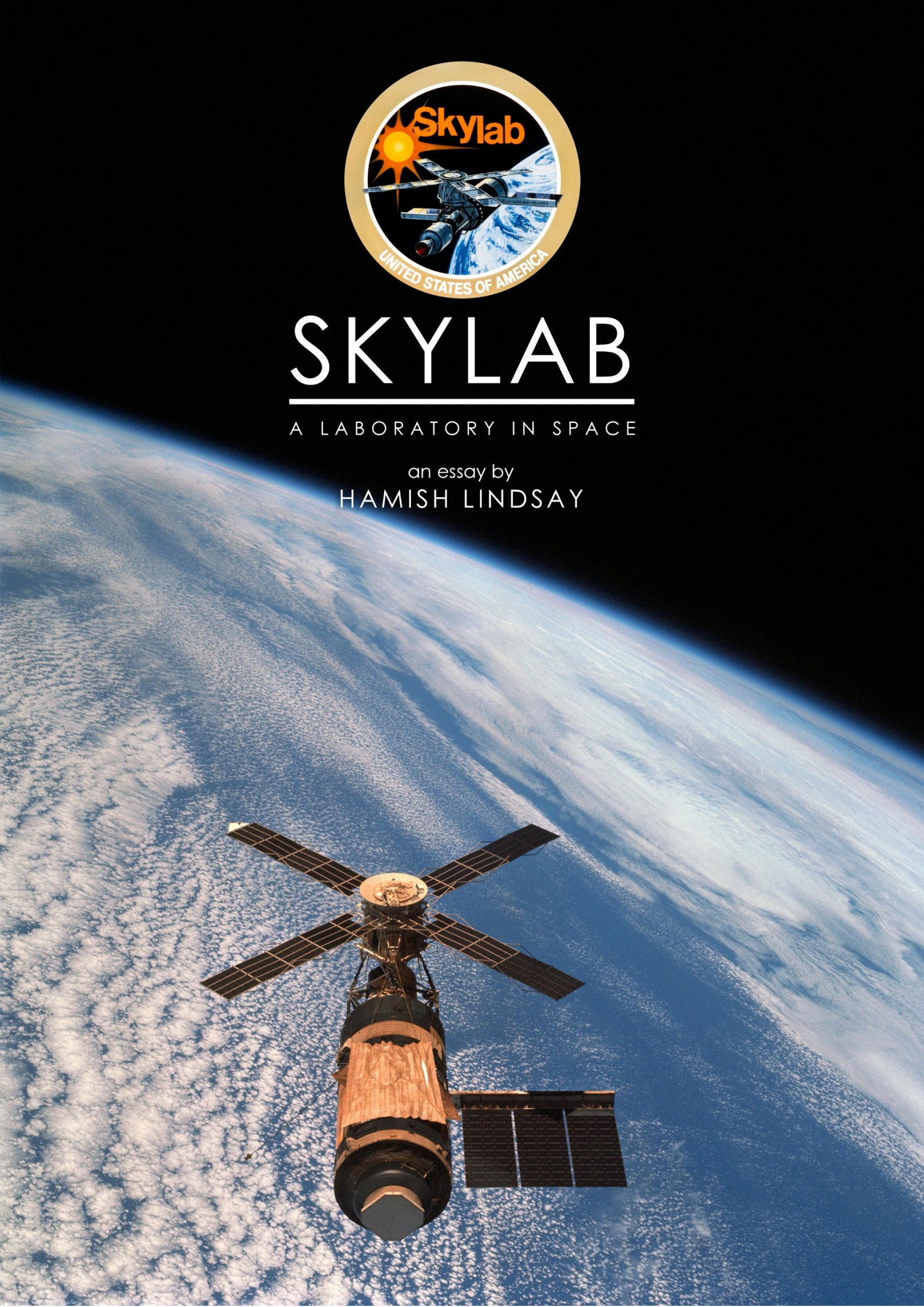

SKYLAB

A LABORATORY IN SPACE

an essay by

HAMISH LINDSAY

"The legacy of the Skylab Program,
to be passed on to planners and operators
of future manned space programs,
is best stated in two words: 'Can do!'."

Rocco A. Petrone, Associate Administrator of NASA

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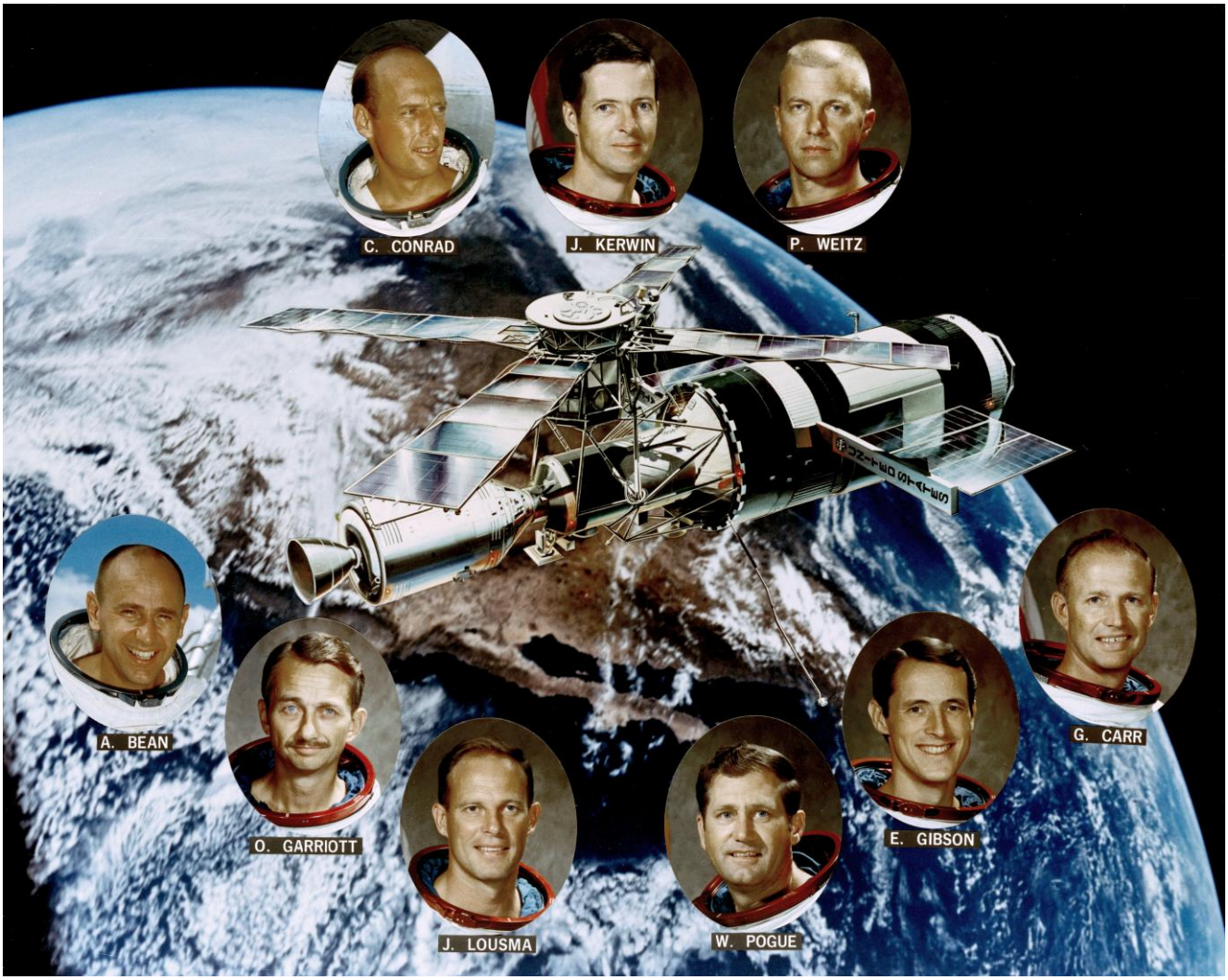
Extracted from content available on the
Honeysuckle Creek Tracking Station
website, developed by Colin Mackellar

www.honeysucklecreek.net

THE SKYLAB CREWS



The astronauts of Skylab crewed missions I, II and III. Image: NASA/JSC

EDITORIAL NOTES

This description of the Skylab was written by Hamish Lindsay and includes tables listing key mission statistics, activities and times.

Times used in this essay reflect measures such as: Ground or Mission Elapsed Time (GET/MET), Coordinated Universal Time (UTC), Greenwich Mean Time (GMT), Australian Eastern Standard or Daylight Time (AEST/AEDT), US Eastern Standard or Daylight Time (US EST/EDT), or other time zones as appropriate.

Indented and italicised text are excerpts from interviews by Hamish Lindsay with astronauts and NASA personnel, air-to-ground conversations, or other relevant commentary and quotes.

The honeysucklecreek.net website is regularly updated with new content, which also includes additions to the subject matter of this essay.

- ONLINE CONTENT - AUDIO – VIDEO – WEBSITE

This essay contains additional content which includes audio, video and website material, available via the internet. Click the icons or scan the QR code using your phone or tablet.

An internet connection is required.

LISTEN WATCH WEBSITE	Click these icons for a direct link to the online audio and video files, website or webpage content.
	Scan the QR icon with your phone or tablet for audio or video files, website or webpage content.

Skylab I Fact Box

Launch
Launch Complex – 39A, Cape Kennedy
Monday, 14 May 1973
1330:00 US EDT / 1730:00 UTC
[Tuesday, 15 May 1973, 0330:00 AEST]

Launch vehicle
Saturn V – AS-513

Skylab statistics
Mass – 76,540 kilograms
Width – 17.0 metres (with one solar panel)
Height – 11.1 metres (with telescope mount)
Diameter – 6.61 metres
Pressurised volume – 351.6 metres^3

Major components
Apollo telescope mount
Payload shroud
Multiple docking adapter
Airlock module
Saturn V instrument unit

Mission duration
Total time - 2,249 days (~6.16 years)
Total occupied – 171 days

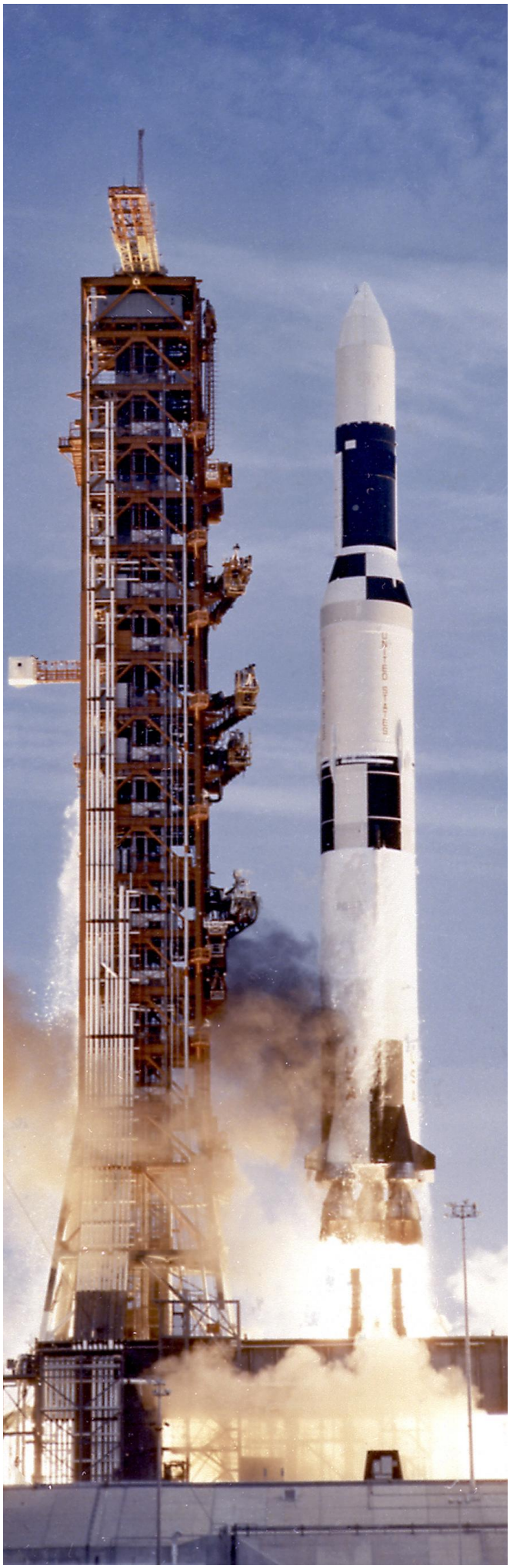
Earth orbital data
Perigee – 434.0 kilometres
Apogee – 441.9 kilometres
Orbital period – 93.4 minutes
Orbits per day – 15.4
Inclination – 50^o
Total orbits – 34,981
Distance travelled – ~1,432,316,160 kilometres

Visiting missions
Skylab II – 26 May – 22 June 1973
Time docked – 26 days 17 hours 02 minutes
EVAs – 3

Skylab III – 28 July – 25 September 1973
Time docked – 58 days 15 hrs 39 mins 42 secs
EVAs – 3

Skylab IV – 16 Nov. 1973 – 8 Feb. 1974
Time docked – 83 days 4 hrs 38 mins 12 secs
EVAs - 4

Re-entry
Skylab – 11 July 1979 – 16:37 UTC
– 12 July 1979 – 02:37 AEST
– 12 July 1979 – 00:37 WAST
Impact location – Western Australia, near Esperance and Rawlinna



Skylab – the United States of America's first orbiting space station. Image: NASA

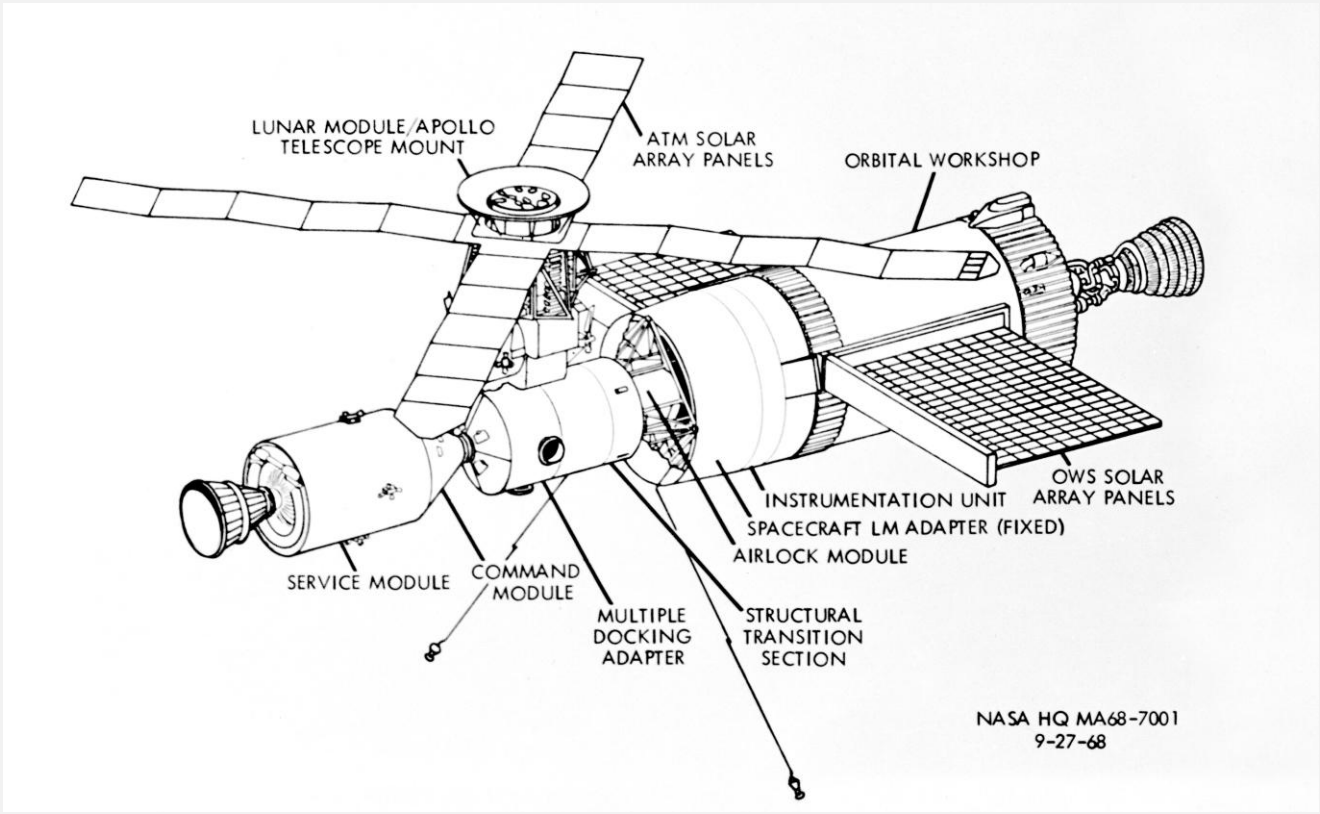
Skylab

A Laboratory in Space

Skylab, America's first laboratory in space, was conceived with a felt pen wielded by Dr. George Mueller on a handy scrap of paper on 19 August 1966 at the Marshall Space Flight Center, near Huntsville, Alabama, and ended as charred, twisted chunks of metal and plastic in the deserts of Western Australia 13 years later.

The concept of converting a rocket casing to a spacelab was thought of by Werner von Braun back in the early 1940s, and he proposed the idea again in 1959, with plans for a project called Horizons to place man on the moon. Although concentrating on the moon missions, von Braun also detailed an orbiting laboratory to be built out of a Horizon upper stage. Dr. George Mueller, NASA's Associate Administrator for Manned Space Flight took hold of the idea of using one of the left over Saturn SIVB rocket bodies and sketched out the concept.

On 10 December 1963 the US Air Force announced the development of the Manned Orbiting Laboratory (MOL), a small space station primarily intended for photo reconnaissance



Components of the proposed 'Wet Design' which included a booster engine. Diagram: NASA HQ 1968

using large telescopes operated by a two–man crew. The station was to consist of an Agena upper stage with equipment installed in its former fuel tanks. The stations were to be launched unmanned, the crew following in a Gemini spacecraft modified with a hatch cut into the heat shield of the capsule. There was only one test flight of a mock–up on 3 November 1966 using a Titan II propellent tank before the whole project was cancelled in June 1969.

Actually, Skylab grew out of a number of projects and proposals, perhaps traceable back to the Orbiting Solar Observatory (OSO) first launched in 1962. Following a recommendation from the 1962 Iowa Summer Study conducted by the Space Science Board, NASA began to develop an Advanced Orbiting Solar Observatory (AOSO) but the whole project was dropped due to lack of funds. The experiments from AOSO were resurrected for later proposals such as the Apollo Extension System (AES) and the Apollo Applications Program (AAP) which planned to use the hardware left over from the Moon landing program. Then, following various ideas which included using a Lunar Module as a control centre and base for the telescope, the Marshall Space Flight Center took the telescope, now called the Apollo Telescope Mount and designed an orbital workshop using the Saturn IVB hydrogen tank. With every possible aid for living and working in orbit, they called it the Saturn Workshop (SWS). This became Skylab.

At first there were two competing concepts for a space station.

The first, called the "Wet Concept," called for launching a Saturn 1B, venting the S-IVB upper stage and refurbishing it, and converting it to a space station while in orbit.

The second, or "Dry Concept," called for outfitting the S-IVB while still on the ground and launching it atop a Saturn V. While the Apollo 11 astronauts were actually on the Moon in July 1969, the decision was made to go with the "Dry Concept".

Skylab was designed as a long duration mission, with two objectives: To prove that humans could live and work in space for extended periods, and to expand our knowledge of solar astronomy well beyond Earth–based observations.

