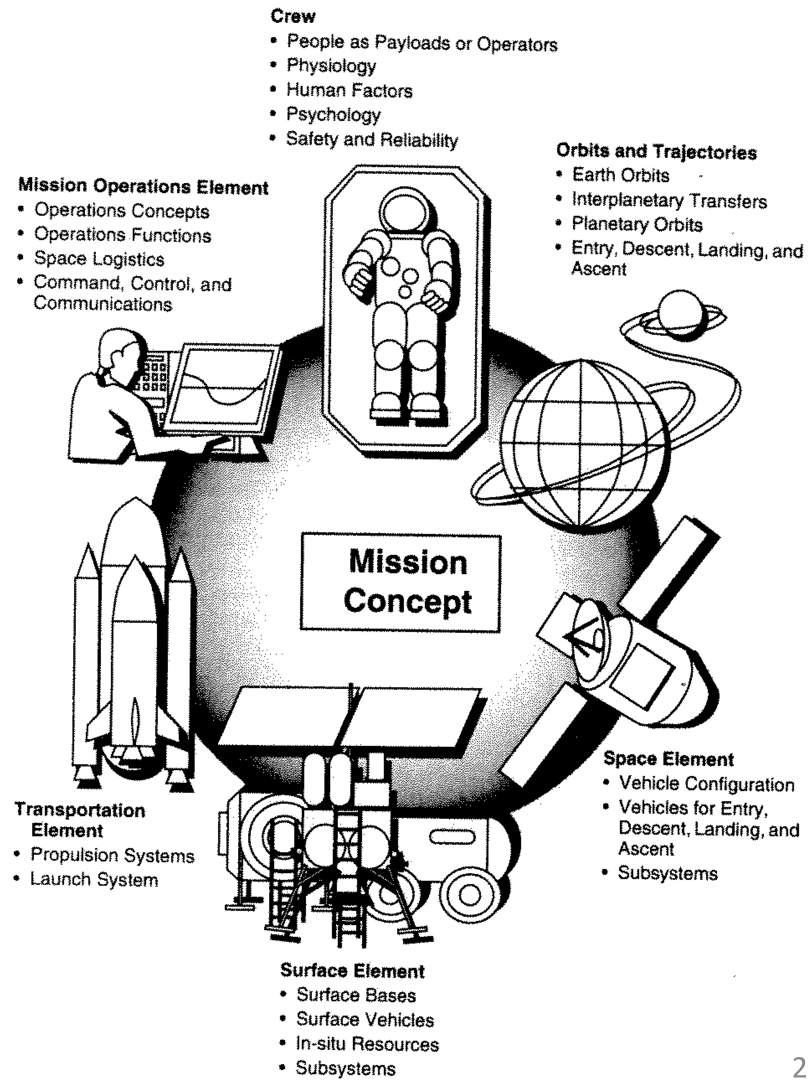
Design/Development of Spacecraft & Module Crew Compartments

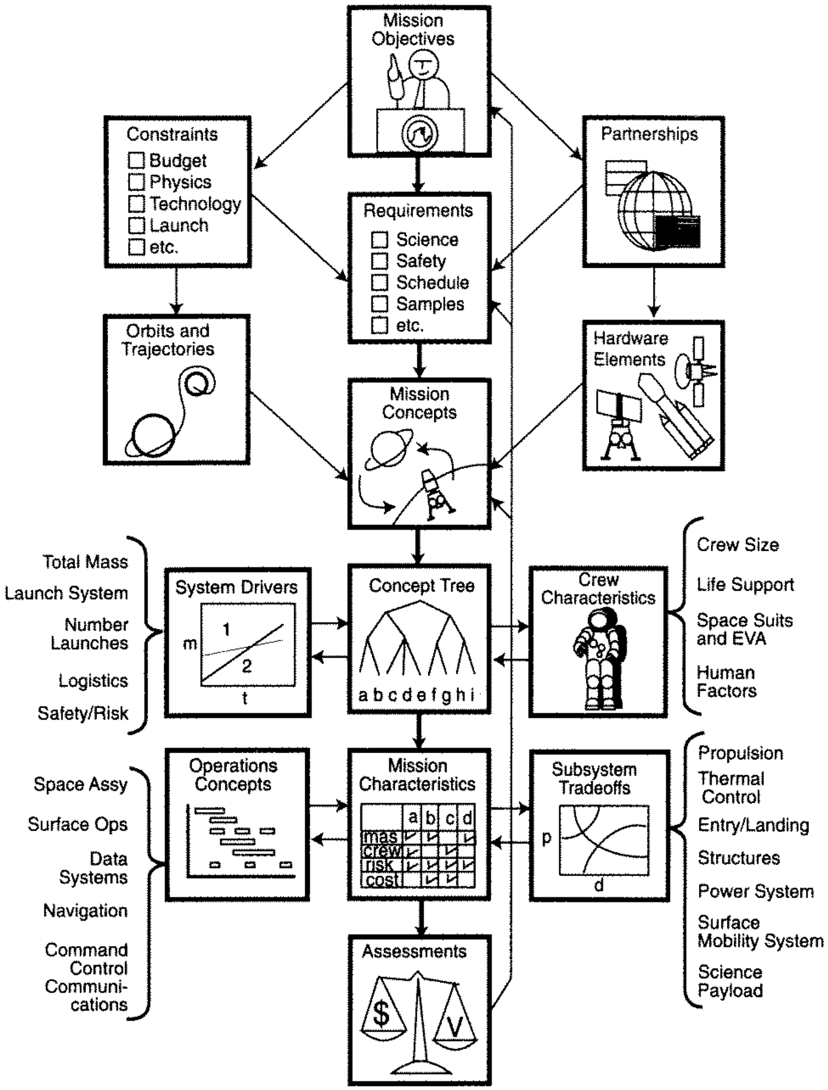
Jerry R. Goodman

Design/Development of Crew Compartments

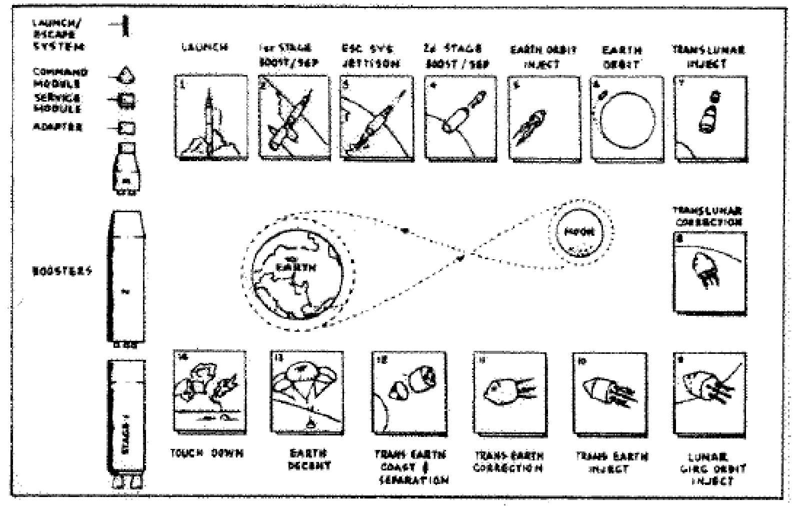
- Programs start with advanced studies of missions, including mission trade-offs & design options. Usually NASA has several study contracts with contractors



Beginning of Design/Development



Ref. 1



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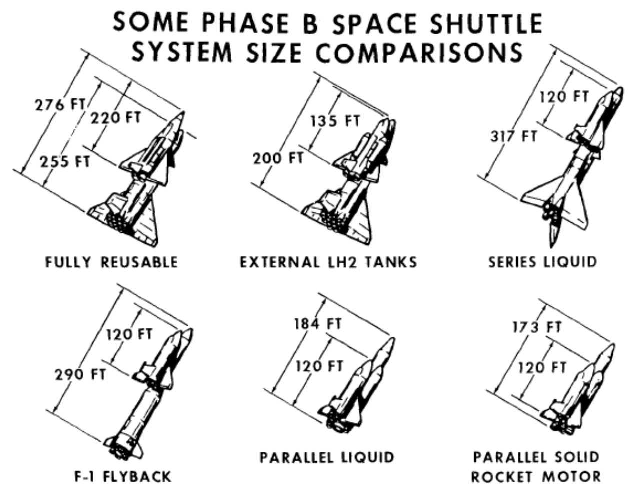


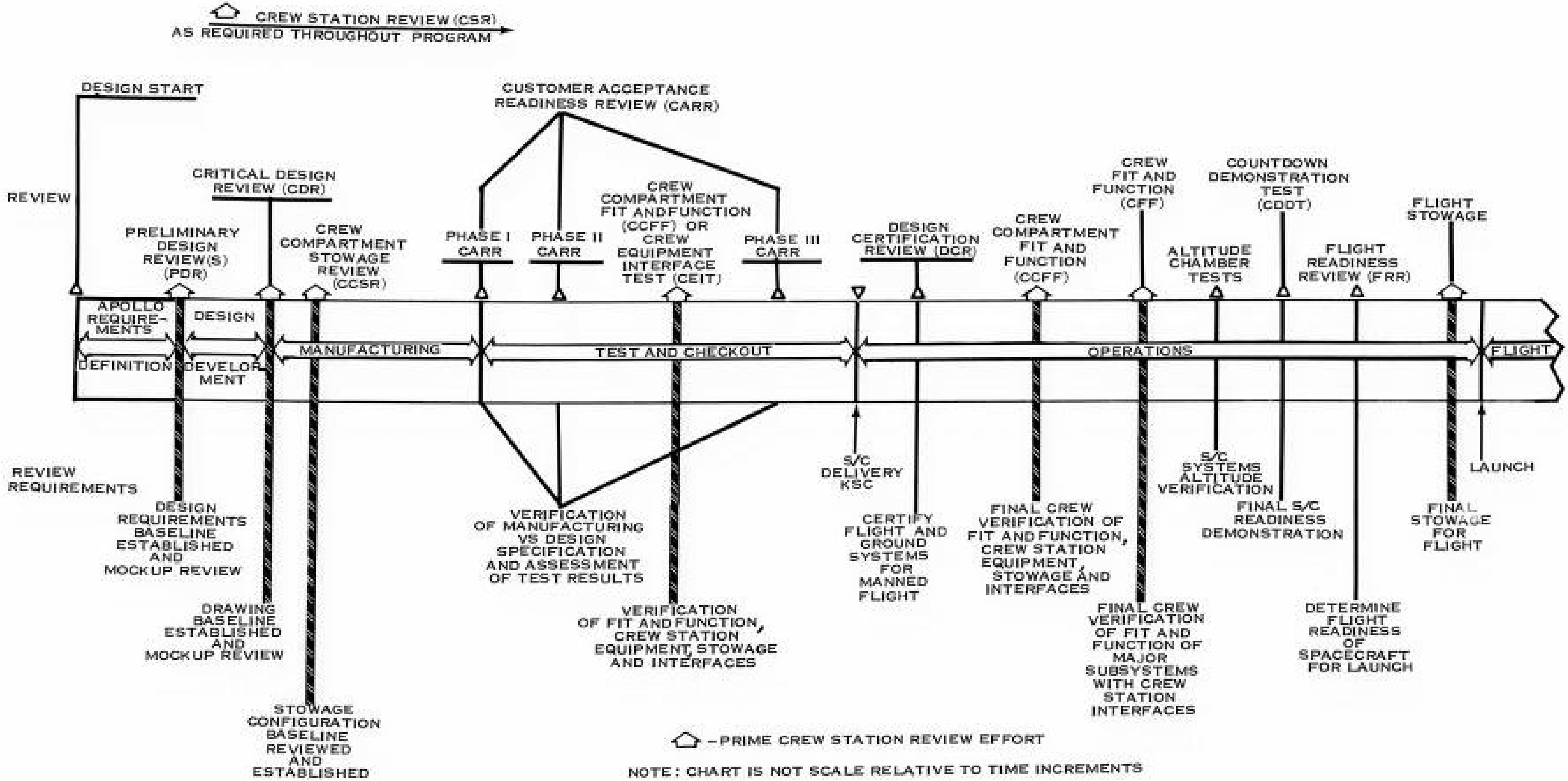
Ref. 3

Re References: 1)"Human Spaceflight-Mission Analysis & Design"; 2) "Human Factors Design Handbook", Woodson,Tillman & Tillman, and 3)"The Space shuttle Keys to Successful Program Management" , R.F. Thompson, Space Center Lecture Series 2010

NASA-S-71-2311-V

APOLLO TECHNICAL AND CREW STATION REVIEWS

Figure __



Samples, Human Factors Participation in Design (Ref.: SP-2010-3407*)

<table>
<tr><td rowspan="5">Preliminary Design</td><td rowspan="5">• Defined mission with performance requirements
• Preliminary exterior boundaries
• Identification of basic items and areas that the crew inter-faces with</td><td rowspan="5">• Gross task definition and analyses (usability studies of components, prototypes, and mockups)
• Human modeling</td><td>• Crew duties</td><td></td><td rowspan="5">• Design engineering
• Systems engineering
• Mission planning
• Training
• Health</td></tr>
<tr><td>• Selection and preliminary design of equipment that interfaces with crew (focus on operability and simplicity)</td><td>• Chapter 4, Anthropometrics, Biomechanics, and Strength
• Chapter 9, Hardware and Equipment
• Chapter 7, Habitability Functions
• Chapter 10, User Interfaces</td></tr>
<tr><td>• Habitable volume requirements and overall architectural layout</td><td>• Chapter 8, Architecture
• Chapter 7, Habitability Functions</td></tr>
<tr><td>• Detailed environmental support range requirements</td><td>• Chapter 6, Natural and Induced Environments
• Chapter 11, EVA</td></tr>
<tr><td>• Final verification test plans</td><td></td></tr>
</table>

*More for later development & operations in Human Integration Design Handbook SP-2010-3407

Significant Design Drivers for Crew Compartments

- **Mission Requirements/scenarios/duration**
- **Orientation of crew to accommodate the range of acceleration and deceleration environments (physiological tolerance reasons)**
- **Constraints on vehicle size, mass, volume , and shapes**
- **Crew Size (number of crew & percentile crewman to be accommodated)**
- **Systems & hardware required for mission**
- **Useable crew compartment volume (Net Habitable Volume), & shape of volume**
- **Rest/sleep accommodations/personal space/recreation**
- **Degree of separation of work & rest/sleep accommodations**
- **Size & locations of controls & displays required**
- **Exercise provisions & locations**
- **Design of crew compartment for flight & ground operations**
- **Habitability factors**
- **Lighting illumination & quality, location of lights, shadowing effects**
- **Ingress/Egress, passageway, & access requirements**
- **Oxygen enriched atmosphere & materials flammability & out gassing**

Significant Design Drivers for Crew Compartments (Continued)

- **Crew restraint/couch, fold ability/ removable, what functions couch has to perform w & w/o suit, load relief on crew, and stroking envelope/G level requirements**
- **Crew reach, visibility/ docking aids/windows size & location, mobility, induced loads, & large number of operations needed to be performed. Effect of suited operations on these items**
- **Stowage for operations, support, survival, etc.**
  - **a) Large number of items stowed (always a concern)**
  - **b) Effect of limited size of module and landing g's**
  - **c) Stroking envelope of crew couches**
  - **d) G-level stowage has to support**
  - **e) Stowage location vs. accessibility vs. need**
  - **f) Effects of mission & mission timeline on stowage**
- **Suited Operations**
  - **a) Pressurized, suited ops return**
  - **b) Inside vehicle, including pressurized suited ops & transfer**
  - **c) EVA**

Comments on Crew Compartment Design

- Loftus* indicates:

1. Relative to the crew-to-spacecraft interface that "The design objective has been to optimize of the achievement of programme objectives, not the configuration of the crew compartment, the displays & controls, or the other interfaces through which the crew affects spacecraft activities"
2. the "characteristics of manned spacecraft have been derived almost completely from the traditions of aircraft"

* From: "An Historical Overview of NASA Manned Spacecraft and Their Crew Stations", Loftus, J. P. ,Journal of the British Interplanetary Society, 1985

