Simulating Space

A Space Training History

Frank Hughes

Training

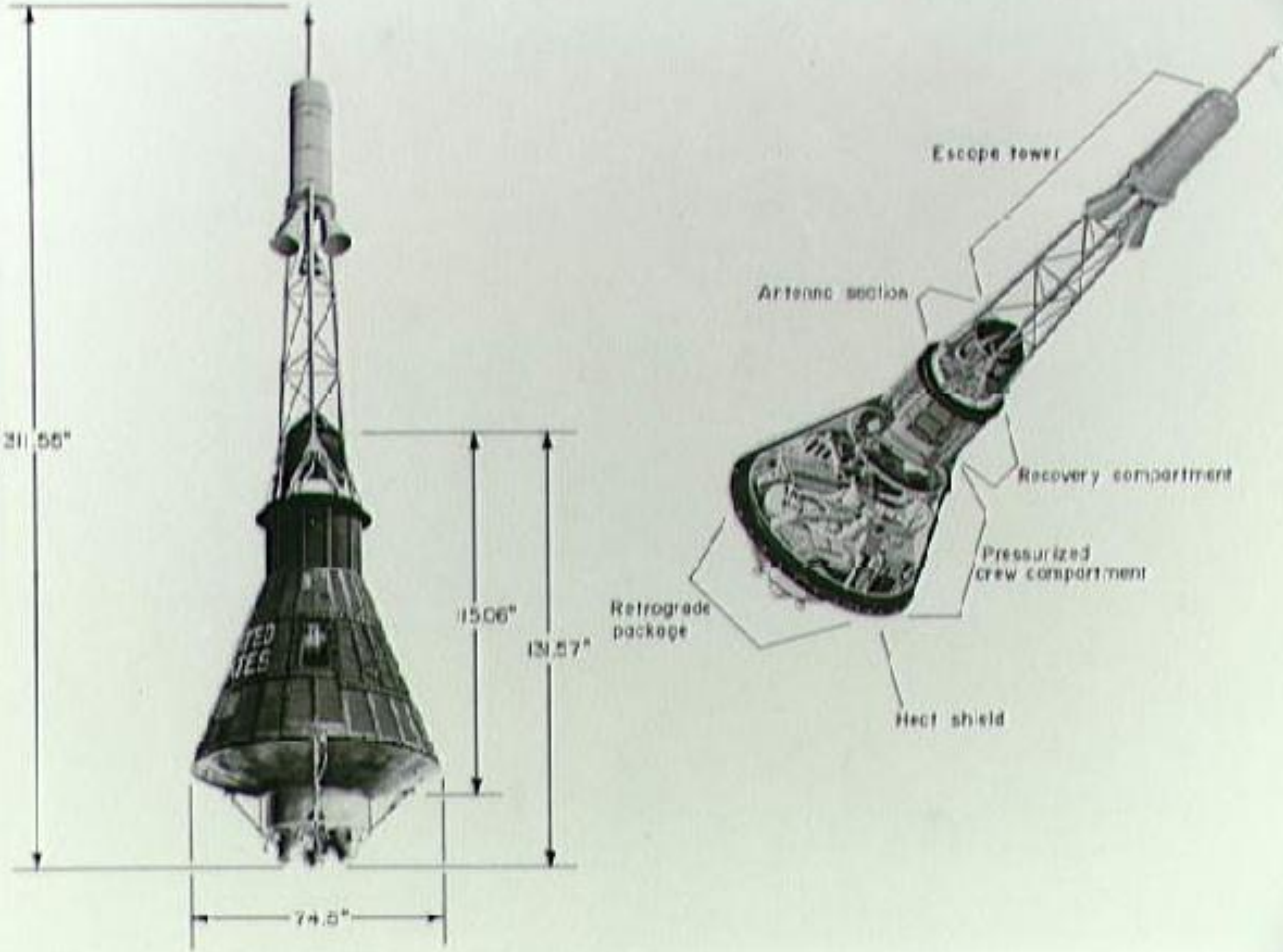
- In 1958, NASA was formed from parts of many agencies:
  - NACA
  - Army
  - Navy
  - Air Force
  - Coast Guard
- Training was occurring in all of these organizations and at many locations

Training

- Definition of training:
  - **An activity leading to skilled behavior** or
  - **The acquisition of knowledge, skills, and competencies as a result of the teaching of vocational or practical skills**
- At the time, when the National Space Act was passed and NASA was formed, no one knew:
  - What the skills would be needed to fly in space
  - What knowledge would be needed to fly in space
  - What attitudes would be needed to safely fly in space
- This created a unique dynamic situation

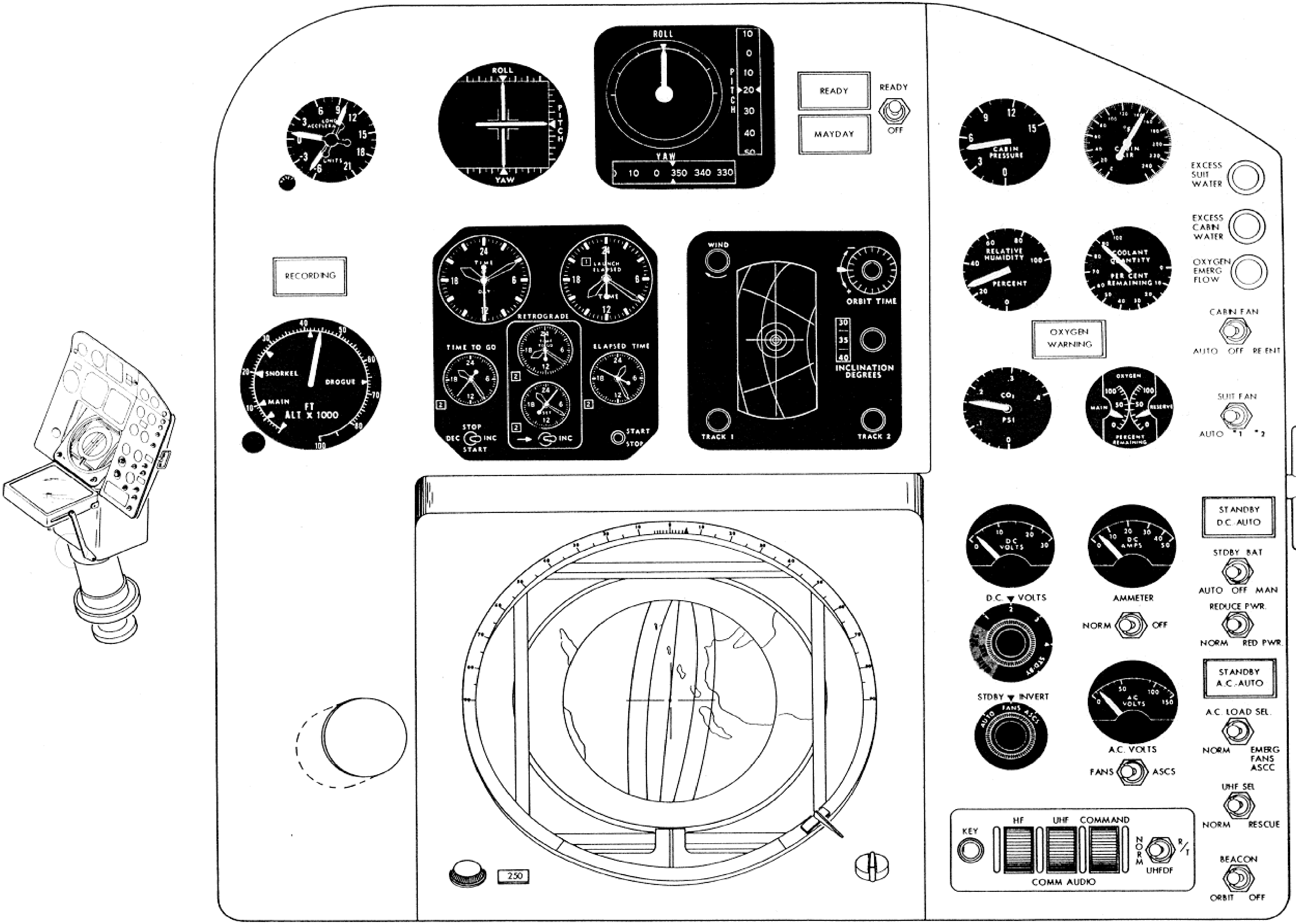
Mercury

- Initiated in 1958, completed in 1963, Project Mercury was the United States' first man-in-space program
- The objectives of the program, which made six manned flights from 1961 to 1963, were specific:
  - To orbit a manned spacecraft around Earth
  - To investigate man's ability to function in space
  - To recover both man and spacecraft safely.



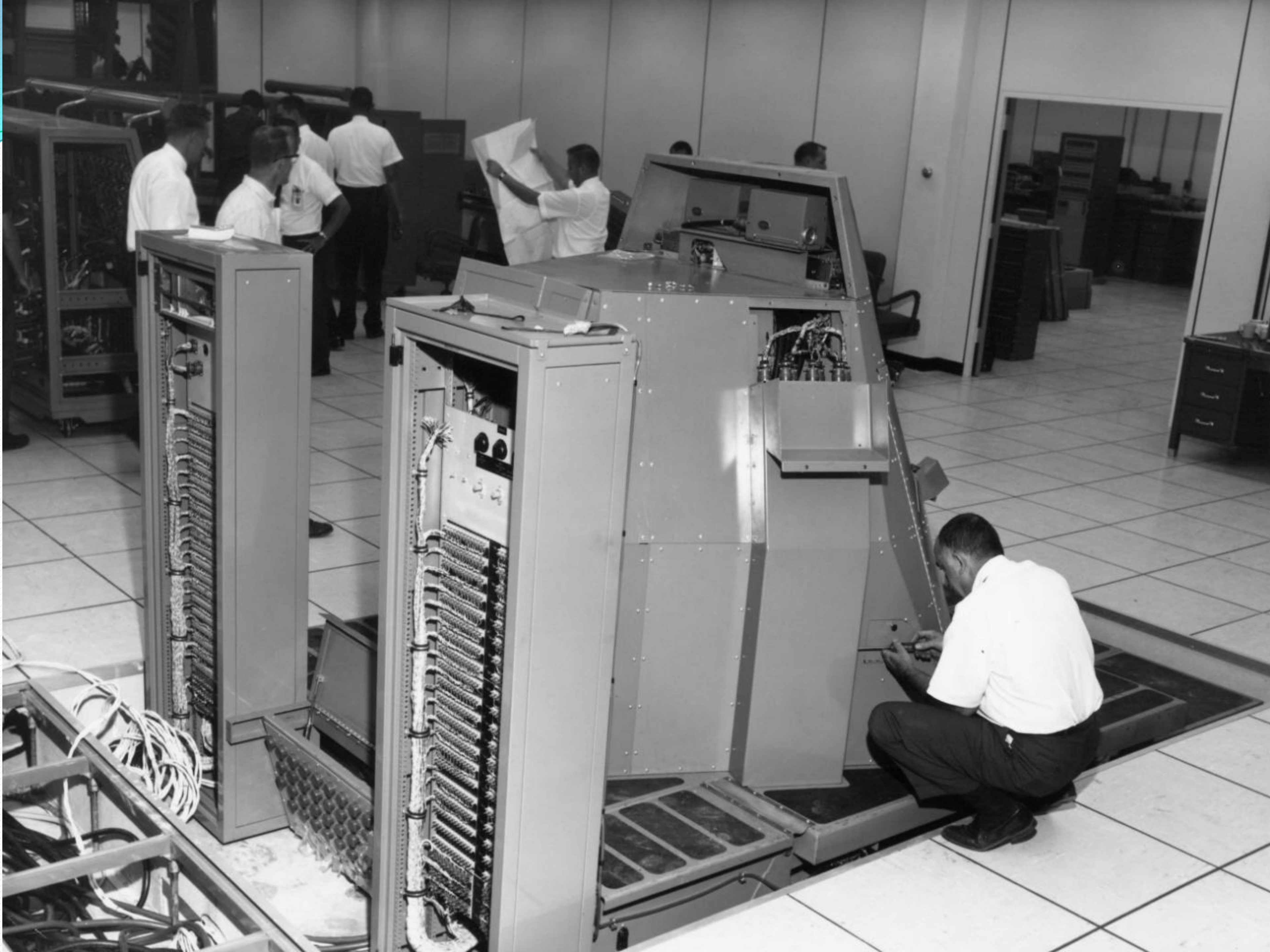
311.56"
115.06"
131.57"
74.5"
Escape tower
Antenna section
Recovery compartment
Pressurized crew compartment
Retrograde package
Heat shield

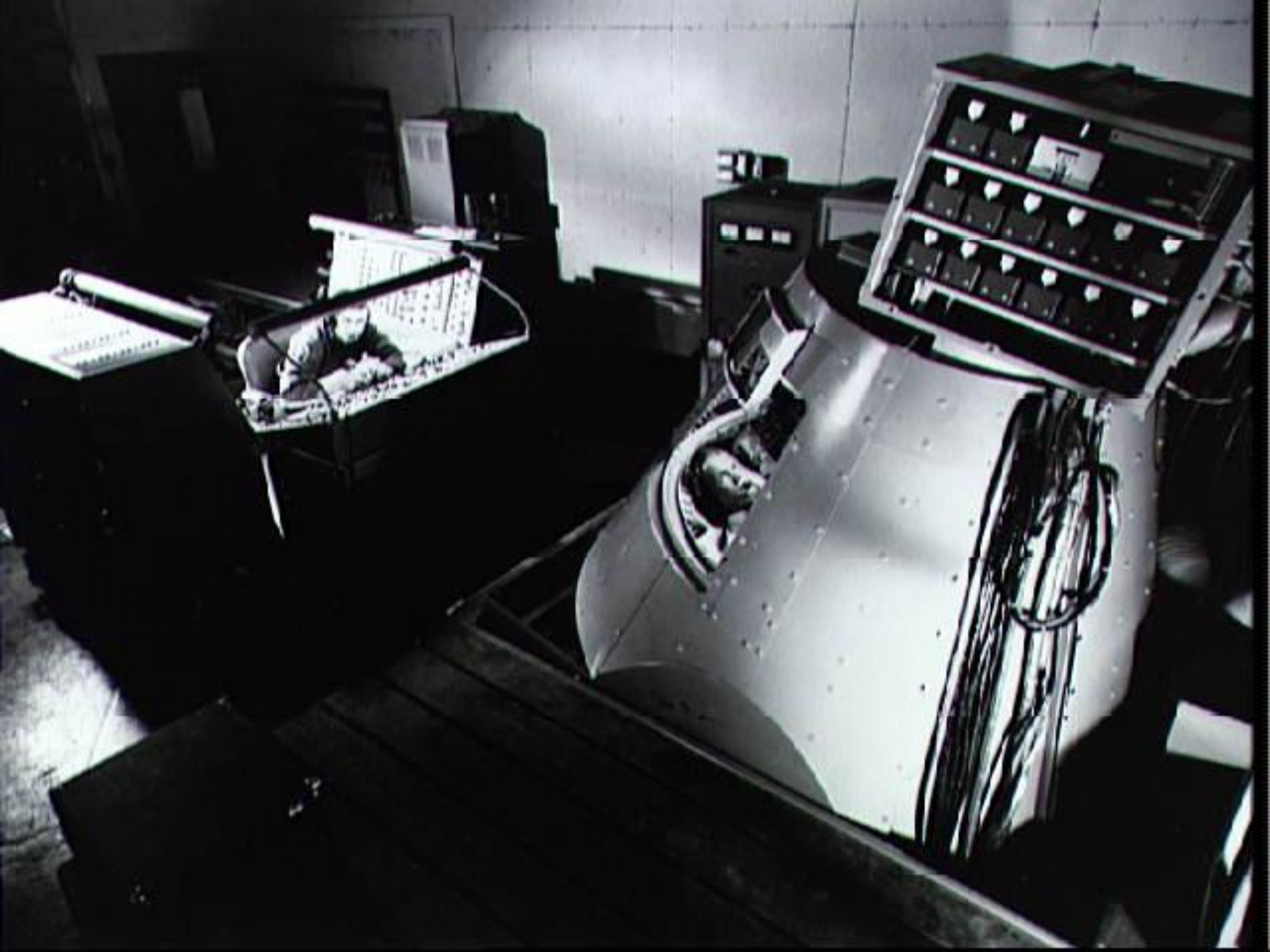
MAIN INSTRUMENT PANEL



Mercury Systems

- Less than 50 switches and controls
- No on-board computer, rate gyros for stabilization
- RCS for rotation, no translation capability
- Three solid rockets for retrofire
- Environmental control good for ~48 hours
- Training:
  - Mercury Procedures Trainer in St. Louis and at MCC-Cape
  - Analog host computers only



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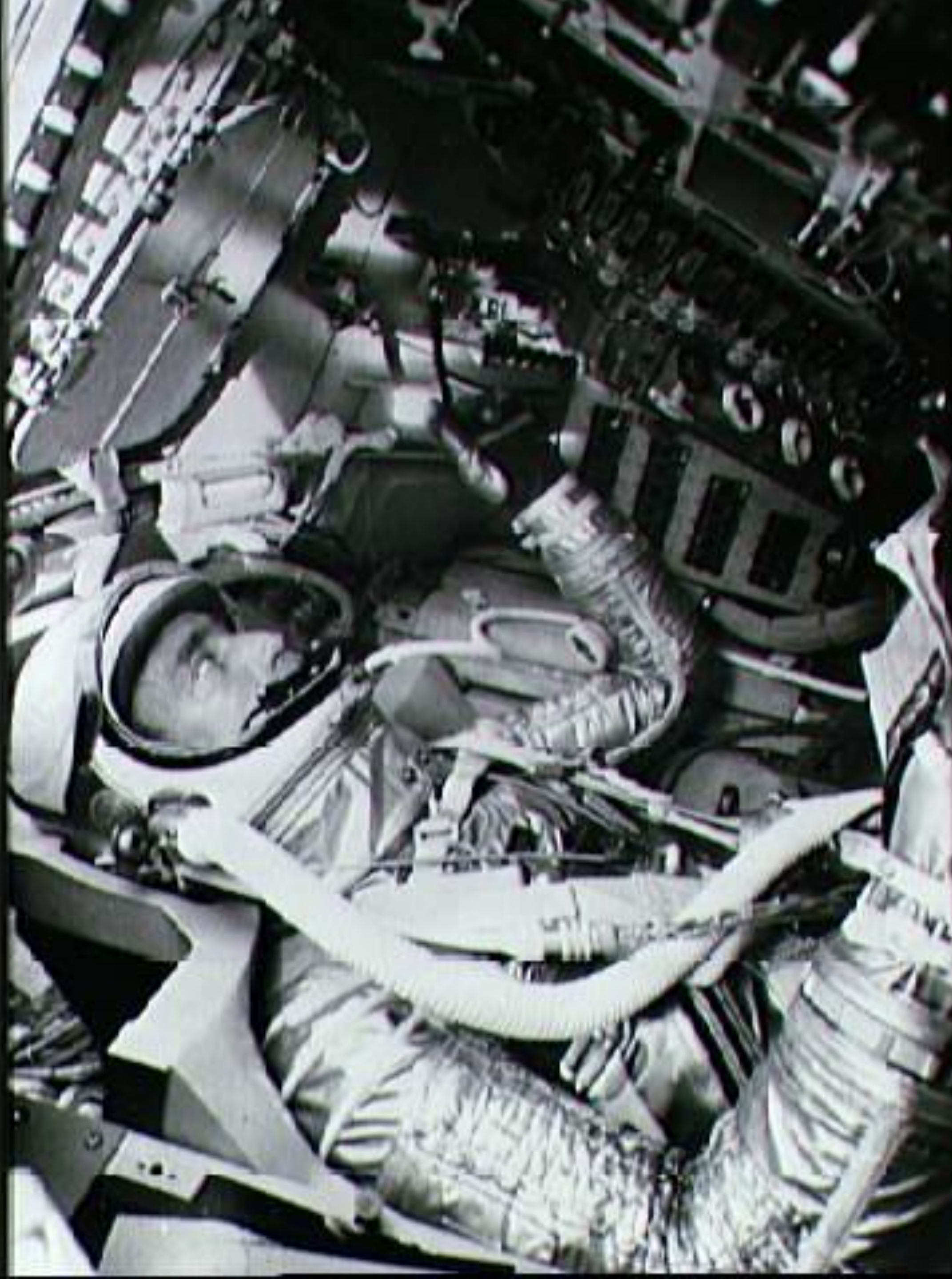
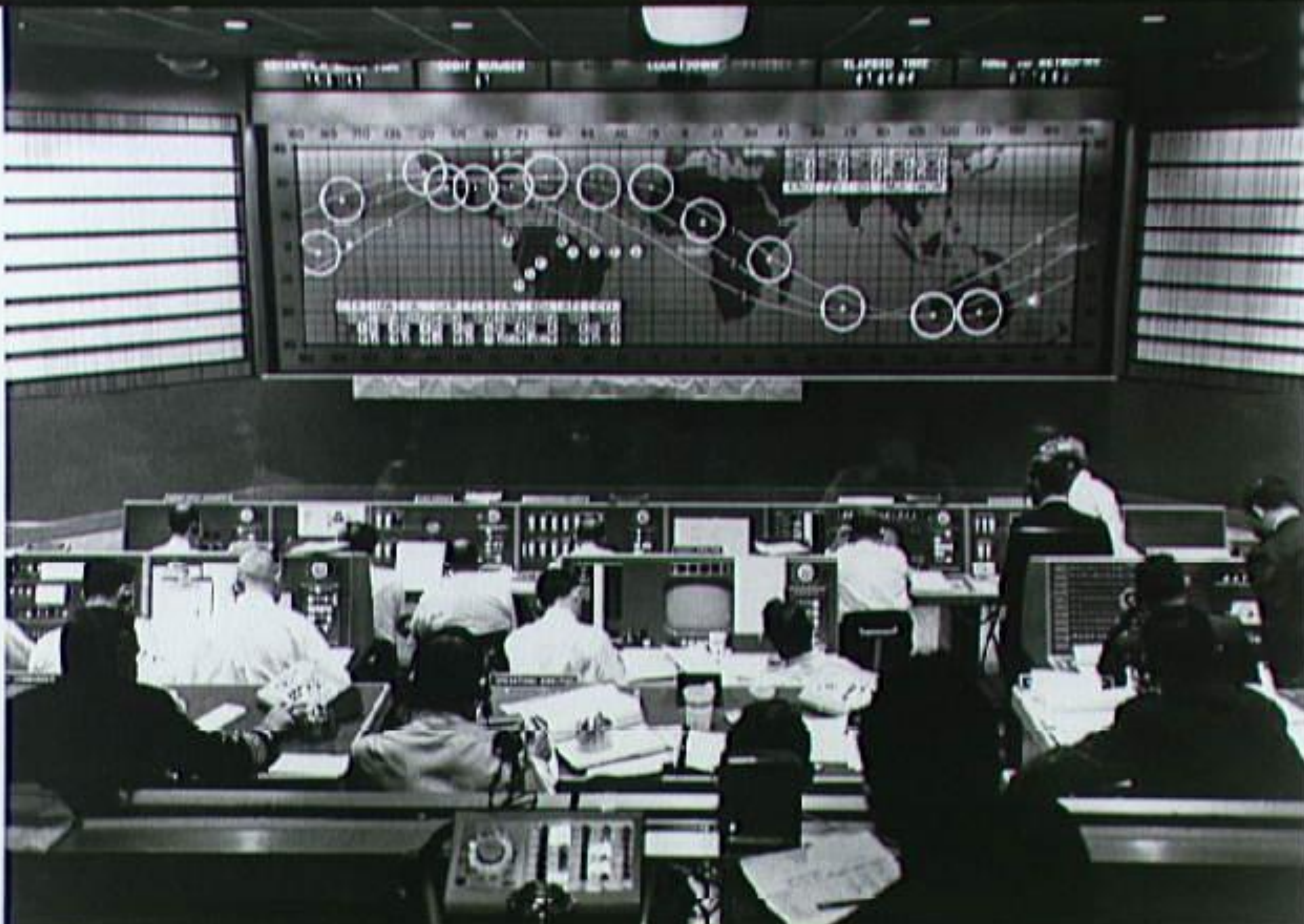




What did we learn?

- Man can work and live in space
- Prepare for flight using simulators is realistic
- Crew can see and acquire photographic and other data from orbit
- Save and ration your fuel

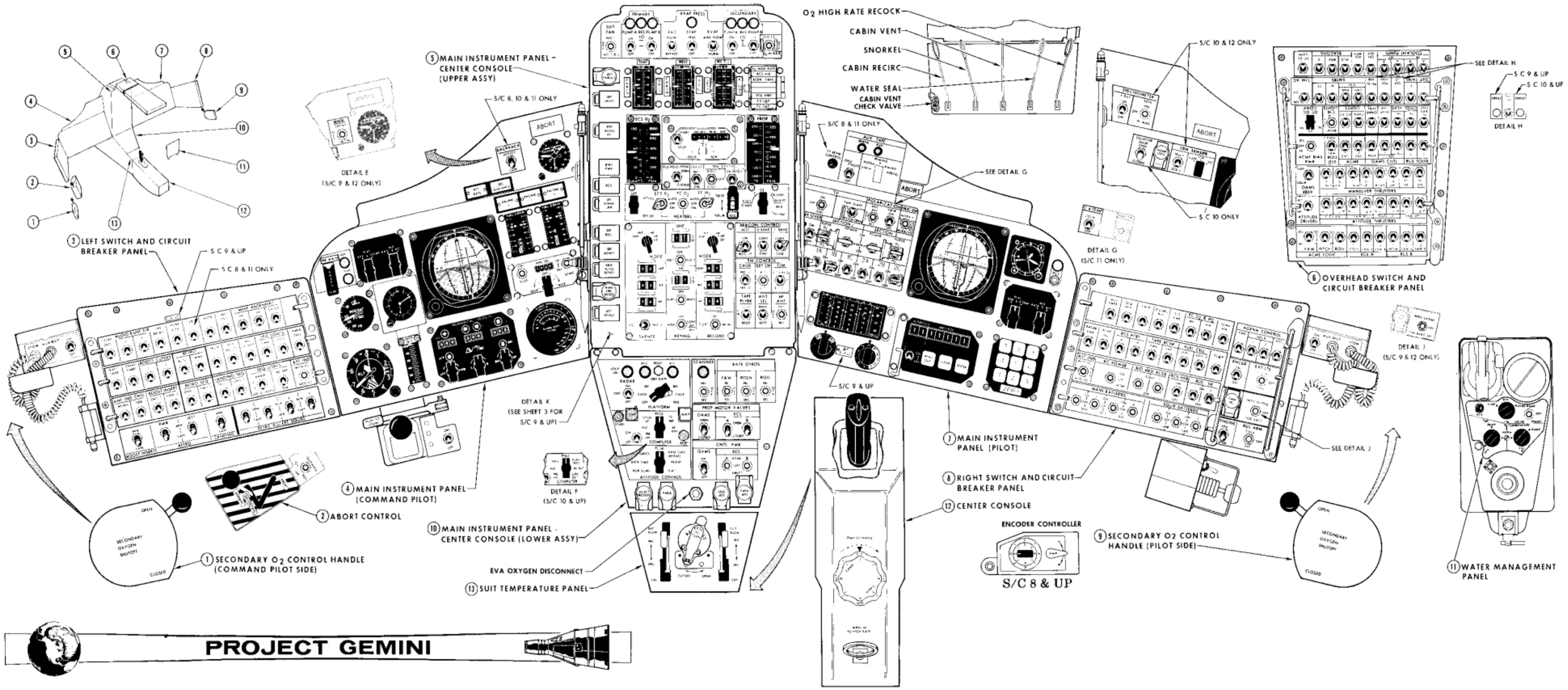
Gemini

- Goals
  - To subject man and equipment to space flight up to two weeks in duration.
  - To rendezvous and dock with orbiting vehicles and to maneuver the docked combination by using the target vehicle's propulsion system;
  - To perfect methods of entering the atmosphere and landing at a preselected point on land

Gemini Systems

- Two person spacecraft that flew 10 manned missions between 1965 and 1966
- Digital computer onboard with 4K memory - could compute and display rendezvous solutions
- Stabilization and control system with rate gyros
- Full rotation and translation capability on-orbit
- Environmental control good for more than 14 days
- Two fuel cells for electric power
- ~200 switches & controls

Gemini displays




MCDONNELL
CAUTION PUT SAFETY BARS IN PLACE BEFORE WORKING UNDER CAPSULE BASE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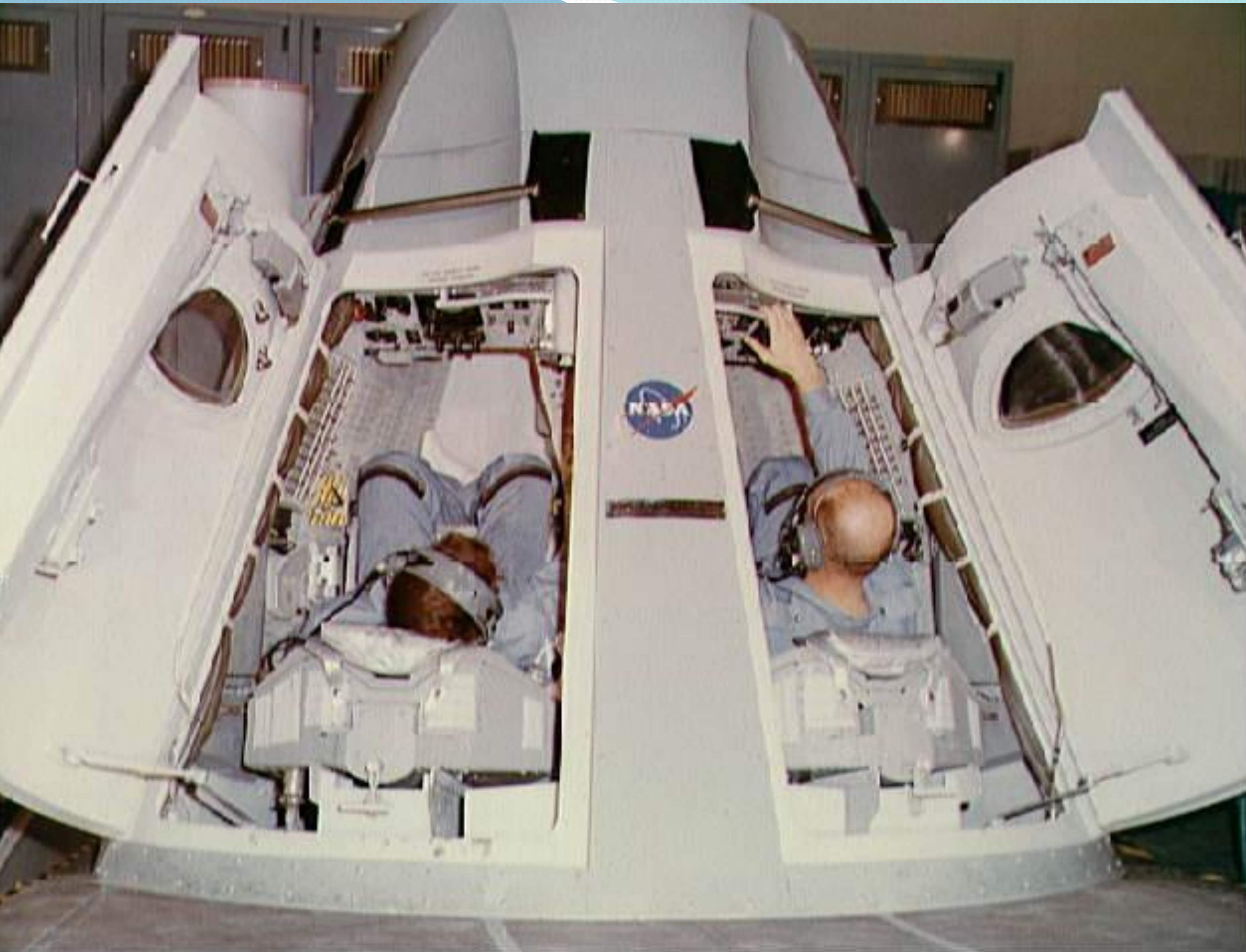