In 1967 the world renowned French industrial designer Raymond Loewy was approached by NASA to present a laboratory habitability study for Skylab. He formed a team of six young

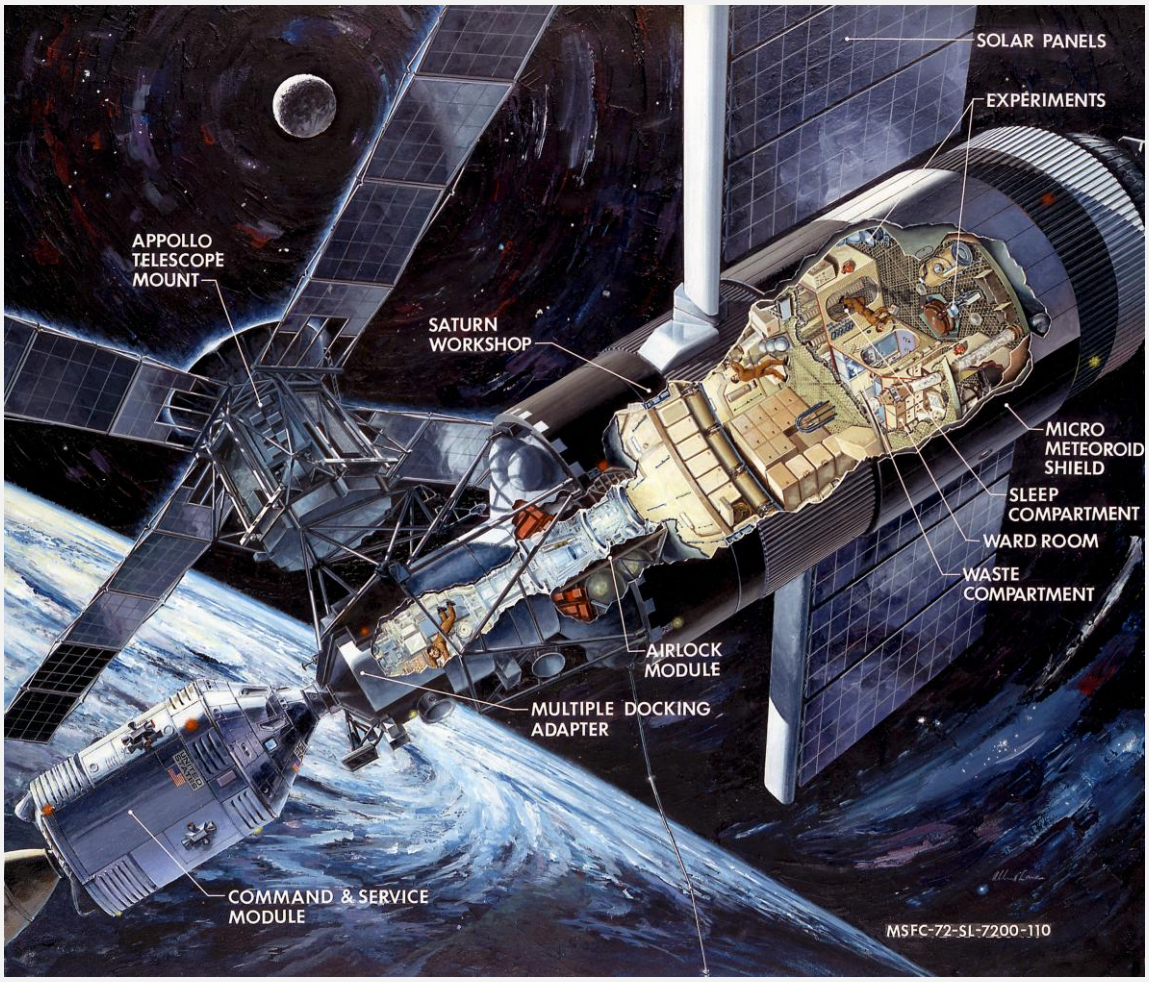


Illustration of Skylab's "ideal" configuration. Cutaway section provides some scale. Image: NASA/MSFC

industrial designers and, though little was known of living under weightless conditions in space, they produced the living concepts of Skylab over a period of six years. They specified four psychological recommendations:

1. That a porthole for the astronauts to view the Earth and stars was essential.
2. That each astronaut be allowed 8 hours of solitude daily.
3. That the astronauts were secured for meals facing each other as they would on Earth.
4. All partitions should be smooth and flush to make them easy to keep clean in the event of uncontrollable space sickness.

Skylab weighed about 100 tons, with a volume of 283 cubic metres and was separated into two "floors." The "upper" floor contained storage lockers and a large empty space for conducting experiments, and two airlocks, one pointed "down" toward the earth and the other "up" toward the sun. The "lower" floor was divided into rooms including a dining room with a table, three bedrooms, a work area, a bathroom and a shower. The station was also equipped with an airlock module for the many spacewalks that were required.

Skylab was made up of the Saturn Workshop (SWS), 15 metres long with a diameter of 6.7 metres, connected with an Airlock Module (AM) to a Multiple Docking Adapter (MDA) 5.2 metres long by 3.2 metres in diameter. The MDA had two ports (one for rescue) to dock the visiting Command Module and allow the astronauts access and contained the control and display panels for the Apollo Telescope Mount (ATM).

When Skylab was first planned, the scientists were not interested in looking at the Earth from space, they could do better measurements on the Earth itself, so they had planned to concentrate mainly on the sun and stars. But after the Apollo lunar missions drew the world's attention to our fragile looking planet floating in isolation in the vast blackness of space, and with interest in

‘Upper’ level with a focus on storage and science areas.

An artist's concept illustrating a cutaway view of the Skylab 1 Orbital Workshop (OWS). The OWS is one of the five major components of the Skylab 1 space station cluster which was launched by a Saturn V on 14 May 1973 into Earth orbit. Graphic: NASA

‘Lower’ level with a focus on living areas.

An artist's concept illustrating a cutaway view of the Skylab 1 Orbital Workshop (OWS). The OWS is one of the five major components of the Skylab 1 space station cluster which was launched by a Saturn V on 14 May 1973 into Earth orbit. Graphic: NASA

Honeysuckle Creek Tracking Station in its Skylab configuration. Image: Hamish Lindsay

ecology and resources gaining momentum, the Skylab Program was drawn into studying the Earth as well. With the longest spell in space two weeks by Gemini VII, and a Soviet flight of 18 days, still not enough was known about the effects of long periods of weightlessness on the human body, so two missions were planned to last at least 56 days.

Skylab extended the life of the Manned Space Flight Network after Apollo 17. Mission Control at Houston and the tracking stations had to make significant changes to adapt to Skylab, including adopting a full 24 hour shift system for the operational staff. The tracking stations increased in size again, installing a VHF/UHF system with vans and antenna towers, and Honeysuckle Creek recruited more staff under a special 12 month contract.

Bill Kempees, Chief Engineer at Honeysuckle Creek: *"We were required to man around the clock, so we had to recruit a considerable number of staff. I remember we had 600 applications for 35 positions – mostly young people. We ended up with 135 people on the staff for Skylab."*

John Saxon, Honeysuckle Operations Supervisor:

"Because of the contract conditions the new Skylab starters were earning more money than the ex-Apollo people one would imagine this would be a recipe for dissent and antagonism, but the combination worked very well, probably due to the intense nature of the work, and because of the long missions, as well as pride in working with teams of up to 25 people. Automation of the equipment, or even remote control, was non-existent, so each person on the team was responsible for his own set of racks or consoles.

Honeysuckle became a twenty–four hour a day, seven day a week station, which marked the difference between Skylab and Apollo, and we were very efficient at operations at times the back end of the station was doing something totally different to the front end. While we were doing tape playbacks between Skylab passes of the data, voice and television back to Houston, the front end that is the antenna and receivers were tracking deep space probes and sending the data over to Tidbinbilla. We have never done anything like that since.

We never really got on top of Apollo, because every mission was different, but with Skylab, by the time we had done 4,000 orbits we were getting smooth as silk everything just clicked into place we became a well-oiled machine.

A group of Skylab passes could last for 12 to 14 hours in each 24, but the passes themselves varied between a minute or so to 15 minutes long. They could be pretty hectic with VHF, UHF, and USB dumps. These dumps were information recorded by a tape recorder at normal slow speed, and 'dumped' down to the station at high speed. With lots of experiments happening simultaneously, it was often a race against time to send all the accumulated data down during the period Skylab was in view of the ground station."

With the possibility of up to five Skylab manned missions, Deke Slayton had to choose fifteen prime crew astronauts from a pool of twenty. He had to resist a push to have only one pilot and two scientists on each mission, as he felt there should be at least two experienced pilots in the first crews for troubleshooting flight problems that were bound to come up. He chose Pete Conrad to Command the first visit, and Paul Weitz from the Apollo Applications Program as pilot. Everybody wanted the first science–pilot to be a physician and Slayton felt Joe Kerwin, a medical doctor, was the best candidate. He was later appointed as the NASA Senior Scientific Representative in Australia, based in Canberra.

SKYLAB I - LAUNCH

SL1 (Skylab 1) - Saturn V (SA513)

EVENT	U.S.A.	AUSTRALIA
Launch – LC 39A	13:30:00 EDT 14 May 1973	03:30:00 AEST 15 May 1973
STATISTICS		
Apogee	431.4 kilometres	
Perigee	433.7 kilometres	
Orbital Period	93 minutes	
Inclination	50°	
Weight (Skylab)	76,540 kilograms	

Skylab 1 was the last Saturn V launched. With the regular successes of the Apollo launches, it was expected to be another copybook mission. It was until just after launch. On a nice warm spring day, at 1330:00 USEDT 14 May 1973 (0330 AEST 15 May) the Saturn V first stage thundered into life on Pad 39A at the Kennedy Space Center and lifted smoothly into the air.

It looked another perfect launch … then 63 seconds later the flight engineers were startled to see their telemetry giving strange indications from the micrometeoroid shield and part of the solar array – it looked as though they had initiated deployment early. Atmospheric drag had torn the shield loose and a portion had jammed one of the workshop solar wings and severely damaged the other solar wing. The staging rocket's blast then tore the wing from its hinges and flung it into space to be lost.

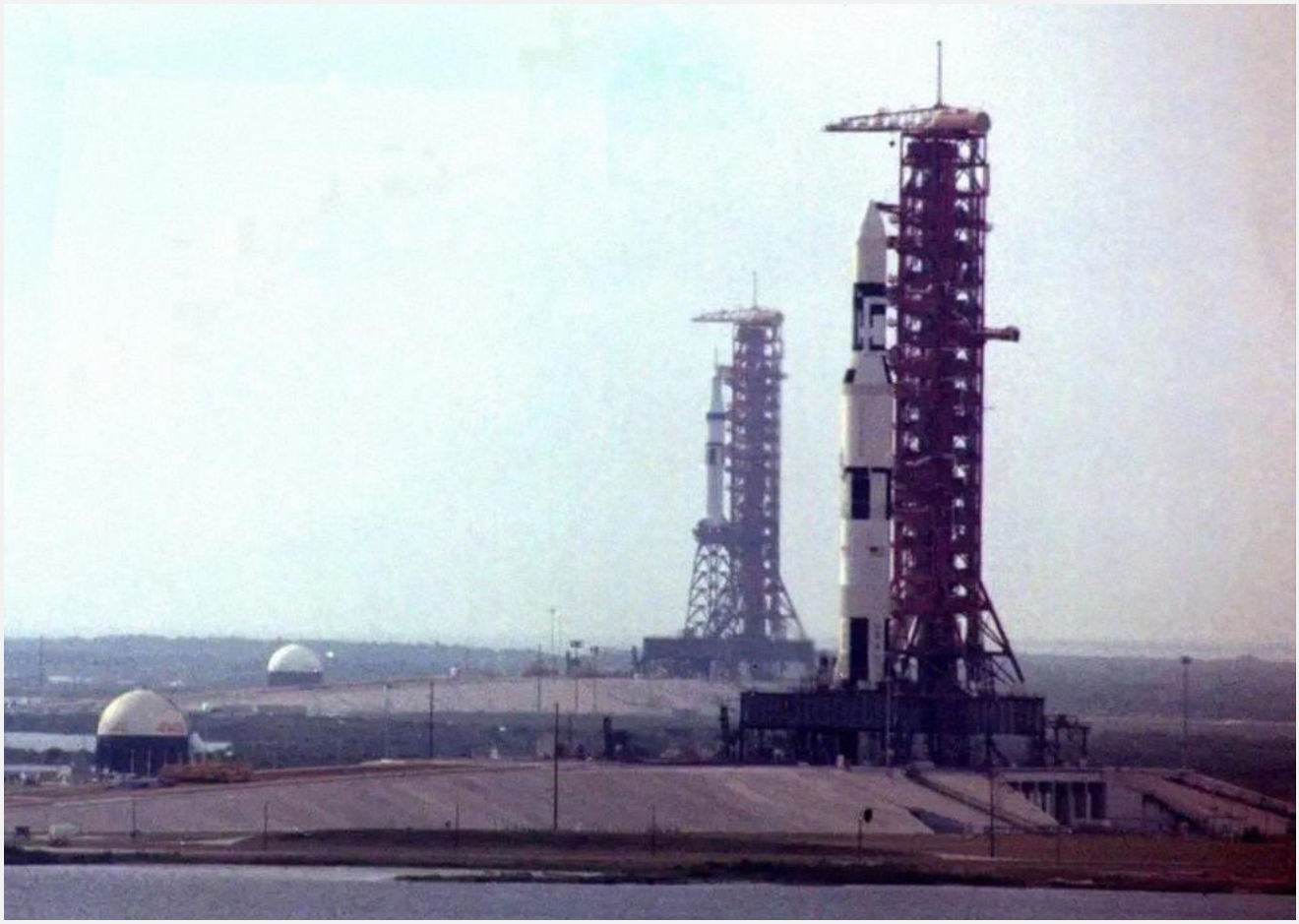
Just over ten minutes after launch Skylab entered a nearly circular orbit above the Earth and manoeuvred around until its centreline pointed to the centre of the Earth.

Unlike Apollo, which spun on its axis on its way to the moon to keep the temperatures evenly spread around, Skylab remained in one attitude throughout the orbit, the heat and cold being controlled by a micrometeoroid shield using black, white and aluminium paints painted in a carefully tailored pattern to control heat losses and gains.

This shield was lost, so the surface of the workshop was left exposed to the sun, and the temperatures rose 93°C above the designed limits.

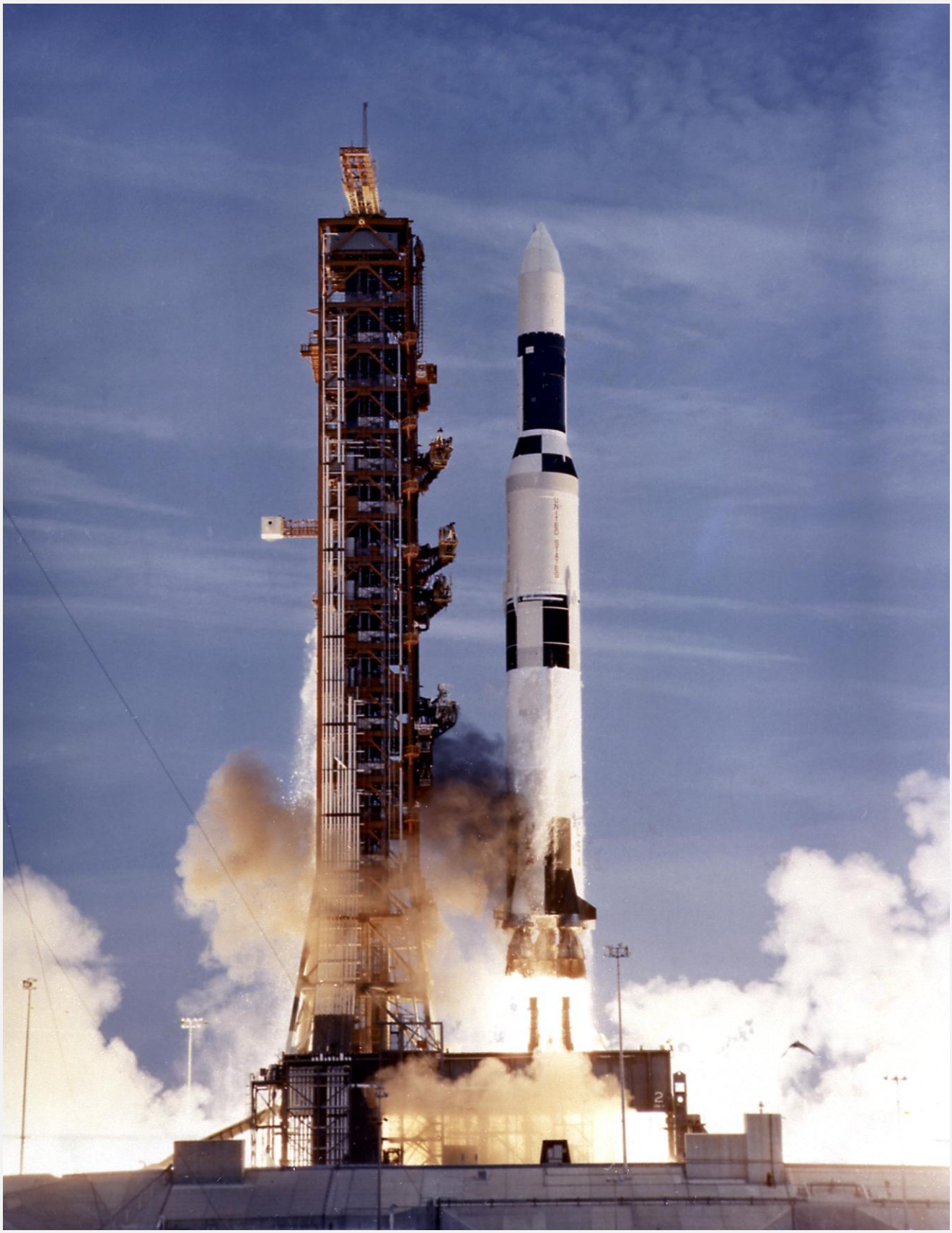
It is interesting that Skylab became overheated out in space – because Apollo 13 became unbearably cold when in trouble. Why the difference? First it should be understood that a passive body in space absorbs and radiates heat. If these are not equal the body will heat up or cool down to a stable temperature where the heat being received equals the heat loss, providing the conditions remain constant. Although there are other factors, the simplistic explanation is Skylab lost its temperature controlling thermal heat shield which was carefully designed to balance the heat absorption and losses in its planned

Above: Double exposure image showing the Saturn V and Saturn 1B launch vehicles.
Images: NASA/KSC
Below: Launch Complexes 39A (foreground) and 39B (background) with vehicles on the pads.



A ground-level view of Launch Complex 39A at the Kennedy Space Center, Florida.

The 104 metre tall Skylab 1/Saturn V space vehicle on the pad soon after being rolled out from the Vehicle Assembly Building (VAB). The vehicle is composed of the Saturn V first (S-1C) stage, the Apollo Telescope Mount (ATM), the Multiple Docking Adapter (MDA), the Airlock Module (AM), and the Orbital Workshop (OWS). Image: NASA/KSC



A mighty Saturn V rocket carries the Skylab space station into Earth orbit.

The Skylab 1 payload included four of the five major components of the space station Orbital Workshop, Apollo Telescope Mount, Multiple Docking Adapter, and Airlock Module. In addition to the payload, the Skylab 1/Saturn V second (S-11) stage. The fifth major component of the space station, the Command Service Module with the Skylab 2 crew aboard, was launched at a later date by a Saturn 1B from Pad B.
Photo credit: NASA

Above: The Saturn V first stage roars away from the pad with 3.4 million kilograms of thrust.
Images: NASA/KSC
Below: Tower clear! Houston now controlling.

environment. The Laboratory was also orbiting very close the Earth. As the Earth radiates roughly the same amount of heat it receives, particularly in the infrared band, Skylab was receiving heat energy from both the Sun and Earth while in daylight, so its temperature went up.

Apart from being away out in space beyond the Earth's reflected heating influence, Apollo 13's electrical equipment was shut down to an absolute bare minimum, so again the carefully planned temperature control for its environment was out of balance. With the lack of internal heat being generated by the spacecraft's electronics, Apollo 13's temperature went down.

After nearly 26 minutes into the flight the solar panels for the telescope mount were successfully set up, but when they tried to extend the two big wing-like solar panels to provide the electrical power for the workshop just before Carnarvon, nothing seemed to happen. When Skylab came up over the horizon, Carnarvon found that instead of 12,400 watts of power there was a paltry 25 watts! As these panels supplied 60% of the power to run the laboratory, added to temperatures going up by the hour, and there was also a gyro malfunction Skylab was in deep trouble, and the mission had just begun!

EGIL, the Flight Controller in Houston for the spacecraft electrical and environmental systems at the launch was John Aaron:

"Right after the spacecraft got into orbit the rules called for me to start powering it up and turn on the heaters to warm up the inside. I told Flight I didn't want to do that because I realised something was really wrong. The power system wasn't activating right, and the temperatures were going up instead of down in the workshop.

The spacecraft designers were at Marshall, and they called me up on the phone and we started this big debate about why I wasn't following the sequence. The phone call lasted until we got all the way to the Carnarvon Tracking Station in Australia and I got live telemetry and we were still arguing and I said, 'Guys, this argument is over because those commands you didn't want me to send I just sent!' and the line went quiet.

You could tell that if we didn't do something, the inside of the workshop was going to get to be 300 degrees (149°C)*, and we could have had a structural failure. We came up with this idea to cut down the heat in the workshop, if we pitched it up at an angle to the sun, high as we can, but not so high that we couldn't generate any power from the solar panels. We flew that thing for two weeks trying to balance between the pitch angle and not drain the batteries to zero. What complicated it further was the attitude reference was a sun sensor with only a one degree field of view, so when we pitched it up 45° we were strictly on gyro compassing to do the attitude. Then we found out we had a gyro failure giving us significant drift rates. So, the way we guided the vehicle was I would calculate pitch angle based on solar array voltage. I had some temperature sensors on opposite sides of the solar arrays, and I could get roll from the differential readings by the way the sun shield on the Apollo Telescope Mount was shading the temperature sensors.*

Now we got into a roll between me and the Guidance Officer. I'd tell Flight that I needed Guidance to generate me a command load that would pitch the vehicle up ten more degrees and roll it three degrees to the left. After a couple more orbits I said, 'Well now something's happened, it's not exactly steady any more – I need five degrees pitch down and roll it back the other way about five degrees.' The third time that happened, about two days into the mission, the Guidance Officer took his headset off, leaned over the console and said to me, 'EGIL – do you know what the hell you're doing?'"

