Space Stations

Osher, Fall 2024

Howard Seltman

Outline

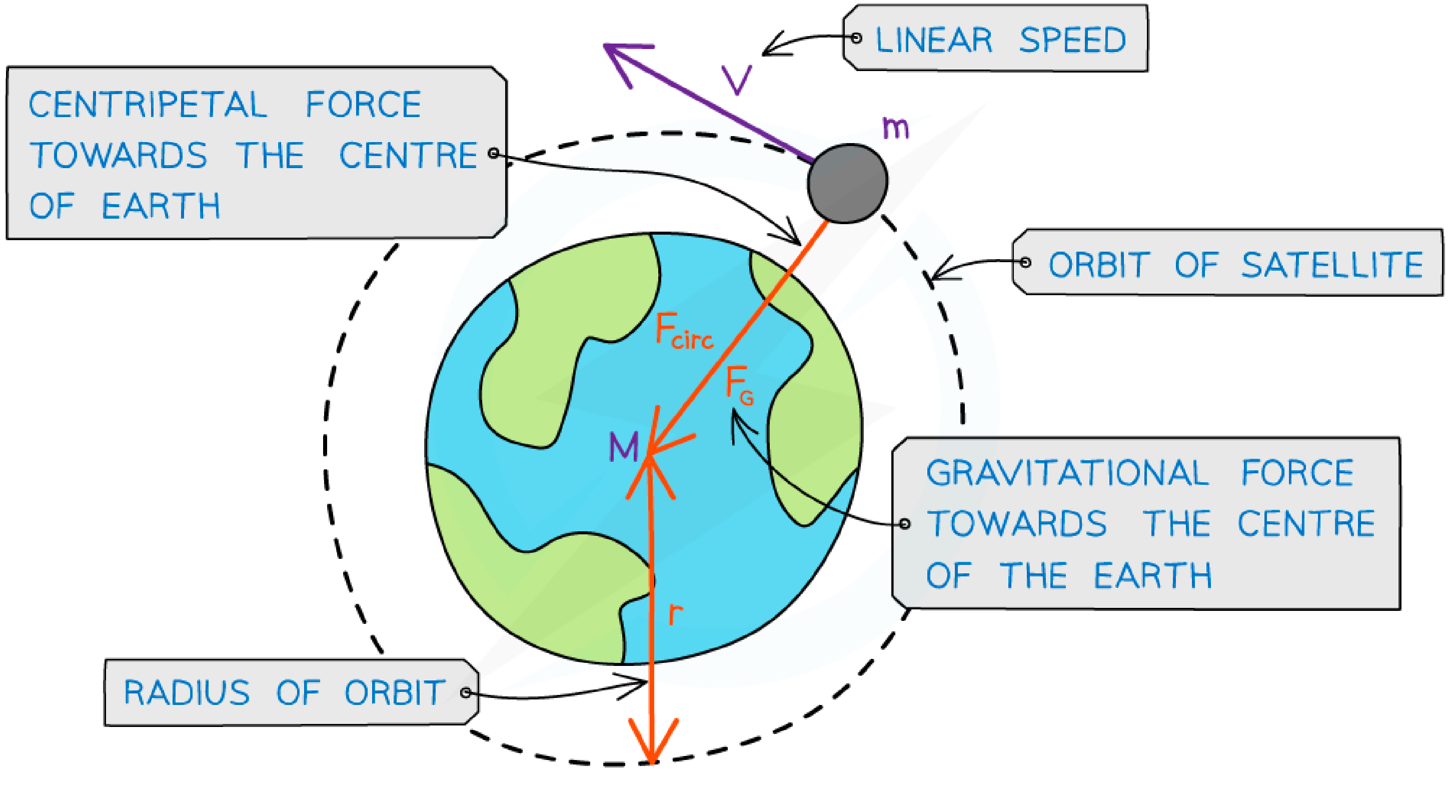
- Week 1: Science and Science Fiction Background
- **Week 2: Early (Non-modular) Space Stations**
- Week 3: Mir, ISS Planning and Construction
- Week 4: ISS Operations
- Week 5: China, Science & Tech Summary, and the Future

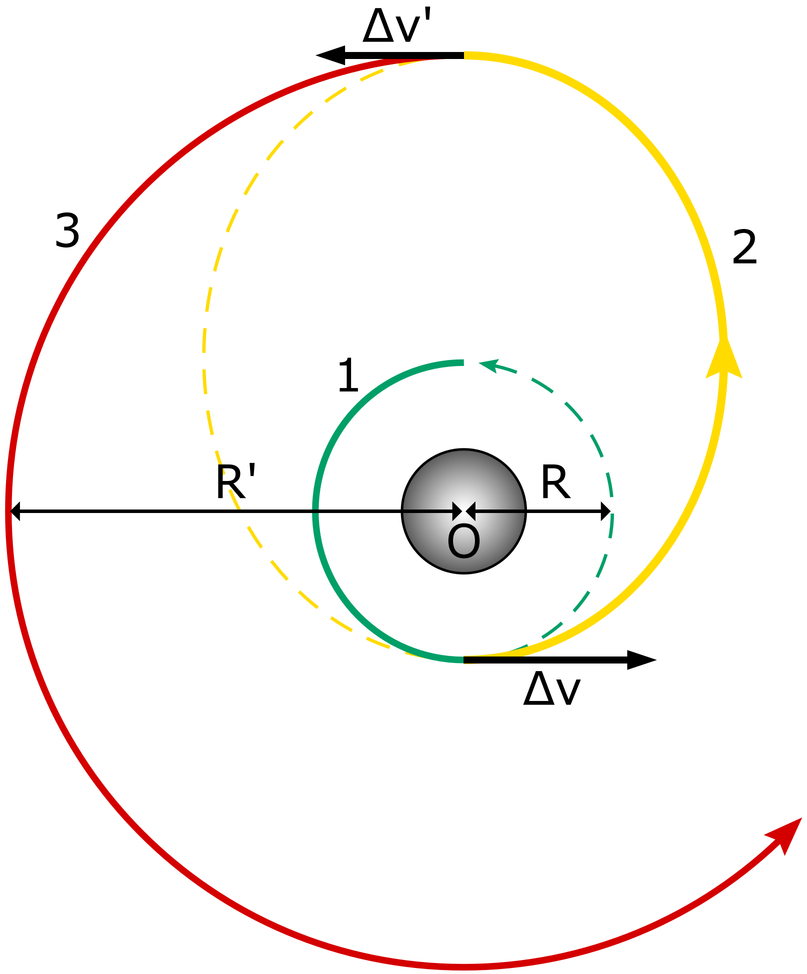
Overview for today

- Orbiting and rendezvous
- Soviet Salyut 1 station (1971)
- US Skylab station (1973)
- Additional Soviet stations before Mir (1973-1986)

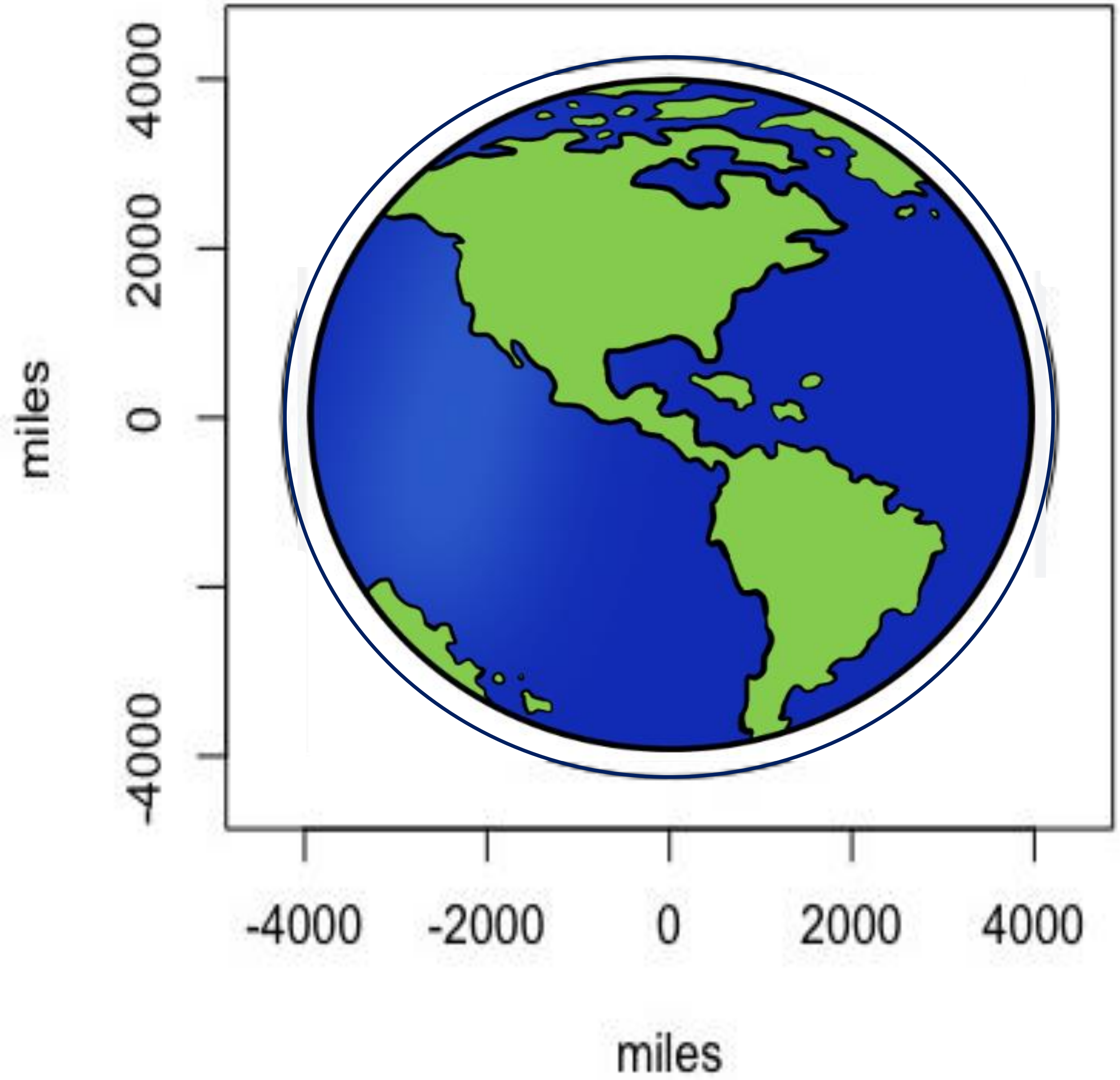
Going into orbit

- Vertical launch then pitch towards the east
- Inclination angle determines orbit, 41.5-51.7 degrees for stations
- Altitude: 200-400 miles
- Speed: 17,100 to 17,200 mph





Orbit size



Buzz Aldrin's MIT doctoral thesis (331 pp.)