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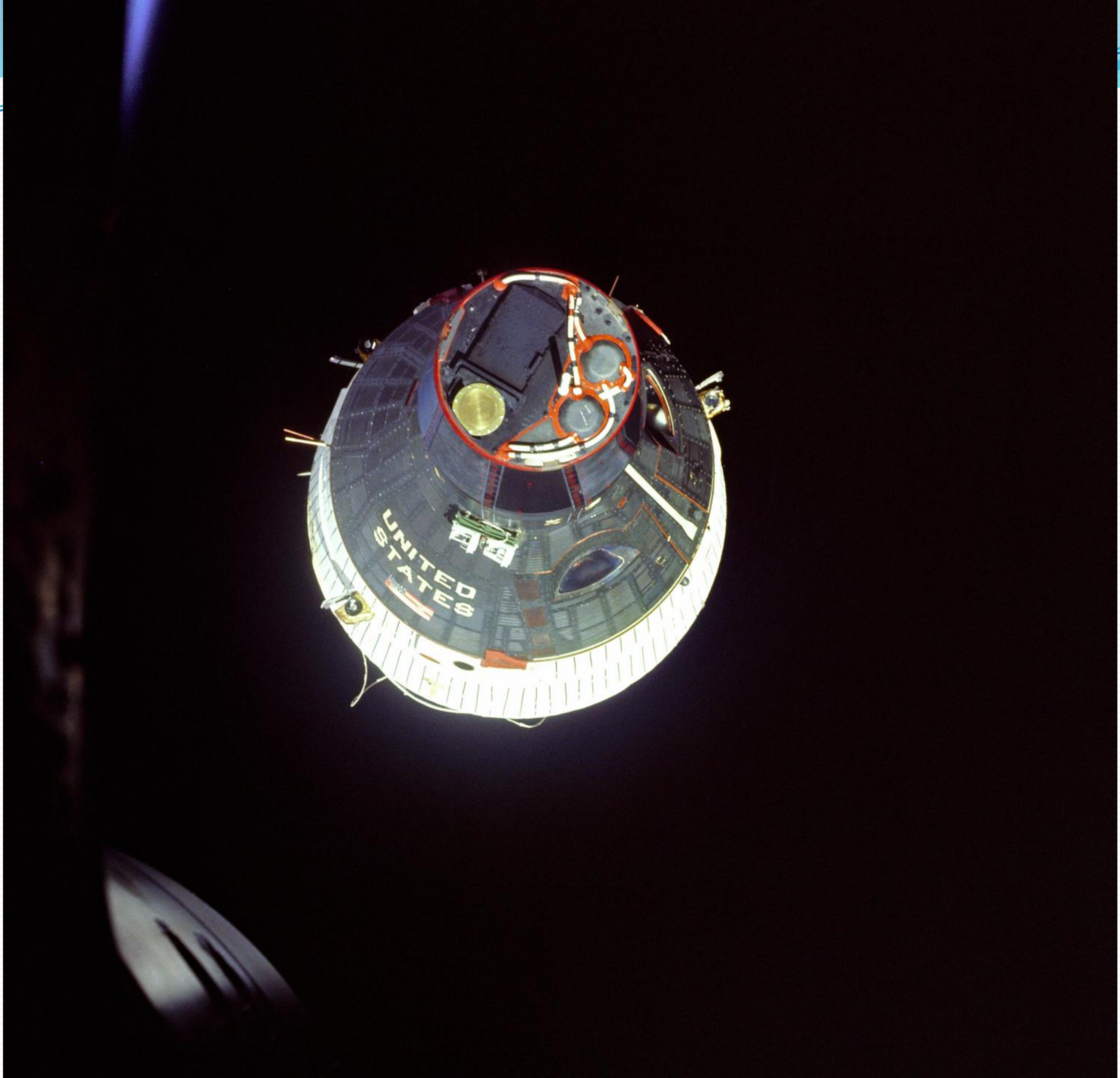
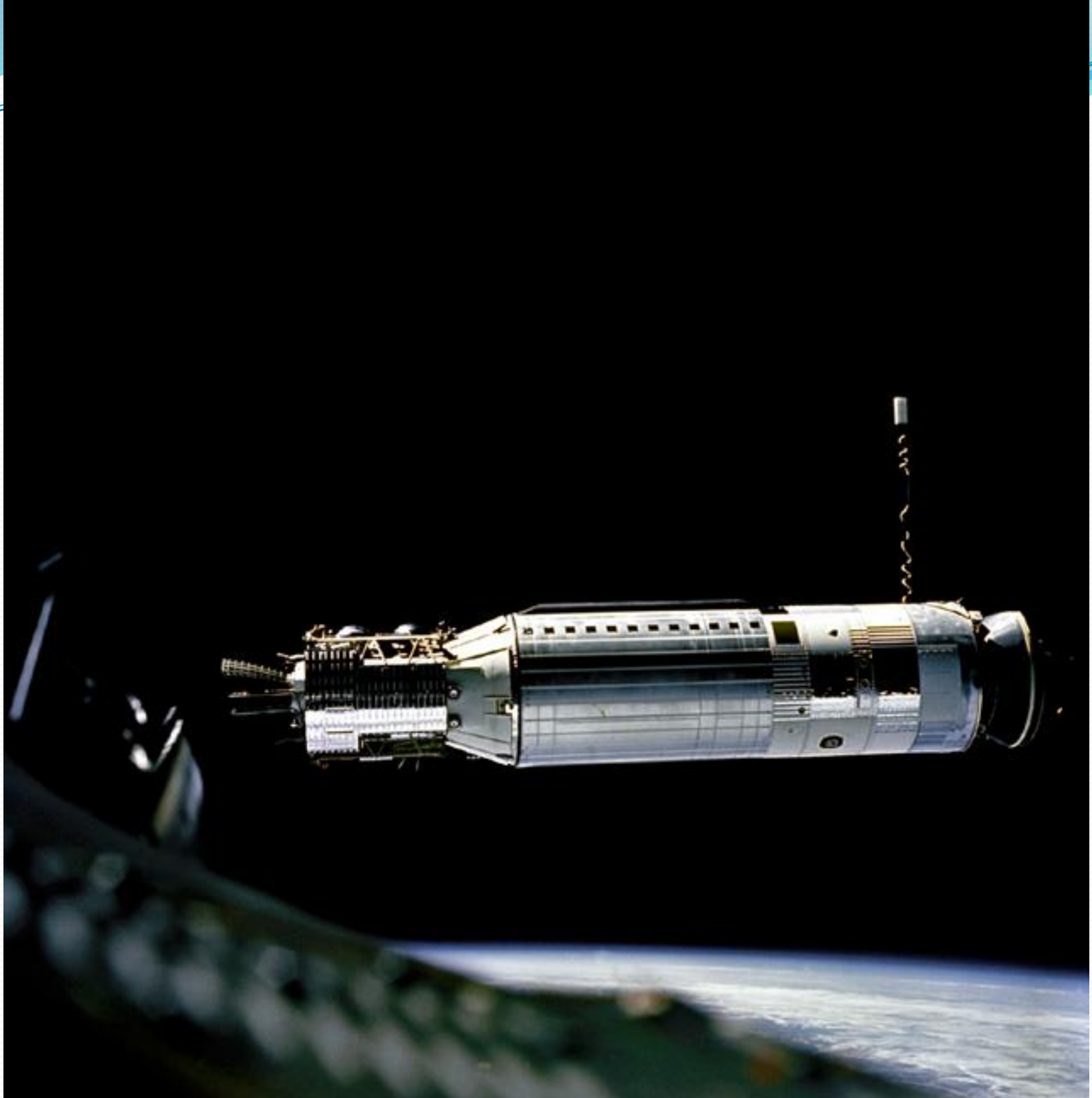
UNITED STATES


UNITED
STATES



What did we learn?

- That rendezvous was relatively easy, done properly
- That docking and station keeping was easy once you understood the physics
- That saving fuel was a life saver
- That people could live and work in space up to 14 days
- That EVA was complicated but finally good planning and training make it much easier
- That tethered operations could save fuel (useful for space elevators in the future)

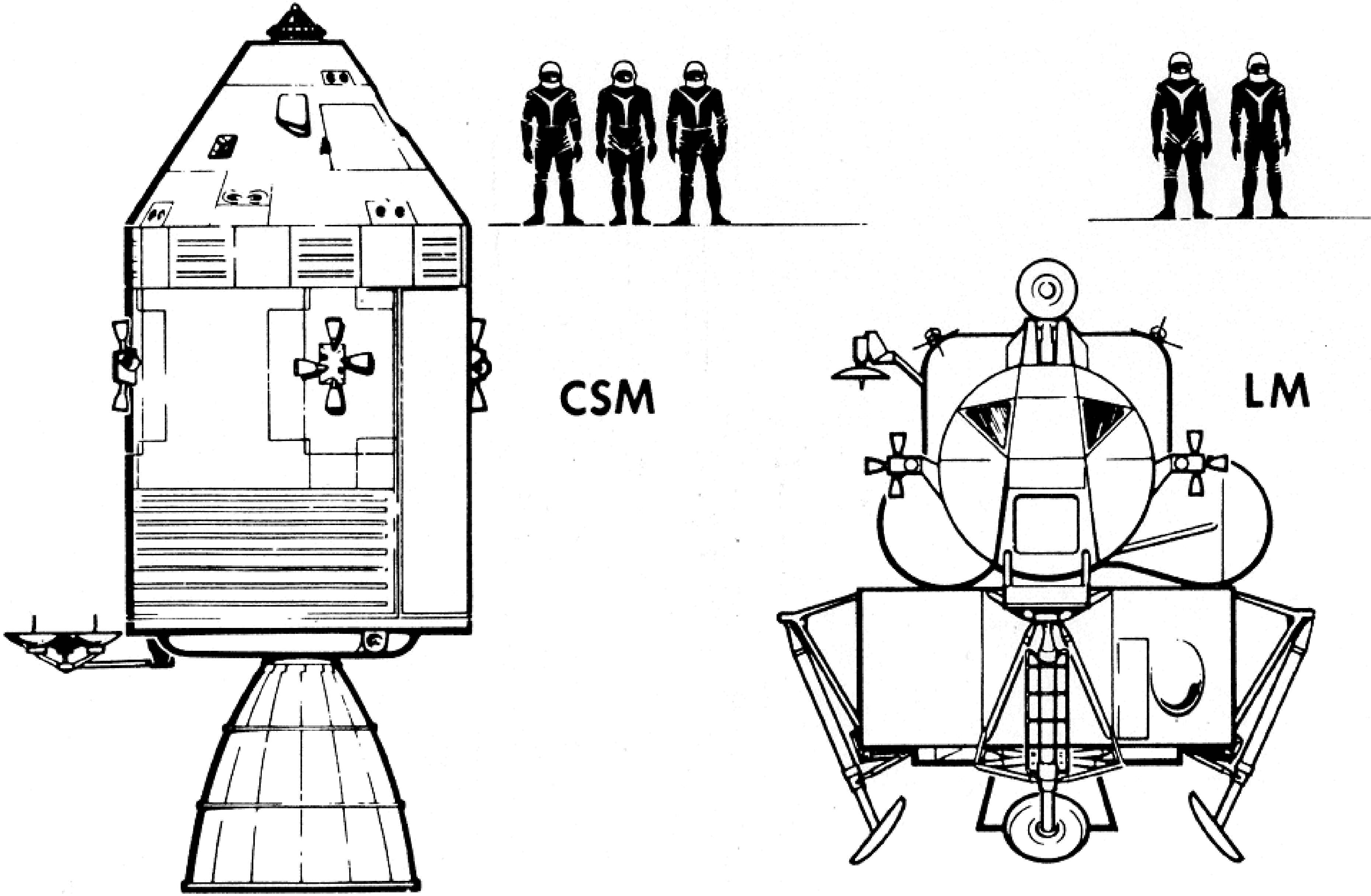
Apollo

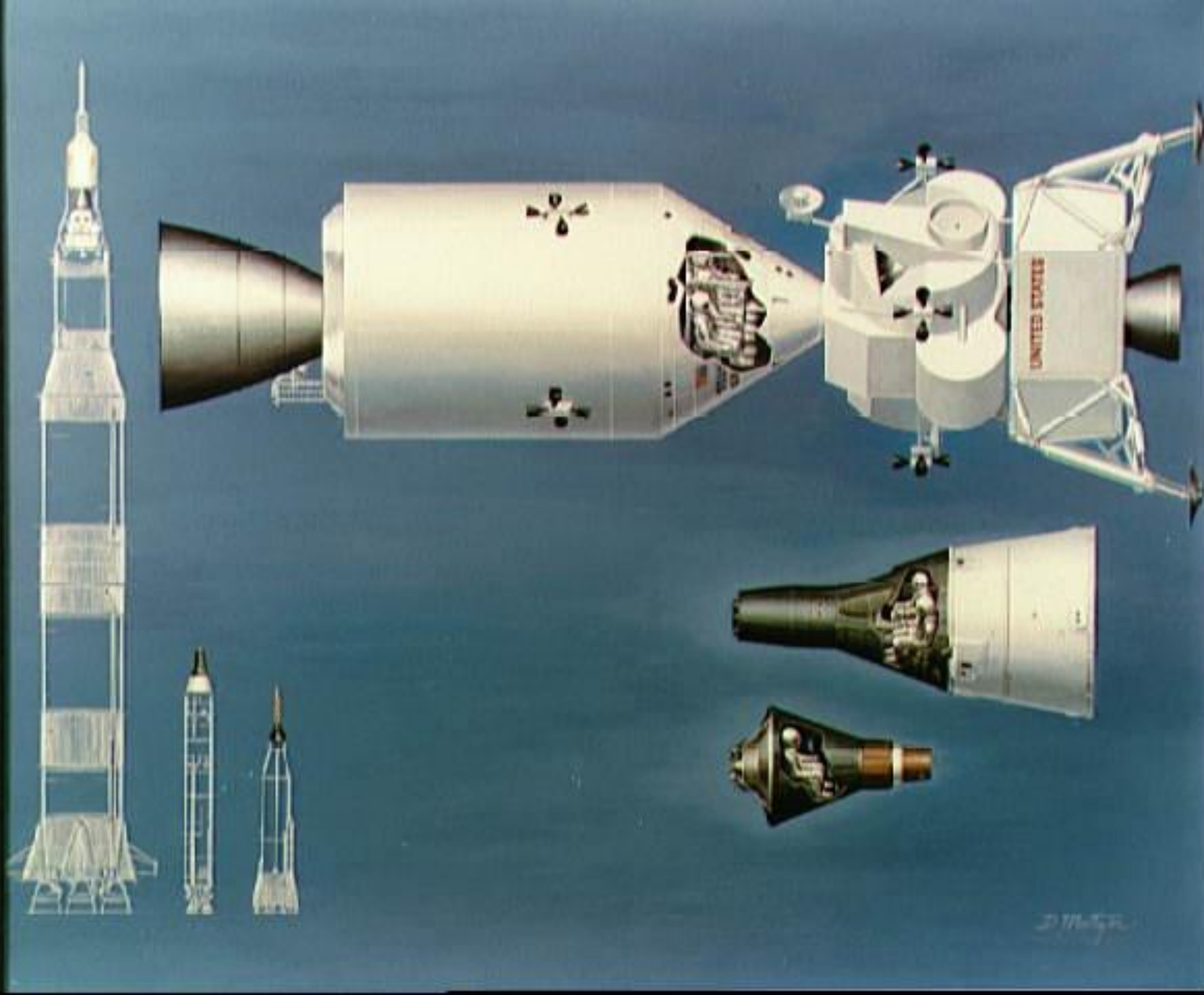
- Goals:
- Apollo's goals went beyond landing Americans on the Moon and returning them safely to Earth:
  - To establish the technology to meet other national interests in space.
  - To achieve preeminence in space for the United States.
  - To carry out a program of scientific exploration of the Moon.
  - To develop man's capability to work in the lunar environment.

Apollo Systems

- Two vehicles – Command Service Module (CSM) and Lunar Module (LM) that flew 11 manned missions between 1968 and 1972
  - Same digital computer in each vehicle (Delco) 36K memory
  - Environmental system good for more than 14 days, more sophisticated
  - Three fuel cells
  - RCS on Service Module, Command Module (for entry) and Lunar Module
  - Large (21,000 lb) engine on CSM to get in and out of lunar orbit
  - Engines on LM ascent and descent stage
  - 350 switches/controls in CM; 200 in LM

APOLLO CSM & LM COMPARISON

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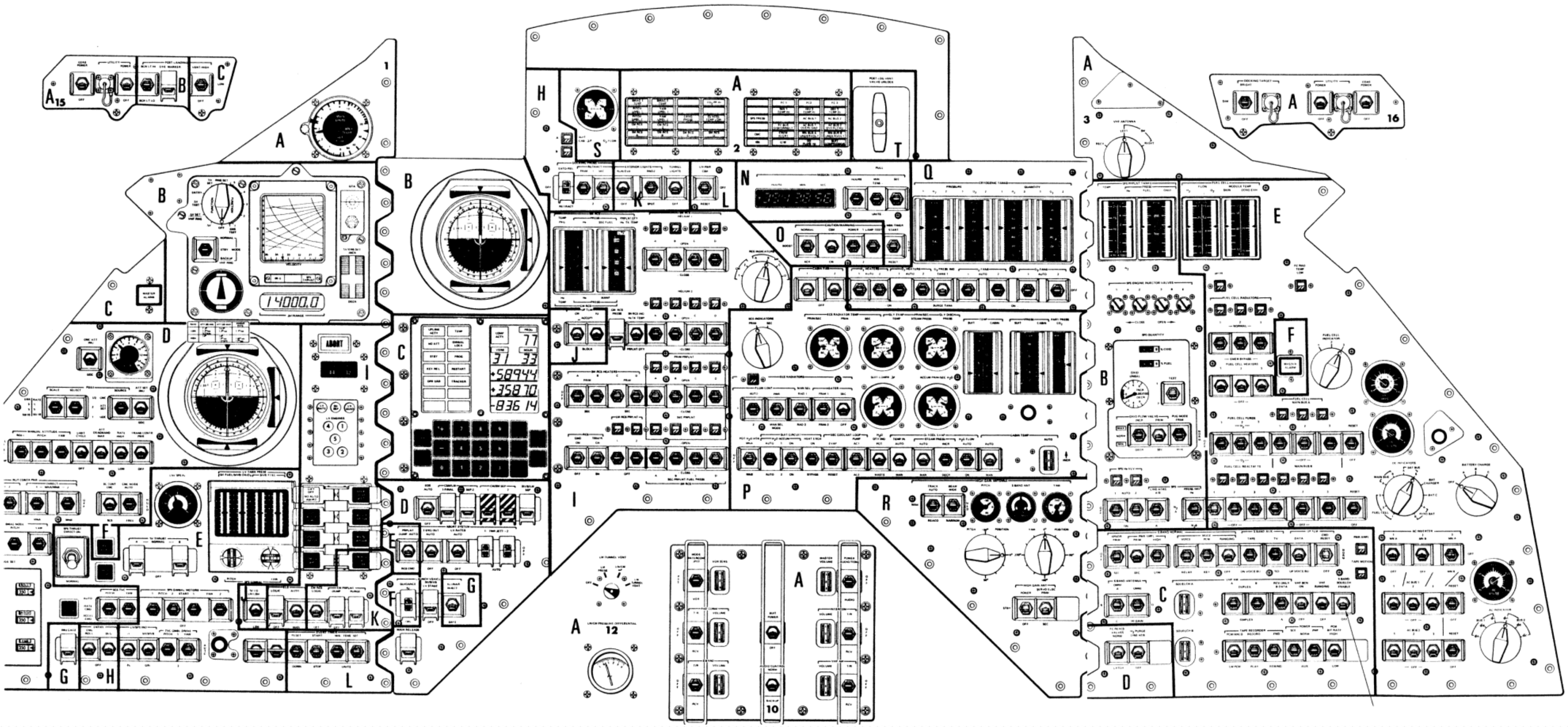
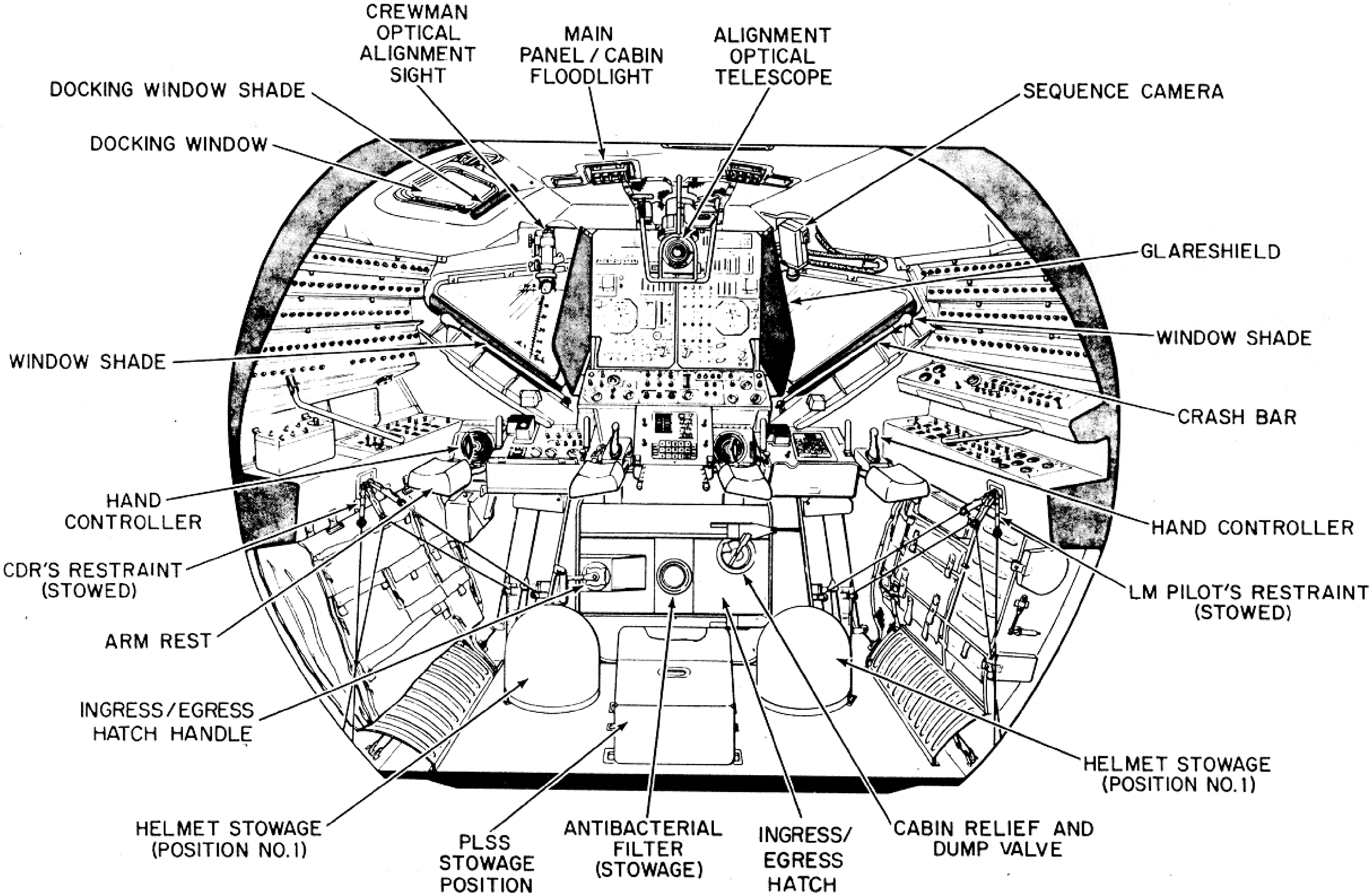
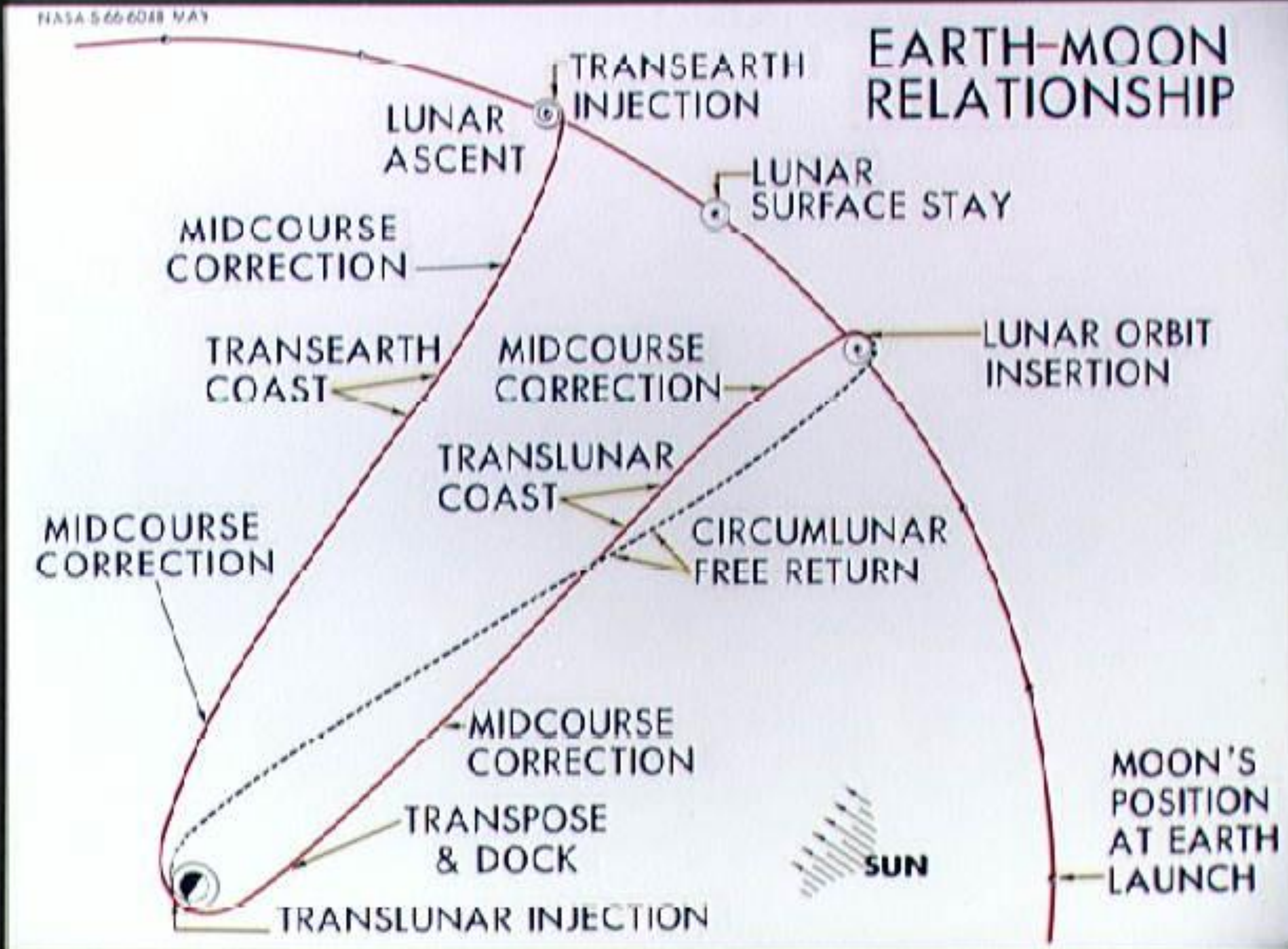
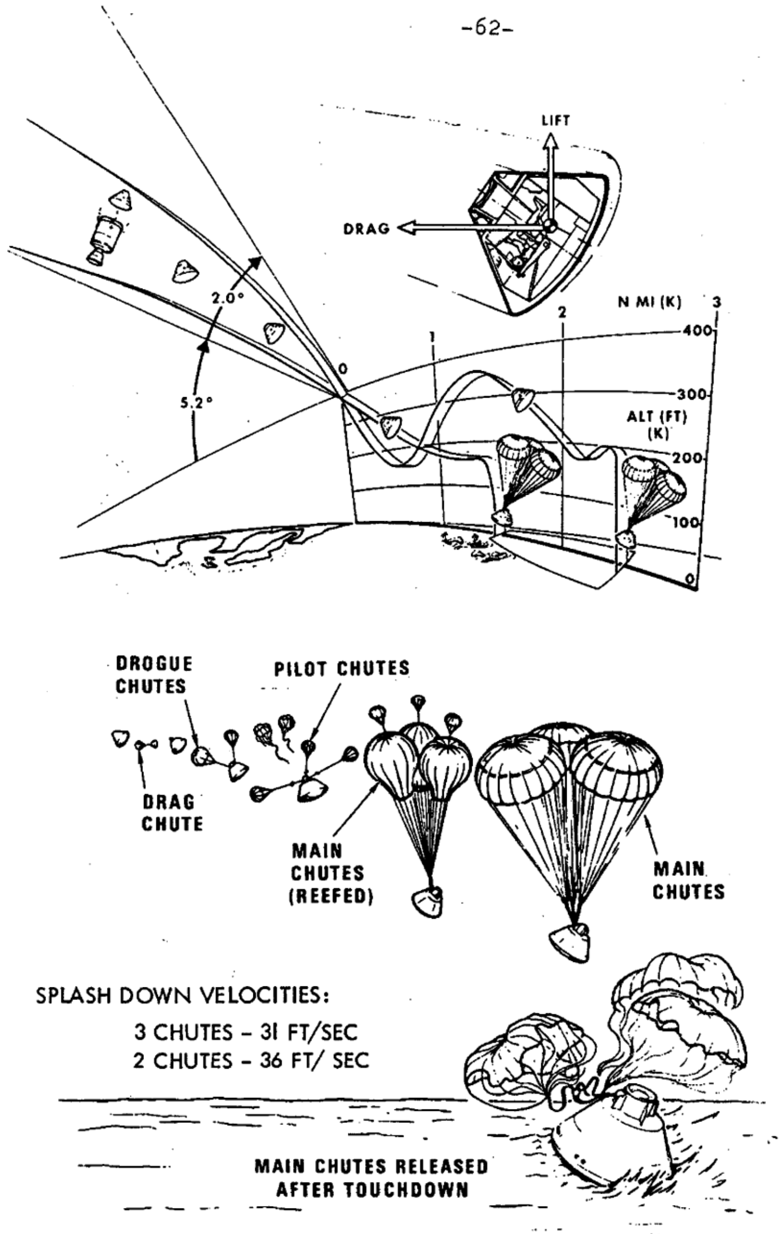
APOLLO COMMAND MODULE MAIN CONTROL PANEL



