



EE-585 – Space Mission Design and Operations

Guest Lecture by Prof Claude Nicollier on **Human Spaceflight**

Ecole Polytechnique Fédérale de Lausanne

Week 13 – 12 Dec 2025

Human Spaceflight chapters

1. Why human spaceflight?
2. The first steps
3. The Space Shuttle
4. My personal spaceflight experience
5. ISS and the Tiangong space stations, and visiting vehicles
6. The space environment - characteristics and hazards
7. The human body and mind in the space environment - astronaut selection
8. Manual vs. automatic control of a spacecraft
9. Extravehicular activity or EVA
10. Space robotics
11. The “New” human spaceflight

1. Why human spaceflight?

We can do a lot, and very successfully, with satellites, automatic space vehicles, telescopes in space, landers and rovers on the surface of planets and their satellites in the solar system, and more...

So why send humans in space? It is expensive and dangerous... So why then?

The reasons behind human spaceflight

- The prestige of a nation or a Space Agency to achieve a difficult goal. Human spaceflight is NOT easy, and if done successfully, it will impress others !
- The inspiration and excitement to be part of a program that requires talent and creativity, pushing out human boundaries, physically and mentally.
- The value for science, as well on LEO as beyond LEO.
- The spinoffs, practical benefits on Earth from human space activity.
- International cooperation, very strong in several human space programs like ISS.
- The economic benefit, in particular space tourism.
- Maybe we will have, some day, to migrate to another world, like Mars, if planet Earth is no longer habitable (Elon Musk's view) - Let us get ready for this !
- Maybe human space exploration is part of our destiny! It may not just be a choice, but a necessity !

2. The first steps

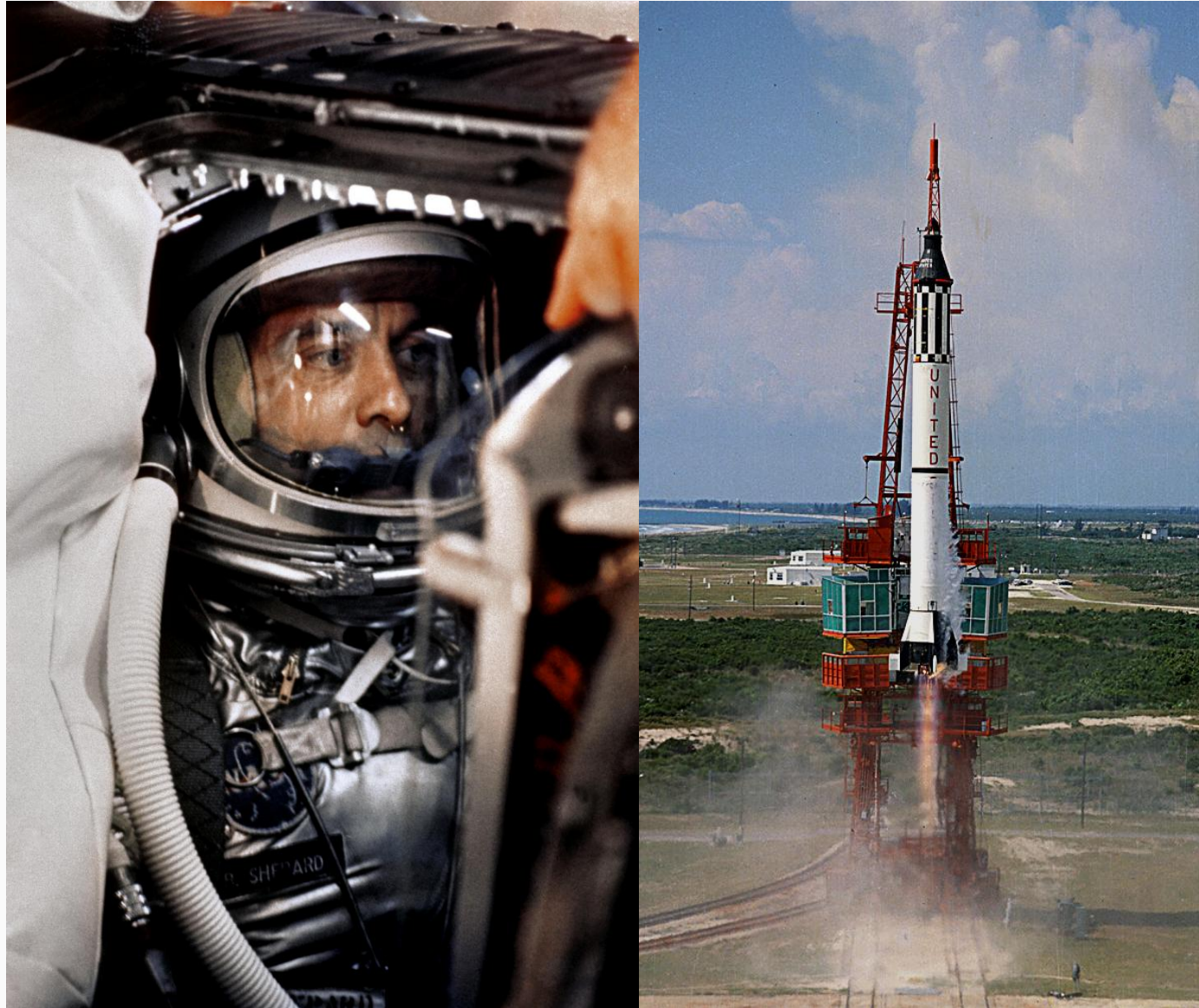
Human spaceflight started in the cold war climate between the US and the Soviet Union in the early sixties. Both parties first sent vertebrate animals into space prior to sending humans. The goal was to verify the survivability of animals in the space environment, including ascent to orbit and return to Earth. Then Yuri Gagarin went up to space for one Earth orbit...



Yuri Gagarin – First human in space - April 12, 1961



Alan Shepard – First US astronaut - May 5, 1961, suborbital



John Glenn – First US orbital flight - Feb 20, 1962



Valentina Tereshkova – First woman in space - June 16, 1963



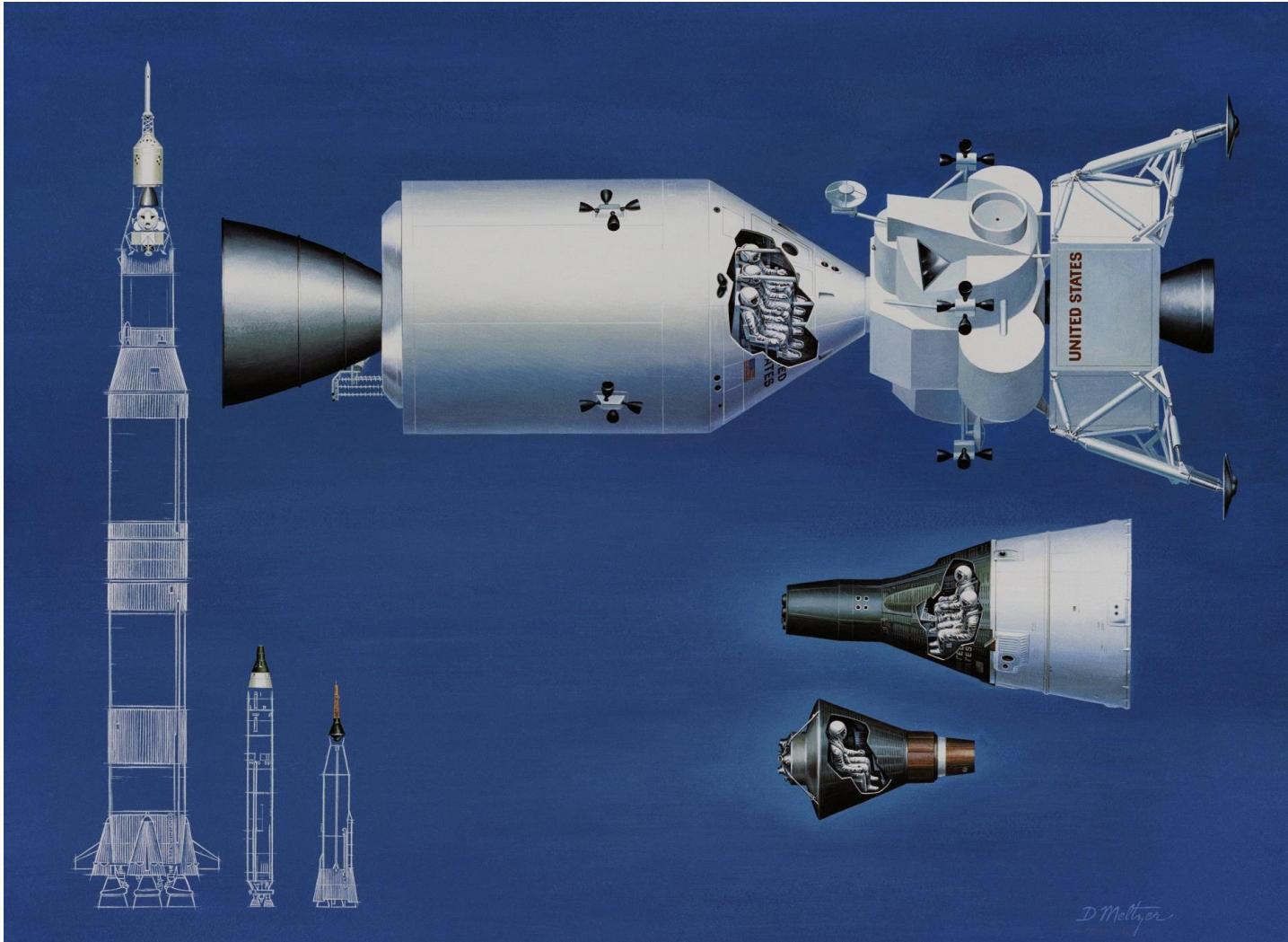
The Apollo program – John F. Kennedy's decision in 1961



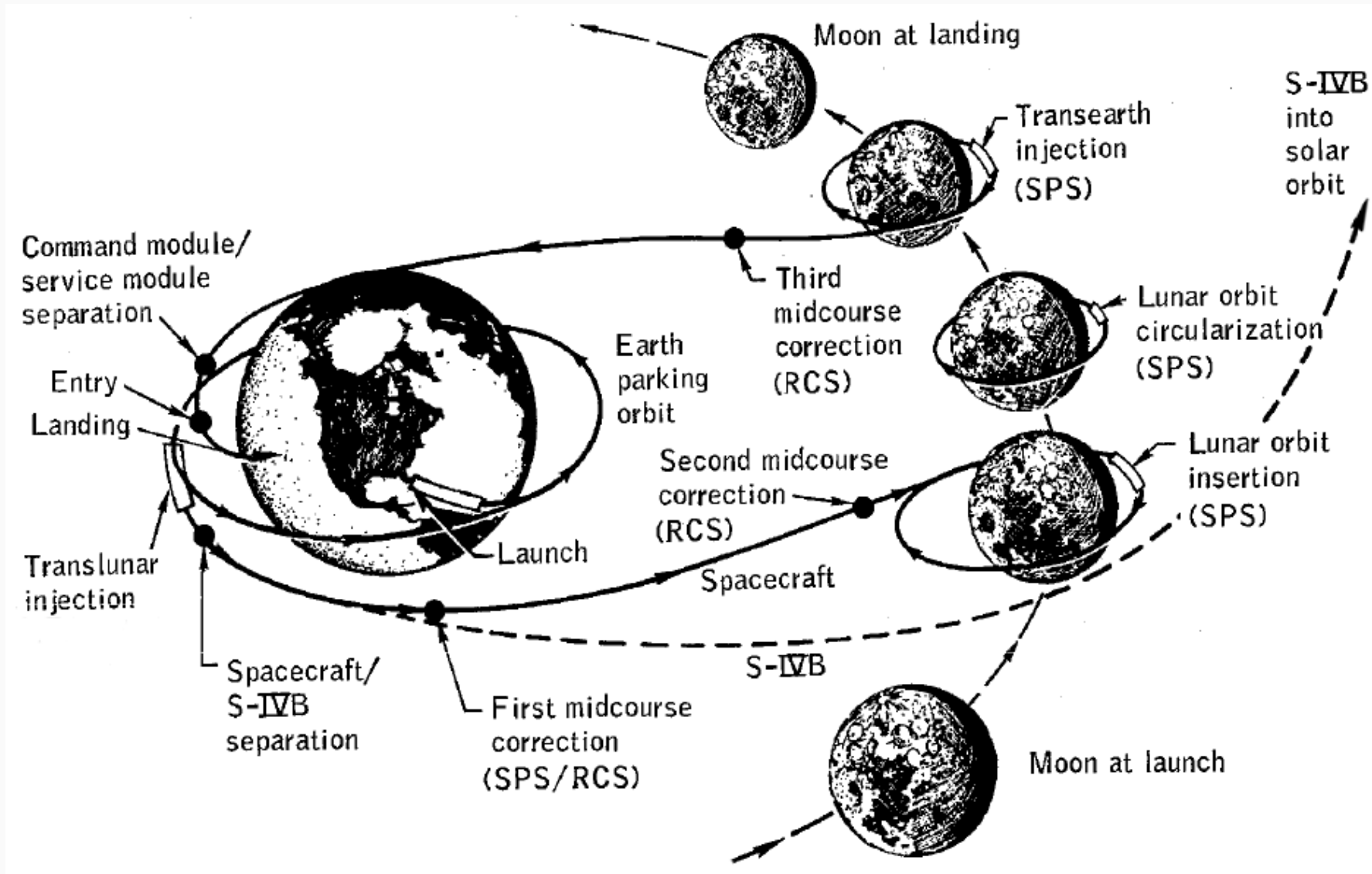
The Apollo program John F. Kennedy's decision in 1961

“We choose to go to the Moon. We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win...”

Mercury, Gemini, Apollo



Apollo mission profile



The Apollo 11 crew

Michael Collins



Neil Armstrong

Buzz Aldrin

2.5 hours on the Moon surface
on Apollo 11, July 21, 1969



Apollo 11 JUL 69
Mare Tranquillitatis
0.67416°N 23.47314°E
LM: 21.6 hours EVA: 2.5 hours

Apollo 12 NOV 69
Oceanus Procellarum
3.0128°S 23.4219°W
LM: 31.5 hours EVA: 7.8 hours

Apollo 14 FEB 71
Fra Mauro Highlands
3.64589°S 17.47194°W
LM: 33.5 hours EVA: 9.4 hours

Apollo 15 AUG 71
Hadley Rille
26.13239°N 3.63330°E
LM: 66.9 hours EVA: 19.1 hours

Apollo 16 APR 72
Descartes Highlands
8.9734°S 15.5011°E
LM: 71.0 hours EVA: 20.2 hours

Apollo 17 DEC 72
Taurus-Littrow Valley
20.1911°N 30.7655°E
LM: 75.0 hours EVA: 22.1 hours

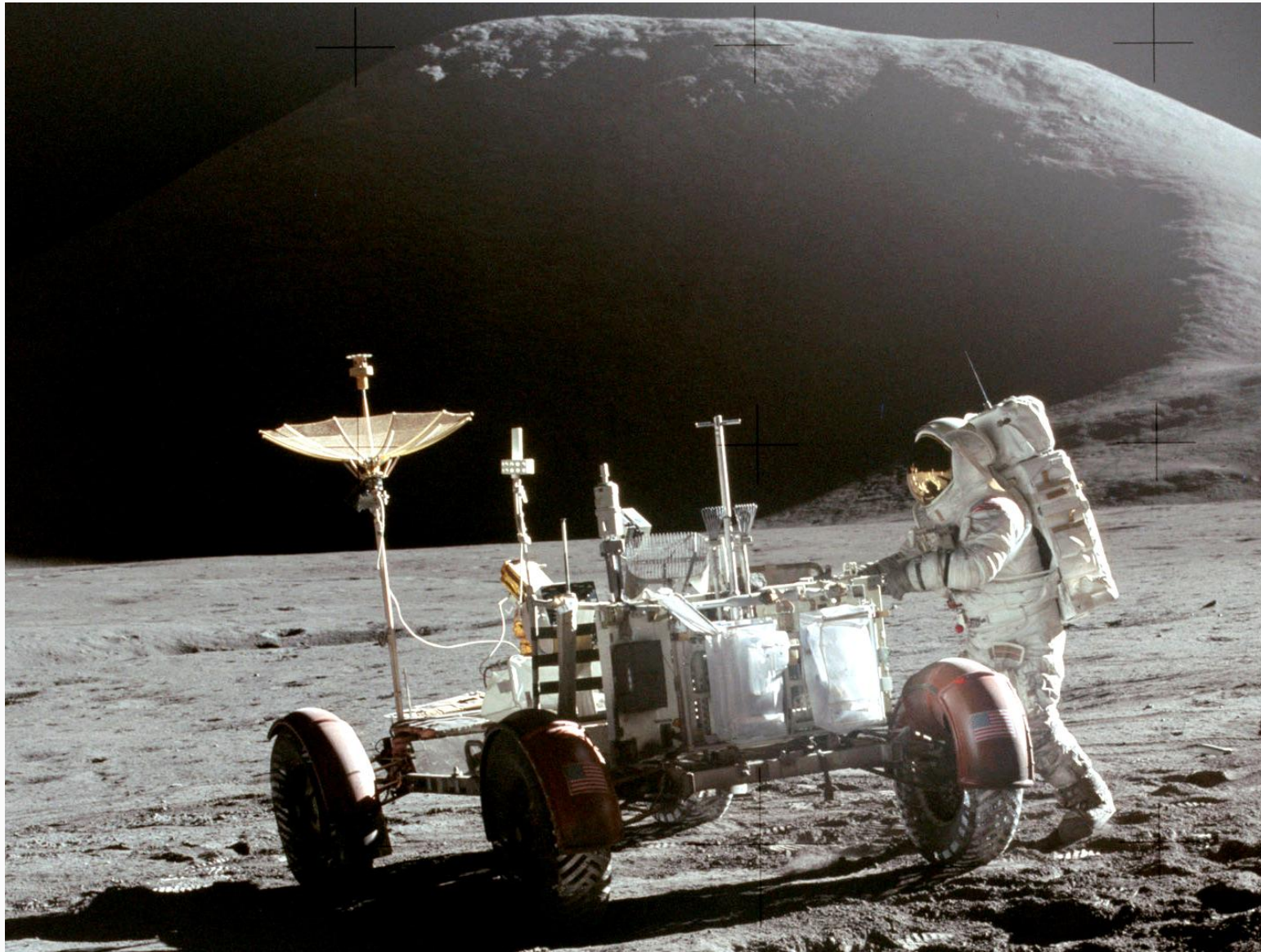


Apollo Landing Sites



Time: 01 Jul 1969 00:00 UT
Phase: 97.8% (16d 00h 51m)
Diameter: 2002.2 arcseconds
Distance: 357960 km (28.09 Earths)
Position: 19h 56m 00s, 25° 08' 12"S
Subsolar: 1.479°N 14.482°W
Sub-Earth: 5.585°N 2.246°E
Pos. Angle: 349.630°

Apollo 15 Lunar Roving Vehicle



Apollo 17, last mission of the program in December 1972



What the Apollo program brought us

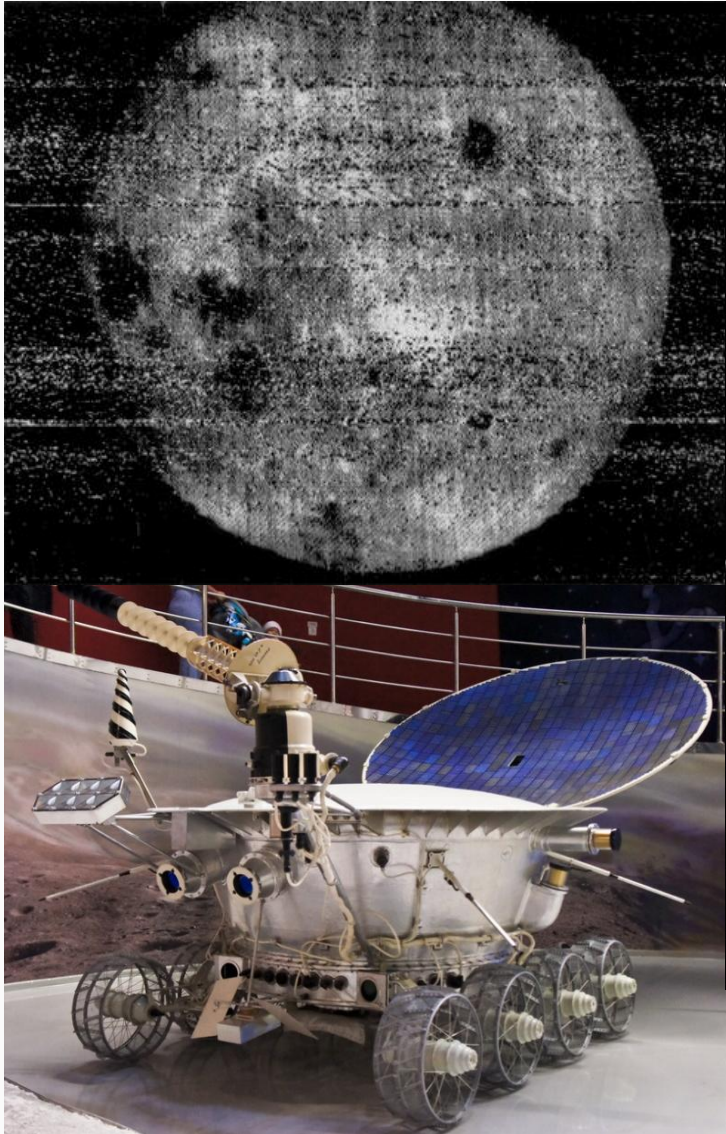


The lessons and outcome of Apollo

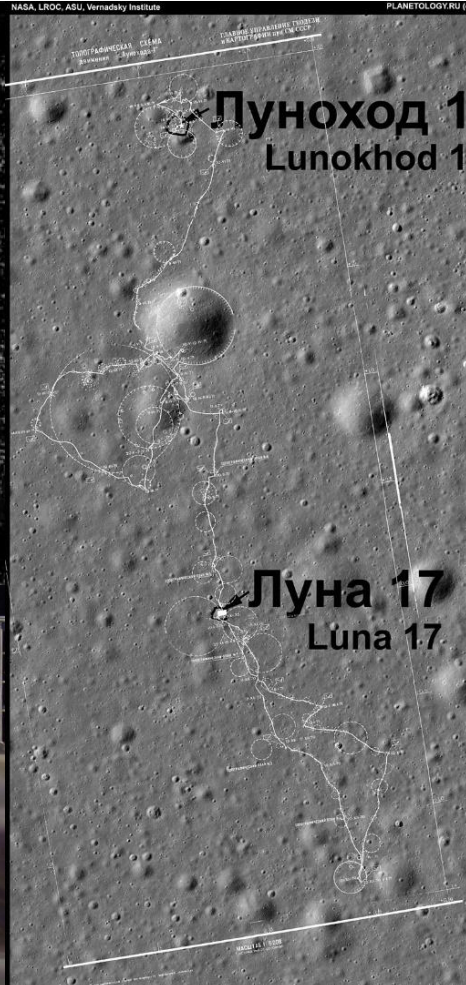
- A huge prestige card for the US, and respect for NASA
- A springboard for all the human space programs that followed
- Knowledge about the Moon, its composition, and origin

Soviet lunar programs

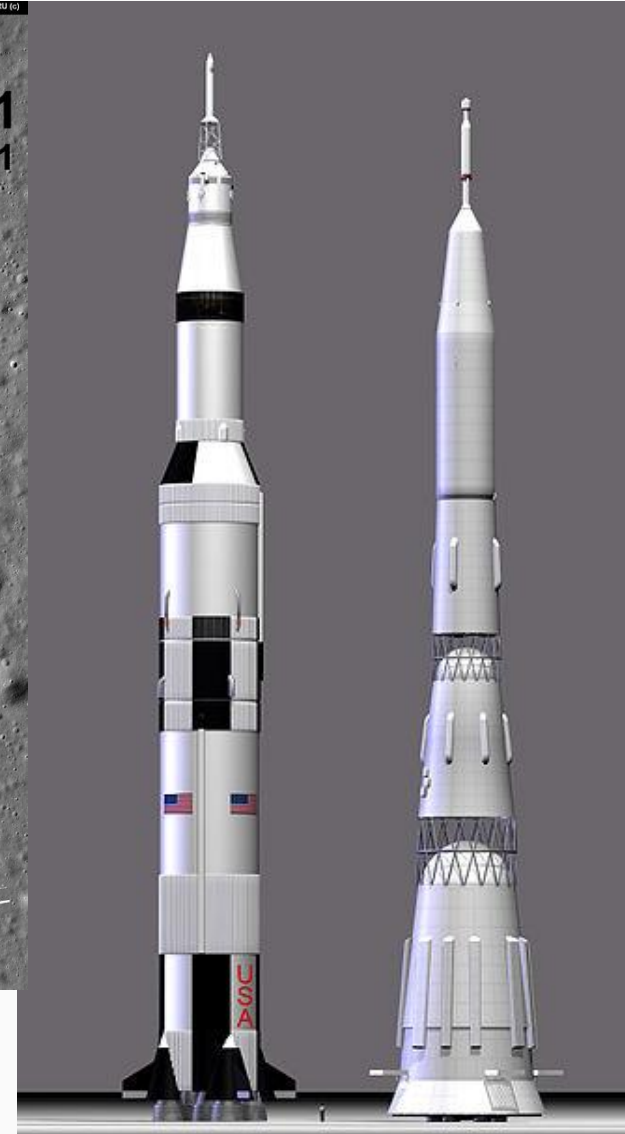
Luna 3
1959



Lunokhod
Moon
exploration
rovers, 1970
to 1973, and
more Luna
missions,
incl. Luna 16
sample
return 1970



LRO picture
2010



Saturn V
and
N1 rocket

Space stations – Salyut, Skylab and Mir - 1971 to 2001



3. The Space Shuttle

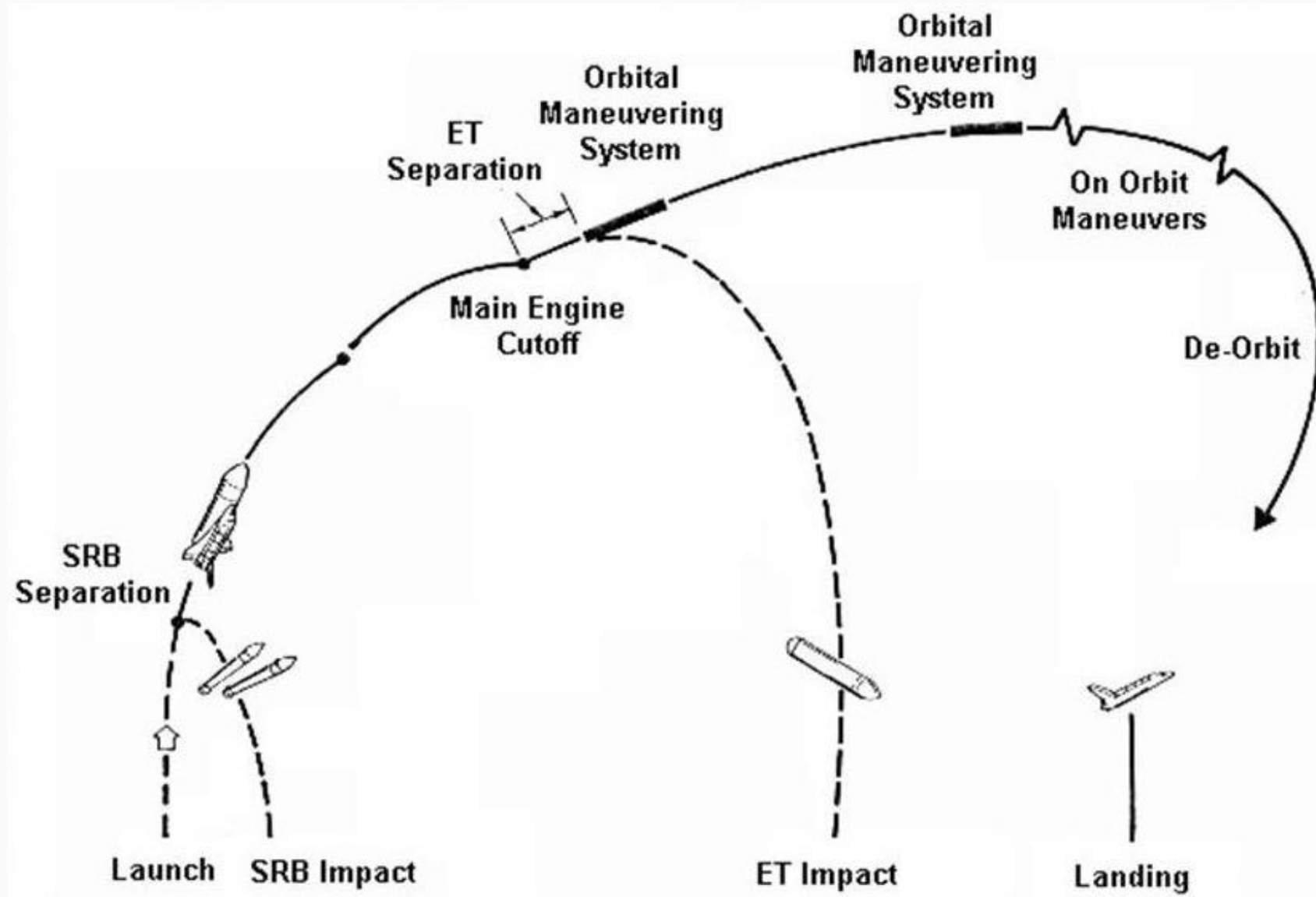
The Shuttle program was launched in the seventies in the US with the idea to replace all non-reusable launchers for commercial, exploration/scientific and defense purposes, and flying frequently.

Mission duration typically 10 to 15 days.

The use of the Shuttle for commercial and defense missions was canceled after the Challenger accident in 1986.



Space Shuttle ascent profile (not to scale)



Shuttle designed to carry humans, but no escape system initially!