Table 6. FACTORS IN GENERAL AND SPECIFIC EQUIPMENT AND CREW COMPARTMENT LAYOUT

1. Mission Related:

- Mission requirements/goals
- Abort requirements
- Contingency requirements
- Mission duration
- Operational requirements/tasks
- Scientific requirements/tasks
- Operations/task criticality and priority
- Operational sequences/timeline integration
- Resupply provisions
- Offloading capabilities
- General Environments, imposed controlled:
  - Structural loads
  - Gravity loads
  - Vibration
  - Temperature
  - Noise
  - Illumination
  - Humidity
  - Ventilation

2. Crew Affected:

- Crew quantity
- Crew command structure/division of responsibility
- Size/anthropometry of crew
- Work-duty/rest cycles
- General communication
  - Crew-to-crew
  - Air-to-ground
- Control/operation manning requirements
  - Information monitoring, visual and auditory
  - Physical movements required
  - Communications, visual or auditory

3. Shirtsleeves and Suited Modes:

- Shirtsleeves
- Partially suited (helmets/gloves off)
- Fully suited, ventilated
- Suited, pressurized
- Suit and suit support equipment donn-doff volume
- Equipment interfaces for suited operations
- EVA requirements of related support equipment

4. Intravehicular Activity, Mobility, Visibility, and Accessability Requirements:

- Shirtsleeves/suited modes
- Detailed task requirements
- Working volume/room required--with and without free orientation
- Visual accessability--with and without free orientation
- Support information or communication
- Translation/restraint aids
- Illumination available

5. Ingress/Egress and Cargo Transfer Requirements and Hardware:

- Requirements:
  - On-the-pad ingress and egress
  - Landing egress
- Crew and/or equipment transfer between S/C--IVA or EVA
- Specific EVA in-flight
- Hardware:
  - Hatches
  - Tunnels
  - Passageways
  - Transfer devices/remote handing
  - Cargo transferred
  - Transfer aids/restraints
  - Lighting

6. S/C Areas by Functional Unit Breakdown:

- Stowage area for equipment, expendables, etc.
- Systems and subsystem installation
- Work/duty station, vehicle management, hardware or subsystems operation
- Rest/leisure
- Recreation
- Exercise
- Sleep station
- S/C records and data management
- Personal area
- Water and food preparation
- Dining area
- Waste management area
- Personal hygiene accommodations
- Donning/doffing stations
- Equipment checkout/repair/maintenance area

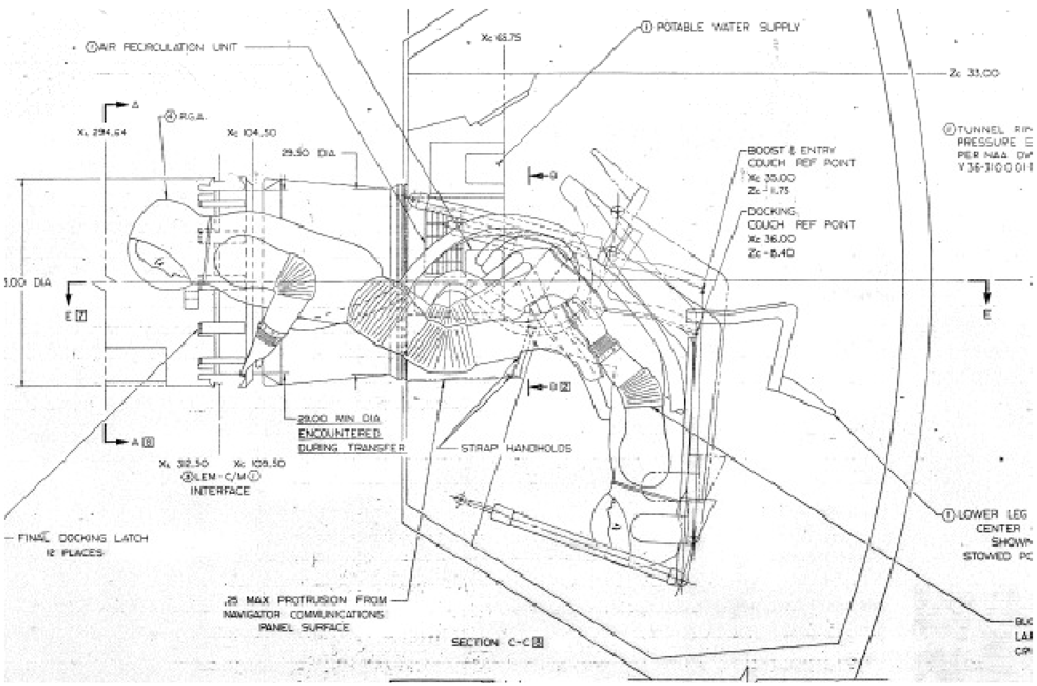
7. Equipment/Equipment Layout:

- Overall spacecraft configuration constraints
- Command controls and displays
- Spacecraft subsystem equipment, controls, wiring, etc.
- Crew compartment closeout provisions
- Emergency equipment/controls
- Stowed and installed crew equipment and support provisions:
  - Crew apparel/suits
  - Food, water, and life support expendables
  - Pilot operational equipment
  - Crew equipment
  - Operational and support equipment
  - Hygienical and waste management provisions
  - Docking hardware
- Temporary stowage configurations
- Stowage configuration at various mission phases
- Couches and seating provisions:
  - Couch/seat articulation envelope
  - Couch stroking envelope (landing)
  - Couch/seat stowage
- Maintenance/sparing equipment
- Flammability and materials control
- Worktables

From: "Crew Station Aspects of Manned Spacecraft", NASA/TP-2006-213725, 2006

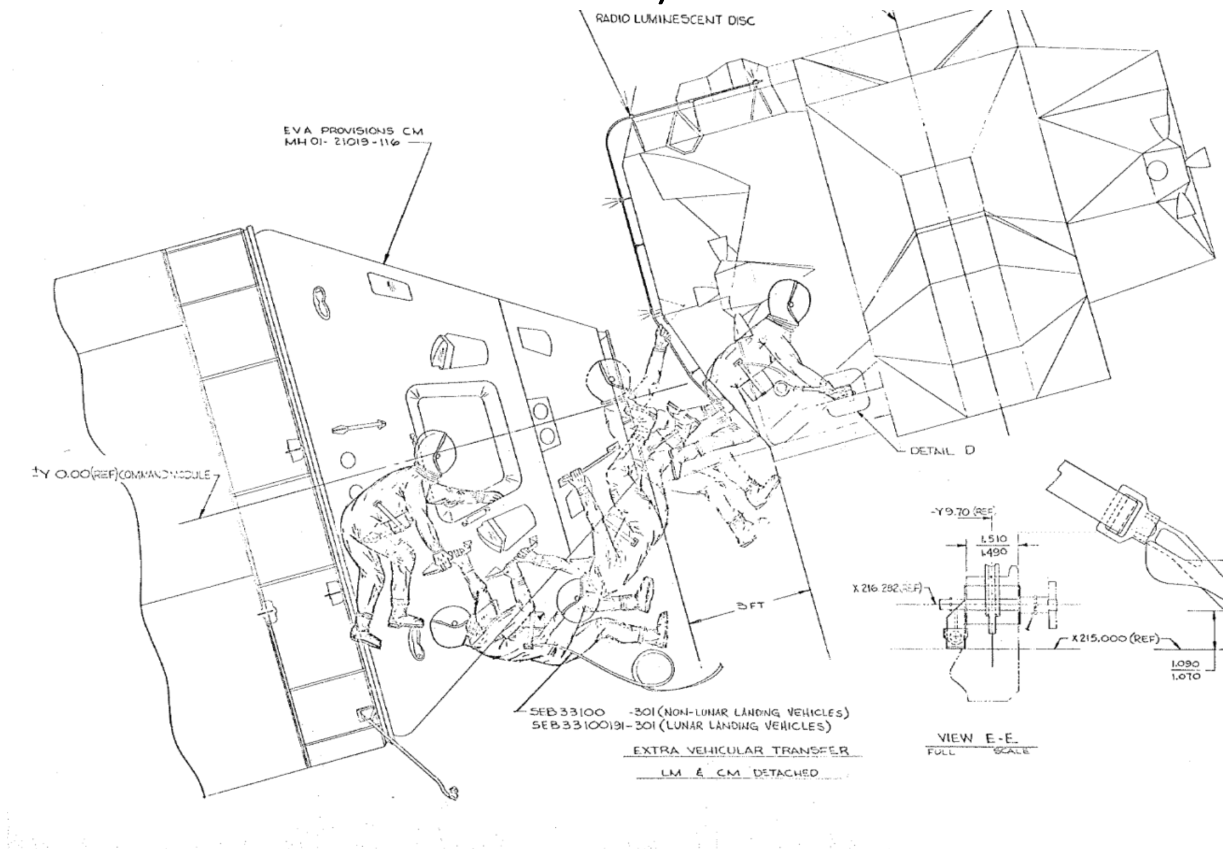
Examples of Mission Assumptions That Drive Design-IVA Transfer

(Good Example of mission driven requirement-tunnel sizing & suited ops for docking mechanisms)



Examples of Mission Assumptions That Drive Design

- Apollo Lunar Module to Command Module in Undocked Case (Good example of mission driven requirement on Command Module circular handrail)



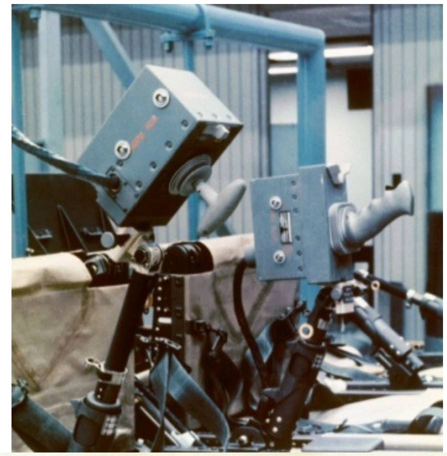
Examples of Problematic Design Assumptions in "Sizing" Crew Compartments

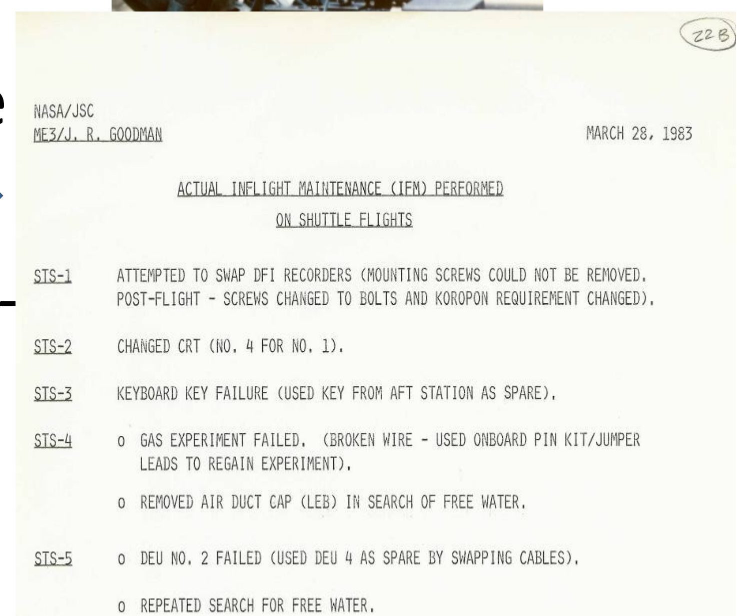
- Lunar Module hatch sized based upon early suit, not good representative PLSS & thermal/meteorite garment

- Apollo Crew Module size & seat spacing vs. Lunar suit design. (Shuttle & Cx faced similar issue-module designed before suits)

Examples of Problematic Design Assumptions in "Sizing" Crew Compartments (Continued)

- Anthropometric requirements for Apollo crews vs. actual crew measurements (example: crew couch armrest adjustment)
- Assumption of "no in-flight maintenance" for Space Shuttle Orbiter (see related chart)
- Assumption no payloads in mid-deck: later traded stowage lockers & attachments for payload installations





NASA/JSC
ME3/J. R. GOODMAN

MARCH 28, 1983

ACTUAL INFLIGHT MAINTENANCE (IFM) PERFORMED
ON SHUTTLE FLIGHTS

STS-1 ATTEMPTED TO SWAP DFI RECORDERS (MOUNTING SCREWS COULD NOT BE REMOVED. POST-FLIGHT - SCREWS CHANGED TO BOLTS AND KOROPON REQUIREMENT CHANGED).

STS-2 CHANGED CRT (NO. 4 FOR NO. 1).

STS-3 KEYBOARD KEY FAILURE (USED KEY FROM AFT STATION AS SPARE).

STS-4
- o GAS EXPERIMENT FAILED. (BROKEN WIRE - USED ONBOARD PIN KIT/JUMPER LEADS TO REGAIN EXPERIMENT).
- o REMOVED AIR DUCT CAP (LEB) IN SEARCH OF FREE WATER.

STS-5
- o DEU NO. 2 FAILED (USED DEU 4 AS SPARE BY SWAPPING CABLES).
- o REPEATED SEARCH FOR FREE WATER.

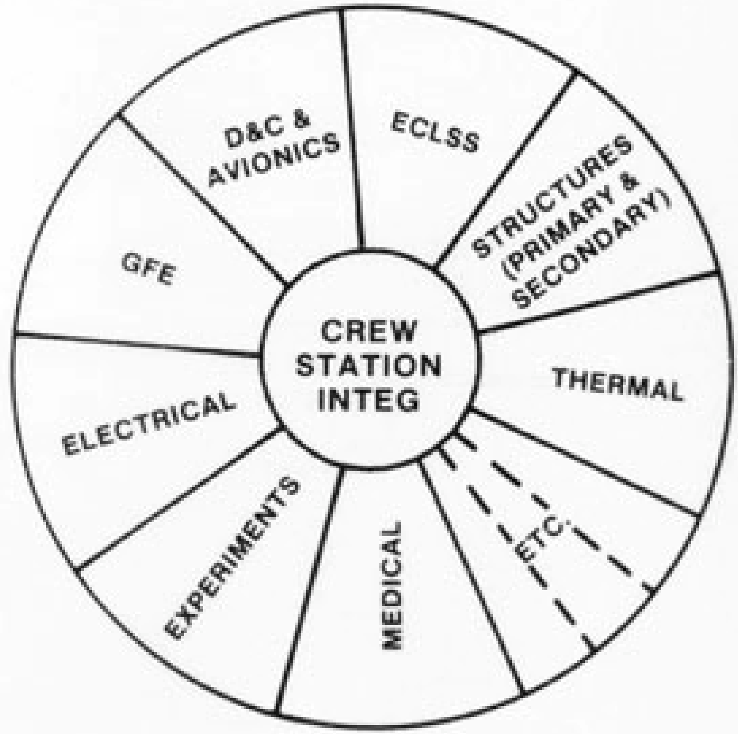
Crew Compartment or Crew Station

- The Crew Compartment or Crew Station is defined as the spacecraft interior and all other areas the crewman interfaces inside the cabin, or may potentially interface.
- It includes the hardware which a crewman uses, operates, monitors, or which is required to support or sustain his activities

CREW STATION INTEGRATION SCOPE

CREW STATION INTEGRATION INVOLVES:

- SYSTEMS INTEGRATION OF MISCELLANEOUS SUBSYSTEMS
- CREW STATION
- CREW PROVISIONS
- CREW EQUIPMENT
- RELATED GFE
- LIFE SUPPORT EQUIPMENT
- HABITABILITY
- CREW CABIN OR MODULE HARDWARE, LAYOUT, & CONFIGURATION
- RELATED SECONDARY STRUCTURE i.e.;
  - CLOSEOUT PANELS
  - ACCESS DOORS/PANELS
  - CLOSEOUT CURTAINS



Habitability

Habitability from Merriam-Websters Third New International Dictionary, Unabridged

- Main Entry: **hab·it·able** Pronunciation Guide
  Pronunciation: habd.bl, -btb-
  Function: *adjective*
  Etymology: Middle English *abitable,* from Old French *habitable, abitable,* from Latin *habitabilis,* from *habitare + -abilis* -able
  : capable of being inhabited : that may be inhabited or dwelt in <the *habitable* world>; *specifically of a dwelling* **: reasonably fit for occupation by a tenant of the class for which it was let or of the class ordinarily occupying such a dwelling**
  \- **hab·it·able·ness** *noun* **-es**
  \- **hab·it·ably** \\-bl, -li\\ *adverb*

