

# SKYLAB

## The first US Space Station

After the abrupt end of the Apollo program, the American space agency NASA devoted all its energy to the Skylab program, which was to use rockets and capsules left over from Apollo for the installation and use of the first US space station in Earth orbit.

Not everything worked as planned, however NASA's engineering ingenuity helped to salvage the mission.

**Since operating the International Space Station (ISS) for 14 years now, and the 50<sup>th</sup> anniversary of Skylab coming up in 2023 this article shall recall the difficulties on NASA's side establishing a permanently crewed orbiting station without vast experiences to draw on.**

**This article salutes the astronauts, engineers and operations personnel "pulling it together", laying the groundwork for finally enabling the construction of the International Space Station by referring to US and Russian experiences and resources and facilitating smooth and successful co-operations in space.**

The Skylab station consisted of a converted Saturn IV-B rocket that used to serve as third stage for the Saturn V.

The large cylindrical hydrogen tank was converted into a large volume ready-to-use station, in which three astronauts would comfortably live, sleep and work. It housed most of the space station's operating systems, all necessary supplies, and numerous scientific experiments. The much smaller oxygen tank served as the astronauts' waste bin. The "Orbital Work Shop" (OWS) section was 14.7 m long, had a diameter of 6.6 m and weighed 25.4 tons. The volume was 275 m<sup>3</sup>, the usable area 35 m<sup>2</sup>.

The airlock (Airlock Module, AM) between the main body and the coupling adapter was 5.1 m long and had a diameter of 3.1 m the tunnel was only 1.8 m with a volume of 17.7 m<sup>3</sup> and a mass of 19.1 tons. The "Multiple Docking Adapter" (MDA) contained the connecting hatch to the coupled Apollo capsule (Apollo Command and Service Module, CSM), it was 5.3 m long, 3 m wide and had a volume of 33 m<sup>3</sup> with a weight of 4.3 tons. The life support system maintained the atmosphere, which was 72% nitrogen and 28% oxygen, with a pressure of 0.3 bar. The tanks were located in the airlock. The internal temperature was adjustable from 16-32°C, the active cooling system worked with a methanol/water circuit. The attitude control system consisted of three 55 cm large so-called flywheels, each with a mass of 180 kg, spinning at approx. 9,000 rpm. Two sun sensors provided optical reference points. Deviations from the desired position were corrected with a multiple system of nitrogen jets, which had a total capacity of 280 km/sec. This achieved an attitude control accuracy of  $\pm 2.5$  arc minutes in the X and Y axes and  $\pm 10$  arc minutes in the Z axis.

