolution ratings in the right-hand column ranges from a high total of 15 [SPATIAL PERCEPTION] to a low total of 27 [ON-ORBIT COMPLETION and ERGONOMIC UTILIZATION]. The highest theoretical total is 9 and the lowest theoretical total is 45. Median value is 27. High and low cumulative values are respectively higher and equal to the median value suggesting that the Design Concepts, taken as a group, demonstrate reasonable capability at solving the group of Design Factors.

- In Matrix 2, the spread of Design Concept 'advantages' to 'disadvantages' in the bottom columns ranges from a high of 4 'advantages' [DESIGN CONCEPTS 3, 6 and 8} to a low of 3 'disadvantages' [DESIGN CONCEPT 5]. The greatest number of 'advantages' or 'disadvantages' that a single Design Concept can theoretically achieve is 10 either way. The cumulative ratio of 'advantages' to 'disadvantages' is 27 to 12. As with Matrix 1, these figures indicate that the Design Concept group collectively demonstrates reasonable design potential, although optimum design solutions are not achieved.

TABLE 10 - DESIGN FACTOR EVALUATION MATRIX 1

DESIGN CONCEPTS :	1	2	3	4	5	6	7	8	9	
DESIGN FACTORS :										
COMMUNAL ORGANIZATION	1	3	3	3	2	2	1	2	2	19
SPATIAL PERCEPTION	1	1	1	2	5	2	1	1	1	15
INTERNAL CIRCULATION	2	1	1	3	2	3	2	3	1	18
COMPARTMENT ADAPTATION	5	5	3	1	1	1	3	1	5	25
ON-ORBIT COMPLETION	4	2	2	5	5	1	4	1	3	27
LIFE-CYCLE MODIFICATION	2	2	1	3	4	2	5	1	3	23
ERGONOMIC UTILIZATION	4	4	5	3	1	3	1	3	3	27
EXTERIOR OBSERVATION	2	1	3	1	3	5	2	5	1	23
EQUIPMENT RATIONALIZATION	3	3	1	5	5	1	2	2	3	25
STRUCTURAL INSPECTION	3	3	3	3	3	1	3	2	3	24

INDIVIDUAL VALUES OF DESIGN FACTOR RESOLUTION RATINGS TAKEN FROM EACH SCHEMATIC DESIGN ANALYSIS SHEET

CUMULATIVE VALUES OF DESIGN FACTOR RATINGS SHOWING ORDER OF SUCCESSFUL RESOLUTION. [LOW SCORES BEST; HIGH SCORES WORST]

TABLE 11 - DESIGN CONCEPT EVALUATION MATRIX 2

	DESIGN CONCEPTS :	1	2	3	4	5	6	7	8	9
DESIGN FACTORS :	COMMUNAL ORGANIZATION	A	-	-	-	-	-	A	-	-
	SPATIAL PERCEPTION	A	A	A	-	D	-	A	A	A
	INTERNAL CIRCULATION	-	A	A	-	-	-	-	-	A
	COMPARTMENT ADAPTATION	D	D	-	A	A	A	-	A	D
	ON-ORBIT COMPLETION	-	-	-	D	D	A	-	A	-
	LIFE-CYCLE MODIFICATION	-	-	A	-	-	-	D	A	-
	ERGONOMIC UTILIZATION	-	-	D	-	A	-	A	-	-
	EXTERIOR OBSERVATION	-	A	-	A	-	D	-	D	A
	EQUIPMENT RATIONALIZATION	-	-	A	D	D	A	-	-	-
	STRUCTURAL INSPECTION	-	-	-	-	-	A	-	-	-

INDIVIDUAL DESIGN CONCEPT BENEFIT RATINGS [ADVANTAGES AND DISADVANTAGES] TAKEN FROM EACH SCHEMATIC DESIGN ANALYSIS SHEET

CUMULATIVE SCORES OF ADVANTAGES AND DISADVANTAGES FOR EACH DESIGN CONCEPT

	1	2	3	4	5	6	7	8	9	Total
ADVANTAGES	2	3	4	2	2	4	3	4	3	27
DIS-ADVANTAGES	1	1	1	2	3	1	1	1	1	12

4 CONCLUSIONS

4.1 CONCLUSIONS FROM THE RESEARCH PHASE

4.1.1 THE NEED FOR A SEMI-PRIVATE LIBRARY/STUDY FACILITY

The Architectural Design Program developed in the RESEARCH PHASE contains a list of all crew activities of a communal or partly-communal nature likely to occur in HM1, and assesses in outline their design characteristics and requirements. The ten types of activity which are individually identified are generally derived from Space Station Reference Configuration Description [ref. 1] with a significant addition - an activity designated "Library and Study" described in the Architectural Design Program.