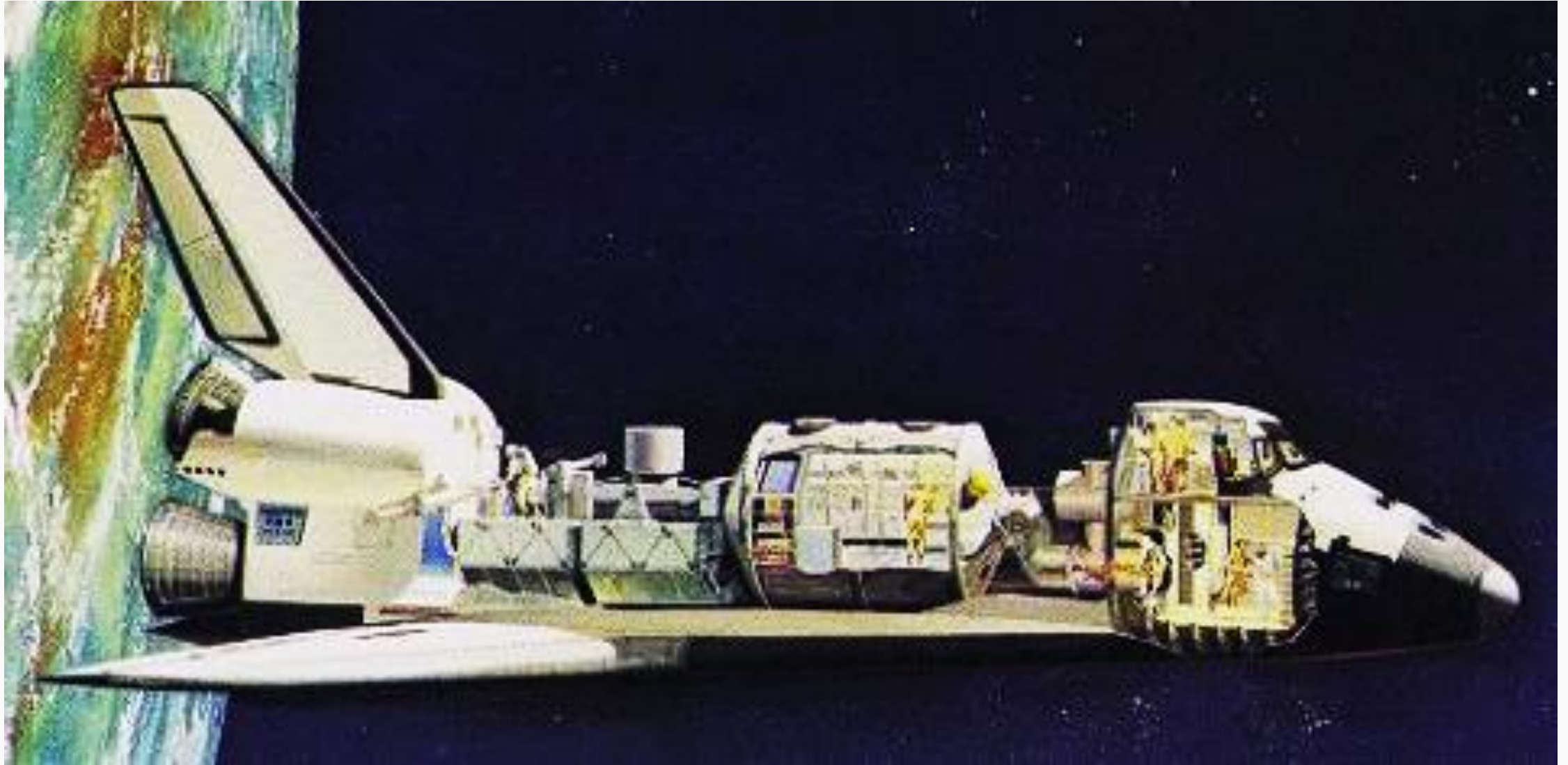
Human rating of the Space Shuttle

- Two-failure tolerance: fail operational – fail safe
- Data processing system providing protection against HW and SW errors
- No single crew error should result in a catastrophic event
- Quality build, and quality control
- Thorough inspections routine
- FMEA (Failure Modes and Effects Analysis)

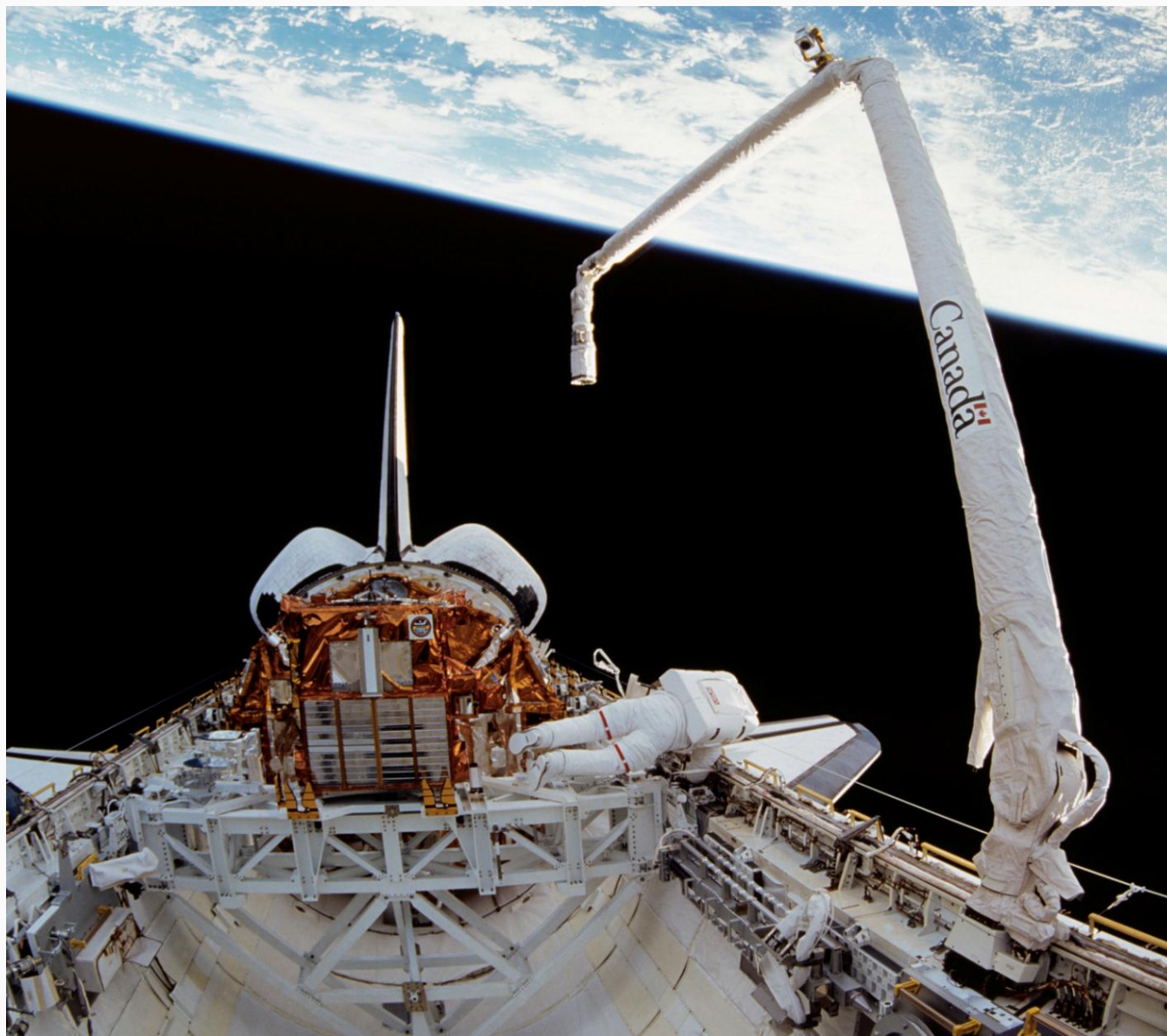
Space Shuttle – On-orbit and landing



Space Shuttle – Spacelab (ESA) - First flight in 1983



Space Shuttle – Remote Manipulator System (RMS, Canadarm)



30 years of Space Shuttle utilization STS 1 in 1981 to STS 135 in 2011



Enterprise
Test vehicle

Columbia
28 missions

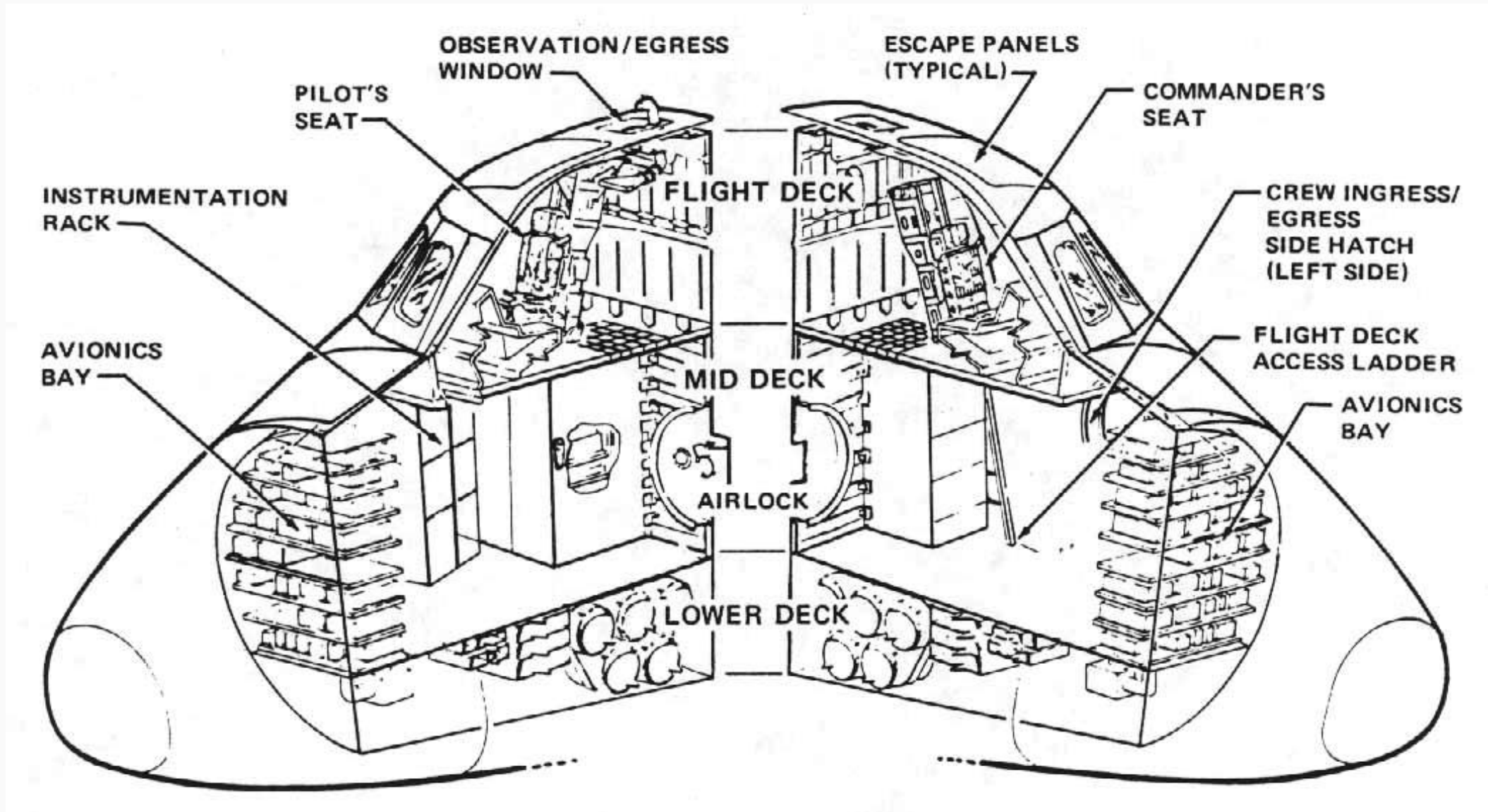
Challenger
10 missions

Atlantis
33 missions

Discovery
39 missions

Endeavour
25 missions

Shuttle – Overall view of habitable compartments



Flight Deck



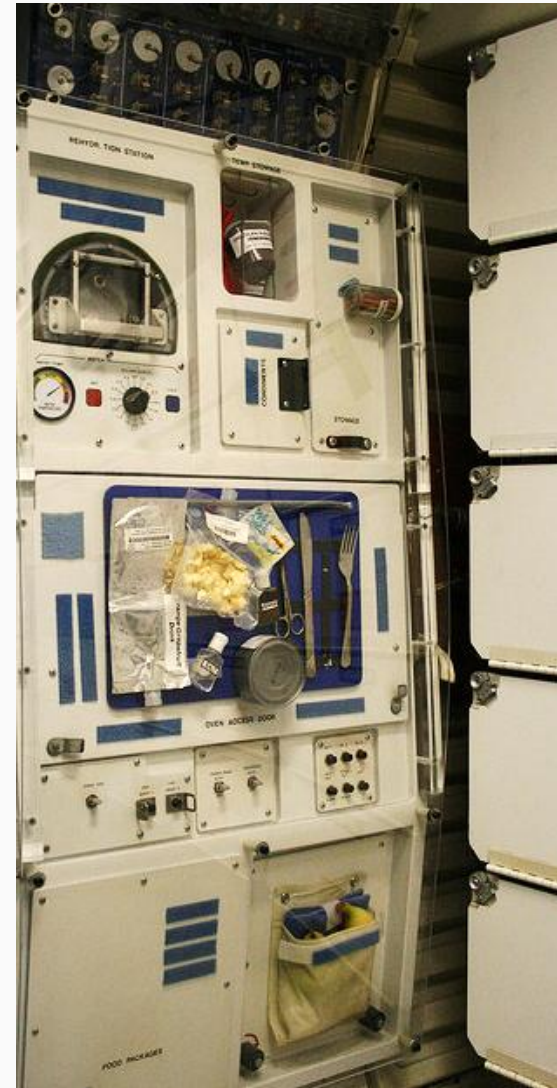
Shuttle – from the original cockpit layout to MEDS (year 2000 to 2005)



The Aft Flight Deck – Playground for on-orbit operations



Food onboard the Shuttle



Food was taken mainly in dehydrated form (no refrigerator on the Shuttle).

Food preparation = re-hydration with selection of the volume and the temperature of the injected water, heater to re-heat the food if needed.

Sleeping...



Waste Collection System

It worked fine if you followed the procedures !



...but sometimes you had to fix it !
Who is this guy ?



Ready for ascent – in the Flight Deck

Camera view looking down from the instrument panel.

Crew members are lying on the back of their seat with their feet up.

The orange Launch and Entry Suits (LESs) were protecting crewmembers against a possible loss of cabin pressure during ascent and entry phases.



... and in the Mid Deck



Launch sequence

SSME (LH2 and LOX) start at T-6 sec
SRB ignition at T=0
Roll Maneuver
SRB SEP at T+2 min
MECO at T+8:30 min
ET SEP at MECO+18 sec
OMS 1 maybe
OMS 2 at MECO+45 min

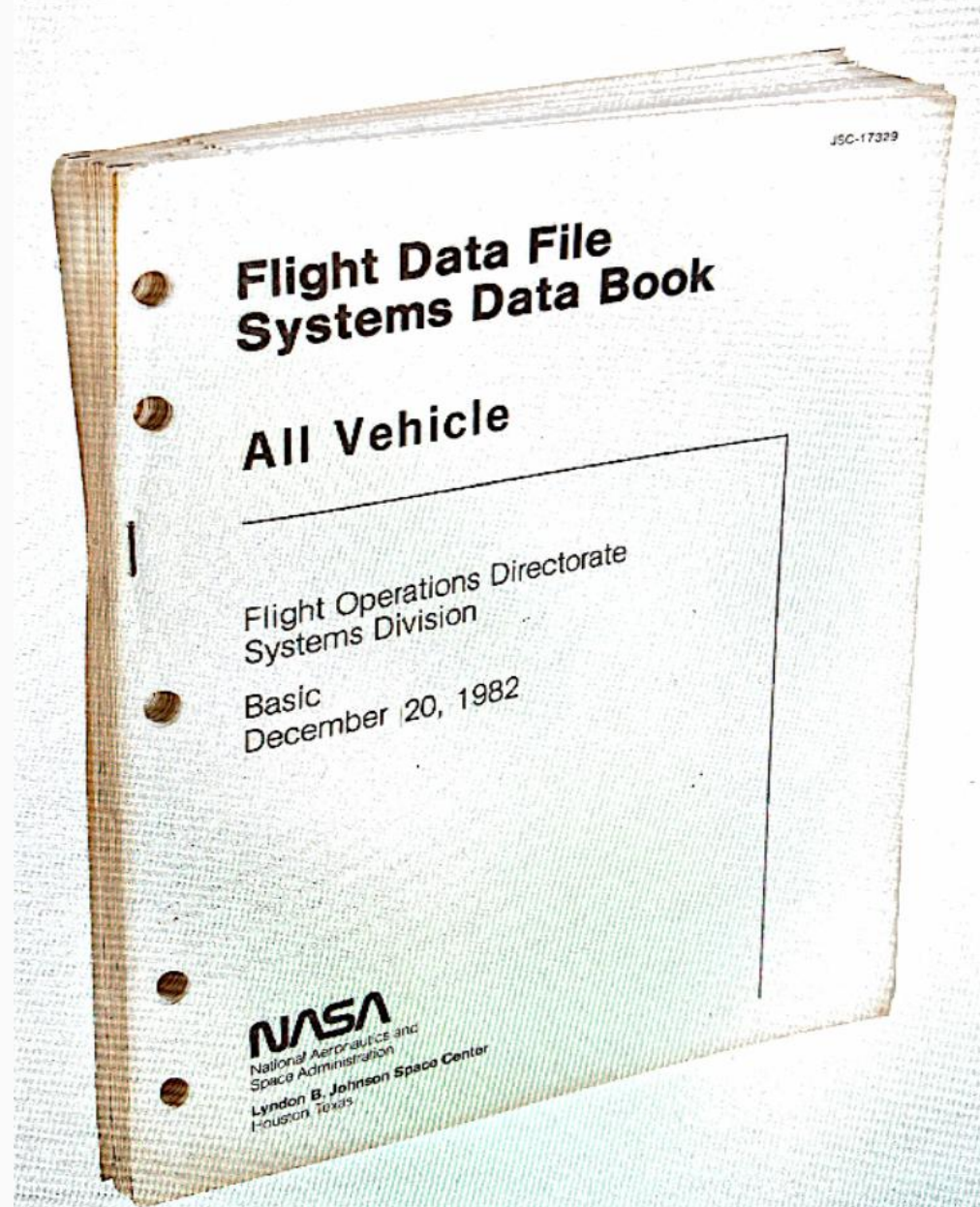


Shuttle launch

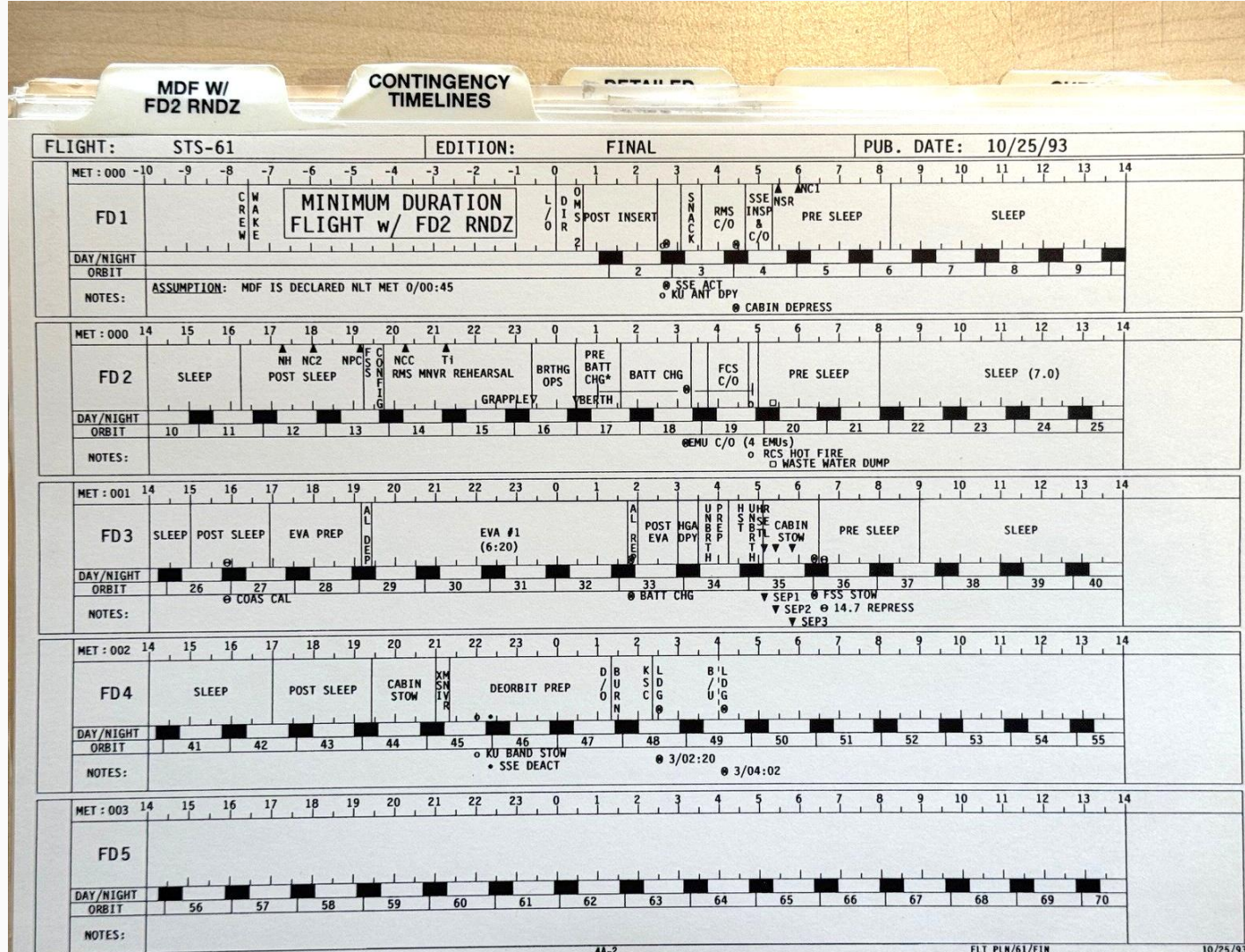
On-orbit operations



Paper flight data File on the Shuttle

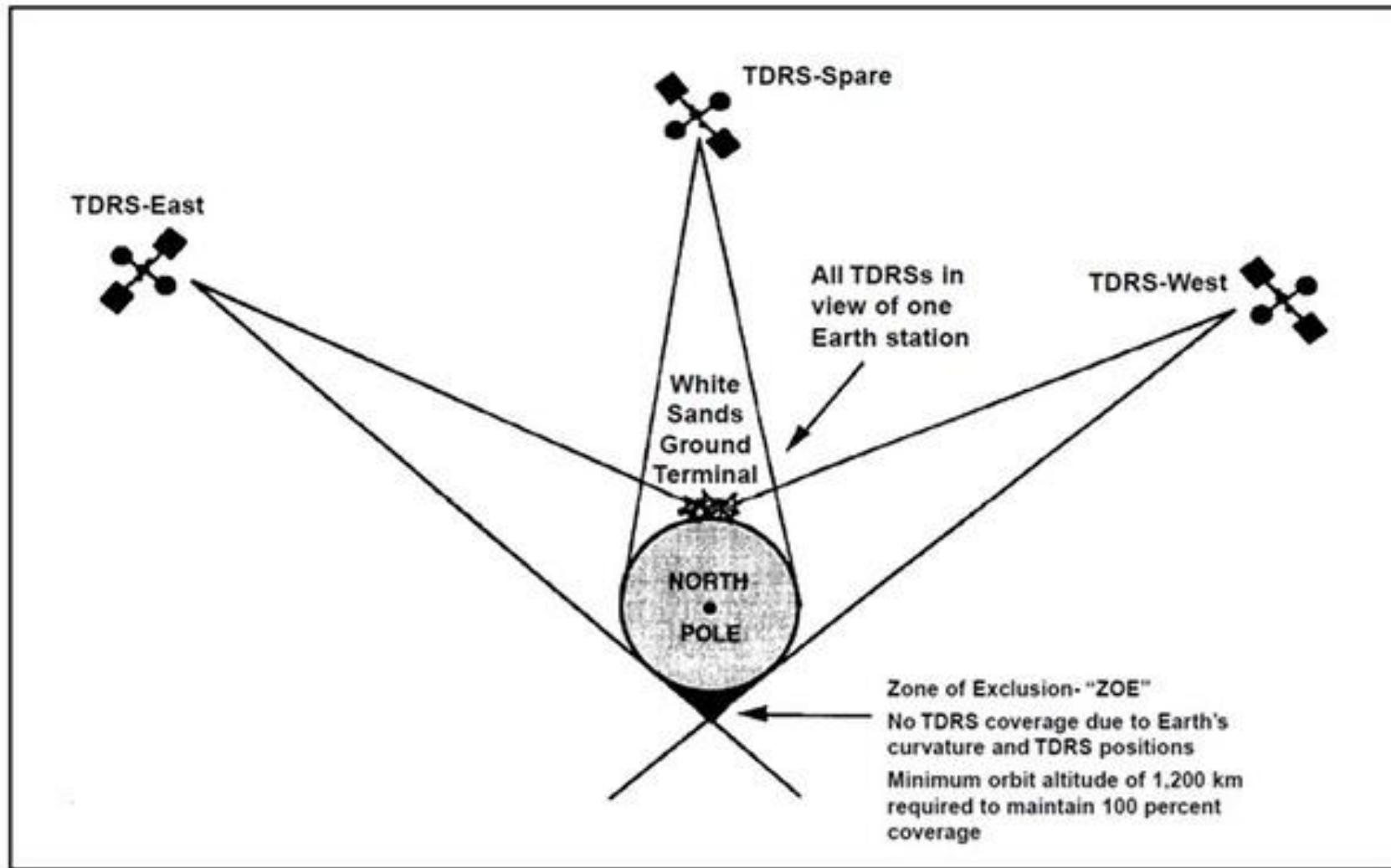


Flight plan in MET, Minimum Duration Mission Hubble repair 1993



Communication and telemetry data/command flow while on-orbit

Via the TDRS (Tracking and Data Relay Satellites) – The latest generation of these satellites provides ground reception rates of 6 Mbit/s in S-band and 800 Mbit/s in the K-band. At the time of Shuttle, we just had TDRS east and TDRS west – the system has been expanded now and is in use by ISS, Hubble, other science spacecraft, and the military.



Re-entry in the atmosphere

Night re-entry in the atmosphere, with a bright glow visible through the forward windows because of the hot plasma outside.

Initial entry angle of attack was maintained at 40° to generate drag and lower the speed in the high layers of the atmosphere, and enter the lower layers with a reduced airspeed/Mach number.

Deceleration of 1.5 g was temporarily maintained during the transition to the unpowered glide portion of the re-entry.



On the steep glideslope (20°) at 300 kt IAS

Steep glide slope of 20 degrees angle towards landing runway at Kennedy Space Center, Florida.

This is the view that the Commander and Pilot had through their head-up displays. The crew could see the runway and adjacent scenery, and essential flight data like the pitch and bank angles, the velocity vector direction, the guidance symbol, the airspeed, altitude, and speed brake position.



Touch down

After main wheels touch down and during pitch down to nosewheel touch down, the brake chute was deployed to shorten the rolling distance.

Note the split rudder speedbrake.



In the OPF or Orbiter Processing Facility



Several months of maintenance between flights.

This resulted in a high cost of Shuttle operation.

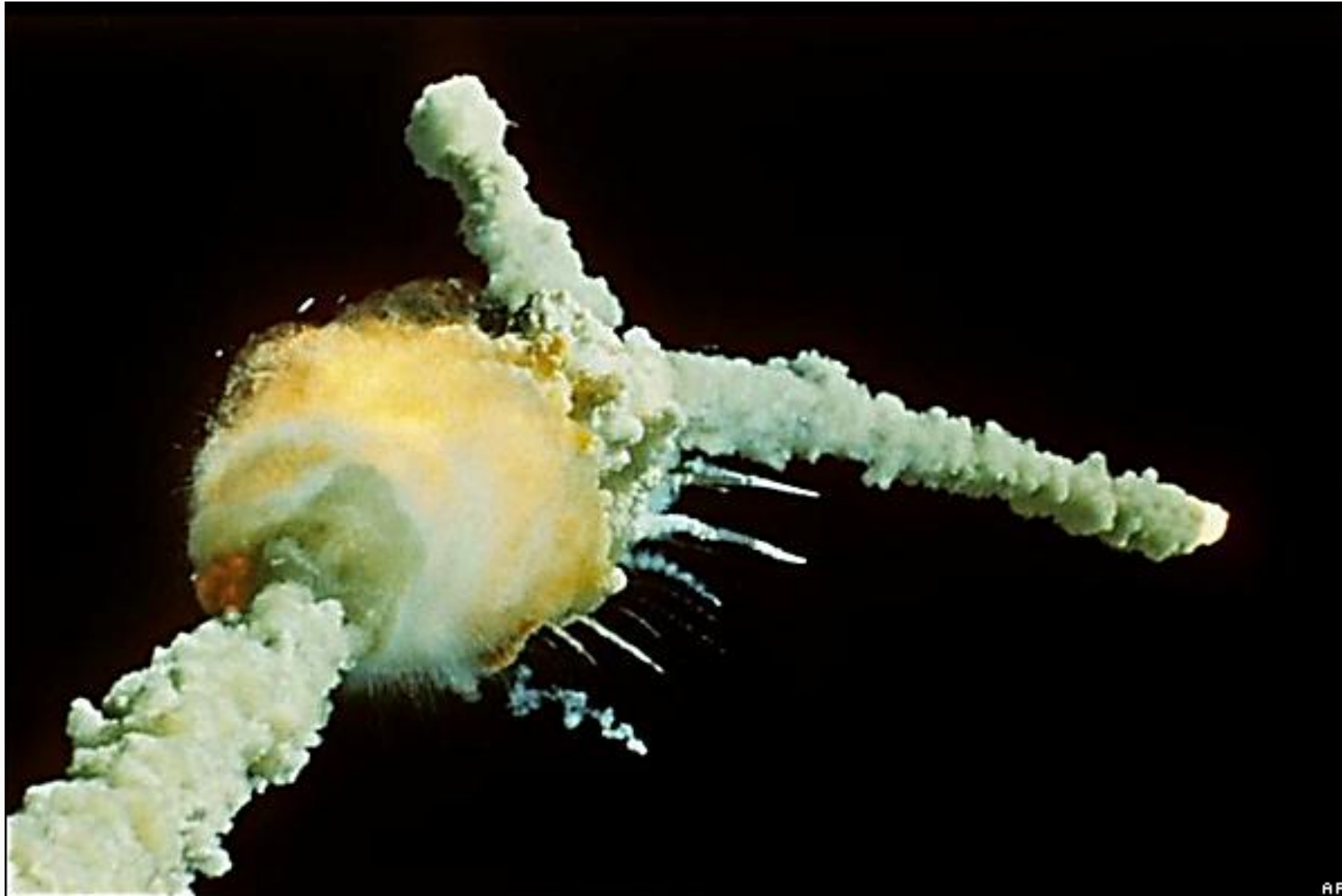
The Shuttle was a very capable space vehicle, but very expensive to operate, and, finally, with a questionable safety record.