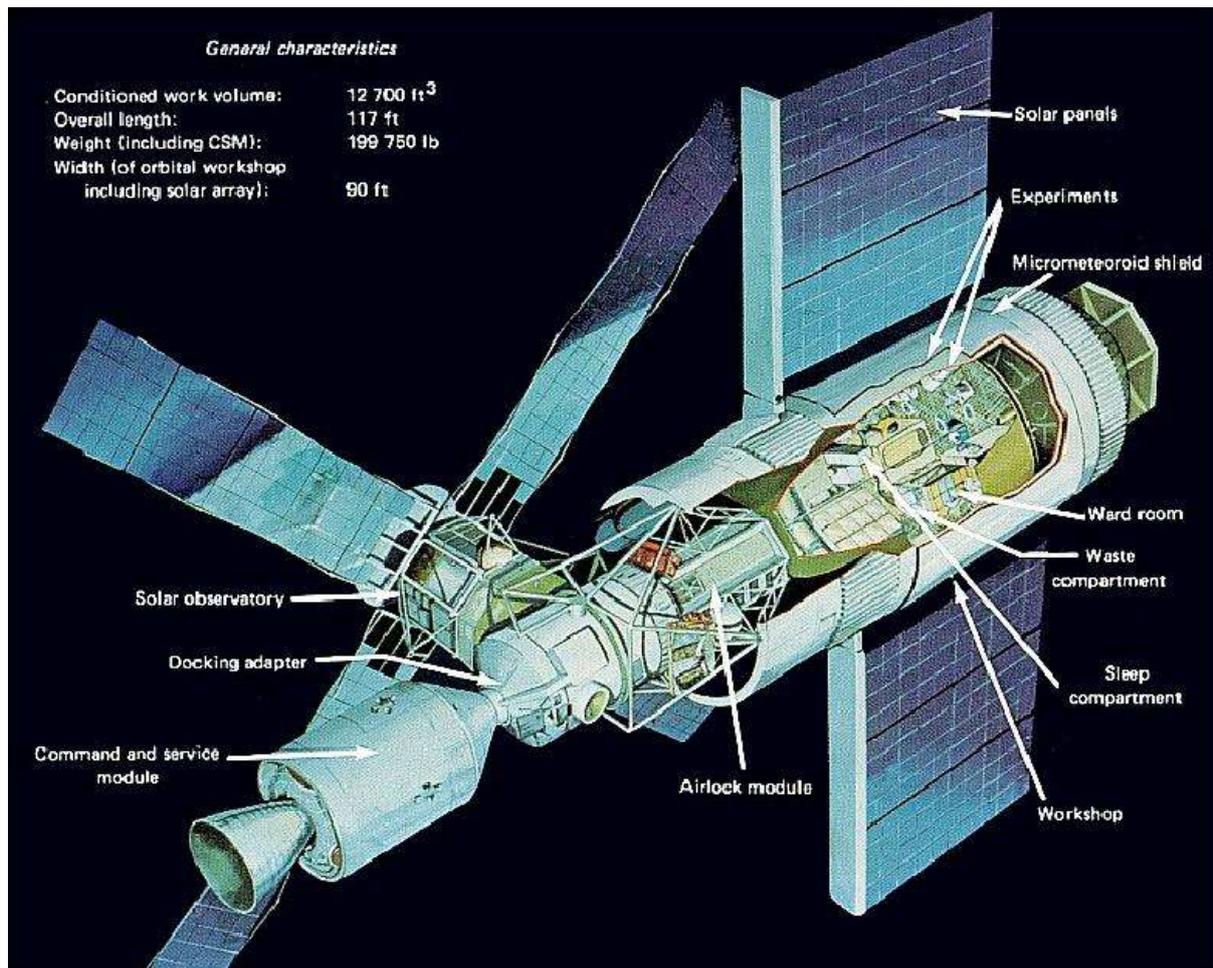
The solar telescopes had an additional, much more precise alignment system. The "Apollo Telescope Mount" (ATM) consisted of a group of sensors for observing the sun in the UV, IR and X-ray ranges. The telescopic mount was 4.4 m wide by 6 m long and weighed 11.1 tons. The operating console for the ATM was located in the docking port.

There also the microwave sensors and the cameras for earth observation were mounted, so they always were aligned perpendicular to the surface. Power was supplied by solar cells, mounted on two large panels on the side of the main body and on four deployable surfaces on the side of the telescope tower. This small "power plant" could deliver a total of 23 kW of electrical power, more than any spacecraft before. The Skylab station was 36 m long and 6.6 m in diameter, and a "wing-span" of 27 m across the ATM's solar panels. The total launch mass was around 89 tons. The first American space station was designed and developed by McDonnell-Douglas and Martin-Marietta in 1969-73 under contract of the "Marshall Space Flight Center" (MSFC) for a service life of 6-9 months.

### Skylab-1

The first American space station was launched on May 14, 1973 with the last available Saturn V rocket, which only used two of the three stages it used for the Apollo launches. The third stage was replaced by a dummy structure. A 442 x 437 km orbit with an 50° equatorial inclination and 93.2 minutes orbital period was achieved. But just 40 minutes after launch the control center in Houston

(MCC) noticed that the flight was not proceeding according to plan. The meteorite shield had obviously been torn off the central body by strong wind forces during lift-off.



*Fig. 1 Skylab was the first American station orbiting the Earth and was occupied by three different Astronaut crews up to three months.*

*The image shows a cut-away functional view of the “wet-station” using the Saturn IV-B stage as laboratory and crew quarters (OWS), and the Service Module (SM) as docking port and attaching the Apollo Telescope Mount (ATM) as solar observatory. (NASA) [2]*

This "skin", made of 0.6 mm thick aluminum was placed at a distance of 15 cm from the shell of the "Orbital Work-Shop" and should also have served as a heat-shield. Now there was a risk of Skylab space station overheating quickly damaging all supplies immediately. To make matters worse, news came that one of the two large sun cell wings had been torn off and the second had not unfolded. This seriously jeopardized Skylab's energy supply.