A Library and Study function is included because of its latent but potential significance, not necessarily evident during the initial Space Station design phases, to Space Station operation and habitability.

Currently, there is no provision for including a semi-private/ semi-communal crew facility on the Space Station. Individual privacy will be obtained by crewmembers spending time in their own Sleeping Compartments. In reality, the nature of private compared to communal accommodation is more complex and demanding. Chermayeff and Alexander, in a notable study on planning for privacy [ref. 6], identify the humanistic necessity of different gradations of privacy in the environment, ranging from the neighborhood through the family to the individual. Stuster, in a study on Space Station analogous conditions [ref. 2], concludes that a "Library" compartment is necessary to provide crewmembers with occasional opportunities for "privacy and quiet reflection".

A brief consideration of life aboard the Space Station indicates how a Library and Study may be an important asset to the social and behavioral well-being of the crew. Crew tours of 90 days in duration, or perhaps longer, will be commonplace. This is at least as long as the longest period U.S. astronauts have spent in Space on the final Skylab mission during 1973/74. It is also important to remember that the size of a proposed Space Station Module is substantially less than the size of Skylab because of STS limitations. As Cohen points out in a review of Space Station Human Factors [ref. 7], the STS cargo bay constraints on the Common Module size will emerge as the the central issue in shaping the limits of the environment on the Space Station.

Also, the crew social mix aboard Space Station is likely to be quite complex and heterogenous. Station Specialists will invariably be U.S. citizens with military aviation backgrounds, while Mission and Payload Specialists will be drawn from a variety of scientific, engineering and cultural backgrounds. Many nations, many organizations and many industries will be represented. Unlike astronauts with military backgrounds, it is probable that Mission and Payload Specialists will have fairly limited training or experience in performing effectively over long periods of time under difficult conditions.

Given this mix of backgrounds, experiences and cultures, it is quite possible that psychological, physiological or socio/cultural problems and tensions will arise during the course of a long crew tour, both in terms of how crewmembers feel about each other as well as how they feel about their surroundings. The Space Station can be designed to minimize such tensions which may otherwise be aggravated by the limited choice of habitable facilities available, where crewmembers wanting privacy may constantly seek the refuge of their private Sleeping Compartments at the expense of social contact or interchange with others. For these reasons, it is concluded that

- **A Library and Study facility for two or three crewmembers to use occasionally will be an essential ingredient in helping to alleviate any social tensions or polarizations which may arise if the only off-duty choice is between a Wardroom and a private Sleeping Compartment.**

This study also recognizes that the programmatic requirements for crew facilities and storage in HM1 are likely to be so extensive and demanding that it may not be possible to accommodate a Library and Study facility at IOC stage. To resolve this problem

- **A Library and Study facility can be configured as an intermittent function at IOC stage in the form of an internally adaptable or deployable enclosure within the Module which would subsequently be relocated as a dedicated facility during post-IOC Space Station expansion and development.**

4.1.2 INTERNAL DESIGN CONFIGURATIONS MUST RESPOND TO CREW SHIFT AND SCHEDULE OPTIONS AND VARIATIONS

The Preliminary Habitability Design Guidelines developed in the RESEARCH PHASE explore in outline the interaction between two alternating crew shifts every 24 hours, based on original crew routine data obtained from Space Station Definition and Preliminary Design, Request for Proposal.

This data is considered to be too demanding on crew time availability, and has been amended to reflect a more realistic and reasonable approach to scheduling by reducing on-duty work/operations time from 10 to 8 hours, and increasing both exercise and recreation time from 1/2 to 1 hour each. Compton and Benson, in their history of Skylab [ref. 8], refer to the excessive workload and lack of free time which contributed to problems experienced by the crew of the final and longest Skylab mission [Skylab 4]. Stuster [ref. 2] recommends scheduling at least 1 hour of uninterrupted relaxation time before sleeping. With regard to exercise, the original allowance of 1/2 hour of daily exercise for each crewmember is insufficient and increased periods are required for satisfactory health maintenance. Gibson, reporting on Skylab 4 crew medical observations [ref. 9], indicates that the third crew benefited from 90 minutes of daily exercise. Boeing, in their literature report on Soviet Space Station activities [ref. 10], record that cosmonauts exercise 2 hours a day or more. Since the U.S.S.R. has acquired substantial knowledge of long-term Space habitability with their Salyut program, their inclusion of long exercise periods has been based on experience.