Work on the Thermal Protection System TPS



Damage to the TPS was frequent and was one of the reasons for lengthy and expensive Orbiter processing between flights.

STS 51L – Challenger accident on January 28, 1986



STS 107 – Columbia breakup over Texas on February 1, 2003



4. My personal spaceflight experience

ESA astronaut of Swiss nationality

Selected in the first group of ESA astronauts in 1978

Four Space Shuttle missions from 1992 to 1999

Retired from ESA in 2007



Claude's four Space Shuttle missions



STS-61
12 days
1993

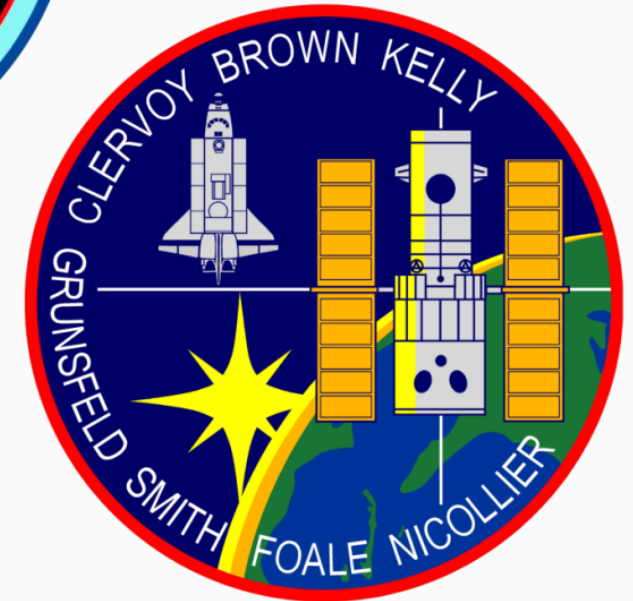


STS-75
15 days
1996

STS-103
8 days
1999



STS-46
8 days
1992



Selected in the first group of ESA astronauts in 1978



Claude Ulf Merbold (D) Wubbo Ockels (NL) Franco Malerba (I) joined the ASI

To NASA Johnson Space Center Houston in 1980 for training on the Shuttle



Shuttle Mission Simulator (SMS)



Shuttle Avionics Integration Lab (SAIL)

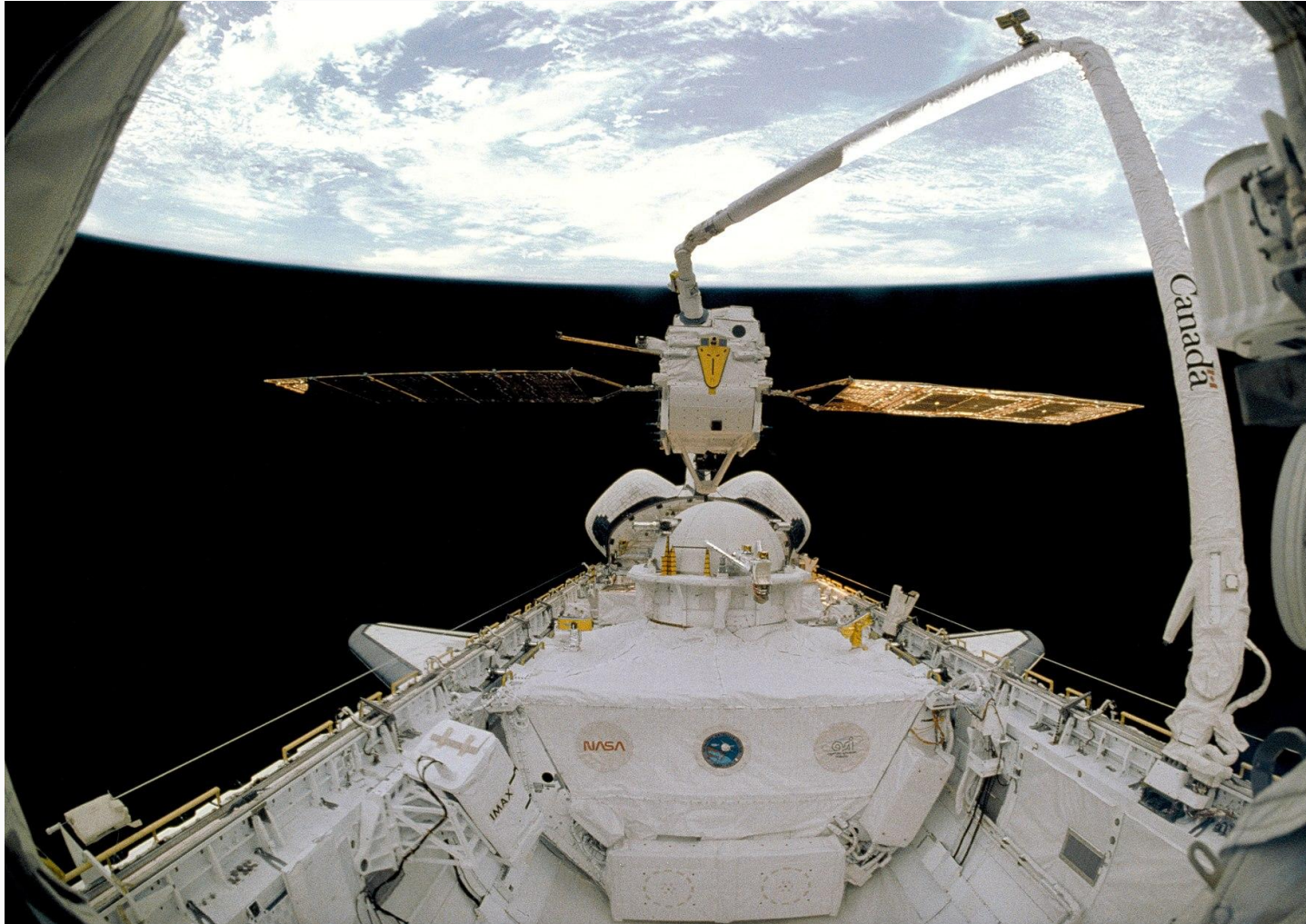
T-38 – Training and traveling tool for astronauts ! Life was good !



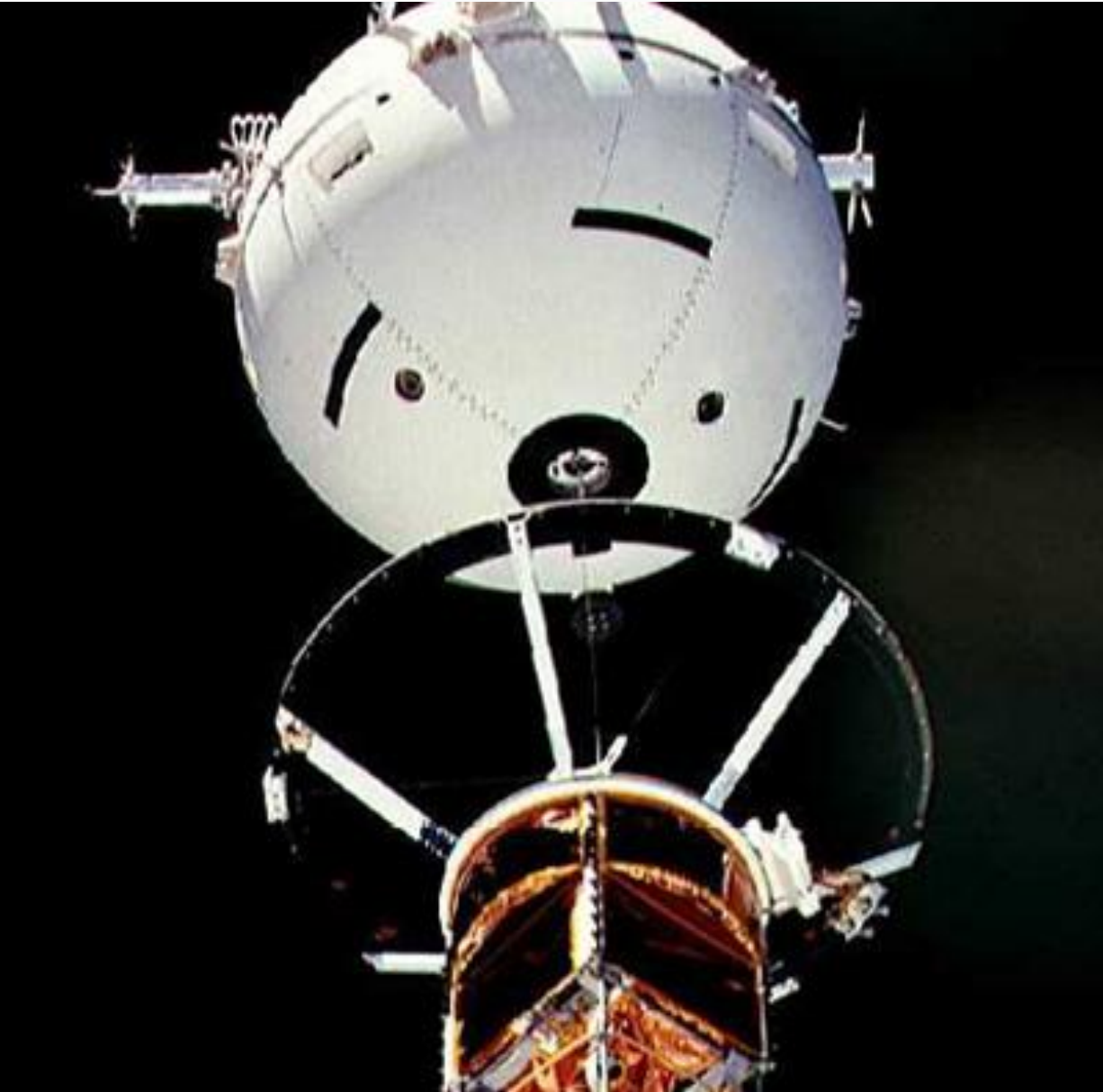
First mission STS-46, July-August 1992, EURECA and TSS-1



EURECA (ESA) deployment



Tethered Satellite TSS-1 (NASA-ASI)



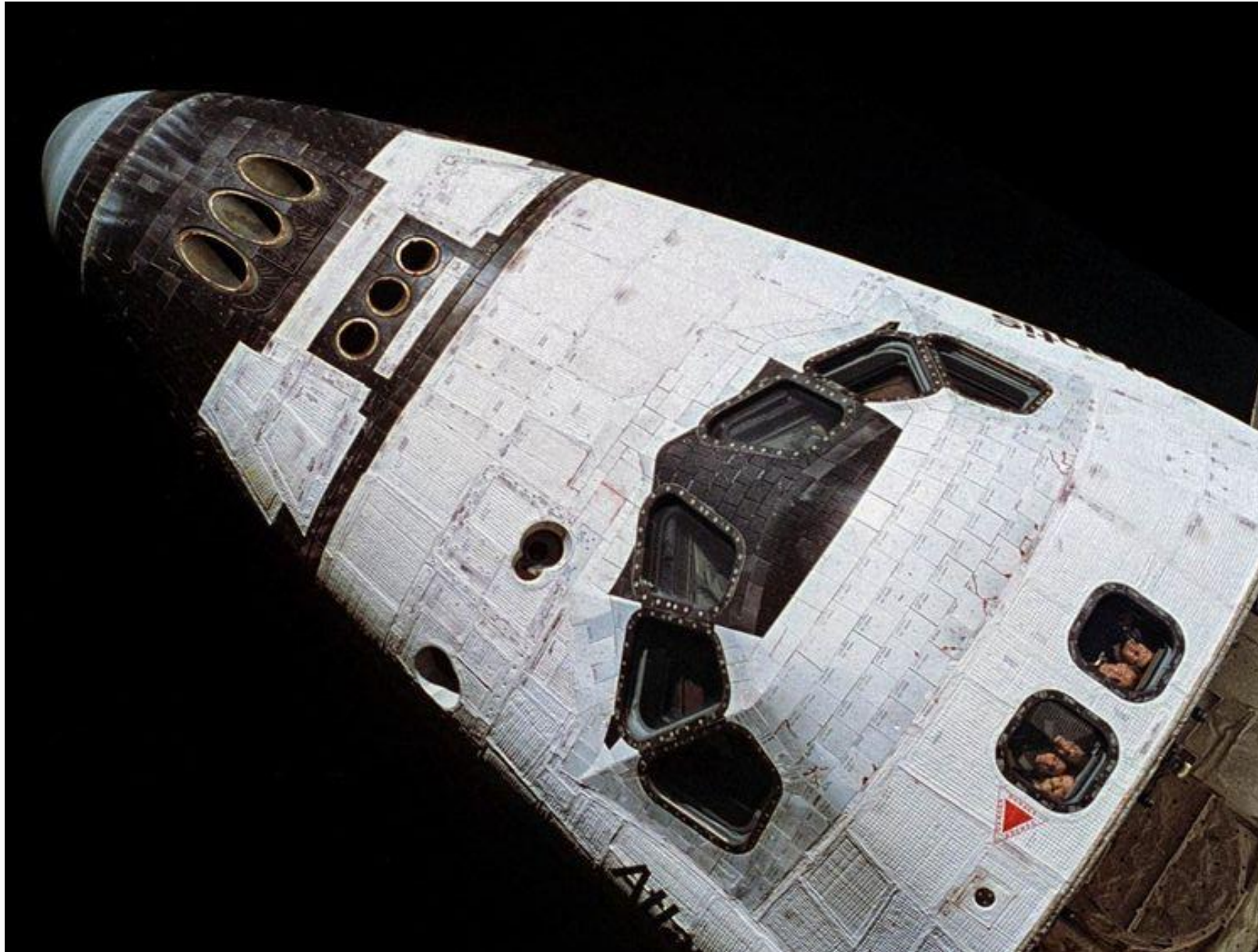
TSS-1 – Satellite stuck at 250 meters distance, deployer failure !



TSS-1R – STS-75 in 1996 - Tether break at 19.6 km tether length



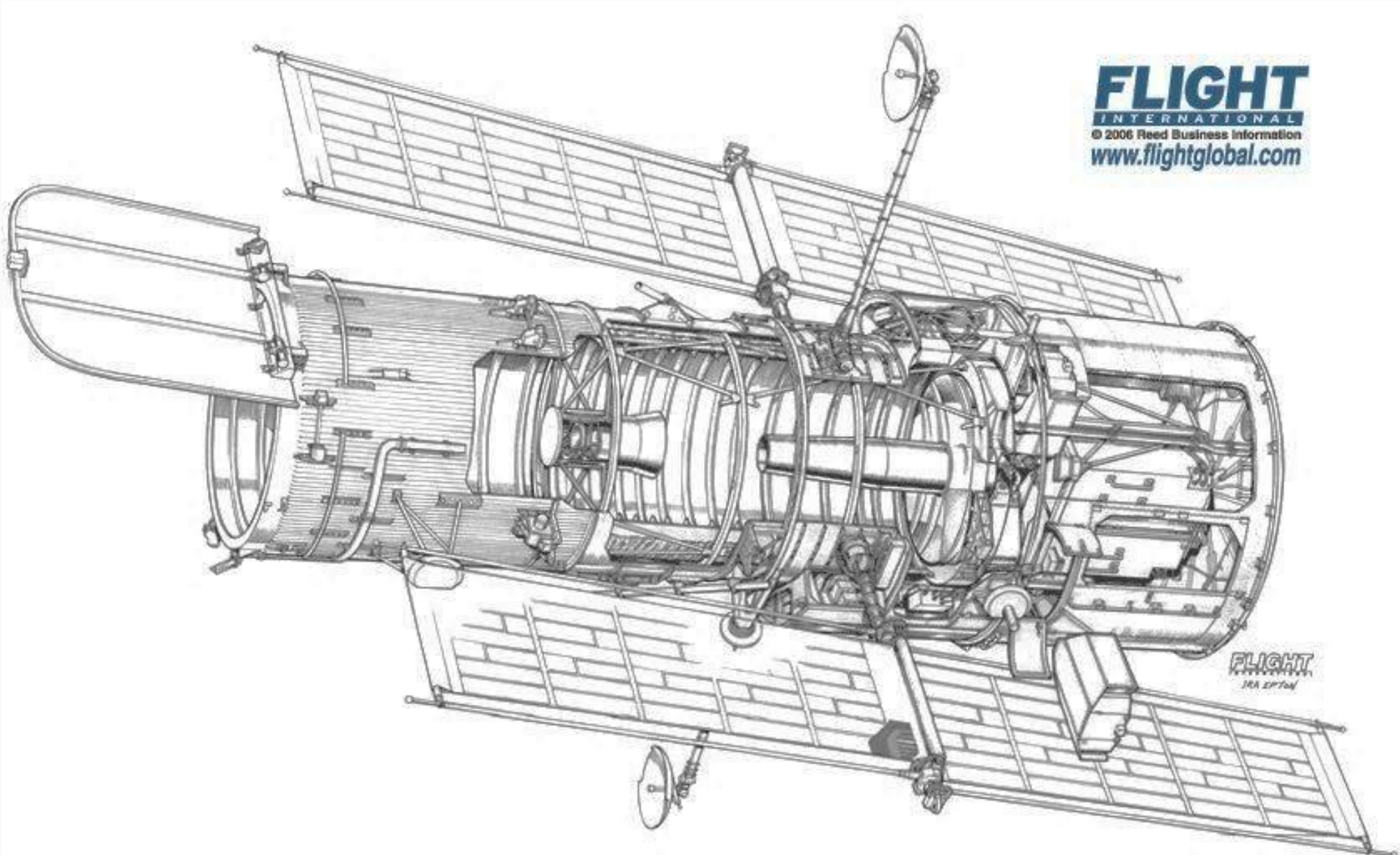
A «Space Selfie» !



Hubble – NASA-ESA project for a serviceable telescope in LEO



Hubble



Hubble release to orbit at 600 km altitude on STS-31 in April 1990



Hubble was installed on its orbit in April 1990, but there was a problem, undetected until a few days after deployment:

A severe spherical aberration of the primary mirror (2 microns too flat at the edge of the 2.4 meters mirror disk).

Crew selected for Hubble SM 1 (STS-61) to fix the optical problem



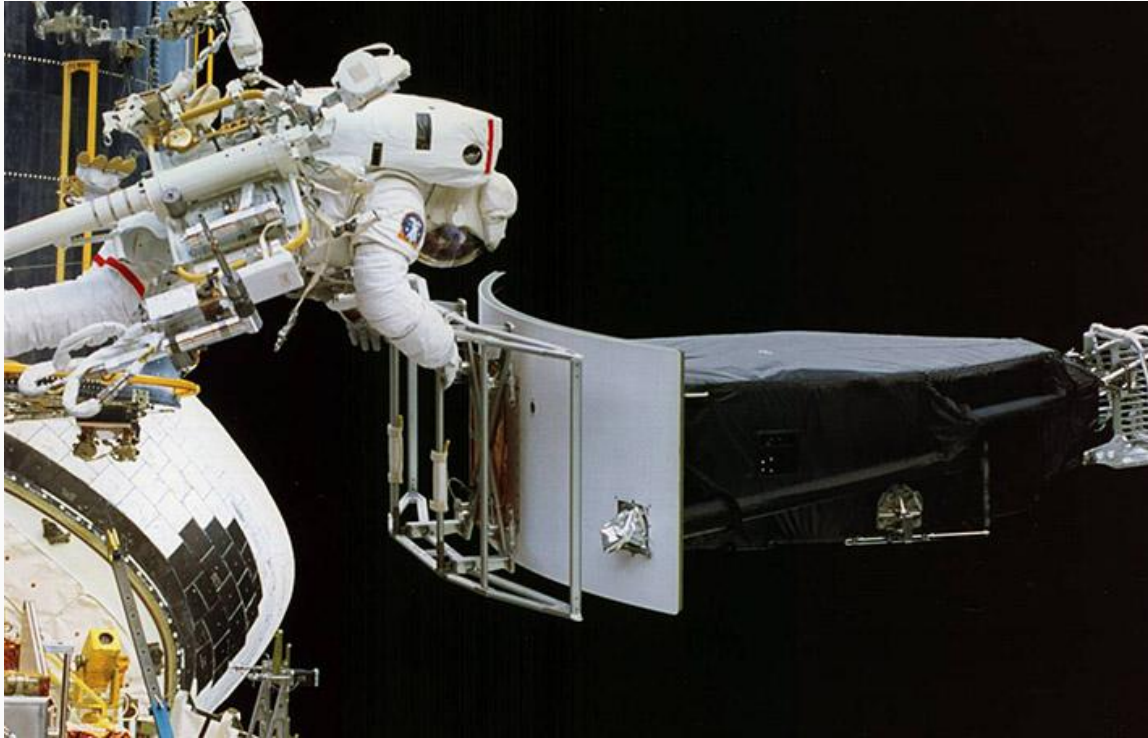
Hubble capture and installation in Endeavour's payload bay



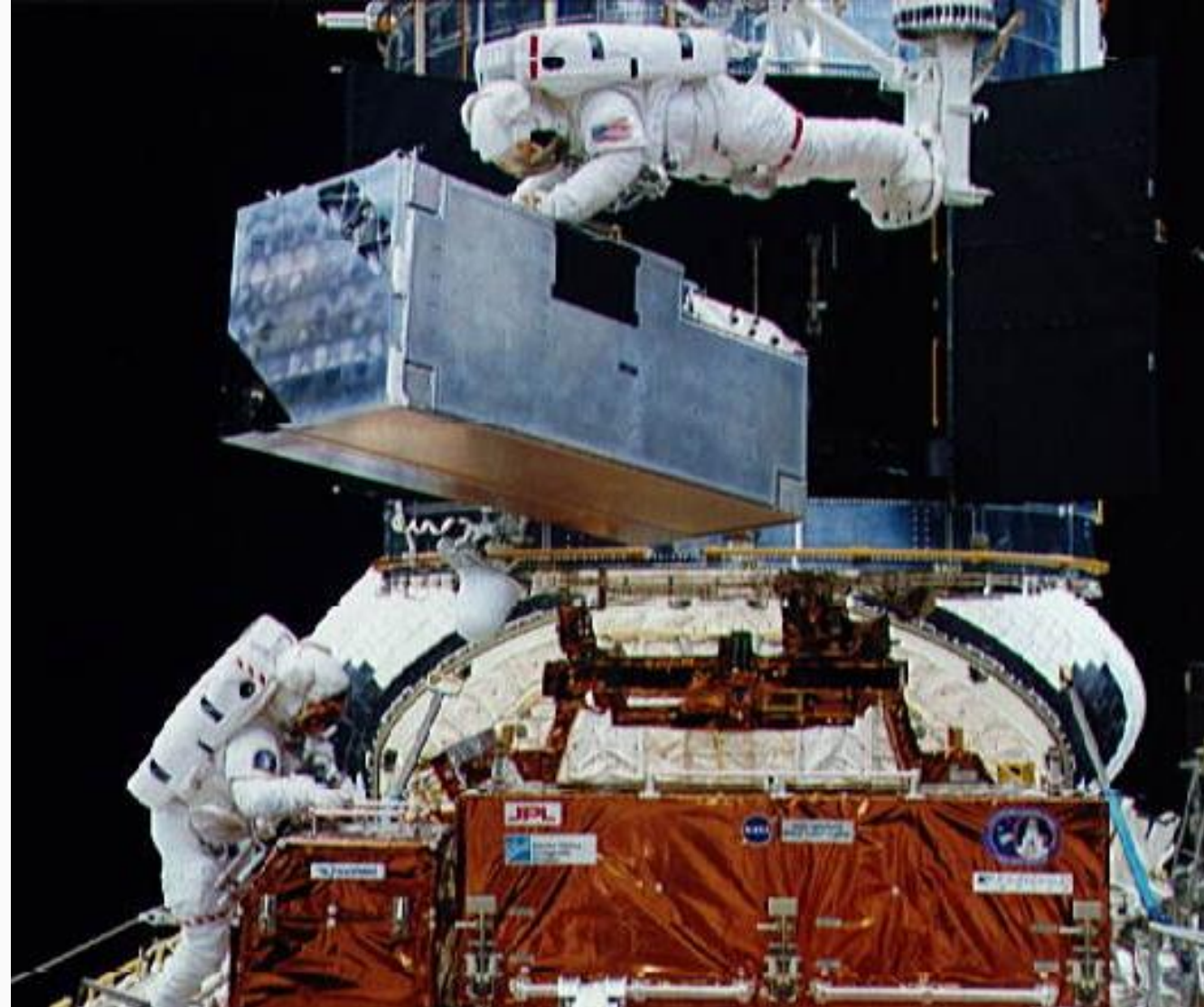
Hubble capture
48 hours after lift off,
December 4th, 1993



Optical fixes through extensively trained spacewalks



Optical correction actions
with WFPC 2 and COSTAR
(Corrective Optics Space
Telescope Axial Replacement)



A total of 5 EVAs
on SM 1



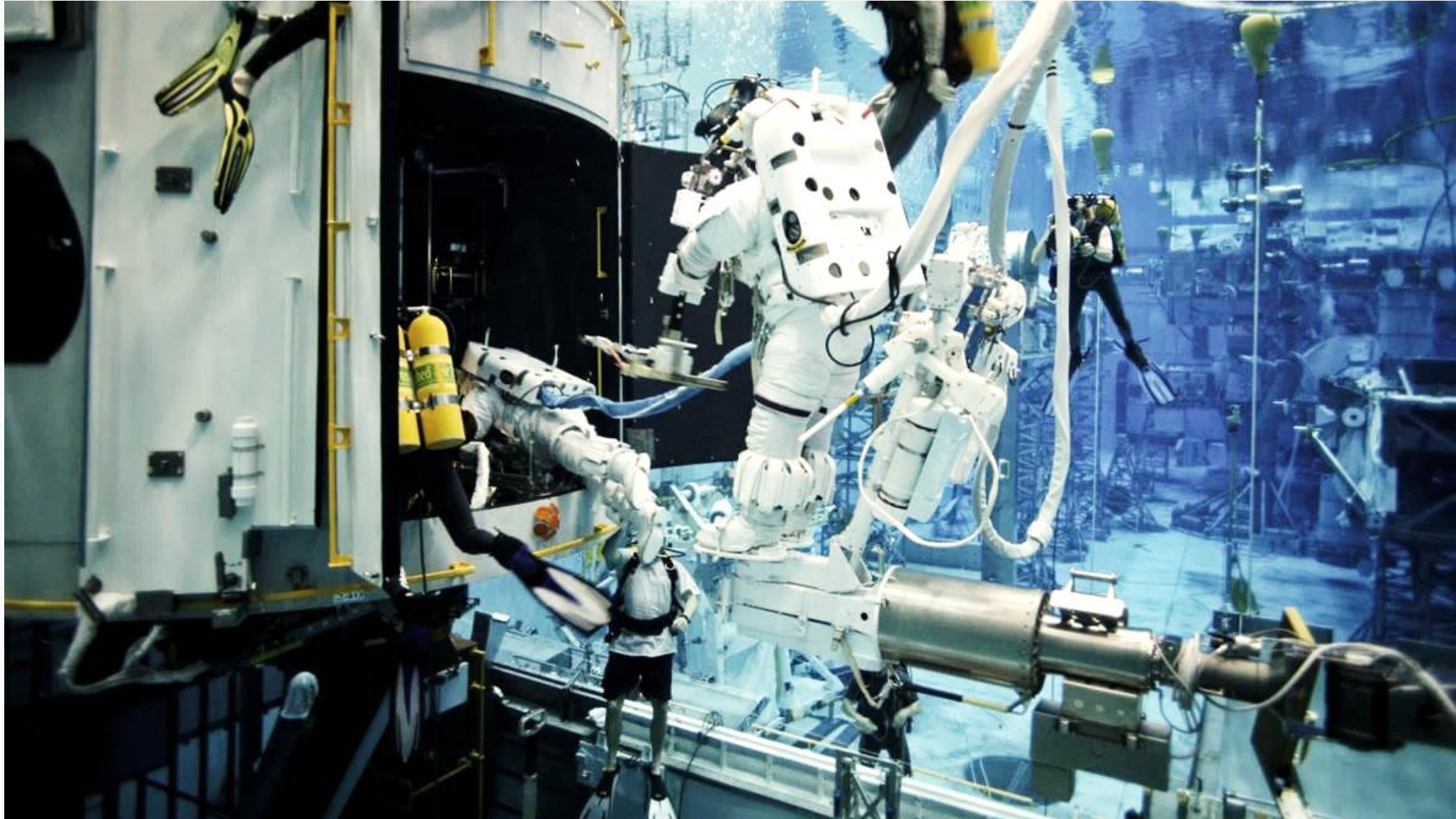
Mission accomplished !