Within 24 hours there were meetings by NASA management to sort out what to do. As the bad news filtered in, a grim determination to rescue the mission at any cost began to grip the key players in this drama. With outside skin temperatures soaring up to 163°C, the engineers feared that the metal might buckle and tear. While the technologists wrestled with the problems, the tracking network steadily monitored the events on board the crippled laboratory, watching among other things, temperatures in the lockers because of excessive heat spoiling food, fogging film, and ruining medical drugs. For example, there were 1,200 aspirins in storage.

The unmanned Skylab 1/Saturn V vehicle launched from Launch Complex 39A. Image: NASA/KSC

Pete Conrad: *"I was in quarantine and had just watched the Lab launch. Right after that was over it looked like a perfect launch we went back to the crew quarters for our last afternoon training as we were due to launch the next day. Then we began to hear over the loop that something was amiss; so just stayed right there. It didn't take very long to find out that something was seriously amiss. Then sometime that afternoon the decision was made that we would return to Houston, so we went down to our airplanes and flew home. Then we spent a hectic five days at Houston working on all different things; we returned to Huntsville and did some quick training in the water tank before going on down to the Cape and we launched on day ten."*

Joe Kerwin: *"Our first duty when we found out there was trouble with Skylab was to call our wives and sweethearts who were having a monster pre–launch party at the officers club at the Patrick Air Force Base – they were having a ball down there – and told them to keep on partying but we weren't going to launch in the morning."*

Bill Schneider, the Skylab Program manager, announced the launch of the first visit would be postponed until 20 May at the very earliest, but it took ten days for the engineers to come up with solutions to the problems. It was an incredibly short time to work out what had gone wrong and provide kits to fix the problems that were only figured out from the telemetry indications.

During those 10 days teams of engineers all over the United States worked around the clock to diagnose the problems and designed, built, tested and delivered the tools and equipment to save the Skylab mission. Engineers on vacation in Hawaii and Japan flew back to help. Many dedicated engineers working long hours, often voluntary, were ordered home to get some rest.

There were many aspects to be considered, for example, temperatures of 149°C could have decomposed the polyurethane insulation bonded to the external walls and created gases lethal enough to cause permanent lung damage and death. So, using nitrogen, the ground controllers pressurised and depressurised the workshop over a period of three and a half days to flush out any toxic gases and instructed the first crew to wear gas masks when they initially entered the workshop.

Within hours of the failure, Jack Kinzler, Director of the Technical Services Division at Houston, and the next door neighbour of Conrad, had worked out a parasol design to keep the temperature down inside Skylab and spent days with a team developing a practical model. He decided to use telescoping fishing rods as models for extendible parasol ribs and bought five at $12.50 each from the local store. Their design was chosen for the first crew to try, eventually arriving by jet only hours before launch.

Finally, all was ready for the first team to visit the laboratory.

Skylab II (1*) Crew – Joe Kerwin, Pete Contrad, and Paul Weitz. Image: NASA/JSC

PRIME CREW
Commander: Charles 'Pete" Conrad Jr
Science Pilot: Joseph P. Kerwin
Pilot: Paul J. Weitz

BACK-UP CREW
Commander: Russell L. Schweickart
Science Pilot: F. Story Musgrave
LM Pilot: Bruce McCandless II

SPACECRAFT
Command Module: CSM-116
Launch Vehicle: Saturn 1B - SA-206

* The official NASA designation for the station launch was **Skylab 1**, followed by three crewed missions: **Skylab 2, Skylab 3, and Skylab 4**.

A common point of confusion exists because early mission patches and some documentation labelled the crewed flights as Skylab 1, 2, and 3. However, the engineering and management teams maintained the 1–4 sequence to account for the station's launch.

SKYLAB II – VISIT 1

SL2 (Skylab 2) – Saturn 1B SA-206 – CSM-116

EVENT	U.S.A.	AUSTRALIA
Launch – LC 39B	09:00:00 EDT 25 May 1973	23:00:00 AEST 25 May 1973

Time in space:	28 days 0 hrs 49 mins 49 secs
Number of Orbits:	404
Distance travelled:	18.5 million kilometres
Total EVA time:	5 hours 41 minutes
Spacecraft weight:	19,979 kilograms

The Skylab 2/Saturn 1B space vehicle during a Countdown Demonstration Test (CDDT) 15 May 1973.

Launched from Launch Complex 39B, Kennedy Space Center, Florida,
this was the launch vehicle for the first crewed Skylab mission.
The vapour being emitted from the vehicle is the venting of cryogenic propellants.
Photo credit: NASA/KSC

The Skylab 2 crew, inside the command module atop a Saturn IB launch vehicle, head toward Skylab.

The command module was inserted into Earth orbit approximately 10 minutes after liftoff. The three astronauts were the first of three crews to spend record-setting durations for human beings in space, while performing a variety of experiments. Image: NASA/KSC

Skylab II Fact Box

Launch
Launch Complex – 39B, Cape Kennedy
Friday, 25 May 1973
0900:00 US EDT / 1300:00 UTC
[Saturday, 25 May 1973, 2300:00 AEST]

Vehicles
Launch vehicle – Saturn 1B SA-206
Command Service Module – CSM-116

CSM statistic
Mass – 19,979 kilograms

Mission highlights
Fly-around inspection of damage
Release the jammed solar panel
Deploy sunshade
Solar flare studies and solar photography
Earth science data and photography
Medical experiments

Mission duration
Total mission – 28 days 00 hrs 49 mins 22 secs
Time docked – 26 days 11 hrs 02 mins 00 secs

Earth orbital data
Perigee – 428.0 kilometres
Apogee – 438.0 kilometres
Orbital period – 93.2 minutes
Inclination – 50°
Total orbits – 404
Distance travelled – 18.5 million kilometres

EVA – Extra Vehicular Activities
EVA-1 – Stand-up EVA (SEVA), CM hatch
When – 00:40 – 01:20 UTC, 26 May 1973
Total time – 40 minutes
Astronaut – Joseph Kerwin

EVA-2
When – 15:15 – 18:40 UTC, 7 June 1973
Total time – 3 hours 25 minutes
Astronauts – Pete Conrad and Joseph Kerwin

EVA-3
When – 10:55 – 12:31 UTC, 19 June 1973
Total time – 1 hour 36 minutes
Astronauts – Pete Conrad and Paul Weitz

Splashdown
CM – 22 June 1973 – 13:49:48 UTC
Location – North-western Pacific Ocean,
off San Diego, California
– 24°45'N 127°2'W
Recovery vessel – USS Ticonderoga

Arrival at Skylab

"Tally Ho! The Skylab. We got her in daylight at 1.5 miles, 29 feet per second."

It was 8 hours after another perfect Saturn IB launch at 0900 USEDT (2300 AEST) 25 May 1973, and Conrad could see the crippled laboratory above the bright Earth below. They did a fly-around Skylab and sent video pictures of the damage back to Houston, confirming that the micrometeorite shield was gone and the single remaining solar panel was stuck down by what looked like a strap of aluminium.

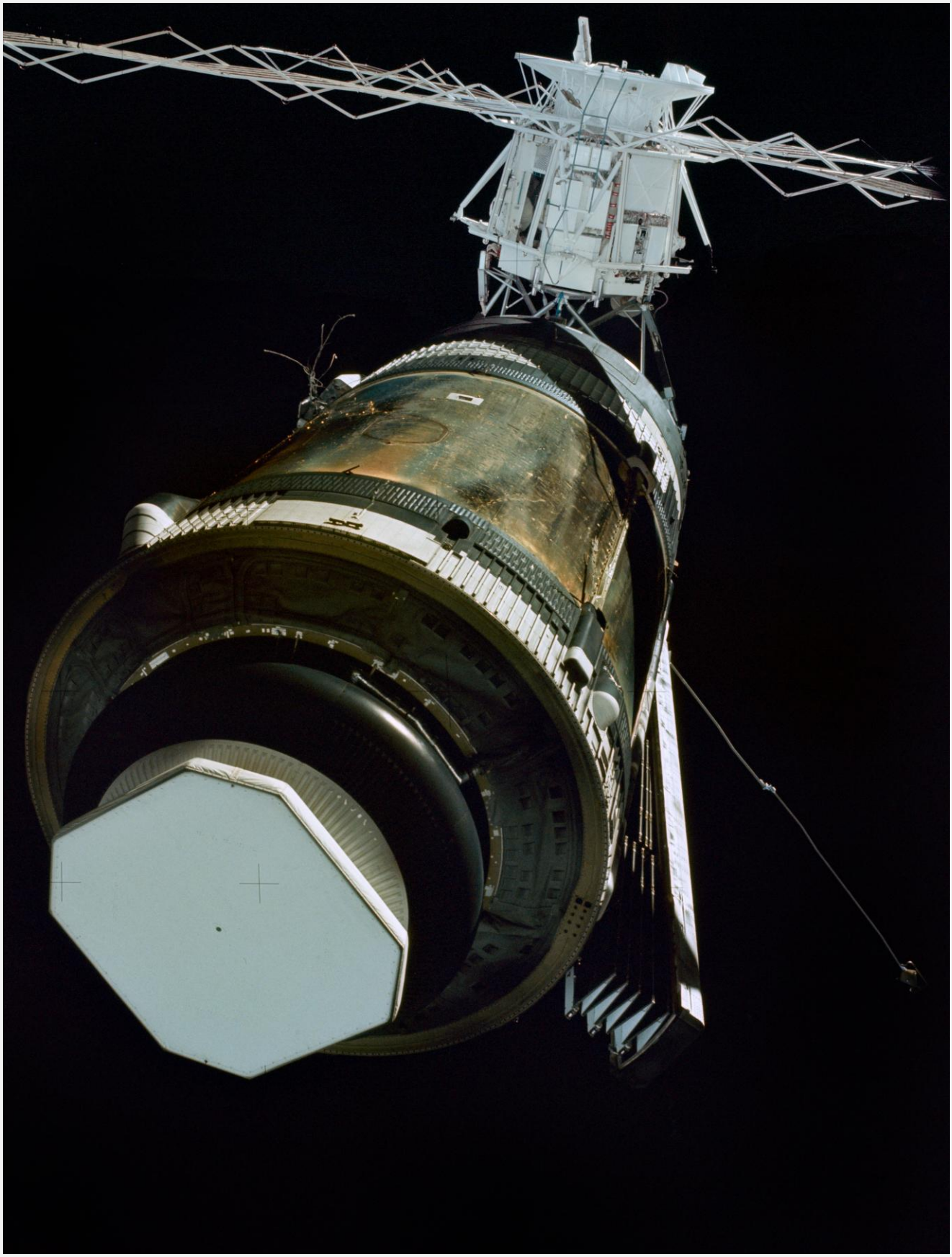
They parked the Command Module by soft docking it to the laboratory, and while the ground crews studied their television pictures of the damage, the astronauts tucked into their first meal.

"Dinner's going pretty good," reported Conrad, *"except that Paul found another one of those tree trunks in the asparagus. I had stewed tomatoes for lunch. It turned out even as goopy as they are, they were real simple to handle, and the same way with the turkey and gravy."*

After discussions with the ground, they decided to do an EVA to try and prise the solar panel loose. Working from the Command Module hatch they tried to free the solar panel beam from the aluminium strap holding it down by cutting it.

Kerwin: *"Weitz was hanging out the side door with a shepherd's crook in his hand – a ten foot pole with a hook in the end – trying to stick it under the opening in the solar panel to pry it up, while I had my arms around his legs to hold him in the Command Module. Pete was flying the spacecraft and every time Weitz would pull on the shepherd's crook the two spacecraft would move towards each other, and the jets would fire on the Skylab workshop, and the jets would fire on the Command and Service Module and Pete would have to haul back on the stick to keep them from colliding – it was pretty spectacular."*

Weitz: *"I tried to pry the beam up, but it didn't work because the aluminium strap was too firmly fixed. We had another fitting on the end of the pole which was a branch cutter This thing is wrapped around your leg and comes up over your ankle to your knee on the inside and you have these scissors held parallel to your leg.*



Skylab 2’s approach to Skylab at long range, fly-around inspection.

The Orbital Workshop with area of missing micrometeoroid shield,
missing solar array (left), detached wiring, and partially deployed solar array (right).

Image: NASA

Above and Below: Damage observed during the fly-around inspection. Images: NASA

These cutters didn't work – they just weren't beefy enough and I couldn't get enough purchase on it to cut through the strap, so we had to give up."

When they entered the night side they closed the hatch and tried to dock with Skylab again, but this time the soft dock latches refused to lock.

Kerwin: *"The three soft dock latches which had worked perfectly the first time simply wouldn't capture. Pete tried and he tried and he tried and he tried again – we went through the back up procedure and it looked like we had a spectacular failure here where we would have to come home because we couldn't dock.*

We finally backed off a little bit and decided to try the last ditch third back up procedure that was in the checklist, which fortunately one of our trainers had shown us a few weeks before launch 'We have never looked at this backup procedure – why don't we just go through it and show you where the wires are,' he had said to us.

This involved an IVA (Intravehicular Activity*) so we had to get back into our suits, de–pressurise the spacecraft again, but this time we opened the tunnel hatch where the docking system was. We went up in there and cut a wire to bypass the soft dock system. We put the hatch back on but this time the deal was we were just going to force it in to where the main hard dock latches might work. In came Pete one more time, hosed on the fuel, pushed the switch to activate the twelve main latches and we counted one, two, three .... we got to about seven and we heard this rat–a–tat sound which was all the twelve latches locking on one after the other – that was a very sweet sound – and we had a good hard dock. We had been up for about eighteen hours by then – we were kinda tired – so we had a snack and went right to bed."*

When Conrad, Weitz, and Kerwin awoke, the first task was to check the atmosphere in the laboratory for any deadly gases.

Weitz: *"We had a sniffer – a glass cylinder with a rubber bulb on one end like a hygrometer they used to test batteries in the old days – with an adapter to go in the MDA hatch. We sniffed that and it didn't show anything, so we opened the hatch. In the MDA it was relatively cool, in the fifties (10°C) as I remember, but when we got in the airlock it was very hot. Pete and I said if it's hot in there we'll go in our skivvies, but then we soon found out why the people in central Africa wear a lot of clothes when they are in very hot conditions – we bundled up rather than took clothes off because of the heat. We made forays into the workshop for about ten or fifteen minutes until we felt we needed a break then we went back to the MDA to cool off for a while. Except for the temperature, everything looked as it should be."*

Kerwin: *"In the lab it was quite warm and it had a somewhat chemical smell – not bad – a sort of gasoline smell."*

The temperature was 54°C, but the humidity was so low they were able keep working for up to five hours at a time.

The next item was the thermal shield. Conrad and Weitz carefully eased the $75,000 parasol developed by Kinzler and his gang through the scientific airlock and extended the struts until the sunshield was in place.

Weitz: *"On day two we went to work putting up the parasol. It took most of the day. As I remember everything went according to plan but as it turned out all the four extendible booms didn't extend, one of them did not, so the thing was not quite a rectangle, but we didn't know that at the time."*

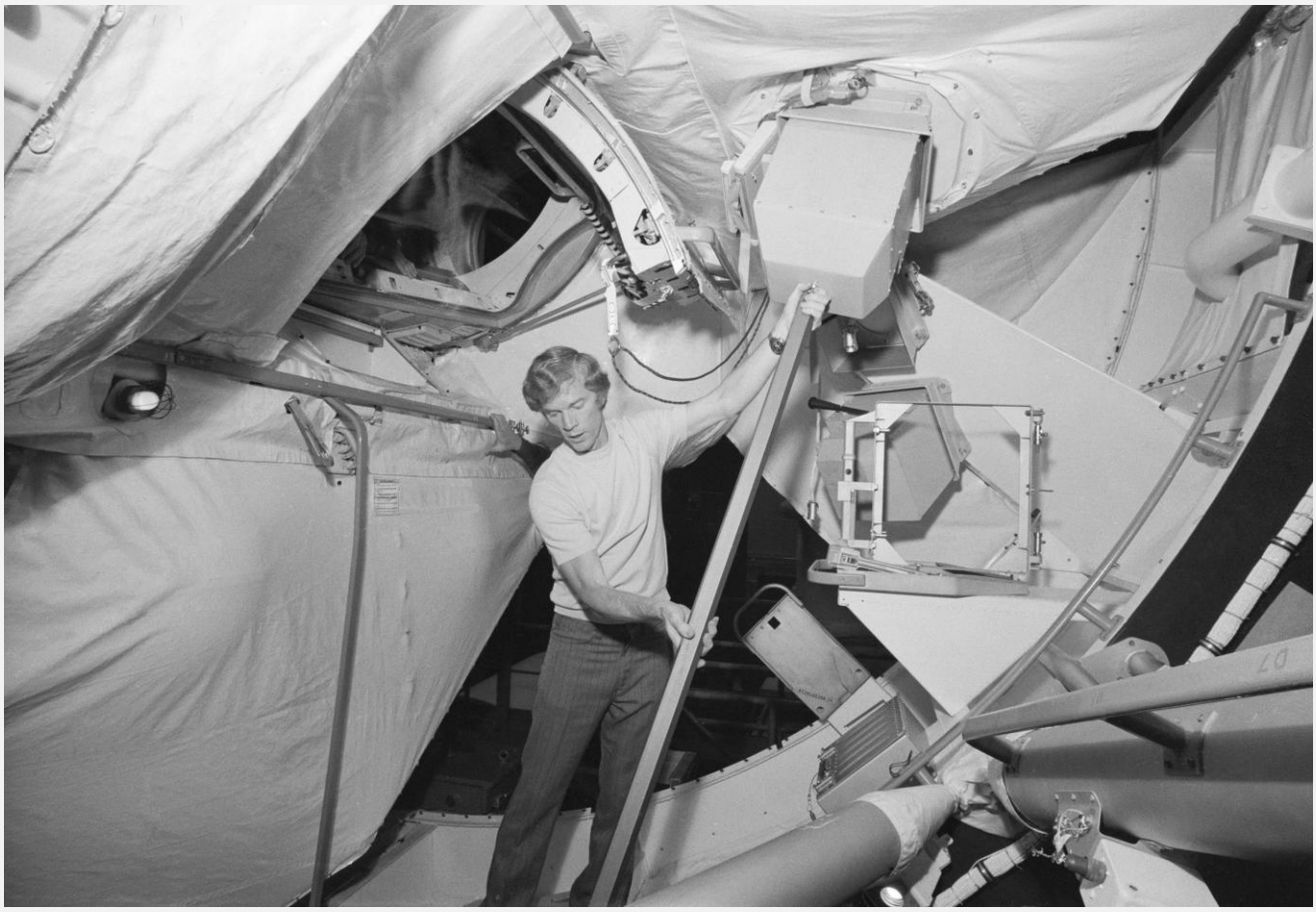
Conrad radioed down: *"The rod extension has gone easily enough. It's pretty warm down here, so we are taking little heat breaks."*

Almost immediately the temperature in the laboratory began to drop, eventually taking a week to stabilise at 21°C.

Weitz: *"The next day things had cooled down a little, so we started the activation procedures which meant moving a lot of stuff. A lot of items were bolted to the triangle floor."*

Now came the most difficult job extending the remaining solar array.

The solar panel beam was extended by a hydraulic piston. This beam was jammed by a strap from the micrometeorite shield lodged there during the launch phase. On the ground at the Marshall Space Flight Center astronauts Rusty Schweickart



Russell Schweickart in Orbital Workshop Simulator (OWS) working out procedure to be used for repair of damaged thermal protection cover on Skylab 2 spacecraft. Image: NASA

and Story Musgrave had developed and practiced the procedures to clear the beam on a mock-up of the laboratory, complete with the strap, as seen on the television pictures sent by Conrad.

Fourteen days after the first docking, Conrad and Kerwin tackled the procedures developed by Rusty Schweickart. Working on the smooth tank–like laboratory with no gravity, toe or handholds to steady them, the two astronauts set up the long handled cutter, like pruning shears, used in the first attempt. They had to wait and fly through an orbital night before they could try it out.

Kerwin: *"I had on my suit an extra six foot tether, just a rope, with hooks on both ends. Where we were there was an eyebolt so we hooked one end of the tether to a ring on the front of the suit, snaked it through the eyebolt and back up to the suit, hooked it again, adjusted it to the right length and I could stand up with my two feet planted one either side of that eyebolt and suddenly I was standing there as steady as you could get with a three point suspension.*

Once we had accomplished that, it was only a couple of minutes work to get the jaws in place. Pete had to help me a little with depth perception to get it exactly right – he said: 'No.... you passed it..... come back, dammit,... no...now....back.....'