The above examples serve to indicate that substantal differences of approach to crew scheduling exist. It can be deduced that variations and changes in crew scheduling are probably inevitable, and that flexibility of scheduling will therefore be essential. The issue of flexible scheduling is significant when alternating crew shifts experience Shift Handovers every 12 hours. Shift Handovers can be planned without conflict of use of facilities in HM1 when the 2 shifts interchange, assuming schedules are fixed. But when schedules are flexible and subject to change, the risk of conflict or congestion arises. Scheduling will become increasingly complex if the number of crewmembers in a shift begins to vary from three to perhaps four persons.

Also, major complications will be introduced if the 2-shift daily routine arrangement changes to a 3-shift arrangement when crew activities will almost certainly overlap in their use of accommodation in HM1, particularly with regard to the use of the Galley and Wardroom. Finally, in the long-term, as the Space Station grows in size and complexity, these issues will become more critical with the potential for increasing conflict over the use of limited Space Station accommodation, facilities and equipment.

In order to achieve efficent use of accommodation and facilities in HM1, and ensure smooth transition from one shift to another on a regular basis, it is important to investigate all potential design configurations for the interior in terms of their impact and effect on all crew routine and shifts under consideration, and to recognize that

- **The feasibility of a 2-shift or 3-shift daily cycle or a 2-shift evolving into 3-shift cycle, with each requiring built-in capability for flexible scheduling and fluctuating crew numbers, will be significantly affected or impacted by the Module internal design configurations.**

This suggests that

- **In view of the difficulty and undesirability of fully preplanning Space Station routines and operations, all potential crew routine options and variations must be cross-checked with Module internal configurations at all design and development stages.**

4.1.3 ASSESSING CREW TRANSLATION AND ORIENTATION IMPLICATIONS OF SPACE STATION POST-IOC EXPANSION

The Preliminary Habitability Design Guidelines of the RESEARCH PHASE examined in outline the proximity relationships and movement patterns applicable to HM1.

Activity proximity relationships and crew movement patterns involve design considerations which extend beyond HM1 to affect all Space Station Modules. Though the anticipated Space Station IOC architecture involves only five Common Modules, subsequent growth will increase this number. The objective of a mature, fully developed Space Station, though not featured in Space Station Reference Configuration Description [ref. 1], is recognized by the Office of Technology Assessment of the United States Congress in a study on the U.S. future in Space [ref. 11].

While effective intra-Module crew translation and orientation depend on the configuration of the interior of individual Modules, inter-Module crew translation and orientation depend on the clustering arrangement and sequence of all the Modules. As the Space Station evolves and expands, the Module cluster will become increasingly complex in terms of crew orientation and translation. Such increasing complexity will require some study if ease of movement throughout the Modules is to be maintained.

The issue of how easily crewmembers move through the interior of the Space Station is highly significant in terms of three key objectives - preservation of safety and freedom of passage through all Modules in the event of an emergency; maintenance of efficient and comfortable crew movement on an operational day-to-day basis; and security against intrusion of proprietary industrial and scientific research activities. During the RESEARCH PHASE, no significant literature or studies were identified which specifically address the issues of crew translation and orientation in an evolutionary version of a Space Station. Because these issues are so important to long-term Space Station operational viability, it is suggested that

- **Research studies are undertaken to examine the implications of Space Station growth and change on crew orientation and translation throughout post-IOC Module clustering options in order to ensure that optimum conditions of operational safety, efficiency and security can always be maintained.**

4.2 CONCLUSIONS FROM THE SCHEMATIC DESIGN PHASE

4.2.1 HIGHLY-ADAPTABLE INTERIOR ARCHITECTURE CONFIGURATIONS ARE LIKELY TO PERFORM BEST IN SPACE STATION OPERATIONAL SCENARIOS

The Design Phase Evaluation of the RESEARCH PHASE of the study demonstrates that the three Schematic Design Concepts [DESIGN CONCEPTS 6, 8 and 3] which are most successful at resolving the greatest range of Design Factors are those with the highest built-in capability for operational adaptation and modification.