The wise man: Milt Heflin, Lead Flight Director of Hubble SM 1



Training for SM 3A (STS-103) to fix another Hubble problem



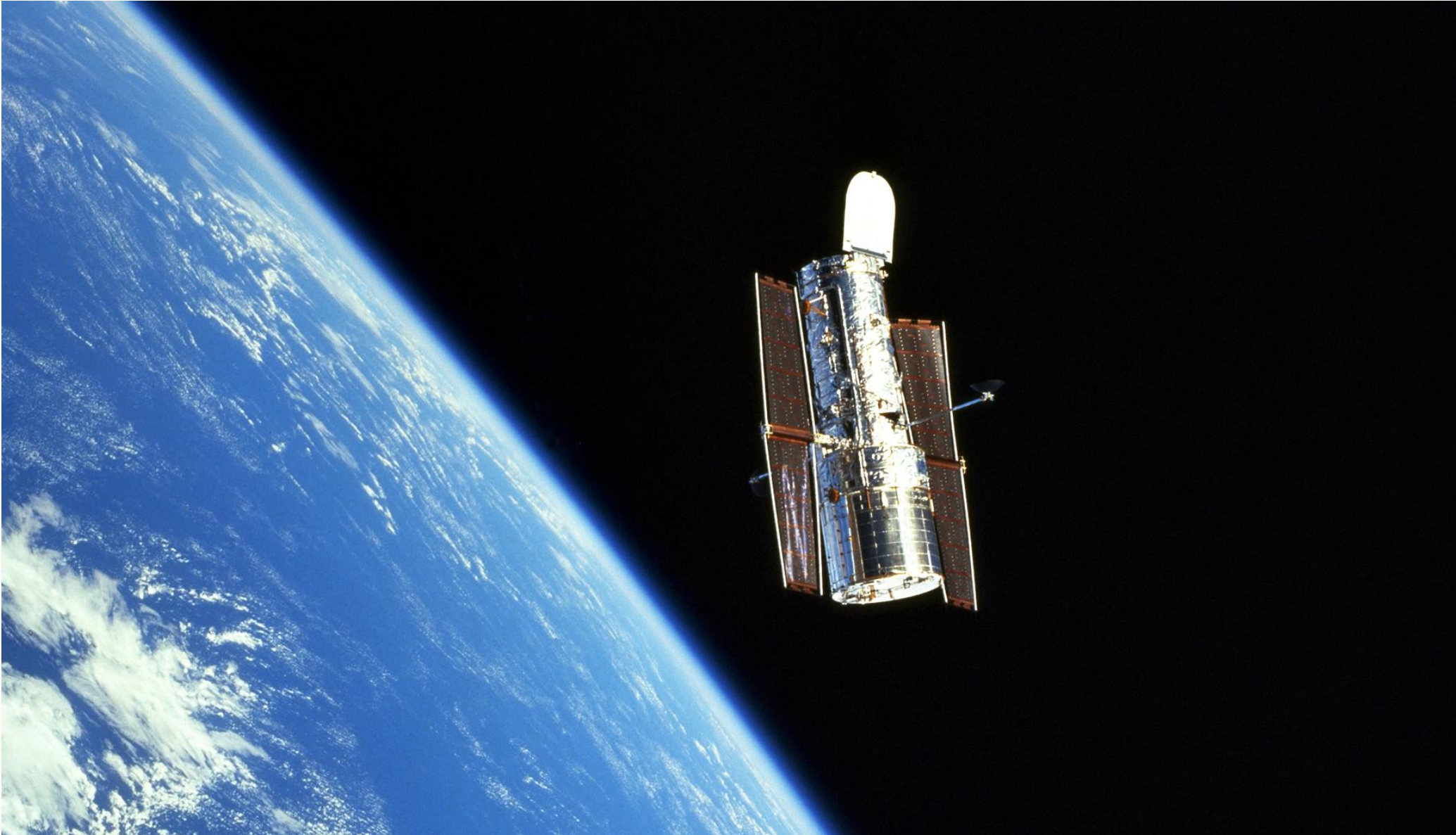
EVA 2 with Mike Foale and Claude, to exchange computer and FGS#2



More than 8 hours spent outside working on Hubble - very tired at the end but really happy!



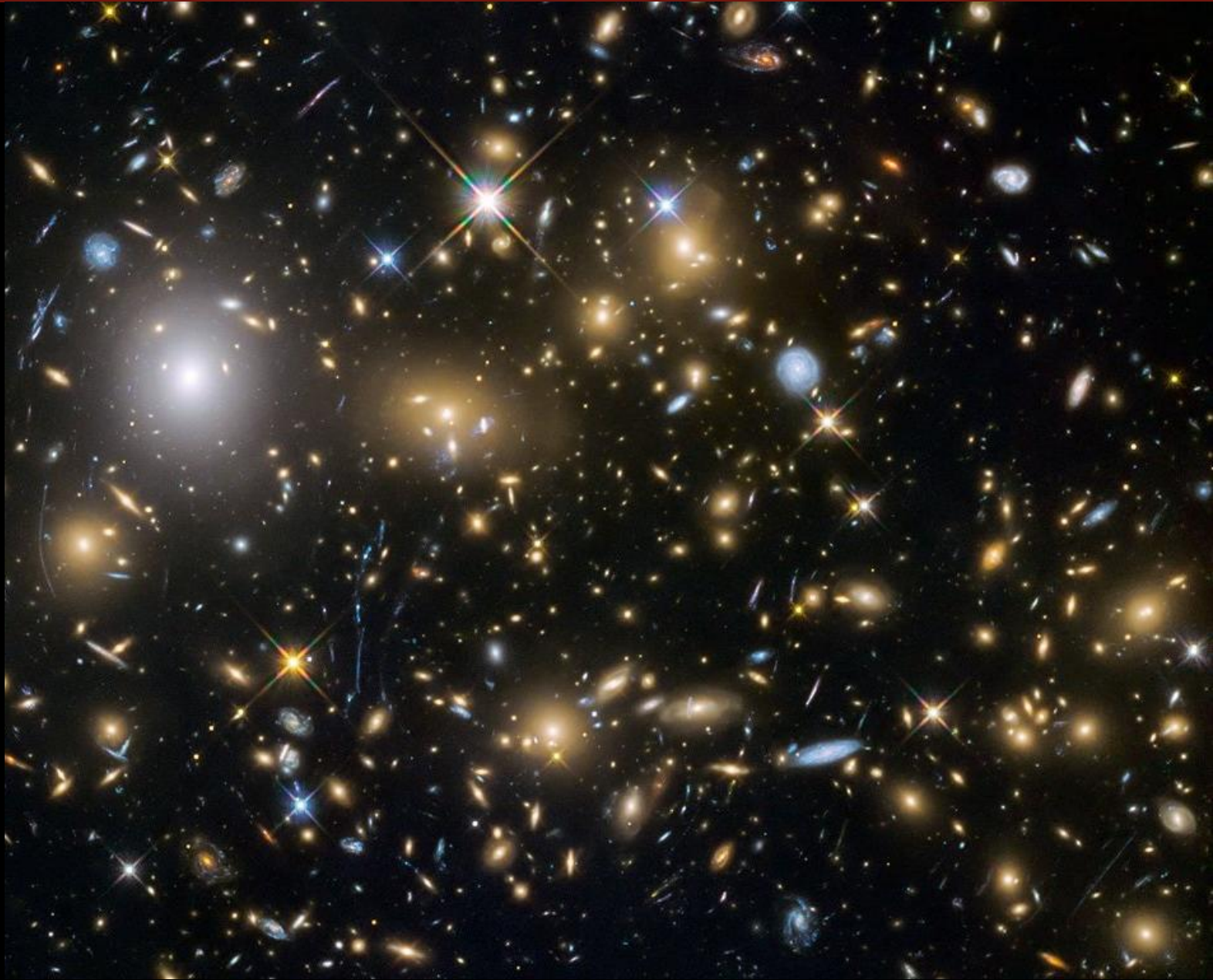
Hubble release on Christmas day, 1999





Hubble close up in the Andromeda galaxy

One of Hubble's Deep Fields – looking very far away in our Universe !



5. ISS and the Tiangong Space Stations, and visiting vehicles

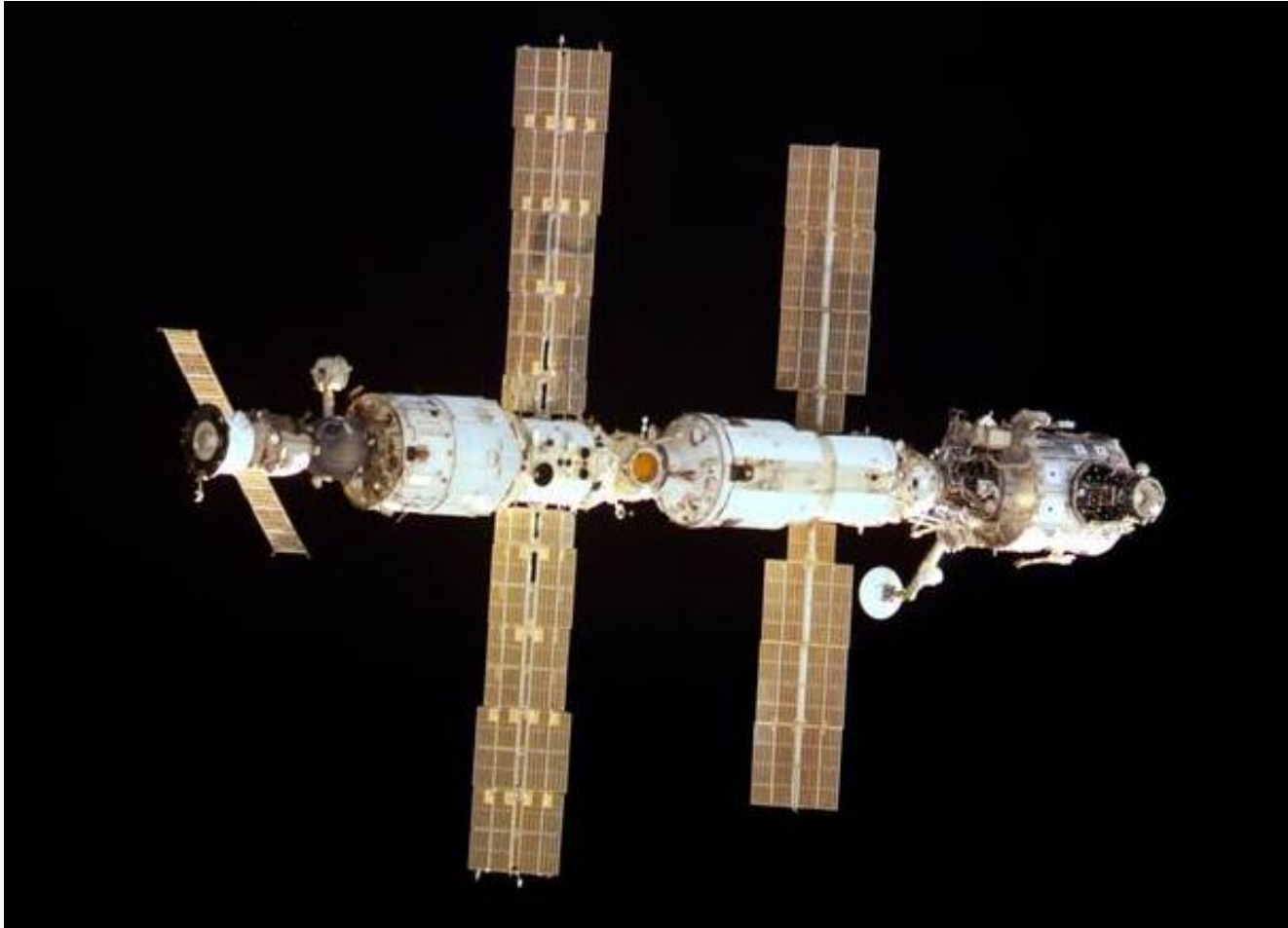
The International Space Station (ISS) and the Chinese Tiangong Space Stations are major human spaceflight tools for research and exploration in the Low Earth Orbit (LEO)



Signing of the ISS Agreements on January 29, 1998



Buildup of ISS



The intent of ISS was to make available a world-class laboratory in space for life science, materials science, Earth observations, solar physics, technology development and support of long-duration spaceflight in the Solar System in the future.

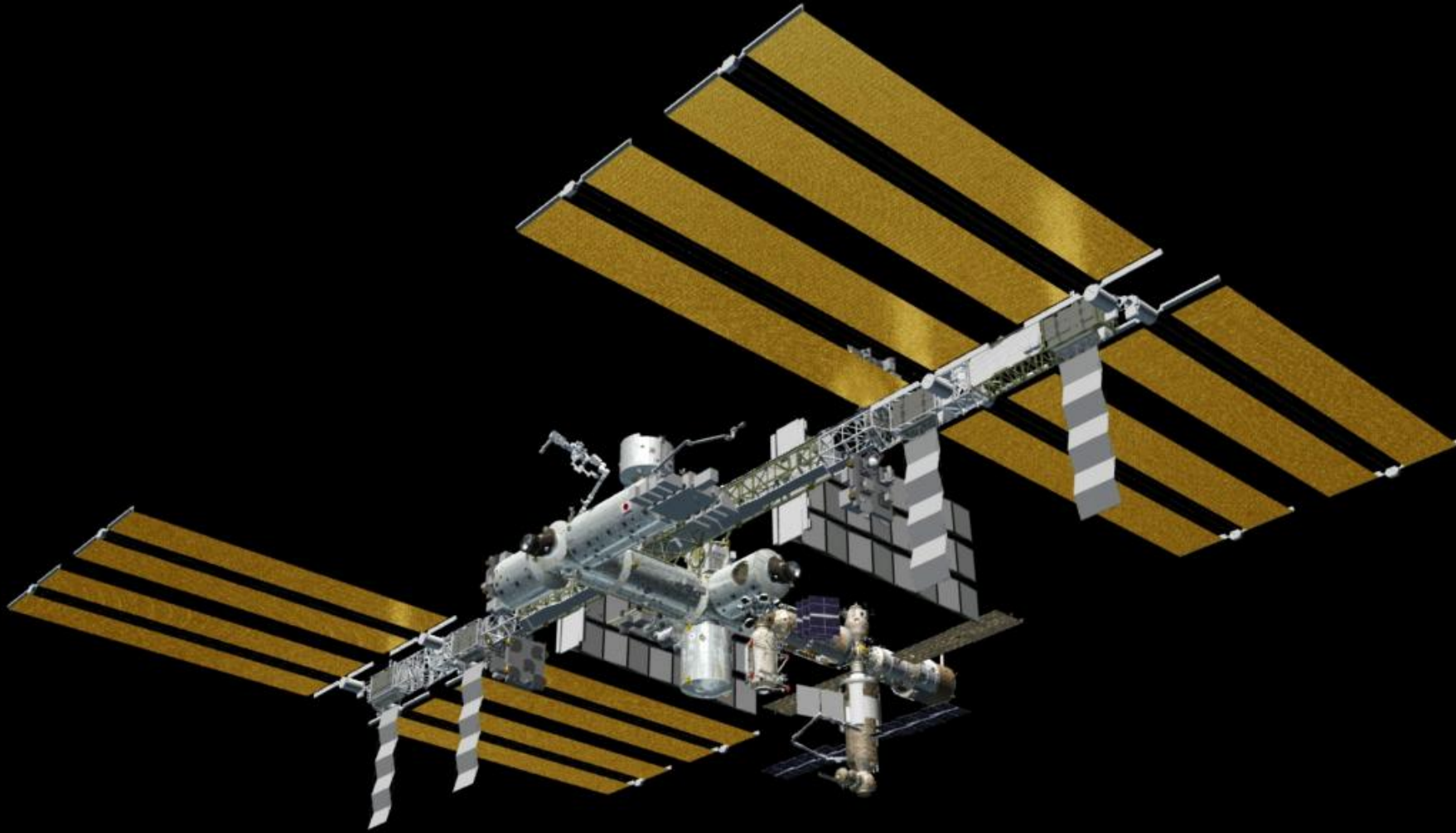
Following the mating of the first two elements: Zarya Russian module, and US Unity Node or Node 1 on STS-88, another Russian module, Zvezda, was added in July 2000.

First ISS crew in November 2000

First human presence in ISS was in November 2000: Sergei Krikalev and Yuri Gidzenko, from Russia, and Bill Shepherd from NASA.

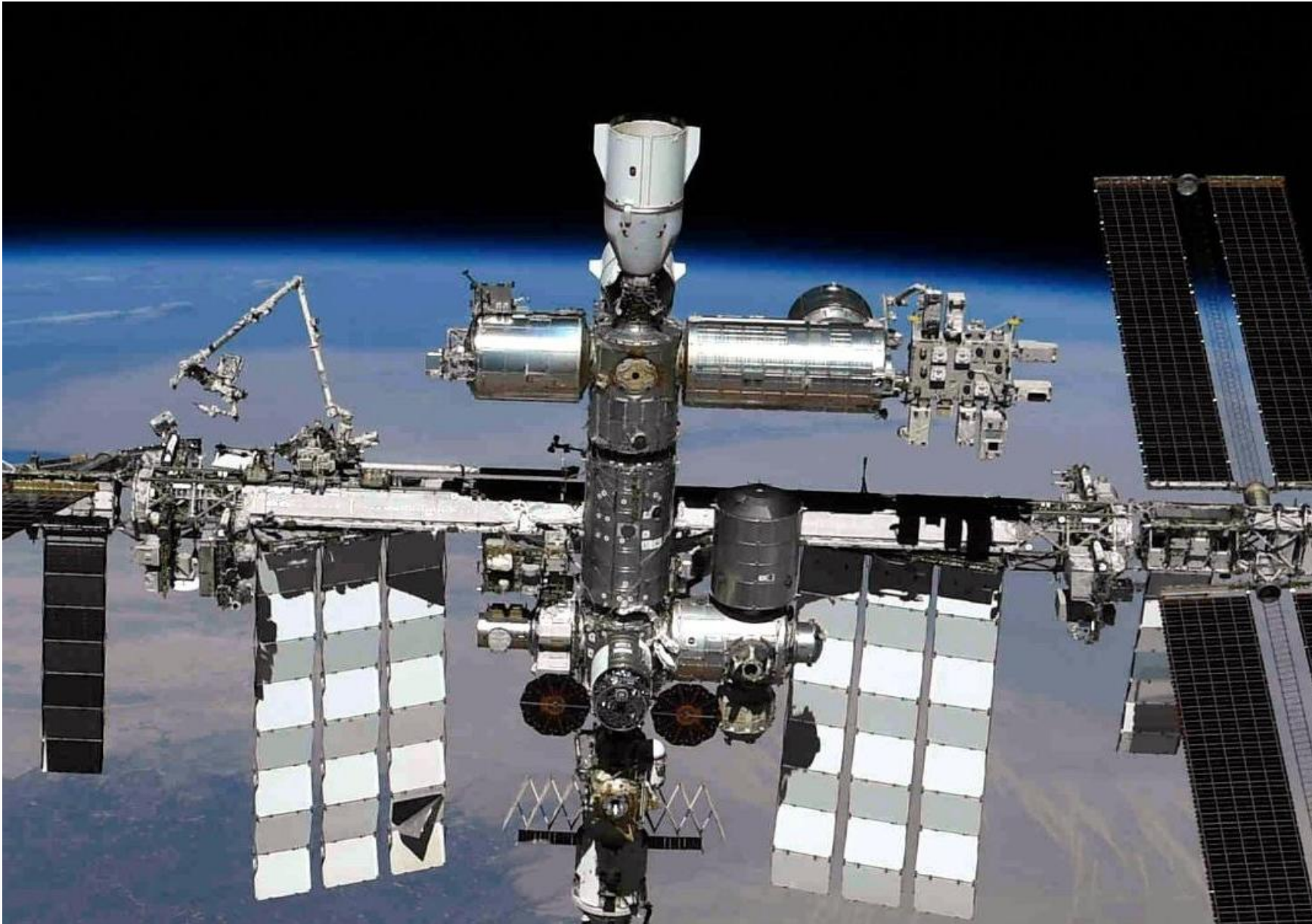


ISS assembly complete in July 2011



Both Shuttle and Proton launchers (Russia) were used for ISS assembly.

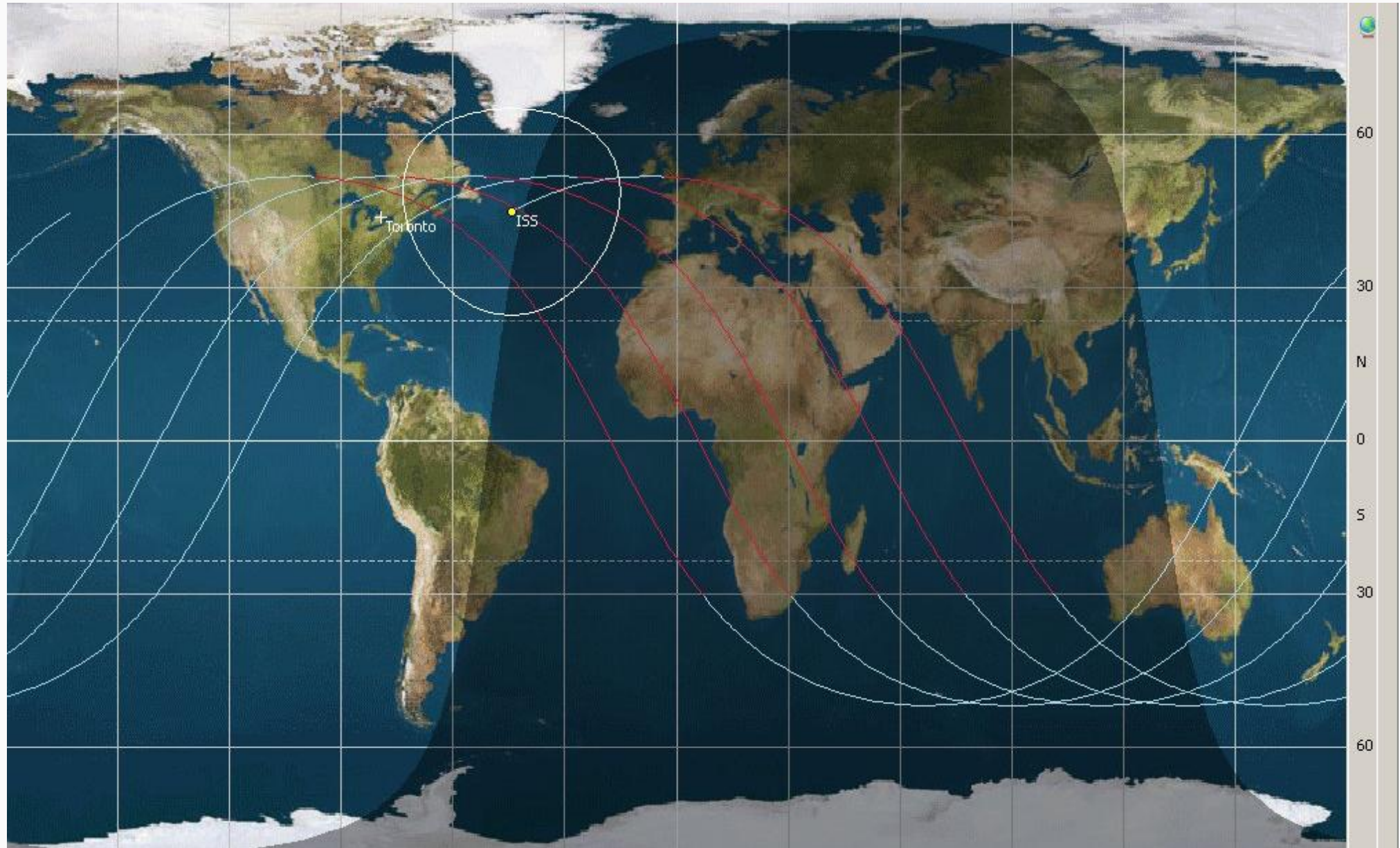
USOS (US Orbital Segment) with Columbus (ESA) and Kibo (Japan)



Inside the ISS US Lab



ISS ground track (51.6° orbit inclination), altitude around 400 km



Cargo and human resupply of ISS with Progress and Soyuz (Russia)



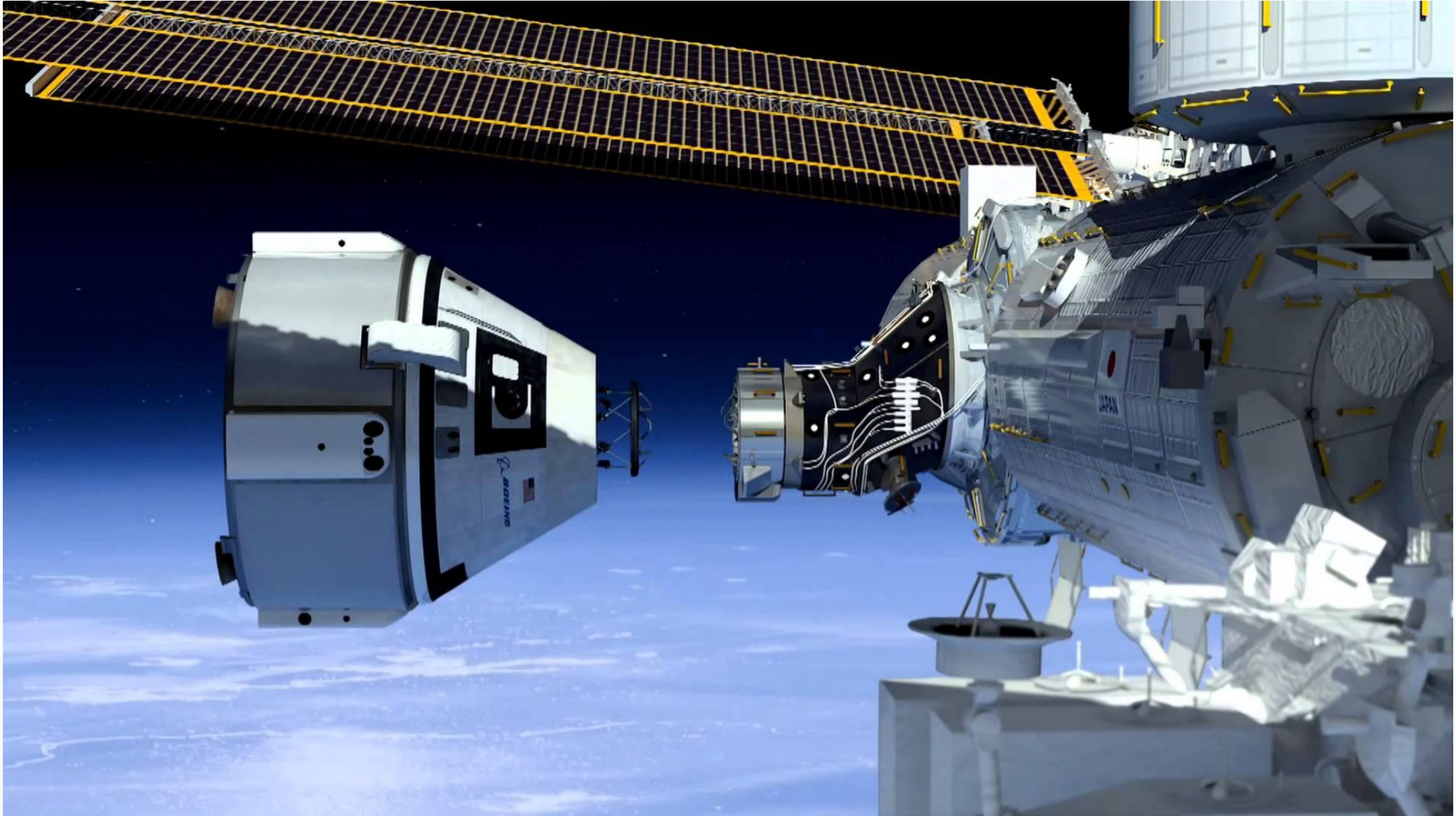
Cargo and human resupply of ISS with SpaceX Falcon 9 and Dragon/Crew Dragon



Recovery of Falcon 9's first stage on every mission!



The Boeing Starliner might become operational some day, but not yet...



Current crew on ISS (December 12, 2025)

Expedition 74 (started Dec 8)

TOP, left to right

Mike Fincke, Commander
Zena Cardman, Flight Engineer
Kimiya Yui, Flight Engineer
Oleg Platonov, Flight Engineer

BOTTOM, left to right

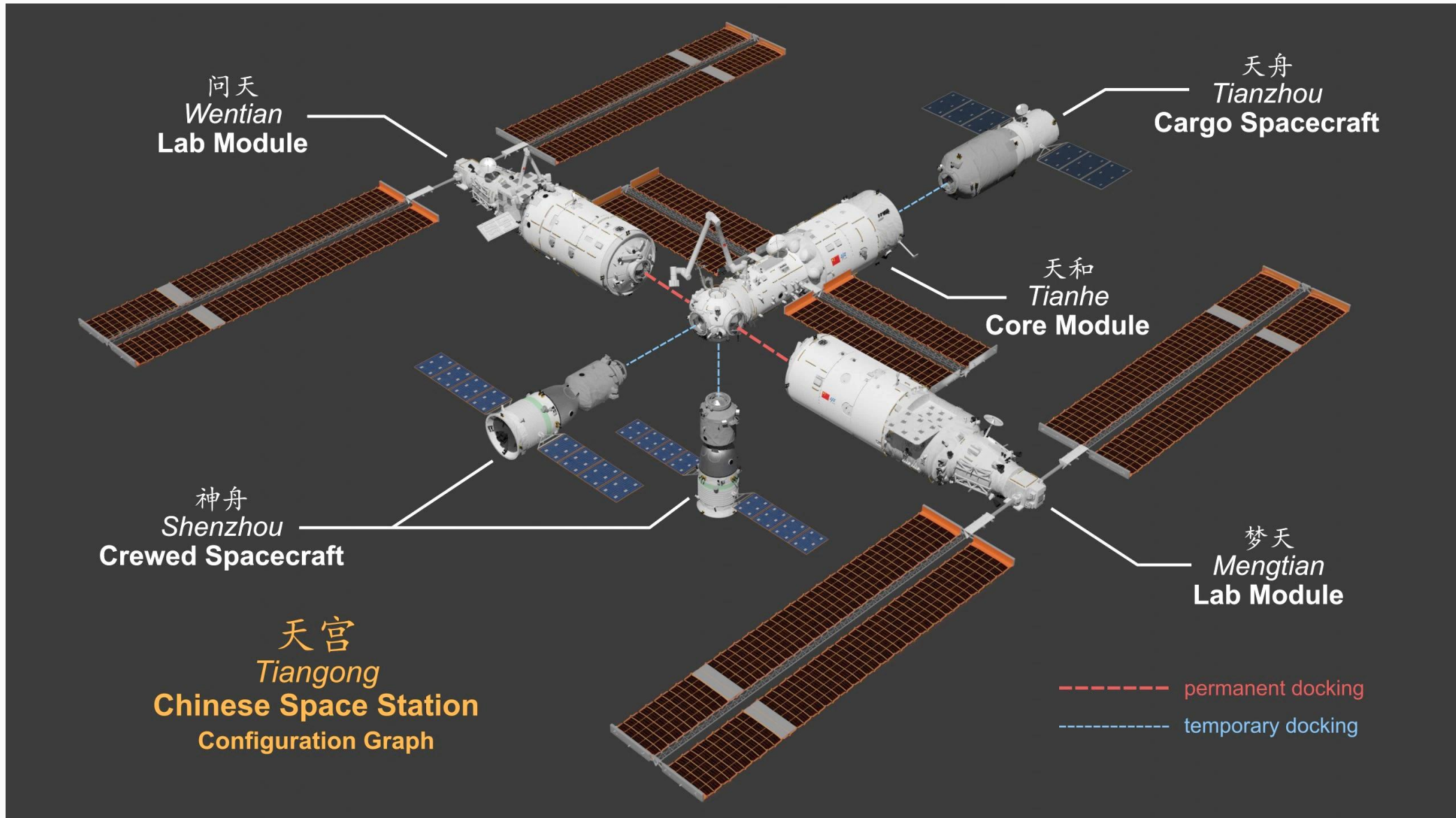
Sergey Kud-Sverchkov, Flight Eng.
Chris Williams, Flight Engineer
Sergey Mikaev, Flight Engineer



The Tiangong Chinese Space Station



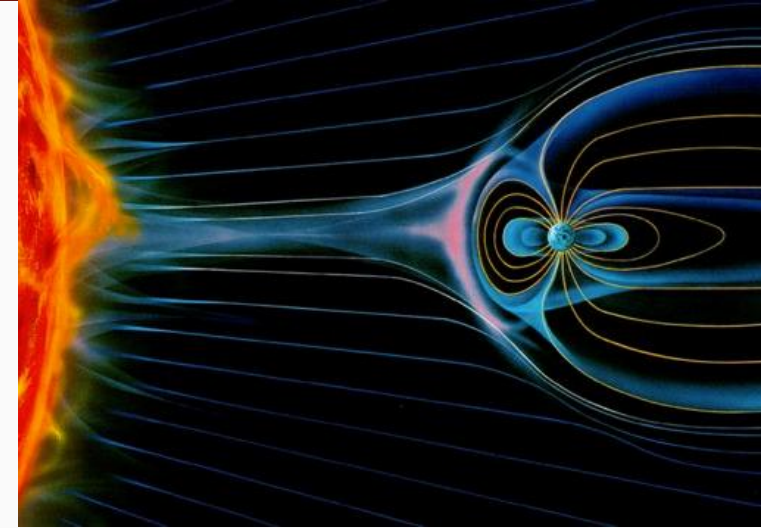
Tiangong Station architecture and crew/cargo resupply vehicles



6. The space environment – characteristics and hazards

Two dominant characteristics of the space environment are **vacuum** and **weightlessness** (or microgravity conditions), although weightlessness is not strictly speaking a characteristic of space, but more a result of the fact that objects and humans are constantly in a state of free fall while traveling in free space.

