Air and Space this Week

Item of the Week

SKYLAB

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NASA had met the bold challenge to "land a man on the Moon and return him safely to the Earth." Pubic interest had turned from the Moon; the TV networks wouldn't even pre-empt the soaps to show later Apollo mission astronauts working on the Moon! What next frontier would challenge America's Space agency, and what next mission would continue to inspire the public?

Everyone then could remember the appearances on Disney, Collier's *magazine, and other places in the 1950s by Wernher von Braun where he talked up going to the Moon. He also showcased his ideas for a "Space Station," a giant wheel-shaped place where astronauts could live and work. Writers like Willy Ley echoed such optimism. There was a lot of scientific and engineering research that could be conducted in low-Earth orbit (LEO), but there had to be some sort of a base that would provide the life-support and other infrastructure necessary. And just how long could astronauts safely endure the free-fall conditions and other aspects of living in Space?*

NASA's answer was two-fold: Build a Space Station and build a Space Shuttle.

SETTING

Forward-looking NASA top leaders foresaw the need for an American Space station after the Moon landing program was successful. The cost of developing an entirely-new station system, in both dollars and time, would likely be prohibitive. What could be done to reduce both? The initial thinking was rather informal; NASA AA for Manned Space Flight George Mueller, jotted down the basic design on scratch pad and presented it to General Davy Jones, the first program director for Skylab, on August 19, 1966, during the heyday of Project Gemini!

NASA had a number of assets at the end of the Apollo program that would facilitate the design, construction, and flight of a Space station. They had a few Saturn V and Saturn I rockets left over from the early cancellation of Moon landings. More importantly, NASA had a vast team of highly-capable and highly-experienced engineers, managers, and contractor partners readily available.

DEVELOPMENT

The plan for an American Space Station fleshed out rapidly from its humble beginnings on a restaurant napkin. An orbiting platform in which astronauts could live and work for and extended period was the goal, and the leftover hardware and Apollo facilities were the nucleus of the tools available.

The Saturn V was the only choice available to handle the task of getting a heavy, heavy spacecraft to LEO. There was no reasonable way (prior to the Shuttle) of getting components of a Space station to LEO and assemble the station there, although one initial plan proposed doing just that, draining the upper stage tank of fuel and then constructing a station around it. But the final basic design concept crystallized early-on. *Skylab* would be based on a modified Saturn upper stage, with solar panel wings, a docking module and airlock, and the Apollo Telescope Mount, which would contain solar telescopes and an independent set of solar panels.

The basic design was set, but there was a LOT of engineering to be done to turn an expendable stage into a working Space station.

The largest component of *Skylab* was its workshop, basically the upper stage. It had a huge internal volume that would be very useful in many respects, but would be a challenge for the life-support and climate control systems. *Skylab* would have a mass of on the order of 100 tons, so a robust and reliable set of systems for managing *Skylab*'s orientation in Space and maneuvering would be required.

Habitability was an issue that became increasingly important for longer missions, so NASA worked with a variety of commercial partners to develop specialty items that would make living and working in Space more convenient and productive.

NASA accomplished the design and fabrication task in a relatively-short time, in spite of the Agency's focus on the Apollo Moon landings; *Skylab* would launch only six months after the final Apollo flight. As only NASA can.

For a diagram of the *Skylab* in launch position and its place on the Saturn V, see here.

THE LAUNCH

Skylab was launched on **May 14, 1973, fifty years ago**. The Saturn rockets had an excellent performance track record. However, on this occasion, things did not go entirely as planned.

The first minute of flight went perfectly, but at T+63 seconds, one of the solar panels partially deployed and was ripped off the spacecraft, damaging its combination micrometeoroid shield and sunshade in the process. Controllers detected the deployment, but could not immediately assess the damage. Other aspects of the flight were normal, including the separation of *Skylab* from the spent second stage. The planned orbit was attained successfully, and the planned sequence of deployment and activation commenced. The payload shroud was jettisoned successfully and the deployment sequence continued apace.