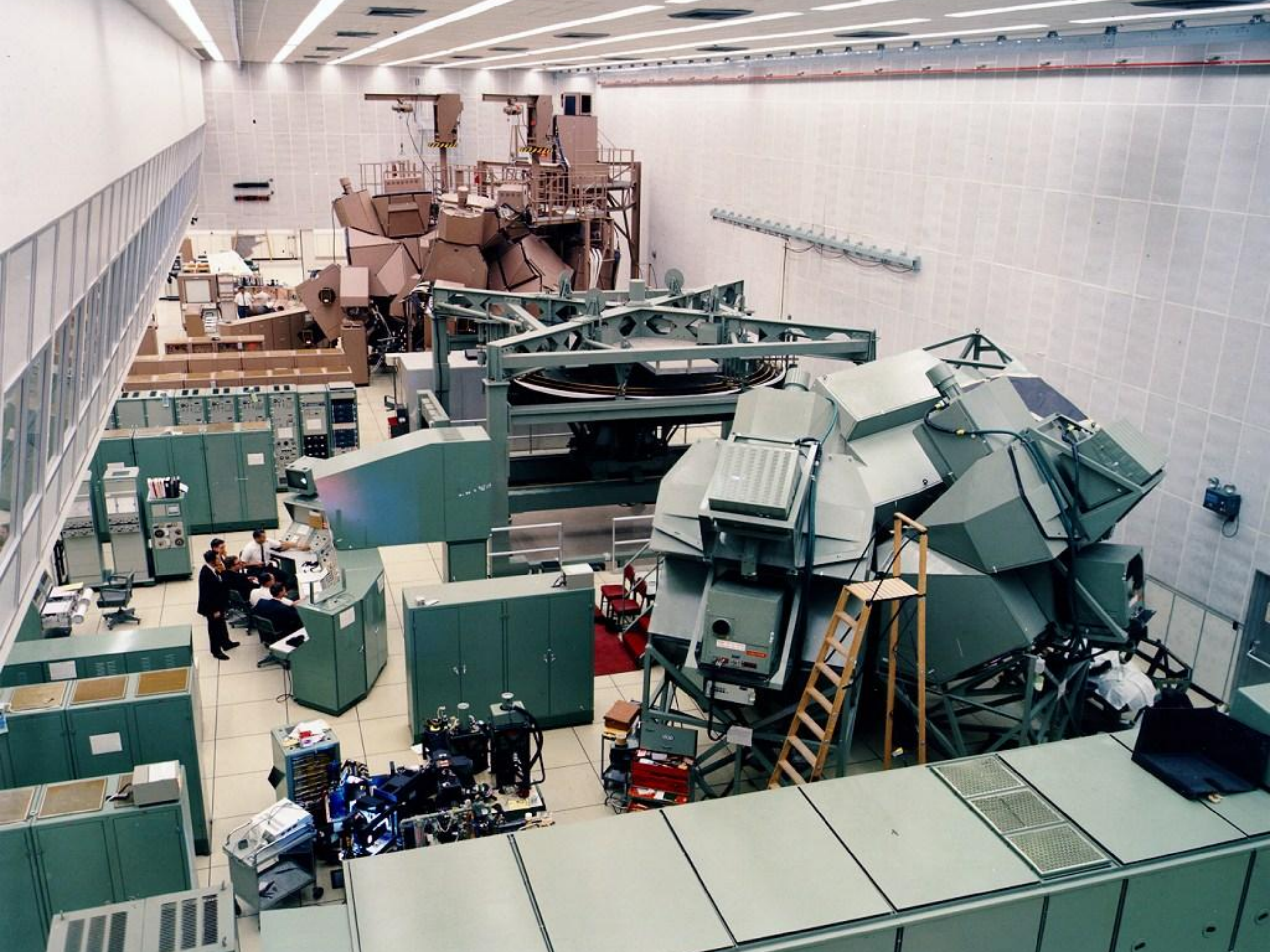
LUNAR MODULE ASCENT STAGE INTERIOR VIEW LOOKING FORWARD

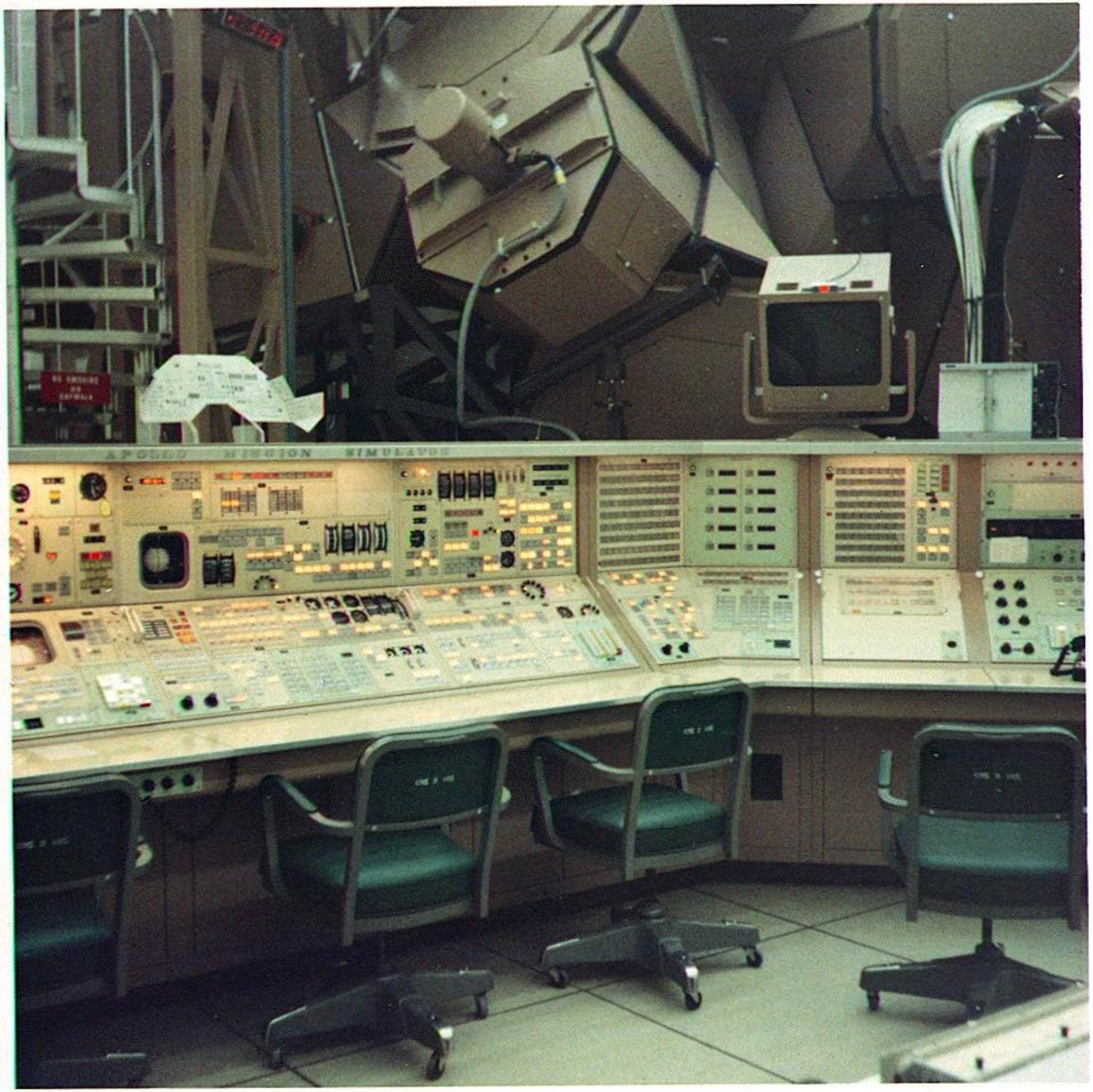



NASA S 66 6048 MAY
EARTH-MOON RELATIONSHIP
TRANSEARTH INJECTION
LUNAR ASCENT
LUNAR SURFACE STAY
MIDCOURSE CORRECTION
LUNAR ORBIT INSERTION
TRANSEARTH COAST
MIDCOURSE CORRECTION
TRANSLUNAR COAST
CIRCUMLUNAR FREE RETURN
MIDCOURSE CORRECTION
MIDCOURSE CORRECTION
MOON'S POSITION AT EARTH LAUNCH
TRANSPOSE & DOCK
SUN
TRANSLUNAR INJECTION