The **radiation impact**, especially outside of the Earth's magnetosphere, is a significant problem for human spaceflights.



The atmosphere and the sky from LEO



This picture was taken in 1996, on Shuttle mission STS-75. The cargo bay of the Shuttle is visible. The vertical stabilizer appears here horizontal, because the plane of the wings is perpendicular to the horizontal velocity vector.

The thin green line is the airglow at about 100 km altitude.

The airglow is due to photoionization of the oxygen atom and de-excitation which produces a luminescence. The airglow is mainly due to oxygen, somewhat also to nitrogen and the radical OH.

The view during orbital day !



Heading towards Aurora Australis

Heading Towards Aurora Australis

Videos produced by the Crew Earth Observations group at
NASA Johnson Space Center

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on our main video page.

Physiological effect of radiation and typical doses

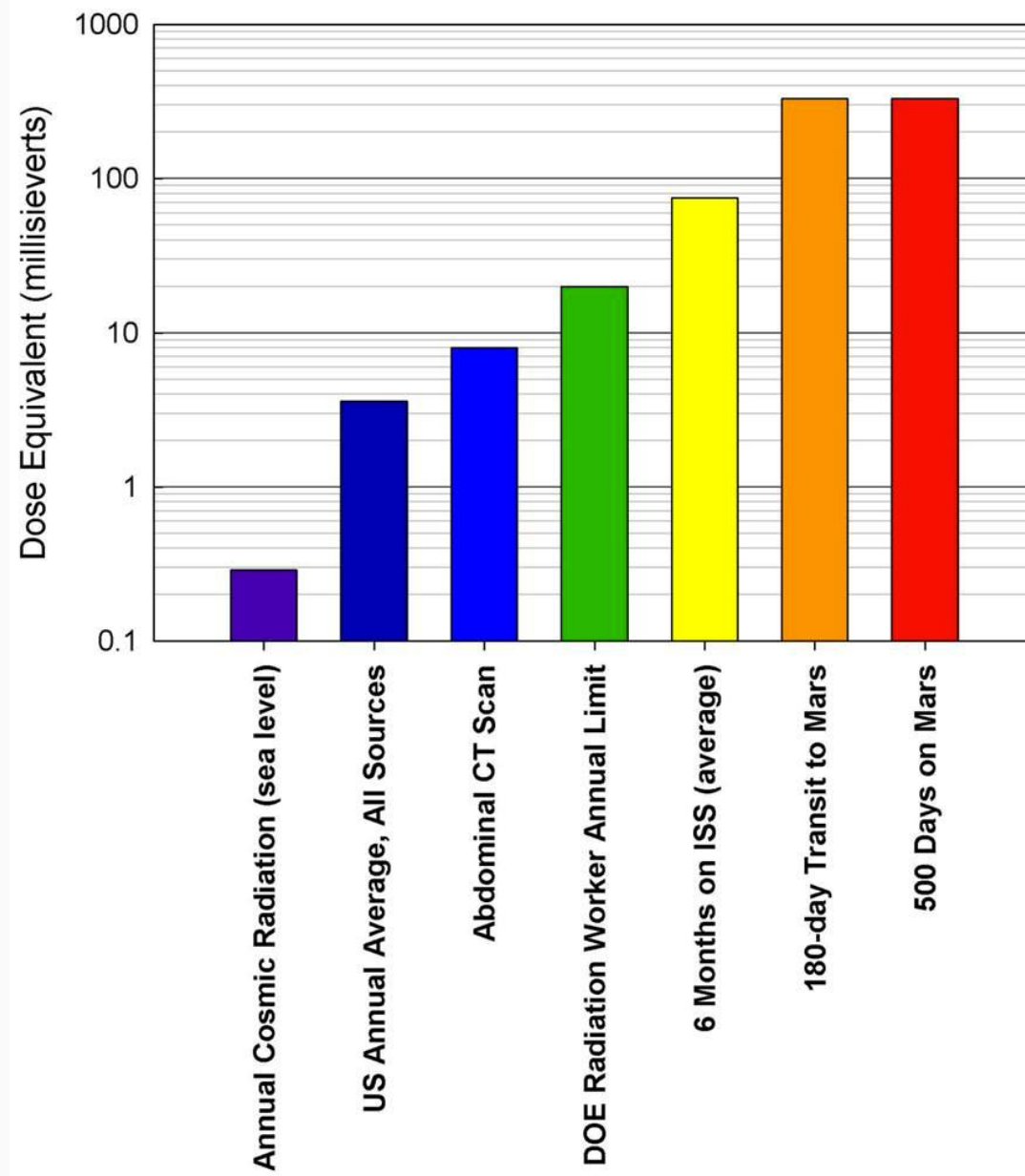
- RAD = Radiation Absorbed Dose = Amount of energy absorbed = 0.01 J/kg (100 erg/g)
- REM = Roentgen Equivalent Man = RAD x Q
- Q = quality factor = function of type of radiation
 - = 1 (x-ray, gamma ray, electrons, beta)
 - = 2-20 (neutrons)
 - = 20 (alphas)
 - = 20+ (iron ions)
- 1 Sievert = 1 Sv = 100 REM.

Effect	Dosage (REM)
Blood count changes in population	15-20
Vomiting "effective threshold"*	100
Mortality "effective threshold"*	150
LD ₅₀ ** with minimal supportive care	320-360
LD ₅₀ ** with full supportive medical treatment required	480-540

Effect	Dosage (REM)
Transcontinental round trip in jet	0.004
Chest X-ray (lung dose)	0.01
Living one year in Houston (sea level)	0.1
Living one year in Denver (elev. 1600 m)	0.2
Skylab 3 for 84 days (skin)	17.85
Space shuttle Mission (STS-41D)	0.65

- *Lowest dosage causing effects in at least one member of exposed population.
- **LD₅₀ is the lethal dosage in 50 % of the exposed population.

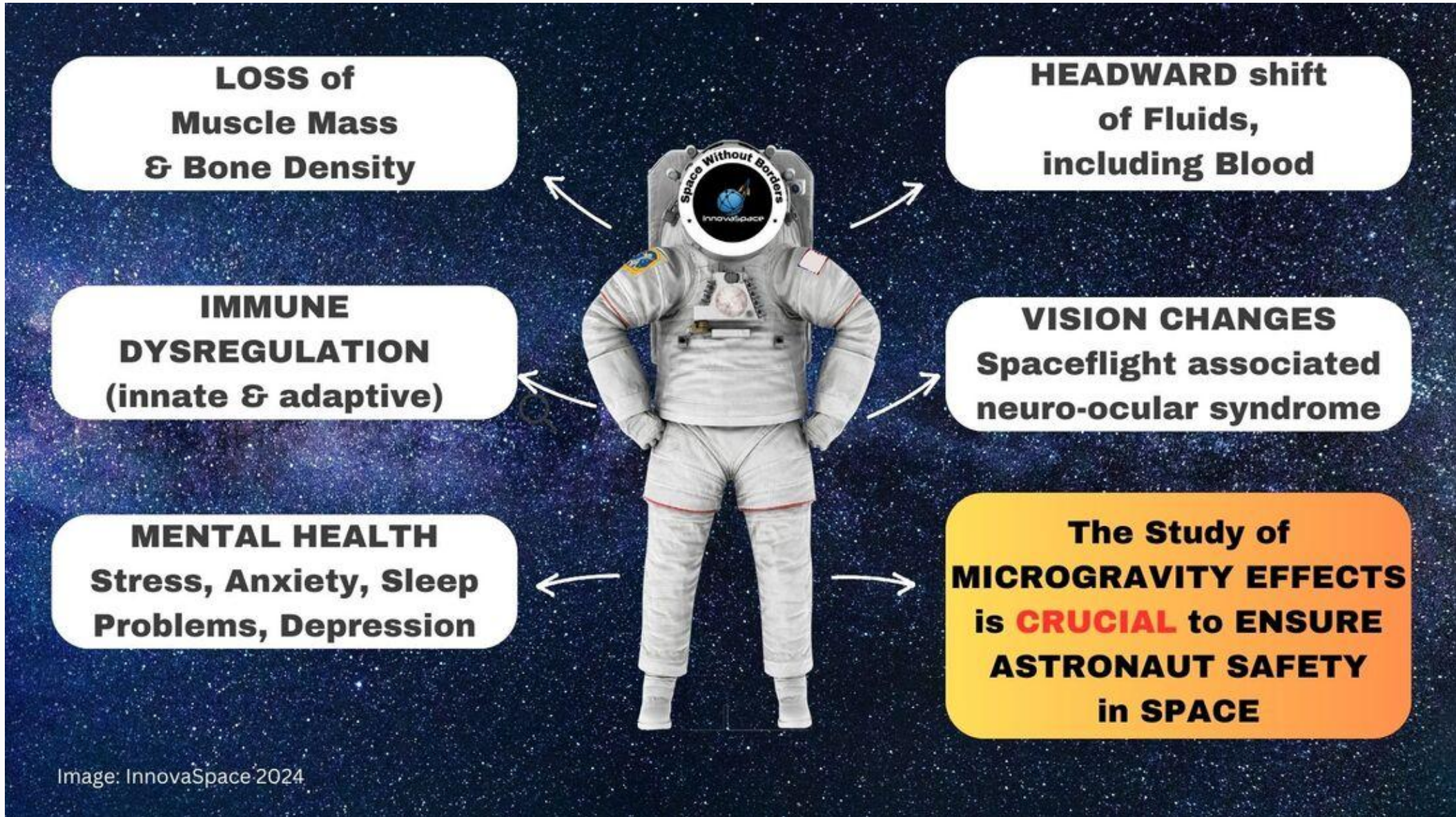
Radiation exposure for various activities



Polyakov, absolute record for longest space mission



Astronaut potential and real health issues related to microgravity



7. The human body and mind in the space environment – astronaut selection

Any space mission puts a high demand on an astronaut, depending, of course, on the nature of the mission and mission duration.

The psychological load is not really high for a short mission in LEO, except for a highly complex or dangerous mission. This load increases on very long missions, or on missions to destinations far away.

You of course always have to accept the hazards of ascent and entry.



Physiological effects in different mission phases

- **Lift off**

Low g forces because the value depends on the lift to weight ratio and we have a high weight at lift off - propellant weight is typically 90% of the wet weight of the spacecraft.

- **On orbit**

Obviously Zero-g or microgravity conditions, short adaptation period (few hours) - need to exercise daily on long duration missions to avoid muscular deconditioning and bone mass loss. The need to exercise is minimal for short missions (10 days or less), Comparison with bed rest or hospital stays.

- **Reentry**

Typically takes 50 minutes to an hour from deorbit impulse to landing or splash down. G-forces briefly 4 to 5 g for a capsule, but was only max 1.5 g on the Space Shuttle.

Astronauts, Spationautes (pour la France), Cosmonauts, Taikonauts

- Many types - Pro with a Space Agency or Pro Private, or Tourist.
- Different names for the space travellers.
- Selection criteria and training vary with responsibility level.



Astronaut Candidate qualification requirements (NASA, 2021)

Basic Qualification Requirements (summary):

1. Master's degree from an accredited institution in engineering, biological science, physical science, computer science or mathematics.
2. Degree must be followed by at least 3 years of related, progressively responsible, professional experience or at least 1,000 hours pilot-in-command time in jet aircraft.
3. Ability to pass the NASA long-duration Astronaut physical.

The selection itself consists in interviews, further medical screening, background investigations, etc.

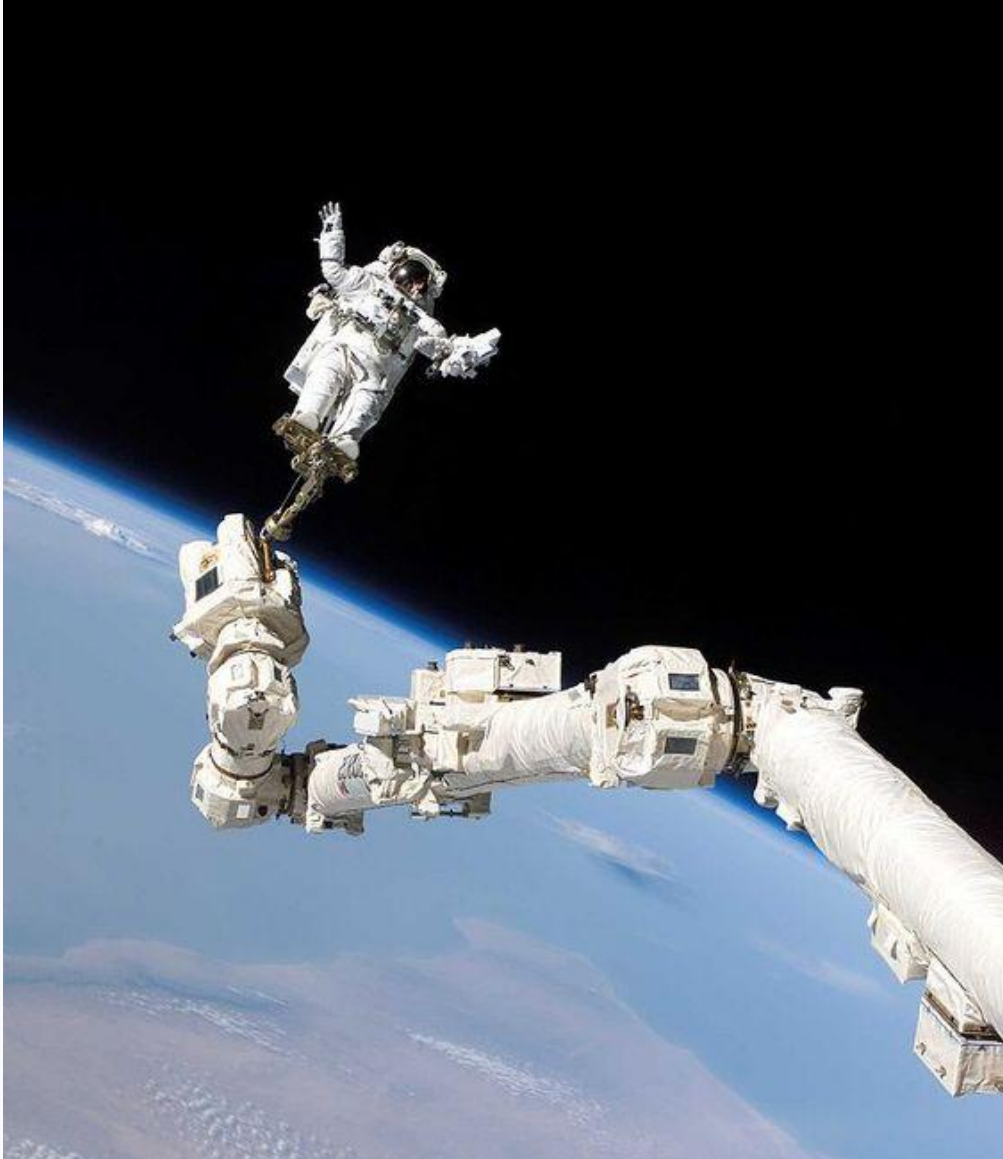
Training and evaluation period (NASA, 2021)

For the ones selected, the training and evaluation period lasts approximately 2 years, during which time they will participate in the basic Astronaut Candidate training program, which is designated to develop the knowledge and skills required for formal mission training upon selection for a flight.

Final selection as an astronaut will depend upon satisfactory completion of the training and evaluation period. Graduation from the Astronaut Candidate program will require successful completion of the following: International Space Station systems training, SCUBA qualification, Extravehicular Activity skills training, Robotics skills training, Russian language training, and aircraft flight readiness training.

At the completion of this period, the astronaut is flight-ready (can be assigned to a space mission or an ISS increment) !

The unpublished requirements...



- **Passion**
- Interest in many disciplines and willingness to learn more.
- Be friendly and loyal, and a good «follower» as well as a capable leader.
- Try to fix things yourself (car, TV set, etc.).
- Be a good communicator.
- Learn to manage risks (mountain climbing, aviation, parachute jumping, etc.).

ESA astronaut selection

The selection criteria for ESA are quite similar, except that the initial application is done on line (22'000 applications in the last selection in 2022), and the candidacy period lasts one year only. There is also no “aircraft readiness training” for ESA astronauts.

The 2022 ESA astronaut selection retained 17 candidates, 5 career, 11 reserve, and one “parastronaut” with a disability. The 5 new ESA career astronaut candidates graduated as astronauts in April 2024. Sophie Adenot from France has been assigned to an expedition on ISS starting in February, 2026, Raphaël Liégeois from Belgium will follow, and then the other three career astronauts Pablo Álvarez Fernández, Rosemary Coogan, and Marco Sieber.

The 17 new ESA astronauts (5 career + 11 reserve + one parastronaut) Nov 2022



Marco Sieber, a medical doctor from Bern, is the new ESA/Swiss astronaut!

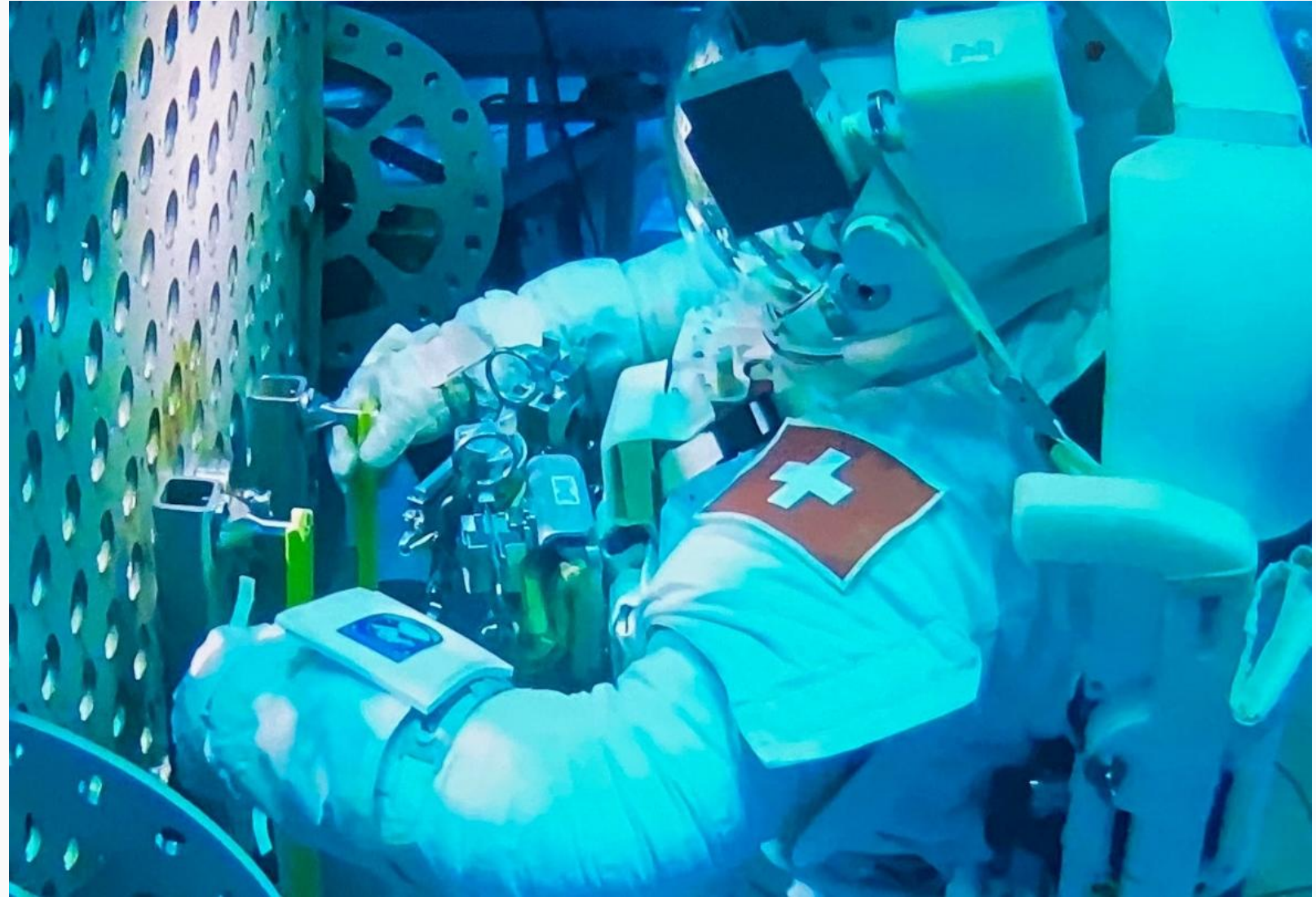
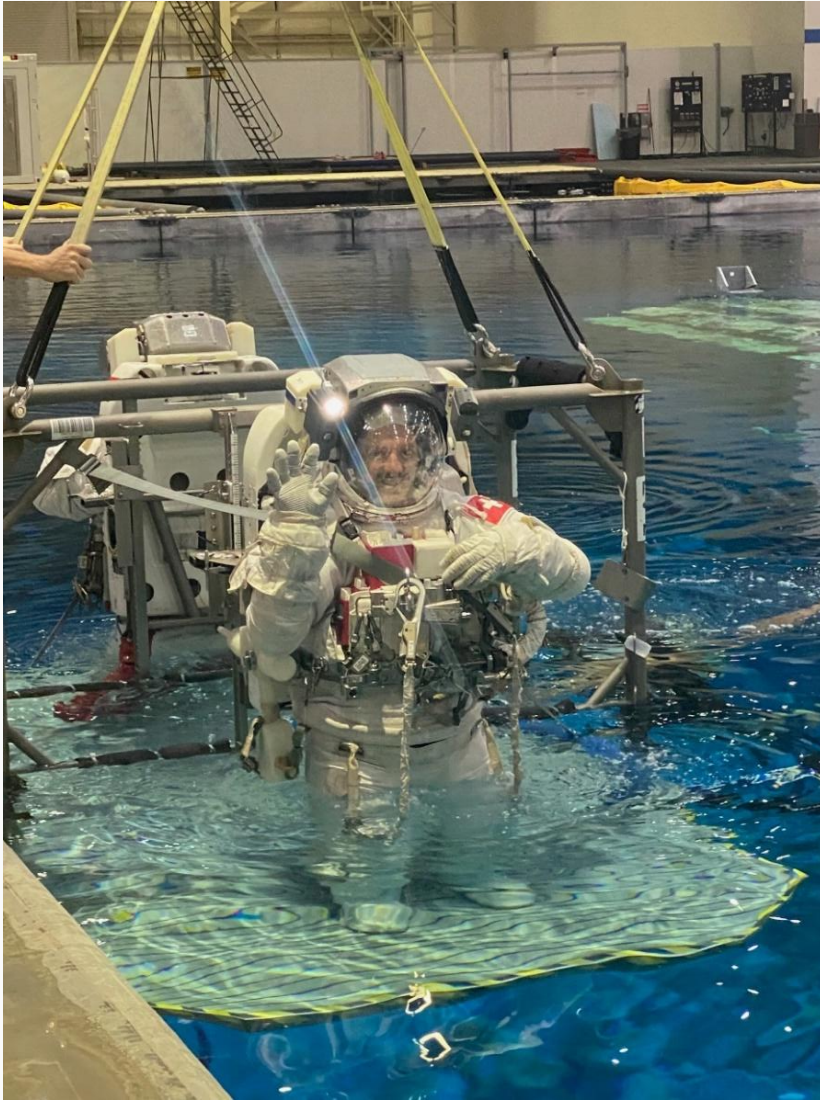


One of 5 «Career astronauts» in the
ESA Astronaut Class of 2022

Marco Sieber in pre-EVA training at the European Astronaut Center in Cologne

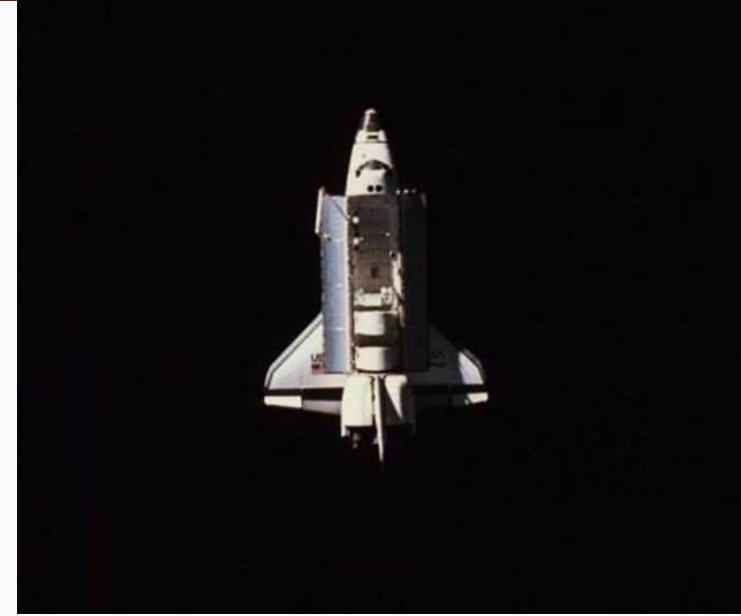


Marco's first suited training run in the NBL at JSC Houston in August 2024

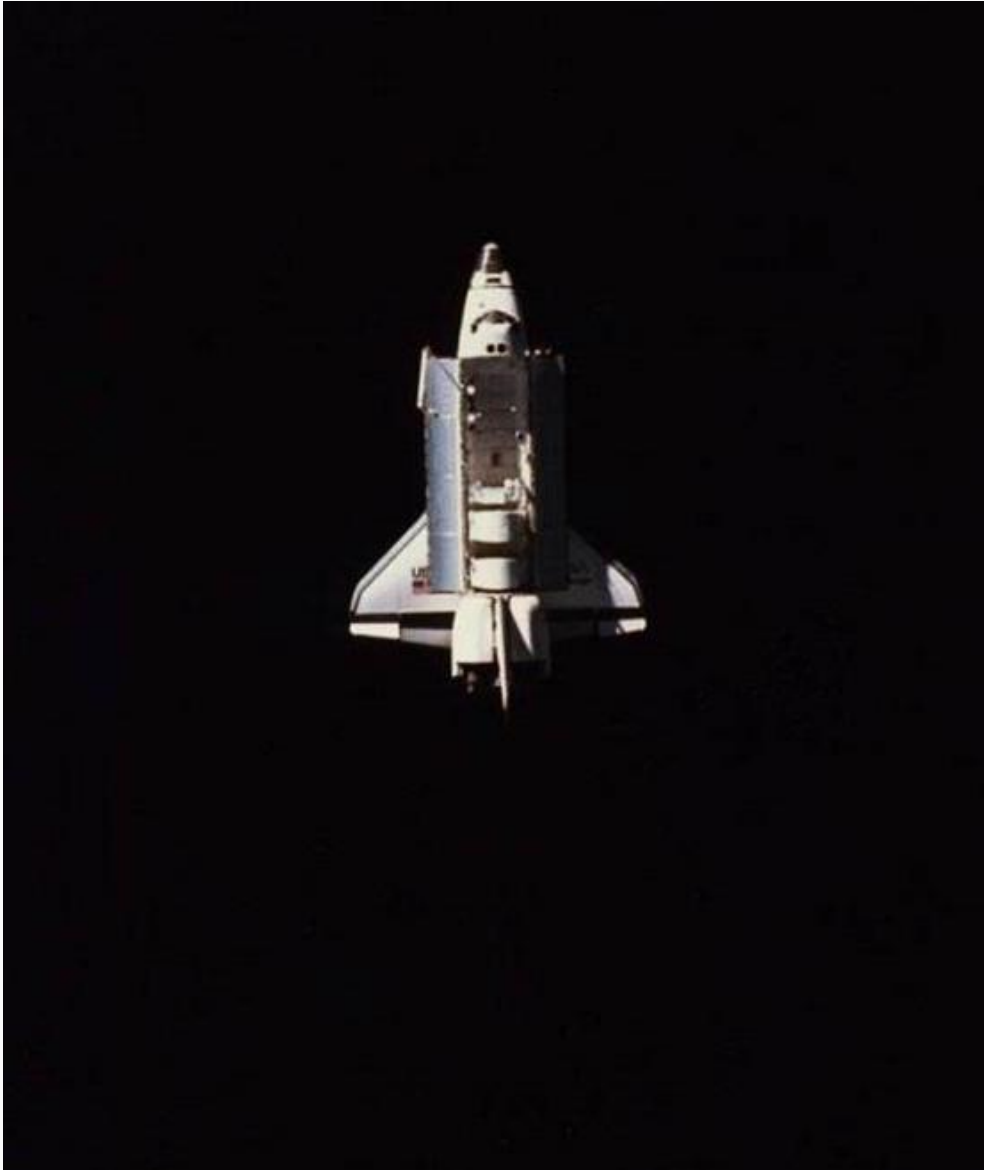


8. Manual vs. automatic control of a spacecraft

Any human spacecraft can be under manual or automatic control, or a combination of the two



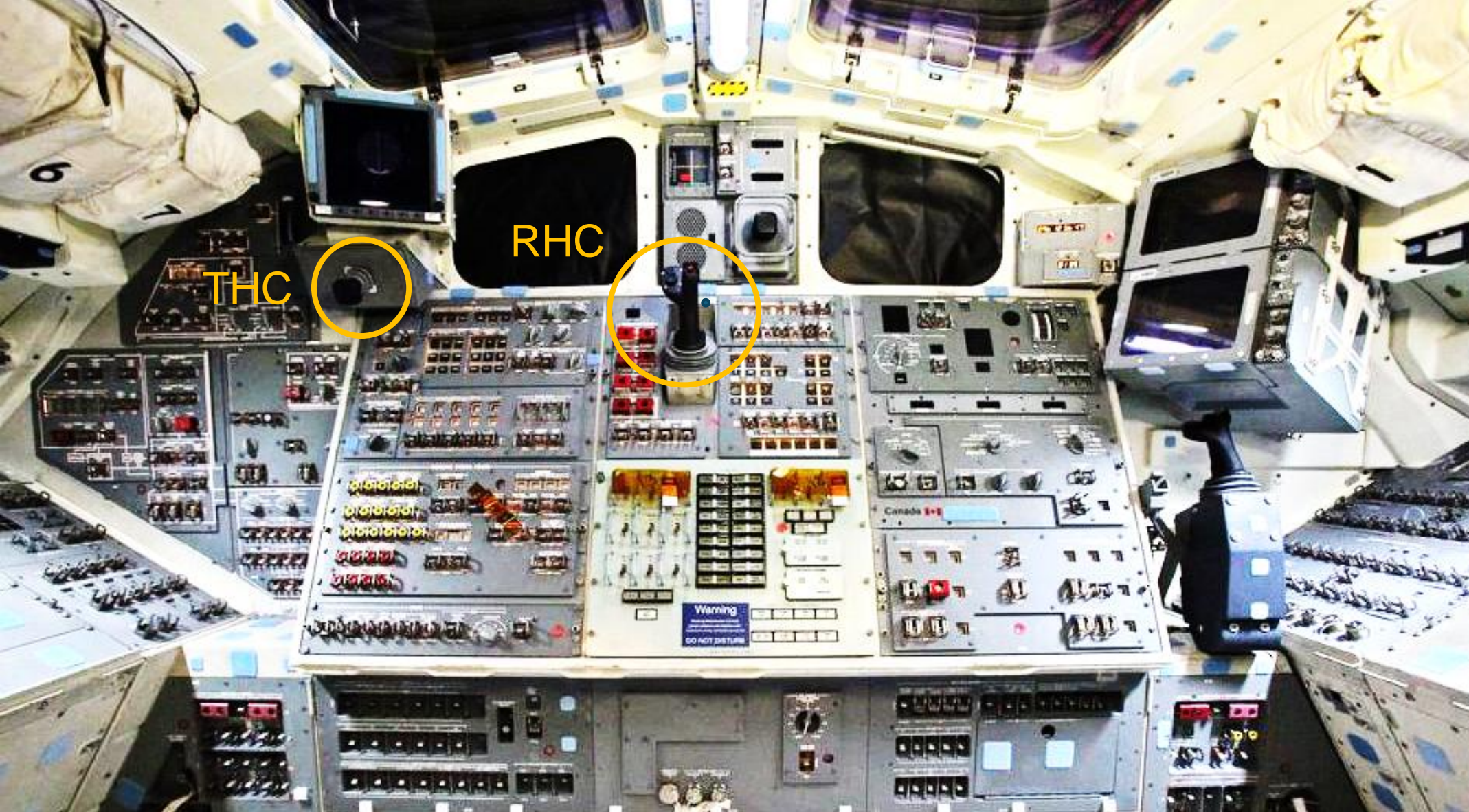
Space Shuttle control in translation and rotation



Translation control of the Space Shuttle was always in the **manual mode**, using the Translation Hand Controller or THC.