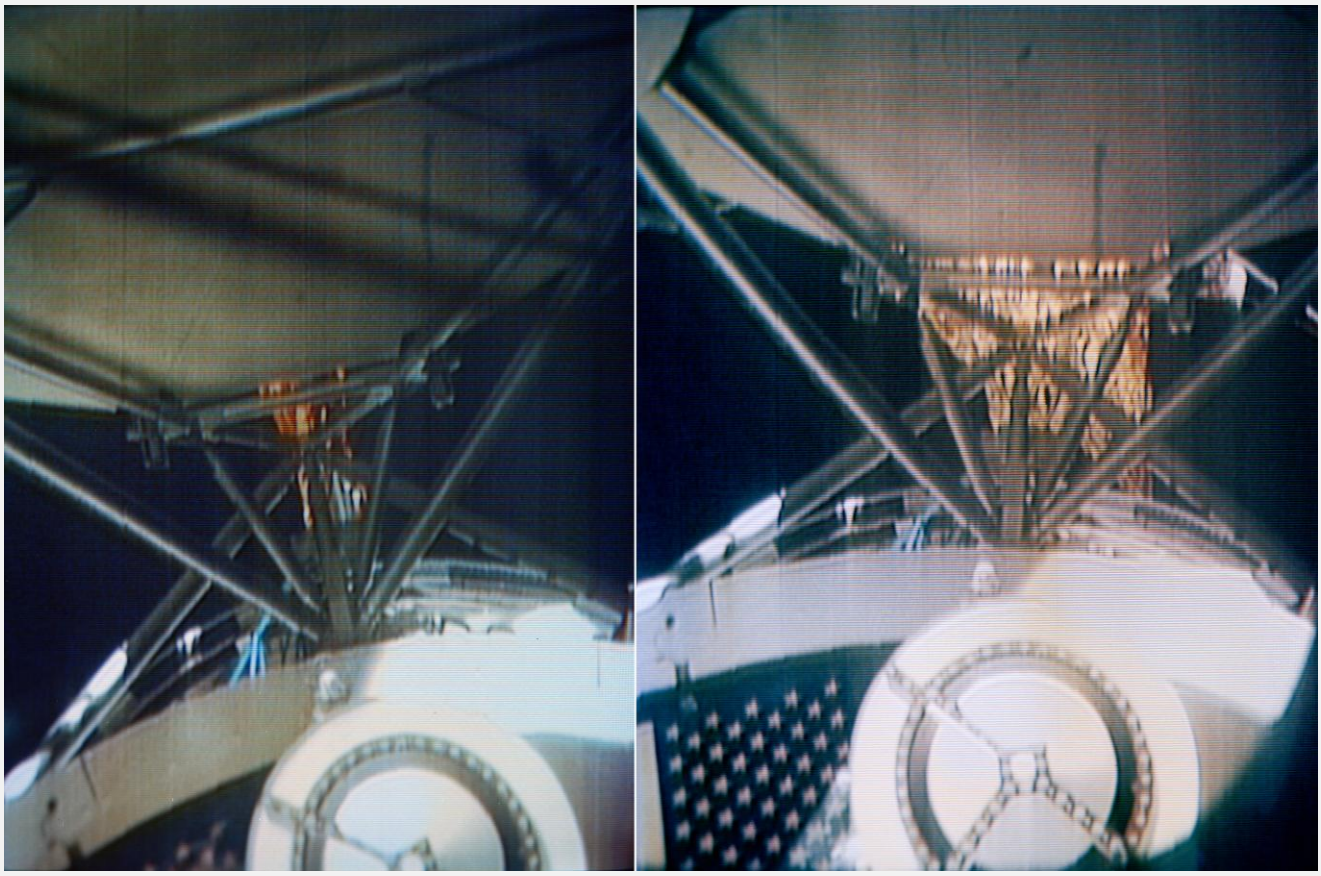
So, it went on and I pulled the rope just hard enough to tighten the jaws against the strap but not hard enough to cut it. That was very important, because Pete was now going to use that twenty five foot pole as a handrail. He went hand over hand down to the solar panel, trying to take care not to cut himself, and attached another rope to the cover of the solar panel."

Conrad hooked one end of the rope to a vent module relief hole on the beam, and the other end was secured to an antenna support truss on the solar observatory.

Kerwin: *"First we tightened the jaws the rest of the way and cut the strap of aluminium. When we did that the panel came out another few inches and stopped."*

Above: The "parasol" solar shield being tested at the Johnson Space Center. The simplicity in design and deployment, did not require an extra EVA, or significant additional training for the astronauts.
Images: NASA/JSC

Below: The parasol deployment being seen from a TV camera in the Command Module.
The sunshade is only partially deployed in these pictures.



Conrad, inspecting the jaws, suddenly found himself tumbling out into space to be brought up with a jerk by his umbilical cord. *"…that shot me out into the boonies!"* he chuckled. He looked back to see the solar panel was only extended about 20°.

Kerwin: *"We knew that would happen – that's what they told us at Houston – that the joint is very cold, it's frozen, you're going to have to break the friction That was what the second rope was for, so now we disposed of the twenty five foot pole then the two of us worked our way under the remaining rope and stood up between the rope and the lab. That exerted just enough tension on the solar panel cover to break the friction.*

Suddenly – I want to say there was a cracking sound but of course there wasn't because we couldn't hear it – but there was this sudden release of tension in the rope, and we both went flying ass over tea kettle into space. We hand-over-handed our way down to some structure, turned around to look, and there was the solar panel fully deployed, sticking out ninety degrees, and the panels were already starting to come out."

At the other end of the radio link the flight controllers heard Conrad say, *"Whoops, there she goes...!"*

…and within six hours the solar panel was functioning and sending 7,000 watts of power to the workshop, enough to ensure the missions could go ahead as planned.

The Skylab mission, the whole $2.6 billion project, was saved!

One essential need of the Lab was to keep a steady attitude of at least 2.5 seconds of arc for 15 minutes for the experiments, which included compensating for crew movements. There was no steady ground to mount equipment on, so two systems kept Skylab in position. The first system used three electrically driven double gimbal mounted Control Moment Gyros (CMG) to stabilise the whole Lab within 3 minutes of arc. For the more precise attitude control required by the solar instruments a Pointing Control System (PCS) used the Sun's centre for a reference and could control the ATM's direction in steps of 1.25 seconds of arc. The whole system was automatic with manual overrides.

To run Skylab a digital computer handled complex operational commands by the crew or remotely from the Mission Control Center through the tracking stations.

The astronauts found that life in the laboratory was quite different to the gravity controlled environment of Earth. They had special shoes with triangular or mushroom shaped wedges on the soles for locking into the floor to hold them in place but had to remember which ones they were wearing. If they pulled clothing out of their storage, all the other items would come floating out too, filling the room.

Conrad: *"Hey, I tell you could go anywhere you wanted to. You could get out of control a little bit enroute though. We never went anywhere straight we always did a somersault or a flip on the way, just for the hell of it."*

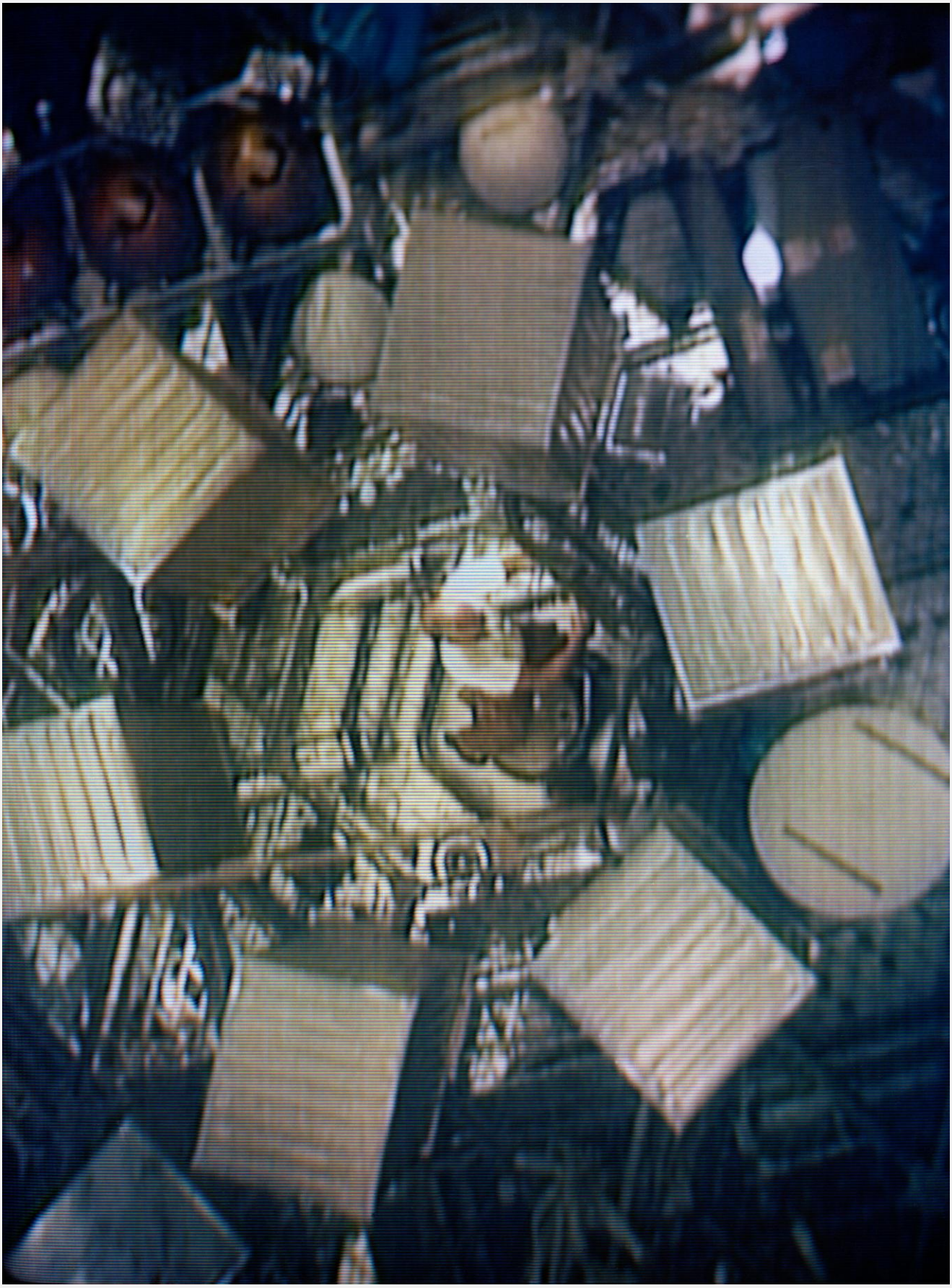
The astronauts soared around the laboratory with cartwheels, flips, and gymnastic manoeuvres, sometimes to the music of 2001 – A Space Odyssey.

Which way is *"up"* in a cylindrical, gravity free workshop? The astronauts found *"up"* and *"down"* relative.

Kerwin: *"You do have a sense of up and down, and you can change it in two seconds whenever it's convenient. If you go from one module into the other and you're upside down, you just say to your brain 'Brain, I want that way to be up,' and your brain says, "Okay, then that way is up.' If you want to rotate 90 degrees and work that way, your brain will follow you. I don't think it's vestibular at all. I think it's strictly eyeballs and brain. It's remarkably efficient."*

Weitz: *"After you have been training in a 1 g workshop for two years you get a definite sense of up and down. To me up was always towards the docked Command Module. If you look at any of the pictures or movies you will see that we are always moving around with our heads towards the Command Module and our feet down towards the trash airlock.*

Long ago we had a very prolonged argument about what shape the doorways between the



An interior view of Skylab’s Orbital Workshop.

The colour TV camera aboard the space station captures Pete Conrad floating up through the hatch. Food lockers are in the foreground.
Photo credit: NASA/JSC

Scientist-astronaut Joe Kerwin demonstrates weightlessness in the forward compartment of Skylab. Mission commander, Pete Conrad is visible on Kerwin's right. Image: NASA/JSC

different compartments should be. I remember Walt Cunningham had very strong feelings that in zero g you float so they only need to be circular. Fortunately, we made them standard doorways mainly because of the 1g training on the ground. Once you get used to that in the 1g training 'up' was always towards the Command Module."

They were able to float along head first or propel themselves forwards in a standup position. They had contests to float the 27 metres all the way down the middle of the laboratory without touching any sides, or hatches. The normal time was 45 seconds, but if they lined themselves up first, it was 15 seconds. The less agile astronauts could take up to twenty attempts before they were successful. On one run Conrad held a television camera in front of him for the viewers on Earth to share the effect of floating through the laboratory.

Kerwin, *"If you're floating reading a book, your head goes a little further back than it ought to and your shoulders are up. You put the book on your lap, where it's supposed to be, but that's uncomfortable in zero G and after a minute you feel, 'Oh, to heck with it' and just let your arms float up and let your head float back and you read with the book straight in front of you."*

On the ground the tracking stations began to fall into a rhythm synchronising with the orbits of the space station above. American Jim Smith, Telemetry technician at Honeysuckle Creek became keen enough to draw graphs of the events he could see from the data passing him:

"I was in the Decom area at the time and went through the software manual to find the things that were likely to be changing. You only had up to six minutes per pass to read all this stuff manually dial up the 8 bit word and convert it to decimal to see the event or information. I remember telling Saxon that the solar panel hadn't deployed within two minutes of acquisition. I used to watch the voltages come up from the solar panels as the laboratory came out of the darkness into the sunlight. Nearly everything that happened was recorded in the

telemetry. For instance, every time an astronaut relieved himself it would raise a signal bit."

For recreation the crew were supplied with Velcro-tipped dart sets, playing cards, balls, books, exercise equipment, and a tape player.

Kerwin: *"We broke the darts out once, but the darts went end over end – they were not aerodynamically competent in an atmosphere equal to 30,000 feet so we put them away. We had a deck of cards with Velcro tips on the corners, but we never used those We also had a rubber ball – we played with that a little bit just throwing it around trying to clear ninety feet from the Command Module to the trash compartment but that was not an everyday thing. Our recreation was pretty much just looking out the window or playing with weightlessness doing acrobatics – that was a lot of fun."*

Watching the Earth through the round 187 cm window in the wardroom kept them occupied for hours. The view was constantly changing as Skylab raced around the world in great sweeps, 50° North to 50° South, taking in Southern Canada to South Africa, Southern Russia and over the southern tip of South America. The crew were surprised how much time was spent looking at oceans, deserts, snowfields, and mountainous areas, where there were no signs of life. When he returned to earth Carr passed the comment:

"Not much of the Earth is hospitable to man. We're all crowded into small areas." Conrad: "I've spent a lot of time in space before at 150 miles, but this 237 miles is just unbelievable. You can really see the curvature of the Earth."

They preferred to watch the Earth with the horizon at the usual right angle, or horizontal, but sometimes the horizon would drift around, so they unconsciously moved with it.

Gibson, from the Skylab-4 visit, found this bewildering at times: *"You might start out with your feet on the floor, and the other guys sitting behind you, and a little while later you would look back and find the other two guys were upside down above you, still sitting at the wardroom table, which was upside down too."*

The crew slept at the same time in small compartments about the size of a small closet, equipped with a locker, a privacy curtain, and a sleeping bag with blankets. Sometimes before going to sleep, they would play tapes, Conrad listening to country and western, Weitz the popular songs, and Kerwin classical. All the crews usually slept well, usually an hour or so less than on Earth, some with their heads near the floor, and some stretching out like a hammock. As the most comfortable way to go to sleep was to be totally free, Gibson tried going to sleep in the upper deck of the workshop but was always bumped awake as the forced air currents nudged him into the walls and equipment.

Conrad: *"Every night PJ* (Weitz) *disappears, and we don't see him until next morning we call him the night wanderer."*

Weitz: *"I tried for a day or two, but I was not comfortable sleeping with what I perceived as hanging on a wall, even though it was zero g. I wanted to get a good night's sleep. I didn't wander that far. Each night I would take my bunk up into the upper part of the workshop and lay it out so up was towards the Command Module. Also, those sleep compartments were small, and I preferred to have more space."*

It wasn't always easy to get to sleep. As the laboratory swung around the world from day to night each 93 minutes the skin creaked and popped with the change in temperature. If the thrusters fired during the night to keep the laboratory's attitude, they sounded like bursts of gunfire. If anyone got up he would wake the others.

The Skylab toilet was a hinged, contoured seat mounted on the wall – it was uncomfortable and awkward to use but did work. The astronaut sat on the seat, fastened a belt across his lap, and used forced air drawn into a plastic bag to collect the faecal matter. The shower was a cylindrical cloth enclosure fed with water from a preheated pressurised portable bottle. With only 2,722 kilograms of water on board, bathing showers was rationed to 2.8 litres of water per shower per week, the liquid soap and water were carefully measured before the mission and rationed out no luxurious long hot showers if you were feeling a bit seedy!

Pete Conrad (right) and Joe Kerwin preparing meals in the wardroom area of the crew quarters.
Image: NASA/JSC

Weitz was first to try the shower: *"It took a fair amount longer to use than you might expect 15 minutes of shower and 45 minutes of cleaning up, but you came out smelling good!"*

…so, it wasn't really a success. They found it was easier to rub down with wash cloths.

Weitz: *"Zero g is both good and bad. It's a great environment for moving around, to play in, and to work in, but it's not so good when it comes to things like going to the bathroom or brushing your teeth and you like to spit the toothpaste out into the sink and watch it go down the tube, instead of having to spit it out into a used towel, or something like that."*

The bathroom became the barber shop every few weeks, the barbers sucking the cropped hair away with little vacuum cleaners.

When the first crew opened their personal hygiene kits they found the high temperatures had caused the hand cream and toothpaste tubes to rupture, but they were able to find enough to keep them going for their stay. In the second visit, Bean found that when he opened his locker his toothbrush, razor, and anything else in there just floated out. So, he lined the bottom with Velcro and tacked small patches to each item and found he could lay everything out in a neat, orderly fashion Navy style.

As creatures of the planet Earth, we have to take our 24 hour system with us where ever we go, even though there may be no day and night such as when travelling through space. Though Skylab had 16 sunrises and sunsets in one Earth day, the astronauts found that it was important to keep a regular 24 hour schedule, or they found that life became chaotic. They scheduled an astronaut to be cook for the day and tried to make a point of eating together to relax and keep in touch.

Bean commented: *"When we stopped letting the food times move around, things kind of stabilised out for us."*

Based on Houston time, a normal day began at 8:00 am with breakfast. By midday they were ready for a light meal of tuna spread or dried beef. The big meal of the day with meat, vegetables and dessert was in the evening at around 6:00 pm.

The Skylab 2 Command Module floats in the Pacific Ocean following splashdown southwest of San Diego, California. A recovery helicopter hovers in the foreground, while the USS Ticonderoga approaches. Photo credit: NASA

They tended to save a snack of ice cream or cookies for a supper when they could relax at the window before going to bed at around 10:00 pm. One chore before turning in was a tour around the laboratory to make sure everything was secure and to check on the alarms. Apart from a fire and a wake up alarm, there was an alarm in case of a flare erupting on the sun, another was in case the laboratory was punctured by a meteor, when one of them would have to jump out of their sleeping bag and find and plug the hole with a rubber plug. Luckily none of these emergencies occurred.

In the ward room they found it was easier to eat standing up, as sitting meant bending, and bending in zero gravity tired the stomach muscles. The table, of course, had been designed for sitting at, and they found difficulty placing their knives, forks, and spoons, and ending up pinning them down with rubber bands. Generally, the natural surface tension kept fluids in place on the food containers, but Conrad commented:

"We were continually reaching out to get a ball of gravy or something else that had got away."

The food they had chosen on Earth tasted different and bland in the laboratory probably because of their nasal stuffiness and the low laboratory pressure, about a third of the Earth's atmospheric pressure at sea level, which also made smelling and talking difficult. They had to shout to be heard at times, 4.6 metres the maximum distance sound would travel, so sometimes they became hoarse.

If an astronaut paused with a spoon of food half way to his mouth to answer a question, the spoon would stop, but the food would continue on its way and splatter all over the face, so the astronauts found it was safer to bring the food and mouth close together when they were eating.

There were 20,000 items packed in 100 cabinets around the laboratory so there were 6 men and a computer in Houston standing by to quickly locate any item. As they went about repair jobs there was often a continuous stream of objects heading for the extraction screen screws, nuts, Swiss army knives, and screwdrivers. They couldn't put objects down, or in a pocket as they just floated

away. They couldn't leave them in the air for too long because no matter how hard they tried there was always some motion left to it, and they had to keep checking it was still where they had left it. If they lost an item it would usually turn up on the air recirculation screen in about 20 minutes.