Habitability

- Considered to be involved with necessities, quality of life, & crew comfort, or reasonably fit for occupation and capable of being in inhabited
- Elements of habitability are*:

  - **environment**
  - **crew compartment architecture & habitable volume**
  - **mobility & passageways/visibility**
  - **work**
  - **rest/relaxation/sleep**
  - **food & water/drinks**
  - **personal hygiene**
  - **housekeeping**

Ref.: "Habitability Design for Spacecraft", Franklin, G. 1978

Tools used in Crew Station Design/Development

- Crew Station Reviews from start of development through operations
- **Mockups & trainers have been a key asset in Apollo & Shuttle Orbiter design, development, and training for flight and resolving problems with design prior to flight**
- Concept Mockups-usually foam-core or cardboard, wood, or sheet metal combinations
- Increased fidelity mockups to follow design status (they provide form, fit, & function)
- Bench check evaluations of hardware function & configurations
- Mockups are updated into hi-fi trainers. Mockups can be in one-G , WET-F (underwater), in aircraft parabola's to simulate g's, or in other forms
- Mockups & Simulators are used for vision, reach, & procedures (design development, & training)
- Computer Aided efforts will be discussed later session by Jim Maida-but, this **does not** replace the need for mockups!
- Iterative reviews **significantly** add to crew **familiarization & training**

Mockups & Others

Model

- To shape the fashion in a pliable material to give a 3D appearance to construction.
- Fashion in imitation of a particular mold to design or imitate forms

Mockup

- A structural model built accurately to scale (as out of plywood, cardboard, canvas, clay) chiefly for study, testing or display

Prototype

- An original on which a thing is modeled.
- Prototype aeroplane – the first full scale pilot flying model of a new type of airplane

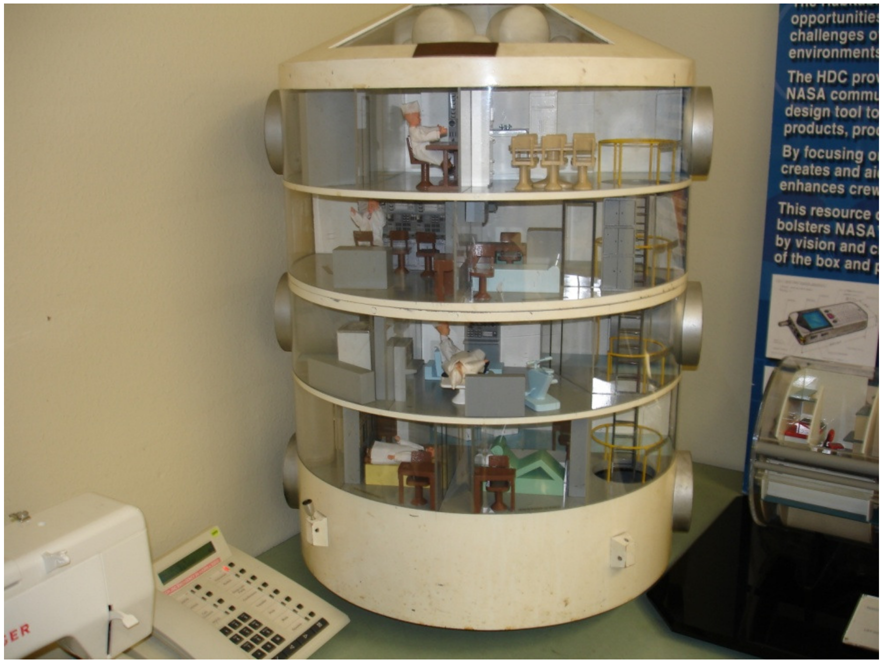
Trainer

- Mechanical device for training pilots that simulates x
- Any of numerous machines or devices used in various forms of training

Simulator

Models


image as an organization dr
willing to think outsid
boundaries.

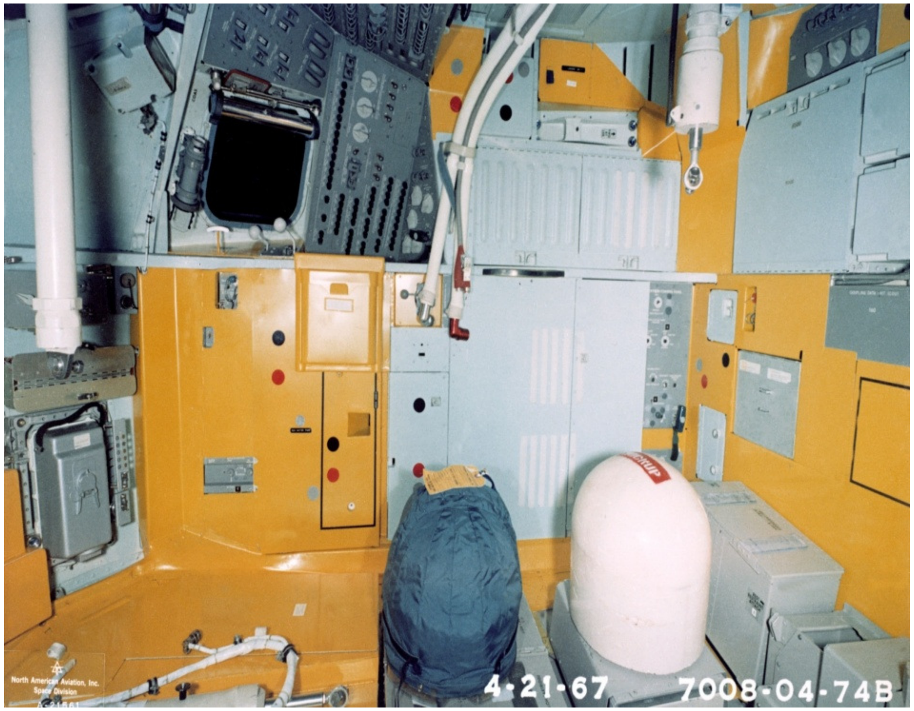

opportunities
challenges o
environments
The HDC prov
NASA commu
design tool to
products, proc
By focusing o
creates and ai
enhances crew
This resource
boisters NASA'
by vision and c
of the box and p