LINE-OF-SIGHT GUIDANCE TECHNIQUES
FOR MANNED ORBITAL RENDEZVOUS

by

Edwin Eugene Aldrin, Jr.
Major, USAF

B. S., United States Military Academy
(1951)

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF SCIENCE

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
January, 1963

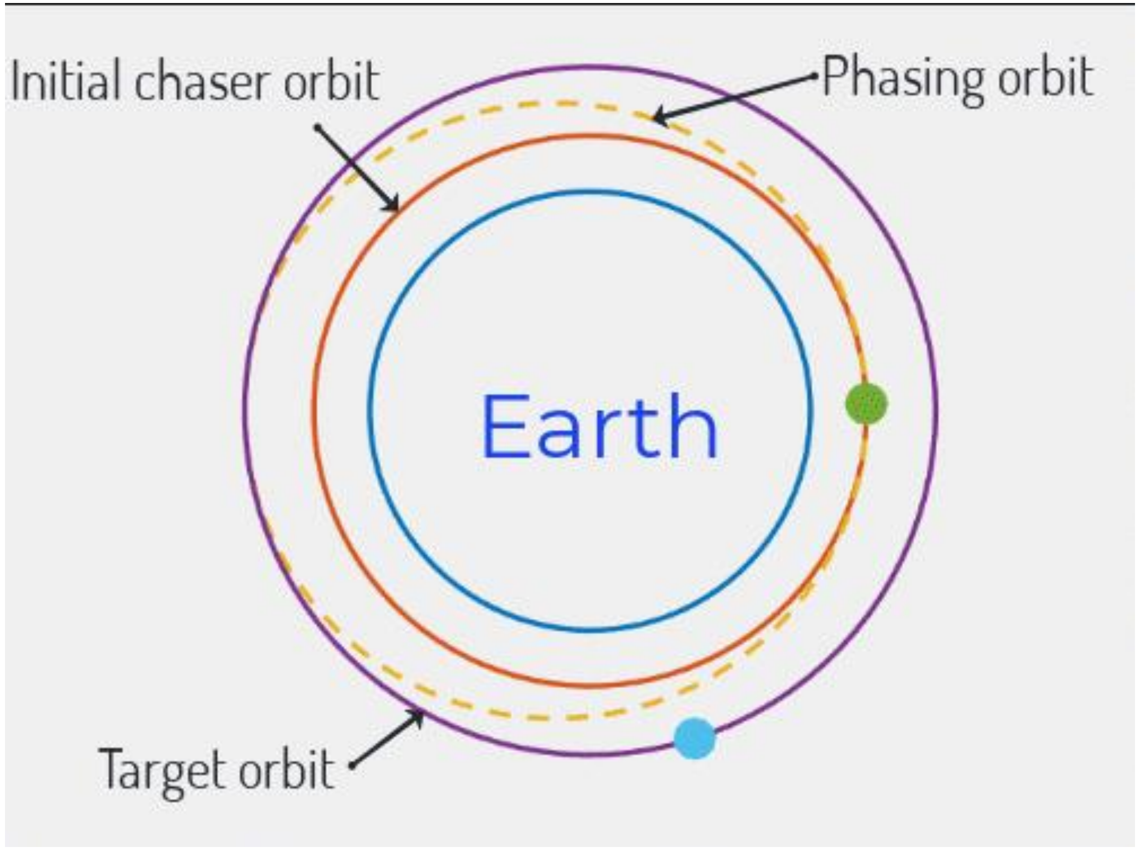
DEDICATION:
In the hopes that this work may in some way contribute to their exploration of space, this is dedicated to the crew members of this country' s present and future manned space programs. If only I could join them in their exciting endeavors.

INTRODUCTION:
Operational missions which might employ such a back-up mode of rendezvous guidance are the Gemini mission, the Apollo landing abort maneuvers or rendezvous from the lunar surface and various future space station ferry missions.

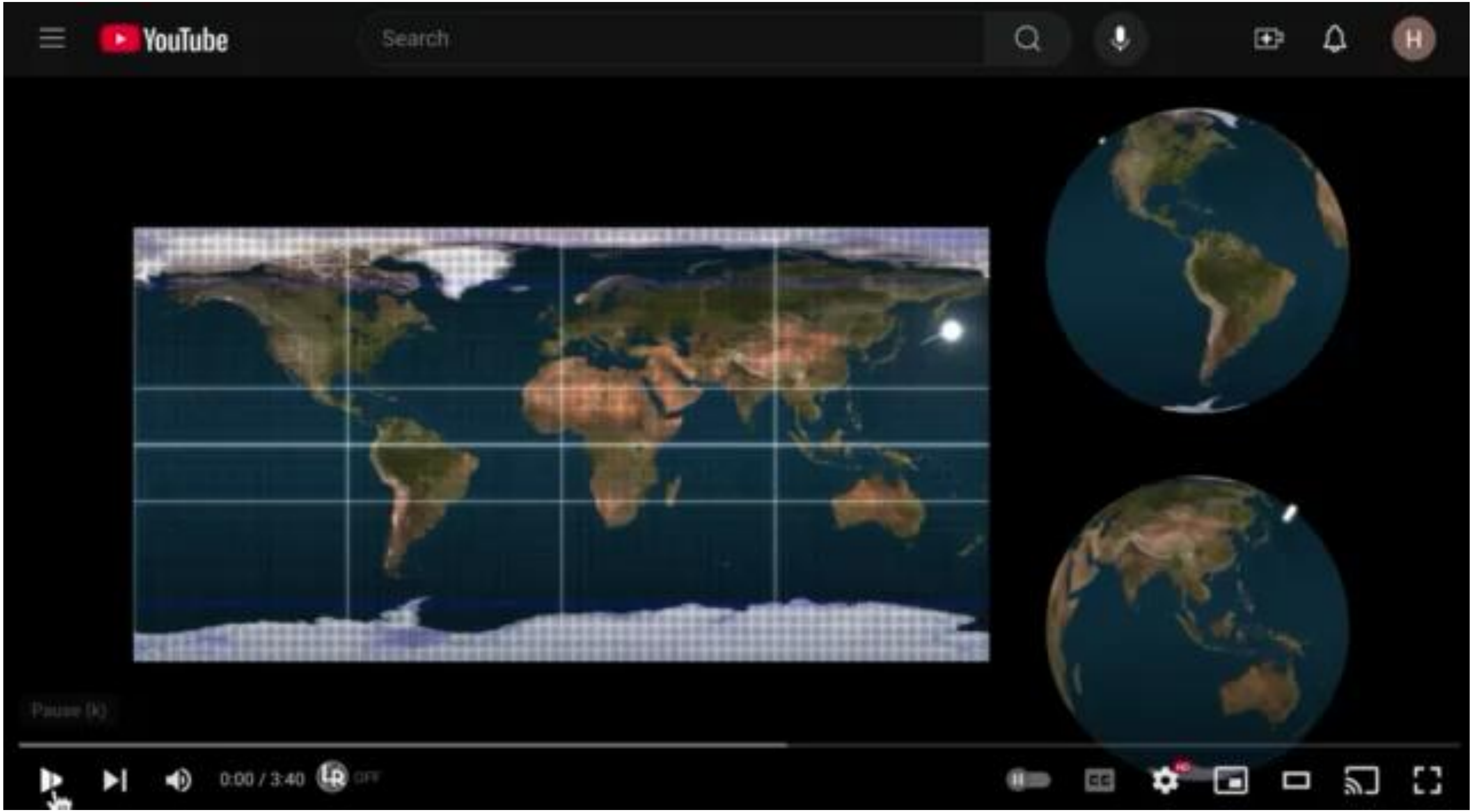
SUMMARY AND CONCLUSIONS
The possibility definitely exists in these type missions to have unmanned ferry vehicles ... [with] commanding ferry corrections based on visual observations made by controllers located in the space station.

Rendezvous and docking

- Circular orbit for the interceptor below and behind the target
- May or may not have radar or microwave ranging
- Interceptor, in the lower orbit, moves faster, and can catch up
- Firing engines in the forward direction adds energy raising the orbit (but slowing the spacecraft)



Orbits

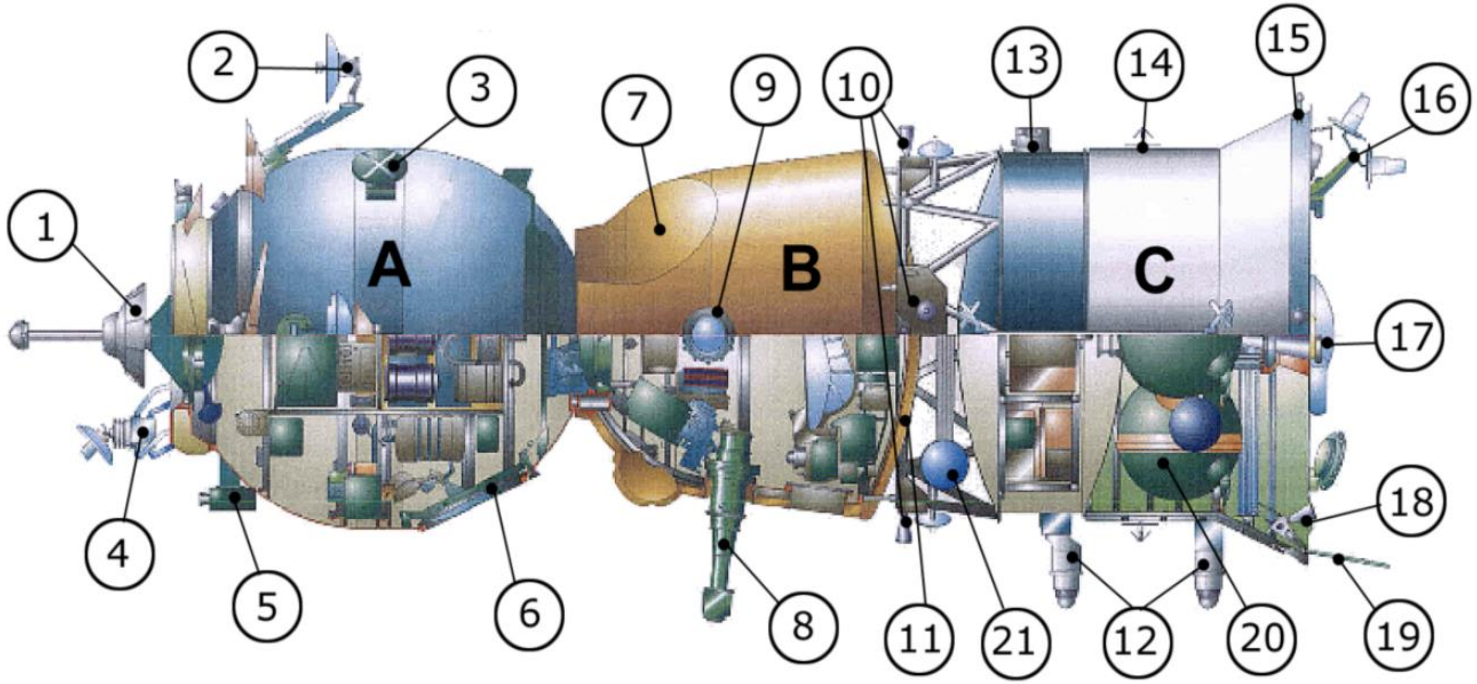


Space capsule vs. space station

- Volume in cubic feet [living space]
  - Apollo: 190 [140] cubic feet
  - Soyuz: Orbital module 210 [180] + Descent module 140 [88]
  - Salyut space stations: 3,200
  - Skylab space station: 12,000
- Maximum time living in space
  - Gemini 7 (1965): 14 days
  - Soyuz 9 (1970): 18 days
  - Salyut 1 (1971): 23 days occupied
  - Skylab (1973-1974): 171 days (28-84 per crew)
  - Salyut 7 (1982-1986): 816 days (50-237 per crew)
- Electricity
  - Soyuz: Chemical batteries till 1967, solar panels up to 600 watts
  - Apollo: Fuel cells, up to 2000 watts
  - Salyut: 4,500 watts
  - Skylab: 11,000 watts

