Down, But Not Out: The Near-Loss and Recovery of America's First Space Station

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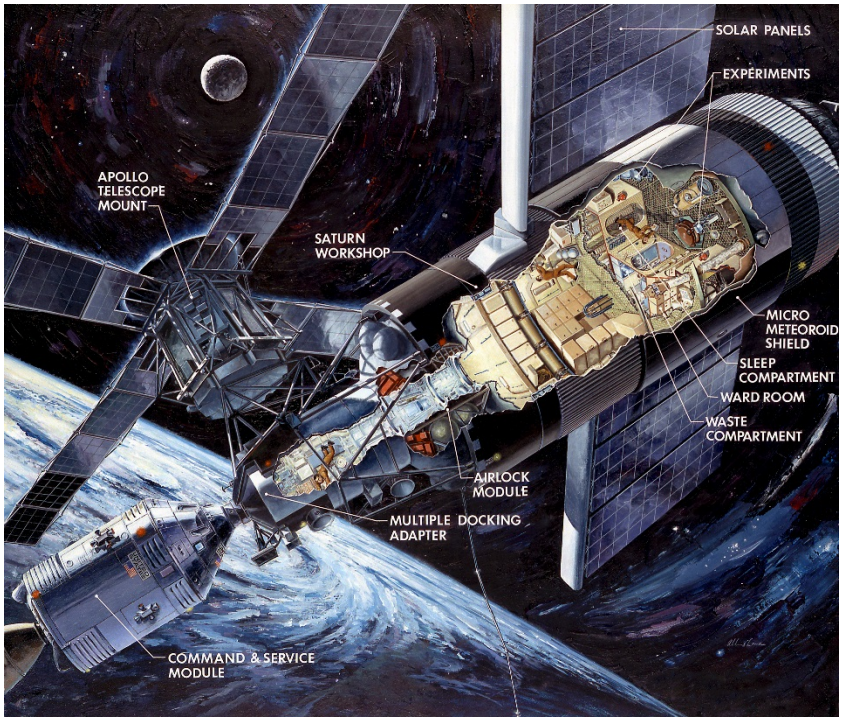
Skylab Design



An artist's cutaway rendition of Skylab as it was intended with both Solar Array Systems (SASs). Source: NASA

- One of the major concerns for Skylab was protecting the space station and its inhabitants from micrometeorite impacts. Engineers devised a large, flexible external meteoroid shield that covered Skylab. It also acted as a thermal barrier, reflecting the Sun's light.
- According to design criteria, the shield—although flexible—was to be a "structurally integrated part…capable of withstanding the dynamic forces imposed during the mission."
- For power, Skylab relied on a Solar Array System (SAS) that consisted of two, large solar cell assemblies (SAS-1 and SAS-2) with a third incorporated into the design of the observatory telescope. During launch, the assemblies were stored accordion-style inside beams that lay flat against the workshop and secured by tie downs.
- The nominal Skylab mission called for the launch of the unmanned S-V vehicle and Skylab payload into orbit, with the manned Skylab 2 mission launching 24 hours later for rendezvous.

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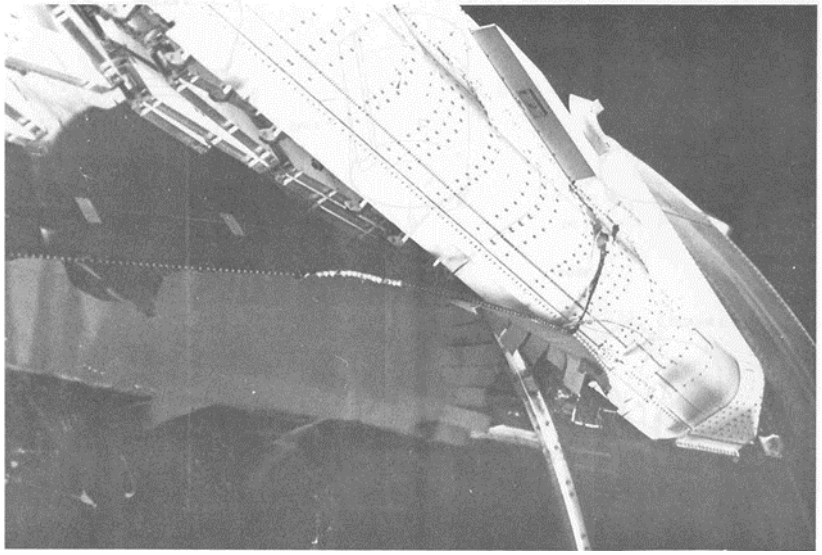
What Happened



Photograph from orbit showing longitudinal aluminum angle bent over the SAS-1 wing. This angle was later cut, releasing SAS-1 for full deployment. Source: NASA

- May 14, 1973, Skylab launched from Kennedy Space Center (KSC).
- At 63 seconds into flight, the shield deployed early and was lost. The SAS-2 assembly became unlatched.
- At 10 minutes after launch, the workshop separated and entered Earth orbit.
- Although controllers were able to position Skylab and deploy many of the station's systems (including the four solar arrays of the solar observatory), they did not receive confirmation signals that Skylab's SAS and meteoroid shield had deployed.
- As temperature inside Skylab rose 200°F higher than designed for, controllers determined that the shield was lost.
- The Investigation Board reported that the most probable cause of the flight anomaly was the breakup and loss of the meteoroid shield as a result of aerodynamic loads unaccounted for in design. The breakup tore the tie-downs securing SAS-2 to the workshop. SAS-2 was lost 593 seconds into the flight when the exhaust of the S-II stage retro-rockets impacted the array.