Apollo Mockups

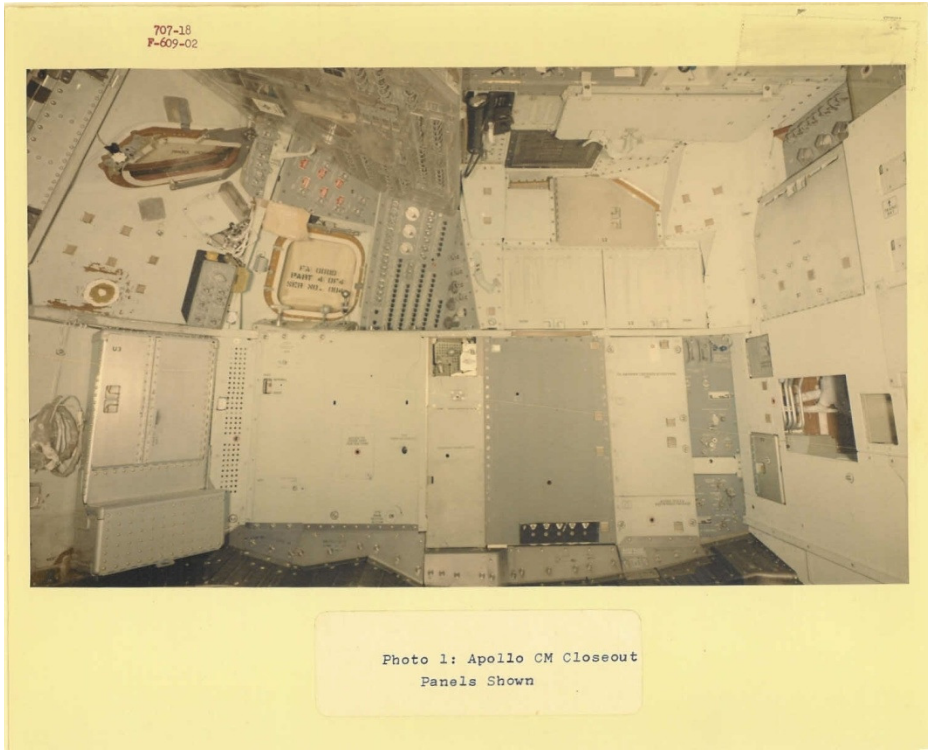
Apollo Bench Review

Apollo Mockups

- Lo-Fi Closeout Panels

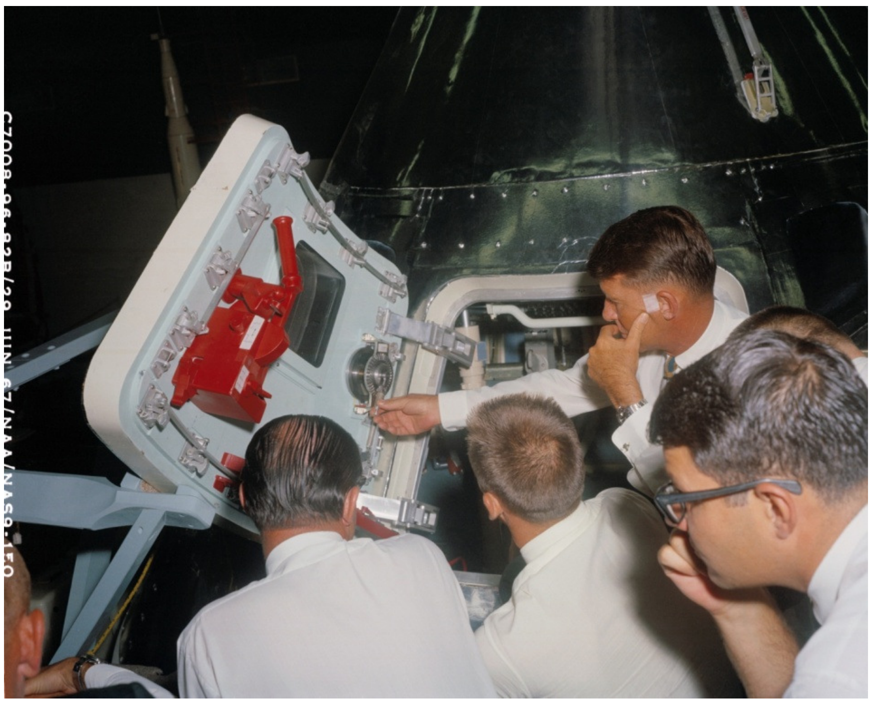


- Hi-Fi Closeout Panels

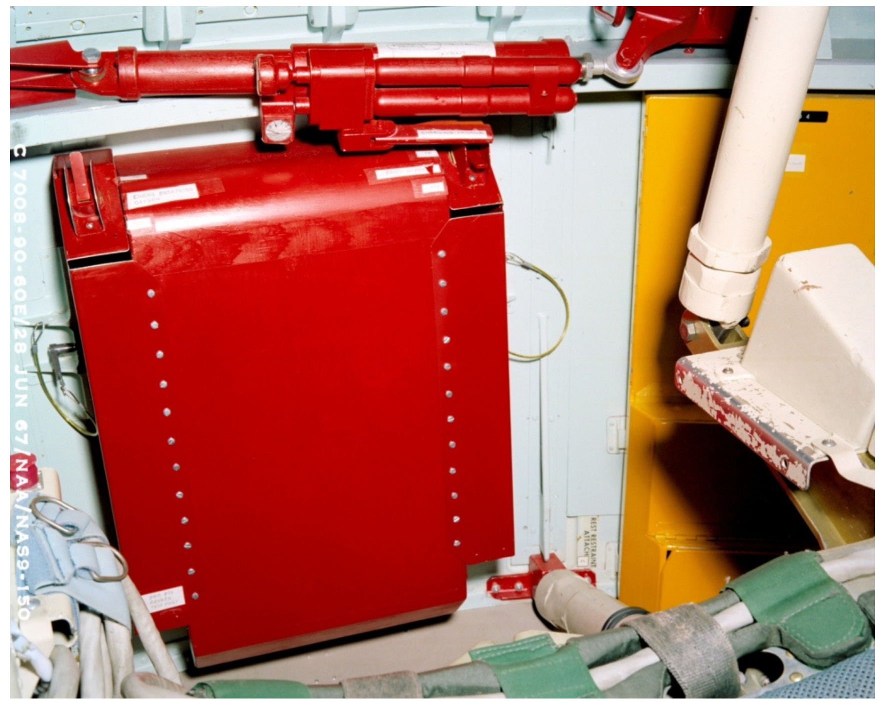


Apollo Mockup Post Apollo 1

- Side Hatch redesign

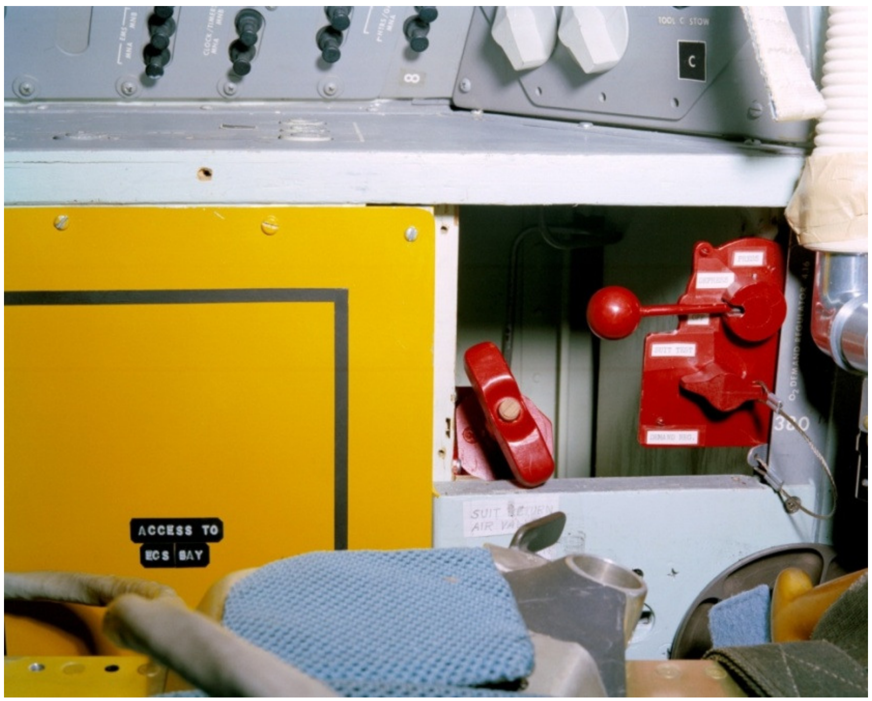


- Cabin Repress & Hatch Counterbalance



Apollo Mockups

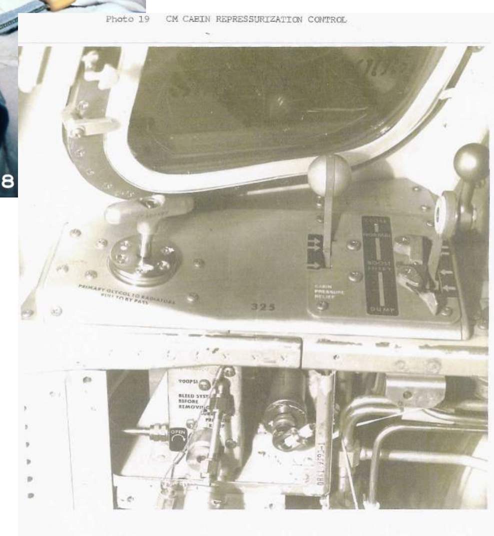
Lo-Fi Valve Location & Actuation



Hi-Fi Valve Location & Actuation

Can't reach valve

With Extension

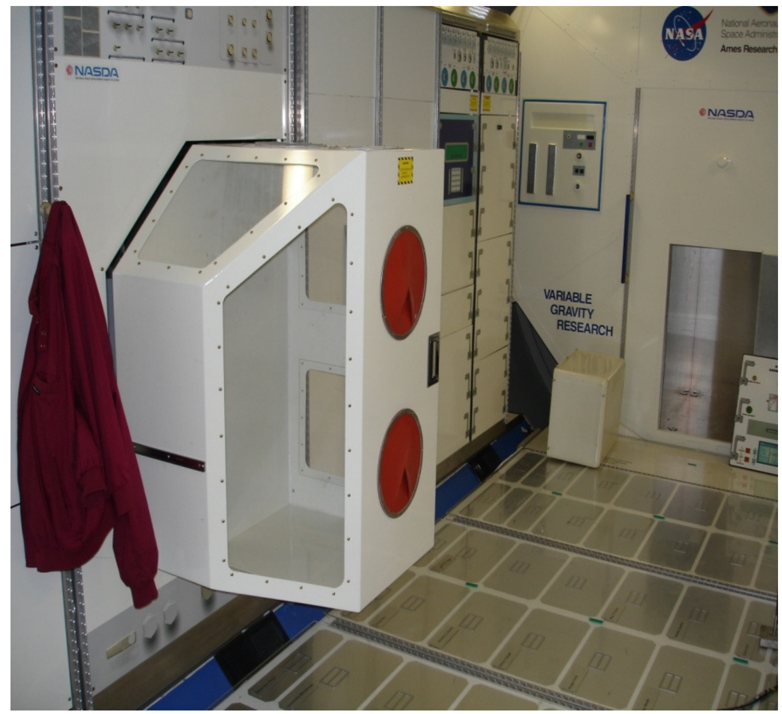


Space Shuttle Trainers

ISS Trainers & Mockups

- JSC ISS Mockups & Trainers

- Japanese CAM Mockup



Partial Mockups & Prototypes

Aft Flight Deck, Orbiter

Forward Bulkhead Orbiter EVA WET-F

ISS Muffler Prototype

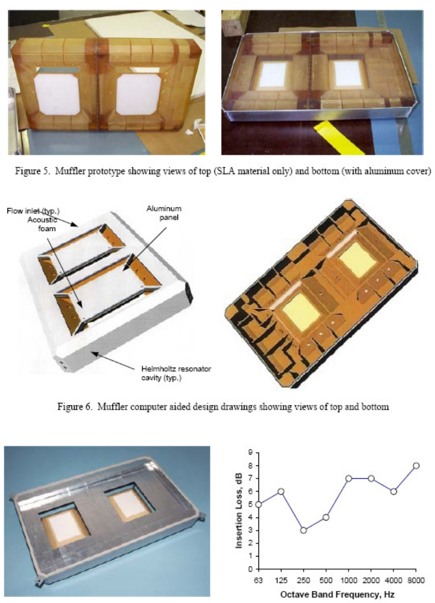


Figure 5. Muffler prototype showing views of top (SLA material only) and bottom (with aluminum cover)

Figure 6. Muffler computer aided design drawings showing views of top and bottom

Figure 7: Muffler prototype with bottom cover

Figure 8: Muffler broadband insertion loss

U.S. Muffler Prototype for ISS

Prototype TESS

Orion Mockup

More Partial Mockups & Prototypes

Orion Mockup with Foam-core

JG Russian Fan Muffler Concept

Sizing of Orbiter Crew Compartment

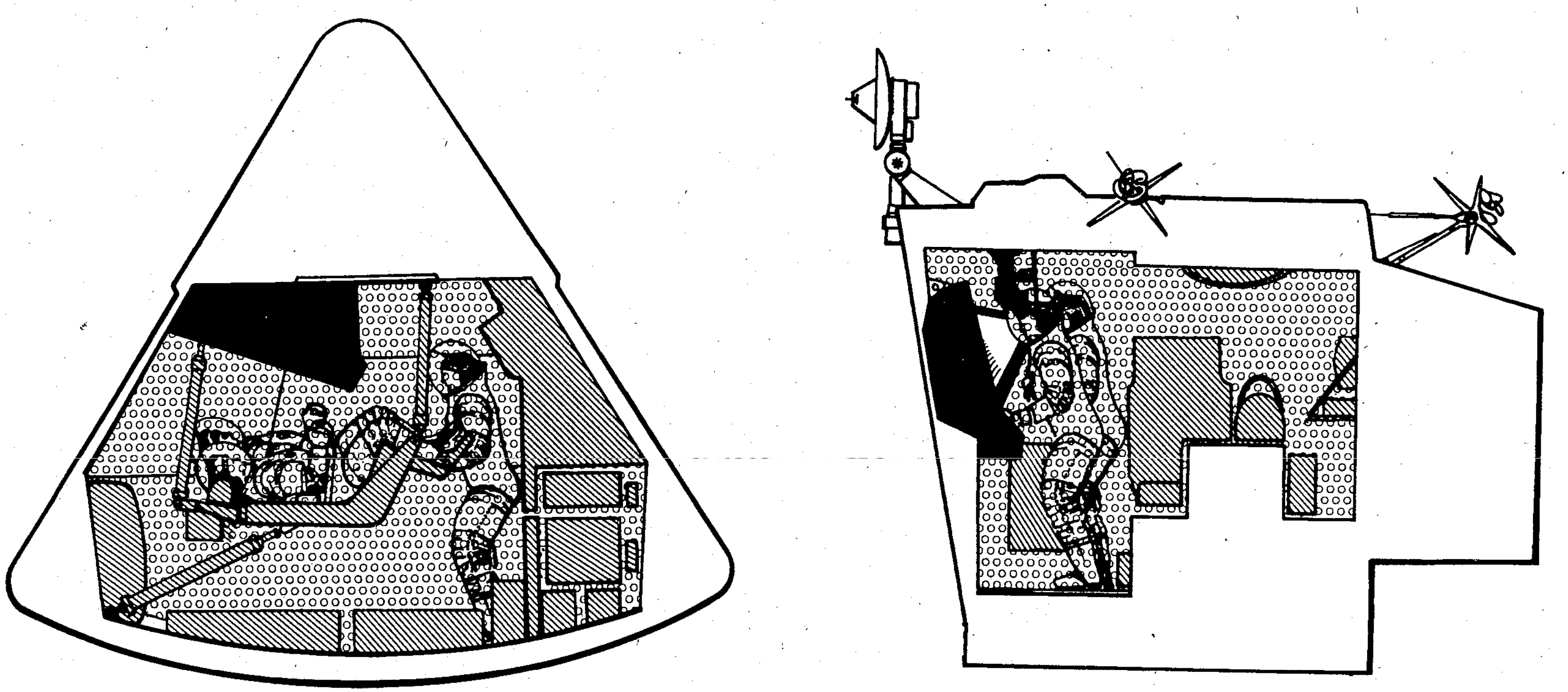
Cabin was designed to accommodate:

- A total crew of seven (three to operate the Orbiter & for up to four payload specialists)
- The Orbiter was provisioned for 28 man-days and up to 42 man-days with no systems change
- All crew systems (such as seats, etc.) for crew size > than four and all consumables for durations greater than 28 man-days, shall be provided in kit form and shall be charged to payload

NASA-S-71-2303-V

Figure 29

VEHICLE VOLUMES



COMMAND MODULE

TOTAL PRESSURIZED VOLUME	-	306 FT^3
CREW, HARDWARE, AND PRESSURIZEABLE VOLUME BEHIND PANELS, ETC.	-	156 FT^3
EFFECTIVE FREE VOLUME	-	210 FT^3

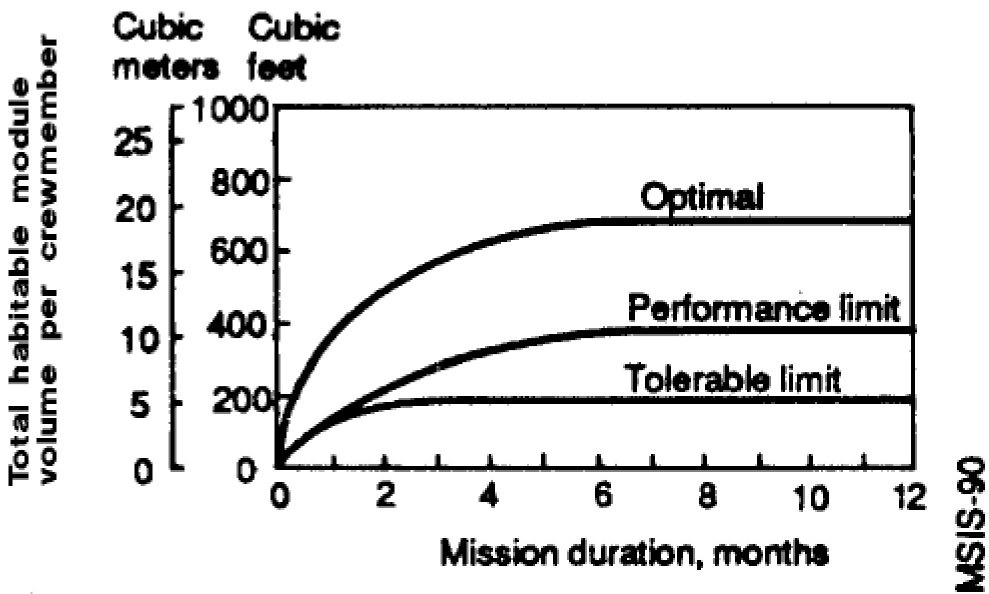
Modified from: J. P. Loftus and R. L. Bond, "Crew Tasks and Training," Lunar Landing Symposium (Houston, Texas: NASA-MSC, 1966).

LUNAR MODULE

TOTAL PRESSURIZED VOLUME	-	195 FT^3
CREW, HARDWARE, AND PRESSURIZEABLE VOLUME BEHIND PANELS, ETC.	-	45 FT^3*
EFFECTIVE FREE VOLUME	-	150 FT^3*

*ESTIMATE

Habitable Volume Requirement Per NASA- STD-3000



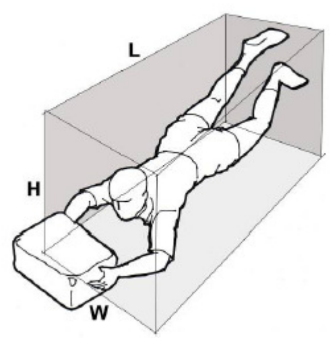
Reference: 78, page 2-39

Figure 8.6.2.1-1 Guideline for Determination of Total Habitable Volume per Person in the Space Module

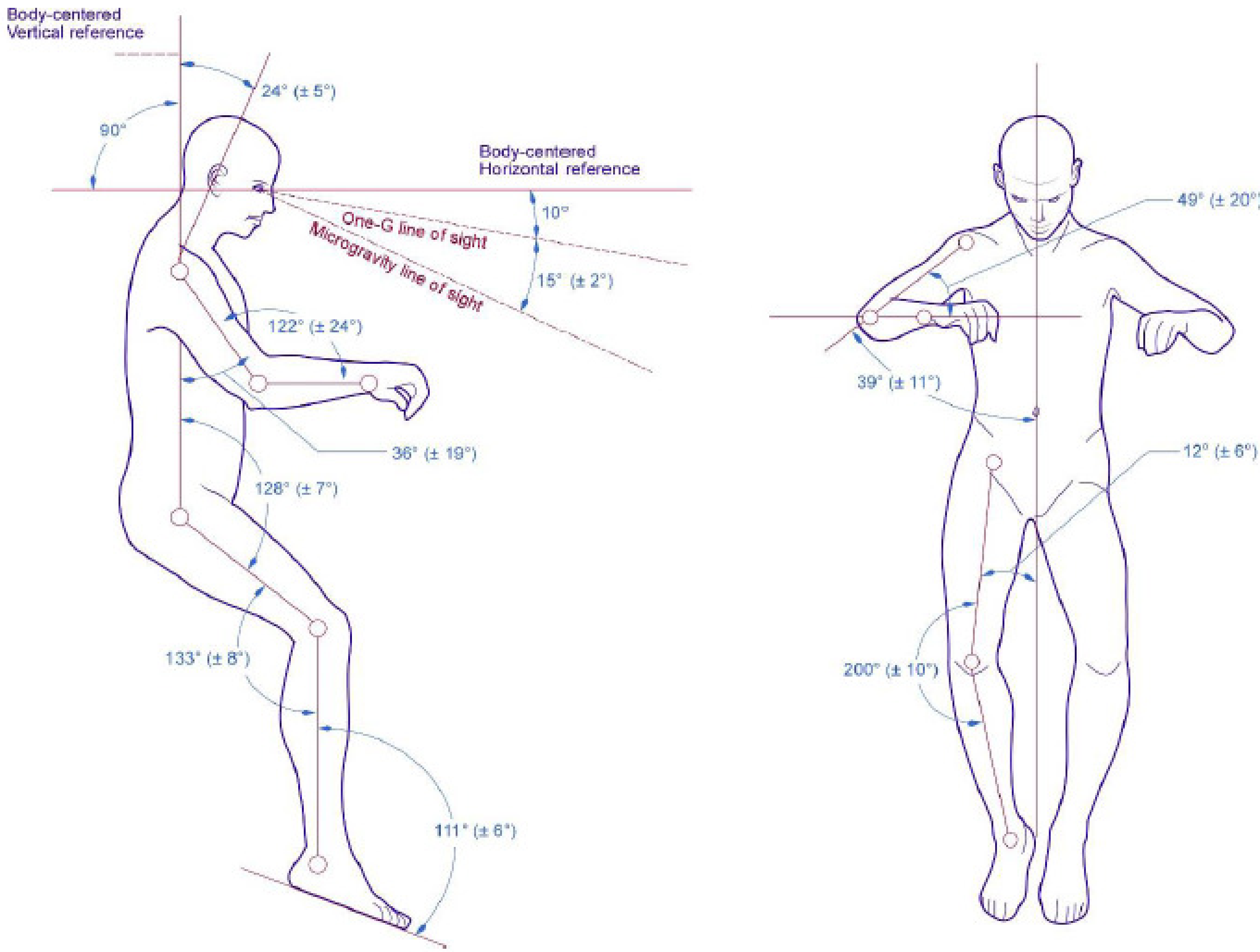
Shape of Habitable Volume

- **Note: It’s not only the volume that’s required, it’s the <u>shape</u> required to perform the operation**

- **4.3.3.1.1 Clearance (From: NASA Handbook)**
Sufficient room is necessary for all crewmembers (suited and unsuited) to fit through passageways and for unsuited crewmembers to safely and comfortably perform tasks in a workstation or activity center. It is important to note that the critical dimensions for body clearance in 0g will often differ from critical dimensions in a 1g environment. People do things differently in 0g, which may affect clearance.

Figures of Human Body Postures and Volumes	Applicable Functions	Dimensions (m)		Volume (m^3)
	Egress, translation, passageways	H	0.70	**2.55**
		L	2.96	
		W	1.23	

Neutral Body Posture, Ref. NASA Handbook, SP-2010-3407



Spacecraft Volumes

Table 2 Interior sizing of American spacecraft[3]

Characteristic	Mercury	Gemini	Apollo CM	Apollo LM	Skylab	Apollo-Soyuz	Shuttle Orbiter
Volume (habitable), m^3 (ft^3)	1.02 (36)	1.56 (55)	5.94 (210)	4.53 (160)	[a]5.94 (210)	[a]5.94 (210)	35 (1300)
Pressurized volume less volume of equipment, m^3 (ft^3)					[b]344.98 (12,190)	[c]3.1 (109)	
Duration (max.), days	1-1/2	13-3/4	12-1/2	3	84	9	7–30
Crew size	1	2	3	2	3/5	3	2–7

[a]Command module.
[b]Orbital workshop.
[c]Docking module.