Soyuz spacecraft

- Launched from a Soyuz rocket
  - Four boosters
  - Three stages
  - RP-1/LOX
  - 8.8 minutes to orbit
- Three modules
  - Orbital [A]
  - Descent (and ascent) [B]
  - Orbital [C]
- Life support for 3 for 30 days
- Lifetime in space: 6 mos.



Orbital module (A)

1 docking mechanism

2, **4** Kurs rendezvous radar a

3 television transmission ant

5 camera

6 hatch

Descent module (B)

7 parachute compartment

8 periscope

9 porthole

11 heat shield

Service module (C)

10, **18** attitude control engines

12 Earth sensors

13 Sun sensor

14 solar panel attachment point

15 thermal sensor

16 Kurs antenna

17 main propulsion

19 communication antenna

20 fuel tanks

21 oxygen tank

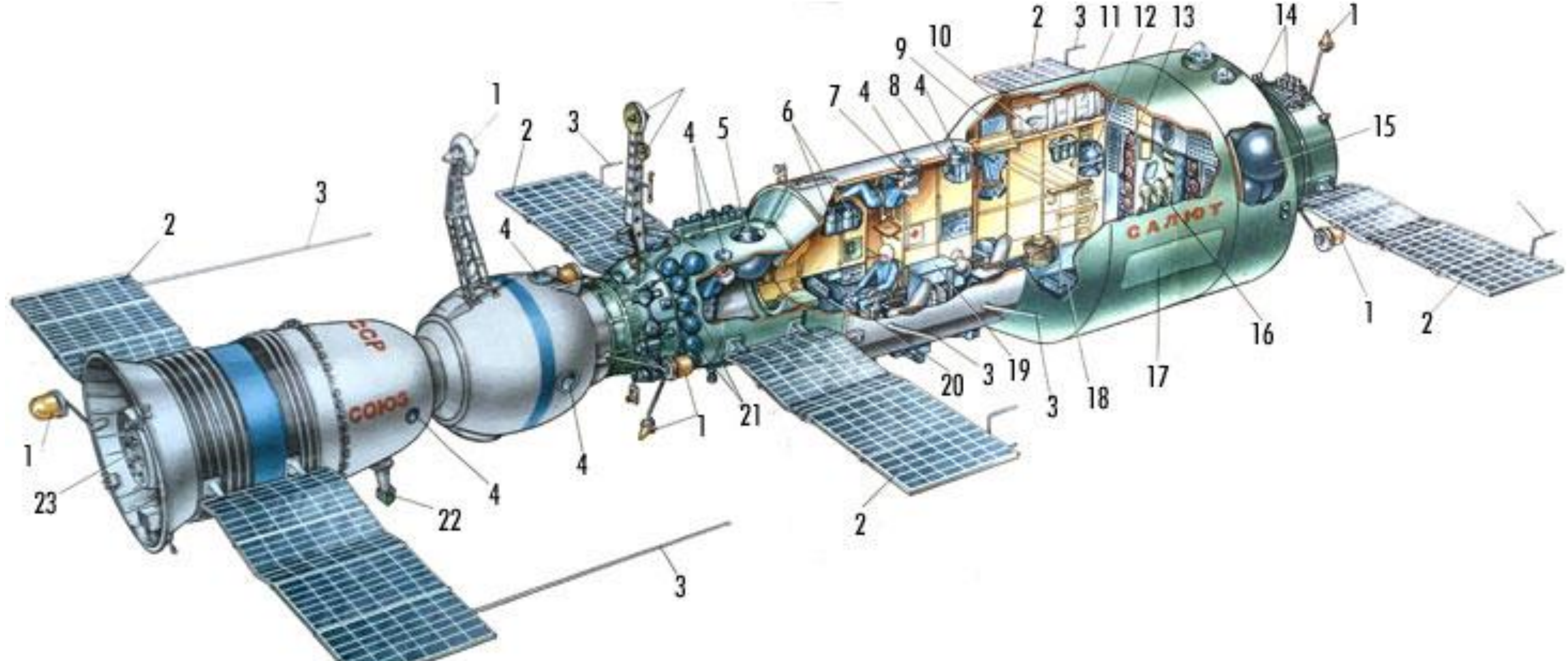
Soviet space stations: background

- Initial interest was in military stations (“Almaz” = diamond)
- Big failures in attempted moon launches in the late 60’s changed the emphasis to space stations
- *The Story of Space Station Mir* by David M Harland

> Speaking on Radio Moscow on 9 April [1971], Academician Boris Petrov, the chairman of the Intercosmos Council of the Academy of Sciences, said that small orbital platforms that would be manned by several specialists would appear in the near future. He said that these would operate for periods of between one month and one year, and would later be superseded by large laboratories which would be assembled in orbit and remain in use for several years.

Soviet Salyut 1 space station

- Launched April 19, 1971
- 66 ft long, 13 ft diameter, includes the Orion 1 Space Observatory



Source: RKK Energia / RussianSpaceWeb.com

Salyut 1 Crew arrives

- Soyuz 10, launched April 22, 1971, could not get a hard dock
- New York Times, April 25, 1971 reported “Soviet Workshop in the Sky” with a two-year lead on the U.S., but also:

  “The secrecy, which pervades nearly all aspects of the Soviet space program, has kept official descriptions of mission objectives and mission events to a minimum, often leaving in doubt what the actual accomplishments were.”

- Soyuz 11 with Georgy Dobrovolsky, Vladislav Volkov, and Viktor Patsayev arrived June 7
- Had to repair ventilation and spend first day on Soyuz

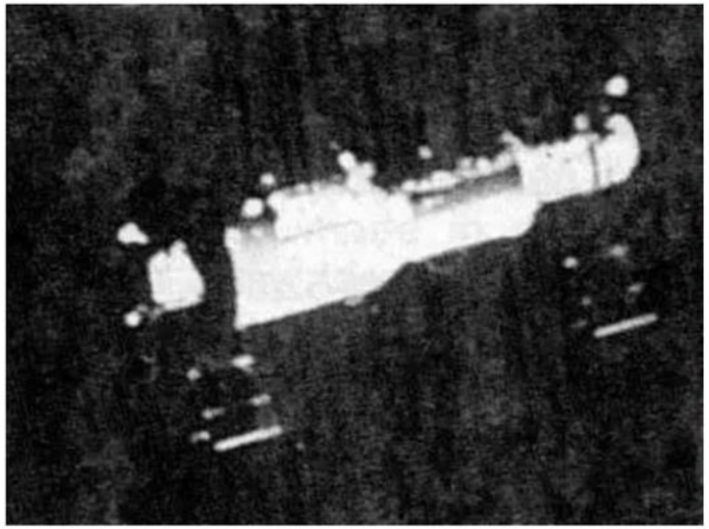
Soyuz 11 crew on Salyut 1 (3:38)

- Near daily live TV broadcasts
- Cast ballots (first from space)
- Patsayev turned 38 years old (first birthday spent in space)
- Grew Chinese cabbage and onions
- First space toilet (primitive)
- Maintaining of altitude and attitude
- Earth monitoring
- Exercise (2 hours) and health monitoring
- Telescopic observations
- Small electrical fire on day 11
- Stayed 23 days

https://www.youtube.com/watch?v=hWUJi4uhreg

Soyuz 11 Return to Earth

- Departed June 29, 1971; photographed Salyut as they departed

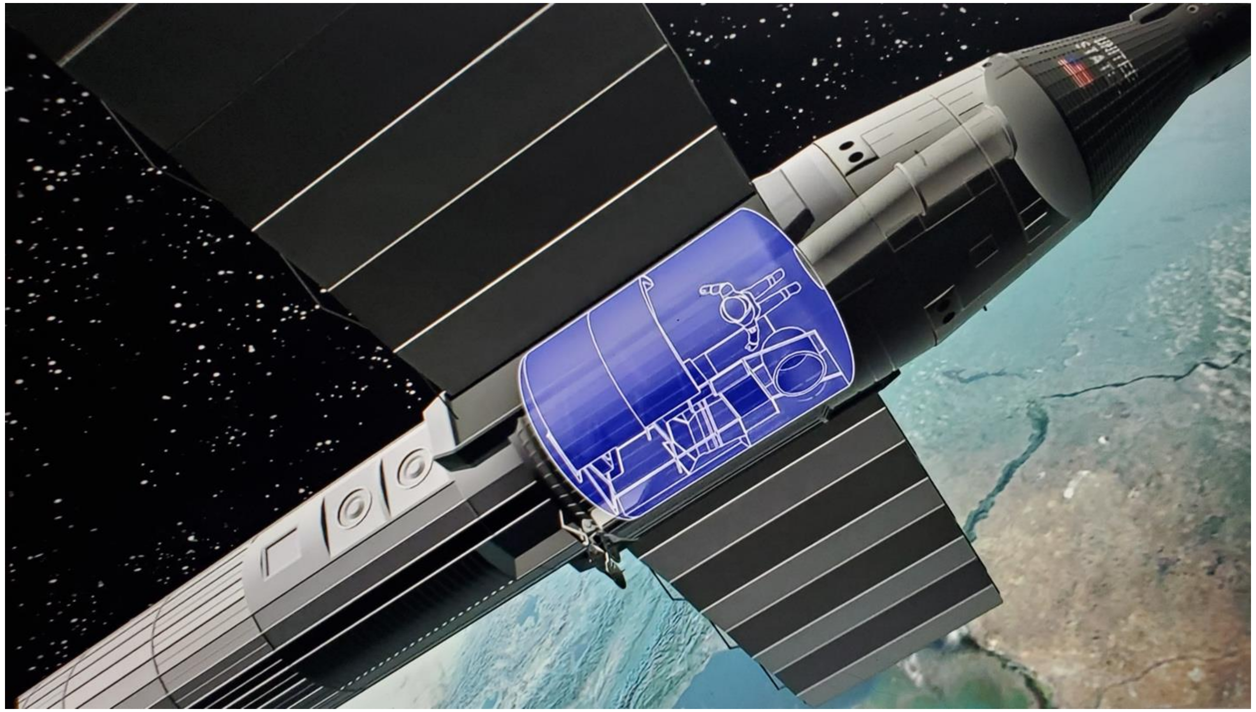



- Decompression resulted in death of the cosmonauts


- Salyut 1 station deorbited 6 months later

U.S. Military "Manned Orbital Laboratory"