Incorporating a design capability for operational adaptation and modification is likely to be an important requirement in helping to ensure that Module internal architecture configurations remain efficient, versatile and comfortable environments throughout the life of the Space Station. The three Design Concepts that address these issues demonstrate various approaches based on the concept of a modular, internal envelope composed of interrelated elements and equipment which are articulated and interfaced to allow substantial on-orbit reconfiguration or replacement. The Design Concepts suggest that changes may range from day-to-day or even hour-to-hour modifications based on intensive crew scheduling requirements of multi-purpose facilities, up to Mission- length or longer term modifications based on Module change-out or upgrading requirements of configuration elements and equipment.

The long-term, life-cycle performance of the Space Station will be substantially affected by decisions made during the design development stages. Space Station Reference Configuration Description [ref. 1] defines a requirement for five Common Modules at IOC stage, two of which will be internally configured for crew habitability. Subsequently, the emergence of any mandated requirements for Space Station cost reductions or deferrals in response to U.S. Government legislation, or other budgetary pressures and uncertainties, may affect this program figure. A potential reduction of the IOC Module cluster from five to two or three Modules would increase significantly the design constraints on Space Station habitability by introducing the unavoidable need for a multi-purpose habitability Module to include both crew living and sleeping accommodation.

This reduction would not be desirable in the long-term because of adverse crew habitability implications. Adaptable and modifiable internal architecture would be able to resolve this need by enabling a Module to be configured initially as a multi-purpose habitability Module with combined living and sleeping accommodation, and later be converted and up-graded into a dedicated living or sleeping Module as permitted by Space Station expansion policy.

A further, and perhaps less obvious, advantage of adaptable and modifiable internal configuration architecture relates to the issue of long-term crew physiological and psychological attitude and response to their internal surroundings.

Configurations which are flexible and changeable are likely to induce more crewmember interest and less boredom than configurations which are fixed and dedicated. A crew can actively participate in altering the shape and size of its living environment perhaps at its own suggestion and under its own control. The opportunity for maintaining crew interest in, and awareness of, its surroundings is increased, with consequent behavioral and social benefits for crewmember relationships with themselves, their work and their contacts on the Ground. Crew-initiated changes may be in response to a wide range of functional variables including fluctuating crew numbers, revised crew shifts and timelines, appropriate crew interpersonal relationships [e.g. married crewmembers], specific Mission or Payload Specialist objectives, or simply cultural or personal preferences. A built-in capability for adaptation, modification, reconfiguration or replacement will assist all such changes. Therefore,

- **Highly-adaptable and modifiable internal Module configurations which can adjust kinetically to changing Space Station functional requirements will be able to maintain higher levels of IOC, post-IOC and long-term operational efficiency than dedicated or fixed internal configurations.**

As well as influencing functional issues, kinetic internal Module configurations can also positively influence crew perceptual and psychological issues. In particular,

- **This built-in capability for change will additionally provide an environmental feature and stimulus by allowing crews to initiate and experience configuration architecture changes as and when they occur.**

4.2.2 CREW SPATIAL PERCEPTION AND INTRA-MODULE TRANSLATION WILL BENEFIT FROM HORIZONTAL, BUT NOT VERTICAL, INTERNAL DESIGN CONFIGURATIONS

Most of the Design Concepts developed in the SCHEMATIC DESIGN PHASE respond creatively and effectively to design issues concerned with maintaining enhanced spatial perception and efficent crew translation throughout the Module. Effective response is achieved both by Design

Concepts based on fixed and dedicated compartmental architecture, and by Design Concepts based on adaptable and modifiable multi-purpose architecture. Though the Design Concepts do not specifically address programmatic requirements for internal storage capacity [such as the notional 33% storage/66% free-volume ratio] in the SCHEMATIC DESIGN PHASE, sufficient volume remains undefined and uncommitted in most cases to enable this requirement to be absorbed without undue detrimental effect.

The majority of Design Concepts are horizontal configurations. It is clear that, as far as crew spatial perception and cognition are concerned, the ability of horizontal configurations to exploit Module end-to-end viewing distance and associated visual perspective is an important feature which will assist in maintaining crew visual awareness and acuity during long Space Station tours. Conversely, vertical configurations are divided up into a series of compartments by transverse floors which obstruct Module end-to-end viewing and hinder spatial appreciation. This is apparent in one Design Concept with a vertical configuration [DESIGN CONCEPT 6] where crew activities are organized into a series of vertical compartments resulting in a reduced sense of interior spaciousness and an increased sense of confinement. Spatial perception in vertical configurations is inevitably restricted to individual compartments where optimum view distances are governed by the Module diameter, not length. In this situation, the need for occasional long-distance viewing and ocular focus will fully depend on regular window observations.