Despite a lot of time spent on repairing the laboratory, the first crew found time to conduct many of the required scientific experiments and observations. Sometimes Mission Control piled on too many tasks, and Conrad would point out,

> *"About two or three times now you got us doing things where we got 89 pieces of gear out, and you got us running all over the spacecraft."*

After taking more than 25,000 photographs of the sun, and nearly 7,500 photographs of the Earth, the first crew left the laboratory on 22 June to splashdown into the Pacific at 0649 USPDT, (2349 AEST) 1,287 kilometres west of San Diego to be picked up by the USS Ticonderoga. They had proved beyond doubt that man could do useful work in the environment of space. To preserve the effect of the space environment as long as possible the Skylab astronauts stayed inside the spacecraft until it was lifted aboard the carrier, then they went straight to the medical centre.

Kerwin: *"From a personal point of view the mission was everything I expected of it – a truly wondrous feeling being in orbit around the Earth, looking back down on it – I was in orbit, not just the spacecraft. We came back with a very good feeling of 'Thank God we were able to get the job done and continue the mission.'*

Twenty six years later I have even more satisfaction from the experiments we did than I did at the time. I think now that the set of medical and human factors investigations that we did was thoroughly well organised and has stood the test of time."

The SL–2 crew were the first in history to perform a major repair work in space, Conrad proudly saying, *"We can fix anything."*

He summarised the mission with:

> *"I never got tired of looking out that window, I never got tired of zero gravity. We'd schooled ourselves for 28 days, so we were ready to go home, although we sort of hated to leave it and get back to one g. This is the mission that I remember the most; the one that taxed me the most; and the one that gave me the most satisfaction being able to salvage Skylab."*

… and Pete Conrad had flown on both Gemini V and Apollo 12.

During a US-USSR Summit in June 1973, the Skylab II (1) crew presented plaques to Soviet General Secretary, Leonid Brezhnev and US President, Richard Nixon. Image: NASA

Skylab III (2) Crew – Owen Garriott, Jack Lousma, and Alan Bean. Image: NASA/JSC

PRIME CREW

Commander: Alan L. Bean
Science Pilot: Owen K. Garriott
Pilot: Jack R. Lousma

BACK-UP CREW

Commander: Vance D. Brand
Science Pilot: William B. Lenoir
LM Pilot: Don L. Lind

SPACECRAFT

Command Module: CSM-117
Launch Vehicle: Saturn 1B - SA-207

SKYLAB III – VISIT 2

SL3 (Skylab 3) – Saturn 1B SA-207 – CSM-117

EVENT	U.S.A.	AUSTRALIA
Launch – LC 39B	07:11:00 EDT 28 July 1973	21:11:00 AEST 28 July 1973

Time in space:	59 days 11 hrs 8 mins 51 secs
Number of Orbits:	858
Distance travelled:	39.4 million kilometres
Total EVA time:	13 hours 43 minutes
Spacecraft weight:	20,121 kilograms

The second trip to the laboratory was brought forward by three weeks because of a failing gyroscope and a deteriorating emergency thermal shield, the parasol, put up by the first crew.

On top of a Saturn 1B rocket, Skylab 2 roared off into the sky at 0711 USEDT (2111 AEST) on 28 July and in 8 hours spotted the flashing lights of the

Skylab III Fact Box

Launch
Launch Complex – 39B, Cape Kennedy
Saturday, 28 July 1973
0711:00 US EDT / 1111:00 UTC
[Saturday, 28 July 1973, 2111:00 AEST]

Vehicles
Launch vehicle – Saturn 1B SA-207
Command Service Module – CSM-117

CSM statistic
Mass – 20,121 kilograms

Mission highlights
Over 300 hours of solar observation
Completed 39 Earth science data passes
Spider adaptation experiment
Deployed a Twin-polar solar shield
Space adaption studies for longer missions
Testing the M509 astronaut manoeuvring unit

Mission duration
Total mission – 59 days 15 hrs 08 mins 51 secs
Time docked – 58 days 15 hrs 39 mins 42 secs

Earth orbital data
Perigee – 423.0 kilometres
Apogee – 441.0 kilometres
Orbital period – 93.2 minutes
Inclination – 50°
Total orbits – 858
Distance travelled – 39.4 million kilometres

EVA – Extra Vehicular Activities
EVA-1
When – 17:30 – 23:59 UTC, 6 August 1973
Total time – 6 hours 29 minutes
Astronauts – Owen Garriott and Jack Lousma

EVA-2
When – 16:24 – 20:54 UTC, 24 August 1973
Total time – 4 hours 30 minutes
Astronauts – Owen Garriott and Jack Lousma

EVA-3
When – 11:18 – 14:03 UTC, 22 Sept. 1973
Total time – 2 hour 45 minutes
Astronauts – Alan Bean and Owen Garriott

Splashdown
CM – 25 September 1973 – 22:19:51 UTC
Location – North-western Pacific Ocean,
off San Diego, California
– 30°47'N 120°29'W
Recovery vessel – USS New Orleans

laboratory from 627 kilometres away. While they were manoeuvring towards it, the flight controllers on the ground noticed a pressure drop in one of the four sets of quad thrusters on the Service Module.

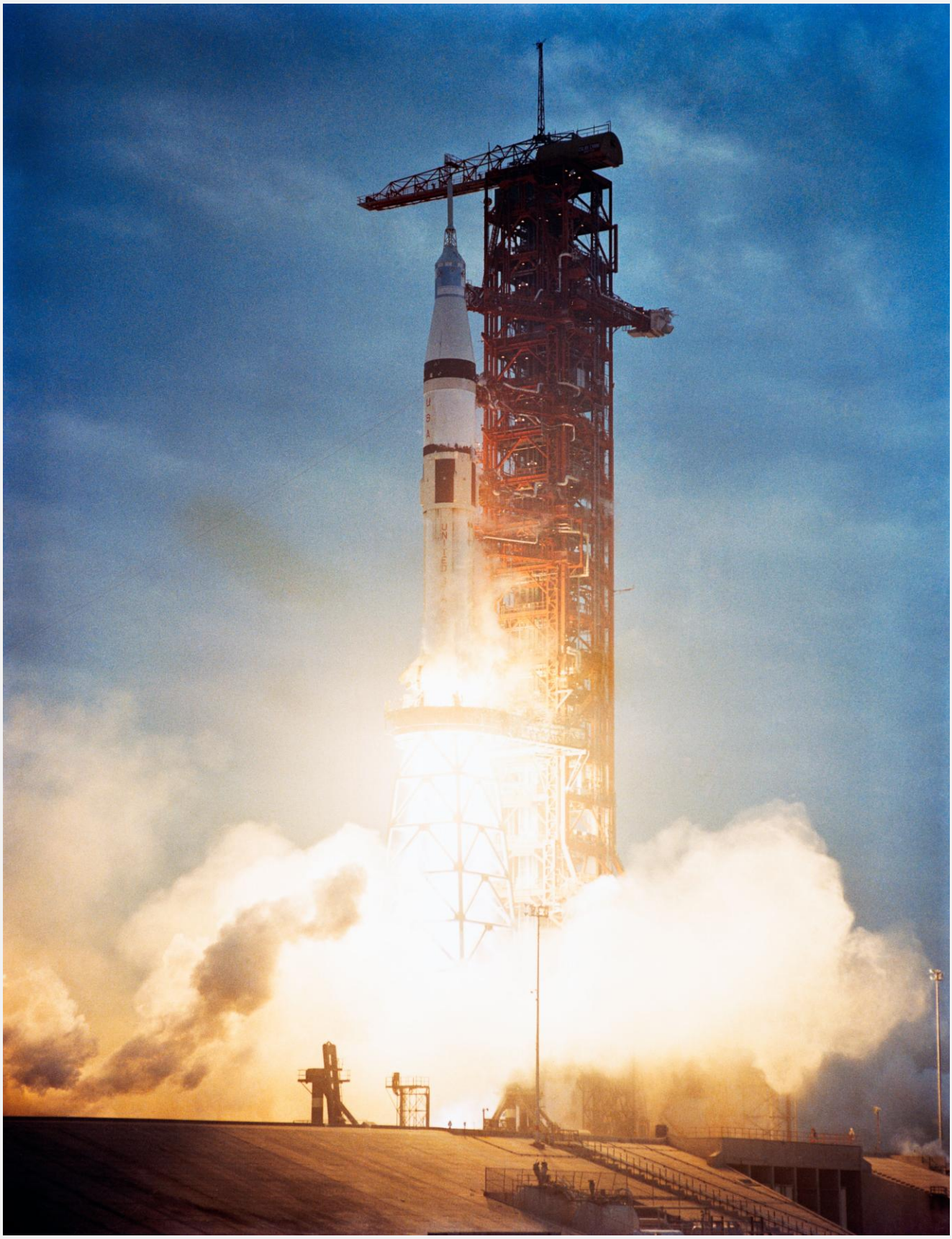
Alan Bean, *"The way it came up was strange – I saw something go by the right window by Jack Lousma and I thought 'What was that?' Jack saw it too and he said, 'I think a thruster just went by the window – it looked just like a thruster.'*

Of course, it was ice that had been frozen inside the thruster and come loose, and it was shaped just like a thruster. We were busy wondering what it was when the alarm went off to say there was a low pressure in the thruster. This meant there was a leak and that we had seen a slug of frozen oxidiser. So, we closed the fuel lines that went to that thruster because with it leaking you are losing fuel or can even have an explosion.

We all began to worry about braking with the rendezvous, as now we only had about half the braking – or less – also as we braked that would put in velocities up and down and left and right we didn't want. The person who really saved the day was Owen Garriott, because after the mid–course correction I did some braking while he read the range and range rate and did the calculations in his head – he was very good at that – and he said we're way too fast you're going to have to break some more. I didn't want to because if you break too much you waste a lot of fuel, but I felt he knew what he was talking about, so I braked for a little while.

He did some more calculations and said, 'You're still going way too fast you're going to have to brake some more.' I said I've been braking all this time I'm afraid to brake any more, and he said you're going to have to brake some more, and I said I'm not going to do it, so he then floated out of his couch down into the lower equipment bay which was something he never did. I thought he's real upset because he knows something, and I don't agree, so I thought I'd better do what he says because he's the guy who is good at doing this stuff in his head."

Owen Garriott, *"Yea, we only had two thrusters available instead of four, only one had failed but we had to turn off the opposite one and that way*



Lift-off from the Kennedy Space Center, Florida.

The Skylab 3/Saturn 1B space vehicle is launched from Launch Complex 39B.
Skylab 3 is the second of three scheduled Skylab crewed missions.
Image: NASA/KSC

Skylab as seen by the Skylab III (2) astronauts prior to docking. Image: NASA

you can have a balanced torque when you try to make an attitude adjustment. So, when you wanted to slow down you had to brake for twice as long, and I can only assume Alan thought he was braking twice as long. When I made the estimates based upon how close we were getting and how fast we were moving in it was clear we needed to brake more and that was what I was advising him. I can't remember being mad or anything – I just felt I had done everything I could."

Bean, *"So, I started braking, trying to keep the nose straight, but every time I brought it back to point at Skylab that would put velocity back in again. I was afraid I was going to fly past the lab, in fact Jack said 'Don't hit it' – he could see we weren't slowing down like we wanted to. I said I'm not going to hit it but I was afraid I would go whistling by it. We braked just underneath it – it was luck, pure luck. I just braked the whole time, and I'm sure my heart rate was higher than it's ever been in any space flight because I was so afraid we'd miss the Lab. Anyway, it worked out and we did it."*

The good news of the docking was passed to Houston through Carnarvon.

Bean, *"Then after we had been there six days we got an alarm from the Command Module in the*

middle of the night, so we zipped up there and found another thruster was leaking. We isolated that one, so now we had two thrusters out. Houston had to make a decision whether they would leave us up there, because if we lost another thruster we wouldn't have enough control to get back. That's when they began to talk about a rescue, in case another thruster went out, but another thruster didn't go out so they didn't need to rescue us."

Concerned that the rest of the thrusters might fail before the end of the flight, stranding the astronauts in space, Mission Control began to look at a rescue flight. On 2 August a rescue mission was initiated, to be flown by astronauts Vance Brand and Don Lind. While they trained on the simulators, engineering teams were again busy 24 hours a day, 7 days a week, analysing this new set of problems. The earliest the rescue mission would be ready to fly would be 34 days away.

The Director of the Manned Spacecraft Center, Chris Kraft decided advised Bean and his crew: *"Go ahead with your work just as if this were a normal mission."*

A Skylab rescue mission, by modifying a Command Module to take five astronauts, had always been considered a possibility but by the next day from readings on the ground the two thruster leaks didn't seem related, and simulations had found it was less serious than first thought as Skylab 2 should be able to get back with the two remaining Service Module thrusters assisted by the smaller thrusters on the Command Module.

In contrast to the first crew, Lousma developed motion sickness, becoming quite nauseated after his first meal. Later in the day both Bean and Garriott began to perspire and their stomachs began to rebel with the same problem, which lasted for three days.

Bean advised the ground, *"We're not as spry up here right now as we'd like to be."*

By the fifth day they had completely recovered and were able to achieve more than called for by the flight plan.

On 6 August Garriott and Lousma climbed out of the hatch and after changing films and inspecting the whole laboratory, erected a new solar shield over the first team's parasol. Packed by professional Navy parachute riggers using an accordion folded fabric covered in silicone paint, they pulled the material over an A frame of aluminium poles and tied it down, and this shield kept the laboratory's temperature under control for the rest of the mission.

The laboratory's astronomical observations were very successful, due to the close teamwork between the astronauts in space and the professional astronomers standing by at Houston throughout the manned periods, backed by the willing support of observatories all over the world.

Sun watching was the most popular activity with all the astronauts one of the few times any astronaut used the word pleasant about the laboratory.

Bean explained: *"The solar console is the only time you really have by yourself. It's really pleasant work to spend two or three hours here."*

They could see the sun in action any time they wanted filaments streaking out, flares leaping up, enormous bubbles larger than the sun itself, forming and bursting.

Nineteen experiments were chosen from 3,409 proposals submitted in a nation–wide competition, which included a number of creature experiments. Two minnow fish were a bit lost in weightlessness, continually swimming in small loops, but their hatchlings seemed quite at home in the new environment.

Arabella and Anita, two Cross spiders, a common American backyard species, were let loose for an experiment suggested by Judith Miles of Lexington High School in Massachusetts. Arabella began making tangled webs with some difficulty, but as she acclimatised to zero gravity by the third day, she began to spin normal webs. *"After her three day adaptive period, she seemed to enjoy zero g as much as the three of us did,"* Garriott noted. Anita, on the other hand, already used to zero gravity by the time they let her loose, made normal webs straight away.

A close-up view of Arabella, one of the two Skylab 3 common cross spiders *"Araneus diadematus"*, and the web it had spun in the zero-gravity of space aboard the Skylab space station. Image: NASA

Fishing and the sea were another experiment. The National Oceanic and Atmospheric Administration (NOAA) wanted to tie Skylab's observations of the sea and its fish population with reality on the surface and organised a mammoth game–fishing experiment in the Gulf of Mexico. 138 boats fanned out and reported the fish they saw or caught in coordination with Skylab's passes overhead to see if they could be related to the colour of the water indicating water temperature, plankton, and depth.

The Prank Tape with Helen Garriott

One day [10 September 1973] the mission was humming along, when the Flight Controllers suddenly sat bolt upright in their recliner chairs as a female voice filled their earphones and speakers,

"Hello Houston, this is Skylab. Are you reading me down there?"

A stunned silence followed as the Controllers looked at each other for an answer. Had the lines got mixed up? Was somebody fooling about with the Skylab loop? Who the hell was this woman?

While they were still trying to figure out what to do even the comedians hadn't thought of a procedure to cover this situation there was another call,

"Hello Houston, are you reading Skylab?"

There was no doubt it was clearly a woman's voice coming down the link from Skylab.

A hesitant Bob Crippen, the Capcom, answered, *"Skylab, this is Houston. I heard you all right, but I had a little difficulty recognising your voice. Who have we got on the line here?"*

Skylab: *"Houston, Roger. I haven't talked with you for a while. Is that you down there, Bob? This is Helen here, in Skylab. The boys hadn't had a home cooked meal in so long, I just thought I'd bring one up. Over."*

By now a small crowd was gathering around the Capcom this was going to be interesting.

"Roger, Skylab. I think somebody's got to be pulling my leg, Helen. Is that really you? Where are you?"

Owen Garriott with his wife
Helen Mary Walker Garriott. Image: NASA

Skylab: *"Just a few orbits ago we were looking down on the forest fires in California. You know the smoke sure does cover a lot of territory. And, oh, Bob, the sunrises are just beautiful."*

A pause, and then an urgency crept into the voice,

"Uh, oh. I have to cut off now I see the boys are floating up towards the Command Module and I'm not supposed to be talking to you. See you later, Bob. Bye."

The gang around the Capcom and at the consoles shook their heads in disbelief as uproarious laughter rang in their ears from the crew in Skylab.

Owen Garriott, *"It started about two months before launch. I knew I would certainly be seeing some sort of natural event from space such as forest fires or hurricanes. I also knew who the Capcoms were going to be – Bob Crippen and Karl Henize – so I prepared four different scripts in which I would show my wife talking about seeing either a hurricane or a forest fire and talking with either Bob or Karl and left a gap in there for the appropriate answer. I gave the scripts to both Crippen and Henize.*

It think it was about day 43 of the mission, sure enough there were forest fires in California, and I knew they had been in the newspapers. I knew Bob Crippen was going to be the Capcom, in fact I had just been talking with him. I just made one comment at the end of one our ground station passes: 'Bob I will have something for you on the next pass' and he said 'Roger, Owen,' – he knew exactly what I was talking about. When the next station came along in about fifteen minutes he had a chance to pull this little script out of his pocket and review the words he was going to say. When we had AOS (acquisition of signal at the station) *all I did was open the mic and start the tape recorder."*

After the pass the Flight Director asked, 'What's going on, Bob? How did they do that?' and Crippen answered, 'Gee – the voice just came down, and I responded as you saw – I don't know how they did it.' How we did it was never explained until the twenty-fifth anniversary party in Houston and all the Flight Directors were there and I told them then."

Listen to the Prank Conversation

Prank tape segment with Helen Garriott *"on Skylab"*, *"speaking"* to Capcom Bob Crippen in Houston Mission Control.

With thanks to Phil Maier who recorded this at Honeysuckle Creek on one of the 1" voice tapes.

LISTEN

2.1mb mp3 file. Running time – 2m 16s

On their last day the crew were woken up over Carnarvon with a record of Dean Martin singing *"Going Back to Houston"*, played up the radio link, and they landed 9.6 kilometres from the USS New Orleans at 1519 USPDT on 25 September (0819 AEST on 26 September).

Above: Mission Commander, Alan Bean during EVA3.
Images: NASA
Below: Science Pilot, Owen Garriott retrieves an imagery experiment during EVA3.

Alan Bean is strapped in to the back-mounted, hand-controlled
Automatically Stabilized Manoeuvring Unit (ASMU), aka M509 Astronaut Manoeuvring Equipment .
This was a testbed for the Manned Manoeuvring Unit (MMU) used on later Space Shuttle missions.
Image: NASA

Pranked! The Skylab 3 crew setup three mannequins as a surprise for the Skylab 4 astronauts. Image: NASA

Above: Skylab 3 Command Module in ‘Stable One” position, attended by Navy recovery divers.
Images: NASA

Below: Jack Lousma, Owen Garriott and Alan Bean on board the USS New Orleans.

Skylab IV (3) Crew – Jerry Carr, Ed Gibson, and Bill Pogue. Image: NASA/JSC

PRIME CREW

Commander: Gerald P. Carr
Science Pilot: Edward G. Gibson
Pilot: William R. Pogue

BACK-UP CREW

Commander: Vance D. Brand
Science Pilot: William B. Lenoir
LM Pilot: Don L. Lind

SPACECRAFT

Command Module: CSM-118
Launch Vehicle: Saturn 1B - SA-208

SKYLAB IV – VISIT 3

SL4 (Skylab 4) – Saturn 1B SA-208 – CSM-118

EVENT	U.S.A.	AUSTRALIA
Launch – LC 39B	09:01:00 EST 16 Nov. 1973	01:01:00 AEDT 17 Nov. 1973

Time in space:	84 days 01 hr 15 mins 30 secs
Number of Orbits:	1,214
Distance travelled:	55.5 million kilometres
Total EVA time:	22 hours 22 minutes
Spacecraft weight:	20,847 kilograms

With the successes of the first two visits, NASA decided to extend the last period to 84 days. It was a philosophy that each successful period in space was extended by two. Project Mercury's longest mission was 7 days, Gemini was 14 days, and Skylab had 28 days and 56 days, but the last visit was only 84 days because of the limited resources of Skylab.