- U2 program to find Soviet nuclear launch sites stopped in 1960
- December 1963: Johnson announces $1.5 billion MOL
- 17 trainees trained on vomit comet and centrifuge
- Competition: NRO's Corona project: Keyhole digital satellites
- Cancelled June 1969 at $3 billion

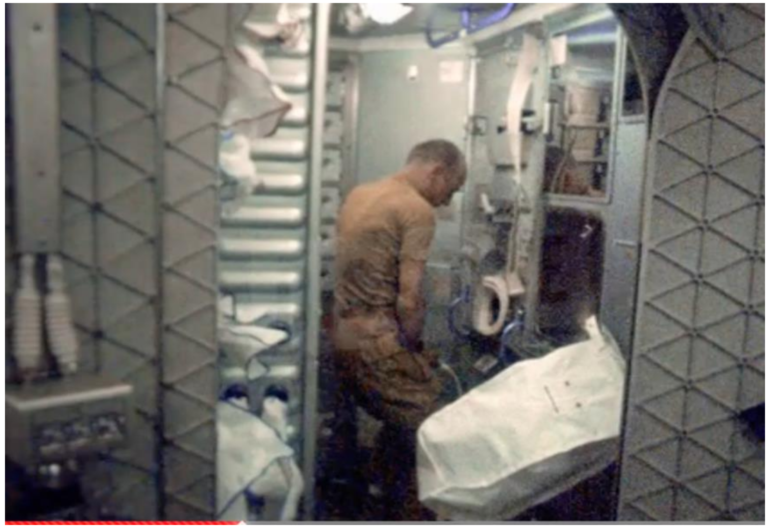


U.S. Skylab Development

- Early (1959): artificial gravity
- Wet vs. dry
  - Wet: S-IVB as usual third stage of Saturn S1-B, but put into orbit
  - Dry: S-IVB as pre-outfitted third stage of Saturn V
  - For wet: all expensive Saturn V’s accounted for
  - For dry: outfitting required lots of work in pressure suits at zero g
  - Dry chosen by 1966

Skylab miscellaneous

- Human factors: Industrial designer Raymond Loewy
- Food: 70 items, mostly canned, rehydrated and heated
- Excrement: bagged for scientific study
- Computers
  - dual 100-pound IBMs with 16 K RAM
  - 0.5 MIPS
  - ten buttons (0-7, enter, clear)
  - for attitude control and telescope pointing



Skylab miscellaneous

- Big discussions about medical procedures – training in blood drawing and first aid with time spend in a busy urban ER
- Learned to extract teeth on volunteers at U.S. Air Force dental clinic
- New attitude control systems – cold gas thrusters and gyrodynes instead of chemical thrusters
- Astronauts needed 2500 hours each in trainers and simulators

Concerns about temperature control

- A ship, station, or spacesuit in orbit varies between -250 ^{o}F and +250 ^{o}F
- People, supplies and equipment have narrower tolerances
- The sun and electrical system generate heat
- Heat can be reflected, radiated away, or stored/moved around
- Solutions include multilayer insulation, electric heaters, reflective coatings, sun shields, louvers, radiators, and heat pipes

Concerns about micrometeoroids

- About the size of dust grains, they “sandblast” a spaceship over time
- Average relative velocity of 22,000 mph
- A Whipple shield uses thin layers to disperse the energy over a larger area
- As opposed to using thicker walls, weight is greatly reduced

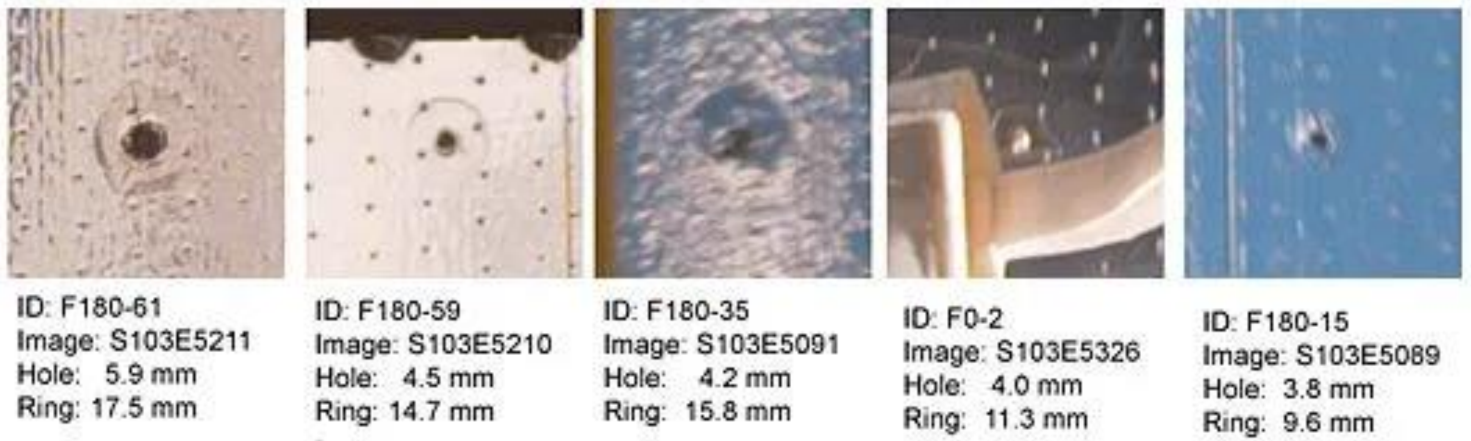
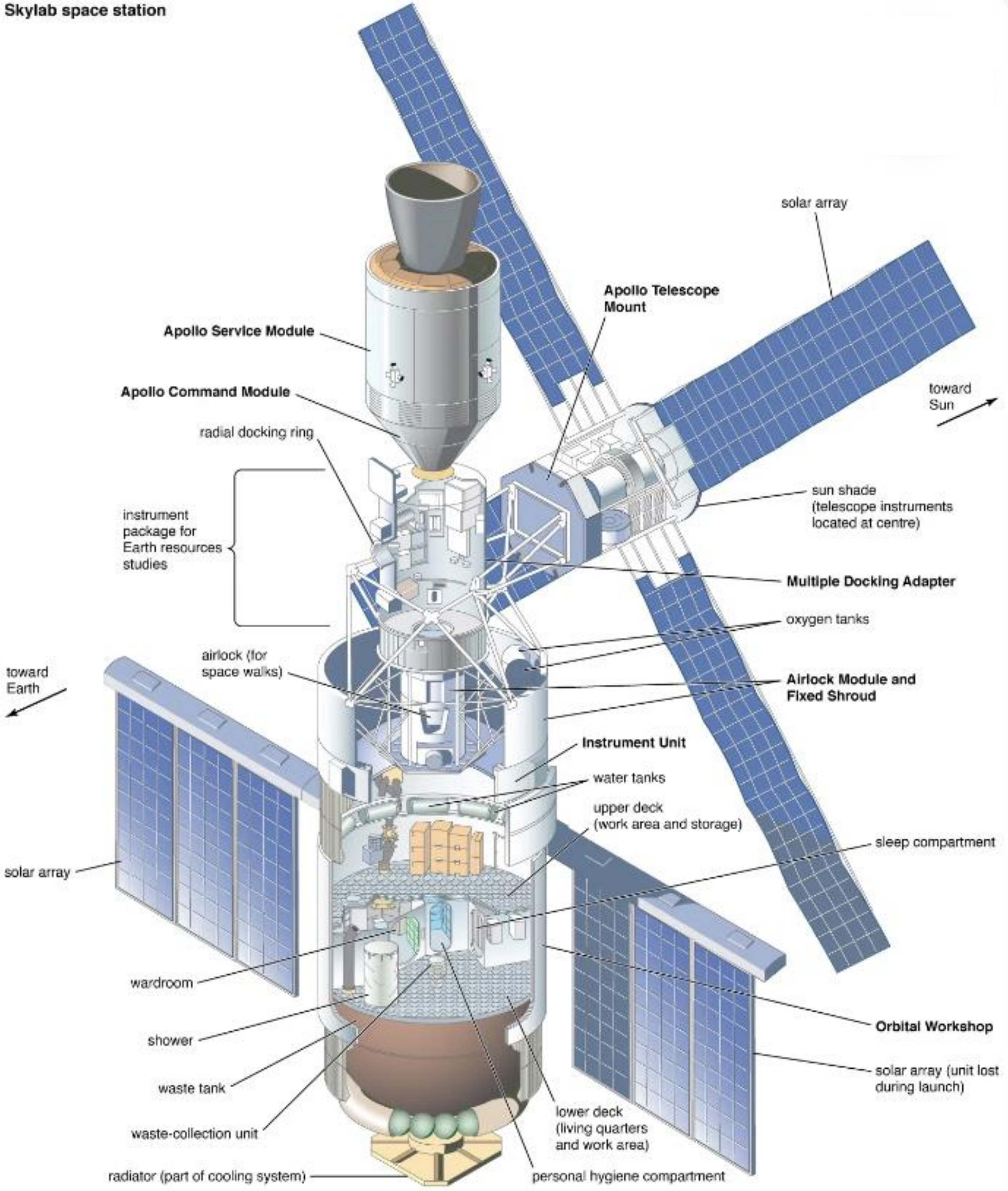


Figure 1. Five HST impact sites photographed with 400 mm lens.