Rotation control was **either manual or automatic**. The manual mode was using the Rotational Hand Controller or RHC. The automatic mode was using the Digital Autopilot or DAP, typically selecting a body vector to be pointed to a selected target, like the Center of Earth COE, a point on the Earth surface, or the Sun, and specifying the Shuttle rotation state around the pointing vector (Omicron).

Shuttle Aft Flight Deck with THC and RHC



Shuttle Aft Flight Deck with RHC and THC



John Young on the left-hand side, Commander, and Bob Crippen, Pilot of STS-1, the first Space Shuttle flight, on April 12th, 1981.

RHC: 3 degrees of freedom rotation along P, Y and R.

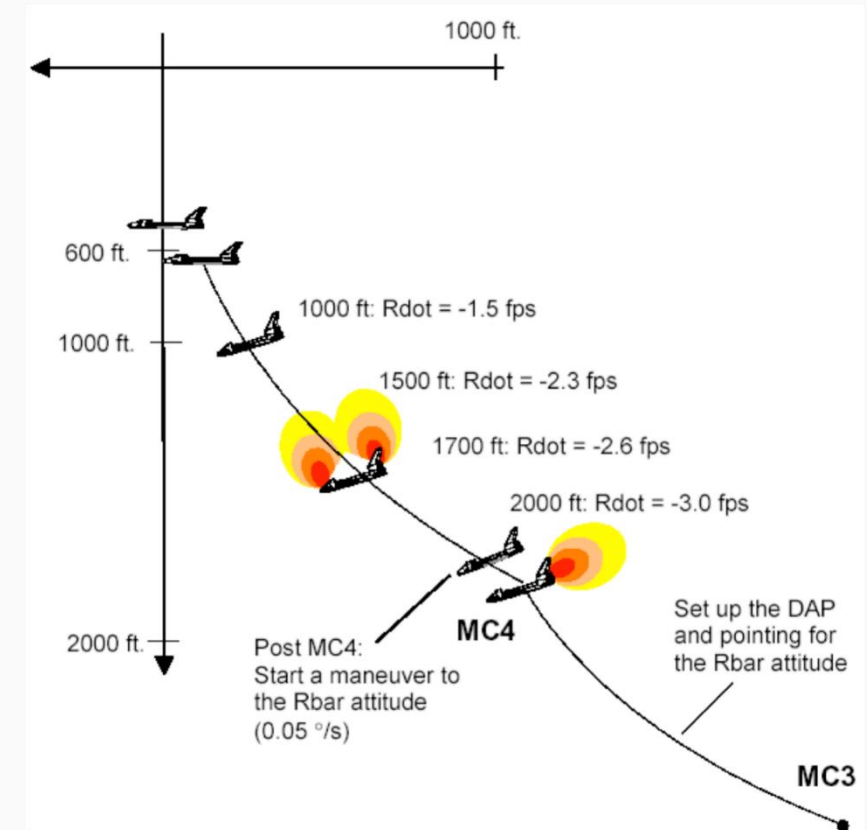
THC: translation along X, Y or Z axes.

Typical Shuttle final manual approach to the target

The target is represented as the intersection of the two axes (the blue ball), the vertical axis to the COE, and the horizontal axis along the target's velocity vector to the left (circular orbit).

On a typical Shuttle rendezvous, the Shuttle came from behind and below. On the last orbit before final rendezvous, there were several mid-course corrections or adjustment of the trajectory of the Shuttle versus the target in order to come on the proper relative final trajectory.

Braking was done manually to reduce the range rate to the target. The rendezvous ended with docking with the target (ISS for instance), or RMS grappling of the target (Hubble).



Soyuz automatic approach to ISS



Today, SpaceX Crew Dragon Capsule

A very modern flight deck - You fly like playing games on your smartphone...





SpaceX Crew Dragon automatic approach to docking with ISS

9. Extravehicular activity or EVA

Two types of EVAs:

1. In space EVA
2. Surface EVA

The challenge is the well being and safety of a crewmember is a really hostile environment. The physiological constraints of the human body have to be strictly respected, with margins.



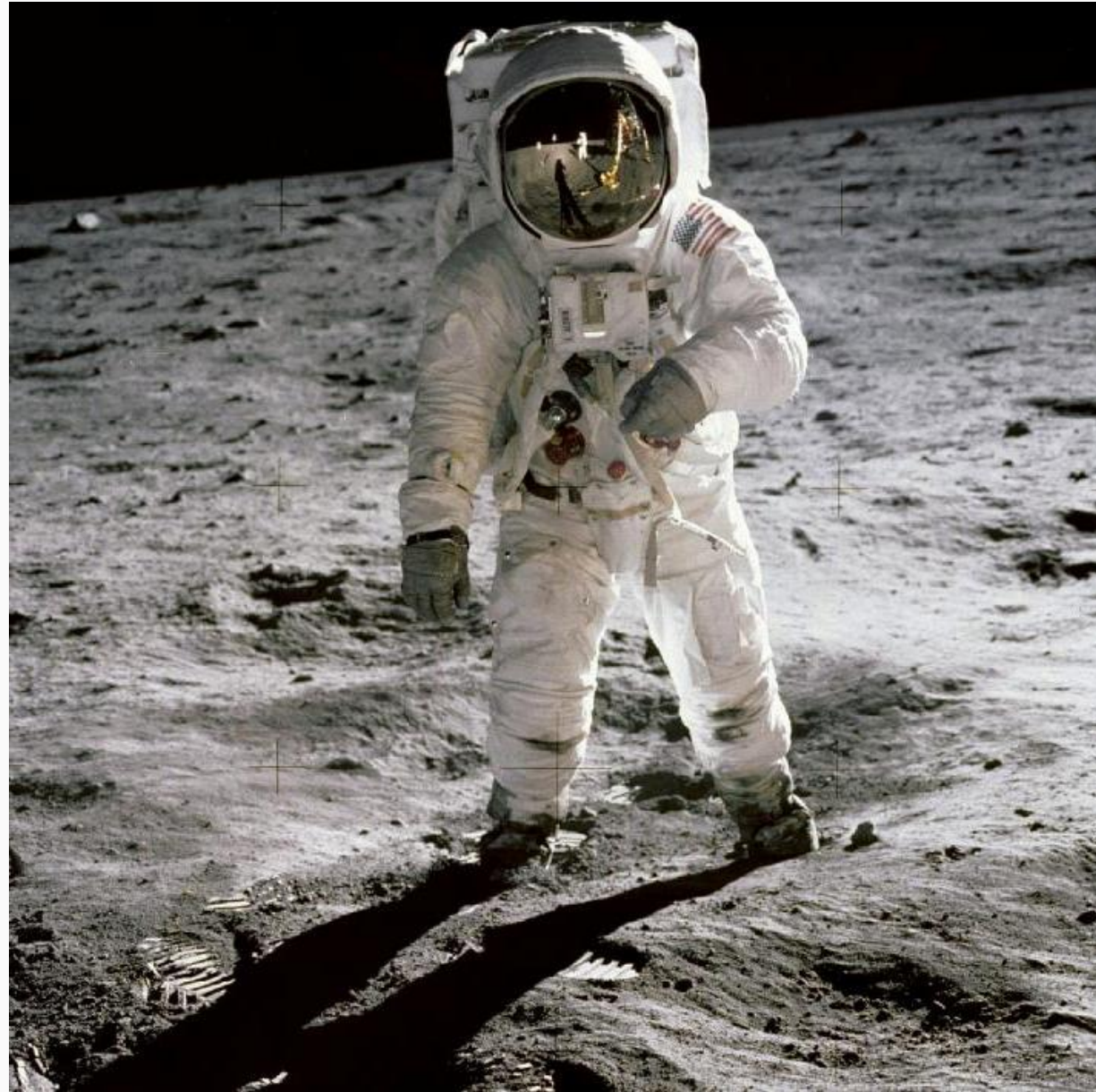
First spacewalk – Alexei Leonov - March 18, 1965



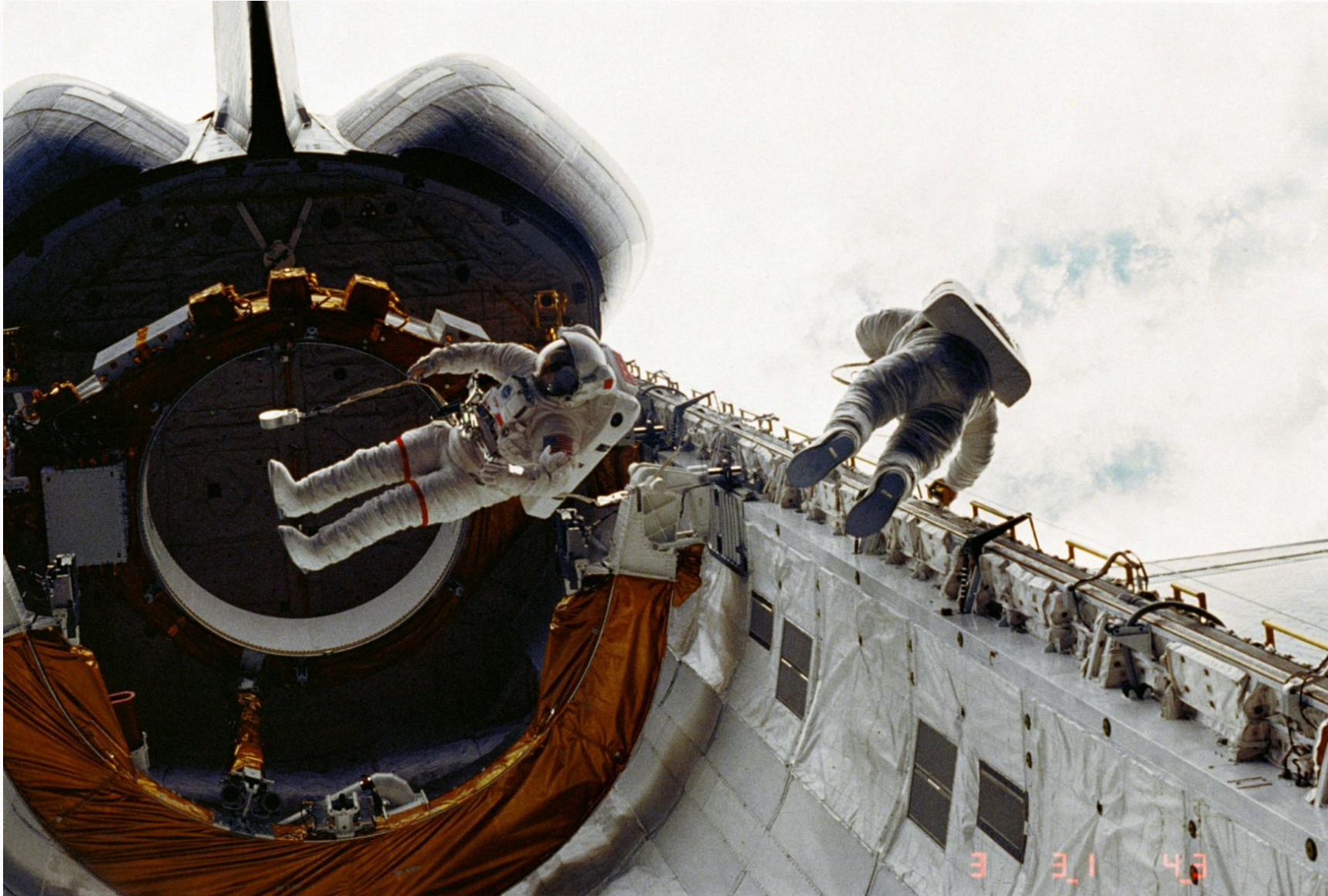
First US spacewalk – Ed White - June 1965



Apollo Moon surface EVAs – 1969-1972



First Space Shuttle spacewalk – STS-6 - April 1983

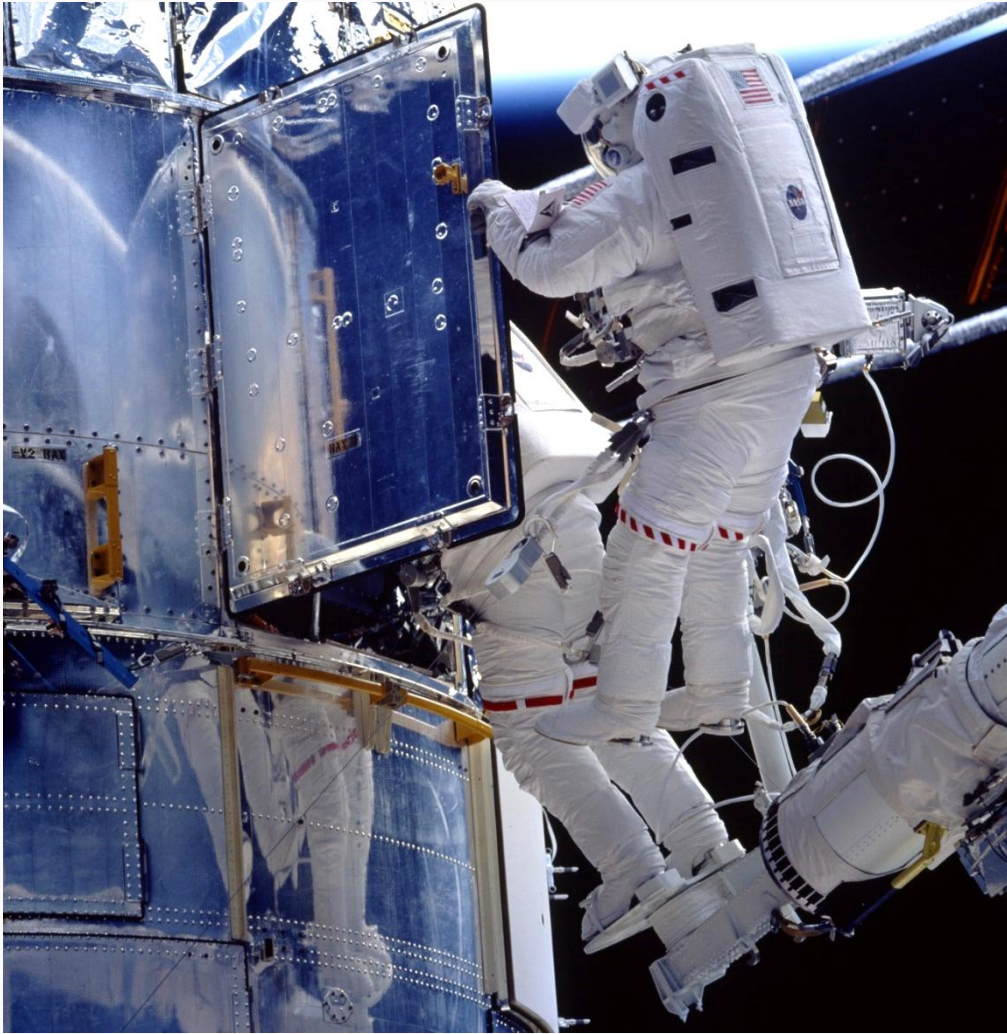


With NASA's new EMU spacesuit (Extravehicular Mobility Unit).

Tethered spacewalk with a portable life support system – normally 2-person spacewalk.

Up to 8.5 hours duration spacewalks.

STS-103 EVA2 – Mike Foale and Claude Nicollier - Dec. 23, 1999



Exchange of Hubble's main computer, and of Fine Guidance Sensor #2 (FGS2)

Launch and entry suits



The real pilots on STS-1:
Young and Crippen



↑
The high fashion of SpaceX

Shuttle LES

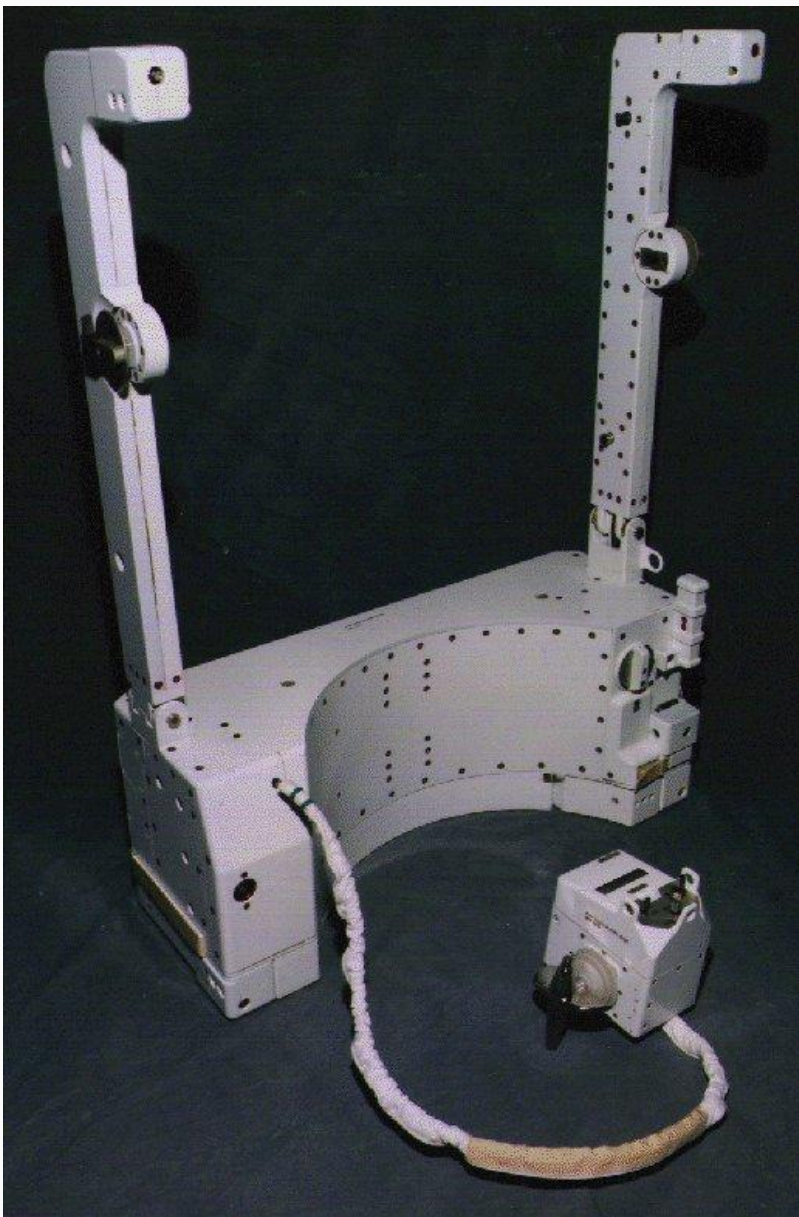
SpaceX space suit, also called “Starman suit”, was jointly designed by Elon Musk, SpaceX CEO, and Jose Fernandez, a costume designer

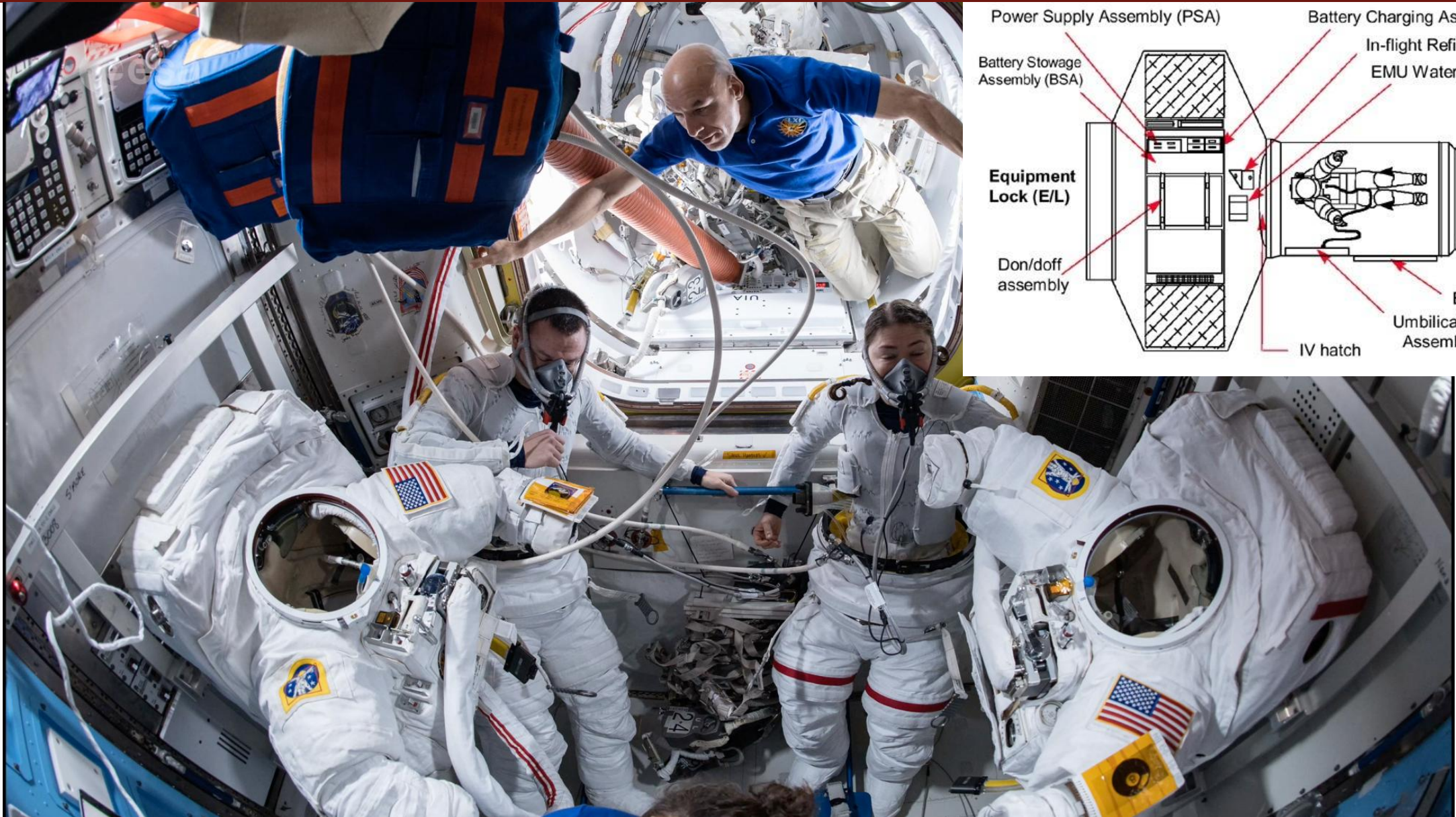


MMU or Manned Maneuvering Unit – on 3 Shuttle missions in 1984



SAFER (Simplified Aid For EVA Rescue), used for ISS spacewalks

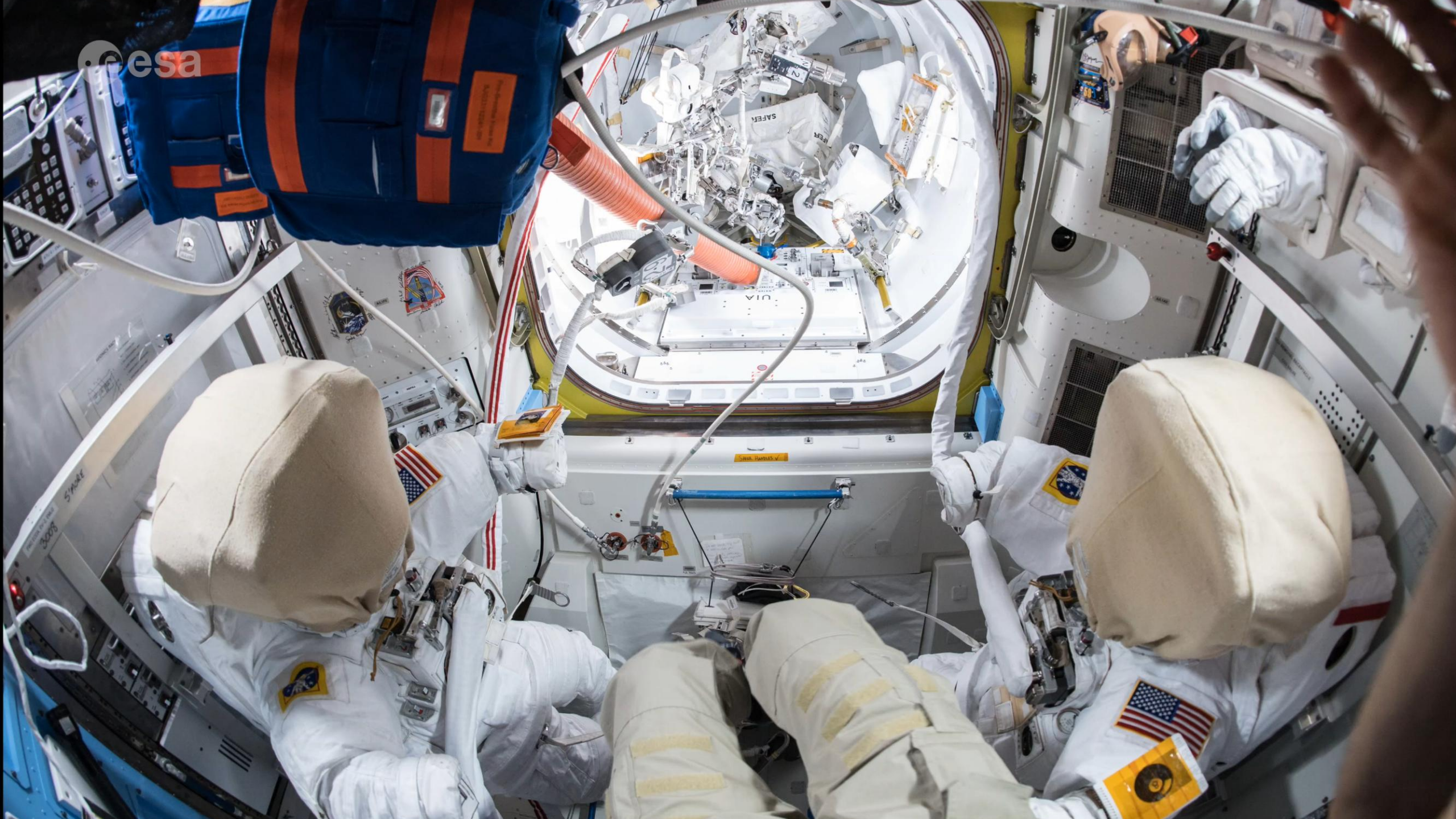




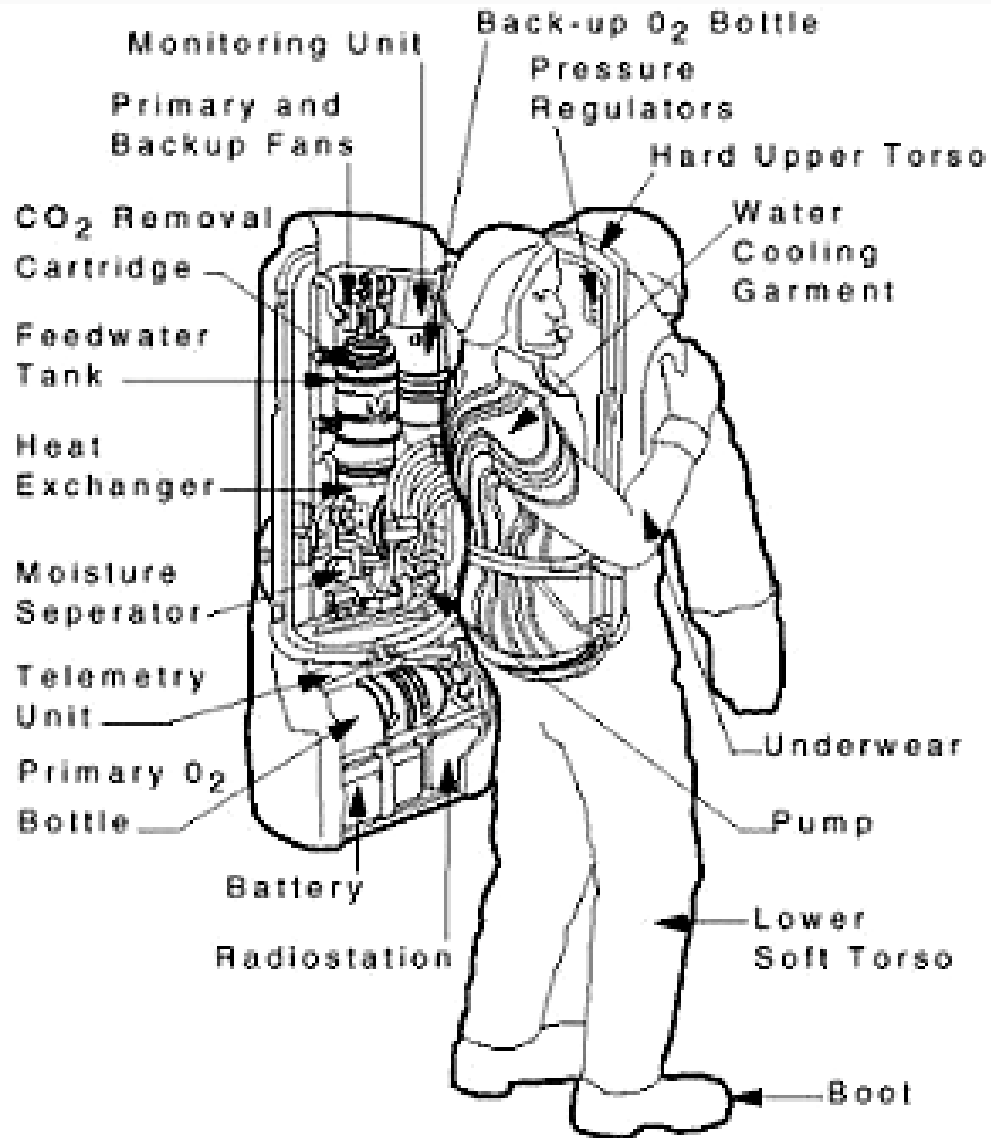








Russian Orlan spacesuit (5.8 psi 7 hours)



New AXIOM/Prada EVA suit



Always properly attach your safety tether
when you go spacewalking !