From: "Design of Interior Areas", Perner C. & Langdoc,W. Chapter 7,Space Biology and Medicine1993

ISS Internal Volume by Stage								
Date	Flight/ Stage	Module/Element	Module/Element Pressurized Volume (ft^3)	Module/Element Habitable Volume (ft^3)	Total Station Pressurized Volume* (ft^3)	% Complete Pressurized Volume	Total Station Habitable Volume* (ft^3)	% Complete Habitable Volume
Nov-99	1A/R	FGB (Zarya)	2423	903	2423	7.56	903	7.15
Dec-98	2A	Node 1 (Unity)	2016	1030	4439	13.86	1933	15.31
		PMA-1	205	187	4644	14.50	2120	16.79
		PMA-2	185	157	4829	15.08	2277	18.03
		Z1 Dome	59	53	4888	15.26	2330	18.45
Apr-00	1R	SM (Zvezda)	3411	1339	8299	25.91	3669	29.06
Oct-00	3A	PMA-3	185	157	8484	26.49	3826	30.30
Feb-01	5A	USL (Destiny)	3938	1228	12422	38.78	5054	40.03
Jul-07	7A	Airlock (Quest)	1192	589	13614	42.50	5643	44.69
Aug-01	7A.1	TeSS	0	78	13614	42.50	5721	45.31
Sep-01	4R	DC1 (Pirs)	523	380	14137	44.13	6101	48.32
Oct-07	10A	Node 2 (Harmony)	2666	1230	16803	52.46	7331	58.06
Feb-08	1E	Columbus	2772	995	19575	61.11	8326	65.94
Mar-08	1J/A	JEM ELM-PS	1494	567	21069	65.77	8893	70.43
Jun-08	1J	JEM PM	4571	1723	25640	80.04	10616	84.07
Nov-08	ULF2	Crew Quarters x 2		156	25640	80.04	10772	85.31
Jul-09	17A	Crew Quarter		78	25640	80.04	10850	85.93
Aug-09	5R	MRM2	523	380	26163	81.68	11230	88.94
Oct-09	20A	Node 3	2666	1190	28829	90.00	12420	98.36
		Cupola	118		28947	90.37	12420	98.36
Jan-10	19A	Crew Quarter		78	28947	90.37	12498	98.98
Mar-10	ULF4	MRM1	614	207	29561	92.28	12627	100.00
Nov-11		DC1 (Removed)	-523	-380	28424	92.28	12118	100.00
Dec-11	3R	MLM**	2472		32033	100.00	12627	100.00
Visiting Vehicles								
		Soyuz	412					
		Progress	270					

* Visiting vehicles (Soyuz, Progress, ATV, and HTV) are not included in the Total Station volumes.

** Habitable volume data not avialable for MLM.

Visibility/Field-of-views/Windows/Alignment Marks

- Windows are used to provide field-of-views for: rendevous and docking alignment; work stations like Shuttle-Orbiter manipulator operations; for photographic operations; alignment & backup for landing(Apollo); viewing of landing sites (Lunar Module); & views for driving (Lunar rover).
- Windows also are a significant habitability bonus for long term operations(see adjacent chart)
- The "**design eye position**" is used in design layout of crew compartments to setup field-of-views to see outside of windows, window design, determine controls & displays locations; & seat support positions

Table 4 Recreation equipment used by 30 astronauts in order of preference[14]

Use of equipment in spacecraft	Importance
Viewing through windows	1
Physical exercise equipment	2.5
Tape recorder, record player	2.5
Books	4
Sports equipment	5
Radio	6
Newspapers	7
Magazines	8
Photographic equipment	9
Radio equipment for personal communication	10
Television	11
Writing equipment	12
Playing cards	13

From: "Design of Interior Areas",Perner C. & Langdoc, W. Chapter 7,Space Biology and Medicine1993

Apollo Rendezvous & Docking, Alignment, & Windows

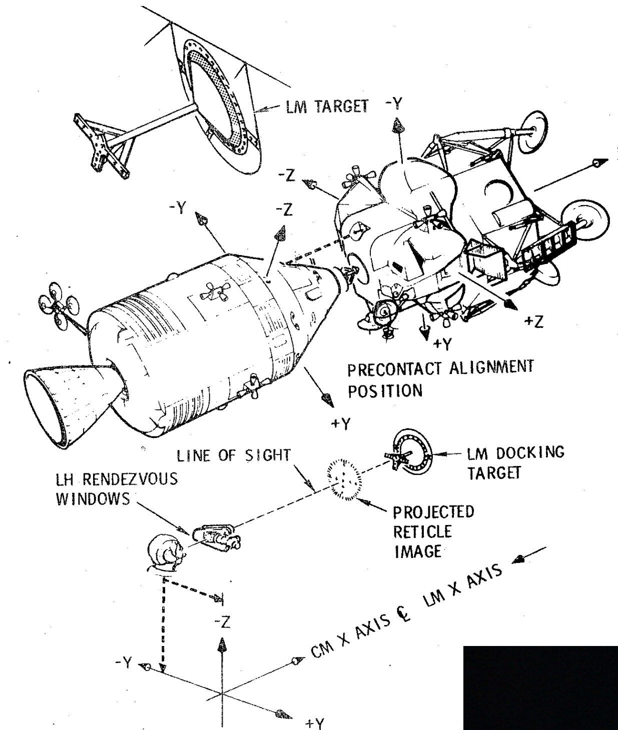
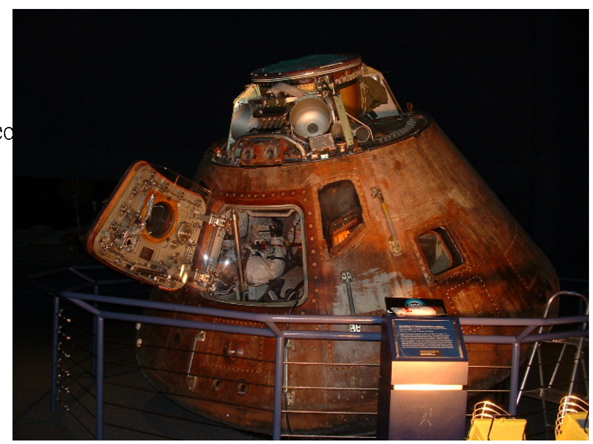
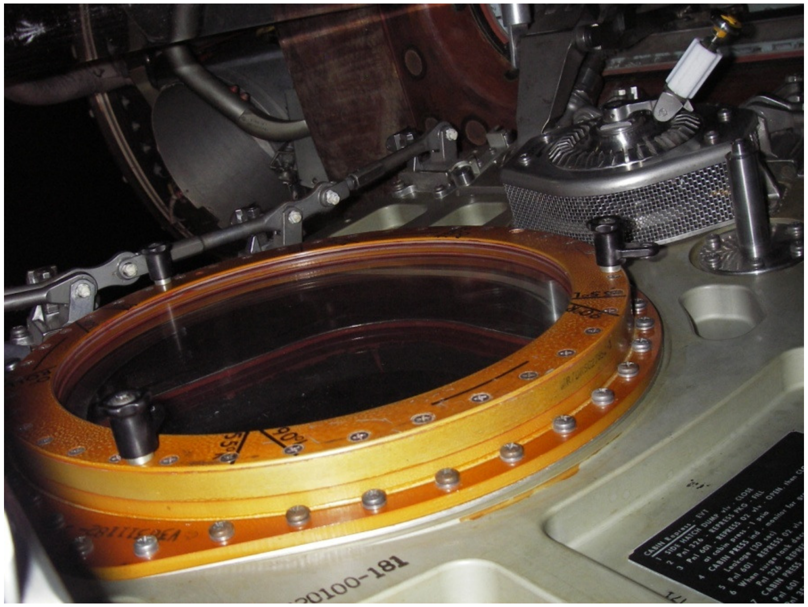


Figure 16.- Predock condition of the CO

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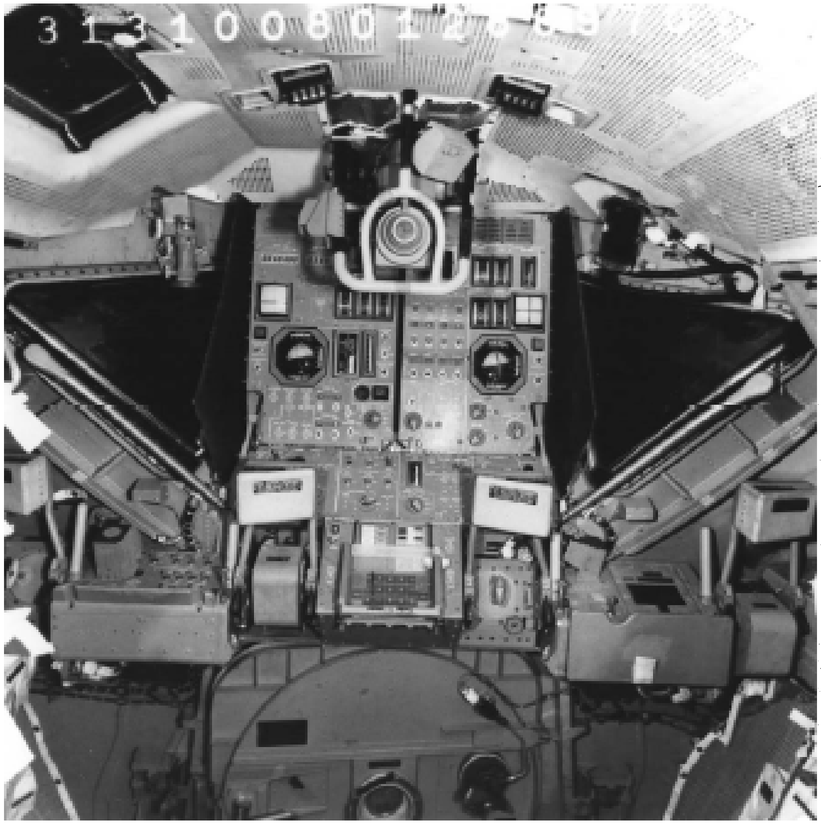
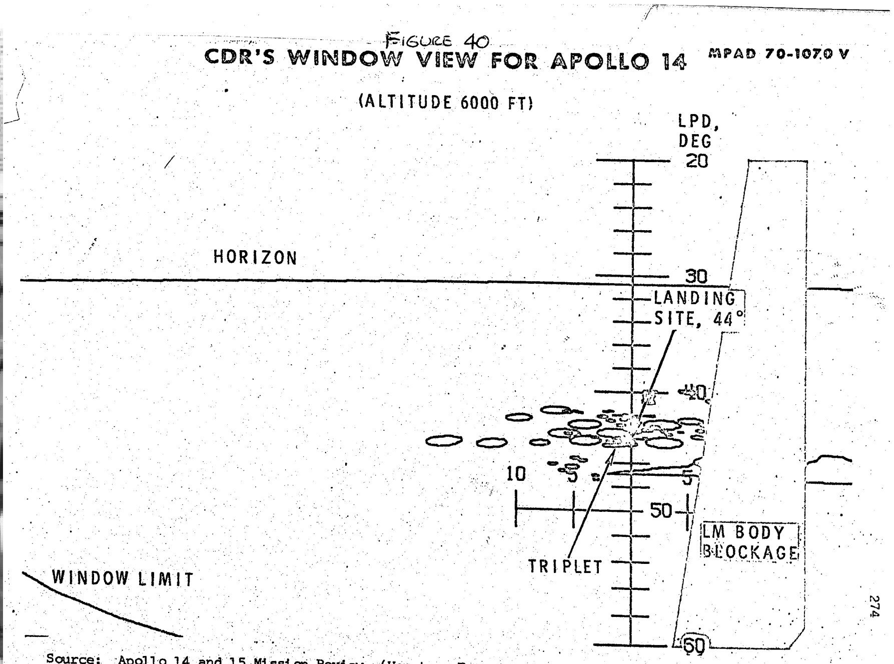
ED095034


EPS SENSOR SIGNAL
MN A
MN B
AC 1
AC 2
C/W
MN A

Lunar Module Windows/Field-of-view





Source: Apollo 14 and 15 Mission Review, (Houston, Texas: NASA-MSC, November 12, 1970).

Orbiter Design Eye Position

3.2.2.1.1.1.1 Design Eye Position. The initial step in determining the crew station geometry shall be to establish the primary design eye position for horizontal flight.

The design eye position is an arbitrary point on the crew station center line assigned to exist mid way between the eyes (external canthi) in the position to be assumed by the crew member under most flight conditions that will permit specified over-the-nose vision and at the same time unrestricted view of the instrument panel.

No specific single design eye position is required for ascent flight. However, seat and headrest adjustments must provide for unrestricted view of required displays and controls as well as for adequate reach to controls used during the ascent and powered abort modes.

From Requirements/Definition Document Crew Station & Equipment, SD72-SH-0107, Space Division, Rockwell International, February 20, 1976

Orbiter Window Fields-of-View

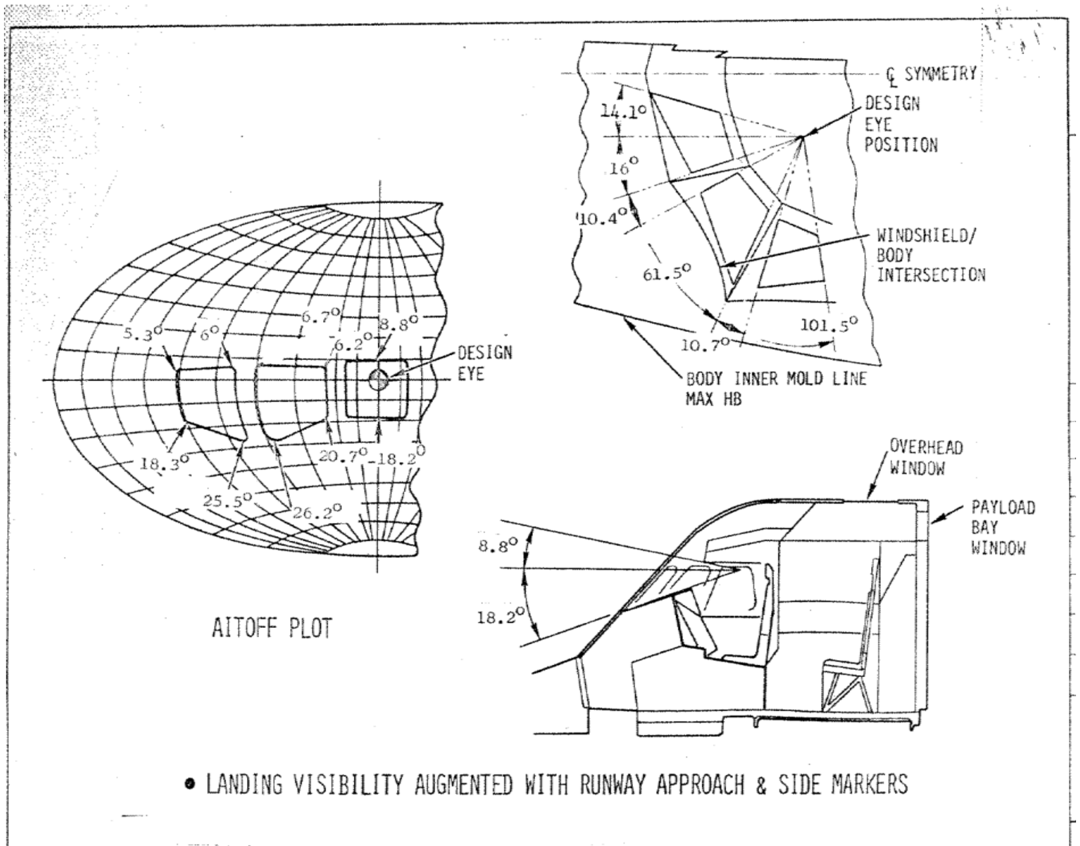
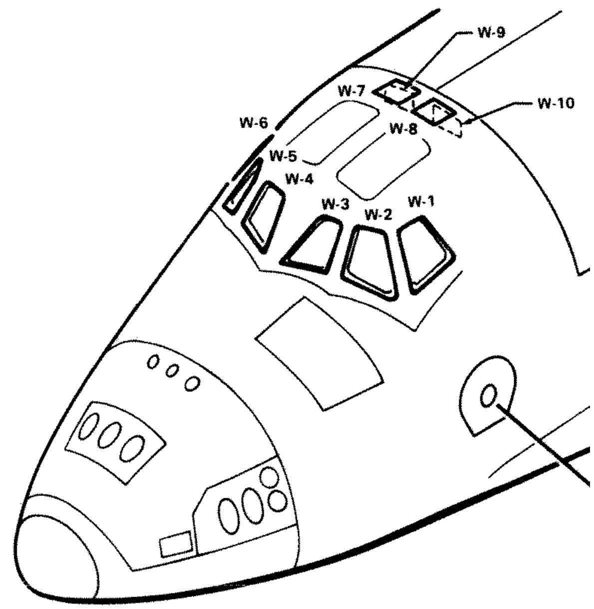