U.S. Skylab Components

- August 1969: McDonnell Douglas gets the contract to convert two S-IVB rockets to an Orbital Workshop and a backup
- Components [tons]:
  - Payload shroud [12]
  - ATM: Apollo Telescope Mount [12]
  - Multiple Docking Adapter [6]
  - Airlock [25]
  - Orbital Workshop (99 ft long, 22 ft diameter) [39]
  - Apollo Command and Service Module [15]
  - Micrometeroid / thermal shield ("a large, flexible, limp system that proved difficult to rig ... and to obtain the close fit that was presumed by the design")

Skylab space station



Break

Skylab Medical Experiment Altitude Test (SMEAT)

- 56-day simulation with 3 astronauts in a hyperbaric chamber (July 1972)
- 1/3 normal atmospheric pressure at 70% O_2
- Goals
  - Obtain baseline medical data
  - Evaluate experimental hardware and procedures
  - Assess medical support operations
  - Train ground teams for supporting long-duration missions

Final Skylab Schedule

- Unmanned Orbital Workshop (OWS) launch for 11/9/1972 to last about 8 months
- 28-day activation mission to launch the next day (to study effects of extended duration spaceflight)
- 56-day second mission launch for 1/19/1973 (operation of Apollo telescope mount)
- 56-day third mission launch for 5/1/1973 (Earth resources observation)
- Possible fourth mission: Docking with a Soviet Soyuz spacecraft

Skylab launch

- Used the last Saturn V rocket (with five F1 engines)
- Launched May 14, 1973
- Seconds after Max-Q, telemetry showed premature deployment of the micrometeroid shield and the #2 solar array
- Five second stage engines continued toward orbit. Telemetry showed failure of separation of stage 2 with the payload, so the engines were burned a little longer to compensate for extra weight and drag.
- Arrived in orbit at 10 minutes with separation of the second stage
- Preprogrammed steps to configure the station began
- Tracking over the Seychelles should have shown 12.4 kW from the OWS solar arrays but showed 25 watts. Four ATM (Apollo Telescope Mount) solar arrays unfolded, but unfolding of the OWS solar arrays could not be confirmed.

Skylab initial problems

- May 15 astronaut launch cancelled and rescheduled for May 20
- CSM could only supply 1.4kW for 14 days, greatly limiting science missions
- Plan: 17-day nominal mission plus 11 days reduced activity to get the planned 28 days of medical data
- Conclusion: micrometeroid shield deployed prematurely and was ripped off by aerodynamic forces, and the solar wings did not deploy for unknown reasons. This caused less protection from the sun with high internal temperatures (100º F), bad for both people and equipment: a sun-shade was needed.
- Eventually the core problem was found to be miscommunication between aerodynamics, structural design, and manufacturing

Skylab problem solving

- Overheating could have resulting in hull rupture, so the station was depressurized. Various attitudes were investigated to find the best balance between heating and power for the small ATM solar arrays. External temperatures reached as high as 225º F.
- Internal temperatures of 130º F risked damaging the consumables for all three missions (the visiting ships could only carry a small amount more). It was concluded that the food would be OK, but the astronauts were given new training to detect spoiled food.
- New film and some medical supplies would need to be sent up
- For heat protection NASA and contractor brainstorming suggested reflective spray paint, window curtains, weather balloons, and extendable metal panels. Ten ideas that were light, easily deployed and fit in the CSM were chosen for further testing.

Skylab new heat shade

- Three ideas for a fabric shield
  - Shield on a pole from the telescope mount: required extensive, unprecedented EVA training
  - Shield deployed by the CSM before docking: least complicated, unknown effects of firing engines close to telescope mirror and ATM solar panels
  - Deploy through the OWS airlock: required a small package, and carried out in a hot ship, but simplest for the crew
- Option 3 is chosen
  - 23 sq. feet of 3-ply mylar and ripstop nylon folded into 8x8 inch package with spring loaded poles
  - Also brought a heavy-duty cable cutter and universal "puller" to try to free the one stuck solar panel that had not broken off
  - Everything tested in the underwater neutral buoyancy pool

Skylab 2: First crew

- Launch: May 25, 1973
- Crew: Charles "Pete" Conrad, Jr., Joseph Kerwin, Paul Weitz
- Confirmed that the airlock was not blocked, and the loss of one solar array, with the second one trapped by remaining pieces of the micrometeroid shield
- Still undocked, Conrad flew as close as 2 feet from Skylab, while Weitz performed a "stand-up EVA" trying to free the solar array while Kerwin held his ankles and feet! A half-inch metal strap which could not be cut or removed with the available tools trapped the array. Twice they had to be reminded that they were on an open microphone.

Skylab 2: First crew

- After several attempts to dock, the astronauts put on their pressure suits, and partially disassembled the docking probe, and the next attempt at docking worked. After a 22-hour day, the astronauts rested.
- The next day they opened the hatches and occupied Skylab for the first time (May 26, 1973). They wore gas masks because of possible toxic outgassing due to the heat. The air was checked, and the masks dropped. The temperature was 130º F, but with low humidity.
- Preparing the sun-shade took 6-7 man-hours, requiring periods of rest in the cool CSM. The sun-shade was successfully deployed, though to only 2/3 of its full extent. The temperature dropped to 90º F.

Skylab 2: First crew

- The crew set up the OWS and started experiments
- On Earth, a team lead by Rusty Schweickart evaluated the solar array problem, and planned an EVA

Skylab 2 accomplishments

- ATM activation: 117 hours of observation with 29,000 frames of data
- Medical experiments, creature comfort testing
- Six experiments were supposed to use the airlock holding the sun-shade, but three were modified to use the other airlock
- In the 28 days, Conrad celebrated his 43^{rd} birthday and 20^{th} wedding anniversary
- Deployment of the backup solar shield was delayed to Skylab 3
- On day 25, they exceeded the Russian Salyut 1 space endurance record
- On day 26, Conrad and Weitz climbed to the ATM to swap out the film cartridges
- Splashdown June 23, 1973, after 28 days and 404 orbits
- The ATM was operated during the inter-crew period

Skylab 3 (second crew)

- T-40 hours: depressurized to 0.65 psi, pressurized to 5 psi
- Moved up from August 17 to July 28, 1973 (36 days after Skylab 2), due to gyro degradation and possible thermal shield deterioration
- Extended plan from 56 to 59 days
- Alan Bean (commander), Jack Lousma (pilot), Owen Garriott (science-pilot)
- Fuel leakage in 2 of 4 RCS units led to starting up a rescue mission
- Rescue mission cancelled as more data came in (loose fittings)
- Many malfunctions and repairs
- Day 10: 6.5-hour EVA to install twin-pole thermal shield and change film
- Many TV broadcasts incl. recorded “This is Helen (Garriott)”
- Return September 25

Skylab 4 (third crew)

- Originally planned for 56 days with return before Christmas; discovery of Comet Kohoutek changed the return date from November to January
- Launch vehicle showed cracks in all 8 fins, requiring replacement of these 485-pound structures
- Mission extended from 70 to 84 days
- Pogue, least sensitive to motion sickness on Earth, had nausea and vomiting which was hidden from the doctors until a conversation not listened to live was transcribed -- public rebuke

Skylab 4 (5:31)

https://www.youtube.com/watch?v=wMzp4U2EIig

Skylab Science

- Riccardo Giacconi shared the 2002 Nobel Prize in Physics for his study of X-ray astronomy, including the study of emissions from the Sun, contributing to the birth of X-ray astronomy
- Multispectral scanner (thermal and near infrared and visible in 13 bands) to detect agriculture, forest, hydrology, geology (260 ft resolution)
- Comet Kohoutek
- Materials science/space manufacturing: metals melting, welding, sphere forming, zero gravity flammability, etc

1979 Skylab re-entry

- Feb 8, 1973: raised orbit, and went home
- 1974 proposed manned deorbit mission
- High solar activity lowered Skylab faster than expected
- Space shuttle was supposed to raise it, but not ready in time
- Tried to control descent into Indian Ocean by using attitude to control drag, then into a slow, uncontrolled tumble at 93 miles
- Broke up over Western Australia at night with pieces found (2500-mile debris track)


SKYLAB DEBRIS HITS AUSTRALIAN DESERT; NO HARM REPORTED

Witnesses in Australia describe effects of falling Skylab fragments

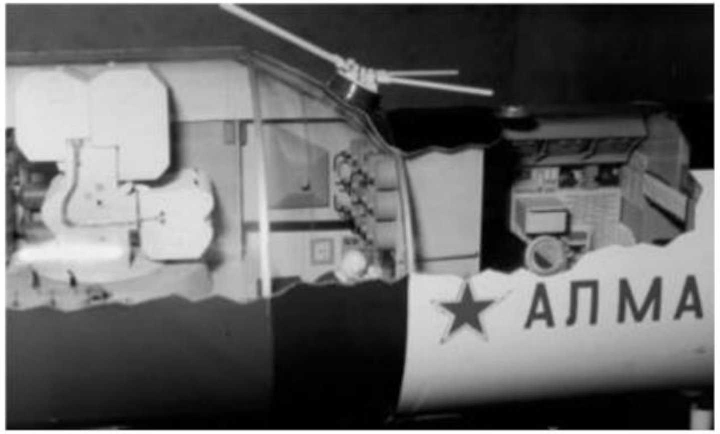
President Sends a Note of Apology — Craft Was Shifted for Re-entry

Soviet Almaz military "Orbital Piloted Stations"

- Almaz's were equipped with a rapid-fire cannon
- Two-ton camera with 18-foot mirrors; developed film in capsule
- April 1973: Salyut 2 lost attitude control and depressurized

- November 1973: Kosmos 613
  - Soyuz kept powered down for 60 days; returned to Earth to study deterioration
  - Concluded that a new ship is needed every 90 days
- December 1973: Soyuz 13 tested the Orion telescope

- June 1974: Salyut 3 (Military)
  - Operated by the crew of Soyuz 14 for 15 days (water reclamation; relay satellites)
  - Soyuz 15 failed to dock
  - Tested cannon on empty station
  - Deorbited January 1975



A model of the Salyut 3 Almaz showing the bulky reconnaissance camera and a cosmonaut at the control panel in the 'wall' that divides the two compartments. Courtesy of Dietrich Haeseler.