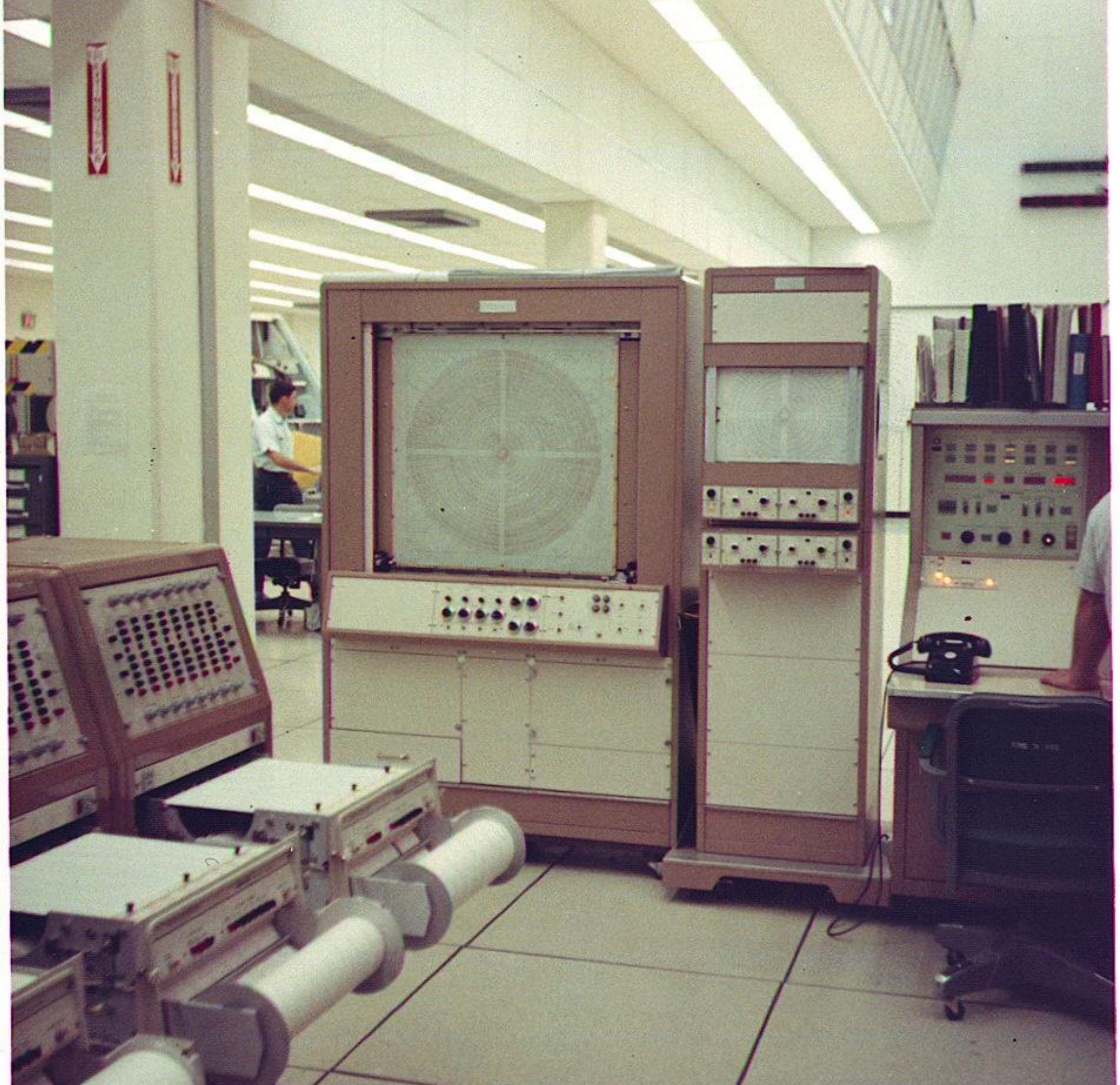


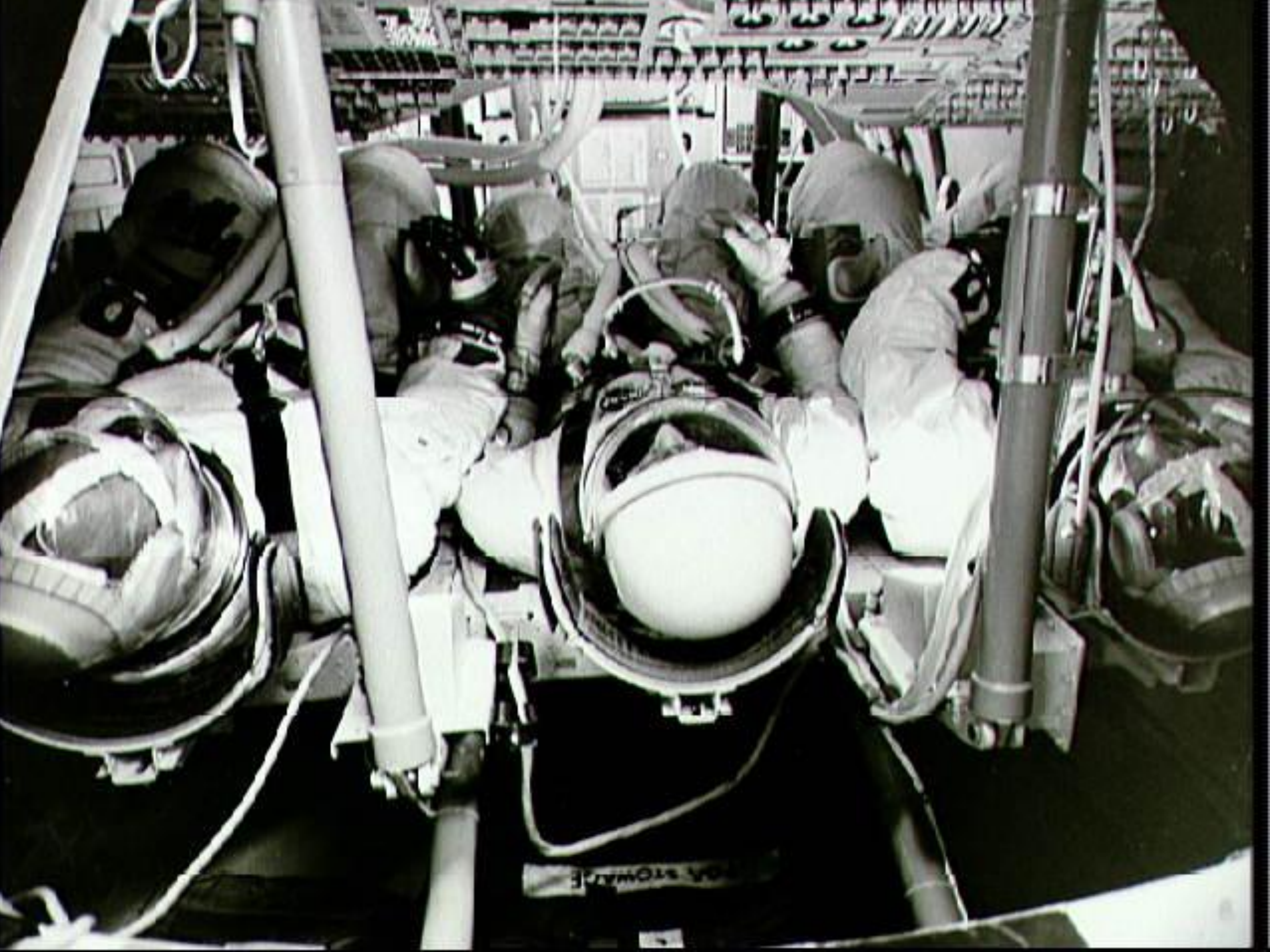
EARTH RE-ENTRY AND LANDING

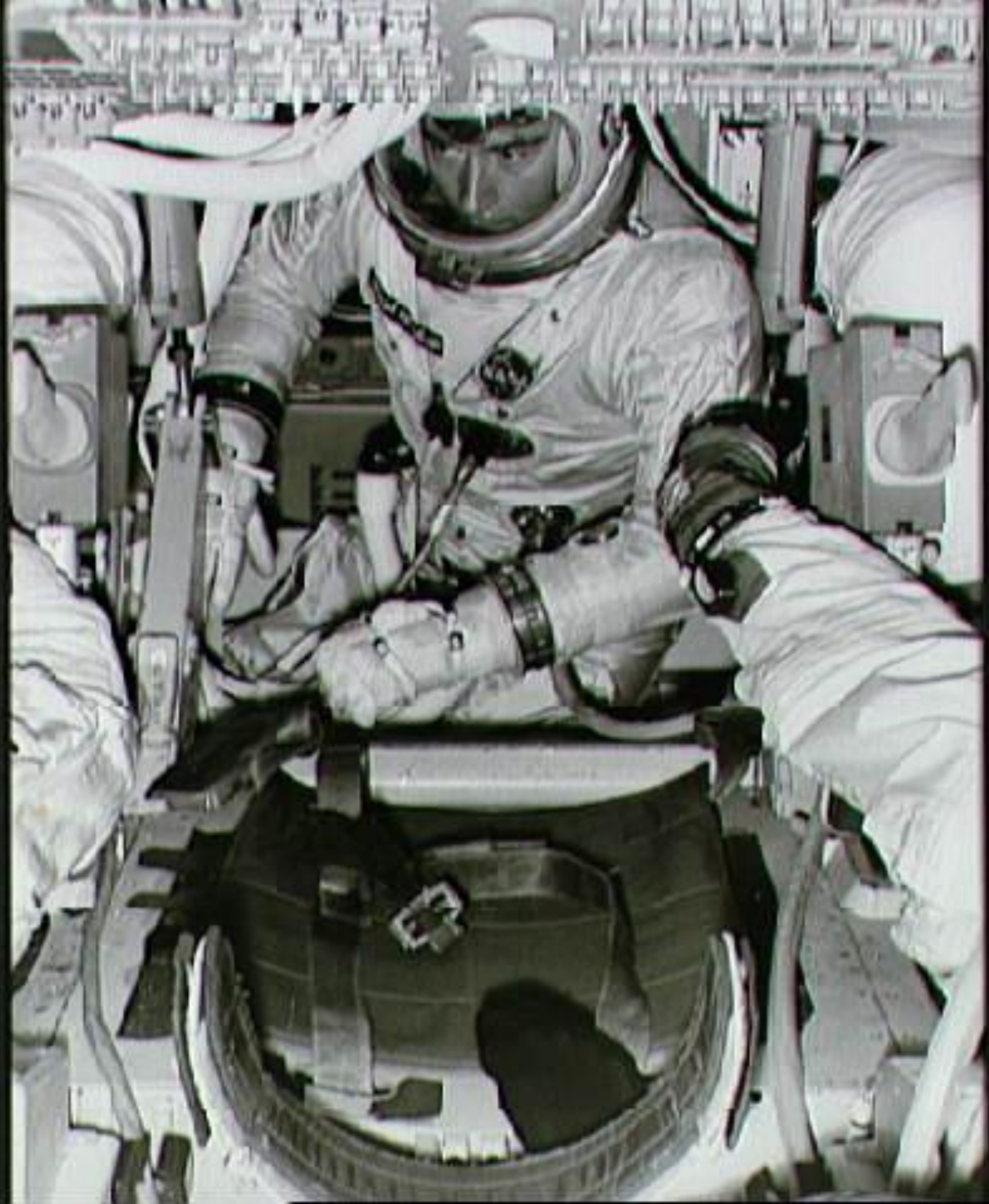


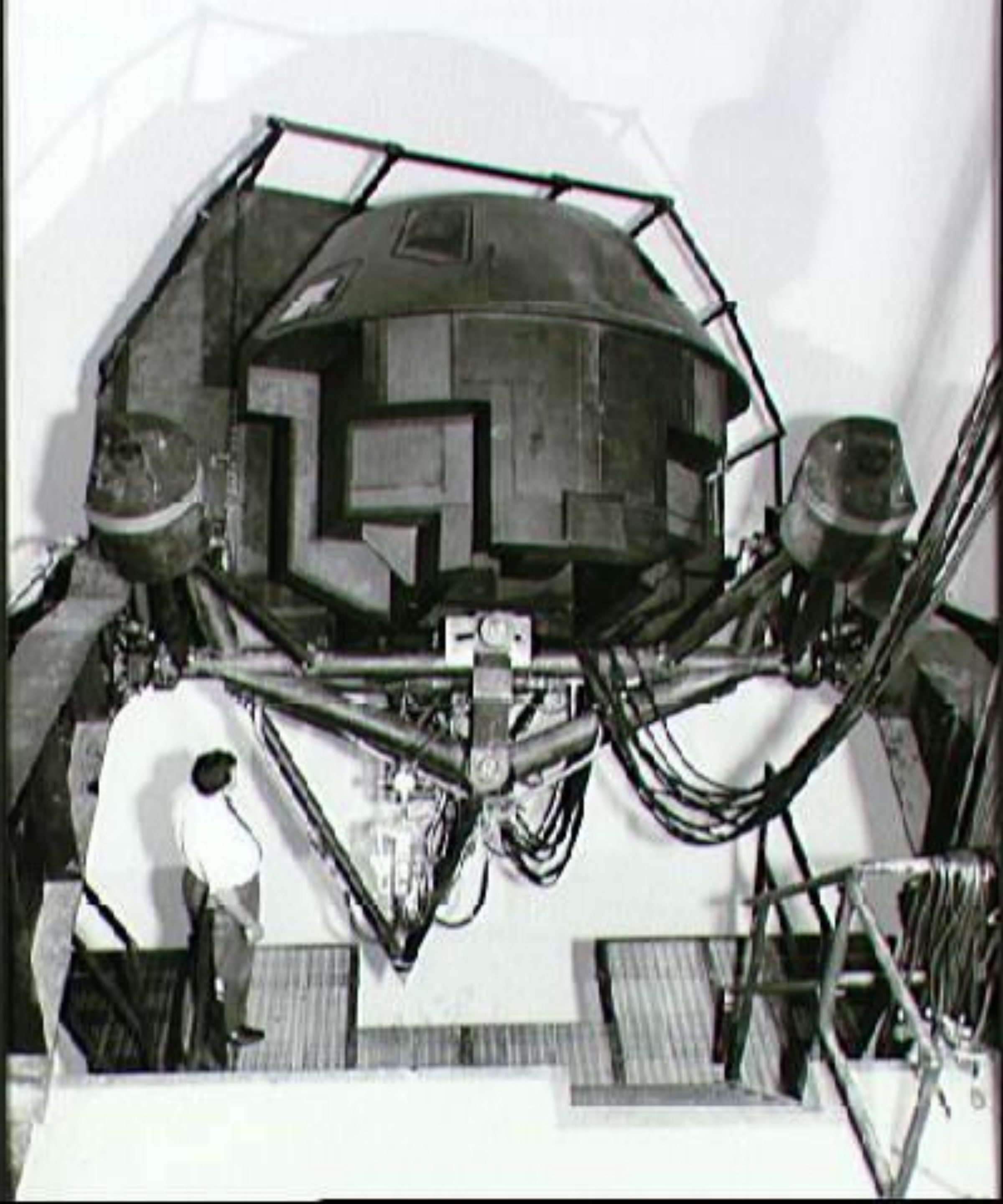

APOLLO MISSION SIMULATOR

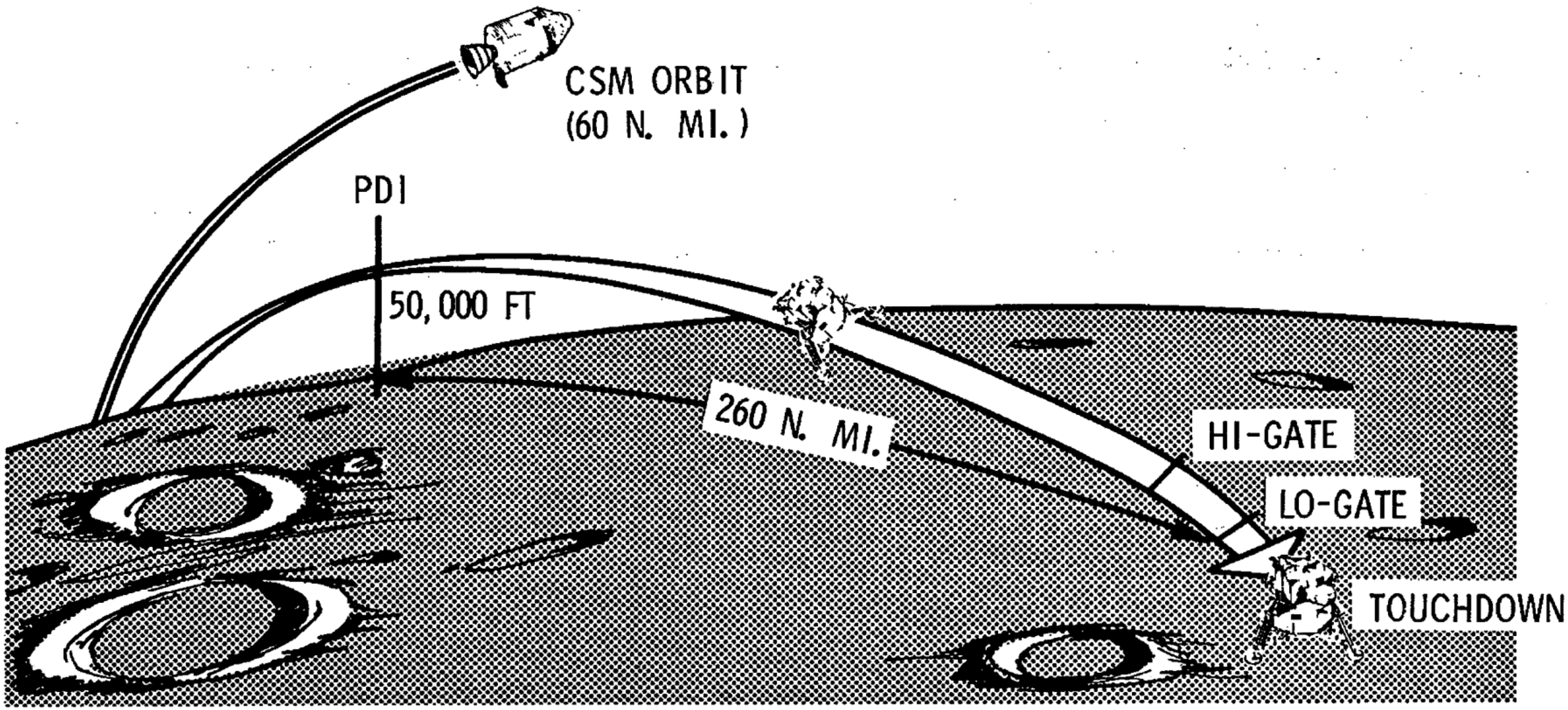

FRESCA







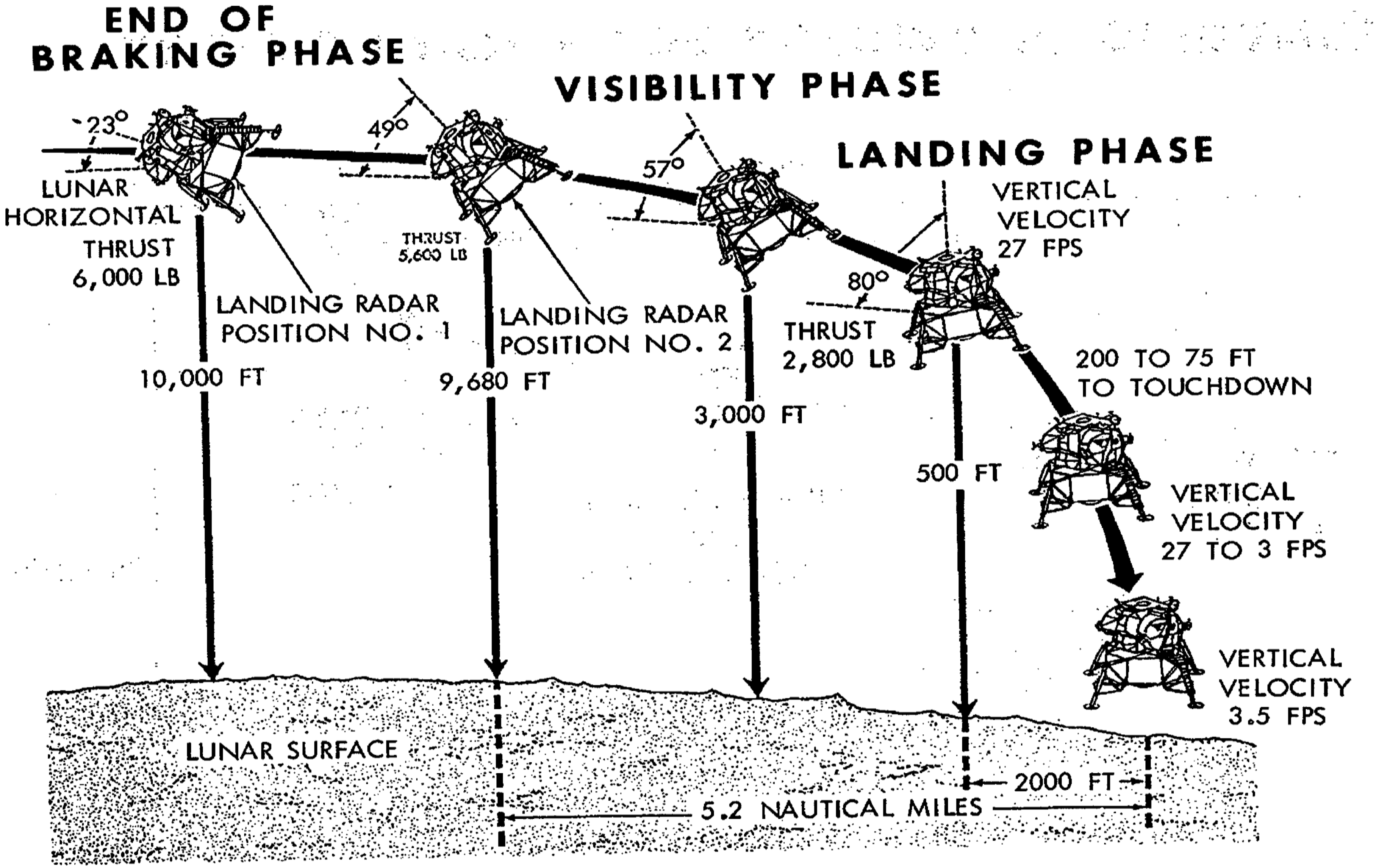




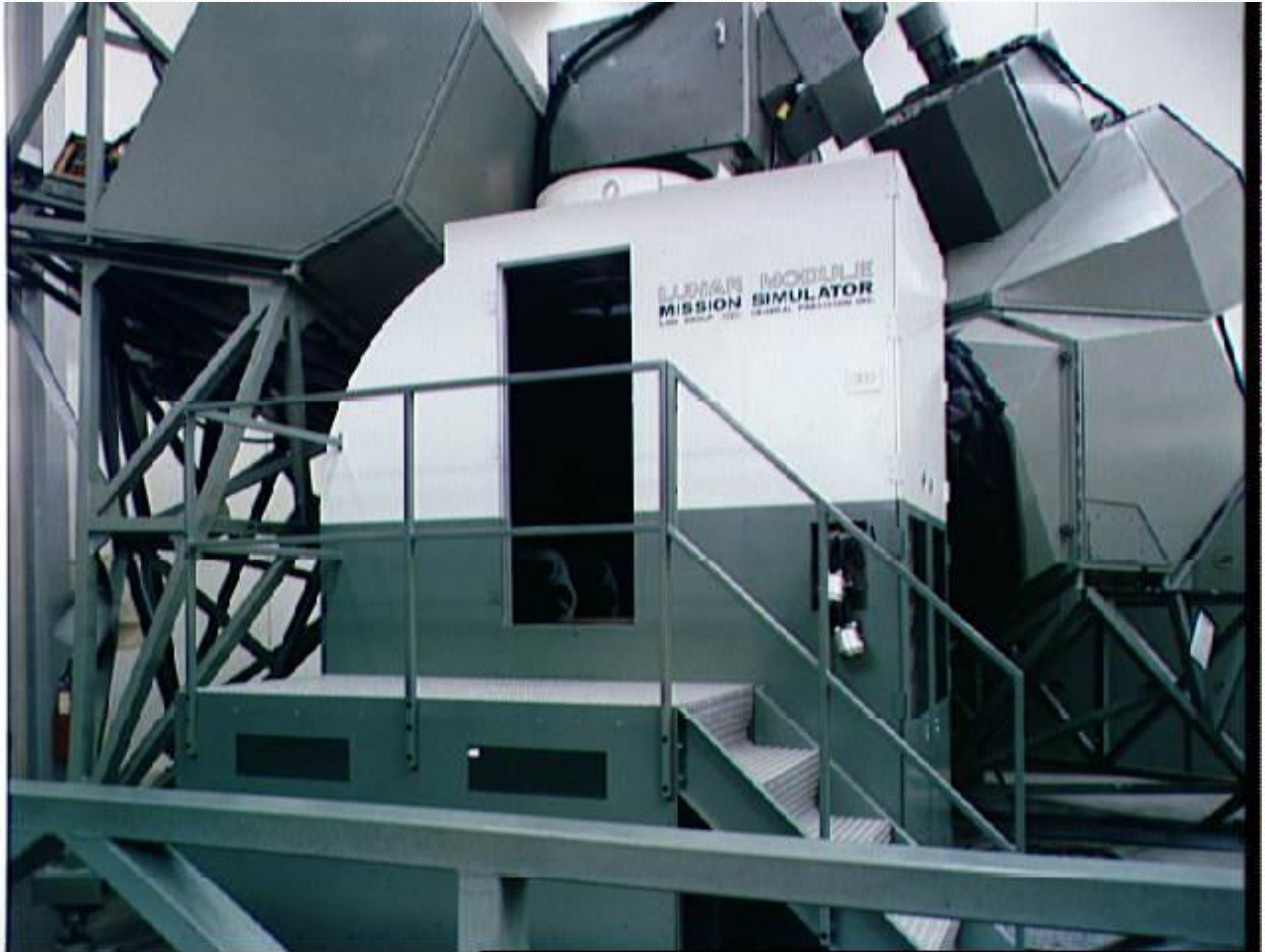
DESIGN CRITERIA

- BRAKING PHASE (PDI TO HI-GATE) - EFFICIENT REDUCTION OF ORBITAL VELOCITY
- FINAL APPROACH PHASE (HI-GATE TO LO-GATE) - CREW VISIBILITY (SAFETY OF FLIGHT AND SITE ASSESSMENT)
- LANDING PHASE (LO-GATE TO TOUCHDOWN) - MANUAL CONTROL TAKEOVER

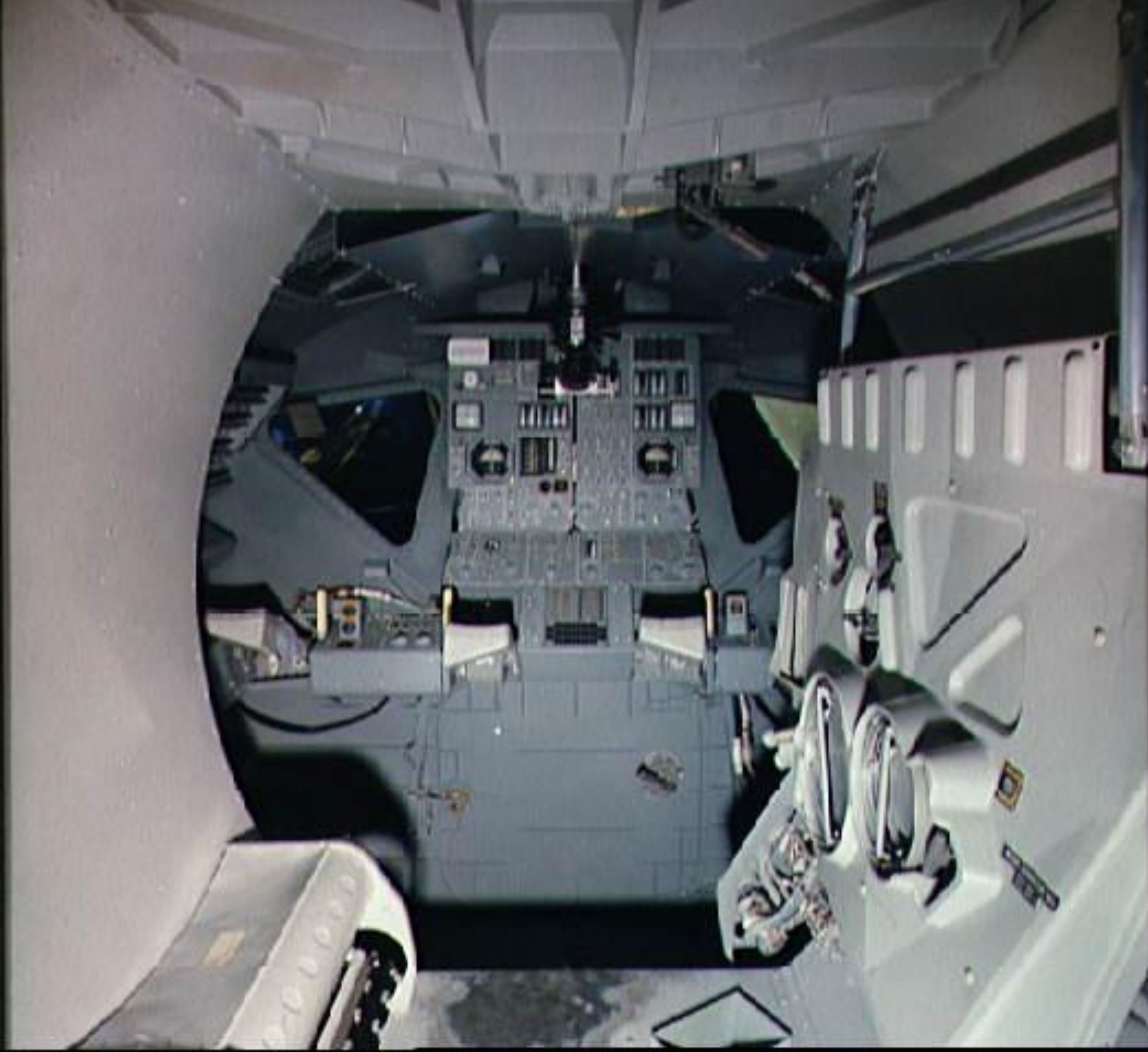
PERATIONAL PHASES OF POWERED DESCENT

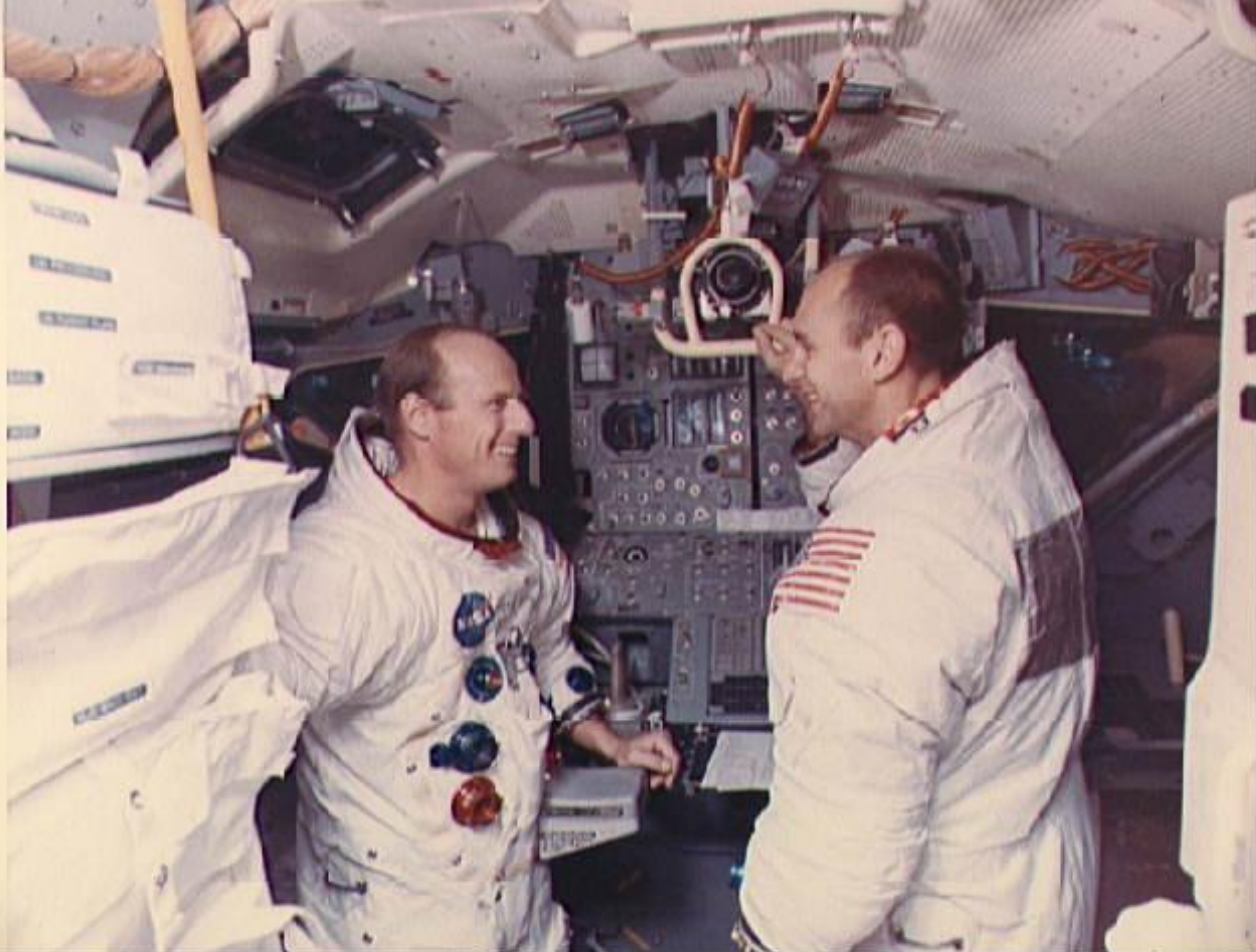


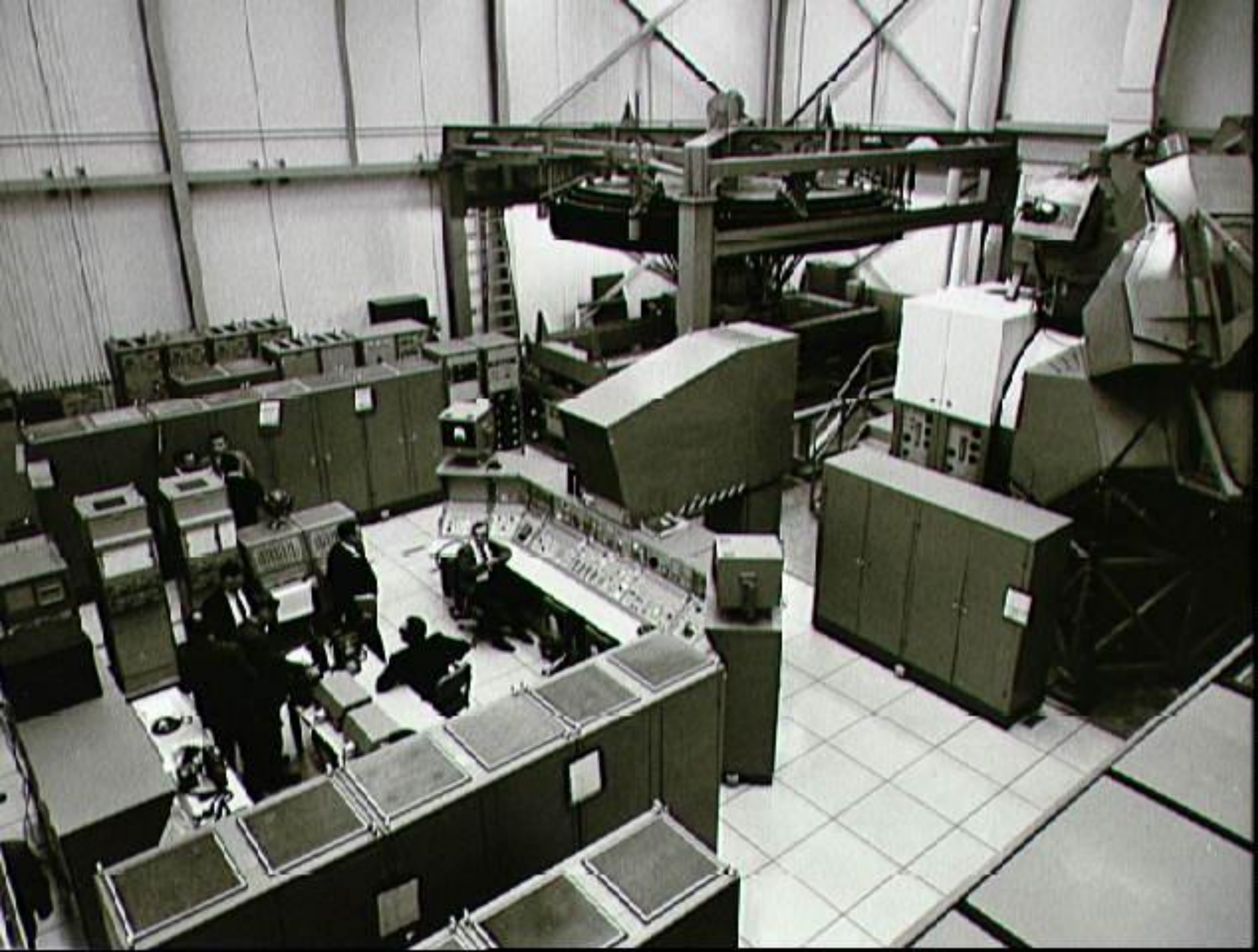
NOMINAL DESCENT TRAJECTORY FROM HIGH GATE TO TOUCHDOWN

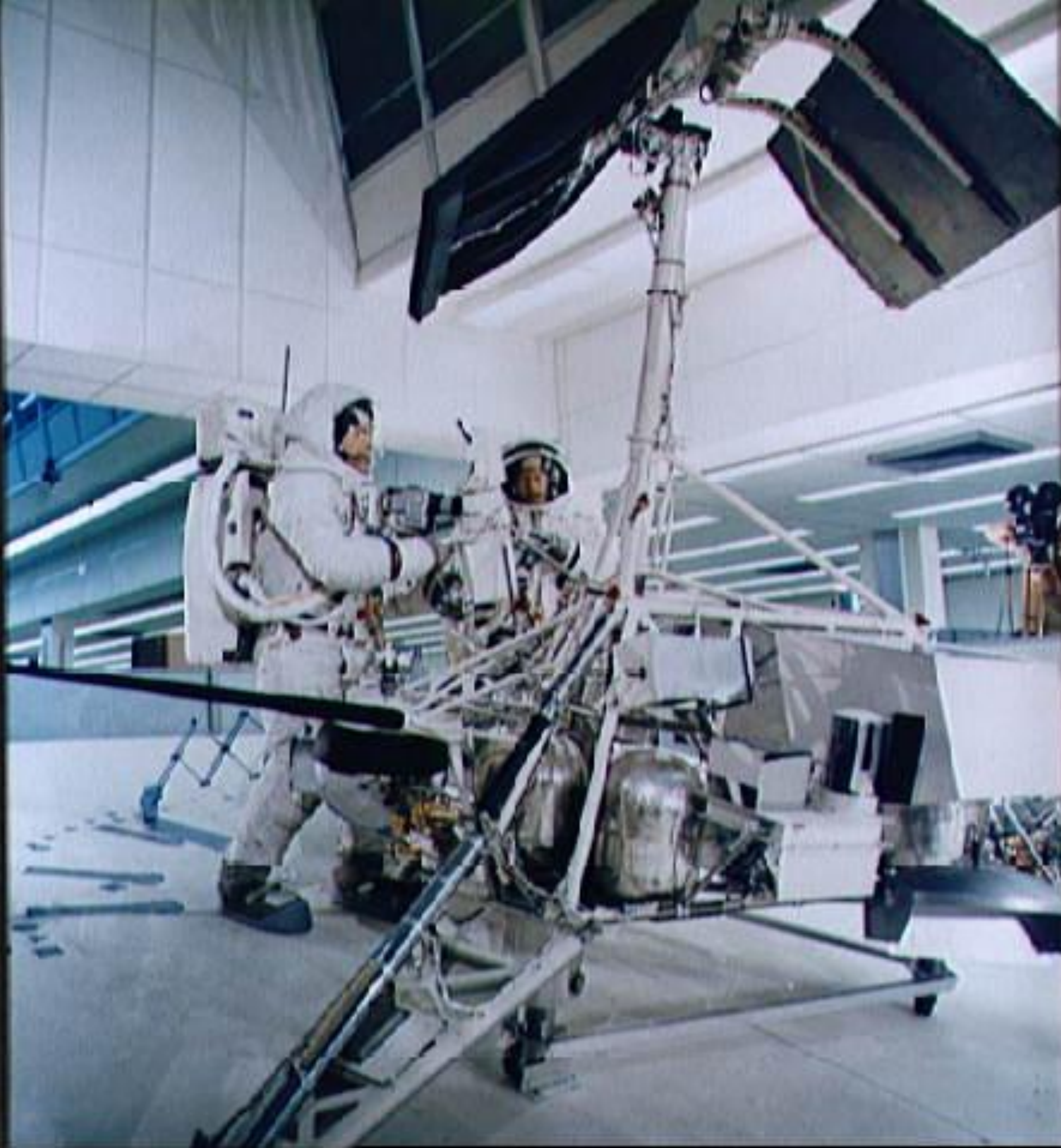


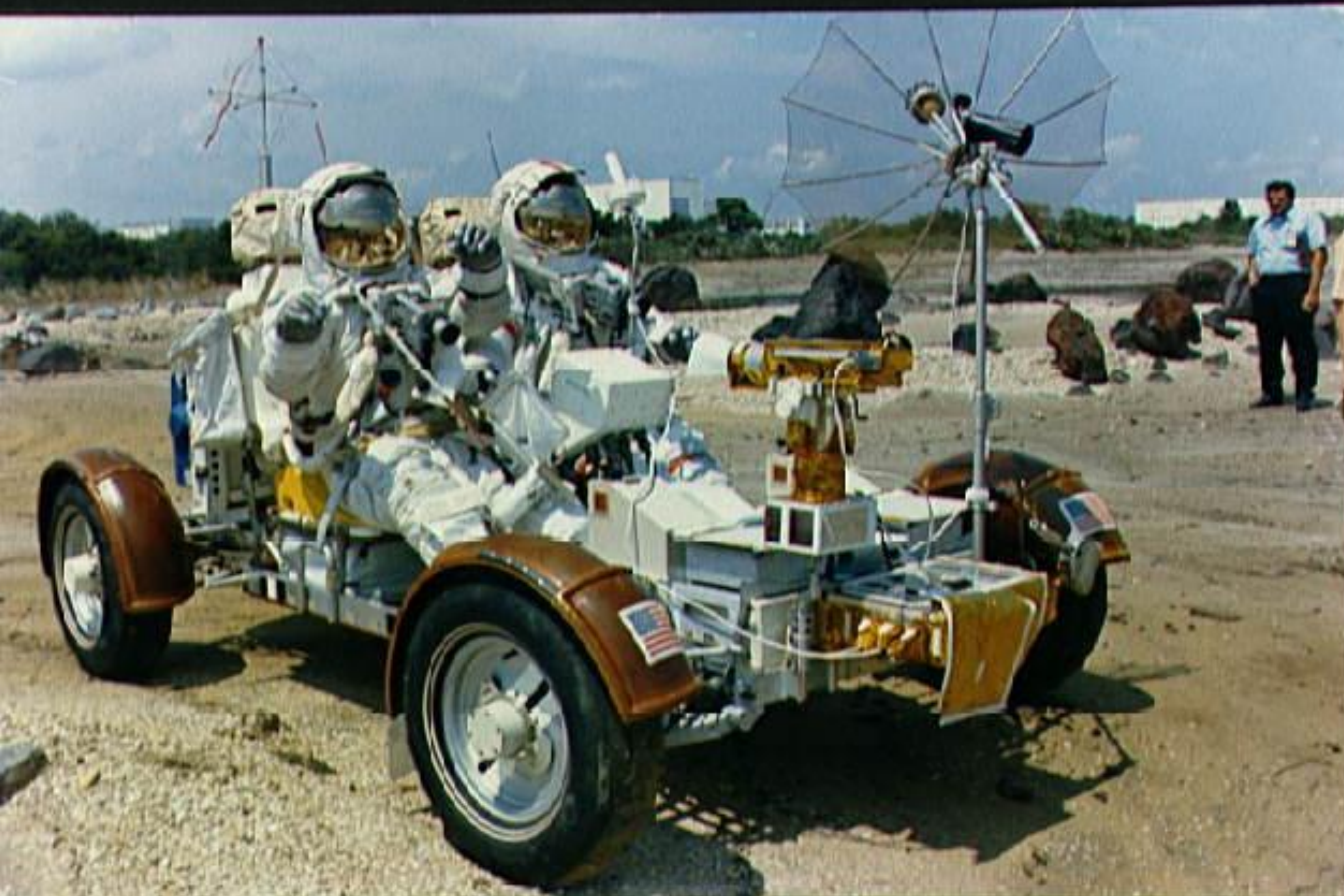
MISSION SIMULATOR









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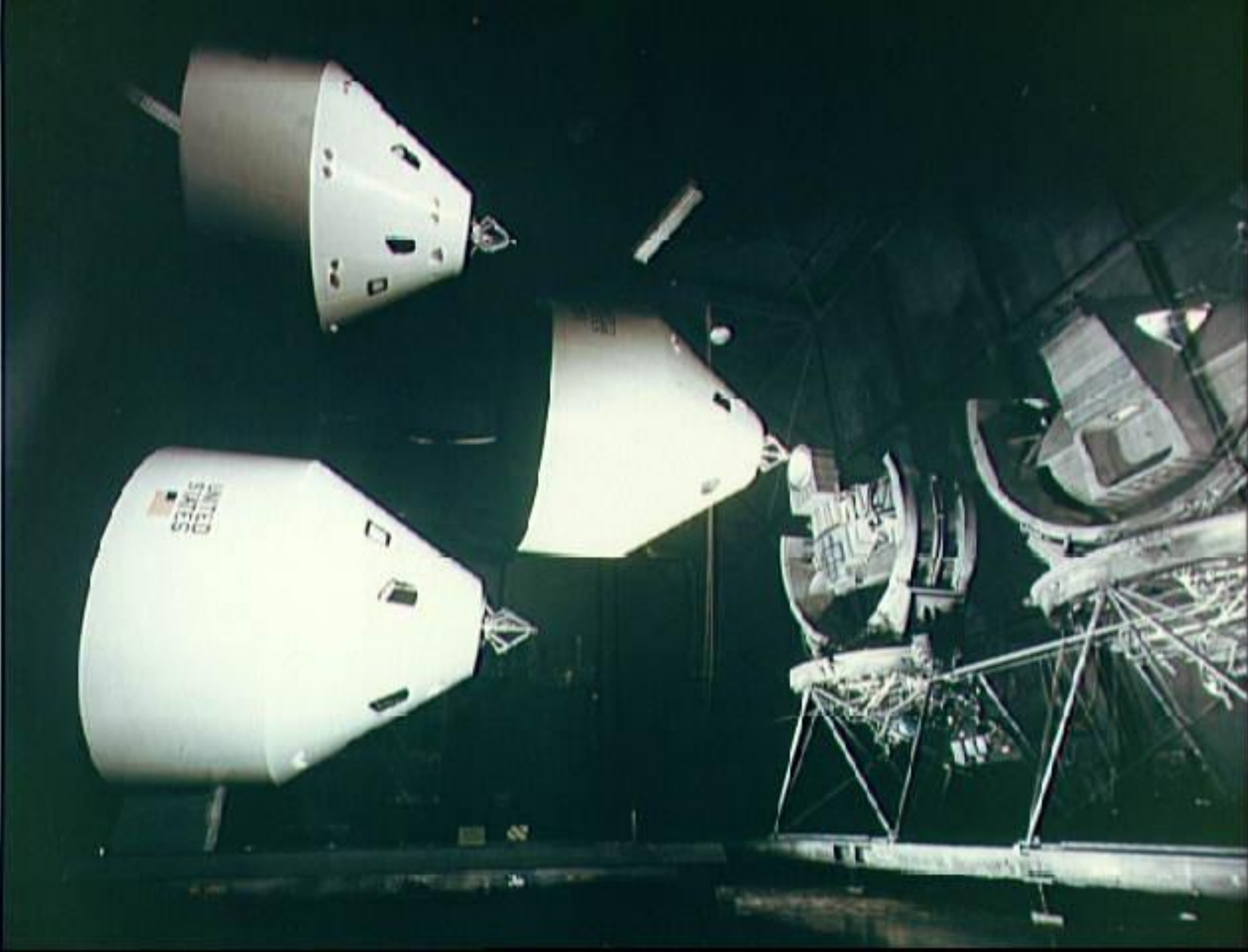
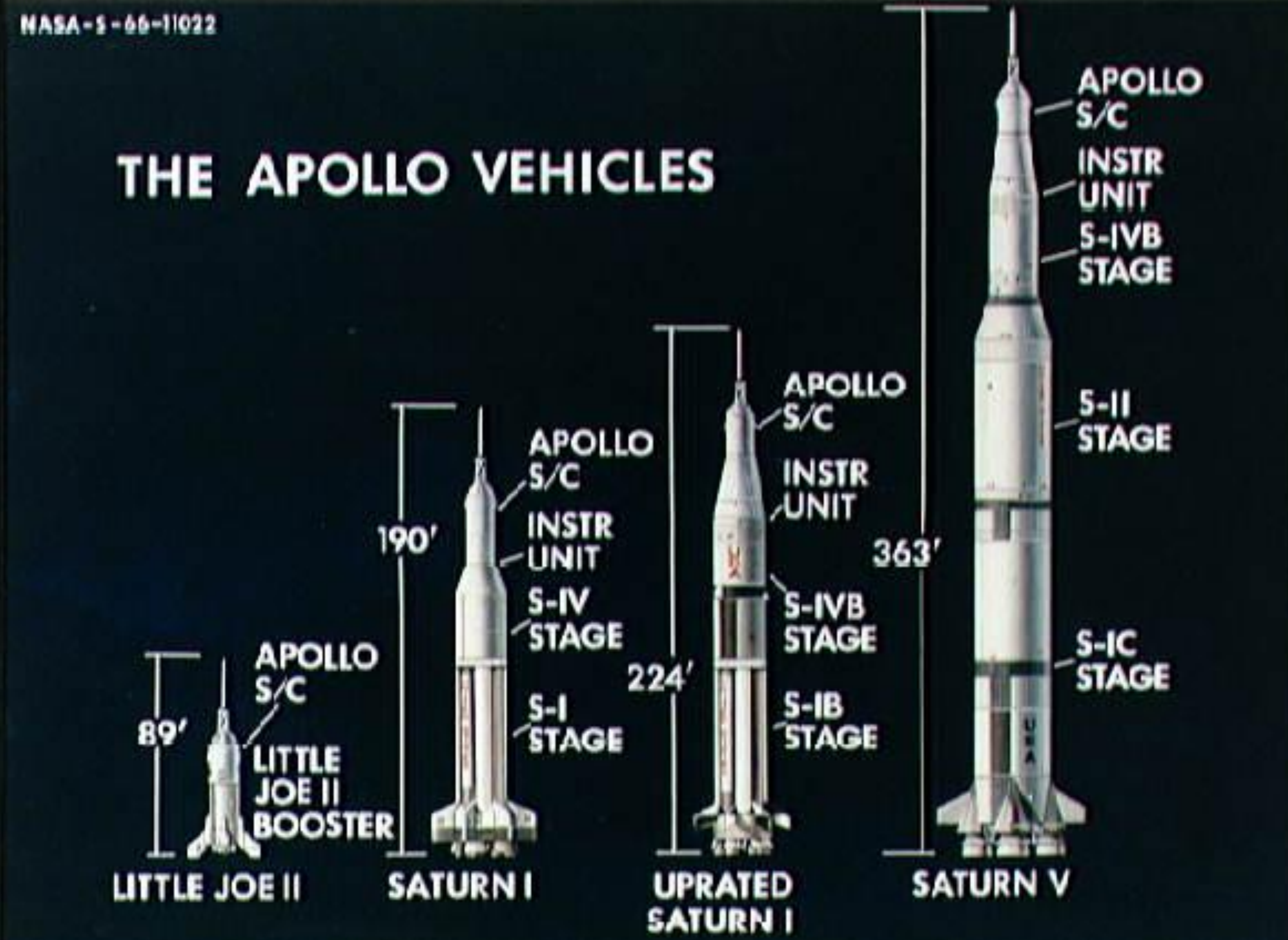
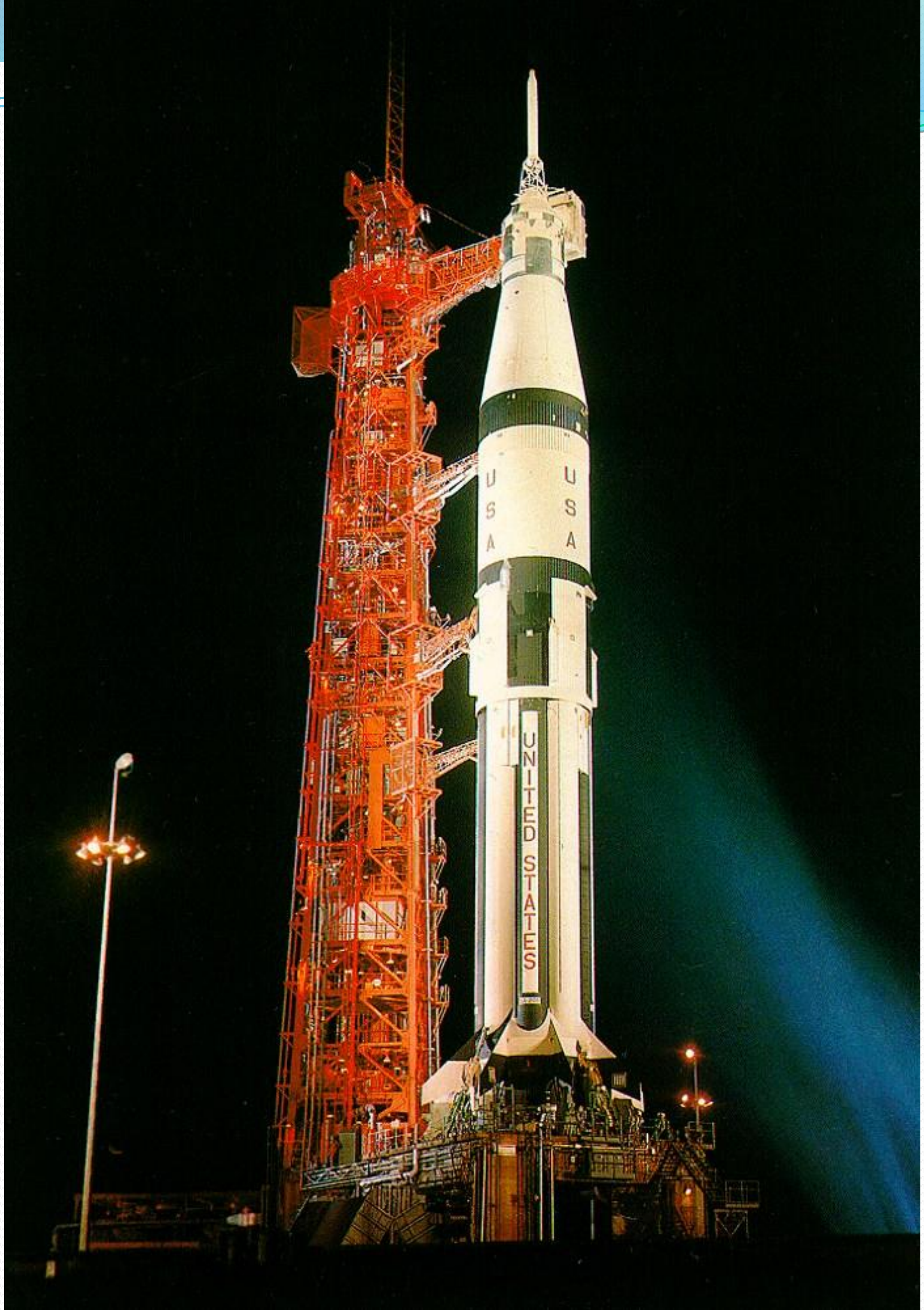