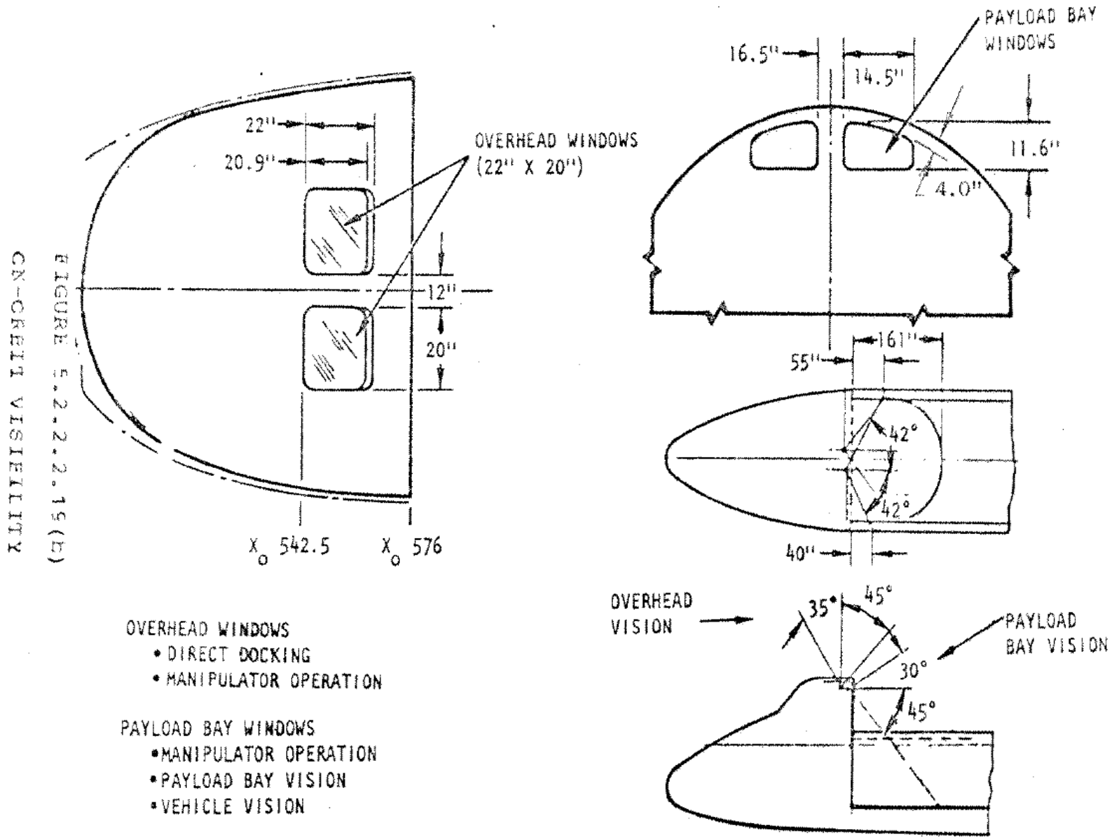
FIGURE 5.2.2.2.19 (c)

VISIBILITY LANDING

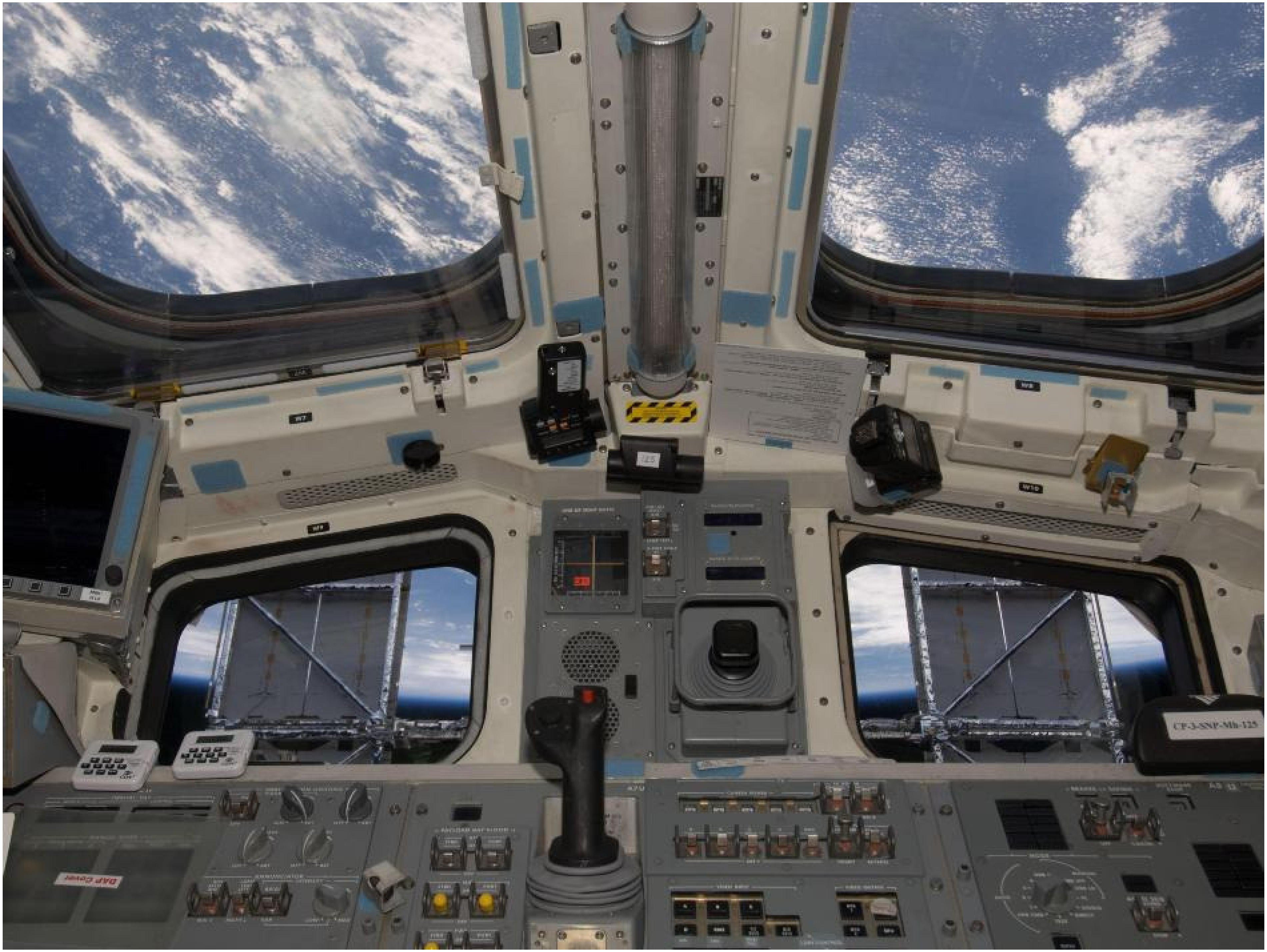


From Requirements/Definition Document Crew Station & Equipment, SD72-SH-0107, Space Division, Rockwell International, February 20, 1976

Orbiter Window Fields-of-View (cont.)



From Requirements/Definition Document Crew Station & Equipment, SD72-SH-0107, Space Division, Rockwell International, February 20, 1976



CP-3-SNP-Mh-125
DAP Cover

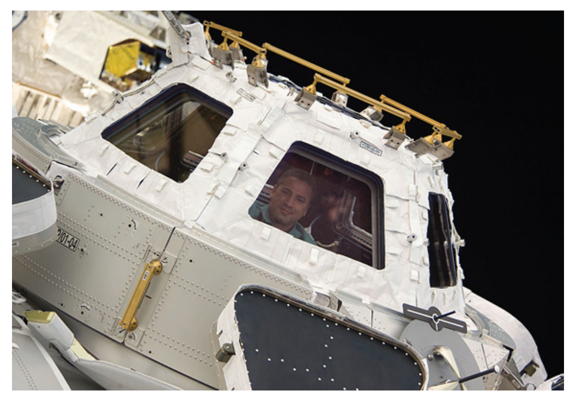

ORBIT STATION LIGHTING
CAMERA POWER
VIDEO INPUT
VIDEO OUTPUT
MODE
AUTO SEQ

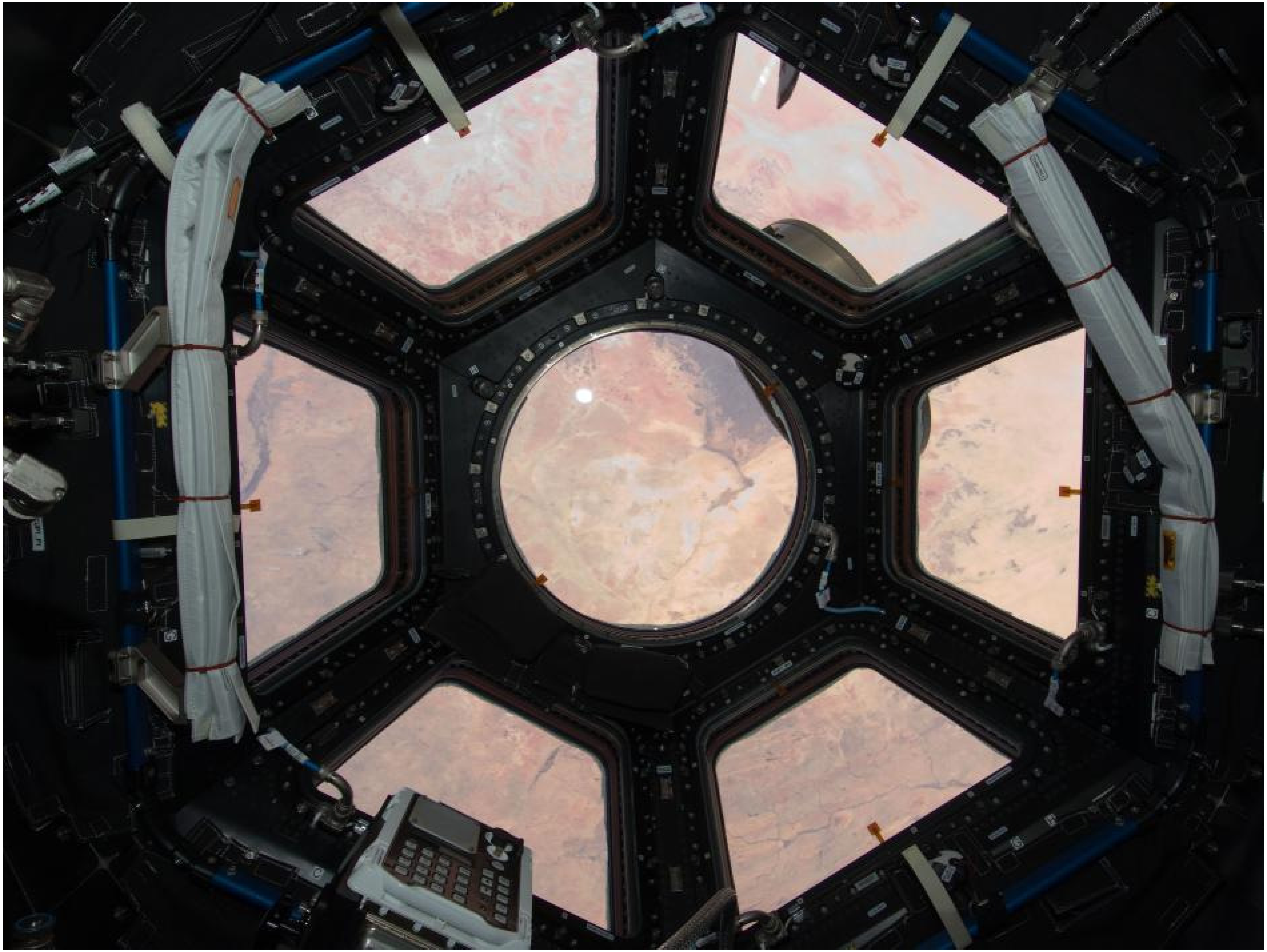
Our Windows on the Earth

US Laboratory Window
50-cm diameter
Telescope-quality
optical glass

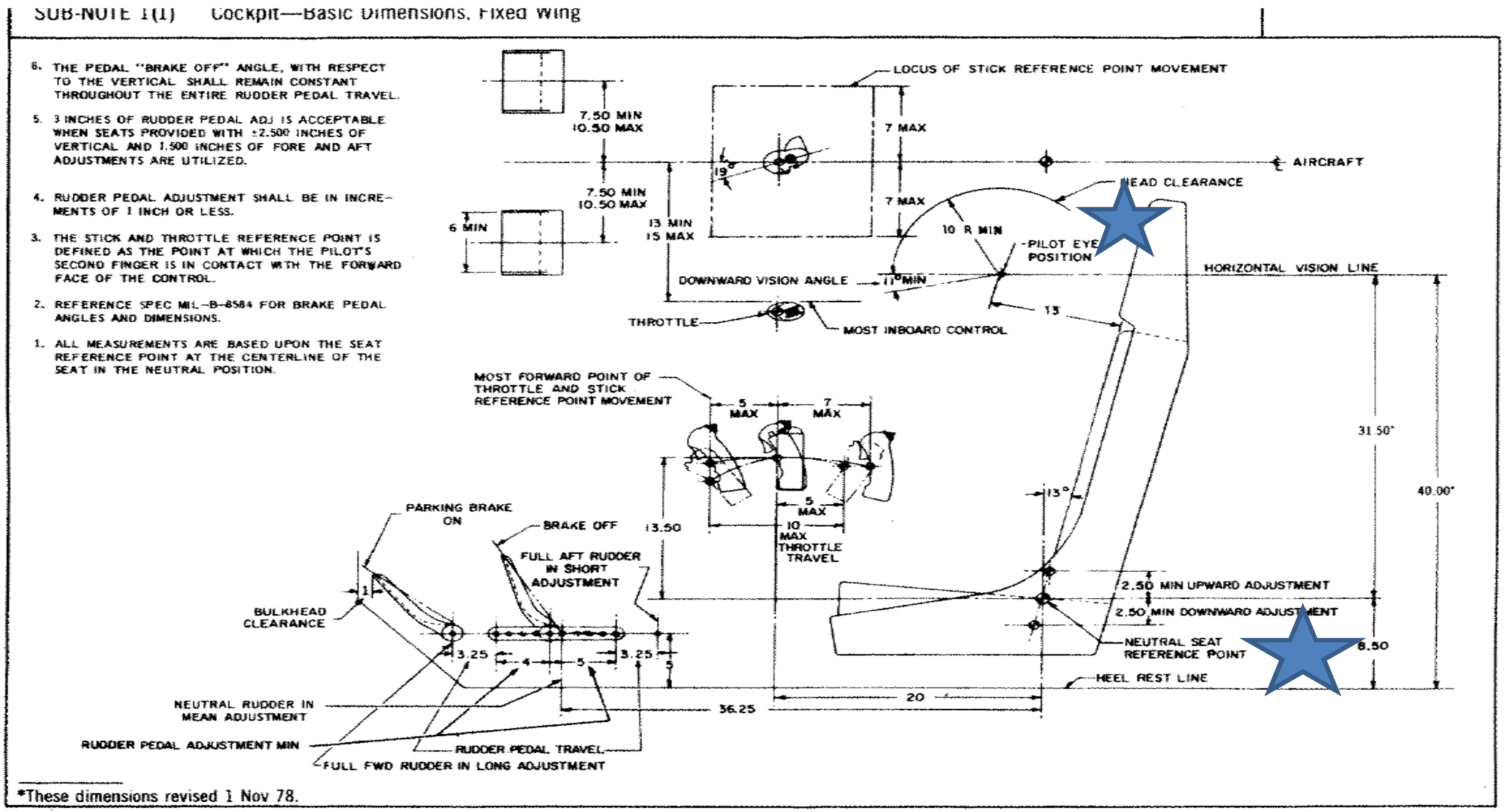
Service Module Window
40-cm diameter

The Cupola
80-cm diameter
(top window)