Salyut 4 Civilian Station

- Launched December 1974 (after Skylab ended)
- New automated attitude and altitude control systems
- Altitude of around 220 vs. prior 150 miles

Salyut 4
Salyut 4 space station at RKK Energia Museum
Credit: © Mark Wade

Propellant control system panel

Salyut 4 Civilian Station

- January 1975: Soyuz 17, two cosmonauts stayed for 17 days
- Teleprinter saved cosmonaut time
- Added stationary bike to treadmill for daily exercise
- One day off each week

Main control panel

Salyut 4 Civilian Station

- April 1975: Soyuz 18a had a launch abort
- May 1975: Soyuz 18, two cosmonauts stayed for 62 days
- First time a Russian station was revisited
- Earth observations found new oil field, used to plan Eastern Siberian railway and hydroelectric projects
- 50 kg of materials, film, and logbooks stowed for return on July 26, 1975
- November 1975: Soyuz 20 docked unmanned for 3 months, with biological experiments, later recovered
- Deorbit February 1976

Salyut 5 Almaz Military Station

- June 1976
- Military stations switched to frequency-shift-keyed pulse-duration modulation on frequencies used by spy satellites
- July 6: Soyuz 21 had 2 cosmonauts and did military experiments for 49 days until a fire broke out and they returned early
- Salyut 23 could not dock
- Feb. 1977: Two Soyuz 24 cosmonauts visited the station
- Returned after only 17 days
- Soyuz 25 cancelled due to the low station propellent
- Salyut 5 deorbited August 1977

Salyut 6 Civilian Station

- Launched September 1977
- Added second docking port and ability to replenish fuel and air
- Automatic docking incl. first Progress supply ships
- 20 portholes, two scientific airlocks, two spacesuits
- All scientific equipment new and improved
- Comfort
  - Extensive soundproofing of equipment
  - Shower
  - 7-day food rotation
  - Books, cassettes tapes, chess set

Salyut 6 Civilian Station

- Oct. 1977: First crew could not dock
- Dec. 1977: Soyuz 26 crew did EVA to check docking system, then docked
- Instead of coordinating activities with com passes, they switched to Moscow time to avoid disrupting circadian rhythms
- Six long-term non-overlapping crews and ten visiting crews; up to 185 days
- First ever docking with a crewed station (bread and salt)
- Visitors included those from Czechoslovakia, Hungary, Poland, Romania, Cuba, Mongolia, Vietnam, East Germany and Bulgaria
- Refueling problem suggest N_2 bladder leak, contaminating fuel
- Soyuz 32 repaired fuel system (emptied and isolated one tank)
- June 1979: Progress delivered 770 lb radio telescope
- 1764 days in orbit, 683 days occupied
- Last crew to May 1981, deorbited July 1982

Salyut 7 Civilian Station

- This backup to Salyut 6 was launched April 1982 because of delays in Mir
- Five non-overlapping resident crews and one first-ever crew handover
- Four visiting crews
- Food packaged individually; added refrigerator
- Improved lighting
- 15 Progress supply ships
- Modified Progress ship with two ports, docked for long periods; an early test of modular design
- Designed for 4 years with crew handovers
- 3215 days (8.8 yrs) in orbit, 816 days occupied, 13 EVAs

Salyut 7 Civilian Station

- First crew of two arrived May 1982
- Svetlana Savitskaya (+2) visited in August 1982
- Rockcress flowered and produced seeds (first in space)
- First manned vehicle to launch a satellite
- In September automatic attitude system malfunctioned
  - Re-entered program as 325 6-digit instructions; and again in Oct.
- Seized bearing in water reclamation system
- Temperature regulation system was letting it get too cold
- First crew left after record-breaking 211 days when attitude control failed completely (without time to increase exercise)

Salyut 7 Civilian Station

- Soyuz T-8 failed to dock because an antenna was torn off by the shroud
- Soyuz T-9 brought the second crew (just 2) in June 1983
- Replaced the attitude control computer
- In early September Progress was refueling Salyut-7 when a pipe burst
  - Disabled attitude control thrusters
  - Continued propellant leak not reported publicly
- Late September handover crew launch had a pad abort
- Another Progress was used for attitude control
- More solar panels installed on 2 EVAs; designed for three crew members
- Second crew returned to Earth in November (5 months)

Salyut 7 Civilian Station

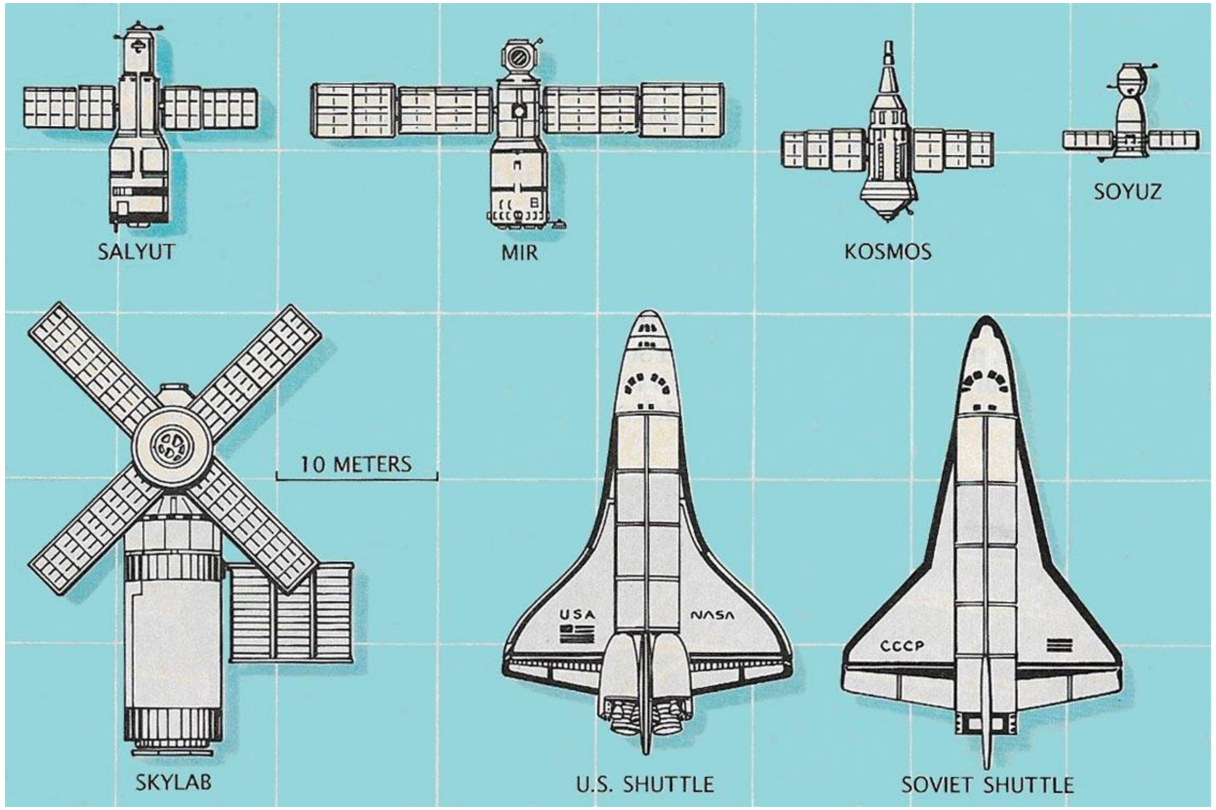
- February 1984: T-10 brought third crew with new tools designed to fix the propellant leak and stayed until October (8 months)
- Earth observation included estimating Ukrainian wheat harvest
- July 1984 Soyuz T-12 launched three visitors to the higher orbit with new more powerful engines: Dzhanibekov, Savitskaya, and Volk

- Savitskaya and Dzhanibekov performed an EVA to test electron beam cutting and welding

Salyut 7 Civilian Station

- Crew EO4-1: Two arrive June 1985 to a dead station crippled by an electrical problem
- Working one at a time in winter garb for two days, they found a bad battery sensor and reactivated the station
- EVAs replaced some solar panels and remove some for return to Earth
- EO4-2 crew of 3 arrives September 1985 (first crew handover)
- One from EO4-1 leaves and two from EO4-2 stay
- Crew 4 returns November 1985 leaving the station in hibernation
- Final visit in week 3!

Summary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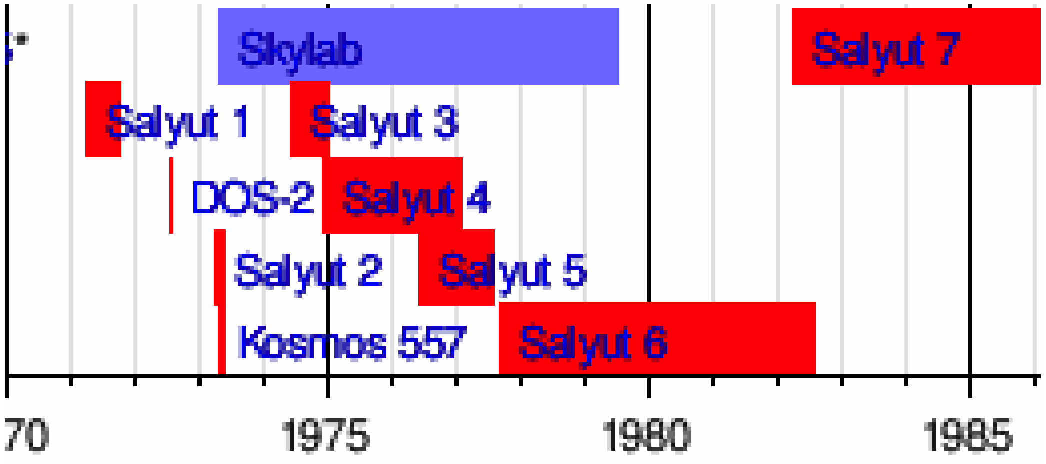
Skylab
Salyut 7
Salyut 1
Salyut 3
DOS-2
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Salyut 2
Salyut 5
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70
1975
1980
1985

Comments and Questions?

Skylab: Atmosphere

- Skylab was designed to operate at 0.3 atmospheres (5 psi) with 70% O_2
  - Knowledge of materials that could stand up to high stress for long periods was limited
  - Needed less strong and heavy walls
  - Smaller gas tanks needed
  - Reduced the risk of depressurization accidents
  - Equipment needs to be tested at reduced pressure
  - May cause uneasiness, reduced work capacity, and lethargy
- Salut's, Mir, ISS, and Tiangong's all work(ed) at 1 atmosphere

Skylab 4 (third crew)