UNITED STATES

What did we learn?

- Guidance and navigation between planets was understood and operationally easy
- Landing on the moon was straight forward with manual controls available
- Lunar surface EVA was OK but suit balance was critical and EVA gloves were a continuing problem
- We felt that we could go back to the Moon and land anywhere with our capabilities
- We could go anywhere else…


NASA-S-66-11022
THE APOLLO VEHICLES
89'
APOLLO S/C
LITTLE JOE II BOOSTER
LITTLE JOE II
190'
APOLLO S/C
INSTR UNIT
S-IV STAGE
S-I STAGE
SATURN I
224'
APOLLO S/C
INSTR UNIT
S-IVB STAGE
S-IB STAGE
UPRATED SATURN I
363'
APOLLO S/C
INSTR UNIT
S-IVB STAGE
S-II STAGE
S-IC STAGE
SATURN V


USA
USA
UNITED STATES

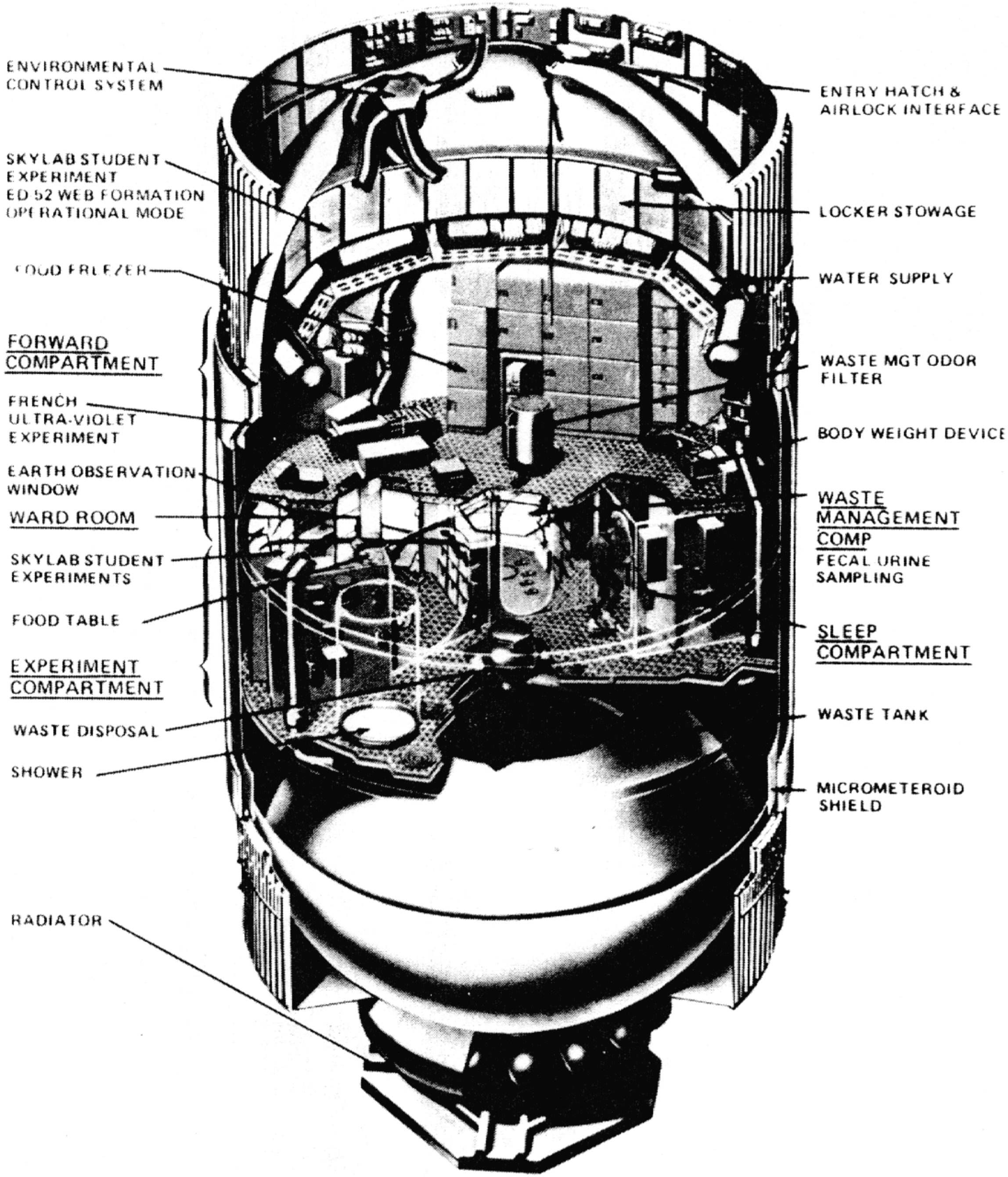
Skylab (Apollo Applications)

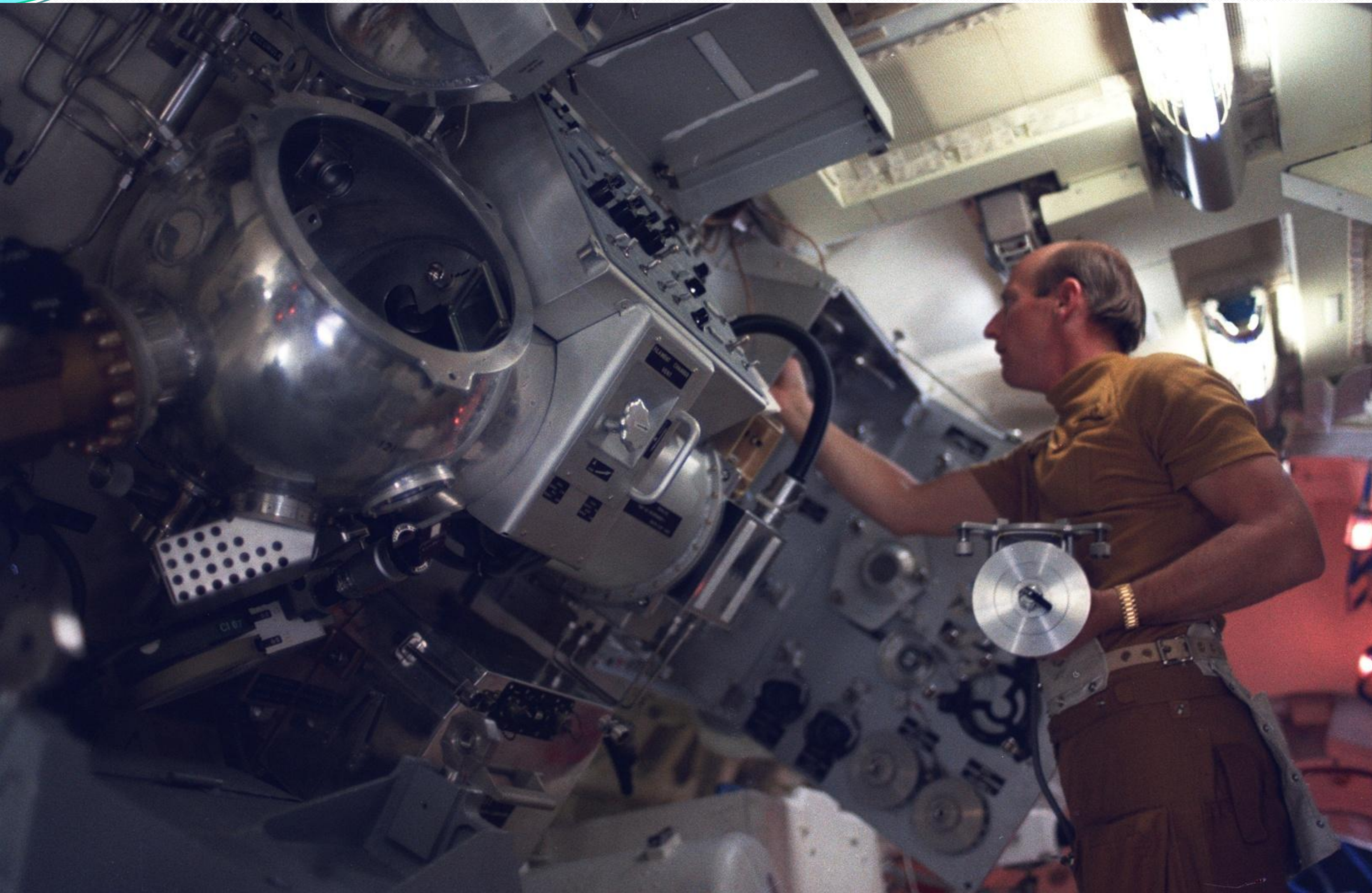
- Goals
  - To prove that humans could live and work in space for extended periods
  - To expand our knowledge of solar astronomy well beyond Earth-based observations
  - It was the site of nearly 300 scientific and technical experiments:
    - medical experiments on humans' adaptability to zero gravity
    - solar observations
    - detailed Earth resources experiments

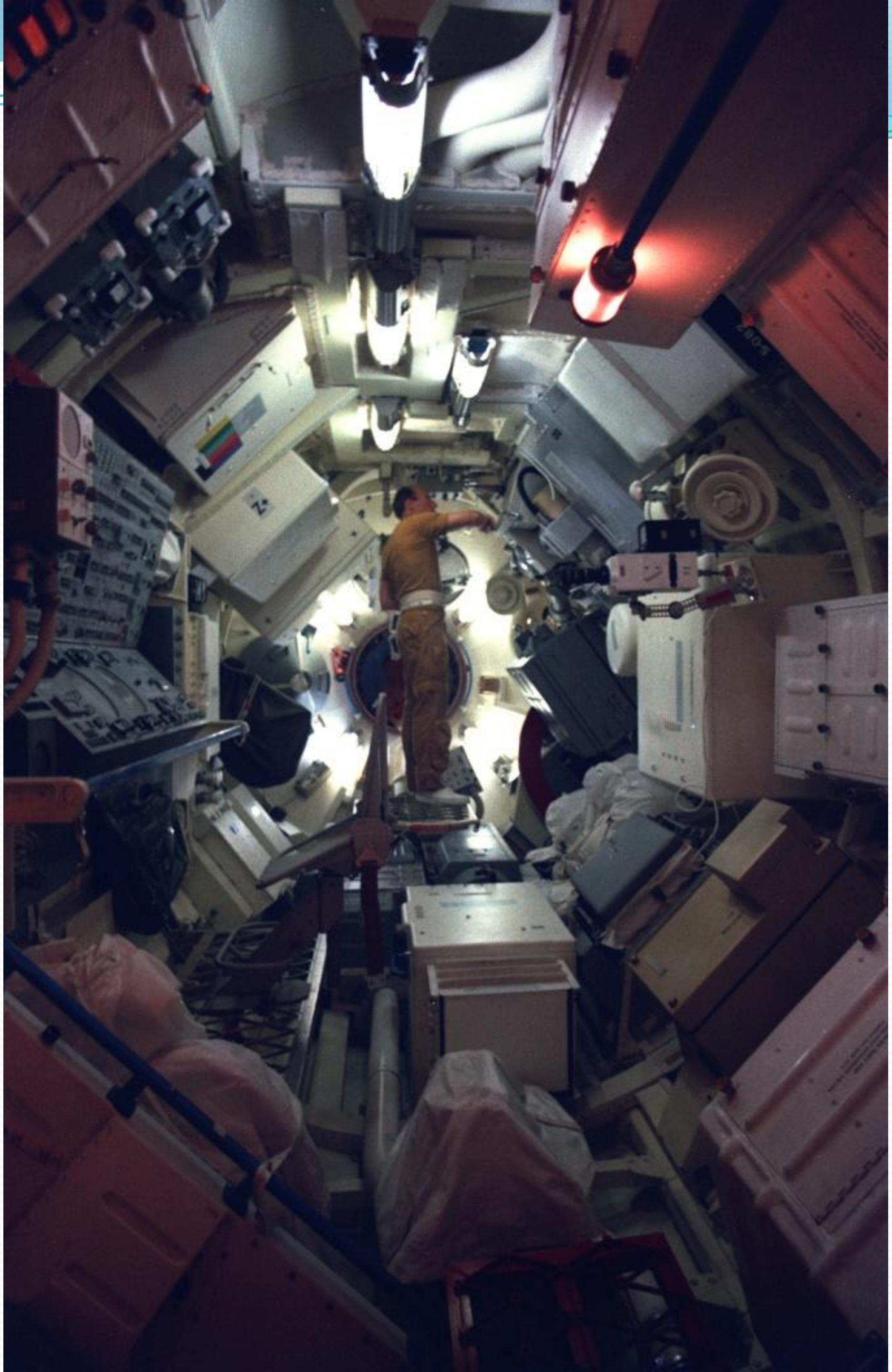
Skylab Systems

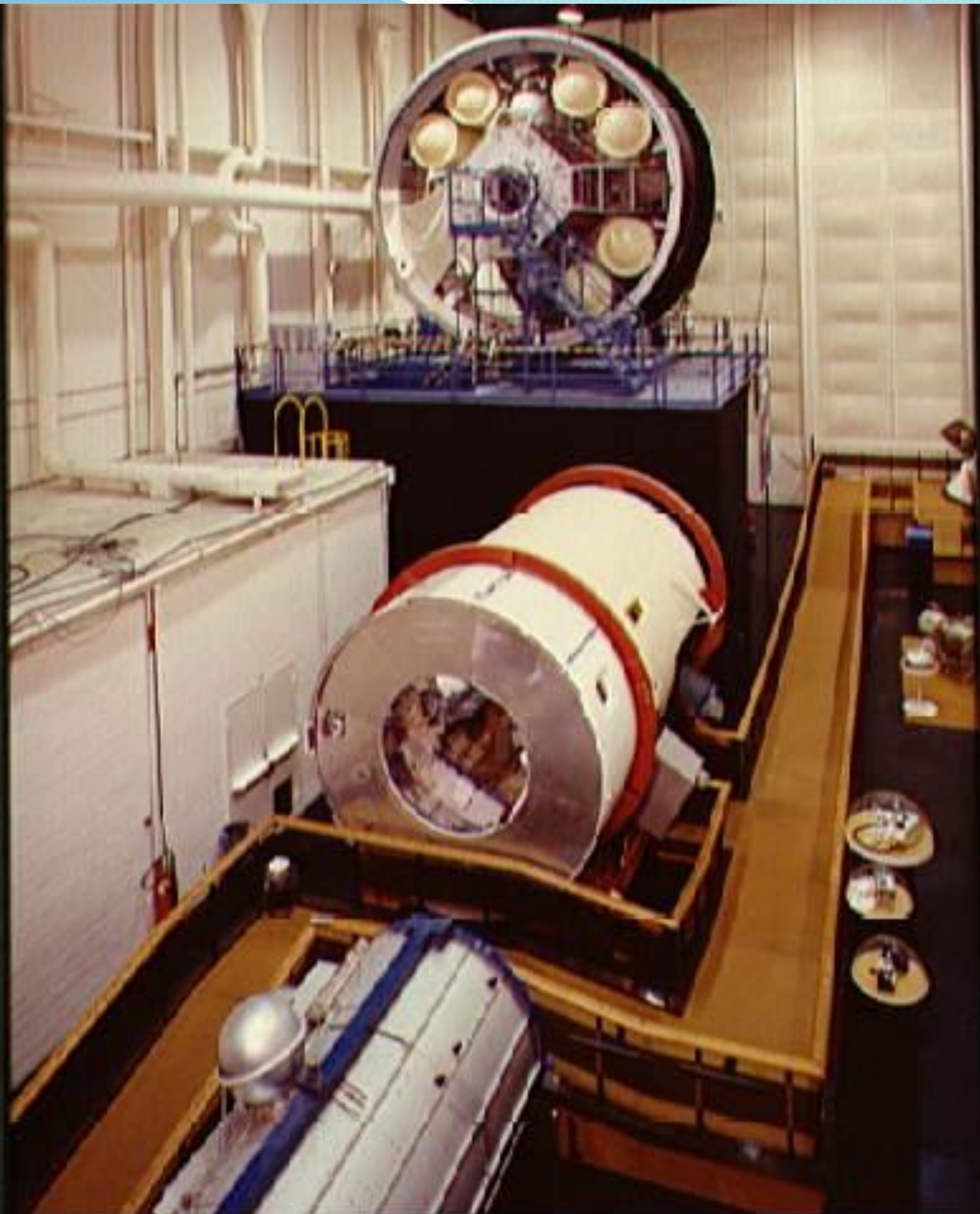
- Build a laboratory inside a surplus S-IVB from Saturn 513
- Flew three manned crews in 1973-1974 on 28, 59, and 84 days
- Performed mammoth amounts of science, engineering and medical studies
- Featured the first private bathroom and toilet

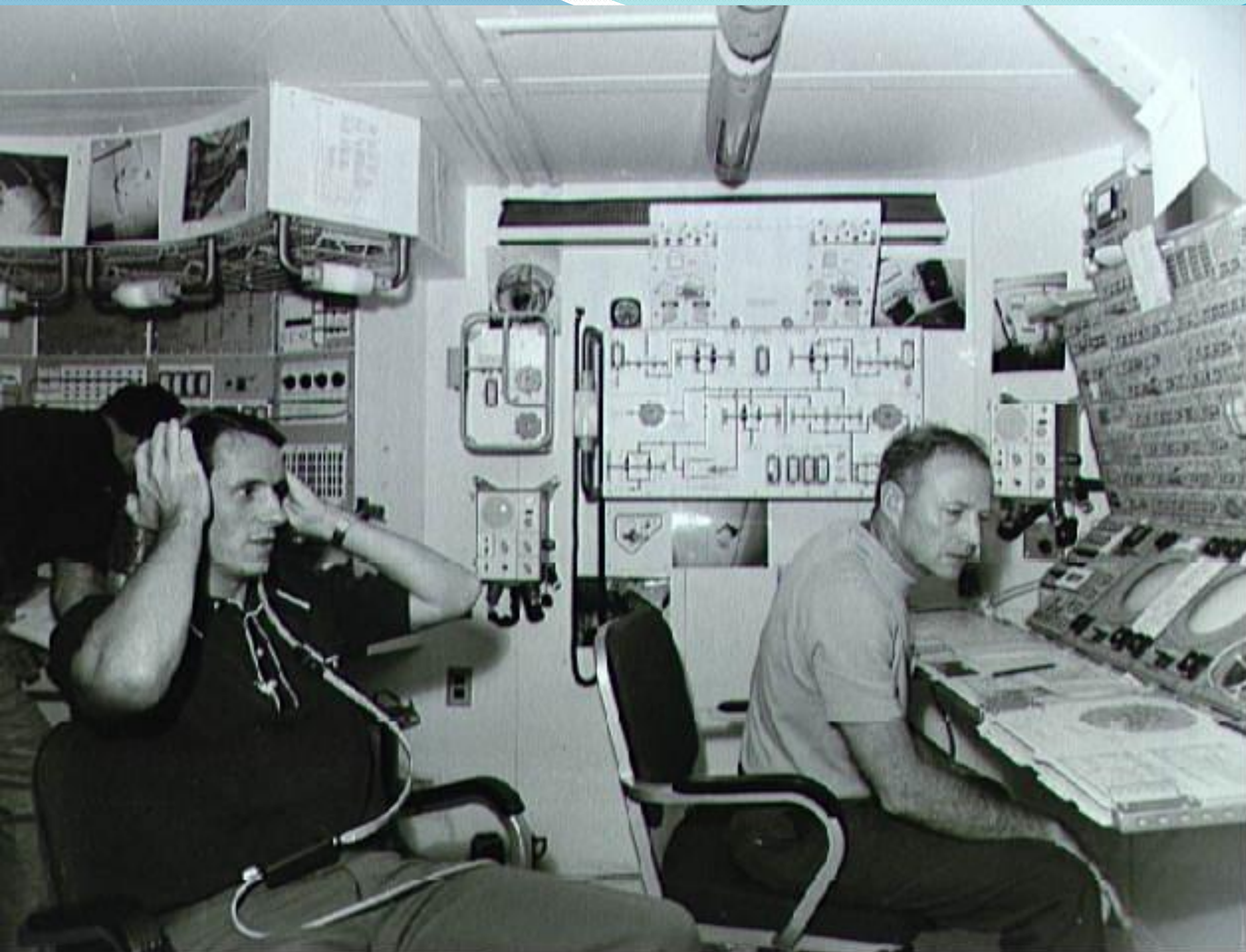
SKYLAB ORBITAL WORKSHOP

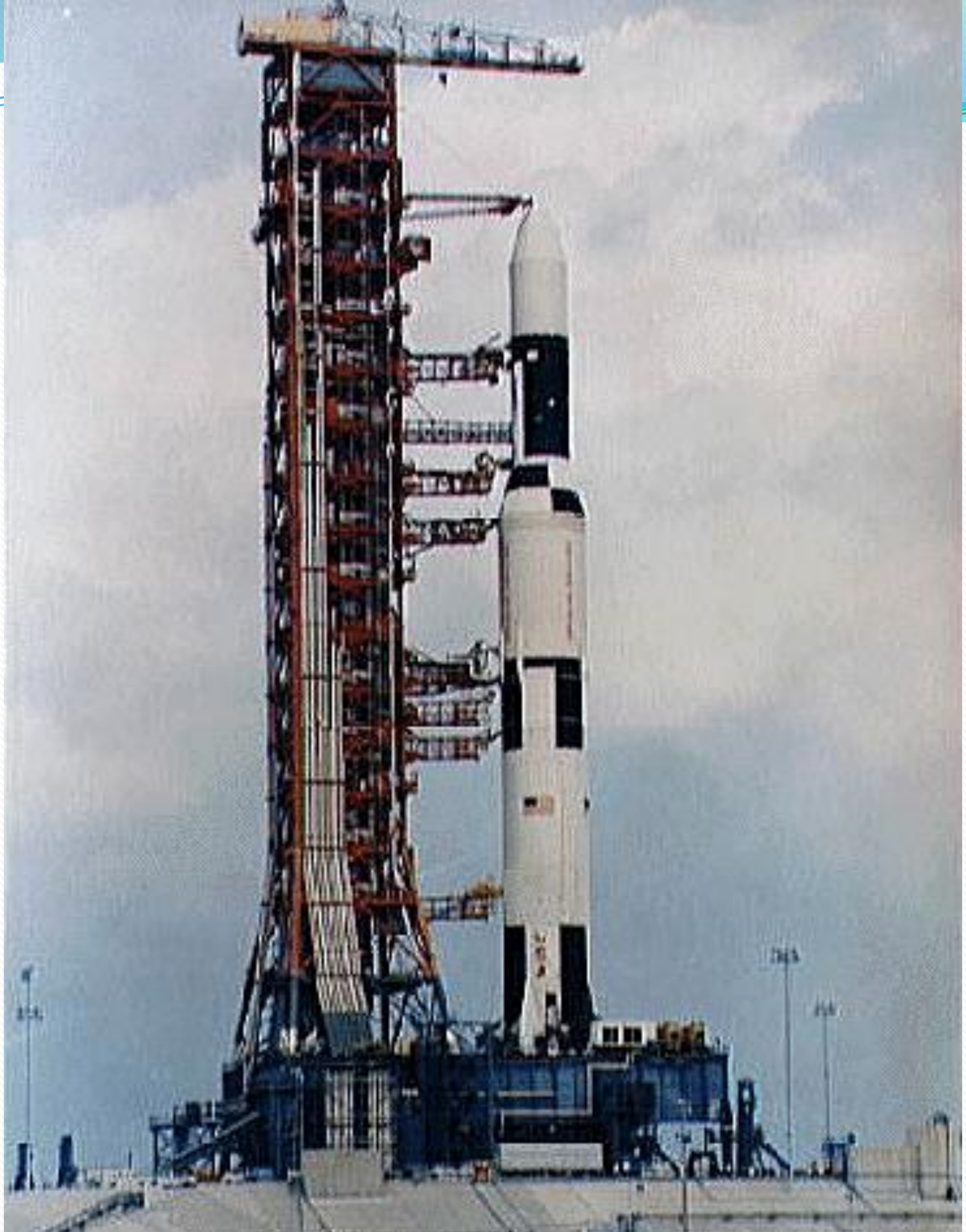












Skylab

A. COMMAND & SERVICE MODULE

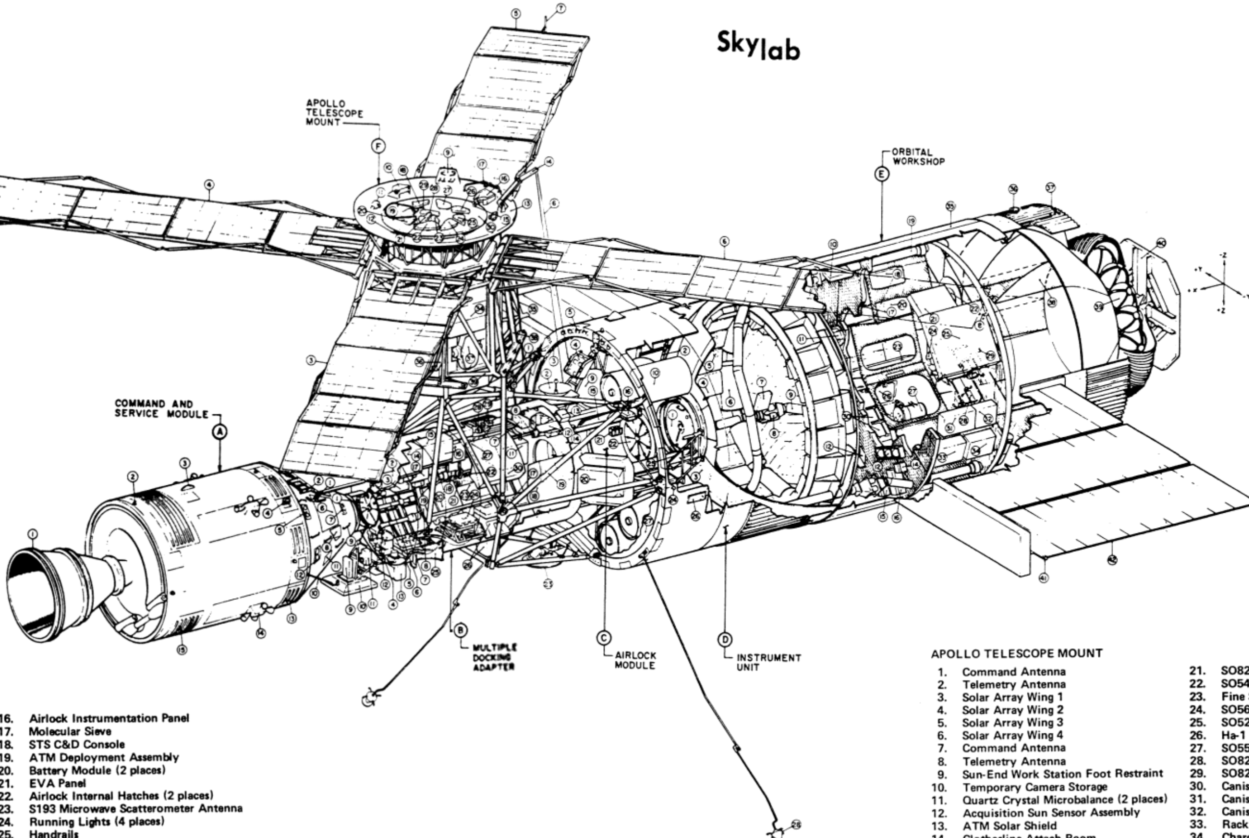
1. SPS Engine
2. Running Lights (8 places)
3. Scimitar Antenna
4. Docking Light
5. Pitch Control Engines
6. Crew Hatch
7. Pitch Control Engines
8. Rendezvous Window
9. EVA Handholds
10. EVA Light
11. Side Window
12. Roll Engines (2 places)
13. EPS Radiator Panels
14. SM RCS Module (4 places)
15. ECS Radiator