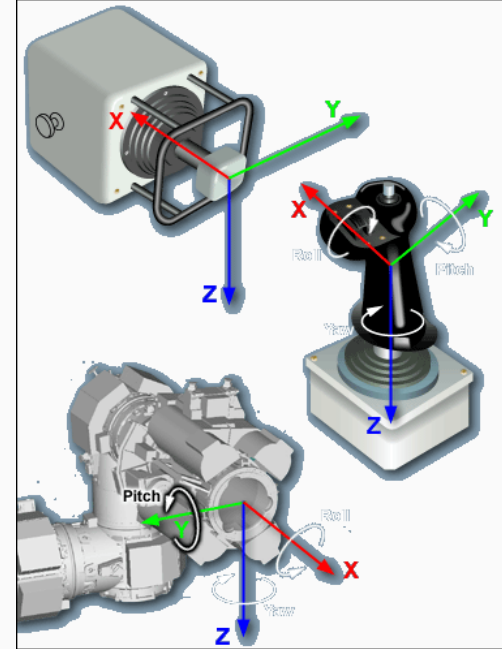


10. Space robotics

There are three types of robots in space:

1. Manipulator robots (SRMS and SSRMS, and others).
2. Robots to support tasks inside the crew compartment (like Robonaut).
3. Robots or rovers on the surface of planetary or satellite bodies in the solar system.

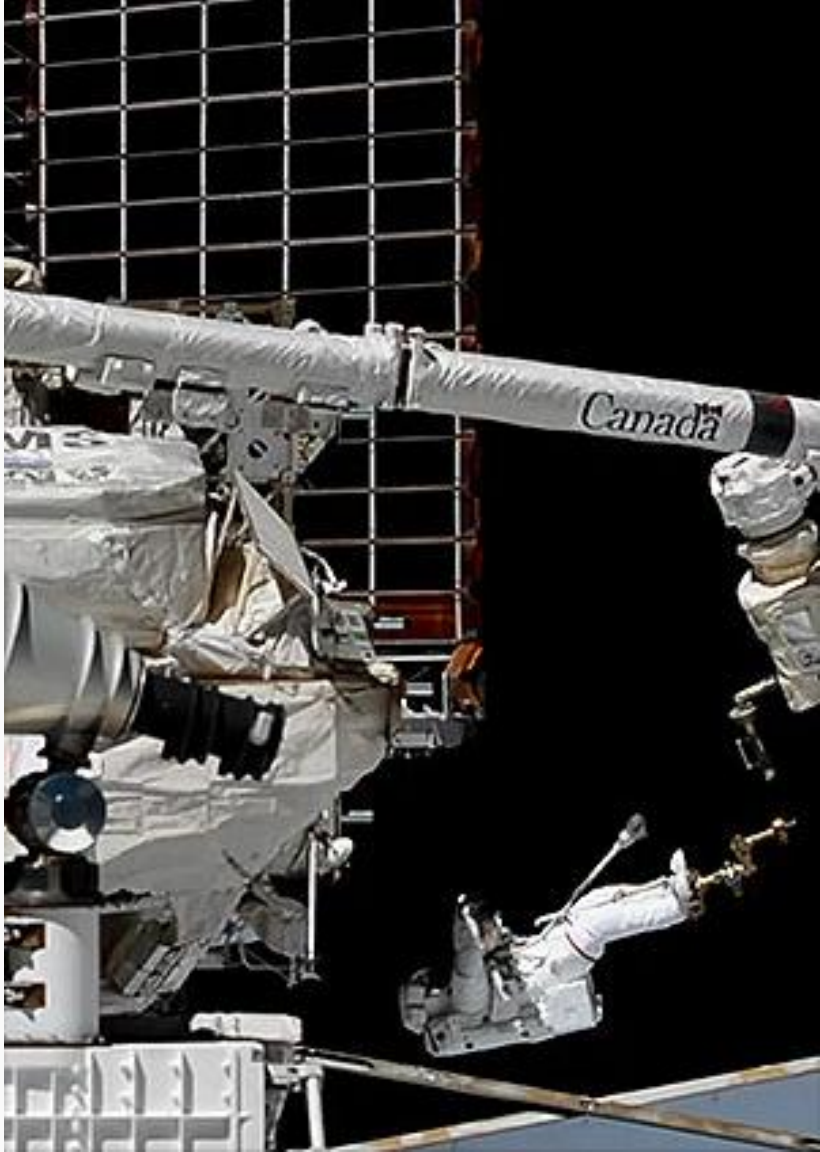
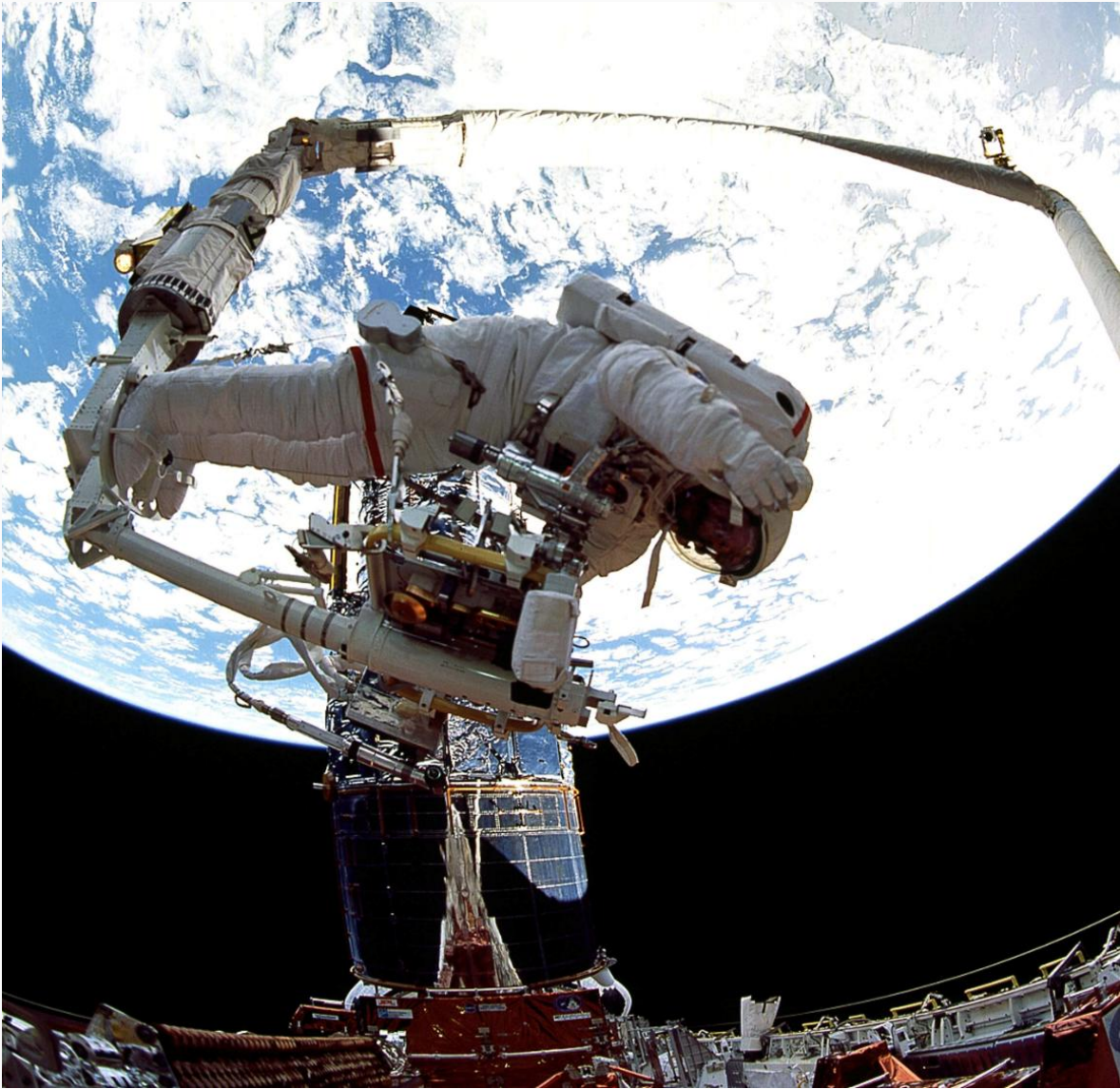
We will focus here on the manipulator robots.



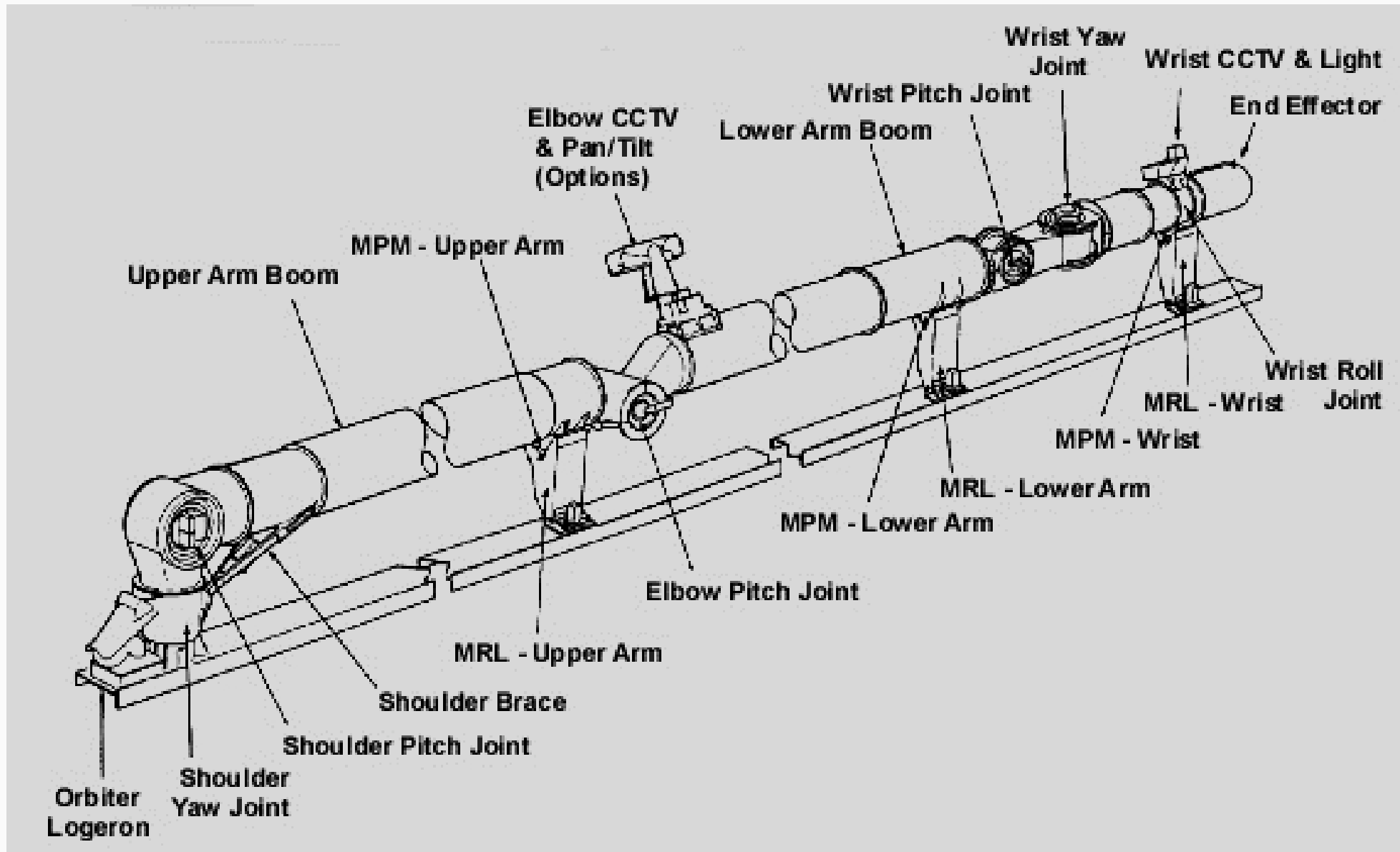
Robotic arms on Shuttle, and on ISS (HTV cargo supply capture)



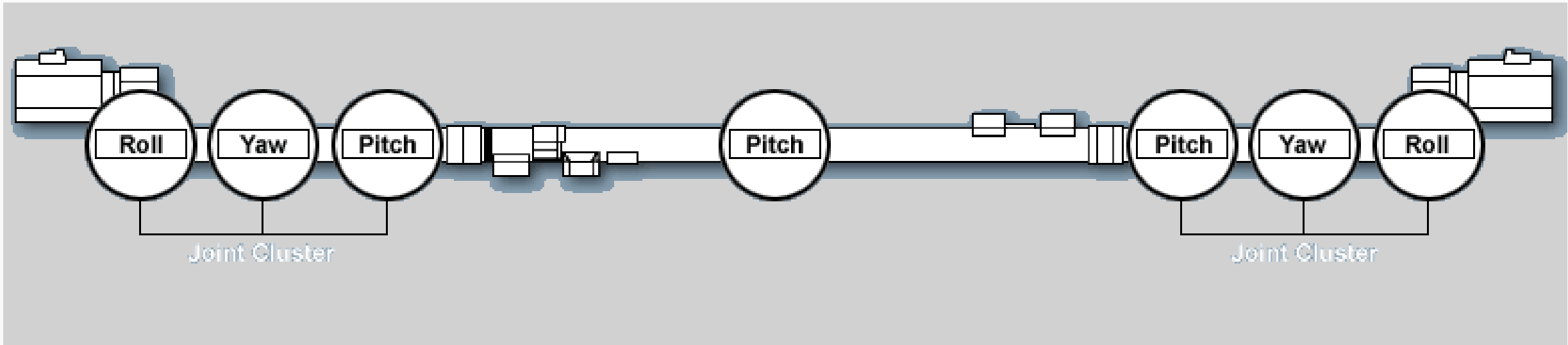
Also essential for EVA support on Shuttle and ISS



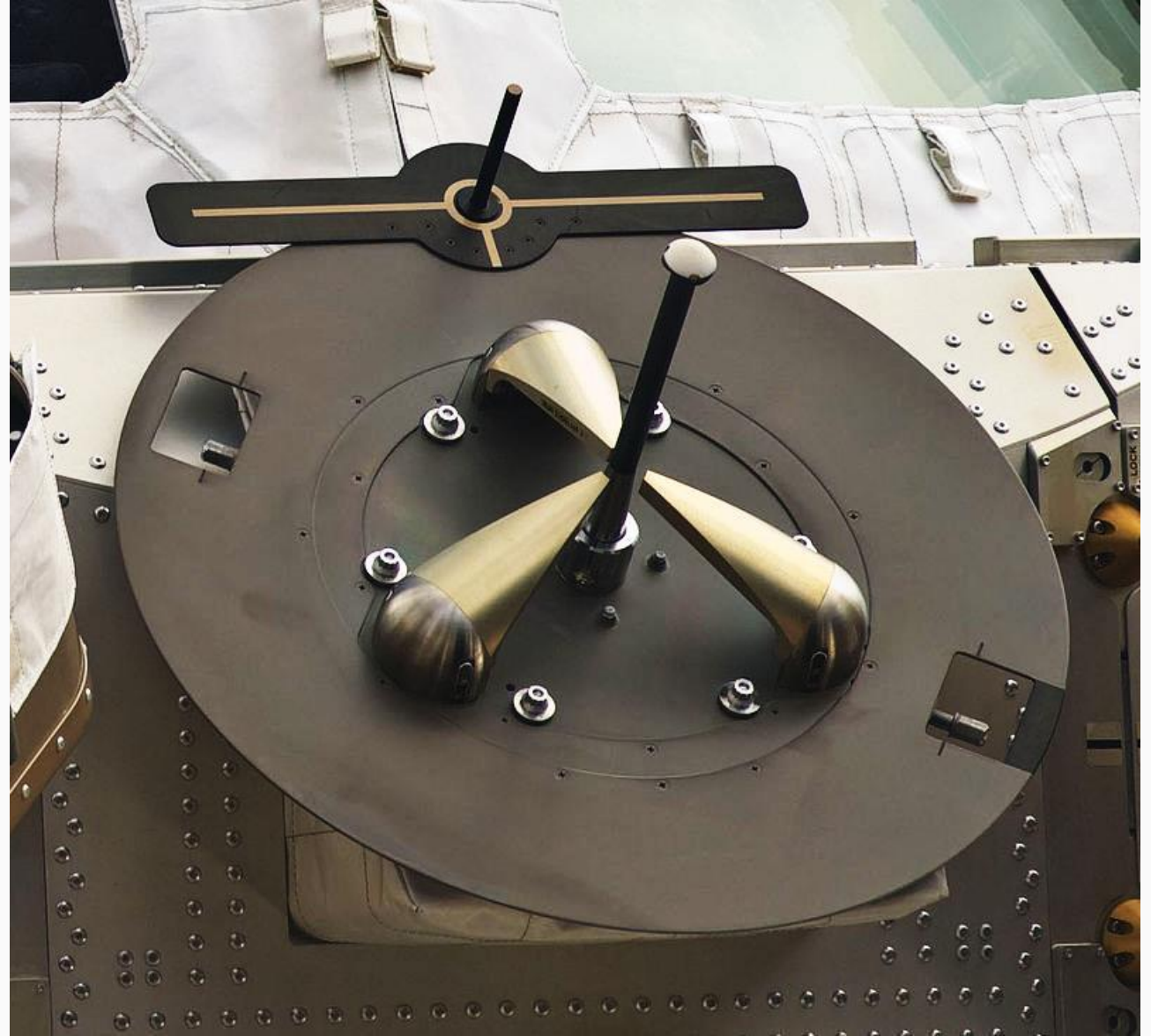
Shuttle Remote Manipulator System (SRMS) or Canadarm 1



Space Station Remote Manipulator System (SSRMS) or Canadarm 2



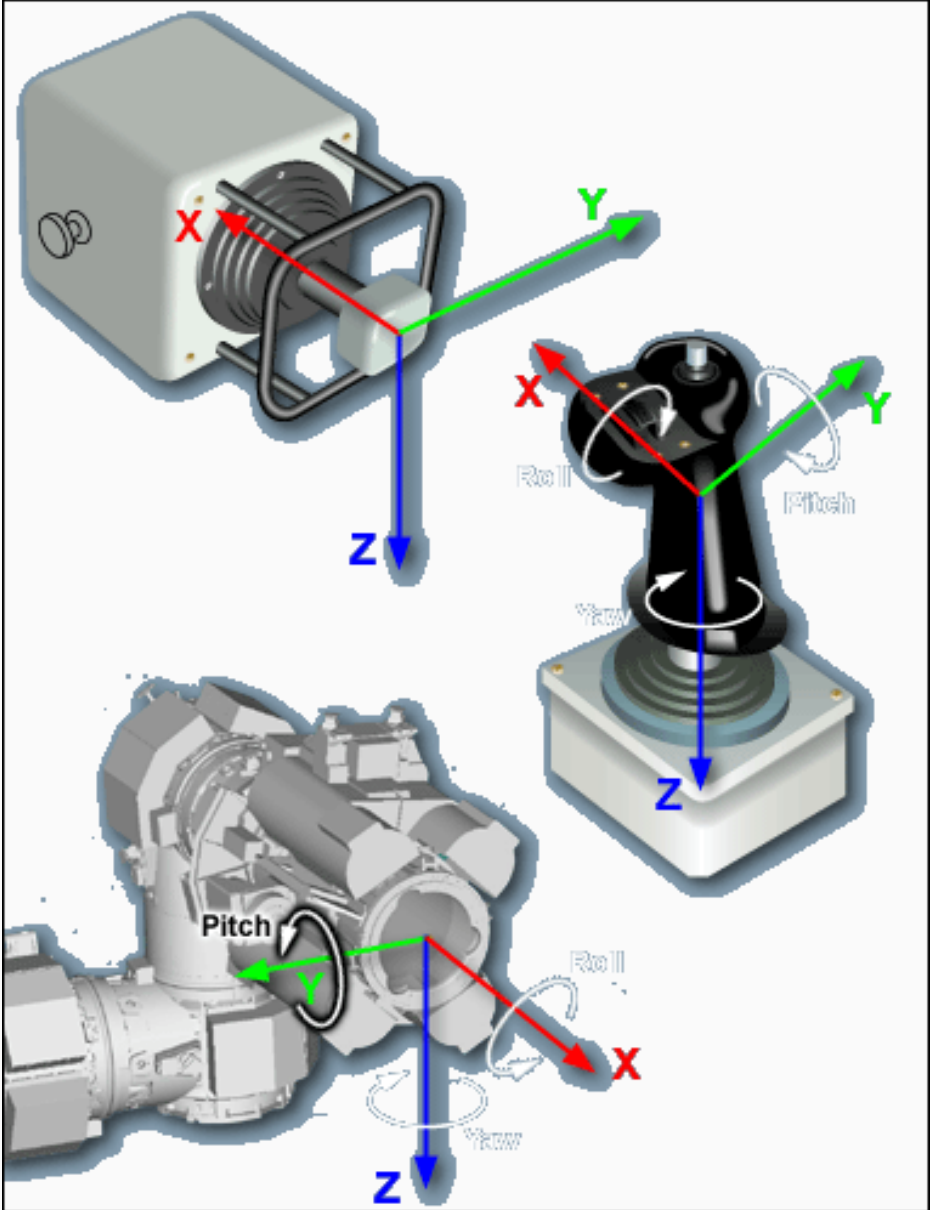
End Effector and Grapple Fixture (SRMS)



Latching End Effector and Grapple Fixture (SSRMS)



SSMRS control

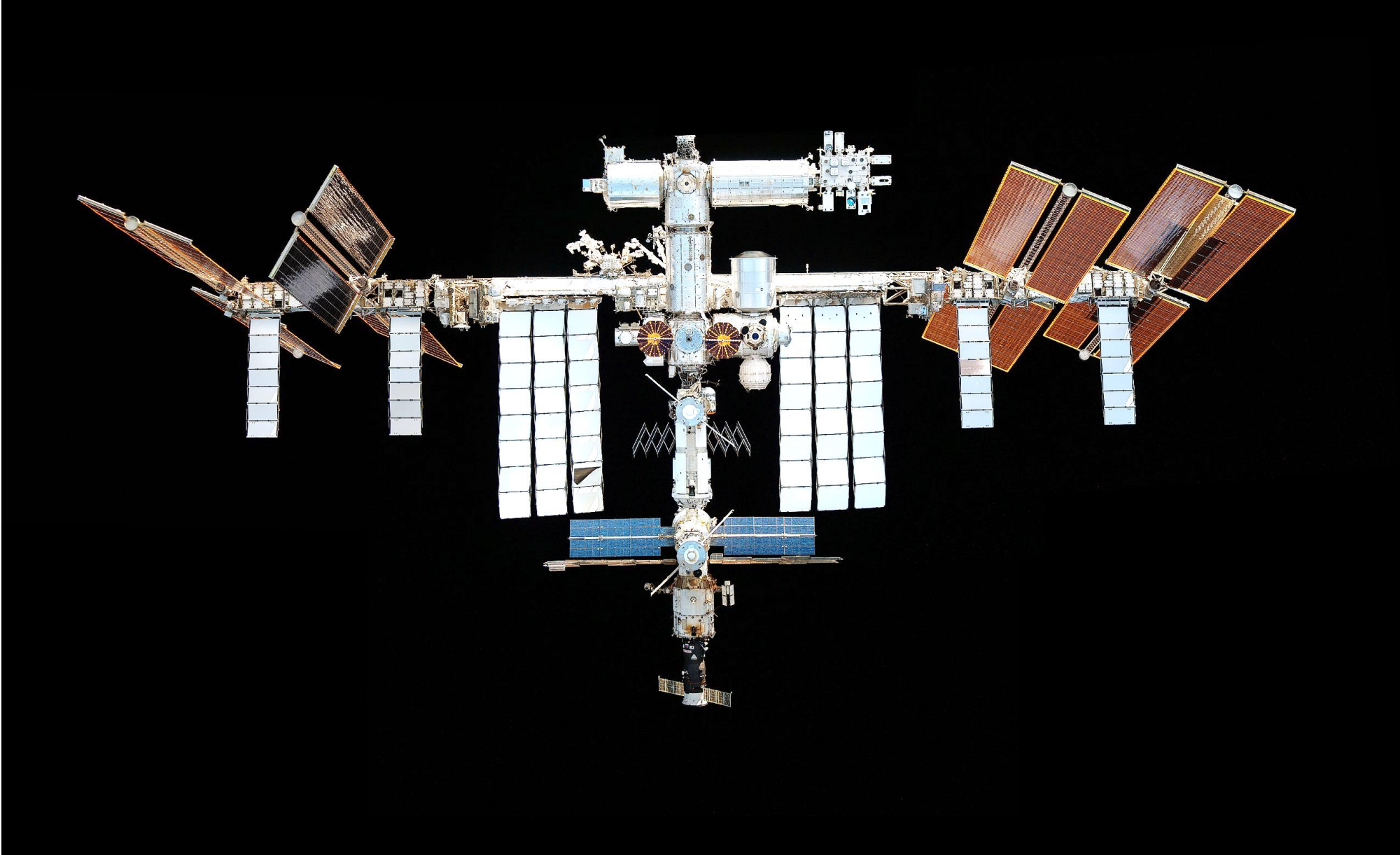


11. The “New” Human Spaceflight

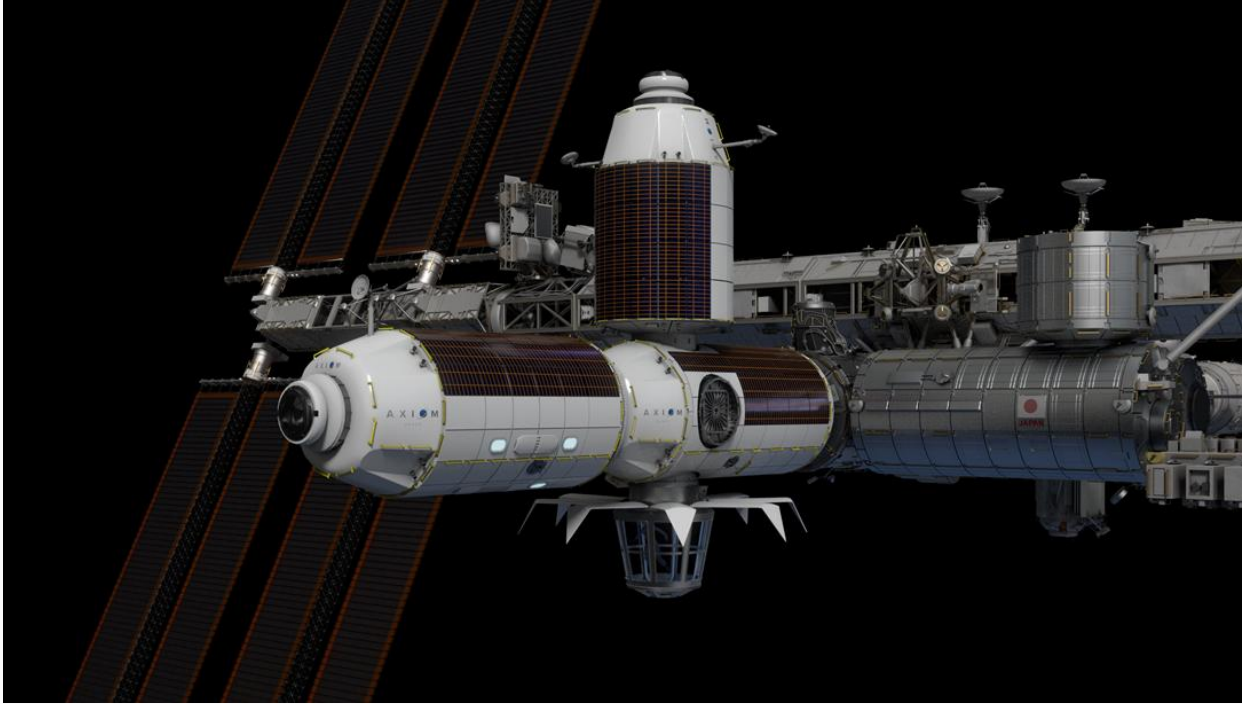
- Private companies (like SpaceX, Blue Origin)
- Recycling of launcher components
- Lower launch costs
- Private Space Stations
- Private astronauts on LEO missions
- Commercialization
- Suborbital flights for tourists and some science
- ARTEMIS program to the Moon
- Mars and beyond
- US-China competition