Skylab IV Fact Box

Launch
Launch Complex – 39B, Cape Kennedy
Friday, 16 November 1973
0901:00 US EST / 1401:00 UTC
[Saturday, 17 November 1973, 0101:00 AEDT]

Vehicles
Launch vehicle – Saturn 1B SA-208
Command Service Module – CSM-118

CSM statistic
Mass – 20,847 kilograms

Mission highlights
Comet Kohoutek observations
75,000 solar observations
First time that a solar flare was filmed in space
Extensive Earth observations and photography

Mission duration
Total mission – 84 days 01 hrs 15 mins 30 secs
Time docked – 83 days 04 hrs 38 mins 12 secs

Earth orbital data
Perigee – 422.0 kilometres
Apogee – 437.0 kilometres
Orbital period – 93.11 minutes
Inclination – 50.04°
Total orbits – 1,213
Distance travelled – 55.5 million kilometres

EVA – Extra Vehicular Activities
EVA-1
When – 17:24 – 00:15 UTC, 22 November 1973
Total time – 6 hours 33 minutes
Astronauts – Ed Gibson and Bill Pogue

EVA-2
When – 16:00 – 23:01 UTC, 25 December 1973
Total time – 7 hours 01 minute
Astronauts – Gerald Carr and Bill Pogue

EVA-3
When – 17:00 – 20:29 UTC, 29 December 1973
Total time – 3 hours 29 minutes
Astronauts – Gerald Carr and Ed Gibson

EVA-4
When – 15:19 – 20:38 UTC, 3 February 1974
Total time – 5 hours 19 minutes
Astronauts – Gerald Carr and Ed Gibson

Splashdown
CM – 4 February 1974 – 16:15:53 UTC
Location – North-western Pacific Ocean,
off San Diego, California
– 31°18'N 119°48'W
Recovery vessel – USS New Orleans

There was trouble before the space vehicle even left the ground.

Hairline cracks were found in the Saturn IB's stabilising fins and some support beams. The fins were replaced, and the beams were strengthened before it was launched at 0901 USEST 16 November (0101 AEDT 17 November) 1973 to rendezvous with Skylab in 7 hours.

After three attempts Carr called down, *"We got a hard dock, Houston. Whew! Glad to be here great to be home,"*

…and the astronauts began to transfer thousands of items, weighing almost an earth ton, into their new home. As they floated into the laboratory they were surprised to find that there were already three astronauts aboard one riding the exercise bicycle, one in the lower body pressure device, and one on the toilet. Bean and his crew had stuffed three flight suits with clothes and propped them in position!

Houston: *"Hey, did you find enough food up there for six?"*

Gibson: *"The other three don't eat much!"*

Carr: *"They are also very quiet!"*

The third crew promptly began on the wrong foot. Shortly after arriving in the laboratory Carr and Pogue were feeling queasy until Pogue finally vomited. Mission rules required them to report the incident to the ground, and to store a vomit sample for later analysis but they decided to keep it quiet.

Carr said: *"We won't mention the barf; we'll just throw it down that trash airlock."*

"It's just between you, me, and the couch," agreed Pogue.

The couch, however, was listening!

They forgot all about it and continued with the mission unaware the whole conversation had been recorded and dumped via a tracking station to Houston where it had been dutifully typed up, along with the rest of the day's conversation, and placed on appropriate desks for perusal by officials the next morning. The public reprimand by Alan Shepard that followed began an uneasy relationship between the crew and the ground controllers until it boiled over and was sorted out later in the mission.

The final time! The Skylab 4 mission launches from Launch Complex 39B. Image: NASA/KSC

The Skylab IV's view of the space station as they approached for docking. Image: NASA

Until they became used to it, they found that the floating about was more difficult. They were overshooting and bumping into objects. When Carr, an aeronautical engineer with a hand in developing the Lunar Rover, tried to get a pill out of a bottle it didn't fall out when he turned the bottle upside down. In the struggle to get it out of the bottle the pill shot out and two of them ended up chasing it across the laboratory.

Reading, a popular pastime on earth, was more difficult in Skylab due to diversions.

> *"It was a shame to read with all that was going on outside,"* said Gibson, *"I would read a little when Skylab was over water, but when we reached the shore I would put the book down, and look at the continent below."*

Carr would sneak off to the Command Module, the most private place, turn the speaker off, and get some reading done that way.

There were so many experiments and observations that they had to be interlaced with each other and with the astronauts living requirements. For instance, one astronaut could be lined up recording a sensitive event on the sun, and the other two might decide to swing the laboratory around to measure an unexpected event on the earth. Or one astronaut could be measuring a delicate reading from the earth when another begins riding the bicycle, vibrating the laboratory.

They also had to work together with parallel measurements and observations on the Earth's surface, watched by aircraft flying below. These were called "ground truths" so that the results could be compared with each other to check the accuracy of the laboratory measurements. A cough, or even just pressing the button on the water fountain at the wrong time could ruin a delicate measurement, particularly when doing measurements on the sun. Some of the cameras could be operated from the ground, so sometimes the scientists looked forward to the astronauts going to sleep so they could make sure of sharp photographs.

As Houston refined their scheduling methods, and encouraged by the affable, responsive second crew, they had the third crew so pinned down with constant tasks that they rebelled.

Top (left and right): Gibson testing cardiovascular function on the bicycle ergometer.
Middle: Gibson taking a blood sample from Carr for a medical experiment.

Bottom left: Carr, assessing Gibson's cardiovascular system in the lower body negative pressure device.
Bottom right: Carr exercising on the treadmill.

"Our system was designed to squeeze every minute out of the astronauts' day," said Neil Hutchinson, one of the Flight Directors, *"We sent up 6 feet of instructions to the astronauts' teleprinter every day at least 42 separate sets of instructions."* Fed up with trying to meet the ground's increasing demands, half way through the third mission all three astronauts took a day off and just enjoyed their favourite activity.

"On the ground I don't think we would be expected to work a 16 hour day for 84 days, so I really don't see why we should even try up here," Carr pointed out to the surprised Houston Flight Controllers, *"We'd all kind of hoped before the mission that everybody had the message that we did not plan to operate at the second crew's pace. I'm also getting the feeling from some of the questions that have been asked of us the last few days that people are beginning to hassle over who gets our time, and how much of it. I'd like to know just exactly what everybody's motives are when they're asking those questions. We'd like to be in on the conversation, and we'd like to have some straight words on just what the situation is right now."*

This frank discussion cleared the air, and Houston dropped the workload and gave them more time to relax, and almost immediately performance and communication with the ground improved. In the end, they completed more work than had been planned.

During their twelve weeks in orbit the astronauts were able to watch vegetation changing colour with the seasons, and a wonderland of sights as they roamed over the Earth's surface.

"Holy Cow!" was a typical exclamation as they watched the lights of the American eastern seaboard from the Great Lakes to the Gulf, *"It's like a spider web with water droplets on it."*

The astronauts found there were endless demonstrations with a simple globule of water. Ejecting water from a syringe, Gibson found that the water formed into a perfect sphere. They made a number of them, and injected coloured dye to make them more visible.

Pogue tried to join two together, *"Okay, we have two bubbles here. We're gonna try to get them together. Actually, I think they are touching and bouncing apart, which is sort of interesting … there we go!"*

…and the two balls fused into a large one. Then he injected air into the sphere with a syringe, and the sphere inflated like a balloon. They could the stretch the clammy water into a long thin strip, or mould it into a wide, flat bar.

Skylab provided the largest single effort to study the Sun ever undertaken. At Skylab's height the Sun's ultraviolet and X–ray emissions are not absorbed by the Earth's atmosphere, and the extremely faint corona, normally only visible in detail during rare total eclipses, could be observed continuously. During all three manned periods the crews had kept an eye on the sun, looking for a solar flare. Gibson, a solar physicist and author of the textbook The Quiet Sun, kept a steady vigil on the Sun, patiently watching and waiting, day after day. At last, he was rewarded on January 21 a bright spot appeared and began to intensify.

With film running low Gibson took a chance and initiated a picture sequence. He was rewarded when the spot erupted, and he photographed the birth and total life of a 4,023,250 kilometre solar flare for the first time in history.

After studying and photographing Comet Kohoutek, Carr and Gibson were out on a spacewalk when the comet came from behind the sun,

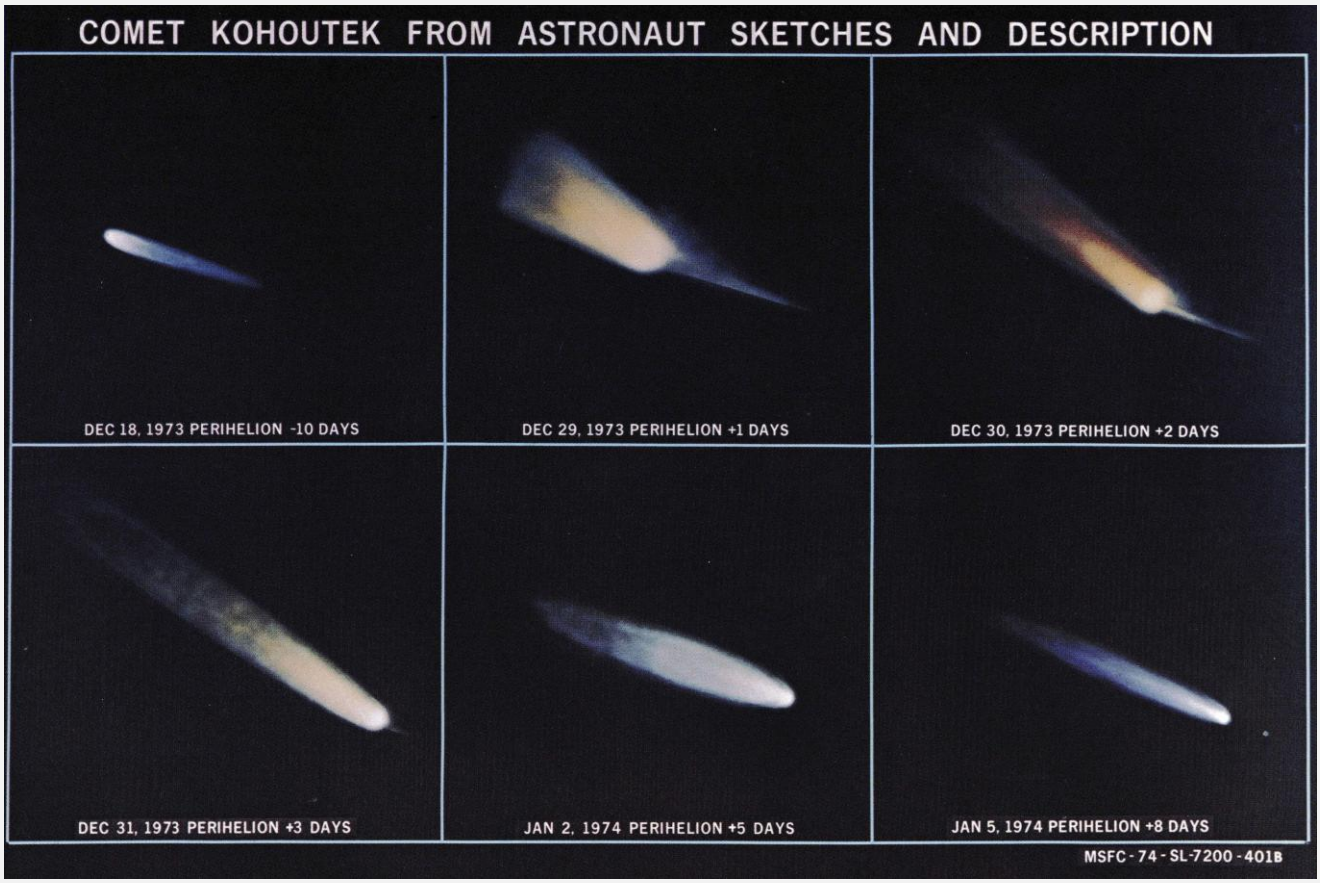
"It looks yellow and orange, just like a flame," Carr reported.

On Friday 8 February 1974 the third crew left the laboratory orbiting the Earth.

"Say goodbye for us," asked Capcom Robert Crippen, *"She's been a good bird."*

Although they knew nobody would be coming back, they left it in full commission, renewing the charcoal air purifying filters, and leaving a bag of food, film, and selected items by the entrance.

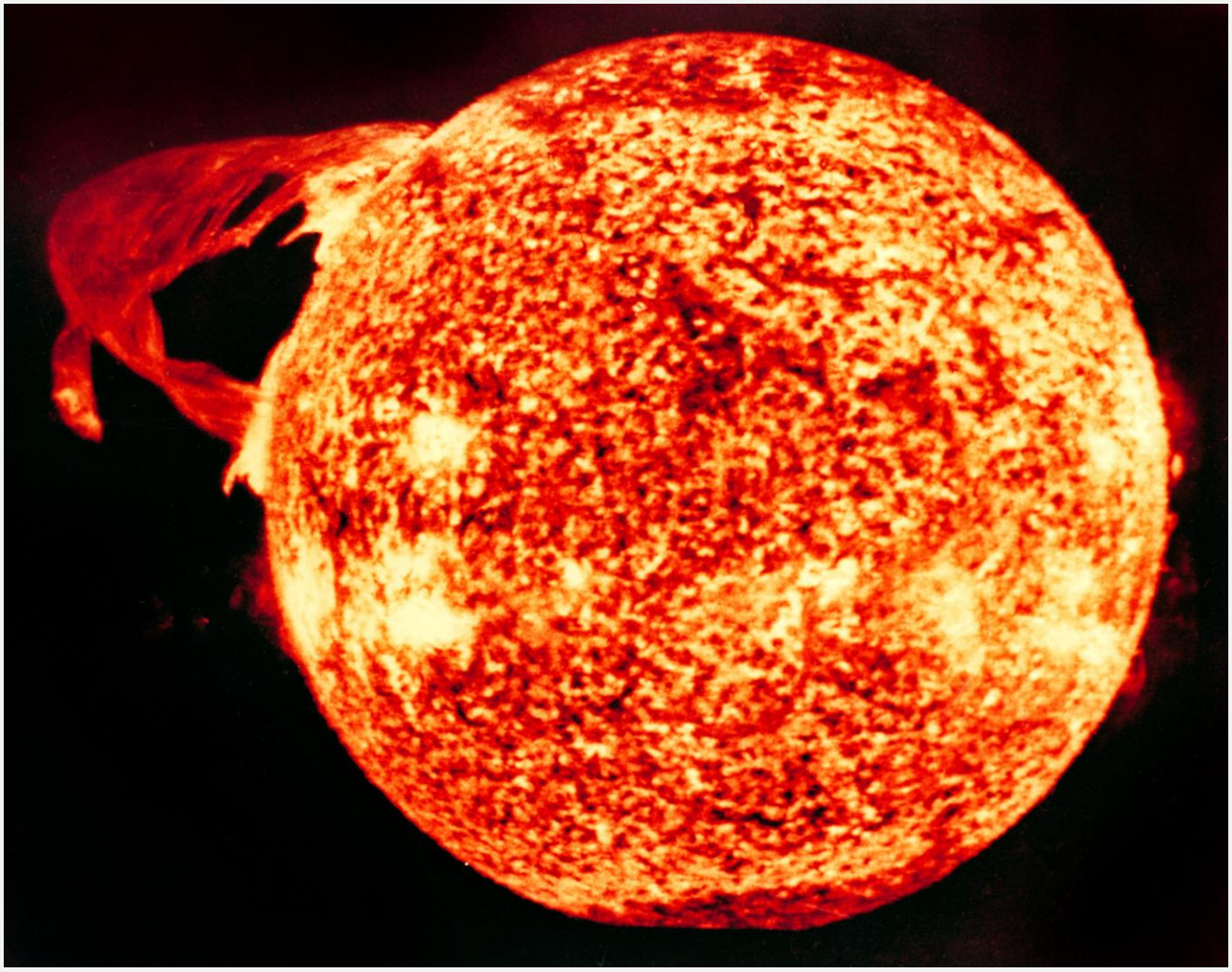
The Command Module splashed down at 0717 local USPST time 8 February (0217 AEDT 9 February) 1974, 4.8 kilometres from the carrier USS New Orleans stationed 282 kilometres south west of San Diego, California.



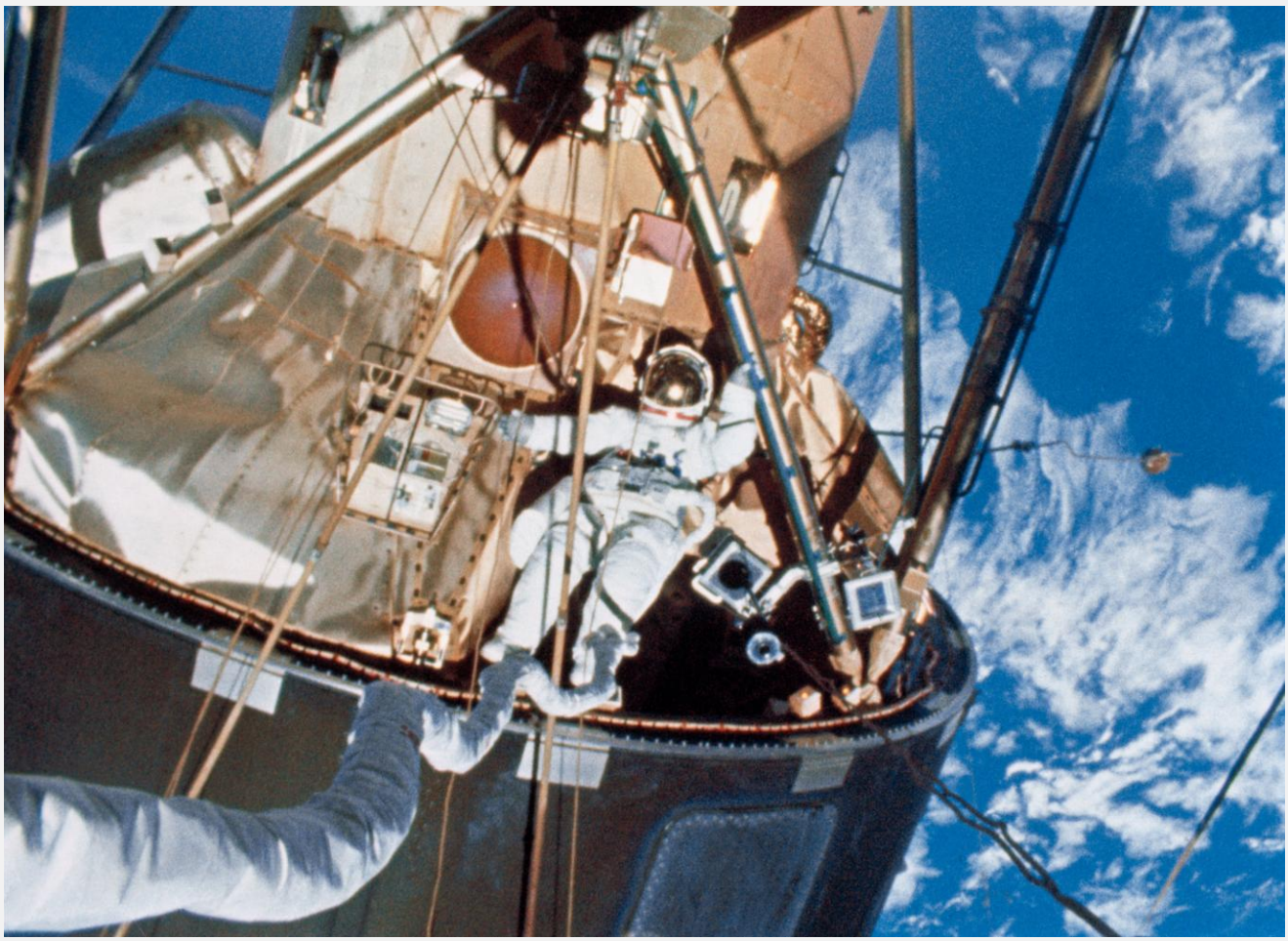
Above: A composite of six drawings made from astronaut sketches and descriptions illustrating the progress of the Comet Kohoutek.

The Skylab 4 crewmen monitored the comet during their mission in Earth orbit. Sketches by the crewmen accompanied by their commentary helped ground-based scientists better understand the status of Kohoutek. The Comet Kohoutek passed the Sun on December 28, 1973 (perihelion) at a distance of about 20,800,000 kilometres (13 million statute miles)." Images and text from a NASA press release, scanned by Phil Maier.

Below: Professor Lubos Kohoutek talking with the crew from Mission Control in Houston. Image: NASA/JSC



Above: A gigantic solar flare captured during Skylab IV.
Images: NASA
Below: Pogue at the controls of the Apollo Telescope Mount.