B. MULTIPLE DOCKING ADAPTER

1. Axial Docking Port Access Hatch
2. Docking Target
3. Exothermic Experiment
4. Infrared Spectrometer Viewfinder
5. Atmosphere Interchange Duct
6. Area Fan
7. Window Cover
8. Cable Trays
9. Inverter Lighting Control Assembly
10. L-Band Antenna
11. Proton Spectrometer
12. Running Lights (4 places)
13. Infrared Spectrometer
14. Film Vault 4
15. Film Vault 1
16. SO82 (A&B) Canisters
17. M512/M479 Experiment
18. Area Fan
19. Composite Casting
20. Film Vault 2
21. TV Camera Input Station
22. Utility Outlet
23. M168 STS Miscellaneous Stowage Container
24. Redundant Tape Recorder
25. Radial Docking Port
26. 10-Band Multispectral Scanner
27. TV Camera Input Station
28. Temperature Thermostat
29. Radio Noise Burst Monitor
30. ATM C&D Console

C. AIRLOCK MODULE

1. Deployment Assembly Reels and Cables
2. Solar Radio Noise Burst Monitor Antenna
3. Handrails
4. DO21/DO24 Sample Panels
5. (Removed)
6. Clothesline (EVA use)
7. Permanent Stowage Container
8. STA IVA Station
9. Nitrogen Tanks (6 places)
10. Oxygen Tanks (6 places)
11. Molecular Sieve
12. Condensate Module
13. Electrical Feedthru Cover
14. Electronics Module 1
15. EVA Hatch
16. Airlock Instrumentation Panel
17. Molecular Sieve
18. STS C&D Console
19. ATM Deployment Assembly
20. Battery Module (2 places)
21. EVA Panel
22. Airlock Internal Hatches (2 places)
23. S193 Microwave Scatterometer Antenna
24. Running Lights (4 places)
25. Handrails
26. Stub Antennas (2 places)
27. Thermal Blanket
28. Discone Antenna (2 places)



APOLLO TELESCOPE MOUNT

1. Command Antenna
2. Telemetry Antenna
3. Solar Array Wing 1
4. Solar Array Wing 2
5. Solar Array Wing 3
6. Solar Array Wing 4
7. Command Antenna
8. Telemetry Antenna
9. Sun-End Work Station Foot Restraint
10. Temporary Camera Storage
11. Quartz Crystal Microbalance (2 places)
12. Acquisition Sun Sensor Assembly
13. ATM Solar Shield
14. Clothesline Attach Boom
15. EVA Lights (8 places)
16. Sun-End Film Tree Stowage
17. Handrail
18. SO82-B Experiment Aperture Door
19. Ha-2 Experiment Aperture Door
20. SO82-A Film Retrieval Door
21. SO82-A Experiment Aperture Door
22. SO54 Experiment Aperture Door
23. Fine Sun Sensor Aperture Door
24. SO56 Experiment Aperture Door
25. SO52 Experiment Aperture Door
26. Ha-1 Experiment Aperture Door
27. SO55A Experiment Aperture Door
28. SO82-B2 Experiment Aperture Door
29. SO82-B Film Retrieval Door
30. Canister Solar Shield
31. Canister
32. Canister Radiator
33. Rack
34. Charger-Battery-Regulator Modules (18 places)
35. Handrail
36. CMG Inverter Assembly (3 places)
37. Control Moment Gyro (3 places)
38. Solar Wing Support Structure (3 places)
39. ATM Outriggers (3 places)

E. ORBITAL WORKSHOP

1. OWS Hatch
2. Nonpropulsive Vent Line
3. VCS Mining Chamber and Filter
4. Stowage Ring Containers (24 places)
5. Light Assembly
6. Water Storage Tanks (10 places)
7. TO13 Force Measuring Unit
8. VCS Fan Cluster (3 places)
9. VCS Duct (3 places)
10. Scientific Airlock (2 places)
11. WMC Ventiation Unit
12. Emergency Egress Opening (2 places)
13. M509 Nitrogen Bottle Stowage
14. SO19 Optics Stowage Container
15. S149 Particle Collection Container
16. SO19 Optics Stowage Container
17. Sleep Compartment Privacy Curtains (3 places)
18. M131 Stowage Container
19. VCS Duct Heater (2 places)
20. M131 Rotating Chair Control Console
21. Power and Display Console
22. M131 Rotating Chair
23. WMC Drying Area
24. Trash Disposal Airlock
25. OWS C&D Console
26. Food Freezers (2 places)
27. Food Preparation Table
28. M171 Ergometer
29. MO92 Lower-Body Negative Pressure
30. Stowage Lockers
31. Experiment Support System Panel
32. Biomedical Stowage Cabinet
33. M171 Gas Analyzer
34. Biomedical Stowage Cabinet
35. Meteoroid Shield
36. Nonpropulsive Vent (2 places)
37. TACS Module (2 places)
38. Waste Tank Separation Screens
39. TACS Spheres (22), Pneumatic Sphere
40. Refrigeration System Radiator
41. Acquisition Light (2 places)
42. Solar Array Wing (2 places)

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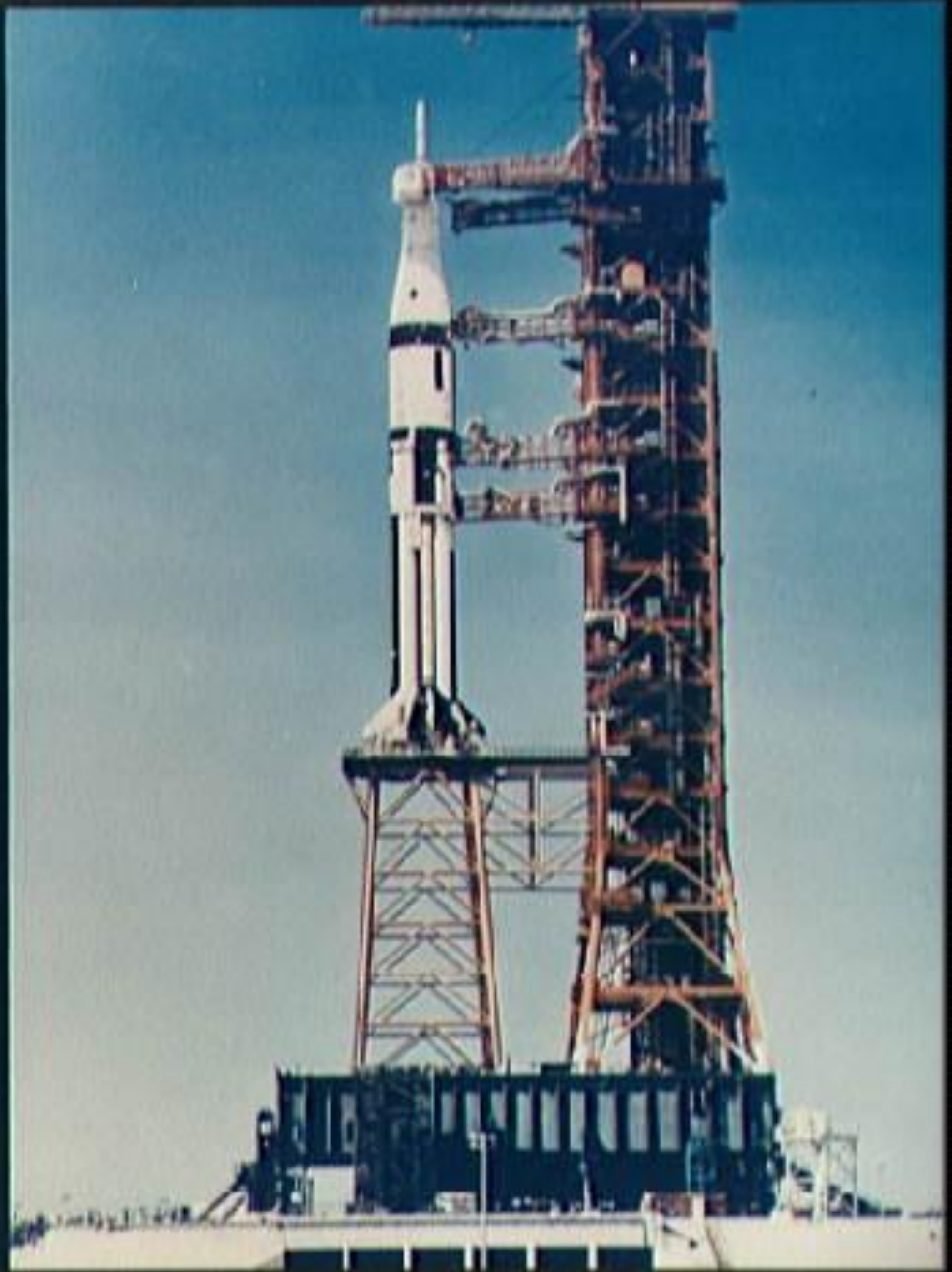
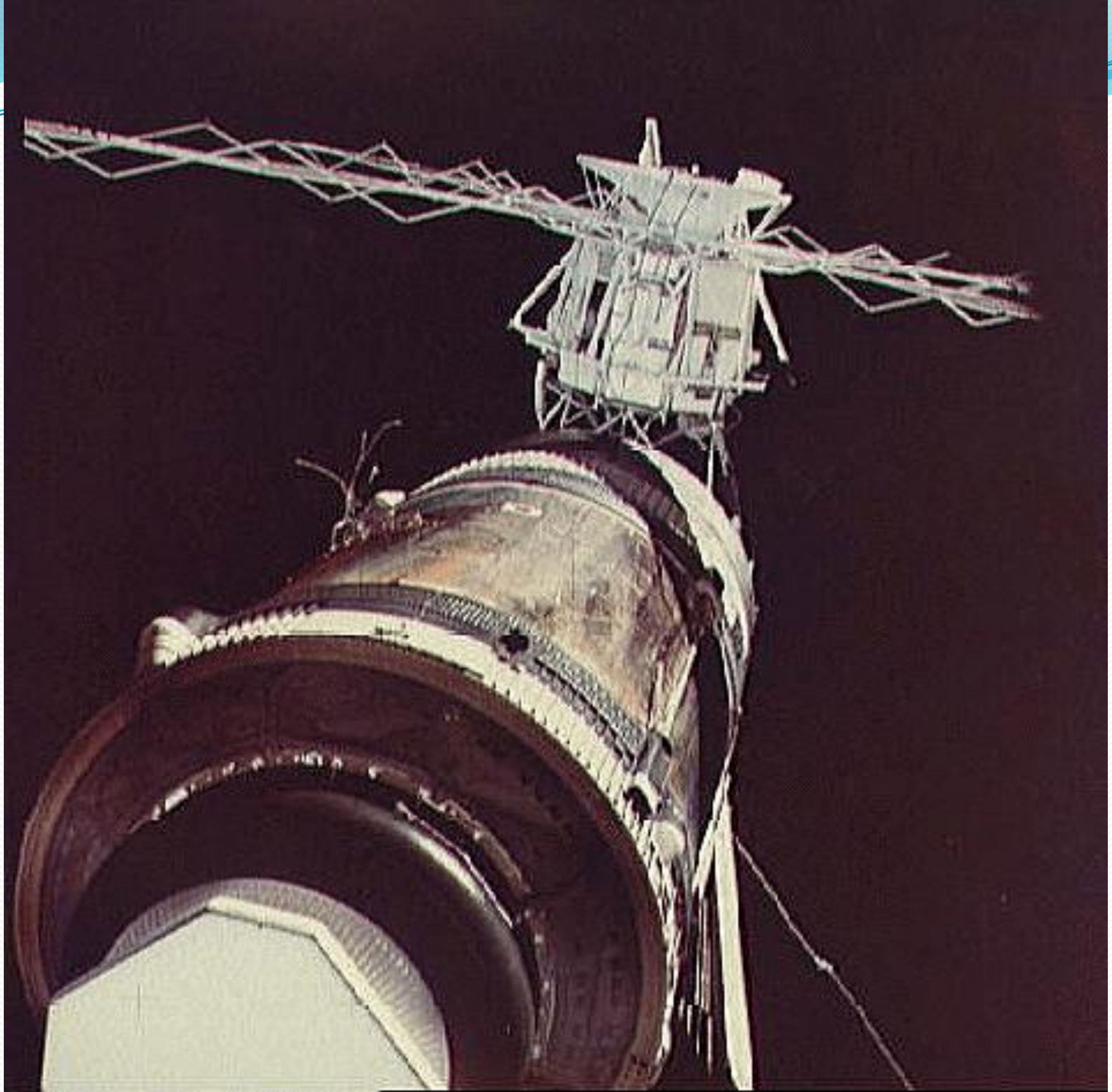
SKYLAB
SATURN IB
LAUNCH
CONFIGURATION
COMPLEX 39B



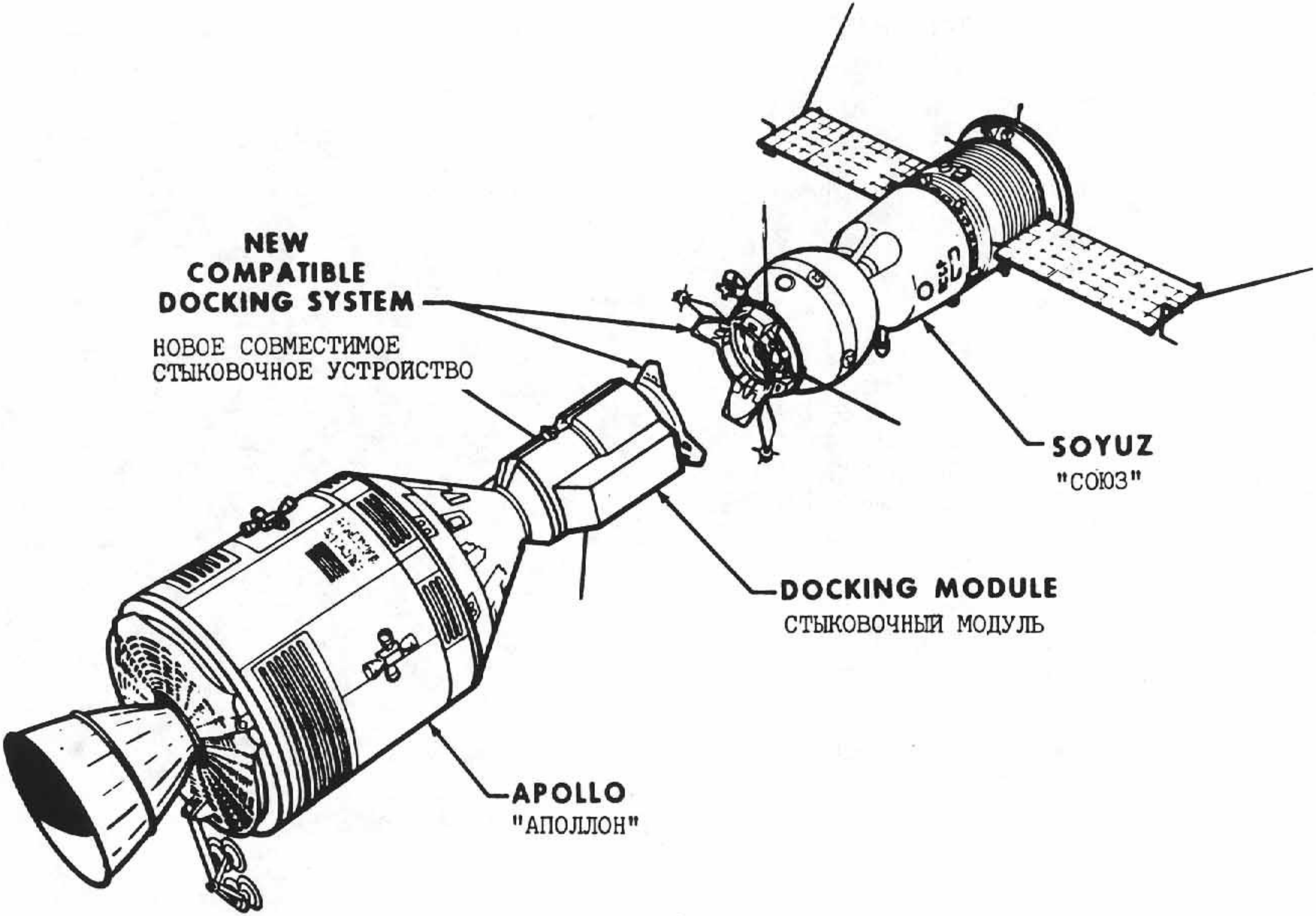


What did we learn?

- Space adaptation syndrome was a real problem in larger spaces
- Maintenance and repair of space vehicles during flight is possible and should be planned
- Could train crews in a simulator that did not look exactly like the vehicle (part task training)
- Realized that only time critical events needed repetitive training, other tasks could be trained in a more relaxed environment
- Timelines need to allow the crew to set their own pace and have "job jars" for tasks that they might do when they have time

Apollo – Soyuz Test Project

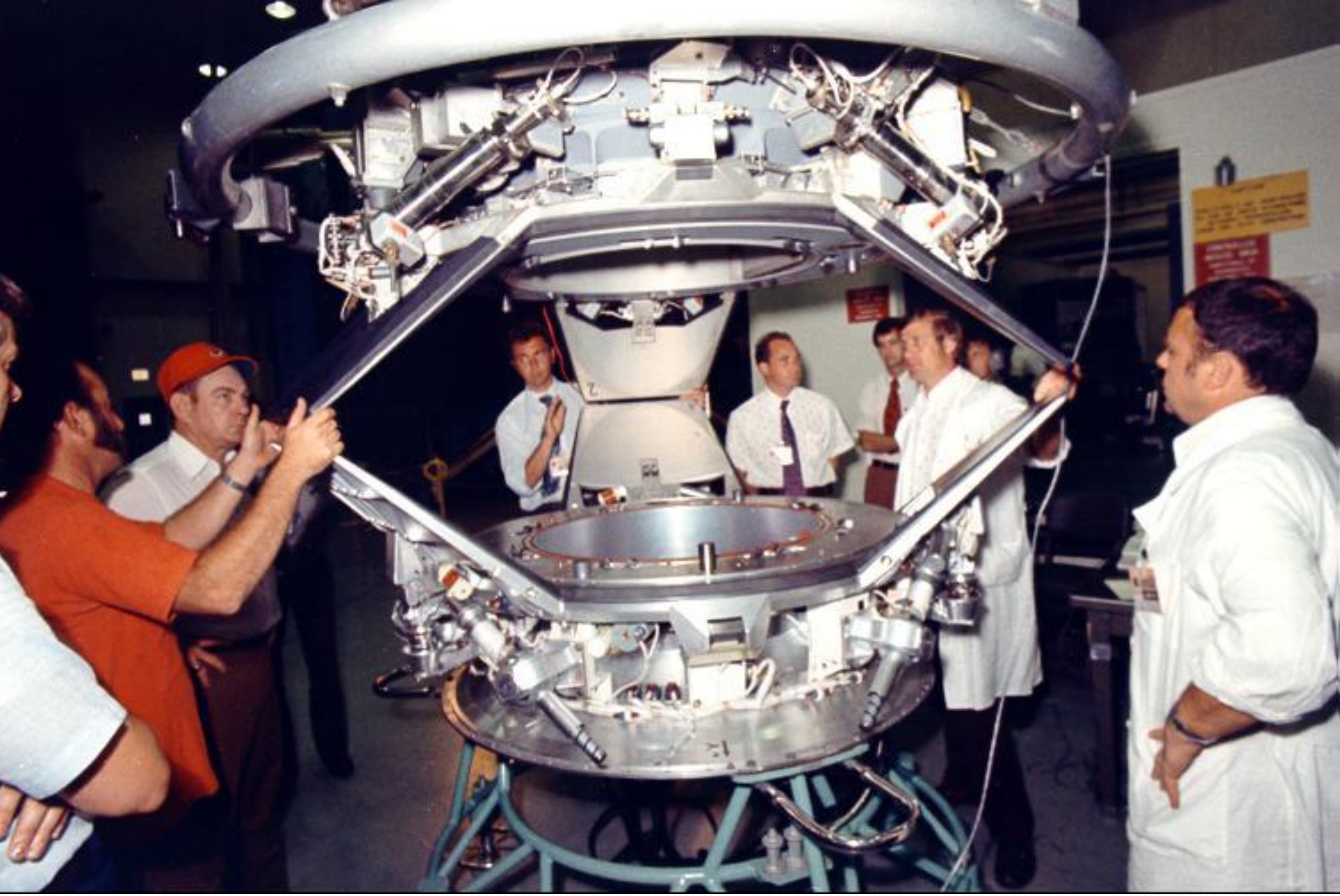
- A détente between the USSR and the US allowed President Nixon and President Brezhnev to sign a protocol to plan and fly a joint mission
- The mission occurred in July 1975
- Successfully showed that an androgynous docking system is possible and that space rescue can be accomplished



- Apollo-Soyuz Rendezvous and Docking Test project

ЭКСПЕРИМЕНТАЛЬНЫЙ ПРОЕКТ ВСТРЕЧИ И СТЫКОВКИ КОСМИЧЕСКИХ КОРАБЛЕЙ


UNITED STATES




SLAYTON

What did we learn?

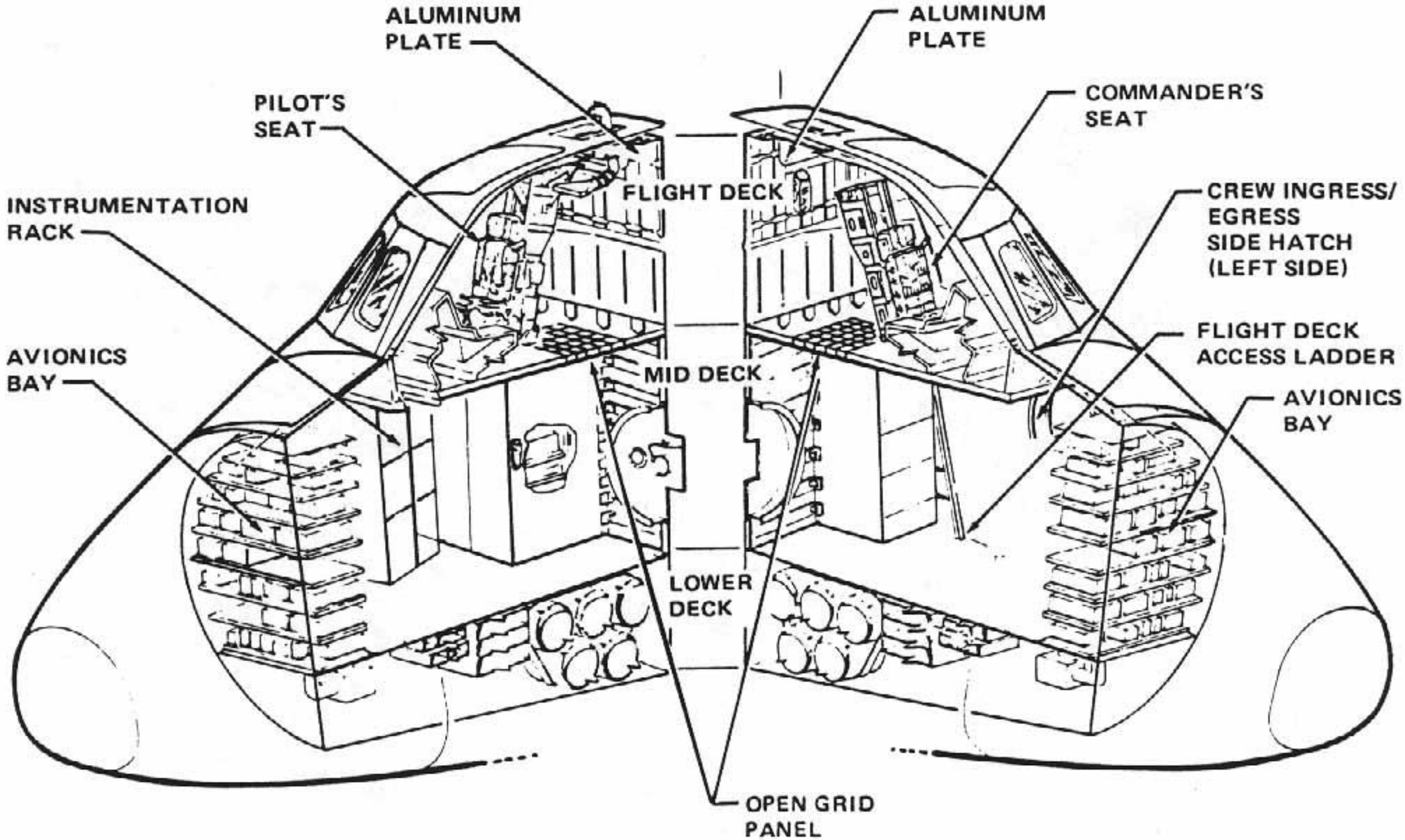
- Space rescue should be possible for all flights and all countries
- Training with
  - two languages
  - two training philosophies
  - two sets of training hardware is difficult and the time required expands
- How to pick out the KGB agents from the real scientists and engineers

The Space Transportation System

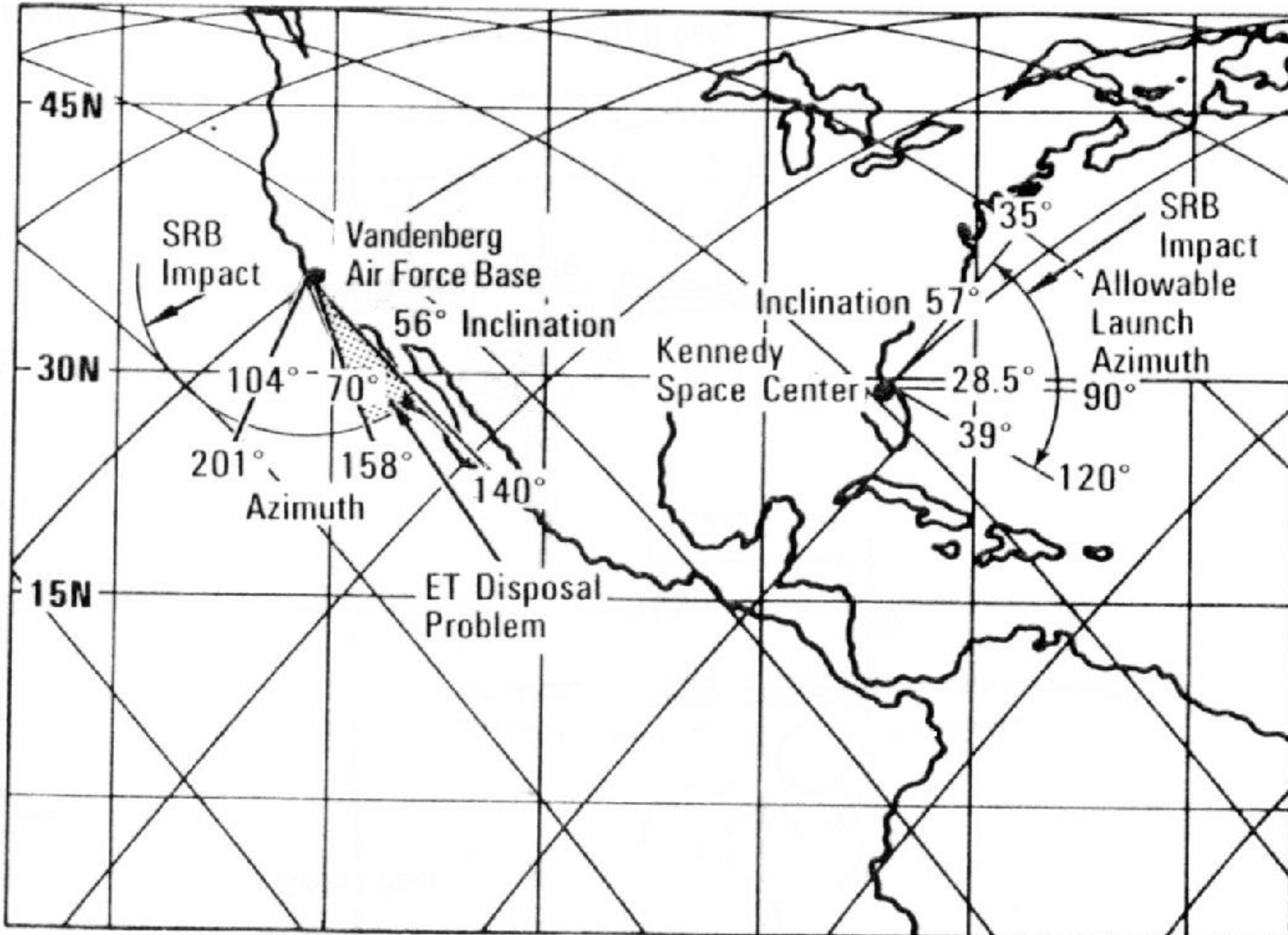
- Space Transportation Goals
  - To create a reusable spacecraft
  - To move cargo from the earth to orbit cheaper and more reliably
  - To increase the creature comforts for the space crews
  - To create the infrastructure to build a station and go further from the Earth