The launch of the first astronaut crew planned for the next day was therefore postponed, and the technicians at the ground station were feverishly looking for ways to save the mission after all. After a few days, engineers presented initial plans for astronauts to stretch a tarpaulin over the center body during an extravehicular activity to reduce solar radiation and cool off temperatures. According to a quick analysis by the technicians, the jammed solar cell wing could be loosened with a bolt cutter, which would cut the obstructing metal wires (Fig. 3).



*Fig. 2 Flight directors for the Skylab 1 and 2 missions.(25 May 1973) --- Four flight directors for the Skylab 1 and 2 missions are grouped around the flight director's console in the Mission Operations Control Room in the Mission Control Center (MCC) at Johnson Space Center during the Skylab 2 CSM "fly around" inspection of the Skylab space station . They are, going counterclockwise from center foreground, Donald R. Puddy (white shirt), Milton Windler, Philip C. Shaffer and M.P. Frank. A view of the Orbital Workshop (OWS) seen from the Skylab 2 CSM is visible on the television monitor in the background. Photo credit: NASA. [3]*

After a few days, the special tools required for a Skylab repair and the work instructions for the dangerous EVA were ready and the astronauts could take off.

### **Skylab-2**

The first crew for the space station was launched from Cape Canaveral on May 25, 1973 on a Saturn-IB rocket, the three astronauts in the Apollo command module were C. Conrad, J. Kerwin and J. Lousma. They were supposed to repair the space station and stay on board for four weeks. Soon the crew reached orbit and also quickly sighted the Skylab station, which made a desolate impression with the one, barely visible solar paddle and without meteorite protection (Fig. 2).

At first, the astronauts maneuvered the capsule close to the stuck solar panel, but they were unable to loosen it and pull it out. Then the crew tried to dock the Apollo CMS to the station, but only succeeded on the 8th attempt. Shortly after docking, preparing and performing their first EVA, the astronauts succeeded in attaching a sun protection cover they had brought with them over the cylindrical central body of the station. It was not until the fourth day that the interior had cooled down enough for the crew to enter into the station. Finally, on Day 7, during another dramatic EVA, Conrad and Kerwin managed to free the stuck solar panel and Skylab was finally operational!

All of the planned experiments could be operated with the just available 6.7 kW of electrical power (including the solar telescope component). So, routine scientific work could begin and by the end of the 28-day mission had completed 46 of the 55 planned experiments, accumulating 392 hours. After 404 orbits, Conrad, Kerwin and Weitz splashed down on June 22, 1973 in the Pacific, having achieved a 392 hours long-term record in space.



*Fig. 3: Artist's concept of an EVA to free the solar array system wing. [4]*

*Fig. 4 Right: Jogging around the ring of the inner hull looks like straight out of Stanley Kubrick's Odysee 2001 movie. [5]*

### **Skylab-3**

The second crew for Skylab was launched on July 28, 1973 from Cape Canaveral on a Saturn IB rocket. The three astronauts were A. Bean, O. Garriott and J. Lousma and they were to remain in orbit for two months. After transferring to the station, the men initially suffered severely from space sickness, so that the planned work was delayed. In addition, there were problems with an attitude control nozzle in the Apollo CSM so that NASA already considered a rescue mission. But things worked out for the better, and the astronauts began their research program, which was occasionally interrupted by repairs to the space station.

Inside the spacious Skylab main body, Bean tested a prototype of the "Manned Maneuvering Unit" (MMU), the shuttle astronauts later would use to maneuver freely in space without a tether. During several outboard maneuvers of all three astronauts a new tarpaulin was stretched over the main body of the space station, improving thermal insulation. The scientific work program was extremely successful and was exceeded by 50% in some areas.