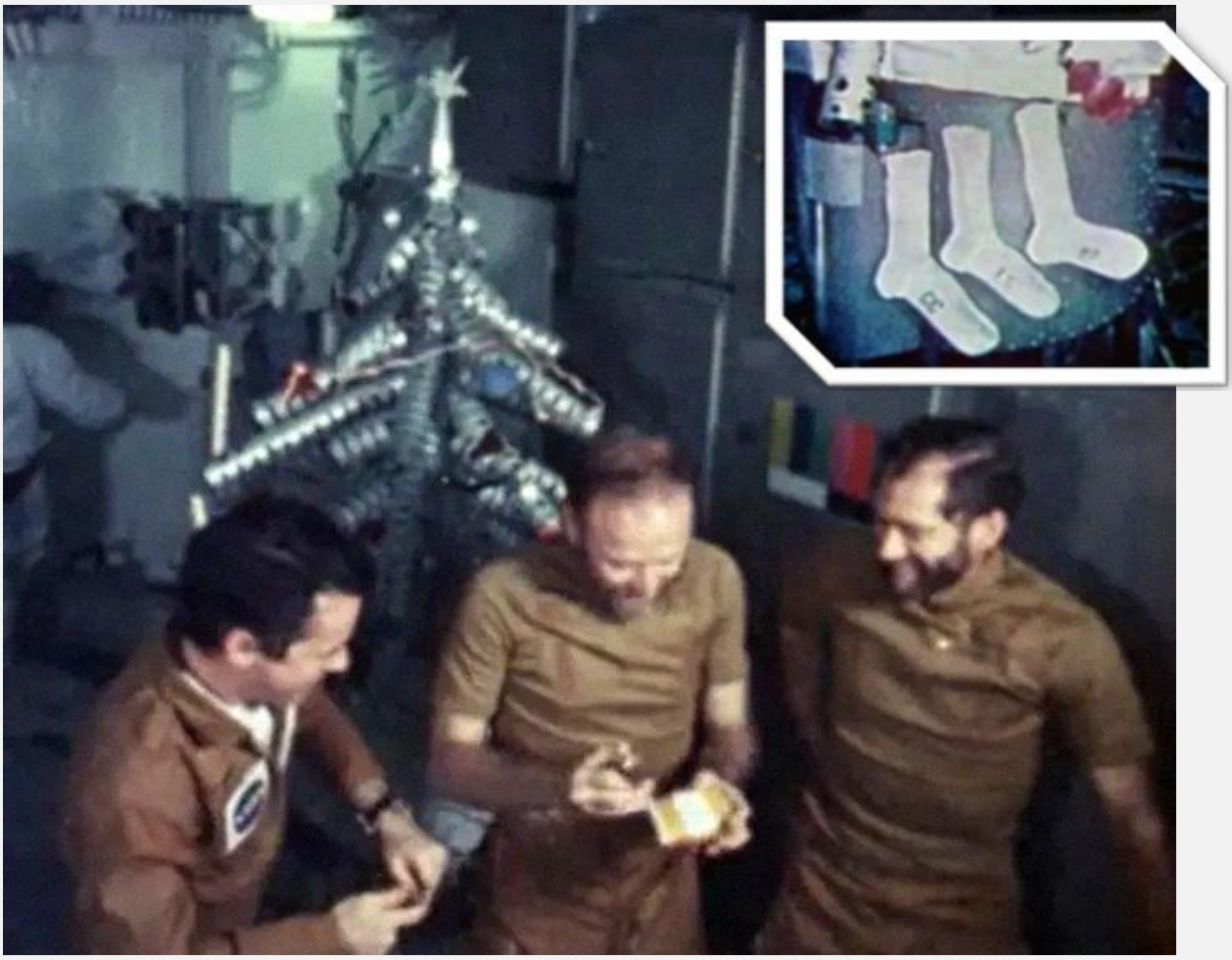


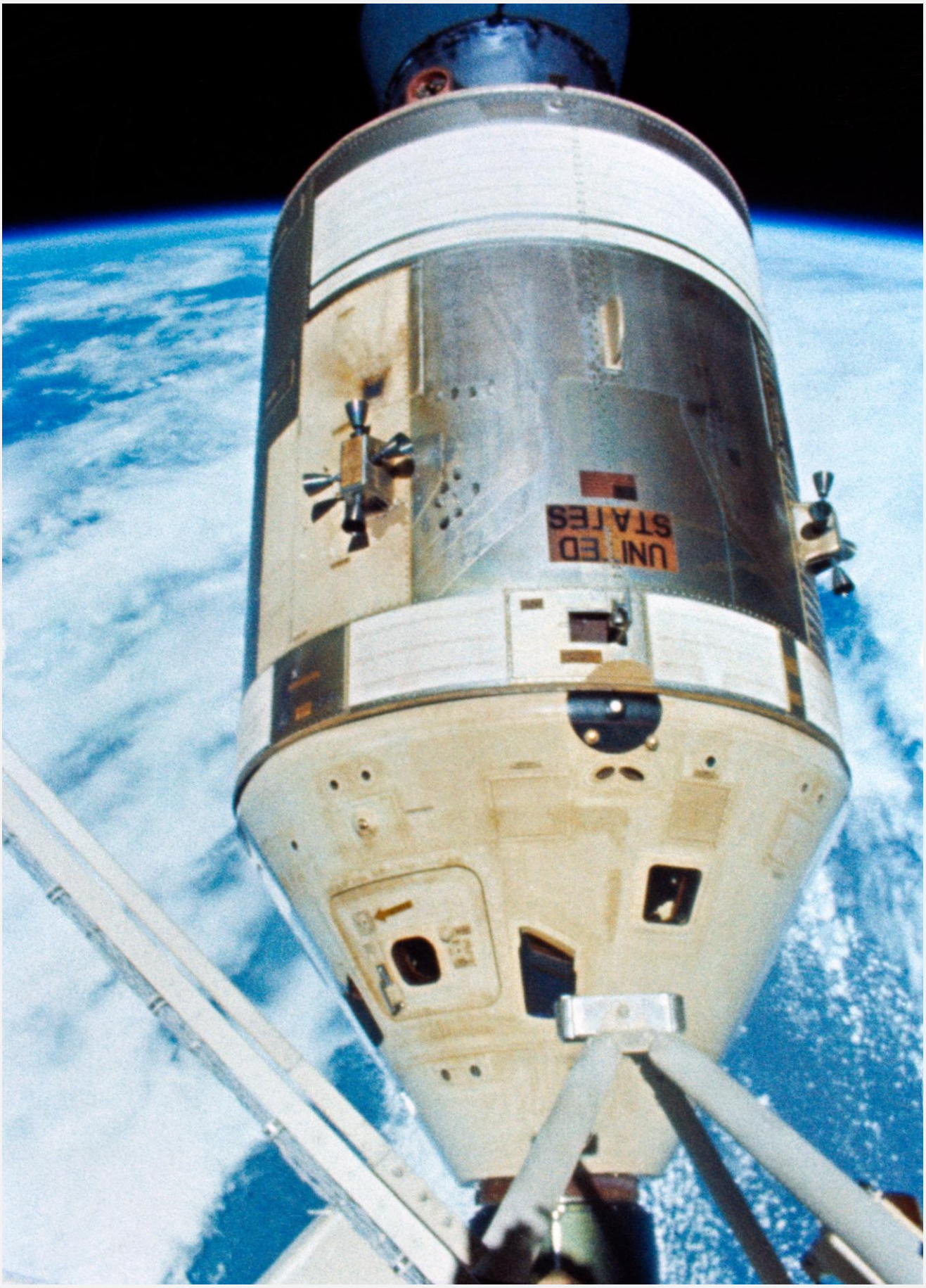
Gerald Carr snapped this photo of Ed Gibson during EVA4. Image: NASA

Bill Pogue and Gerald Carr at the Earth Resources Experiment Package (EREP) panel, in Skylab's Multiple Docking Adapter. EREP consisted of six remote sensors used for Earth observations. Image: NASA

Above: Carr (left) and Pogue, watch Gibson place a shooting star/comet on their makeshift Christmas tree. Images: NASA

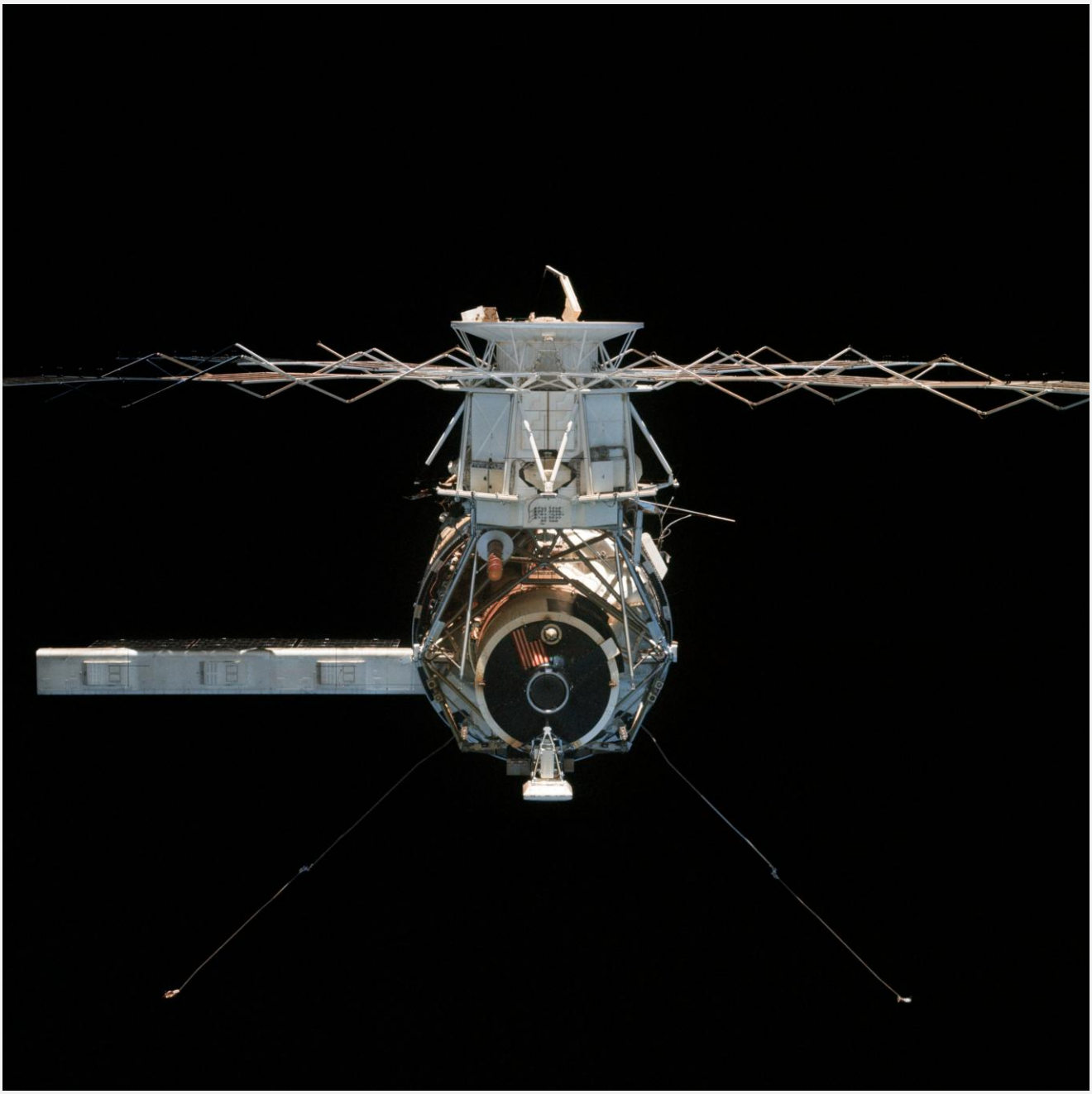
Below: Opening gifts on Christmas Day. The astronauts hung their stockings with care!





The Skylab IV Command Service Module attached to Skylab's Multiple Port Adapter.

Image: NASA



The Skylab IV's view of the now empty space station after undocking. Image: NASA

Kranz's comments on the last visit were: *"We had a very competent, very experienced ground team in Mission Control really charging along and all of a sudden you are faced with a rookie team, and it takes you a few days to figure that out. It was a very strong learning experience for both of us. We had to make some adjustments."*

Chris Kraft: *"This last trip was a lot tougher than met the eye. People on the ground were concerned about their welfare. We didn't think we were sending up too much work, but it turned out to be the case, so we backed off on their request. I think they were overcome by the amount of activity they were required to do but when they got used to doing it they wanted to do more than we had planned in the first place. In the end they ended up doing a lot more than we ever had planned for a day. I think their attitude turned around."*

On 9 February, after some experiments such as erasing a computer memory and reloading it, Skylab was put in a vertical attitude with the docking hatch looking away from Earth in the hope this would prolong its life, and the last command was sent to switch the telemetry off. By this time the laboratory was showing signs of wear and tear. The gleaming gold, white, and silver paint on the outside was becoming

tarnished, the white paint had browned, and the gold had baked and blackened.

Despite the initial setbacks, Skylab had met, or exceeded, every requirement placed upon it.

Originally planned for 140 days, Skylab was manned for 171 days, 13 hours, and 14 minutes, taking the crews around the Earth 2,476 times; a distance of 113,455,650 kilometres. This was a lot more than all the previous American manned spaceflights put together, which totalled 146 days, 21 hours, 36 minutes, and 8 seconds. 565 hours of sun observations were planned, 755 were actually spent; 701 hours of medical experiments grew to 822 hours; and instead of only 60 earth observation passes, they eventually completed 90.

With help from the best scientists from 28 nations, Skylab had looked closely at the Earth 430 kilometres below the crust, the mountains, the oceans, forests, and deserts; the sun above the sunspots, the corona, flares, emissions, and solar wind. The planets, comets, including the Comet Kohoutek, meteors, asteroids, and the stars beyond.

Internally it studied the effect of space on living organisms, including humans, and manufactured specialised items such as perfect crystals. 17 experiments suggested by high school students were tried. Some 60,960 metres of magnetic tape and 50,000 photographs were produced during the mission, which contrasts with the first Mercury flight when a single camera was regarded as a distraction from the task of flying the spacecraft.

Above: After splashdown, the Command Module was floating apex-down position, aka 'Stable Two'.
Below: Gibson, Carr, and Pogue receiving medical attention on the USS New Orleans. Images: NASA

Summing Up the Medical Aspects

Briefly summing up the effect of space and zero gravity on the astronauts some interesting facts were revealed.

Spaceflight produces many unusual stresses on the body and mind high acceleration forces at launch with long periods of weightlessness between, radiation such as heavy energetic atomic particles from the sun (HZE radiation) more intense and dangerous than anything experienced in Earth. High noise levels from life support machinery and rocket motors, long periods of isolation, nagging vibrations, and the absence of 24 hour day/night cycles all take a heavy toll on the metabolism of the astronaut.

The longest flight in space by a human when this was written was completed on the 22 March 1995 by Dr. Valeriy Poliyakov, in the Russian Mir space station. He remained in space for 678 days 16 hours 33 minutes, passing the previous record of one year on 9 January.

There was a marked difference between the three Skylab crews when they returned to Earth. There was also a marked difference between the members of the first crew. When they first walked on the carrier Conrad was quite steady, but Weitz walked with his legs apart to keep his balance. Kerwin was unable to walk a straight line at all. This seemed to reflect back to their exercising in the laboratory Conrad did the most, Weitz less, and Kerwin, the doctor, by far the least.

> Kerwin explained his poorer condition: *"I had a brilliant inspiration as we got close to re-entry, an inspiration which was basically true and has been used by all the shuttle flights. When we came back to gravity we were going to be dehydrated because we had dumped fluid overboard as part of our adaptation to weightlessness, so I needed to drink some extra fluid but the mistake I made was instead of drinking it just prior to re-entry, which is what the shuttle crews do, I decided to drink it after splashdown on the water. As soon as we were in good shape after splashdown I went down to the lower equipment bay and I got a container of strawberry drink, and I chug–a–lugged it. That was a mistake because then I got seasick, though I didn't throw up until I got into the sick bay on the ship."*

The first crew with the shortest time in space were in the poorest shape and the last crew with the longest time the best. It appeared that there was an adapting period and round about the twentieth day was the lowest point, then the body recovered in the following four to five weeks.

> Gibson complained during the flight: *"Our faces are puffed and slightly chubby and red, resembling what you would see in someone hanging upside down in one G, only not quite as pronounced. We also have the feeling of a stuffy nose, and slightly bloodshot eyes."*

They felt they were getting colds all the time and sneezed a lot.

Skylab meals had progressed a long way from the primitive attempts in Mercury. The food intake by each astronaut was calculated by computer, with supplements automatically prescribed to make up for deficits from the previous day.

Motion sickness in space was a serious problem; almost half of the astronauts sent into space during the Apollo period were affected. It appeared to last for the first two or three days in space, then almost all cases disappeared within a week, when repatterning of the central memory network occurred so that unfamiliar sensations from the eyes and ears start to be correctly interpreted. Motion sickness still occurs in today's shuttle flights but is controllable with medication – generally Phenergan. So far there is no evidence that the brain will improve its performance in space with a better blood supply from weightlessness.

Most of the symptoms such as pooling of blood in the legs, muscle soreness, loss of liquid, heart rates, returned to normal in a week or so, the first crew taking longer to recover. In fact, the third crew, which exercised the most, recovered so quickly that their surgeon said that by the fifth day a doctor unfamiliar with them would have a hard time knowing they had been in space at all.

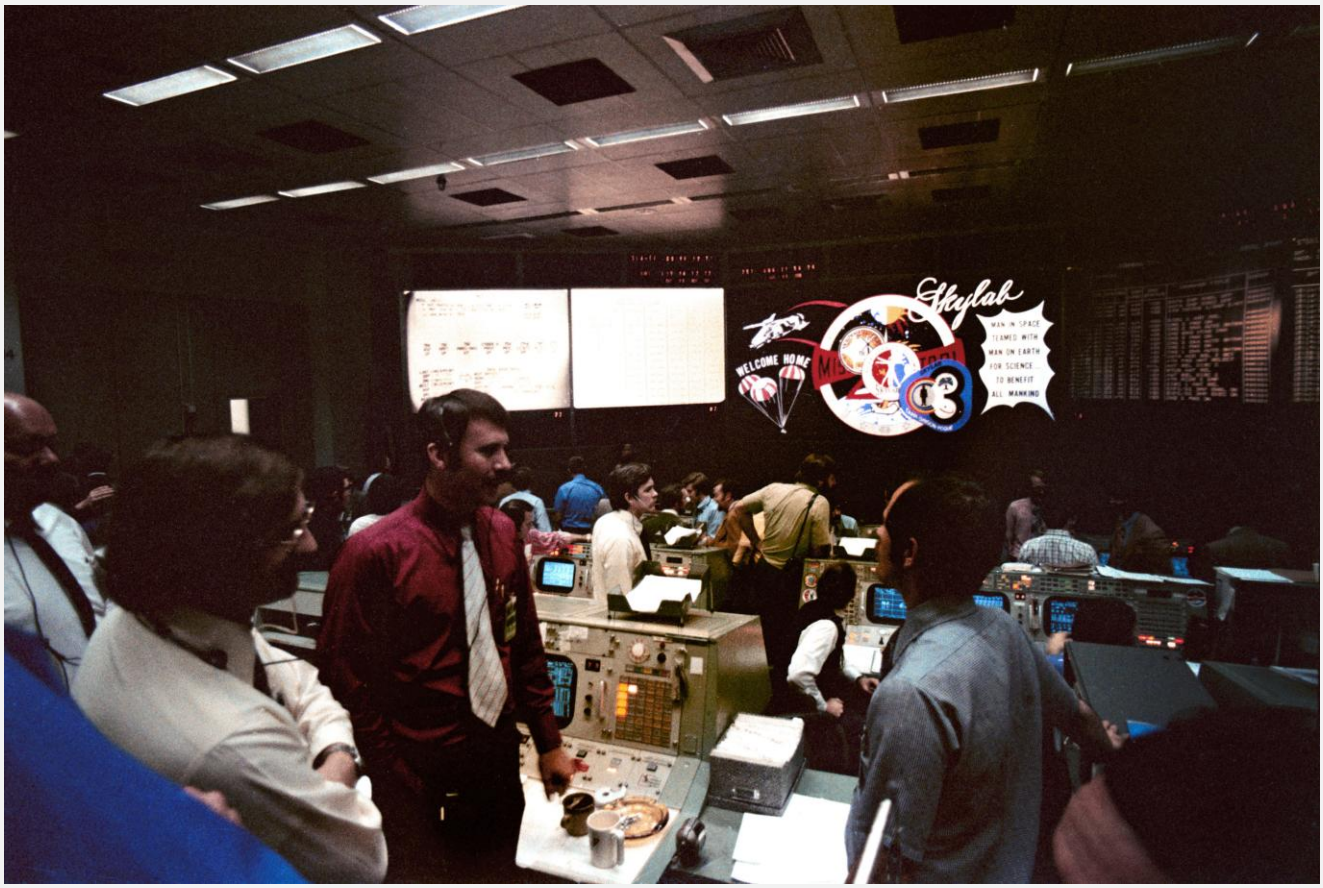
Of greatest concern was the bone calcium loss never stabilised in space at all. Without use, bones and muscle tend to shrink or waste away at a rate that would only allow missions of up to twelve months before remedial measures would be necessary. The Skylab missions produced a

continuous loss of bone and muscle tissue, the last crew suffering the most loss of 7% from their heel bones, but it did return to normal once back on Earth. They all grew 2.5 cm or so in height due to the vertebrae expanding from lack of gravity and more blood being absorbed by the tissue between the disks. Their pulses were generally 20 beats per minute slower than on Earth.