Military Aircraft Use of Design Eye Position & Seat Reference Point

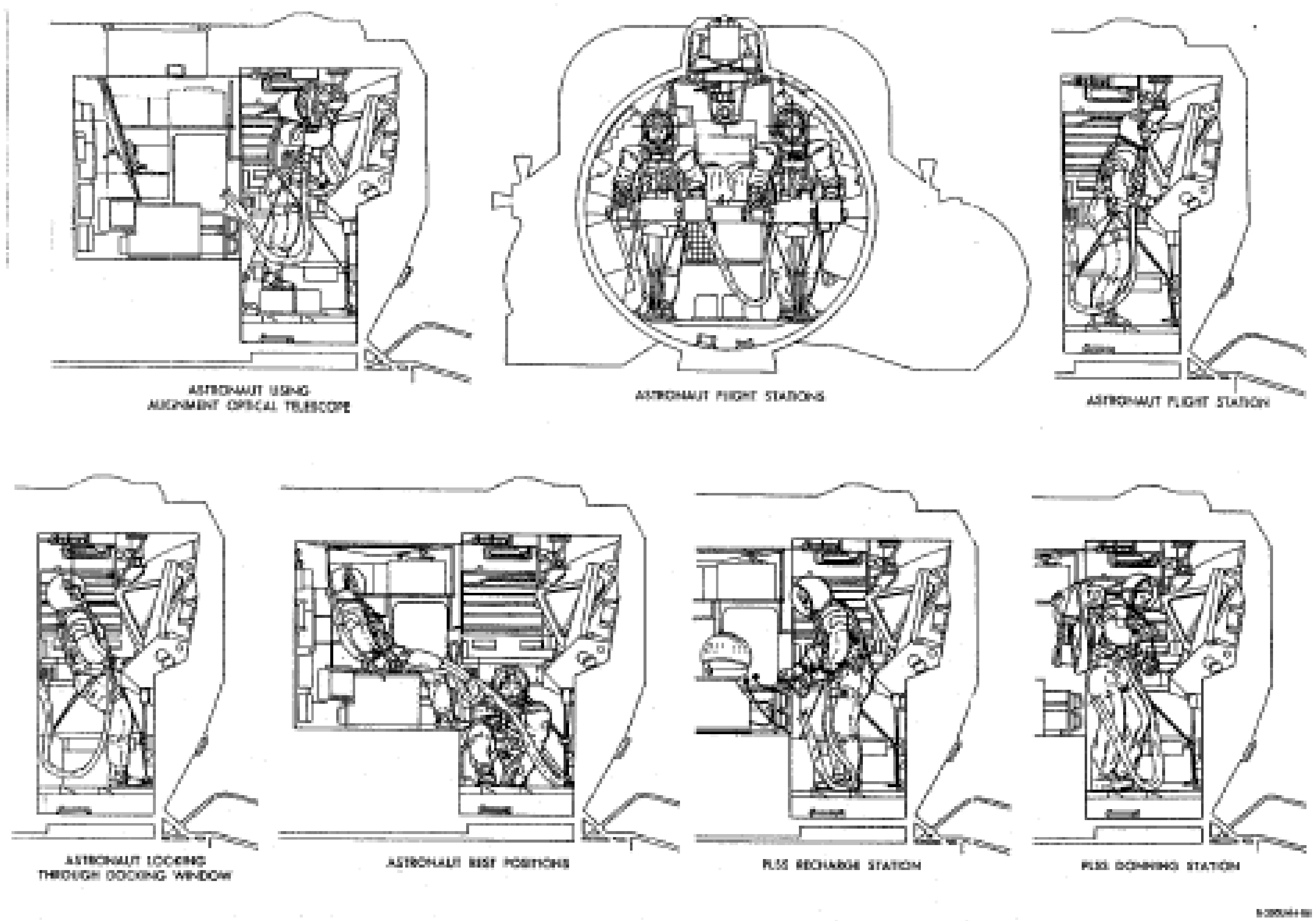


From: Air Force, ASFC Design Handbook (DH) 2-2 Crew Stations and Passenger Accommodations, January, 1988

Crew Positions & Restraints

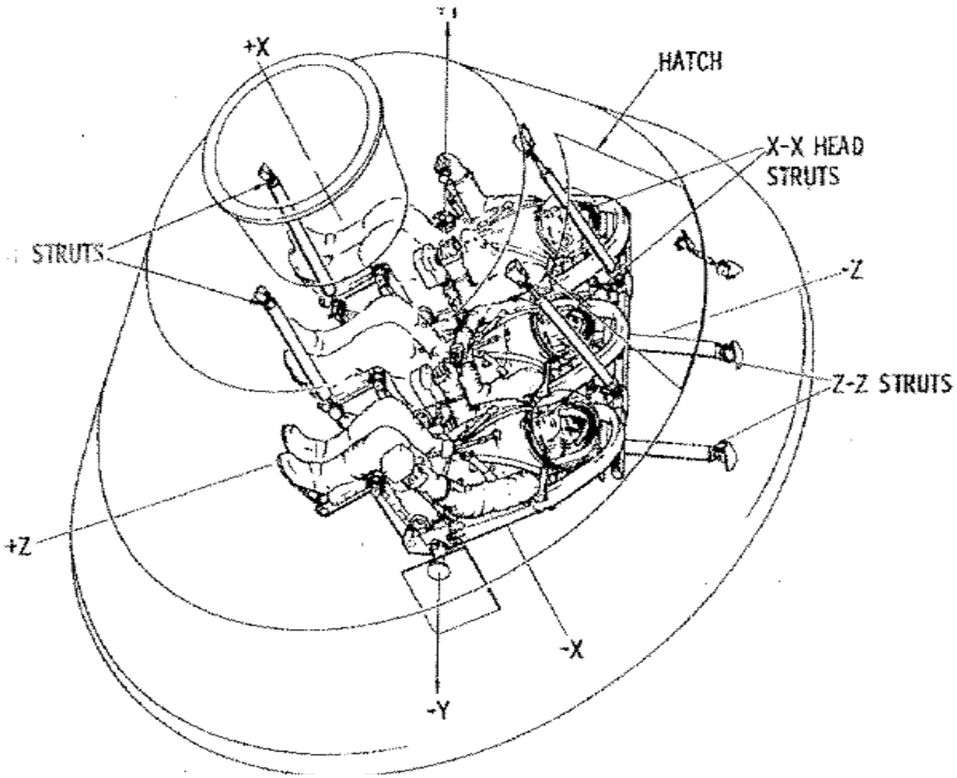
Lunar Module Restraints & Crew Positions

Figure 13 LM CREWMEN FLIGHT POSITIONS



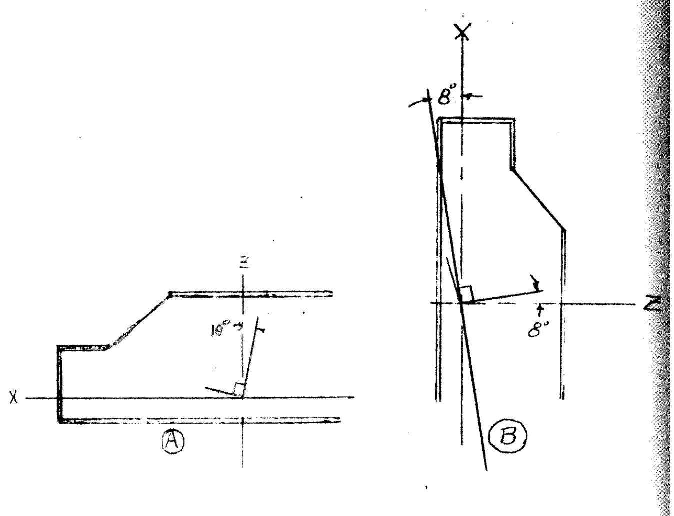
Source: Apollo Operations Handbook, Lunar Module, Vol. I: Spacecraft Description. Apollo Document LMA 790-3-LM, (Bethpage, N. Y.: Grumman Aerospace Corporation, NASA Contract NAS 9-1100, March 15, 1969), p. 1-17.

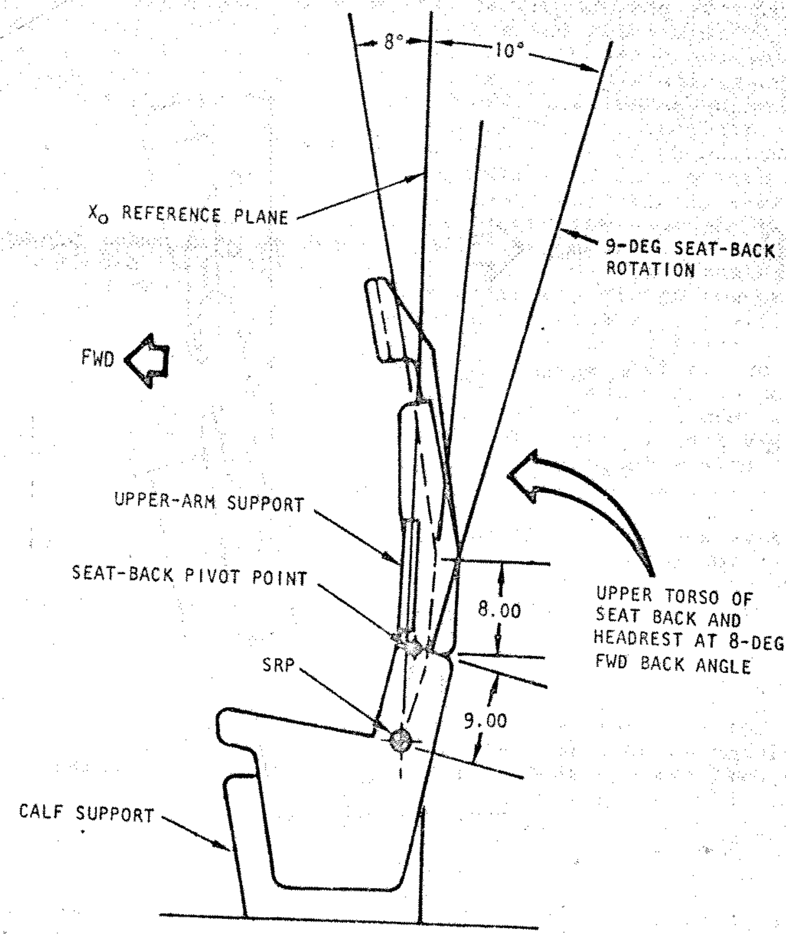
Command Module Launch Configuration



Shuttle-Orbiter Launch & Landing Crew Positions

FIGURE 7. A, Seat back angle for entry.
B, Seat back angle for launch.





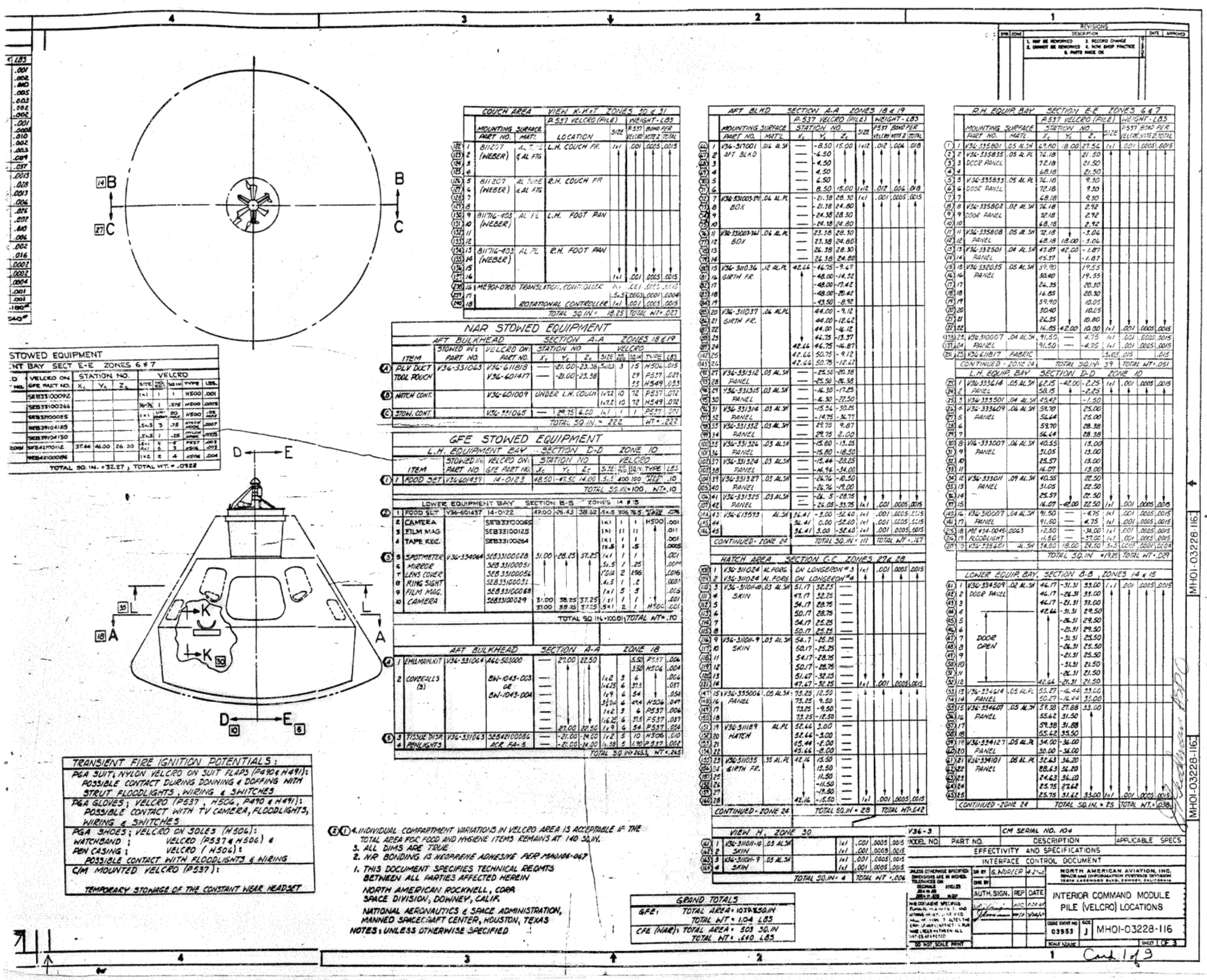
Another example of mission driven design requirement for seat

FIGURE 5.2.2.2.1(b)