ISS today – planned controlled deorbit in 2030



AXIOM private Space Station 2027 - 2029



Initially attached to ISS

and later detached →



The VAST Commercial Space Station

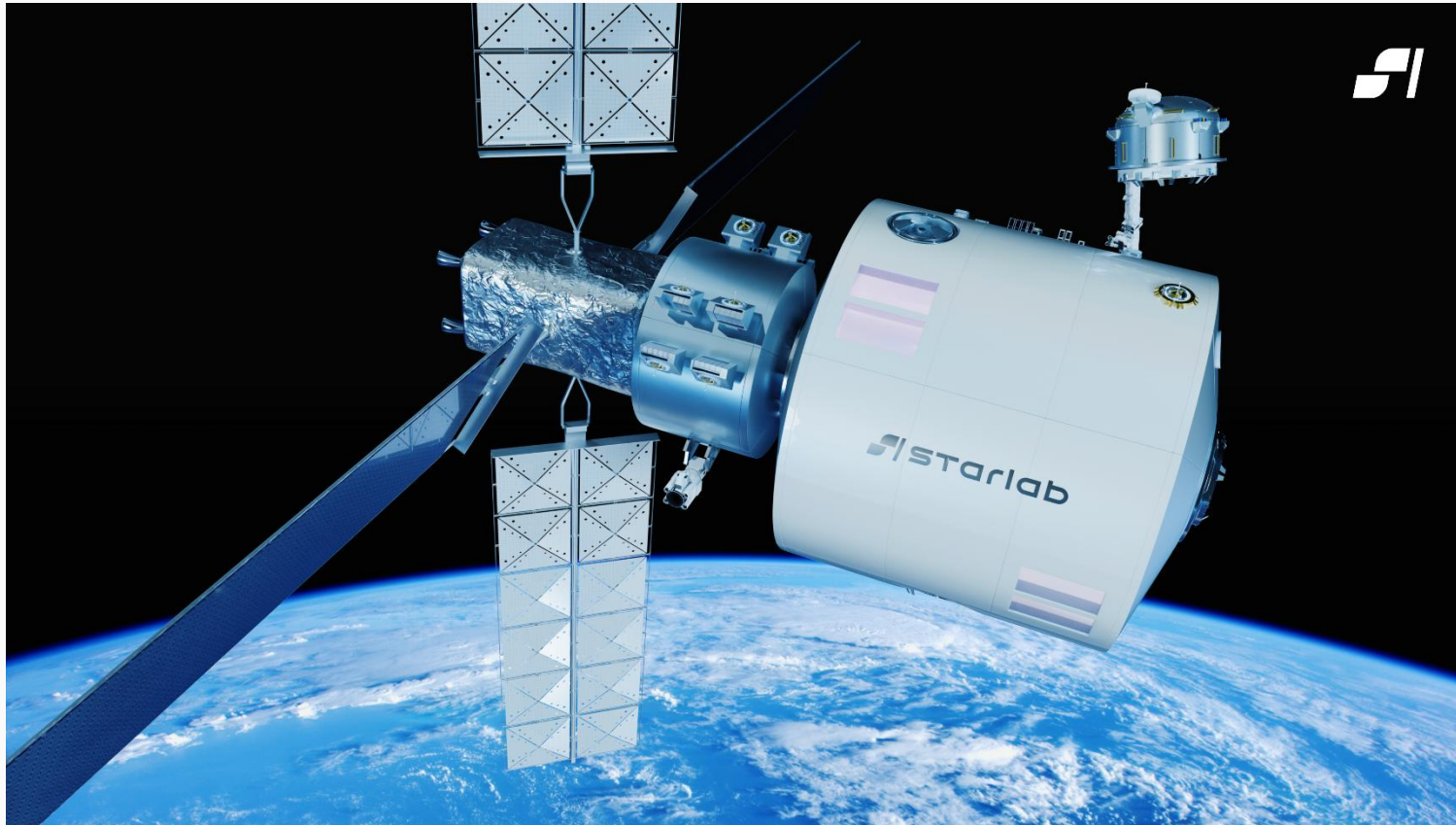


Starting with HAVEN-1
single module Station in 2026
(one FALCON 9 launch)

and evolving into a
multi-module Station later



STARLAB – Commercial Space Station with European participation



Joint venture of Voyager Technologies (USA), Airbus, Mitsibishi, and MDA (Canada), crew of 4 to 8 astronauts, single Starship launch

STARLAB – Commercial Space Station with European participation



More private missions in the future, like this «Polaris Dawn» in Sept 2024





HATCH OPEN



EV1 EGRESS

EVA 1 IN PROGRESS

The CDR of this mission (on left) will be the new NASA Administrator !

Jared
Isaacman



FRAM 2 private mission in April 2025

First human space mission over the poles of the Earth



The crew

ARTEMIS program, to the Moon south pole to stay!

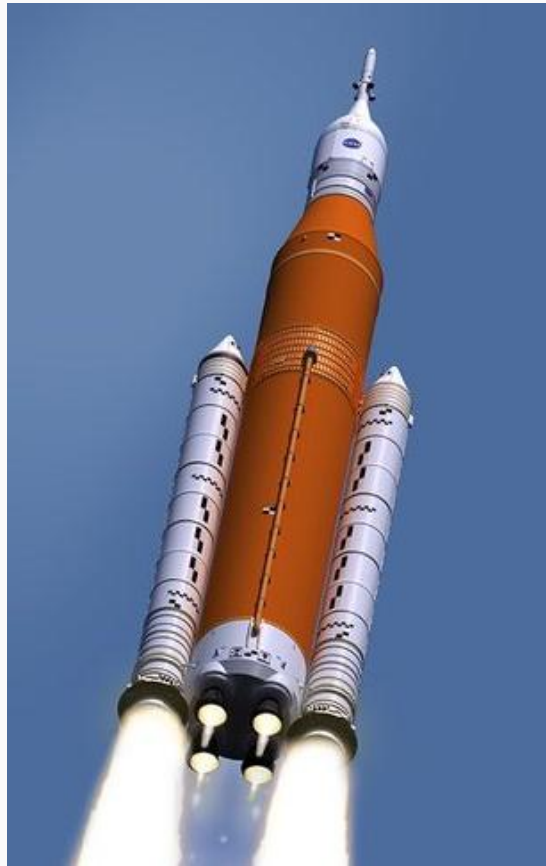
Back to the Moon!

NASA-ESA-JAXA-CSA
and others...

First landing close to the
Lunar South pole in 2027+



NASA Artemis II mission to the Moon (no landing) planned for 2026

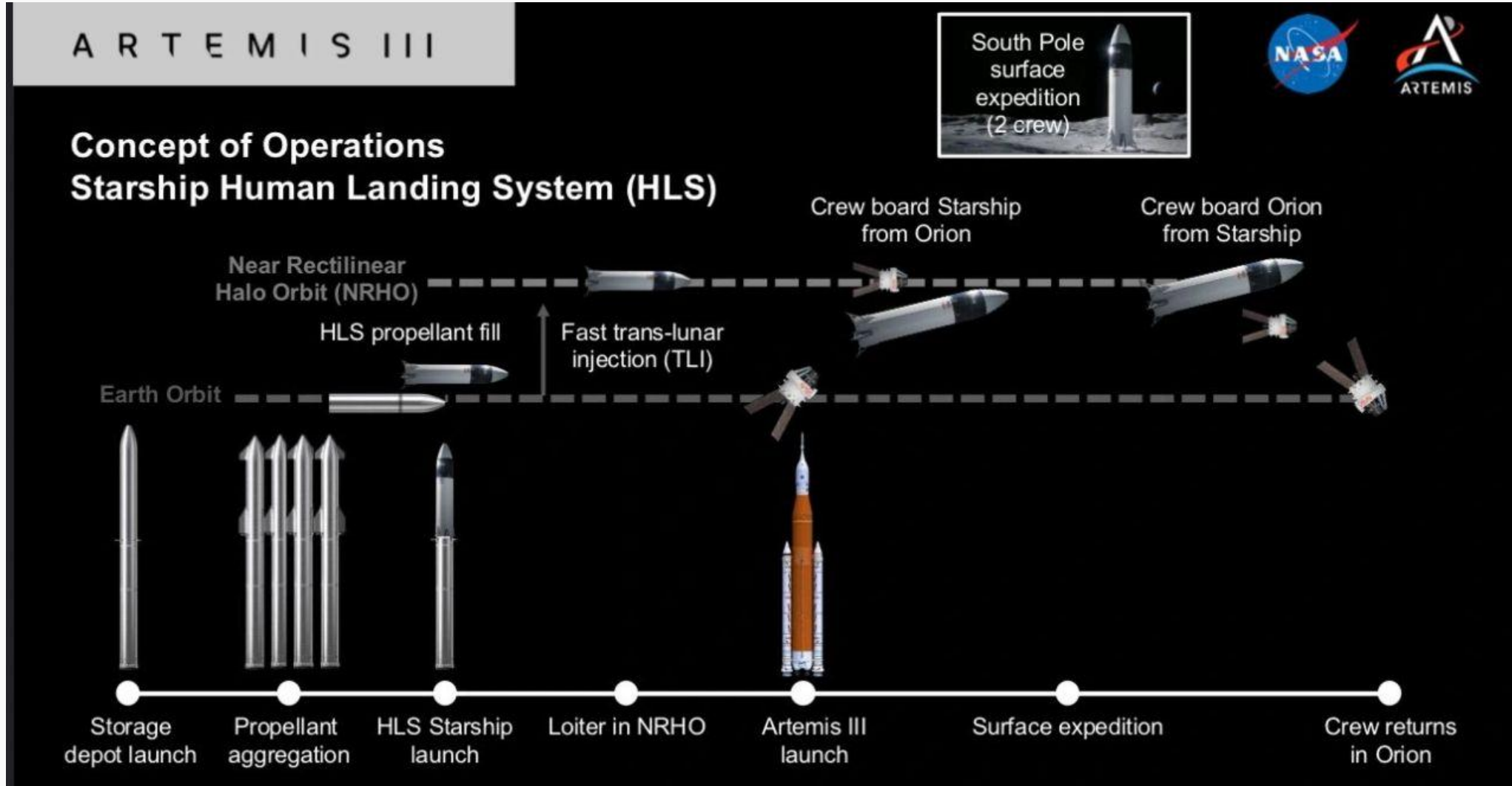


The Artemis II crew



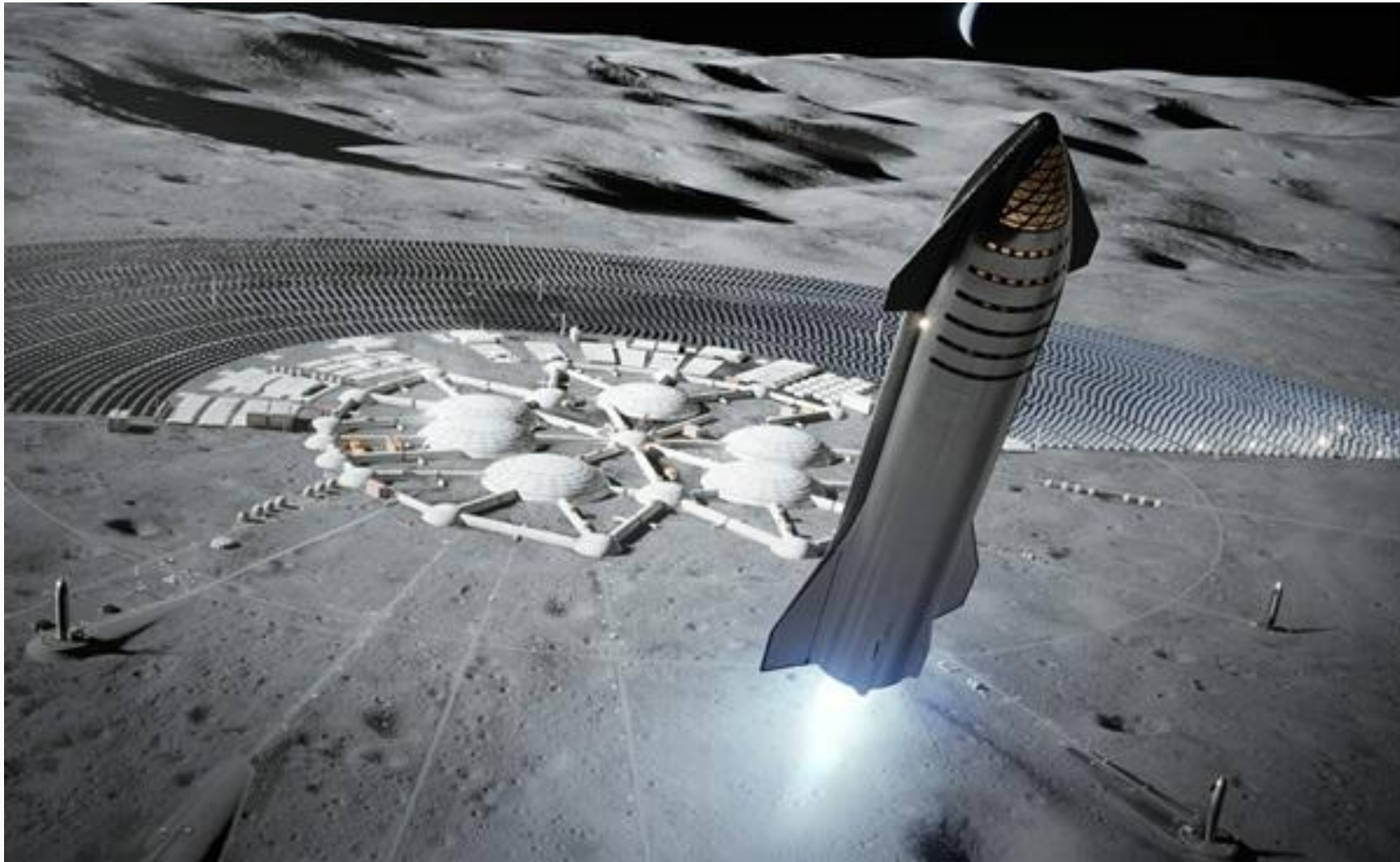
Jeremy Hansen - Christina Koch - Victor Glover - Reid Wiseman

Artemis III plan, 2028 or 2029

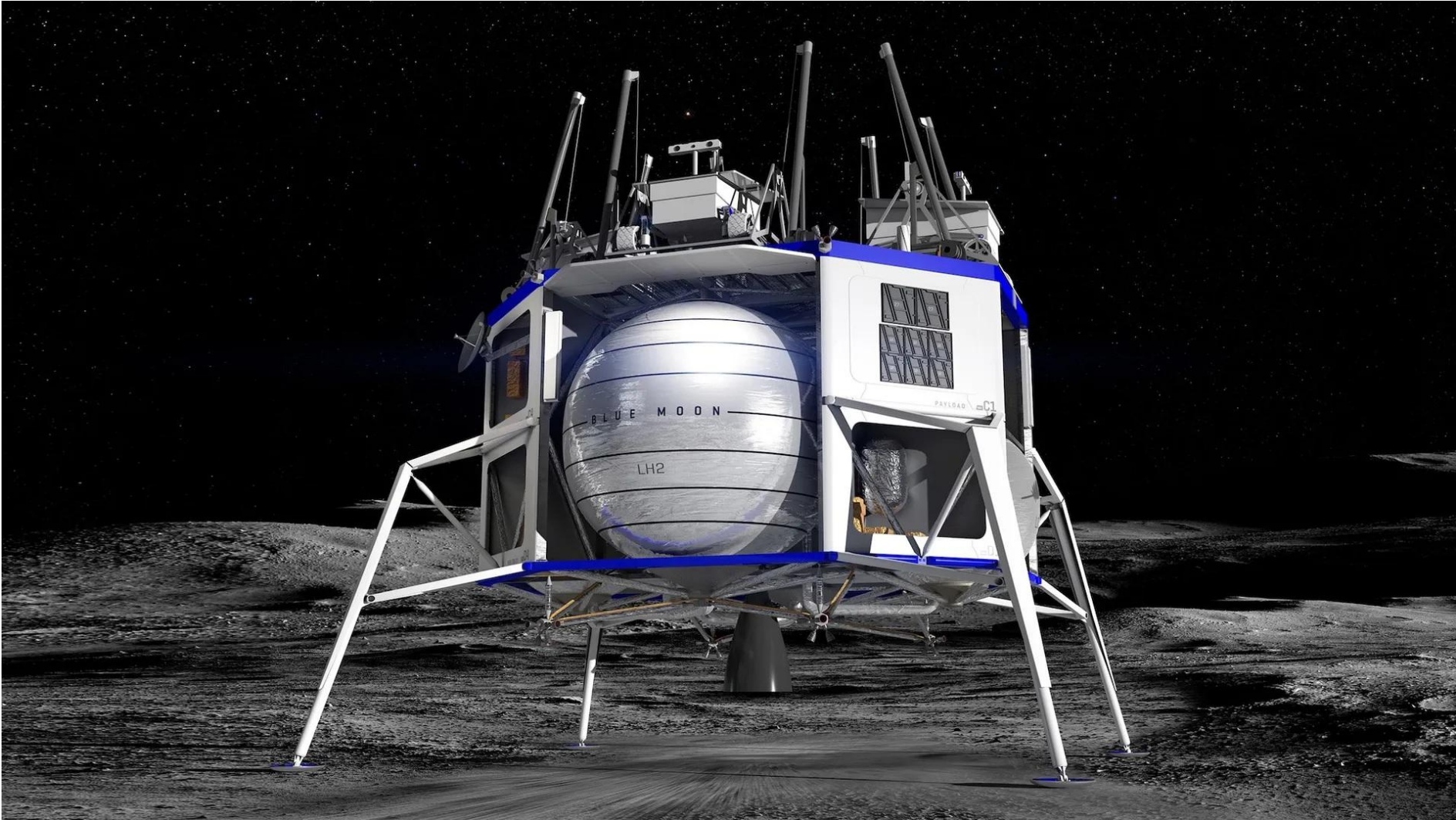


Jeremy Hansen - Christina Koch - Victor Glover - Reid Wiseman

Establishing a Moon base by 2030 – access with a SpaceX Lunar lander



An alternate Lunar Lander by Blue Origin



The obsession of Elon Musk





SpaceX building and testing STARSHIP
for missions to the Moon and Mars

Testing SpaceX Starship second stage recovery, Boca Chica, Texas, 2021



Starship will probably dominate the future of human spaceflight beyond LEO

Starship



lift off

Fifth Starship test October 13, 2024, a remarkable success!



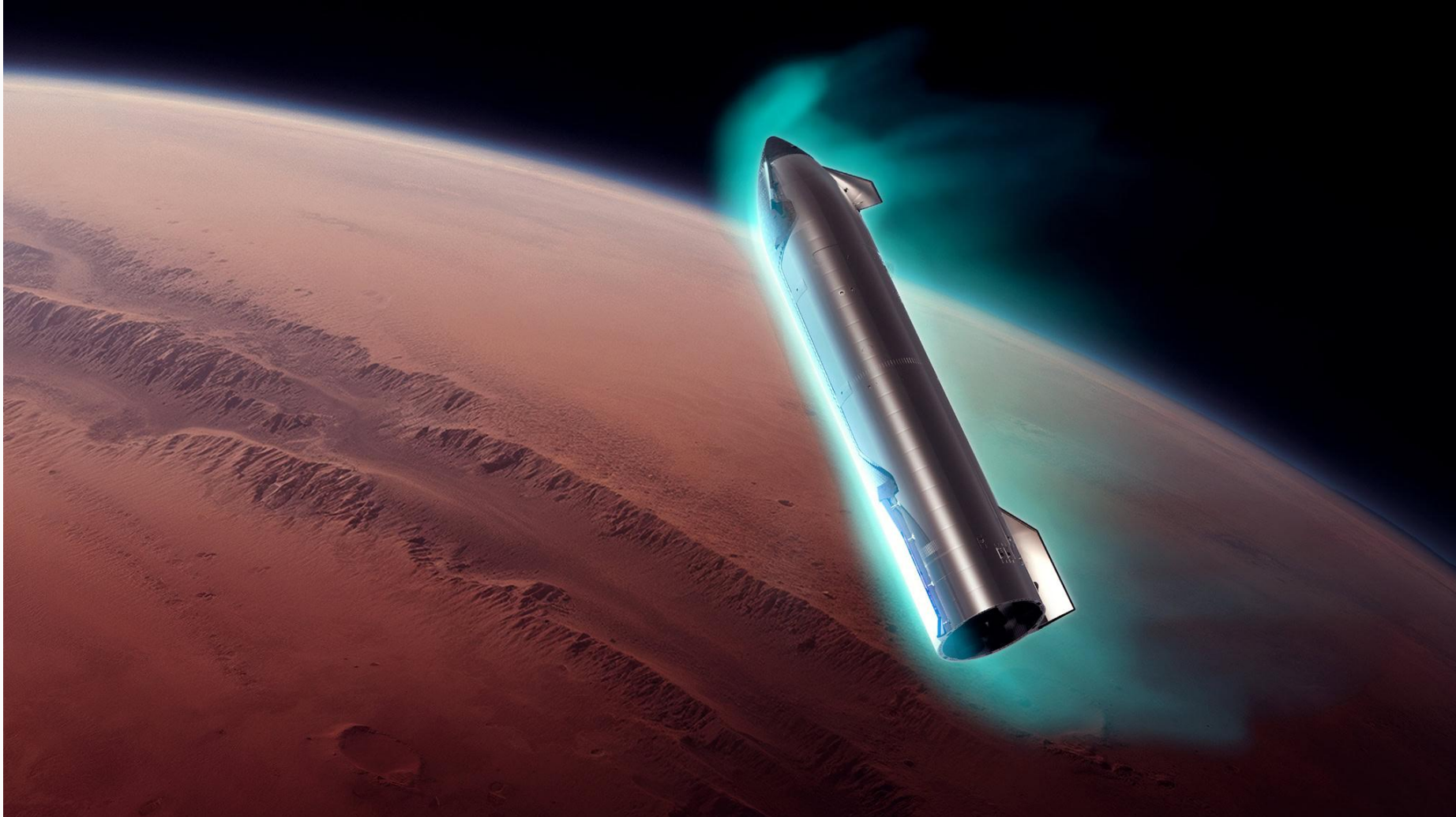
Re-entry of Starship over the Indian Ocean on the sixth test November 19, 24



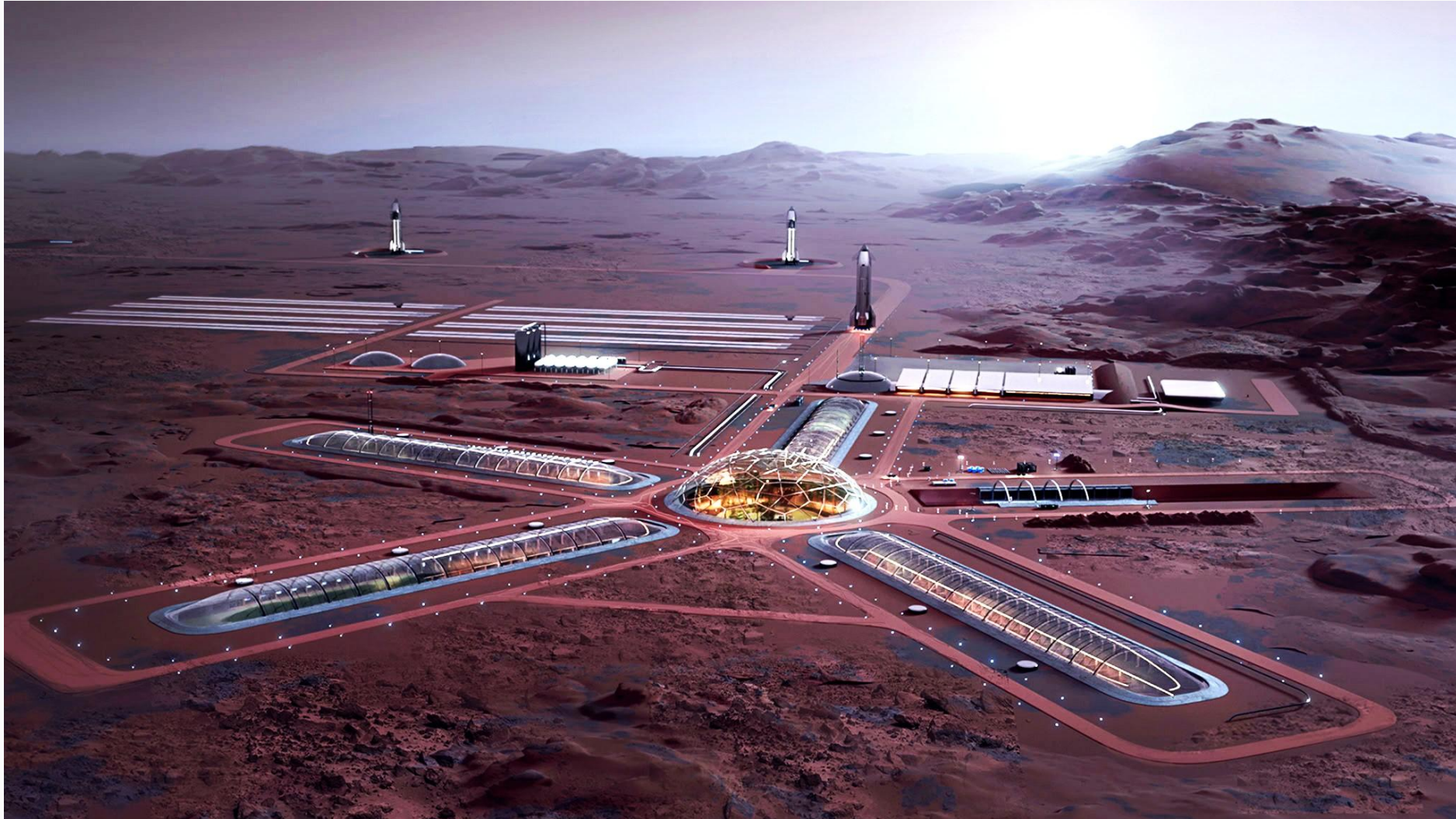
The Ship's final recovery over the Indian Ocean



Starship to Mars



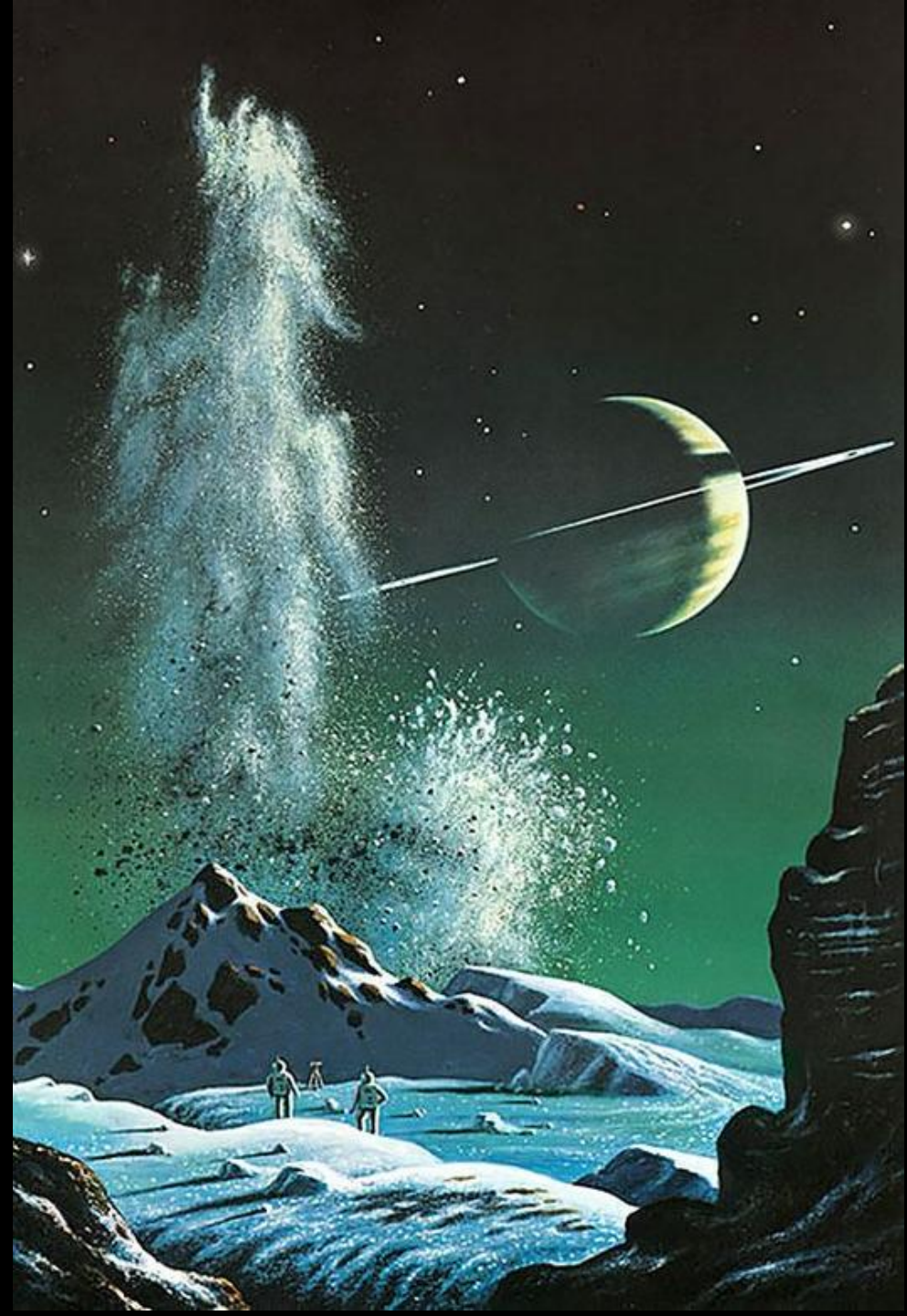
A Mars settlement – Maybe some day in the future, but not very soon!





Technically,
nothing will
prevent us
from going to
all kind of
places in the
Solar System

It will just be
a matter of
choice!





We obviously have a major responsibility to take care of planet Earth and this has to be properly balanced with future robotic and human space exploration efforts,

THANK YOU FOR YOUR ATTENTION – BEST WISHES FOR 2026 !