With regard to crew translation, open movement paths implicit in horizontal configurations ensure effective intra-Module crew translation. This will assist crew safety during an emergency exit procedure and generally help to reduce time taken to move from point-to-point, as well as providing a clear field of vision ahead for recurring crew delivery of equipment and supplies from the Logistics Module or docked STS Orbiter to internal locations throughout the Space Station. A vertical configuration, however, will obstruct free passage through the Module by requiring crewmembers to deliberately orientate towards, and pass through, a series of openings or hatches during translation. This series of bottlenecks will tend to reduce the speed and efficency of crew movement through the Module in day-to-day as well as emergency situations as well as hinder movement of supplies and equipment. To summarize, it is concluded that

- **Horizontal internal architecture configurations are more effective than vertical configurations at accentuating and optimizing crew perception of spaciousness and end-to-end viewing distance and perspective, due to the absence of transverse floors present in vertical configurations which are visually intimidating and restrictive.**

- **Horizontal internal architecture configurations provide potentially unhindered intra-Module crew translation and freedom of movement, whereas the transverse floors inevitably present in vertical configurations act as intermediate obstructions to efficient crew passage through the Module.**

C-2

4.2.3 ON-ORBIT COMPLETION, LIFE-CYCLE MODIFICATION AND PRESSURE-HULL INSPECTION ARE IMPORTANT DESIGN ISSUES INVOLVING VERY SIMILAR CREW ACTIVITIES AND TASKS, AND HENCE PERFORMANCE OBJECTIVES

The Design Phase Evaluation of the SCHEMATIC DESIGN PHASE demonstrates a virtually identical response by the Schematic Design Concepts to design issues concerned with the on-orbit completion and life-cycle modification of HM1, indicating that these issues have very similar operational characteristics.

The value of an internal architecture configuration with an intrinsic capability for on-orbit completion and life-cycle modification is likely to be considerable, and perhaps indispensable, for several reasons.

The need to incorporate an extensive program and inventory of compartments, equipment, supplies and utilities within HM1 may possibly place the gross Module launch weight beyond the payload lift capability of STS, assuming the Module is 100% outfitted before launch. This is likely to be particularly evident if a decision is made to adopt combined Habitability/Laboratory Modules for the Space Station IOC configuration which may involve a more extensive and complex outfitting inventory. The solution may be to reduce Ground outfitting of HM1 to lower the Module gross weight to a feasible figure, and complete the Module outfitting on-orbit. Designing the Module architecture to facilitate this task will be important.

Similarly, it will be important to ensure that HM1 is designed to be easily modified and upgraded during its life-cycle in order to maintain long-term operational efficiency and crew habitability. HM1 initially may be outfitted with a very high level of internal storage capacity resulting in reduced volumes for crew accommodation, or with crew sleeping and living facilities combined into a single Module made necessary by Space Station IOC budget constraints. Neither approach is likely to be successful in the long-term, as habitability conditions and standards are improved or expanded, perhaps in some cases at the insistence of Space Station crews or their various sponsoring organizations.

Module on-orbit completion and life-cycle modification are design issues which both require the rationalization, modulation and articulation of internal architecture elements and equipment to enable physical changes to be made by crews easily, quickly and safely. Both will also require the development and incorporation of advanced types of manual interlocking and retaining devices to enable elements and equipment to be simply interconnected with each other and with the Module structural frame tie-back points by crewmembers. Both will also involve examination of related ergonomic activities including deactivating, dismounting, removing, manipulating, modifying, repairing, exchanging, replacing or remounting elements and equipment. To summarize,

- **Module performance capabilities for on-orbit completion and life-cycle modification are essential if Space Station operational efficiency and crew habitability standards are to be progressively upgraded, or even maintained. Since the two issues involve a very similar set and sequence of crew performance tasks on internal elements and equipment, they can be considered and addressed as a combination.**

The ability of internal architecture elements and equipment to be removed, reconfigured and replaced is also fully compatible with the requirement for Module hull accessibility. Hull pressurization checks and hull and utility system repairs and maintenance will be carried out by regular crew inspections, and complete access to internal Module hull surfaces is essential. The set and sequence of performance tasks involved in pressure- hull inspection will be similar to such tasks concerned with on-orbit completion and life-cycle modification.