The astronauts spent 305 of the total of 1,081 man/hours of experiment time observing the sun, many interesting close-up images could be transmitted to the scientists on the ground with the on-board TV system. Exploring the Earth the crew took over 16,000 photos, they also completed 333 medical experiments, and they observed the behavior of various small animals in weightlessness: spiders skillfully built their webs even at 0 g, which is rated as an extraordinary adaptation capability. Also the presence of science astronaut Owen Garriott's presence as the only science astronaut yet enhanced the quality of the scientific return effectively.

After having spent almost 60 days in weightlessness, the astronauts returned safely on September 2, 1973, having orbited the earth 892 times.

### **Skylab-4**

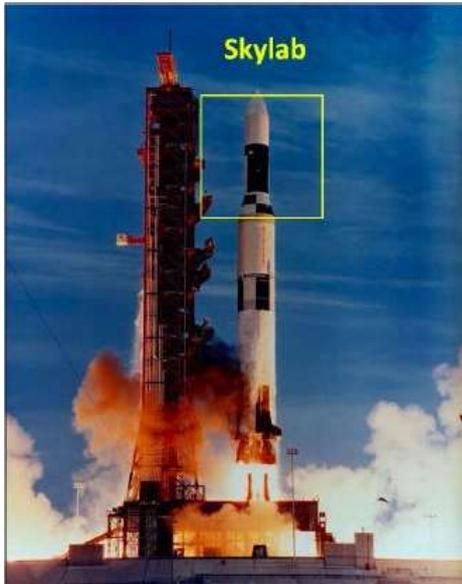
The last Skylab mission started on November 16, 1973 also with a Saturn IB rocket from Cape Canaveral, all three astronauts went into space for the first time, G. Carr, E. Gibson and W. Pogue were scheduled to work in Skylab for three months.

On the second attempt the Apollo CSM could dock with the station successfully, but Pogue immediately suffered from severe space sickness. The astronauts initially tried to hide it. This led to the so-called "communications break" [see also Wikipedia.en description on [https://en.wikipedia.org/wiki/Skylab\\_4](https://en.wikipedia.org/wiki/Skylab_4)], which resulted in serious allegations from the ground station. After a clarifying discussion, the astronauts returned to their scheduled work program.

First, various technical defects had to be repaired, especially the stabilizing gyros showed weak reactions and the cooling system needed new supplies for maintenance.

The scientific work went very well the astronauts executed 56 experiments and 26 demonstrations. They observed the sun for 338 hours and spent a total of 1,563 hours for running and supervising experiments, including observations of comet Kohoutek with a UV camera during various outboard maneuvers.

On February 4, 1974, the three astronauts returned to the the Earth after 1,260 orbits or 84 days, apparently without any negative effects from the long period of weightlessness.



*Fig. 5 The Skylab and the three Skylab crews were launched into Earth orbit from Cape Canaveral, Florida on Saturn-IB rockets and stayed on the repaired station for one, two respectively three months (Photo: NASA)*

*Fig. 6 Right: Skylab in its final repaired configuration (Photo: NASA)*

## Results

Despite serious problems with the attitude control gyros and other systems, the operational life of the first American space station could be extended from the originally planned 140 to 170 days.

The Skylab program cost was a total of \$2.5 billion and yielded 513 man/days in space and nearly 42 man/hours in various outboard maneuvers.

The scientific output of the three Skylab astronaut crews was also extremely successful they brought back 183,000 images of the sun and 40,000 images of the Earth, as well as 101 km of magnetic tape with microwave data of the earth's surface.

Not to mention the numerous and diverse medical and material experiments as well as various biological investigations in which the astronauts themselves served as "guinea pigs".

The three astronaut teams completed an amazing work program onboard of Skylab with experiments in the fields of:

Medicine/biology, solar physics, astrophysics, earth exploration, materials science, technology as well as experiments proposed by students on advanced research subjects

On July 11, 1979, the Skylab space station de-orbited and burned up over the Indian Ocean in the earth's atmosphere without the originally planned visit by a Space Shuttle crew.

## References:

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- [2] Skylab cut-away, NASA
- [3] <https://www.flickr.com/photos/nasa2explore/11086704493/in/photostream/>
- [4] <https://www.flickr.com/photos/nasa2explore/11086396915/in/photostream/>
- [5] Screenshot: <https://www.youtube.com/watch?v=d1sr6aVzW9>
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