Space Shuttle Systems

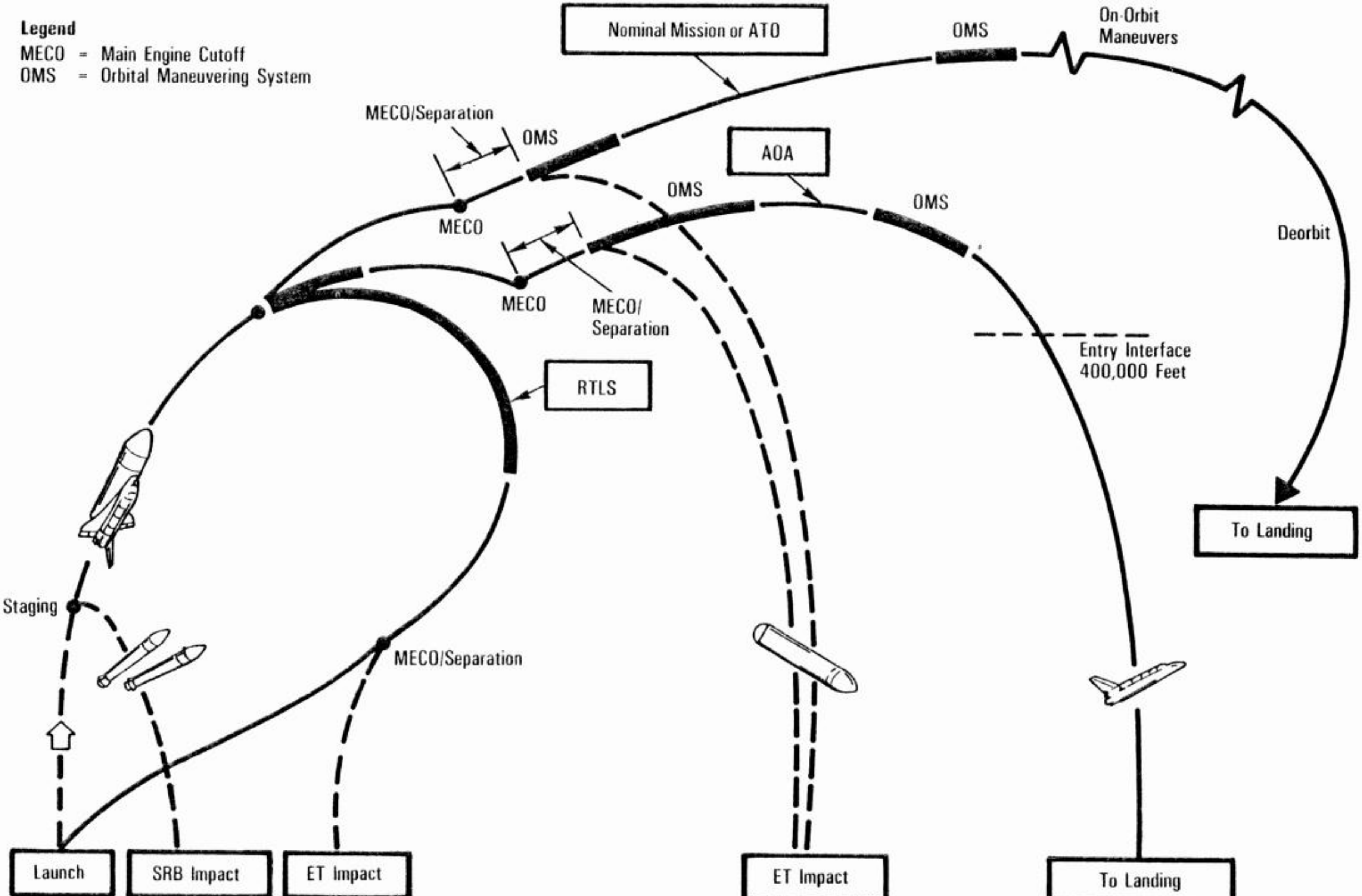
- Five digital computers forming a primary set and a single backup set of software
- A fly-by-wire system to control the spacecraft
- Three fuel cells and environmental control that evolved over time to the best system that had flown up to that time
- Hydraulics required to operate the control systems (rudders, elevons, engine actuators)
- Advanced Hydrogen/Oxygen main engines
- Reusable heat resistant tiles rather than single use heat shields to save money



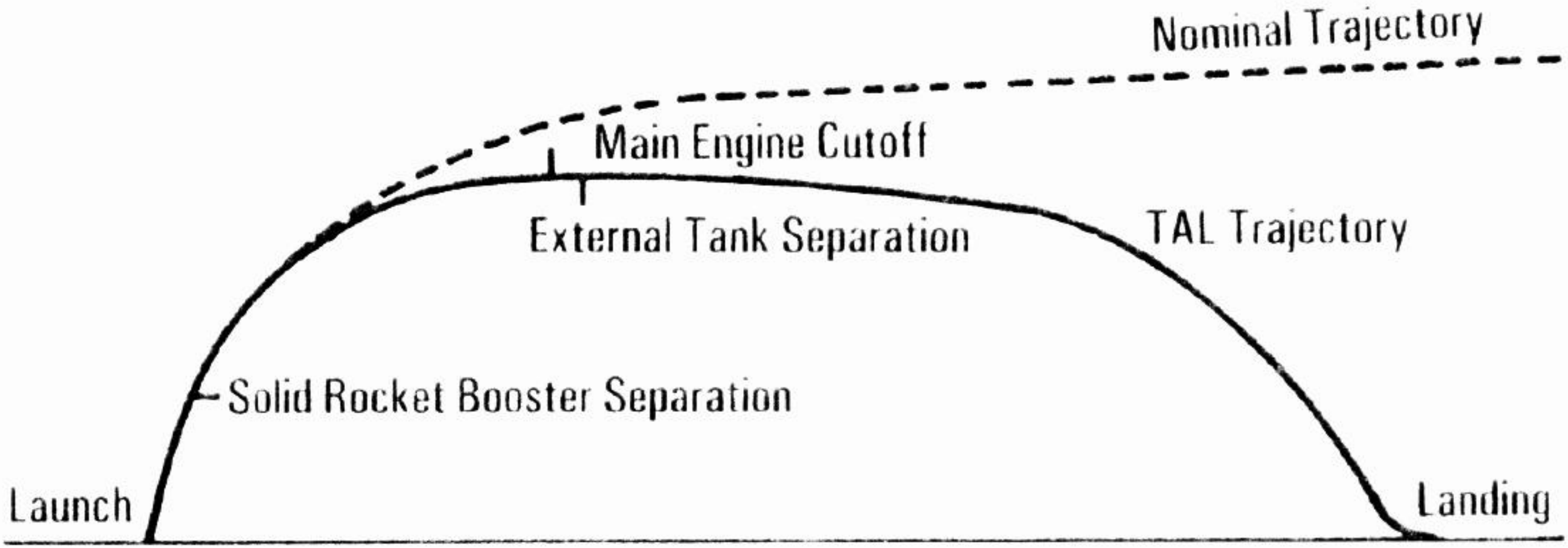
ALUMINUM PLATE
PILOT'S SEAT
INSTRUMENTATION RACK
AVIONICS BAY
FLIGHT DECK
MID DECK
LOWER DECK
ALUMINUM PLATE
COMMANDER'S SEAT
CREW INGRESS/ EGRESS SIDE HATCH (LEFT SIDE)
FLIGHT DECK ACCESS LADDER
AVIONICS BAY
OPEN GRID PANEL



Space Shuttle Launch Sites

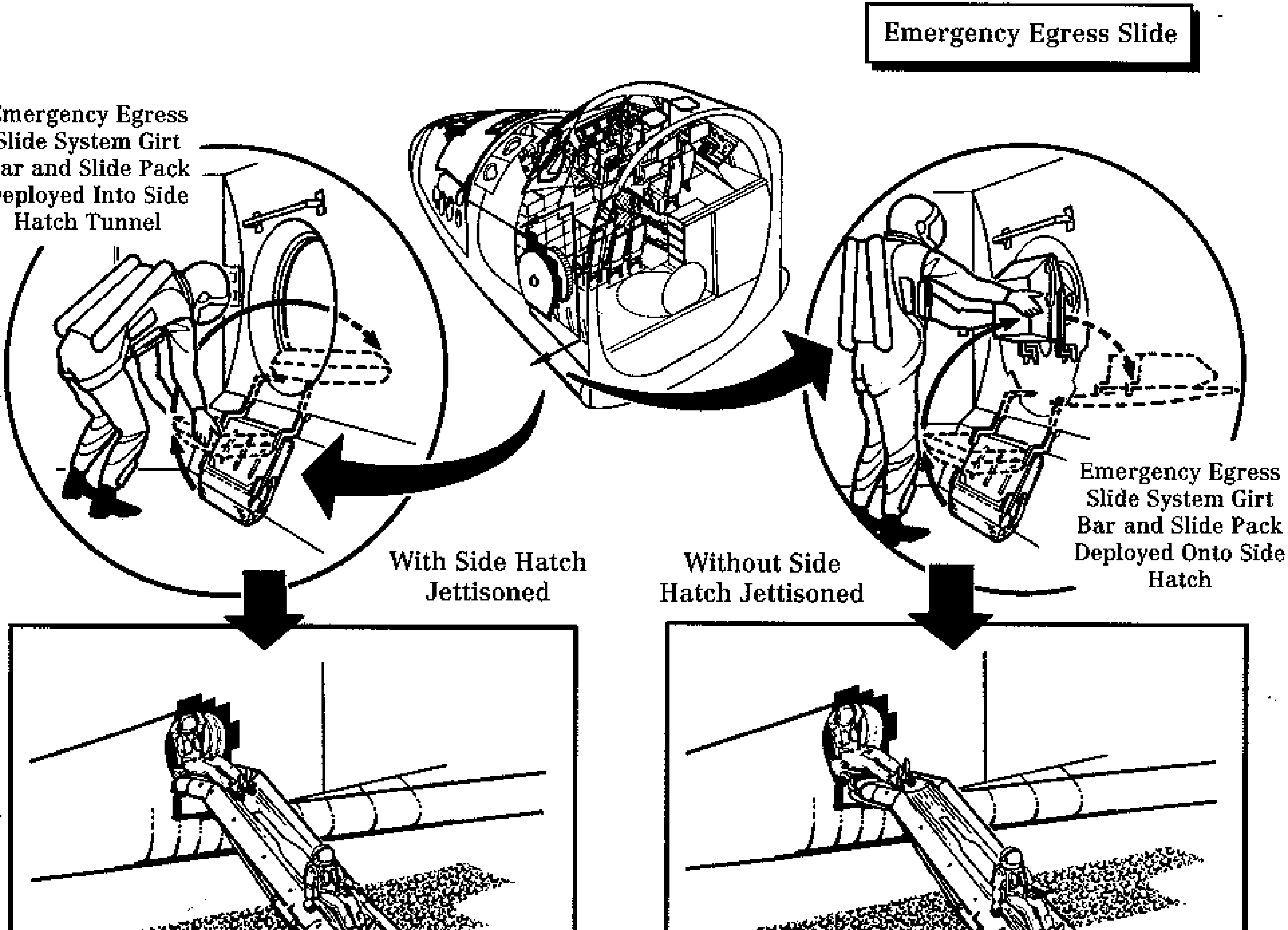


Abort and Normal Mission Profile



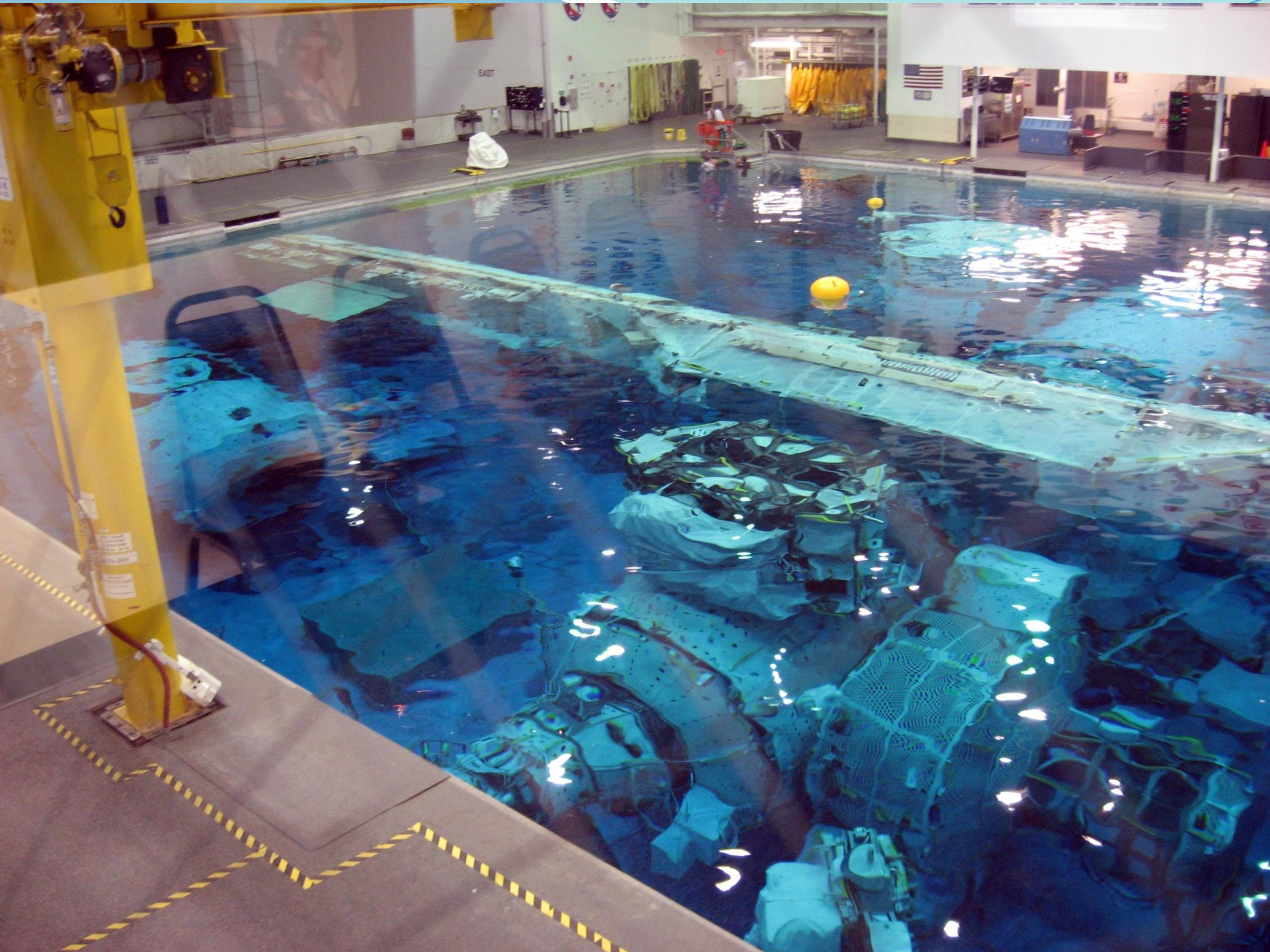
Transatlantic Landing Abort Option

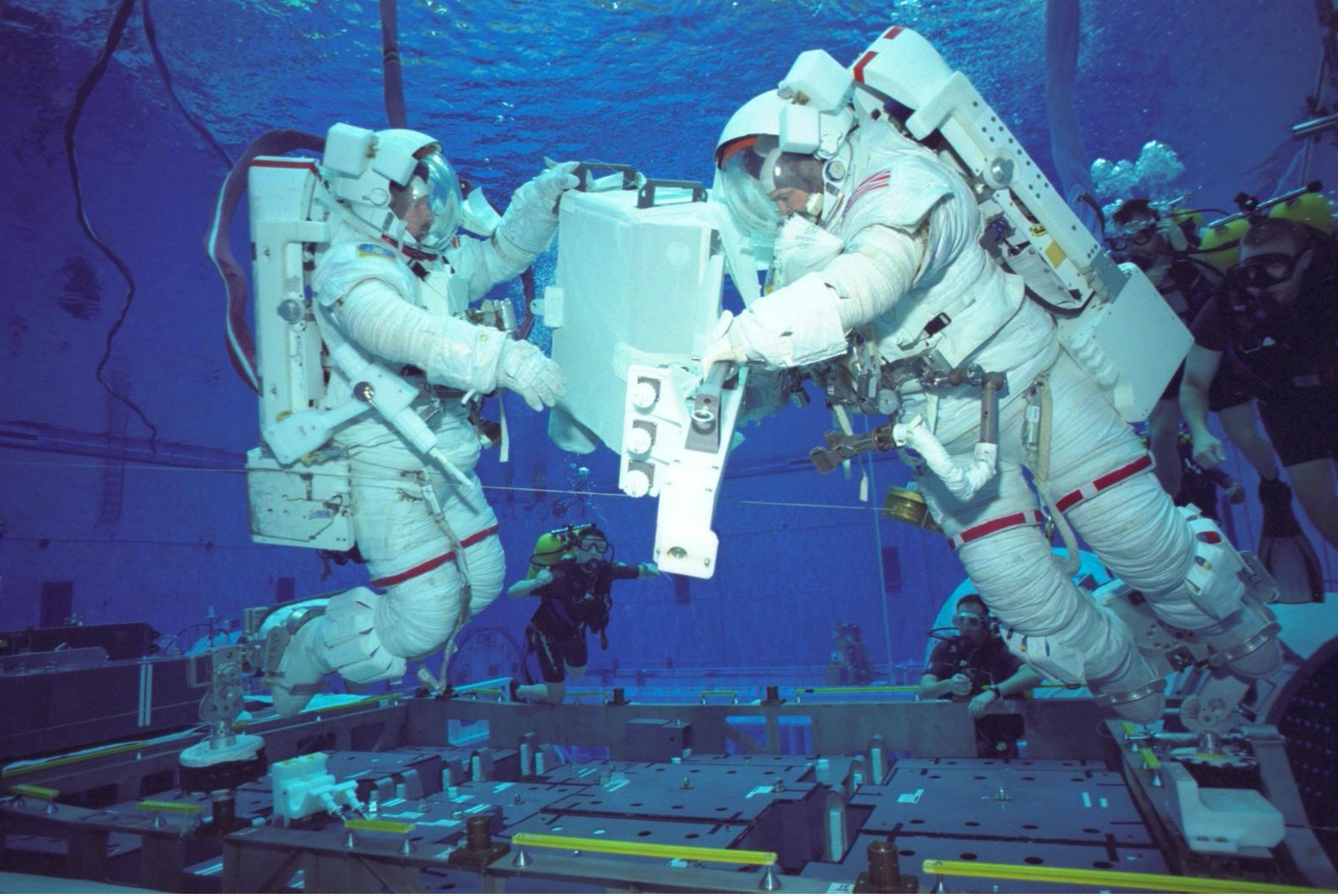
CREW GROUND ESCAPE SYSTEMS

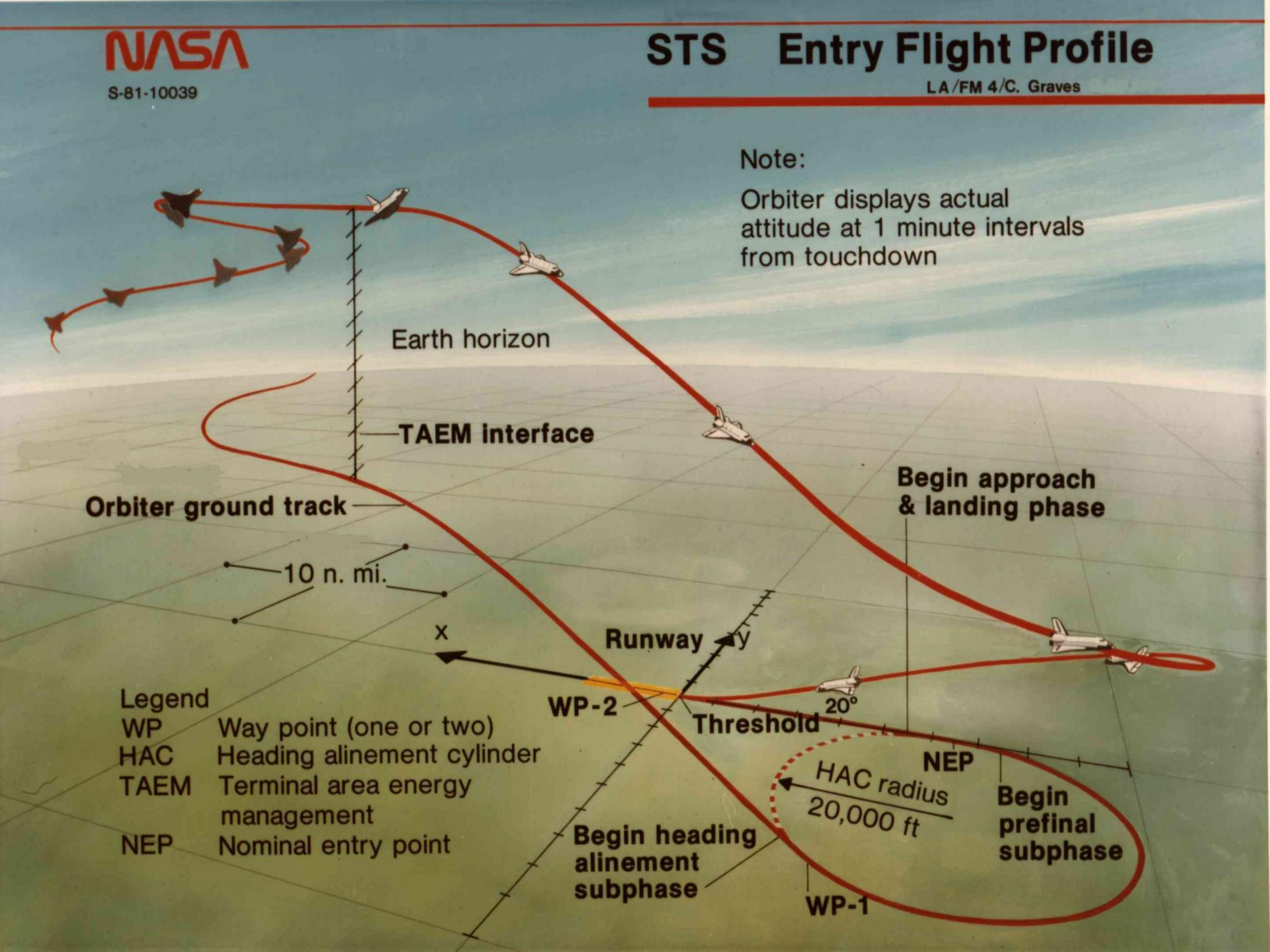


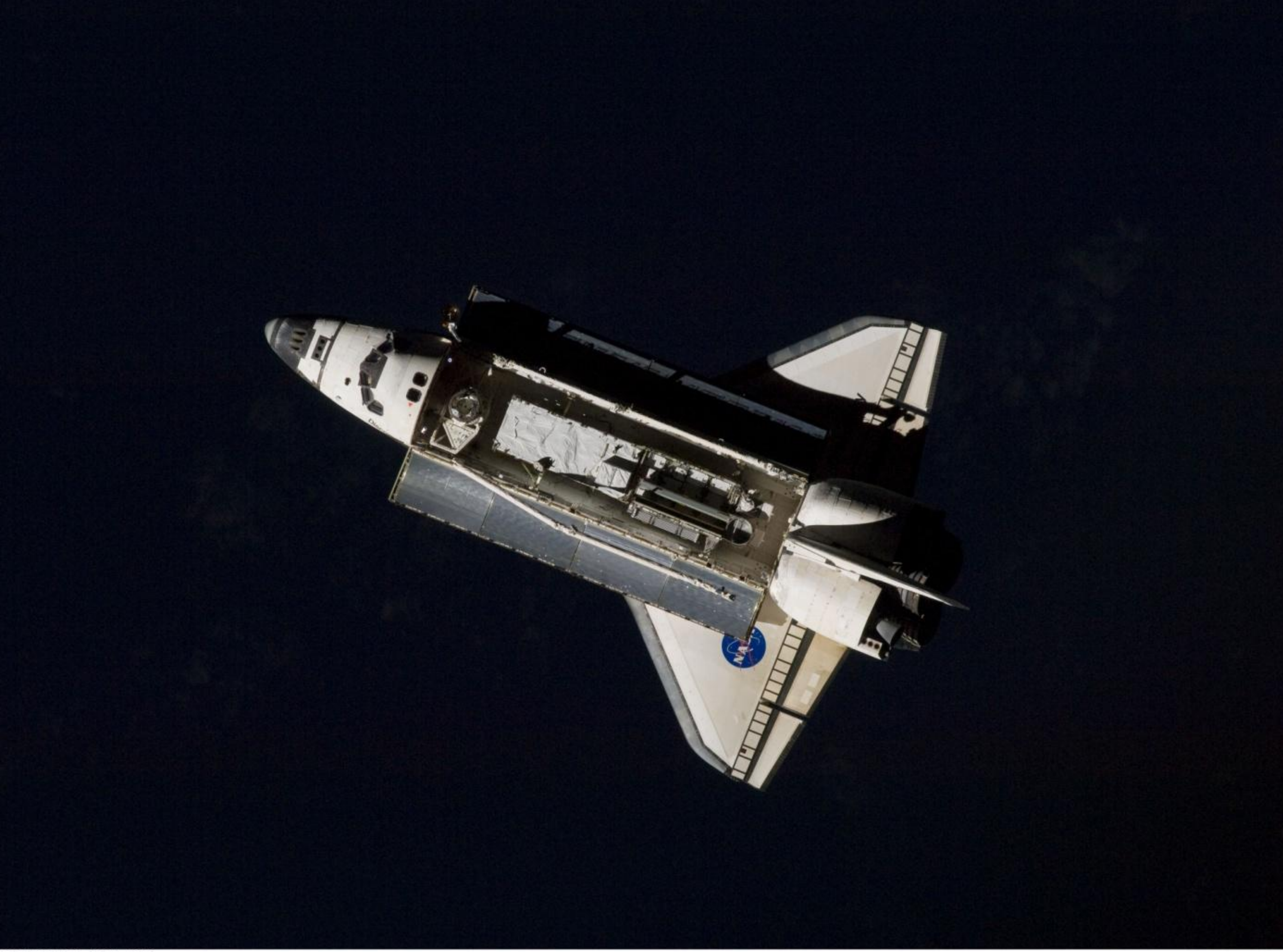

"Atlantis"


R


EAST




NASA
S-81-10039
STS Entry Flight Profile
LA/FM 4/C. Graves
Note:
Orbiter displays actual attitude at 1 minute intervals from touchdown
Earth horizon
TAEM interface
Orbiter ground track
Begin approach & landing phase
10 n. mi.
x
Runway
y
WP-2
Threshold
20°
NEP
HAC radius
20,000 ft
Begin prefinal subphase
Begin heading alinement subphase
WP-1
Legend
WP Way point (one or two)
HAC Heading alinement cylinder
TAEM Terminal area energy management
NEP Nominal entry point



S018E040789

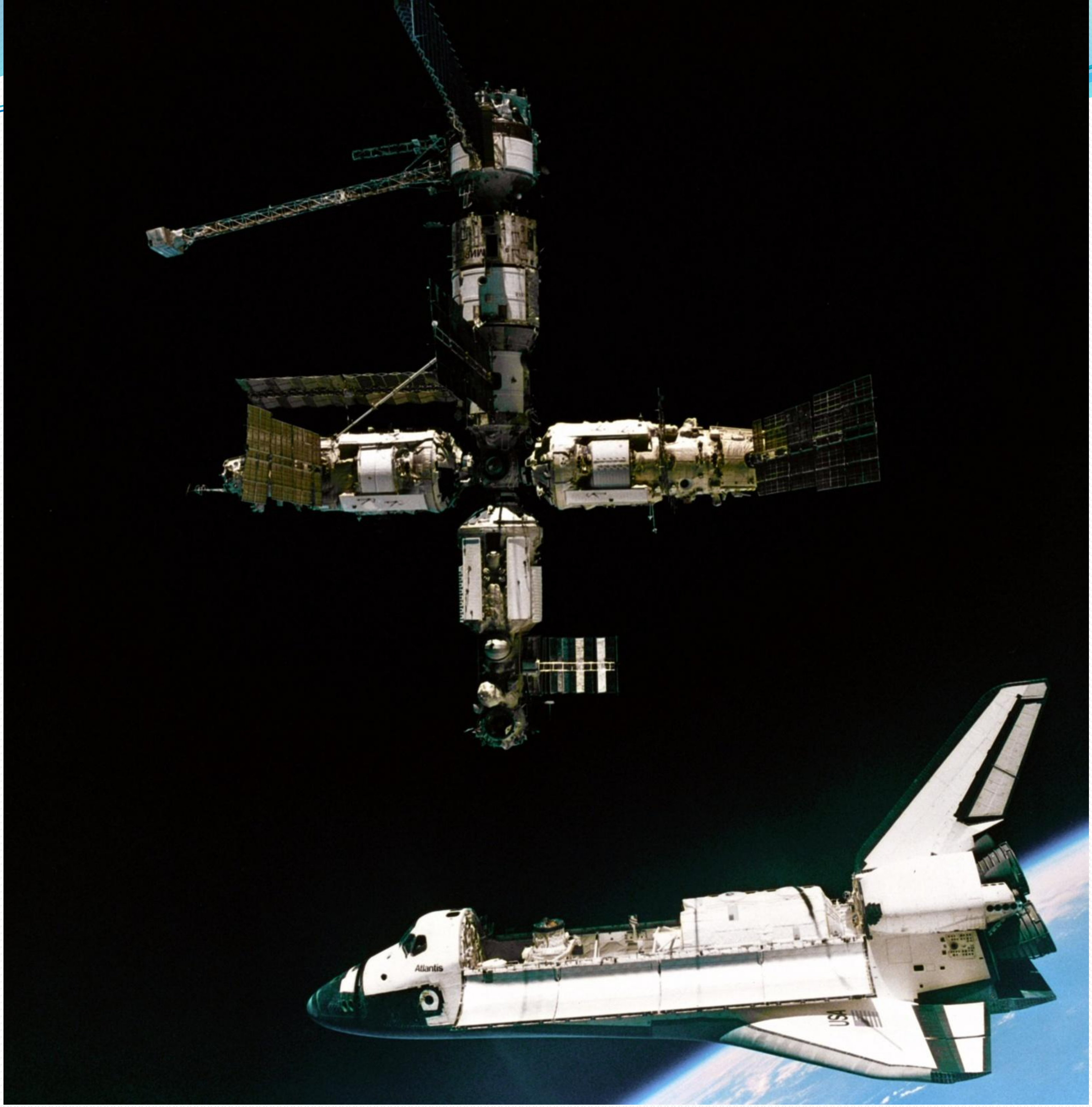

United States

What did we learn?