- **The manipulation of internal architecture elements and equipment for purposes of Module on-orbit completion or life-cycle modification will similarly be required for Module hull inspection. It follows that all three issues can be integrated into a unified design objective.**

5 RECOMMENDATIONS FOR FURTHER RESEARCH

MUCH OPPORTUNITY EXISTS TO DEVELOP INNOVATIVE INDUSTRIAL DESIGN APPLICATIONS FOR THE INTERIOR OF THE HABITABILITY MODULE

The SCHEMATIC DESIGN PHASE of the project has resulted in the development of nine Design Concepts which explore alternative internal architectural configurations for HM1 in outline. Though the objectives of the SCHEMATIC DESIGN PHASE precluded any in-depth study or design of detailed features, several Design Concepts included innovative ideas for individual elements, assemblies, equipment or accessories. Some examples of these are

- Demountable colored /graphic trim profiles designed to enhance visual interest and spatial perspective by simple and selective attachment to various internal neutral surfaces [DESIGN CONCEPT 1]
- Plant/vegetable glovebox chambers designed as transparent faceted modules that interconnect to form a large visual feature that acts as a screen between different crew activities [DESIGN CONCEPT 2]
- Gimballed Wardroom table assembly designed as three flush-nested surfaces which fold-out to match 2-4 person, 5-8 person or 9-12 person crew meeting group sizes [DESIGN CONCEPT 4]
- Articulated crew workstations which deploy out of/retract into perimeter stand-off elements which themselves swing-out to form occasional activity compartment enclosures [DESIGN CONCEPT 6]
- Soft and flexible stretch-pocket packs for multi-purpose on-orbit storage which are roll-stowed for STS transit and unrolled to form interior decorative and functional surfaces [DESIGN CONCEPT 7]
- Pliable compartment membrane-walls of sealed double-skin panels with frictional particle interlayers which are manually positioned and then evacuated to form a fully rigidized enclosures [DESIGN CONCEPT 8]

Though the examples above are highly conceptual, they serve to demonstrate that there is considerable opportunity to improve the design quality and performance of many interior features in HM1, as well as other Modules, during the Space Station detailed design and development stages. In particular, it should be possible to advance the design of internal elements and equipment substantially beyond the standards which were applicable to Skylab in the 1970's, as evident in the Skylab Workshop replica at NASA-Johnson Space Center and described in the Skylab Mission Report on the Saturn Workshop [ref. 12].

Another area where improvements can be made concerns the interface between crew- members and equipment where anthropometric criteria are translated into effective ergonomic and "user-friendly" design. The design of workstations requires particular attention. The realization, following the experiences of Skylab, that neutral body posture in zero-g must be applied to achieve effective crew workstation design, is relatively new and it is evident that much useful research needs to be undertaken on this subject [ref. 3].

The Preliminary Habitability Design Guidelines of the RESEARCH PHASE of the project begin to address such issues. A series of preliminary reference diagrams translate 95% male and 5% female zero-g neutral body postures, drawn from design guides developed by Griffin [refs. 4 and 5], into various ergonomic envelopes for specific crew activities associated with the Wardroom in HM1. These are then organized into different coplanar combinations [for common interpersonal orientation] and provide useful design reference envelopes for typical crew group activities in the Wardroom.

Therefore, much opportunity exists to advance the roles of ergonomic and industrial design for the benefit of the Space Station. Four aspects which deserve special attention are

- **Design emphasis on element and equipment compactness/miniaturization throughout HM1 in order to minimize associated volumetric size specifications and maximize habitable volume available for crew use**

- **Design emphasis on element and equipment multi-functionality/ versatility throughout HM1 in order to minimize performance inflexibility/redundancy and maximize hardware weight/cost efficiency**

- **Design emphasis on element and equipment ergonomic efficiency/user-friendliness throughout HM1 in order to minimize operational inconvenience/complexity and maximize user suitability/comfort**

- **Design emphasis on element and equipment autonomy/self-containment throughout HM1 in order to minimize systems interdependence/ susceptibility and maximize individual functional durability/ seviceability**

To conclude, it is suggested that

- **During the Space Station detailed design and development stages [Phase C/D], supporting design studies of innovative industrial design solutions are performed. These would concentrate on elements, assemblies, components and equipment which together comprise the internal architectural configuration of HM1 with the purpose of achieving optimum operational efficiency and enhanced environmental habitability.**