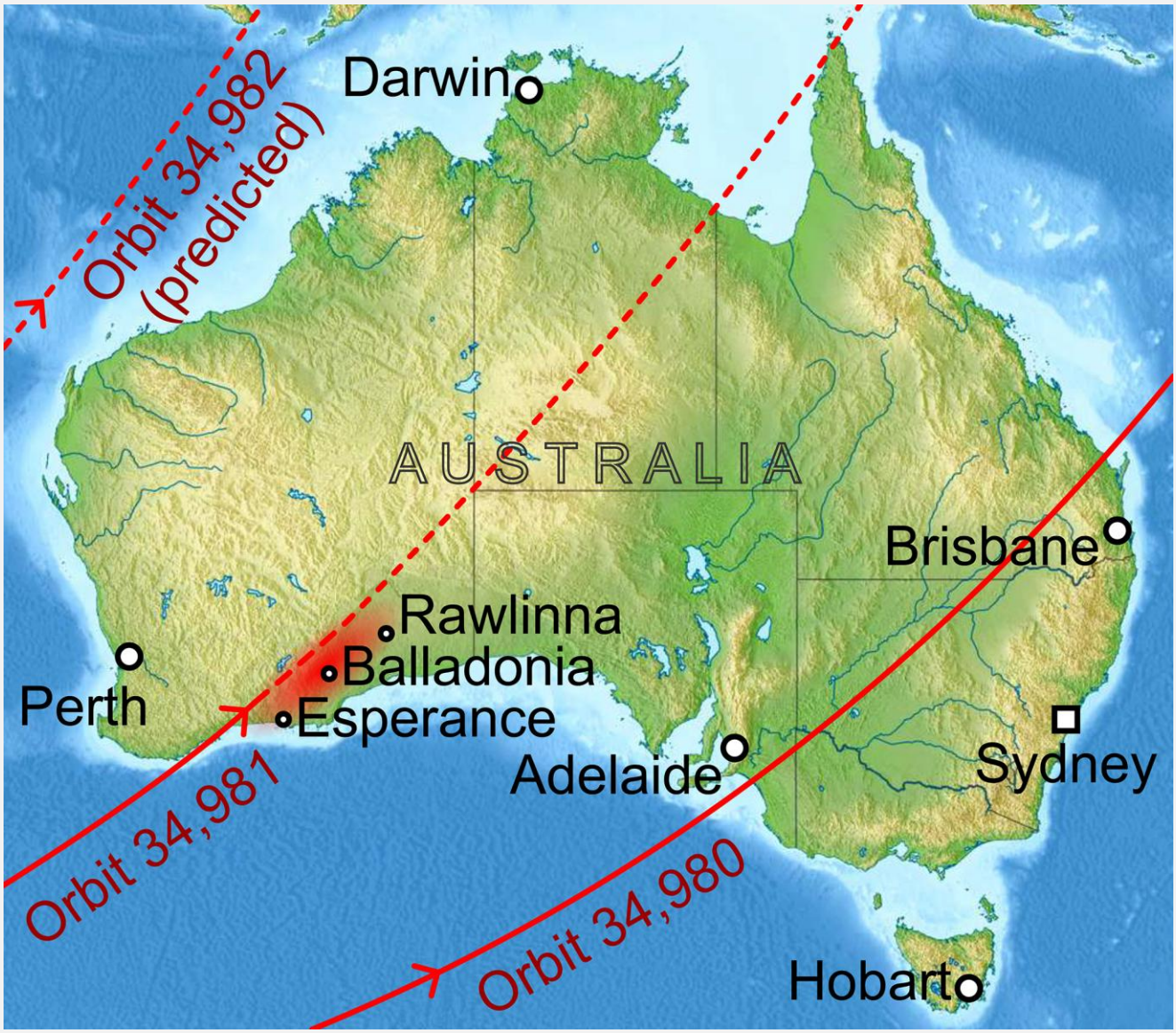
Alan Bean said on his return: *"I felt great in space, but right now I feel anaemic. I feel like I want to lie down all the time."*

Kerwin commented on his return: *"I had an awful feeling that the world was about to swallow me up."*

Rocco Petrone: *"In my opinion, the finest accomplishment of Skylab was the demonstration of the uniqueness of man in space in solving problems and overcoming obstacles in the face of extreme adversity."*



Above and Below: Views of the Mission Control Centre after Skylab IV's splashdown, and the end of the Skylab space station program. Images: NASA/JSC



Skylab came crashing back to Earth over Western Australia, between Esperance and Rawlinna. Diagram sourced via NASA, courtesy of Ben Cooper.

1979 – End of Skylab and the Apollo Era
Skylab Bites the Dust in Australia

NASA had expected and planned to keep Skylab operational until the 1980s and the new Shuttle spacecraft could bring it to life again.

Unfortunately, by February 1978 Skylab's days became numbered when an increase in sunspot activity warmed up the Earth's atmosphere and caused it to expand and reach out for the orbiting laboratory.

Bill Peters was put in charge of a program to try and prolong the life of Skylab:

"We thought that if we could stop it tumbling and lower the drag it would stay in orbit longer. We went out to the Bermuda tracking station in March 1978 as it was the only place that still had the old Skylab ground equipment. There was a guy at Patrick Air Force Base looking at it visually and he could tell when the solar panels were facing the sun. He would call out (on a phone line) 'It's dark - okay now the wings are facing the sun,' and I sent a command to turn it on, and the RF down-link came on immediately. But as soon as the solar panels looked away from the sun it shut down. We only had the solar cells working - no batteries.

Having found we could actually get the thing to power up we came back to the Control Center at Houston and in less than thirty days we designed and built new computers and software and started operations. First of all, we had to charge the batteries. The batteries were turned off as they had special circuits that stopped you using

the batteries if the voltage dropped below a certain level. Each time we tried to turn the batteries on we could get a few milliamps of current into the batteries before the circuitry turned it off again. So, we just kept sending ON commands - we sent thousands and thousands of ON commands through the tracking stations at Bermuda and Madrid, which came on line later. We spent April and May charging batteries until eventually we got them all up to the right voltage. I remember sitting there looking at the strip pen recorder which gave a bleep when the sun sensor came on. At that moment I sent the command, I think it was through Madrid, to hold attitude. We didn't stop it tumbling until about June, when we could enable the gyros to hold the lab in that attitude."

The Shuttle was still struggling to get off the ground, so as Skylab began to approach the first wispy tops of the Earth's atmosphere the increasing resistance began to drag it down until there was a new predicted re-entry in June or July 1979 when it was expected to end its life disintegrating into a molten fireball - but where would it come down?

Bill Peters: *"They had a series of six orbits for it to come down in at the right altitude and as fate would have it we didn't have to do anything to get within those six orbits."*

Toward the end of April, NASA Headquarters issued its first forecast of a re-entry date calculated from NORAD's model. On the 25th, when the workshop had fallen to about 320 kilometres, NORAD estimated a probability of 50% that Skylab would come down by 19 June; there was a 90% chance that it would re-enter between 13 June and 1 July. This format was used consistently for the rest of the waiting period, because it was impossible to give a more precise estimate until re-entry had virtually begun. NASA and NORAD did exchange information and determined the different ways the two computer models treated data. NORAD made a fairly straightforward extrapolation based on recent observations, while NASA continuously took account of changing atmospheric density and the spacecraft's drag profile as it came down.

At NASA headquarters the staff went onto 24 hour duty during the three day Skylab "death watch," beginning on Sunday, 8 July. The Johnson Space Center, the Marshall Space Flight Center, and the Kennedy Space Center stood by. Charles Harlan, Director of the Johnson Space Center's Flight Control Division in Houston commented, *"Clearly you could come in on an orbit with a lot of people and not hit a soul, or you could come in on an orbit with a few people and hit a schoolhouse and kill a bunch of kids."*

Telephones began to ring incessantly with serious, funny, and frightened people wanting to know what was happening and complaining their holidays were ruined. The news media moved in, and by Tuesday there were representatives from the White House, the Federal Preparedness Agency, and the Departments of State, Justice, and Defense set up in the NASA offices. News bulletins were issued every six hours, then every hour as Skylab plunged back to Earth in its final death throes over the Indian Ocean on Thursday 12 July 1979.

They began 111 kilometres over Ascension Island in the Atlantic when the radar station there spotted the big solar panels begin to tear off as the lifeless hulk spun and twisted out of control.

"It's now out of range of all our tracking stations," said NASA, *"The crash line is from Esperance in Western Australia to Cape York in Queensland. The chances of anybody coming to harm are minimal, but people are advised to stay indoors."*

During Skylab's last week in space, the Australian Federal Government set up a special Skylab Communications Centre in the Deakin Telephone Exchange in Canberra. Manned by about 12 officials from 5 departments, it monitored every move Skylab made over a hot line from Washington. Police and emergency services around Australia were put on alert. People all around the Earth under its flight path nervously wondered …

In the United States all aircraft in the northeastern and northwestern areas were grounded as Skylab passed overhead for the last time. Four hundred members of the world's media had gathered at NASA Headquarters in Washington where a statement was issued that Skylab had come down safely in the Indian Ocean, calculated from the last radar tracks.

Above: Operators in Mission Control at NASA's Johnson Space Center in Houston during the Skylab re-entry. Images: NASA/JSC

Below: Managers and flight controllers monitor Skylab's re-entry.

Some celebrations had already begun in America for the safe ending of Skylab.

Then, quite unexpectedly, there were disjointed reports from around the desert 800 kilometres behind Perth.

"There have been reports of sightings of fragments over Australia from Kalgoorlie, Esperance, Albany and Perth," NASA officials announced. In the middle of winding up the story on the end of Skylab the journalists at NASA headquarters in Washington were electrified into action:
"Where's Albany?".... "How do you spell Kalgoorlie?" .... "Where's this Perth?"

…and suddenly the sleepy little outback towns of Kalgoorlie, Albany, Rawlinna, and Balladonia were thrust into the world's major newspaper and media headlines.

Captain Bill Anderson was flying his Fokker Friendship 200 kilometres east of Perth on his final approach to Perth airport when his first Officer Jim Graham saw a blue light through his left window.

Anderson: *"We first saw it at 12:35 local (Perth) time we would have watched it for about 45 seconds. I had the impression it was a bubble shape. As it descended it changed from a bright blue to an almost orangey red and you could see the breakup start to occur. It finished up as a very bright orange ball in the front, and the remainder behind giving off sparks. It was a very long tail, perhaps several hundred miles long."*

Bradley Smith, an employee at Perth's Bickley Observatory, described his sighting:

"We first saw it as a light behind the clouds. It was travelling from south to east about 9° above the horizon. If you can imagine a train on fire with bits of burning fire all the way down the carriages that's what it was like."

John Seiler, managing the remote sheep and cattle station of Noondoonia 850 kilometres east of Perth saw the final moments of Skylab with his wife Elizabeth:

"I was watching for it and saw it coming straight for us. It was an incredible sight hundreds of shining lights dropping all around the homestead. They were white as they headed for us, but as they began dropping the pieces turned a dull red.

The horses on the property ran mad. They galloped all over the place, and the dogs were barking. We couldn't calm them down. Then we could hear the noise of wind in the air as bigger pieces passed over us all the time there was a tremendous sonic boom it must have lasted about a minute. Just after the last pieces dropped out of sight, the whole house shook three times. It must have been the biggest pieces crashing down. Afterwards there was a burning smell like burnt earth."

One cow was reported killed and The San Francisco Examiner offered a $10,000 prize for the first piece of Skylab to be delivered to their offices. 17-year-old Stan Thornton was watching the scene from the roof of his home in Esperance in Western Australia and saw, *"…this bunch of brightly coloured lights, followed by big sonic booms."* His mother had heard something hit the roof of their shed in the backyard, so he climbed up and found sizzling hot pieces of metal laying there.

Within a day he was bound for San Francisco where he collected his prize.

A composite image of all the Skylab crews in the training module at the Johnson Space Center.
Image: NASA/JSC

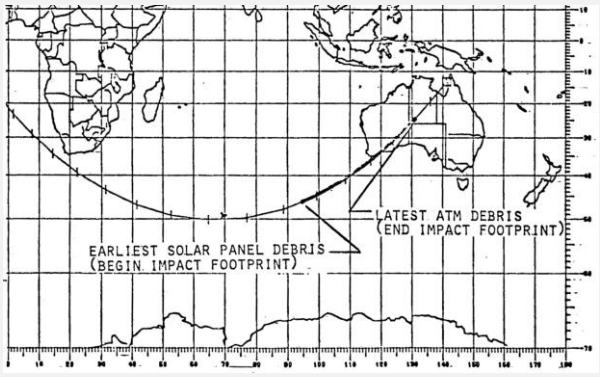
Map on display at the Esperance Museum. Photo: Mike Linney. Ortho-correction by Colin Mackellar.

The expected groundtrack (with error limits) of Skylab's final revolution – Rev. 34,981 – Skylab was travelling from southwest to northeast. Most of Skylab fell near the southern end of the track, in the locality of Balladonia, 250km ENE of Esperance.

Here's the text of the note with the map: "Map showing path of Skylab. First seen as it was flashed around the world on TV, this map shows the path Skylab took when it fell to earth at 12.30am on the 12th July 1979. Many people sat up late in the hope of a sighting. Few slept through the sonic booms and rattling of houses as it crashed around us. That no-one was injured was a miracle. Donated by NASA to the people of Esperance through the Esperance Shire Council."

NASA officially revised its re-entry bulletin to: *"Skylab re-entered the atmosphere at an altitude of 10 kilometres at 2:37 a.m. (Eastern Australian time) at 31.8°S and 124.4°E just above the tiny Nullarbor Plain town of Balladonia."*

Burning pieces of Skylab were scattered over an area 64 kilometres wide by 3,860 kilometres along the flight path.



Ground track of Skylab's final orbit and the debris footprint in the Indian Ocean and Australia. Graphic: NASA

President Jimmy Carter sent a message to the Prime Minister of Australia, Mr. Malcolm Fraser:

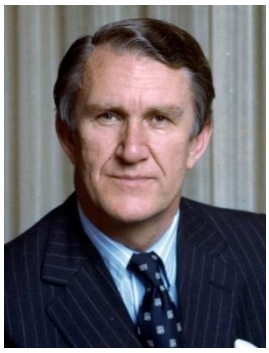
Dear Malcolm,

I was concerned to learn that fragments of Skylab may have landed in Australia. I am relieved to hear your Government's preliminary assessment that no injuries have resulted. Nevertheless, I have instructed the Department of State to be in touch with your Government immediately, and to offer any assistance you may need.

Sincerely

Jimmy Carter

Prime Minister Fraser's reply:

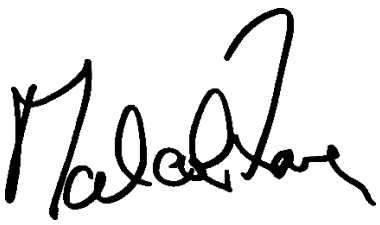


Dear Jimmy,

Thank you very much for your message. It appears we can all breathe a sigh of relief. While receiving Skylab is an honour we would have happily forgone, it is the end of a magnificent technological achievement by the United States, and the events of the past few days should not obscure this.

If we find the pieces, I shall happily trade them for additions to the beef quota.

Warm personal regards,



Malcolm Fraser.

A piece of Skylab at the Esperance Museum.
Image sourced via NASA, courtesy of Ben Cooper.

Skylab, made up of Apollo moon mission leftovers, took 6 years, 1 month, and 27 days to travel 1,413 million kilometres after 34,981 orbits of the Earth.

Dr. George Mueller's dream ended up as a few charred and twisted souvenirs of metal and fibreglass recovered by locals and tourists of the outback of West Australia, briefly setting off a mini boom in fragment hunting as NASA, and other organisations reportedly offered rewards of thousands of dollars for the biggest chunk of Skylab.

Some of the wreckage found went on display in museums and institutions around the world.

One piece of aluminium, thought to be a door weighing 82 kilograms, was found near Balladonia, WA.

The demise of Skylab brought to an end the first steps to send Americans into space. Skylab was the last operational item left from the Apollo days. It chose to end its life between the original Australian Project Mercury stations of Muchea and Red Lake – full circle from where the whole adventure had begun from Australia's point of view, just under twenty epoch making years before.

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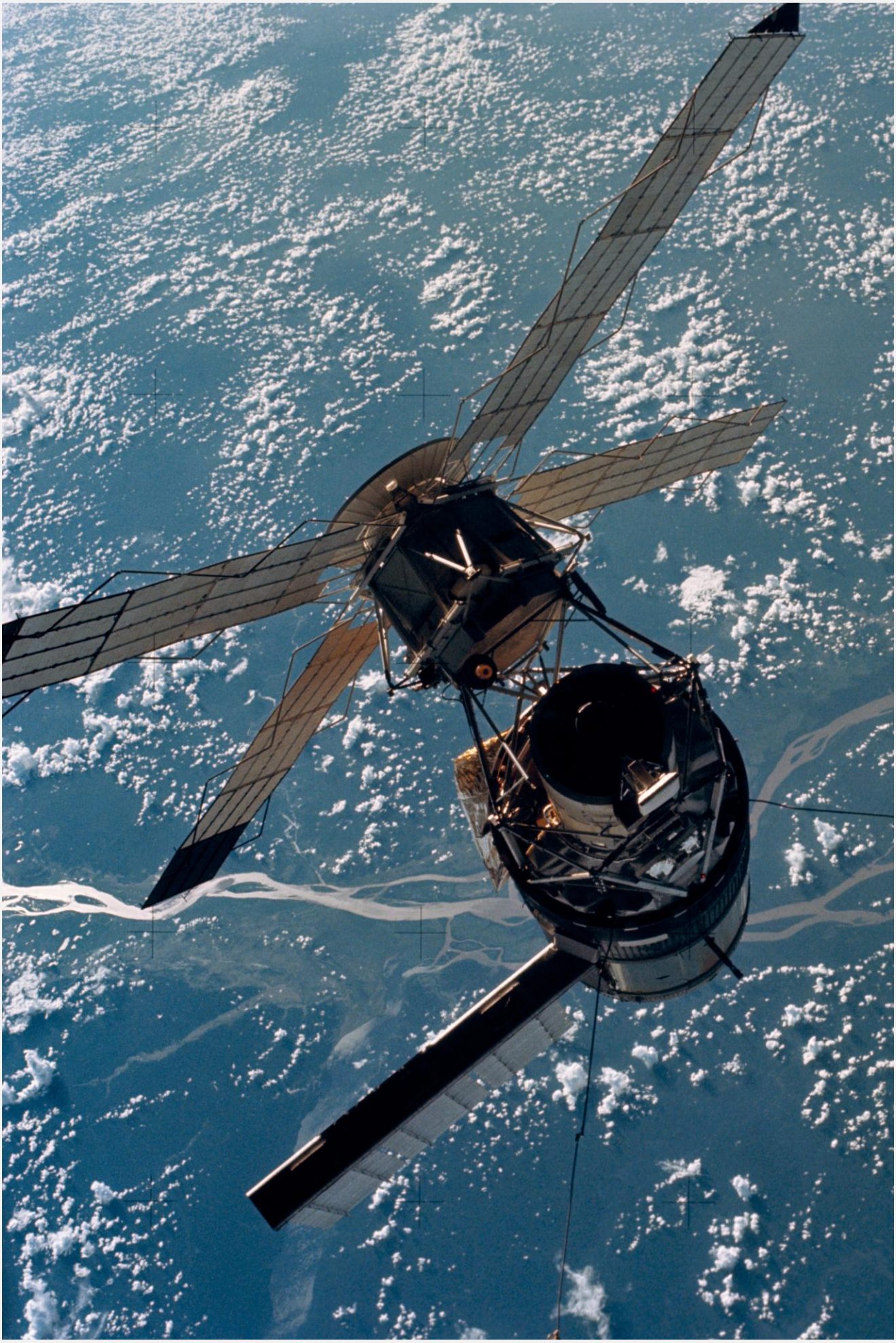

ABOUT THE AUTHOR

Hamish Lindsay (1937-2022) worked at the Muchea, Carnarvon and Honeysuckle Creek space tracking stations between 1963 and 1981.

He wrote many essays on the history of human spaceflight, and was the author of the book, Tracking Apollo to the Moon.