- Over 30 years of training (since 1977) has evolved a highly proficient system
- Complex vehicles and experiments increase training time
- Long training periods increases per flight costs and crew and flight controller family problems
- Flight delays increase costs since the meter runs all the time as you wait to fly, the training continues

Shuttle – Mir

- Goals
  - Rendezvous and dock with the Mir space station which was launched in 1986
  - This carried on an interchange which started in the medical exchanges and the ASTP flight
  - Six Americans stayed on the Mir for periods of 4 to 7 months
  - The US outfitted the Spektr module with medical experiments to augment the station capabilities


Atlantis
USA

S76E5198 1996:03:25 14:28:02

What did we learn?

- Training in two countries, two languages is still very difficult
- More complex systems increases the total training time
- Procedures in two languages in two countries is difficult
- A large body of medical data was obtained and is still being analyzed
- On-orbit stowage and location tracking is central to success – Critical items can be lost, depleted, or discarded
- Well trained crews will react well even to problems unanticipated (e.g., fire and Progress collision/depress)

International Space Station

- To create a multinational permanent outpost in earth orbit
- To create a national laboratory for basic research utilizing high quality vacuum and reduced gravity conditions
- To provide a testing ground for space technologies and human operations systems before we venture further into the solar system

Background

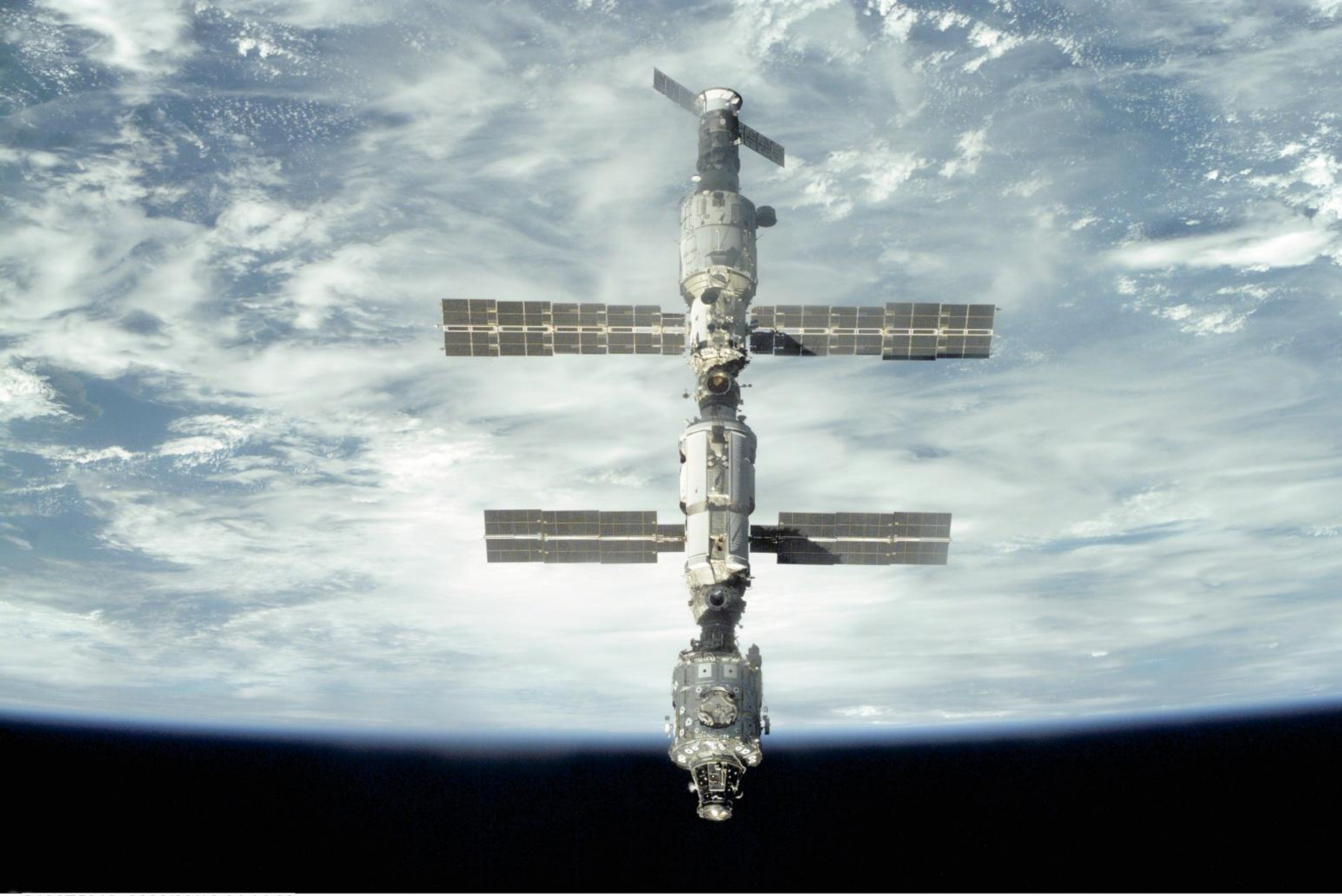
- Crew training for the International Space Station presents a unique set of goals and challenges
- Assembly will involve 16 nations with 11 languages,
- Construction requires 41 Space Shuttle flights, 12 Russian assembly flights
- Also Soyuz and Progress vehicles to ferry crew members and supplies

ISS Training

- The ISS used **distributed operations and training**. Specifically, there are 6 control centers and 7 training sites scattered around the globe
- The training flow that was initially over 4.5 years -- longer than it takes to start and finish most undergraduate programs
- Significant progress was made to shorten this template to 2.5 years, with the ultimate goal of reducing the flow to 18 months

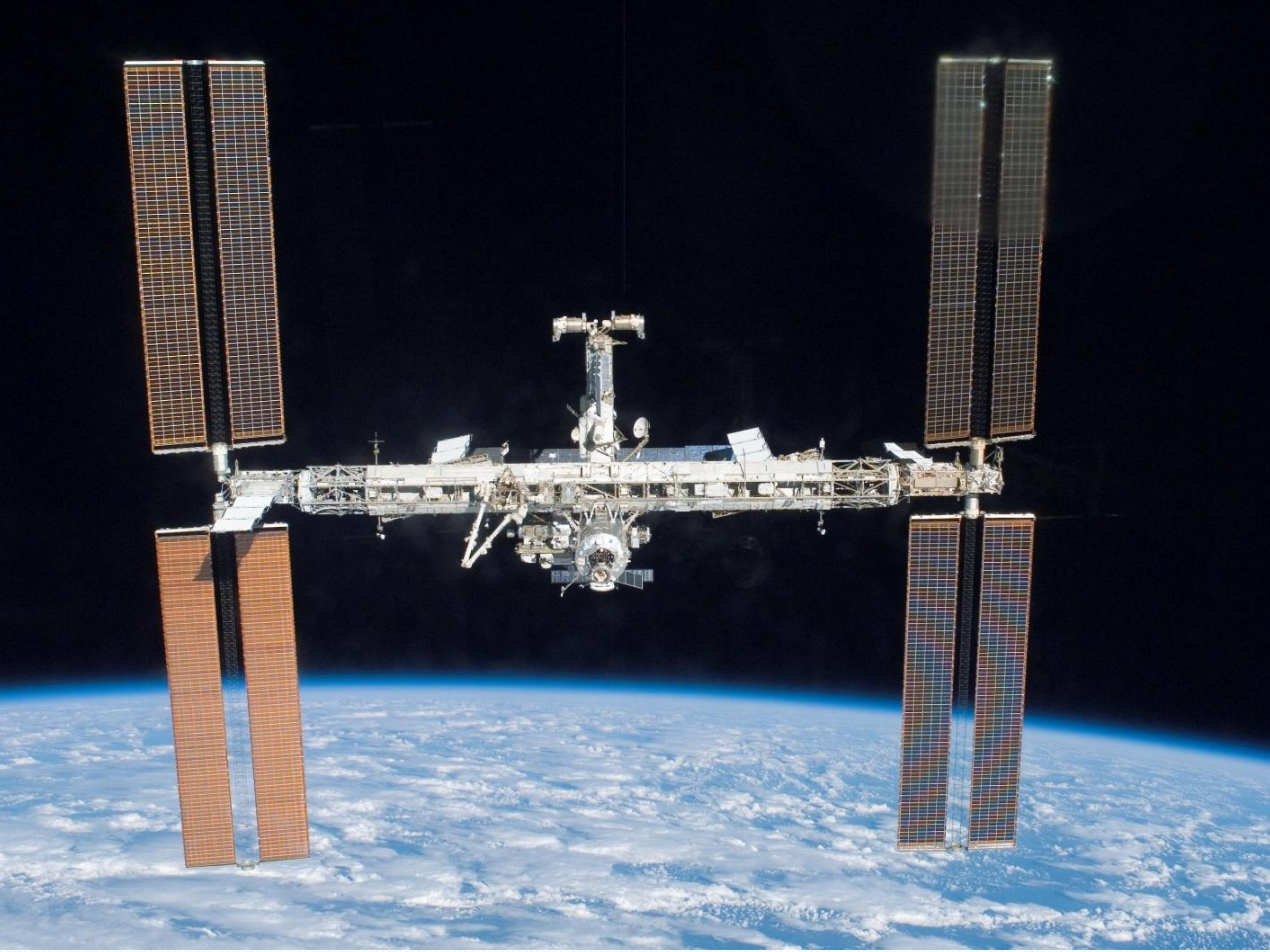
Complexity of Russian involvement

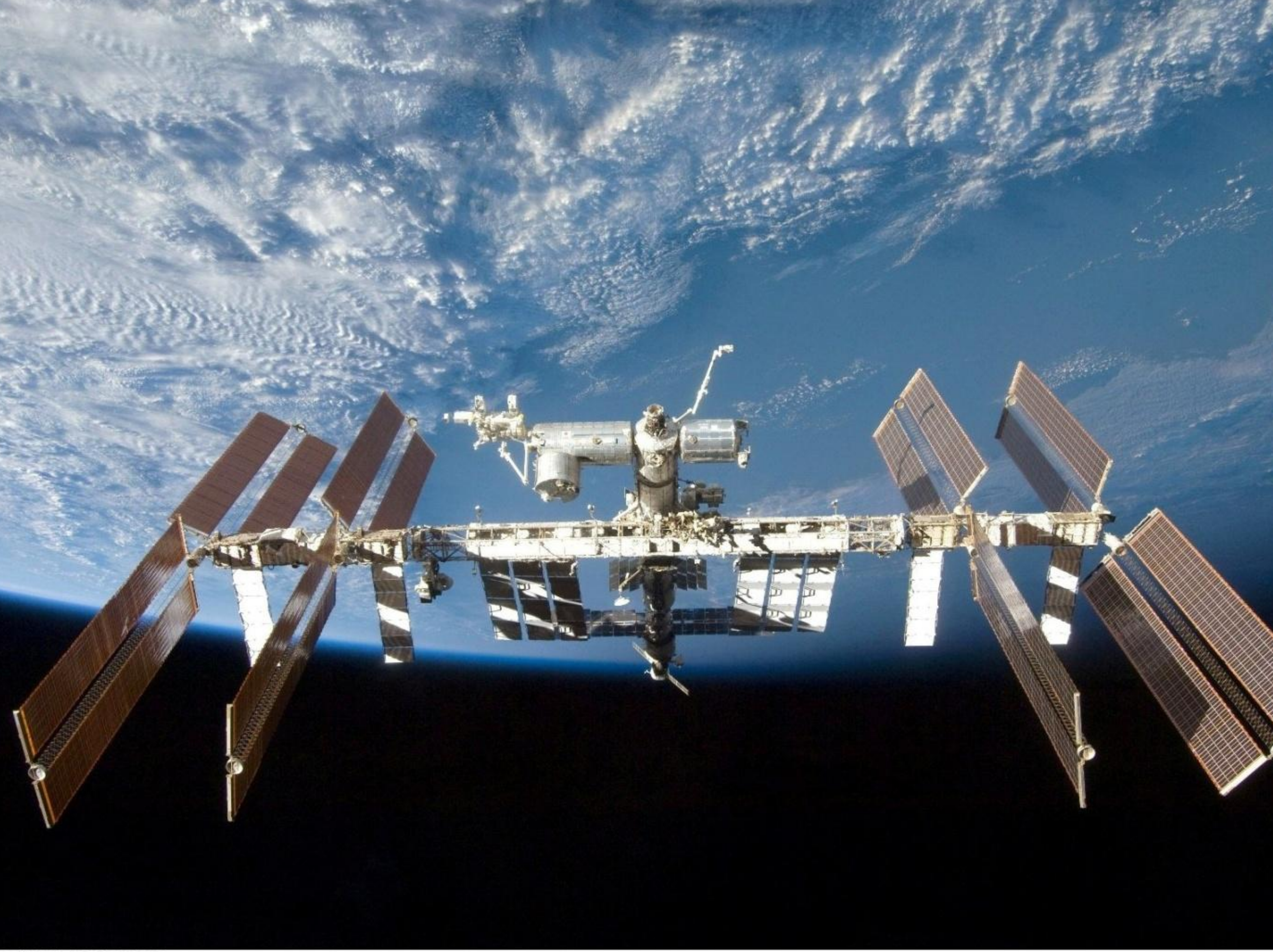
- Russian equipment and systems added
- Russian language abilities needed
- ISS laboratories increased from 3 to 5
- Two entirely different vehicles joined together (procedures and philosophy differences)
- Travel time and costs between JSC and Russia



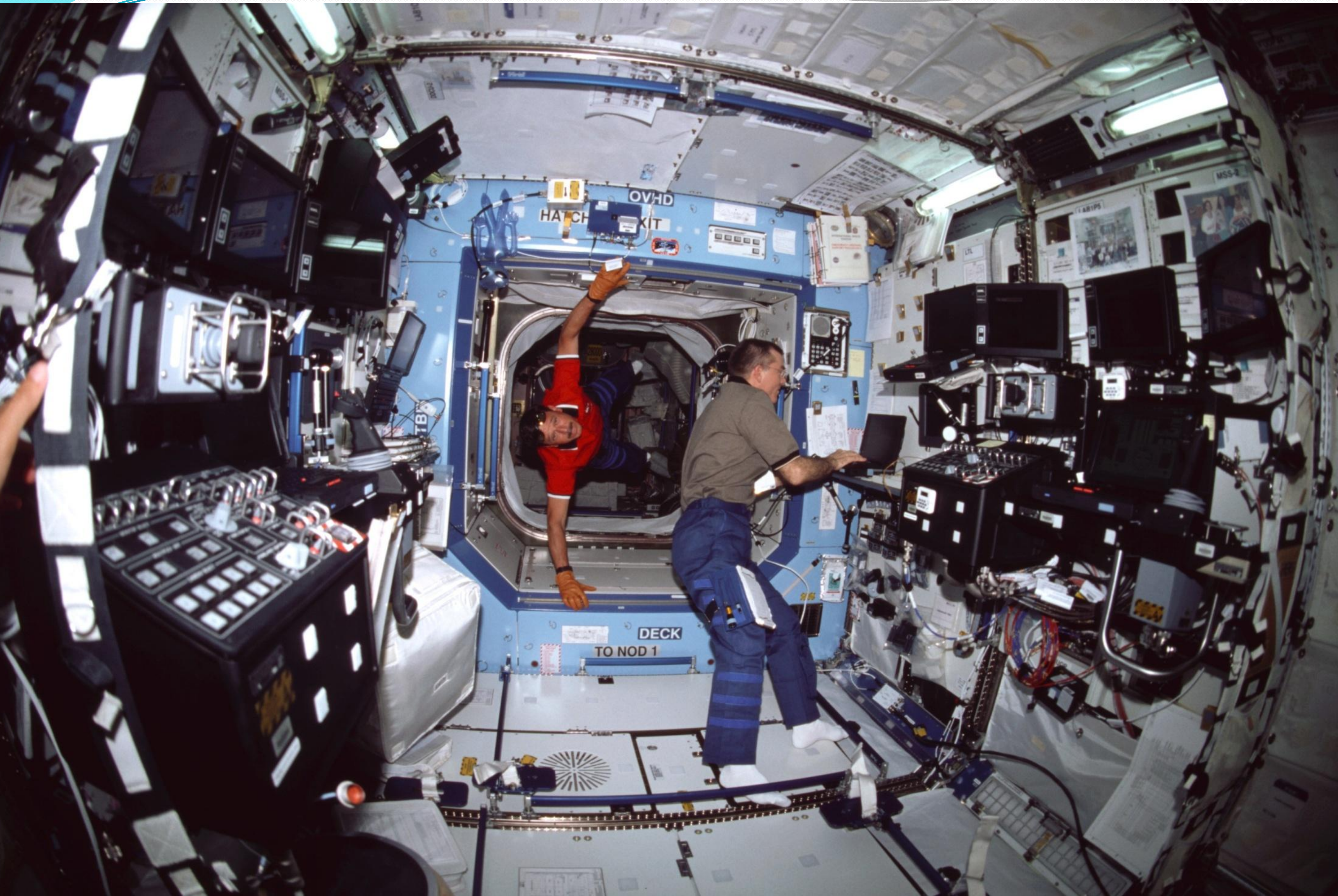
S106E5318 2000/09/18 04:14:33

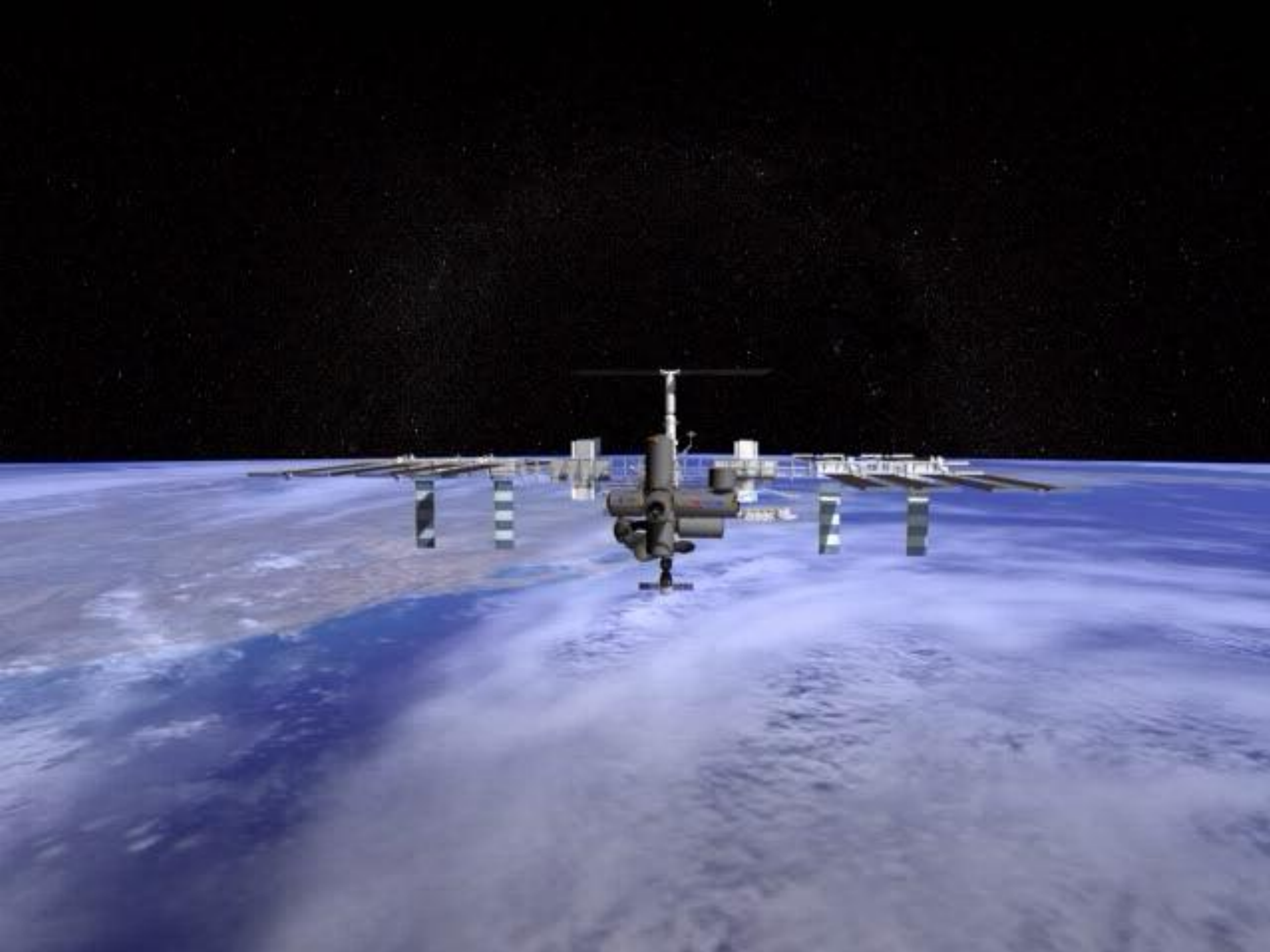
S100E5958 2001/04/29 17:51:35






2/27/1999


OVHD
DECK
TO NOD 1



What are we learning?

- Multinational programs have awesome implication in globalization and cross-cultural impacts
- Training in multi languages and countries is extremely difficult on the crews
- Stowage and tracking of items is more critical than ever – the ISS is as bad as Mir ever was in this area
- We have to design programs with family life in mind, long separations during training period amplifies the problems that will normally occur during long flights

Training hours by Program

Vehicle	Crew #	Training Hours	Guidance Computer RAM
Mercury	1	200	0
Gemini	2	300	4k
Apollo	3	400	36k x 2 units
Skylab	3	800	24k x two units
Shuttle	7	1000+	256k x 5 units
ISS	3	3000	512M x >10 units + PCs
Moon/Mars	?	?	?

The Future

- The Vision for Space Exploration is our challenge
- Systems to leave the earth are adequate and will mature
- Human systems are inadequate – crew training, food systems, medical systems, psychological support, stowage

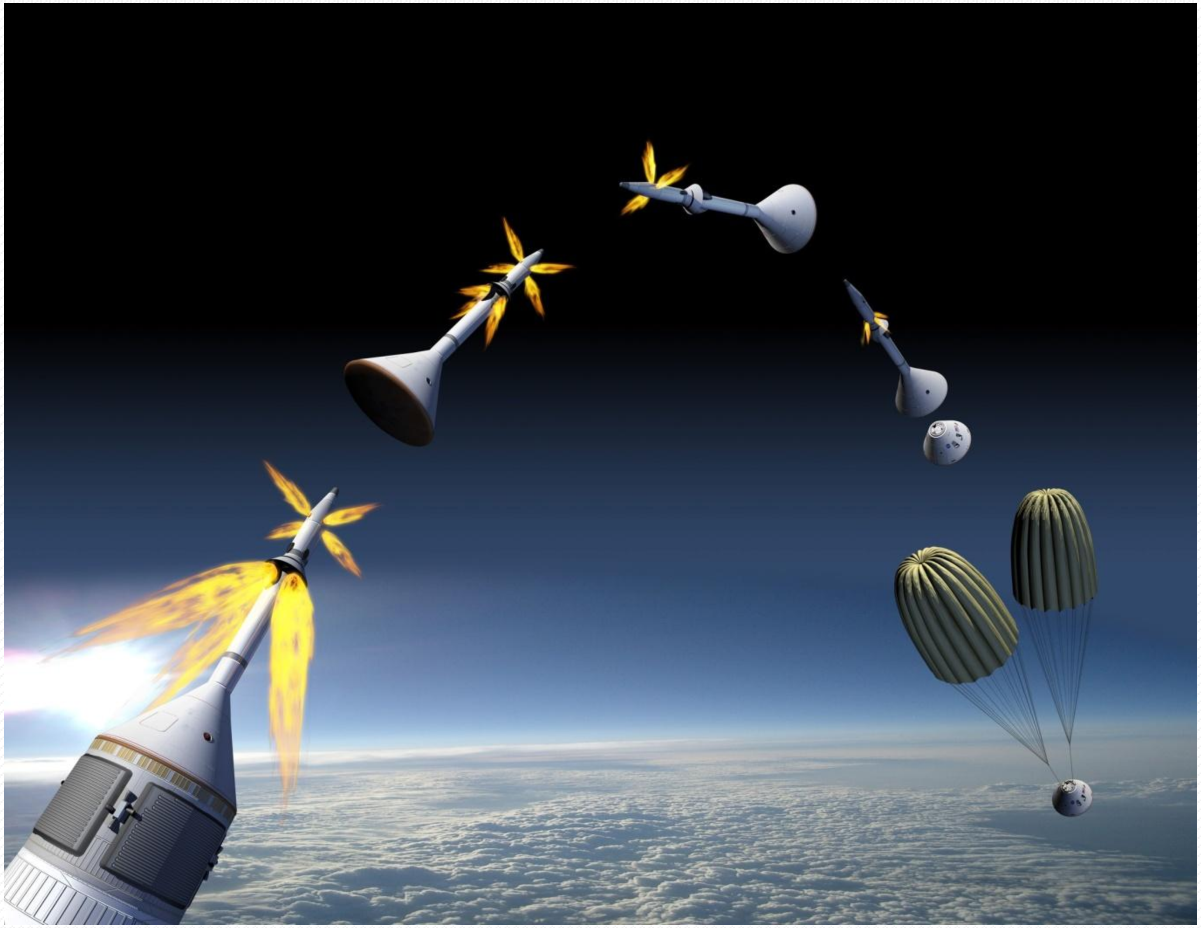
Building on a Powerful Foundation for Future Missions

www.nasa.gov

Launch

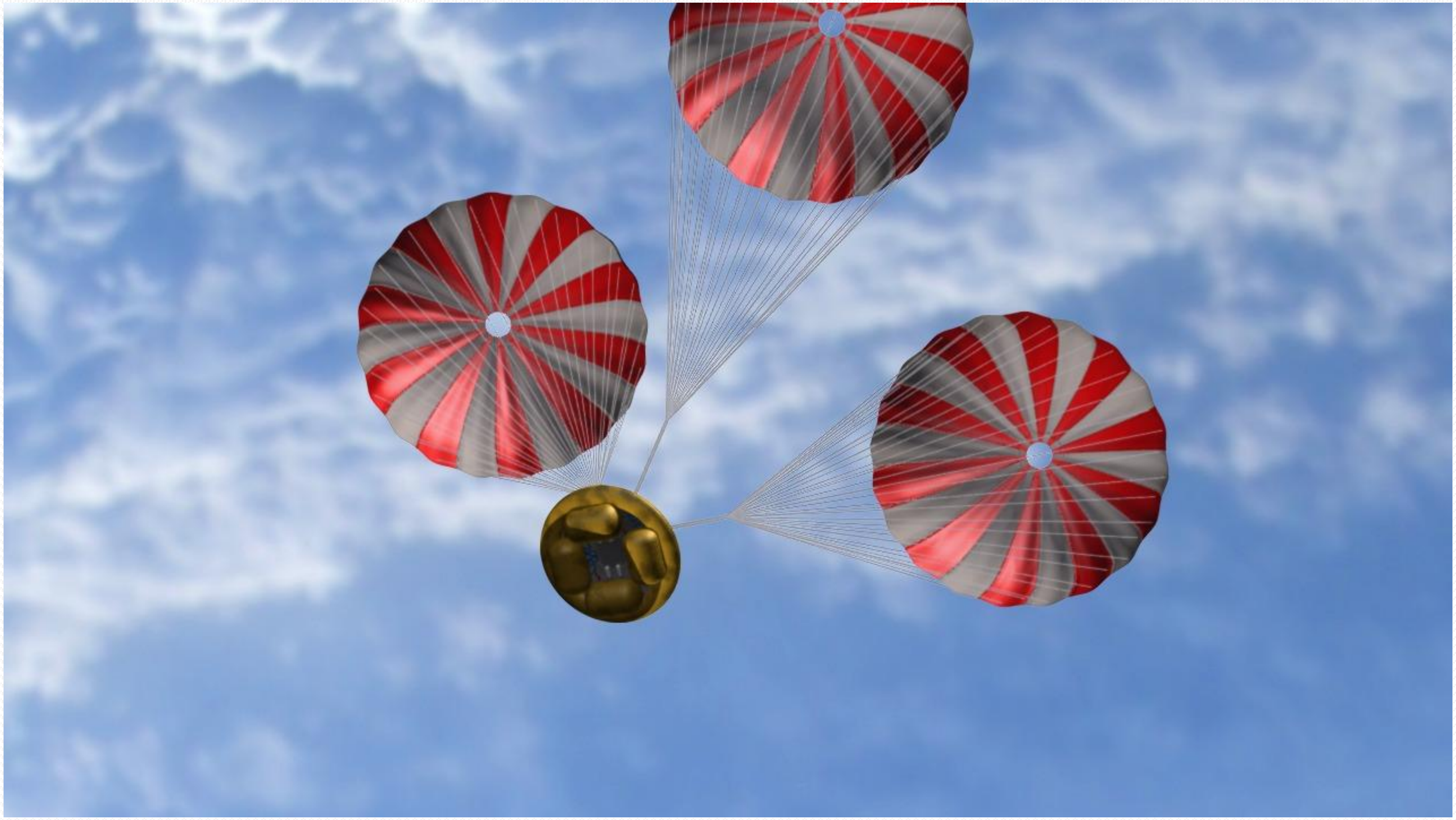
Crew Launch

Abort Training



Rendezvous and docking

Landing… are easy but take time



What do we need to learn?

- Control the number of hours in training
- Start earlier in the training cycle (university?)
- Use just in time training
- Concentrate on the most time critical skills and learn the rest during the mission
- Design with control harmony in mind
- Design for repair in flight
- Design to minimize stowage problems and maximize utilization tracking

Summary

- We need to challenge the children to see the benefit of what we are doing here
- We need to keep them in school and instill the desire to excel the events that have happened
- We need to go further