FLIGHT CREW OPERATIONAL SEAT
VERTICAL FLIGHT CONFIGURATION

Crew Translation Aids & Hardware Restraints

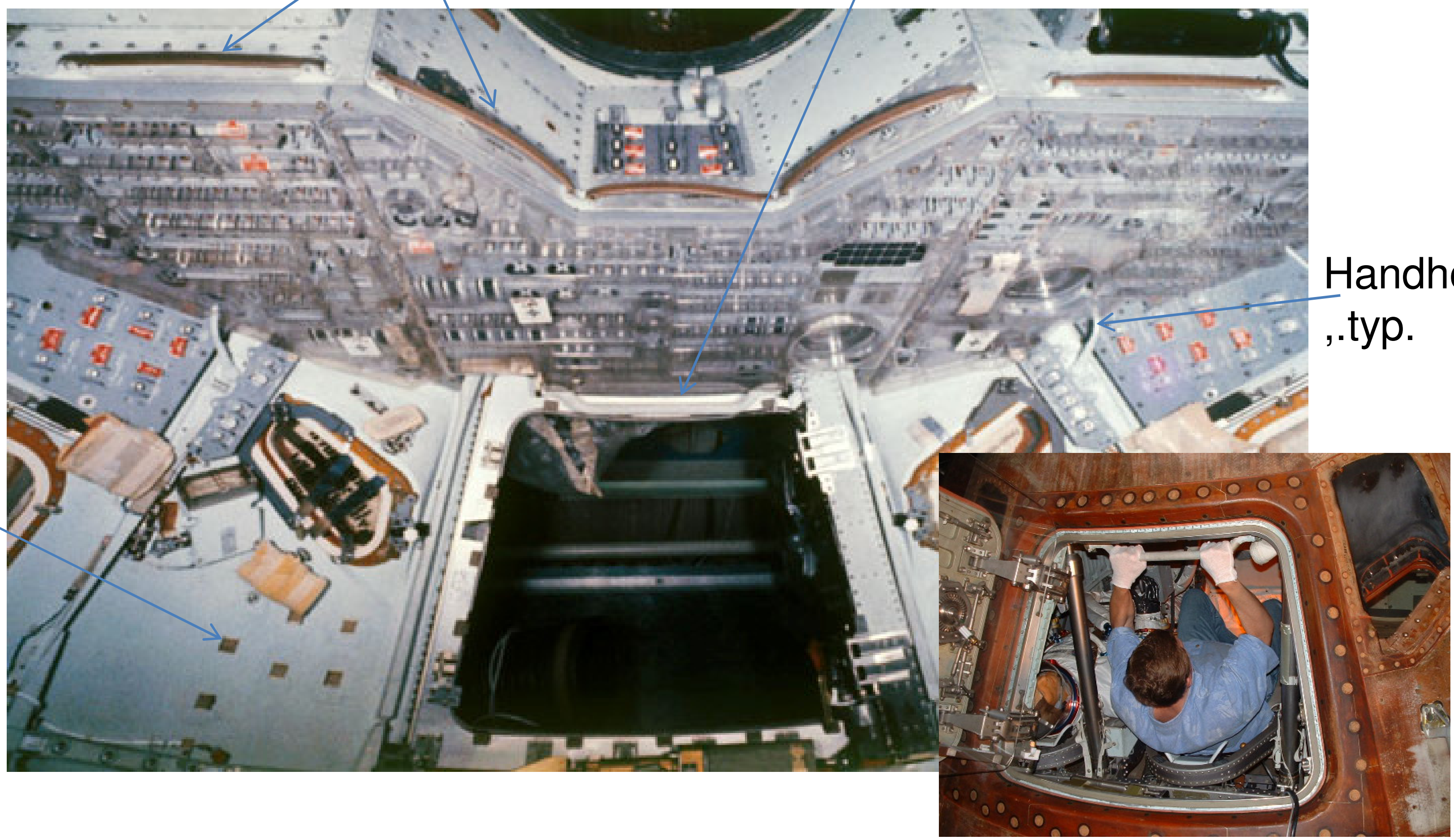
Restraints-Apollo Velcro Map



Apollo Command Module Restraints

Flexible Handholds

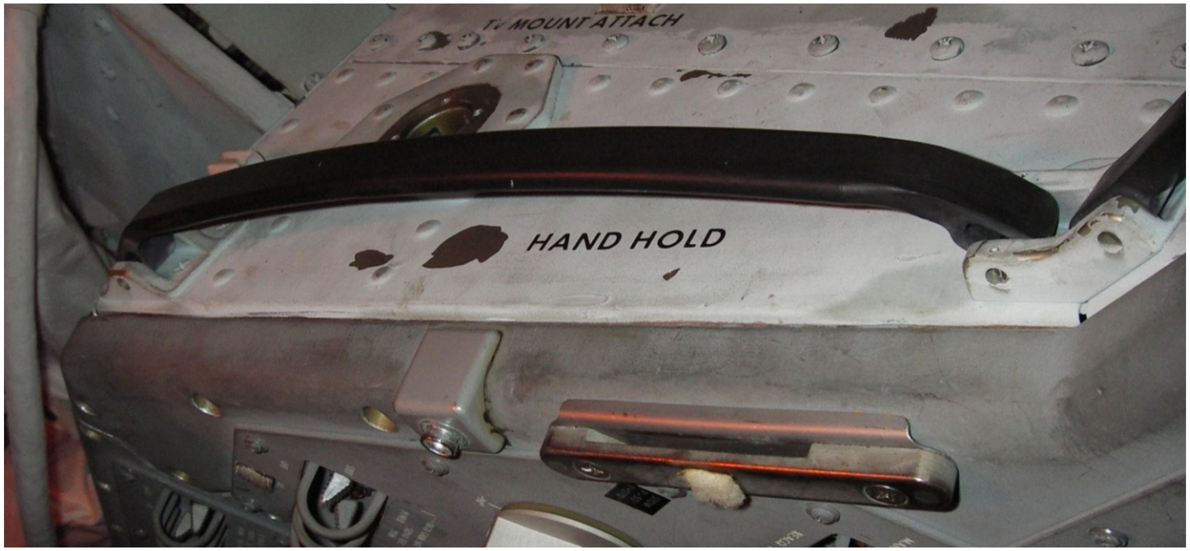
Handhold for ingress/egress through hatch



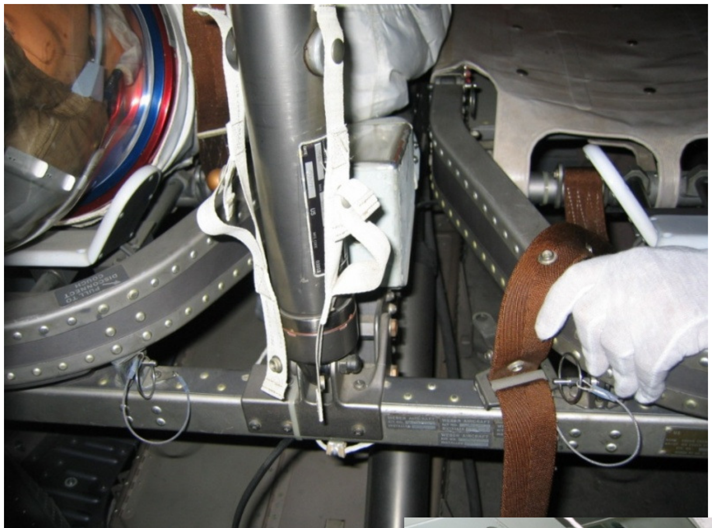
Handhold ,.typ.

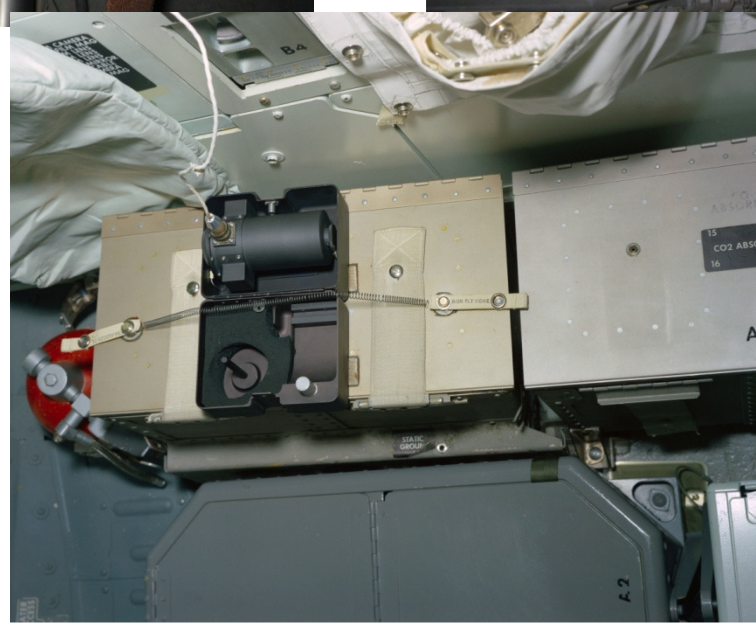
Velcro, typ.

Apollo Command Module Restraints



Apollo Command Module Restraints





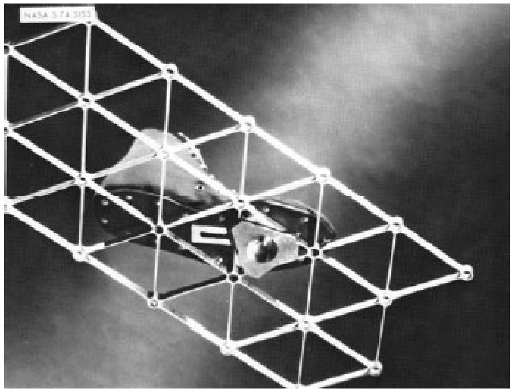
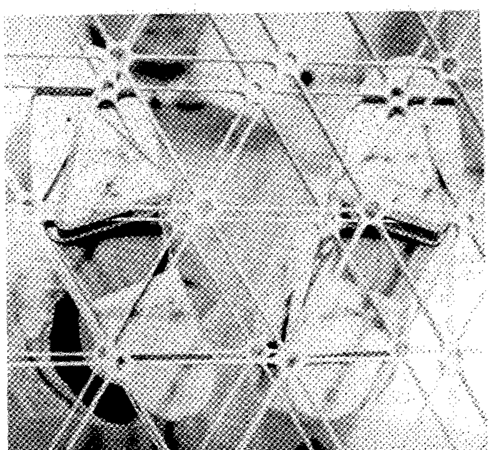


Figure 8.– Triangular cleats.

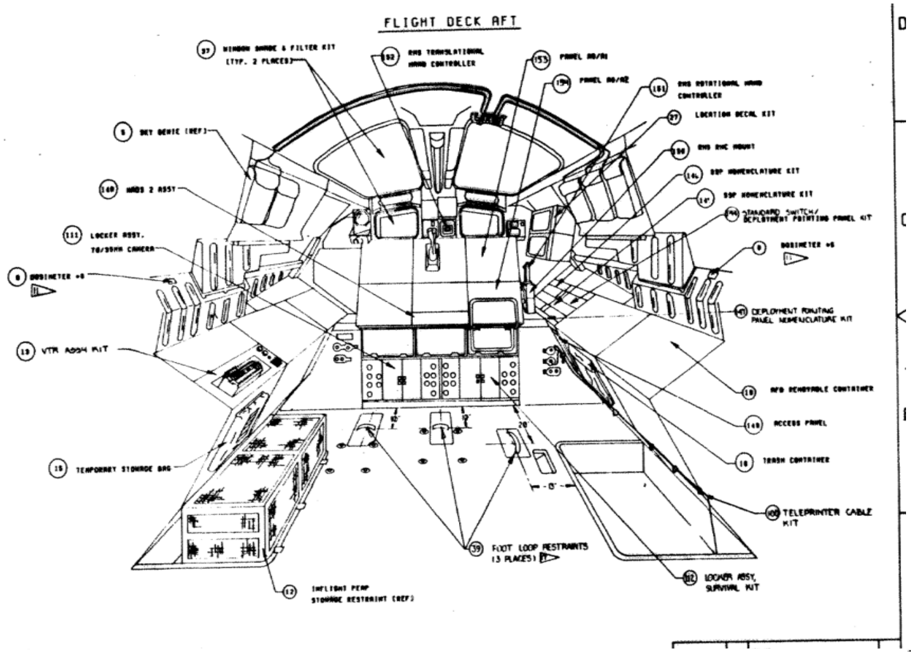


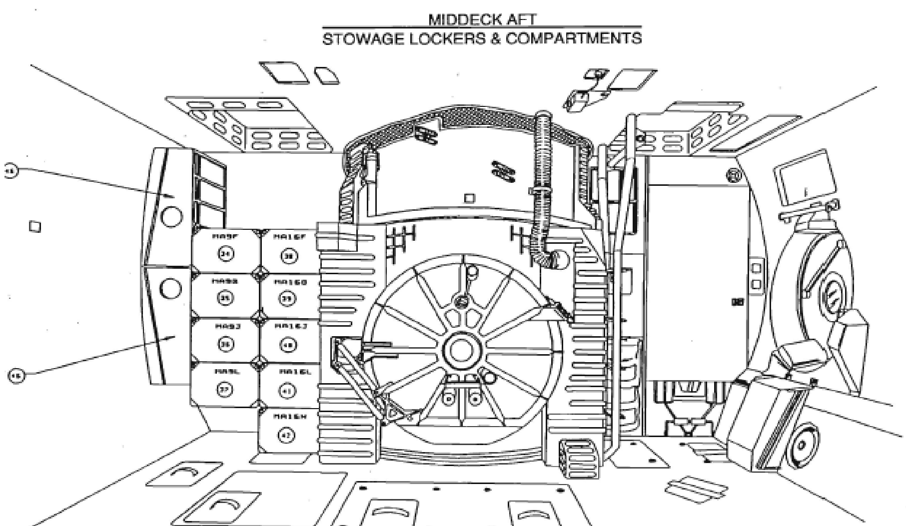
Skylab's floors were made up of triangular grids. Triangular shoe cleats fitted into the grid cavities. With a twist of his foot, a crewman could position himself wherever he chose. A number of other types of restraints were also provided.

Skylab Restraints

When proper restraints were available, manual tasks were performed almost as well in zero g as in Earth gravity. Properly designed foot restraints provided sufficient restraint for tasks not requiring strenuous work with the arms. Many types of foot restraints were located in Skylab. The shoes with the triangular cleats that could be locked into the grid floor were a nuisance to put on and take off but they offered the best all around restraint (fig. 8). Flimsy instep straps such as those in front of the urinal were useless.

Shuttle-Orbiter Restraints





Later Orbiter Mid-Decks

S116E05350

S126E008692

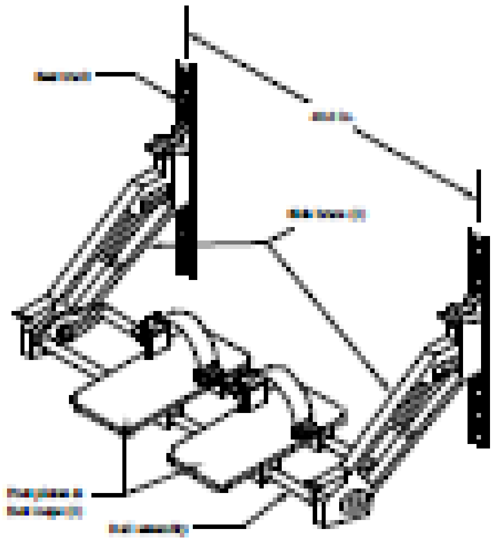

ISS Restraints

ISS005E16289

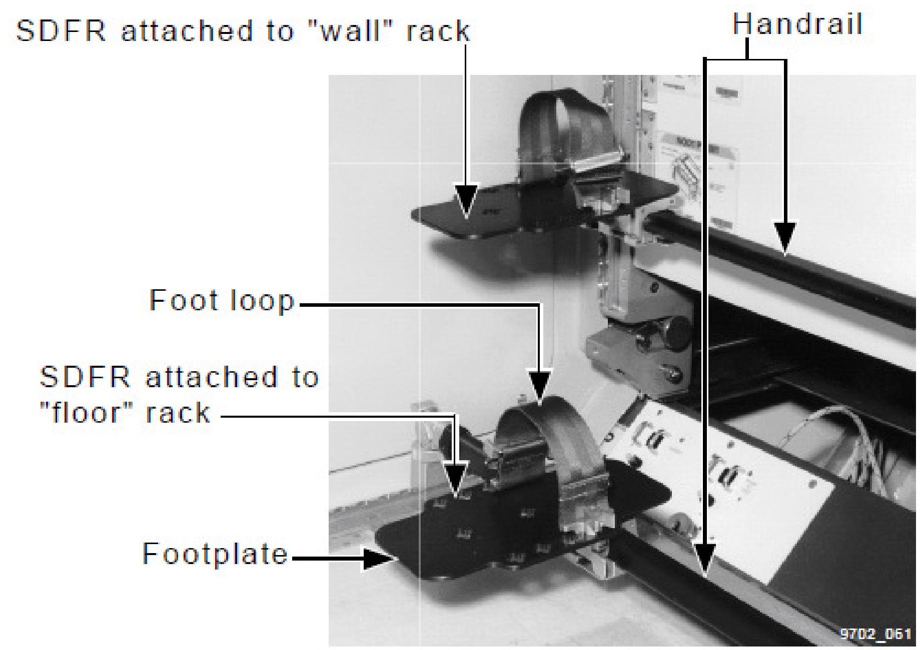
ISS005E17003

ISS Restraints

ISS Long Duration Foot Restraint



ISS Short Duration foot restraint



ISS Handrails

ISS Rack Handle Assembly

From Constellation Human System Integration Requirements (HSIR) on Mobility Aids & Restraints

3.4.3.2 IVA Mobility Aids
[HS5007] The system shall provide mobility aids for the crew to conduct IVA operations.

3.4.3.3 Workstation Restraints
[HS5008] The system shall provide restraints to allow crewmembers to perform two-handed operations at a workstation in 0 g.

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