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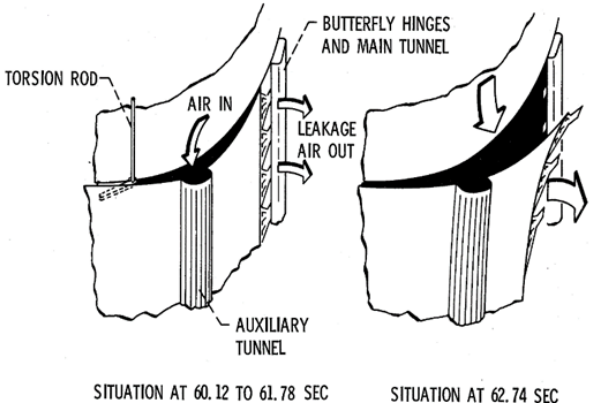
Underlying Issues

- The most probable failure mode was that the internal pressurization of the auxiliary tunnel forced the forward end of the shield away from the shell of the workshop and into the supersonic air stream. The pressurization of the auxiliary tunnel resulted from the admission of high-pressure air into the tunnel through several openings in the aft end.
- The venting analysis for the auxiliary tunnel was predicated on a completely sealed aft end; the openings in the tunnel resulted from a failure of communication among aerodynamics, structural design, and manufacturing personnel.
- These design deficiencies of the shield and the failure to communicate the critical nature of proper venting is attributed to an absence of sound judgment and alert leadership concerning the shield system over a considerable period of time.



Possible meteoroid shield motion from 60.12 to 62.74 seconds. Source: NASA

- The board found no evidence to suspect the design, development, and testing of the meteoroid shield was compromised by schedule or funding limitations. The board also found no inconsistencies or conflicts in management records.

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Assessment

- Skylab 2 was postponed for 10 days to allow time for engineers to analyze the problem and possible solutions.
- Controllers maneuvered Skylab so that the working array of the observatory could maintain minimal power to the station while also reducing the heating effect of the Sun's rays. This stabilized interior temprature around 130° F.
- Engineers developed primary and secondary solar shade devices. Engineers also developed tools for the astronauts to use during Extra-Vehicular Activities (EVAs) to free the partly deployed SAS-1 array.
- Another concern was that Skylab's polyurethane foam insulation might have decomposed under the heat, creating a lethal environment inside the workshop.
- Two weeks later, the crew assembled an extended cable cutter tool and severed the debris pinning the SAS-1 assembly. Without power from the array, the second and third Skylab missions would have been unsuccessful.

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Recovery

- Skylab 2 launched on May 25, 1973 from KSC, carrying a three-man crew to the damaged station. Eight hours later, as Skylab 2 closed the distance, the crew confirmed SAS-1 as partially deployed and SAS-2 as missing. Skylab 2 attempted orbital repair to unpin SAS-1 but initial attempts failed. The crew failed eight docking attempts before successfully docked, ending their first day in orbit after 22 hours elapsed mission time.
- The next day the crew entered Skylab and deployed the primary solar shade which reflected enough solar energy to lower workshop temperatures, allowing ground controllers to reposition Skylab at an attitude that immediately increased station power.

Aftermath

- For nearly a month, the crew made further repairs to the workshop, conducted medical experiments, gathered solar and Earth science data, and performed a total of 392 hours of experiments. The Skylab 2 astronauts spent 28 days in space, which doubled the previous U.S. record. Skylab 2 set a record for human spaceflight duration and proved that man, properly trained and equipped, could carry out complex and difficult repairs in space.

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Relevance to NASA

- Complex, multidisciplinary systems (such as the shield) should have a designated project engineer who is responsible for all aspects of analysis, design, fabrication, test and assembly and management must always be alert to the potential hazards of its systems.
- Positive steps must always be taken to assure that engineers become familiar with actual hardware and make productive use of flight data in the learning process.
- The board suggested simplifying the Skylab design if a backup orbital workshop or similar spacecraft was to be flown (e.g., omitting the shield and coating the workshop for thermal control, and relying on the workshop tank walls for meteoroid protection).
- Furthermore, deployable structures that move or involve mechanisms should not be considered a structural piece with responsibility placed on a structures organization. Managers must continuously strive to counteract the natural tendency of engineers to believe that a drawing is the real world. Firsthand experience with how hardware behaves and can fail is essential to design engineers.

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