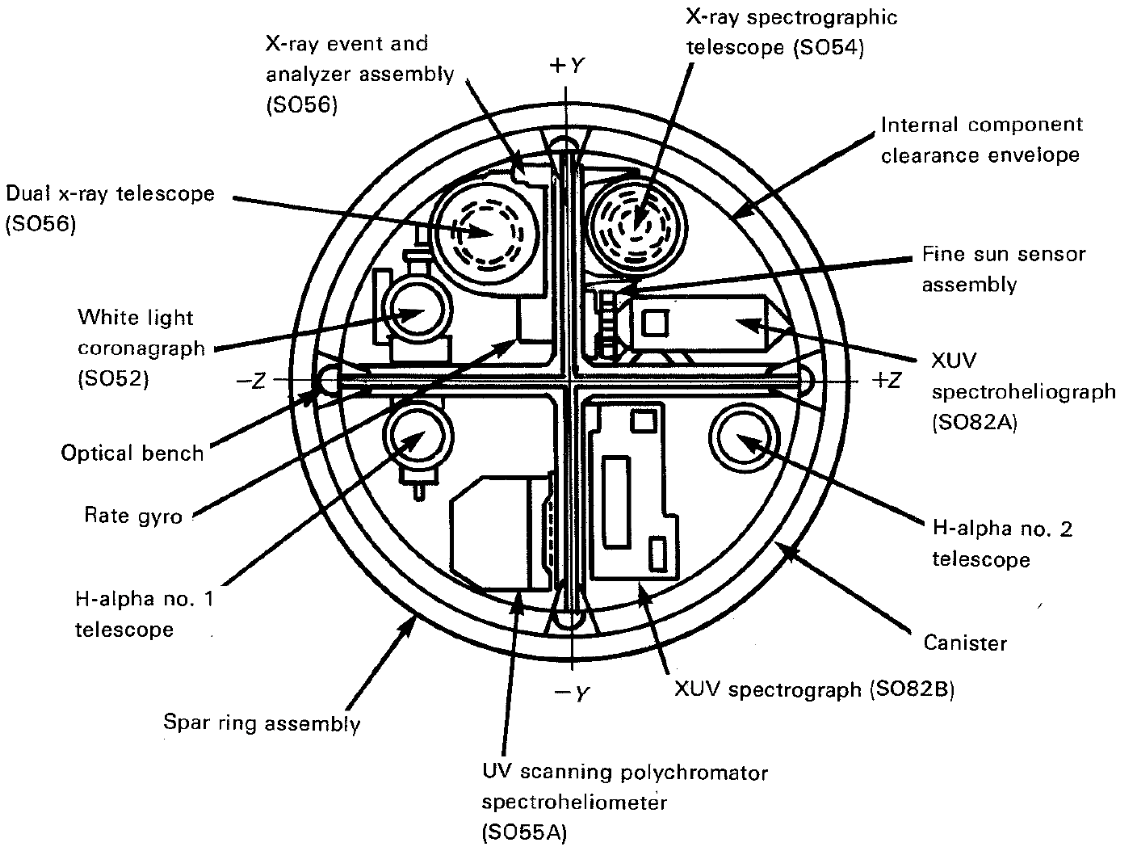
- All rookie crew: Gerald Carr (commander), Bill Pogue (pilot), Ed Gibson (Science Pilot)
- Skylab 3 crew had left 3 stuffed suits on treadmill, Lower Body Negative Pressure Device, and toilet

Skylab Patches

Skylab Science: ATM

- 10 instruments, 2000 watts, astronauts to change film
- Compare to Orbital Solar Observatories at 20 watts, but as opposed to 8 OSO over many years
- Riccardo Giacconi shared the 2002 Nobel Prize in Physics for his study of X-ray astronomy, including the study of emissions from the Sun, contributing to the birth of X-ray astronomy

Cross section through the telescope mount canister, showing the cruciform spar and instruments.



Skylab Science: Earth Resources

- Mix of film and magnetic tape
- Photometer in near infrared to visible in 6 channels (square 59 miles on a side)
- Infrared spectrometer in 2 channels (0.25 miles on a side)
- Multispectral scanner (thermal and near infrared and visible in 13 bands) to detect agriculture, forest, hydrology, geology (260 ft resolution)
- Microwave radiometer/spectrometer/altimeter (digital)
  - Coordinated aircraft flights to compare data
  - Duplicate data every 5 days
  - 15-25 minute passes (3500-6000 miles)
  - Plus military uses

More Skylab Science

- Astrophysics: 3 experiments for outer atmosphere and interplanetary medium and 6 for beyond the solar system, e.g., characterize the nuclei in cosmic rays
- Comet Kohoutek
- Materials science/space manufacturing: metals melting, welding, sphere forming, zero gravity flammability, etc.
- Habitability: privacy, clothing, food, exercise, inventory control, restraints, lighting, etc.
- Student experiments and science demonstrations
- Life sciences: effects on humans, other organisms

Salyut 4 Civilian Station

- Cryogenic infrared spectrometer measured water and temperature in different layers of the atmosphere
- Oxygen measurements contributed to the understanding of short-term variability in the upper atmosphere
- X-ray telescope/spectrometer had first measurements of x-rays
- Nuclear-isotope spectrometer initiated the study of isotopic and chemical composition of cosmic rays
- Density, composition and temperature of the neutral gas and plasma encountered by the station in its orbit led to improvement in coms
- 50 kg of materials, film, and logbooks carefully stowed for return on July 26, 1975
- November 1975: Soyuz 20 docked unmanned for 3 months, with biological experiments, later recovered
- Deorbit February 1976

Science vs. Technology

- 1970: "…the Space Science Review Board asked NASA for assurance that each Skylab crew would include a pilot commander and two scientist-astronauts…. [But] … there would be a considerable amount of technical and engineering duties that would need to be accomplished to keep the station running. The Skylab crew training programme at Houston was initially oriented towards system management and malfunction procedures, mainly because the scientific hardware was not ready, but also because this is what needed to be learned first." -- *Skylab America's Space Station* by David J Shayler p. 122-123
- Slayton had openly stated that to him it was far easier to teach pilots to pick up rocks on the Moon than to teach scientists how to fly jets

Space station Earth daylight passes over the seasons

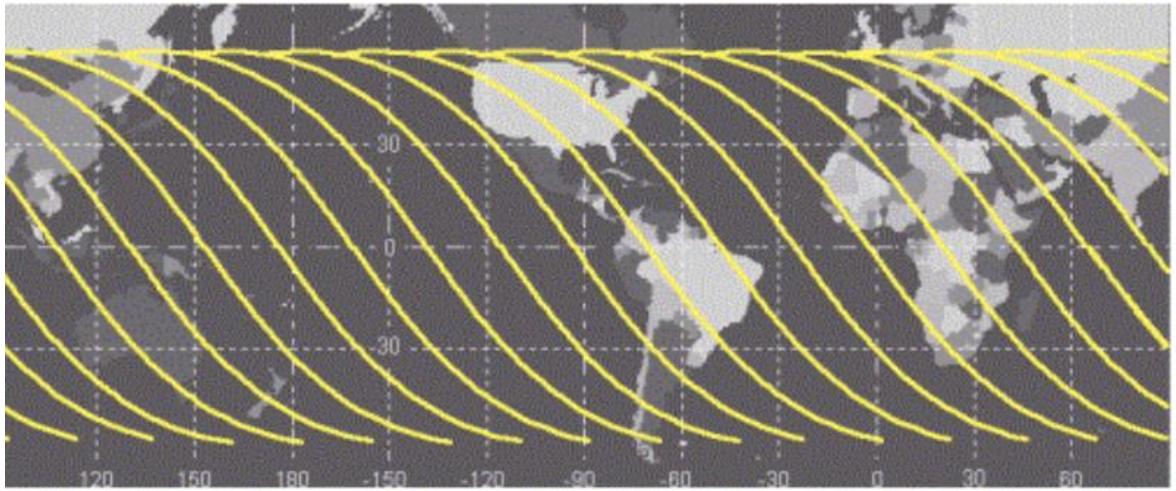


Figure 5. The cycle of daylight procession, from top to bottom: A) 1 day of orbits with daylight on descending pass.

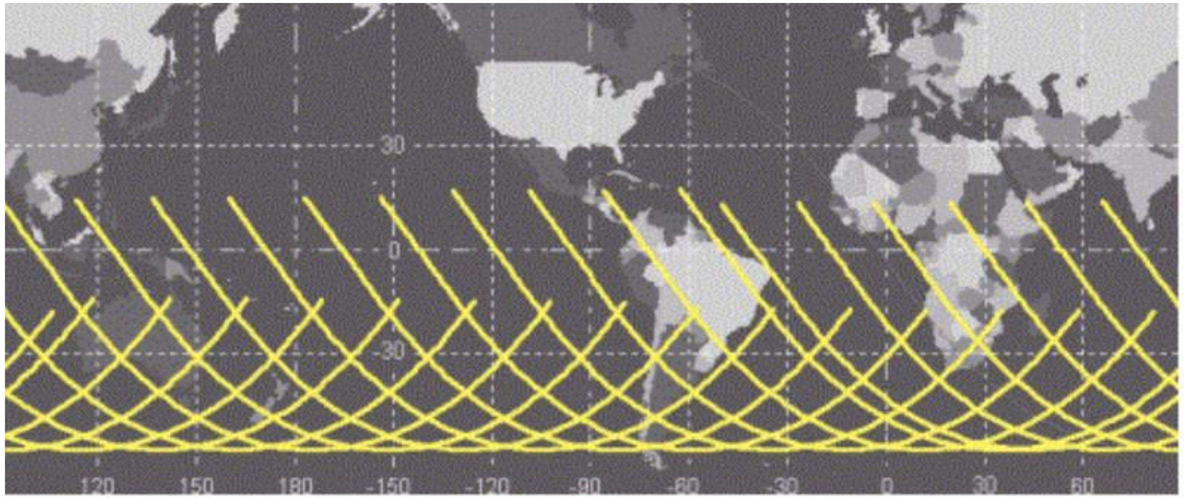
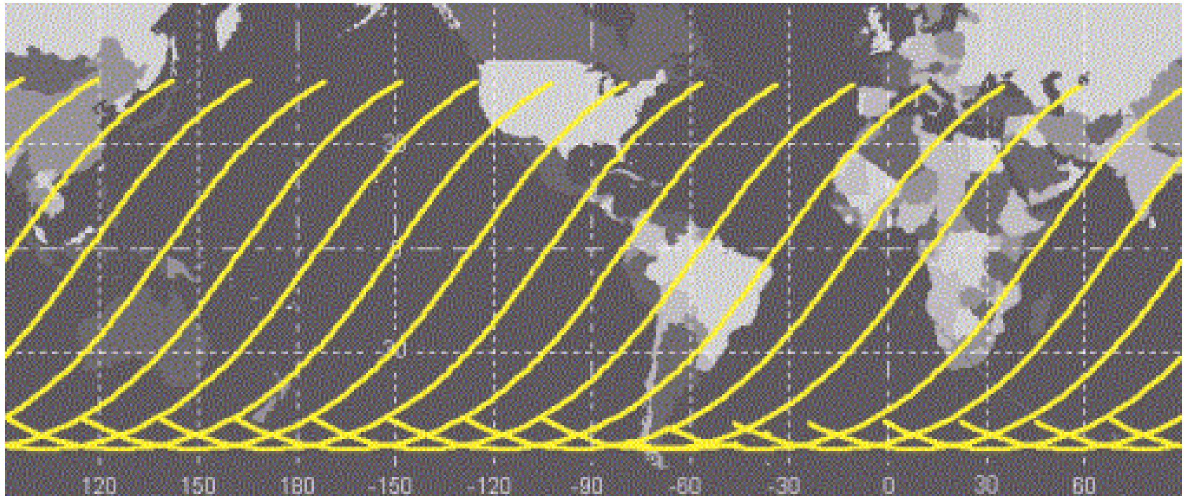


Figure 6. B) 1 day of orbits with daylight in S. Hemisphere.