APPENDIX A

ABBREVIATIONS

EVA	EXTRA-VEHICULAR ACTIVITY
HM1	HABITABILITY MODULE 1
HM2	HABITABILITY MODULE 2
IOC	INITIAL OPERATIONAL CAPABILITY
IVA	INTRA-VEHICULAR ACTIVITY
RFP	REQUEST FOR PROPOSAL
STS	SPACE TRANSPORTATION SYSTEM

REFERENCES

1. National Aeronautics and Space Administration: Space Station Reference Configuration Description, System Engineering and Integration, Space Station Program Office, Johnson Space Center, JSC-19989, NASA TM-87493, August 1984.

2. Stuster, J.W.: Space Station Habitability Recommendations based on a Systematic Comparative Analysis of Analogous Conditions, Anacapa Sciences Inc., Ames Research Center, NAS2-11690, NASA CR-3943, December 1984.

3. Bond, R.L.; and Gundersen, R.T.: Zero-G Workstation Design, Johnson Space Center, Houston, Texas, JSC Internal Note 76-EW-1, JSC-09962, NASA TM-80000, June 1976.

4. Griffin, Brand N.: The Influence of Zero-G and Acceleration on the Human Factors of Spacecraft Design, Johnson Space Center, JSC-14581, August 1979.

5. Cohen, Marc M.; and Rosenberg, E.: Proceedings of the Seminar on Space Station Human Productivity, NASA Technical Memorandum 86673, Ames Research Center, March 1985.

6. Alexander, Christopher; and Chermayeff, Serge: Community and Privacy - Toward a New Architecture of Humanism, Doubleday & Co., Inc., New York, 1963.

7. Cohen, Marc M.: Human Factors in Space Station Architecture 1: Space Station Program Implications for Human Factors Research, Ames Research Center, NASA Technical Memorandum 86702, October 1985.

8. Benson, C.D.; and Compton, W.D.: Living and Working in Space - A History of Skylab, NASA Scientific and Technical Information Branch, Washington D.C., NASA SP-4208, 1983.

9. Johnston, Richard S.; and Dietlein, Lawrence F.: National Aeronautics and Space Administration: Biomedical Results from Skylab, Scientific and Technical Information Office, Washington D.C., NASA SP-377, 1977.

10. Boeing Aerospace Company: Soviet Space Stations as Analogs, D180-28182-1, October 1983.

11. Office of Technology Assessment, Congress of the United States: Civilian Space Stations and the U.S. Future in Space, Washington D.C., OTA-STI-241, November 1984.

12. Marshall Space Flight Center, Skylab Program Office: Skylab-MSFC Skylab Mission Report-Saturn Workshop, NASA Technical Memorandum X-64814, October 1974.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-4010		

4. Title and Subtitle	5. Report Date
Space Station Group Activities Habitability Module Study	November 1986
	6. Performing Organization Code 482-52-21
7. Author(s) David Nixon	8. Performing Organization Report No.
	10. Work Unit No.
9. Performing Organization Name and Address Institute for Future Studies (SCI-ARC) Southern California Institute of Architecture 1800 Berkeley St., Santa Monica, CA 90404	11. Contract or Grant No. NCC2-356
	13. Type of Report and Period Covered Contractor Report
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D. C. 20546	14. Sponsoring Agency Code FLS

15. Supplementary Notes

Point of Contact: Marc M. Cohen, Ames Research Center, MS 239-2
Moffett Field, CA 94035
(415) 694-5385 or FTS 464-5385

Final Report

16. Abstract

This study explores and analyzes architectural design approaches for the interior of the Space Station Habitability Module (originally defined as Habitability Module 1 in "Space Station Reference Configuration Description," JSC-19989, August 1984). In the Research Phase, architectural program and habitability design guidelines are specified. In the Schematic Design Phase, a range of alternative concepts are described and illustrated with drawings, scale-model photographs and design analysis evaluations. Recommendations are presented on the internal architectural configuration of the Space Station Habitability Module for such functions as the wardroom, galley, exercise facility, library and station control work station. The models show full design configurations for on-orbit performance.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Space Station, Human Productivity Wardroom, Galley, Exercise Facility, Architectural Design, Anthropometrics, Ergonomics	Unclassified - Unlimited Subject Category 54

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	102	A06

*For sale by the National Technical Information Service, Springfield, Virginia 22161

NASA-Langley, 1986