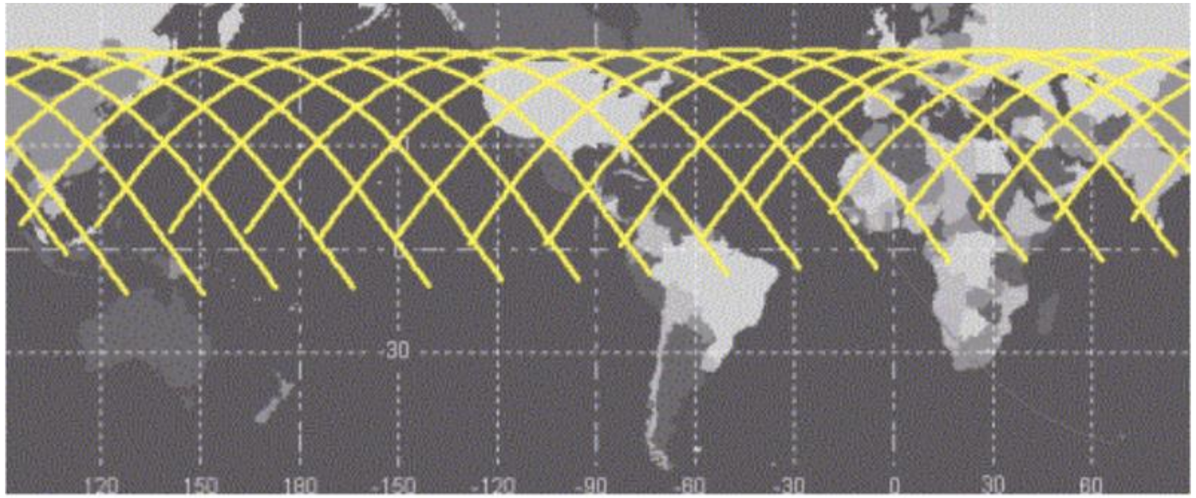
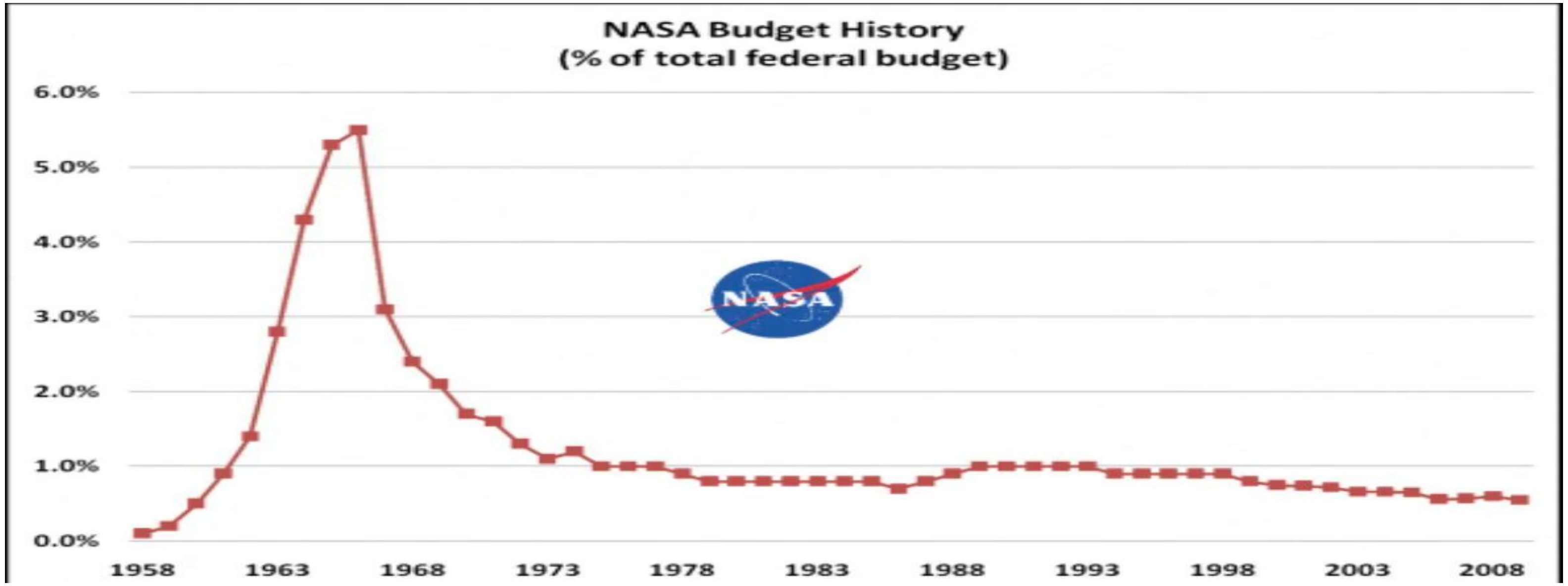


Figure 8. D) 1 day of orbits with daylight in N. Hemisphere.

NASA Budget Over Time



Skylab: Human factors

- Raymond Loewy (1893 –1986) was a French-born American industrial designer
  - Shell, Exxon, TWA and BP logos
  - Greyhound Scenicruiser bus interior
  - Coca-Cola vending machines redesign
  - Studebaker Avanti

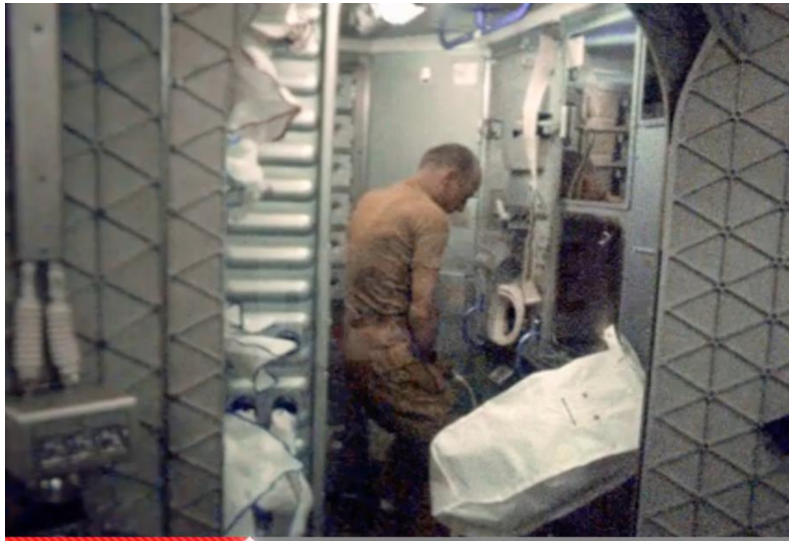
- “Habitability Consultant” at NASA from 1967 to 1973 for design of Skylab
- Suggested
  - wardroom where the crew could eat and work together with a window
  - the color design
  - three different sleeping compartments to create a sense of individual identity
  - crew quarters with storage lockers, privacy partitions, lighting, a light baffle, privacy curtains, mirrors, towel holders and a communication box
  - dining table designed to avoid creating hierarchical positions for crew members

Skylab: Food and Drink

- Astronauts negotiated once weekly glass of wine, but some southerners complained to NASA and Congress, and it was dropped
- Food
  - More than 70 assorted foods
  - In pop-top aluminum cans or plastic pouches
  - Mostly dehydrated, heated for one hour
  - Freezer for meat and ice cream
  - No refrigerator
  - Beverages made by adding hot or cold water to powdered mixes
    - Sipped from squeezable plastic containers with straws
- Daily report of food intake analyzed
  - make-up mineral pills specified for the next morning

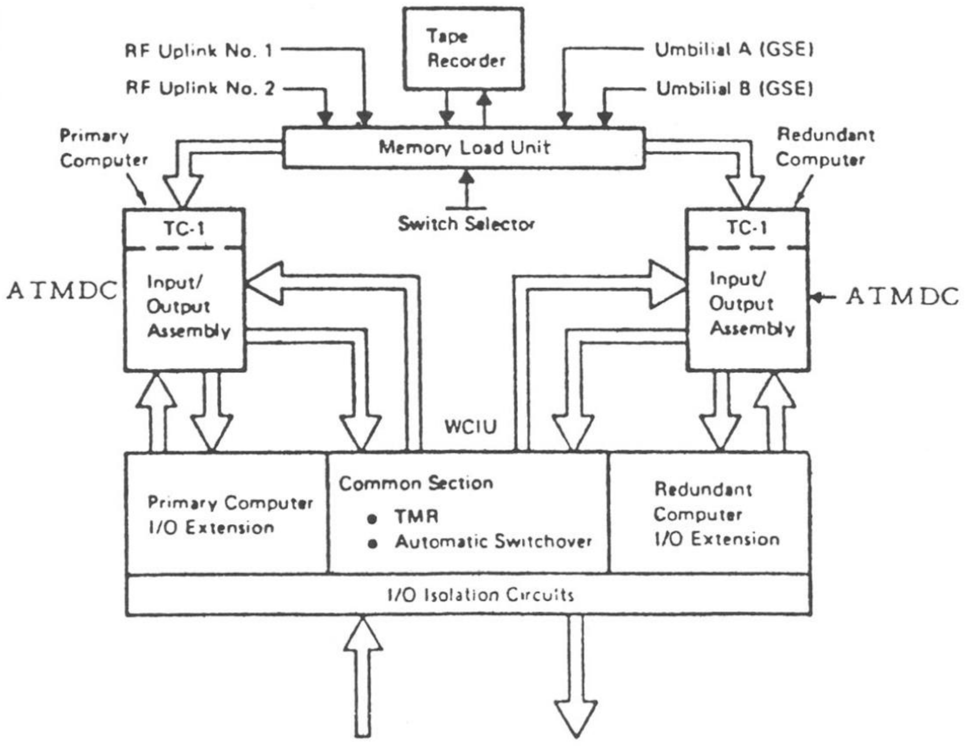
Skylab: Excrement

- “Toilet” designed to collect urine and feces to study calcium metabolism
- Toilet was a hole in the wall with a fan



Skylab: Computer

- Dual IBM System/4Pi computers built in Owego, NY and programmed in Huntsville, AL
- 100 pounds each, 19 by 7.3 by 31.8 inches, 16K memory
- Capable of handling more than 100 input signals
- Skylab Attitude and Pointing Control System (APCS) consisted of an interface unit, magnetic tape, control moment gyros, the thruster attitude control system, sun sensors, a star tracker, and nine rate gyros
- Ideas used in space shuttle



"A block diagram of the Skylab Computer System with the dual ATMDCs, tape memory, and common section shown. (From IBM, Skylab Operation Assessment, ATMDC, 1974)" Image Credit: *Computers in Spaceflight: The NASA Experience*, 1987 (accessed via NASA History's website)

Salyut 7 Civilian Station

- Major repair [Curious Droid 4:30]

https://www.youtube.com/watch?v=8EPbJRsN1Zk