The ground communications network *Skylab* used to send telemetry to the ground was not complete. *Skylab* entered the first gap at the time deployment of the solar panels and meteoroid shield was to take place. When contact resumed, controllers were dismayed that *Skylab* did not send the signal of a successful deployment of either panels or shield. And the temperatures inside *Skylab* were increasing much higher than expected…

The signals received at T+63 seconds, the lack of deployment confirmation, and the rising temperature convinced controllers that the shield/sunshade was lost. They knew that the solar panels on *Skylab*'s observatory were OK, but they worried about the main solar panels, too.

Skylab's first crew was to have been launched in an Apollo Command/Service Module atop a Saturn I booster, a few days after *Skylab* had been placed successfully in LEO. The crew launch was delayed to give engineers time to assess the damage to *Skylab* and determine a fix, if such a fix were possible. Teams of engineers went to work immediately around the clock, as only NASA can.

The temperature issue was critical, because high temperatures could cause insulation on *Skylab*'s interior walls to degrade, reducing its effectiveness and perhaps generating toxic gas. Engineers found a way to orient the *Skylab* to minimize the solar heating. Unfortunately, doing so reduced the effectiveness of the observatory's solar array. The gyrations necessary were a decisive acid-test of *Skylab*'s attitude control mechanisms, at least. Finally, the situation stabilized, with the workshop having a temperature of 130° F and the observatory array producing 2.8 kilowatts. Too hot and not enough juice!

A lot of creative engineering talent was brought to bear on the problems *Skylab* faced. Solutions were debated, designed, and constructed in ten-day's time, again, as only NASA can!

Many sunshade concepts had been considered, but only two were implemented, one immediately, and the second by the second *Skylab* crew. Basically, the first crew was to erect a parasol that would shade *Skylab* from excessive solar heating. The second crew would build a sort of awning by using two poles with a connecting fabric shield.

Detailed analysis of telemetry from *Skylab* showed that one of the workshop's large solar panels was more-or-less intact, but had not deployed; it was somehow jammed. There was no telemetry from the other large solar panel at all.

Special tools to help the first crew install their parasol sunshade were designed and fabricated quickly. The first crew assisted in the process and worked to familiarize themselves with their new duties, including training in the swimming pool "weightless" simulator, the Wet-F. Led by Space veteran Moonwalker Pete Conrad, astronaut rookies Joe Kerwin and Paul Weitz prepared relentlessly and all matters of problems they might actually face, using a variety of tools in the training process.

The Apollo capsule was loaded with extra cameras for recording the damage to *Skylab* during the initial fly-around inspection. EVA equipment that would allow a Spacewalk from the CM hatch, and equipment for detection of and protection from were also placed aboard. Supplies to replace those that might have been damaged by the high *Skylab* temperatures were added.

They were as ready as they could be.

FIRST CREW

Conrad, Kerwin, and Weitz entered their Apollo capsule on the morning of May 25, a mere 11 days after the launch of *Skylab*. The station was operating mostly as planned, with the exception of reduced power and high internal temperature. The were off with a “We can fix anything” on their lips.

The launch and orbital insertion went perfectly, and eight hours later, the first crew was approaching *Skylab*. They were dismayed, but not surprised, to see that one of the workshop’s large solar panels was completely gone. The other large panel had started to deploy, but was hung up on a piece of the departed meteoroid shield. After a detailed inspection, the crew was able to dock normally.

The crew enjoyed their first meal in Space while the engineers on the ground pored over the images taken during the inspection fly-around. The crew buttoned up, undocked, and prepared for their first EVA at the hatch. Conrad maneuvered the Apollo CM/SM, Kerwin handled a 10’ pole, and Weitz held his legs as he leaned out the open hatch. He tried repeatedly to dislodge the strap blocking the panel’s deployment, forcing Conrad to continuously maneuver to avoid hitting *Skylab*. No joy. They were approaching Earth’s shadow, so Kerwin came back in, they closed the hatch, and would have to try again later.

Their attempt to re-dock with Skylab did not go well, either. The capture latches failed to engage during several attempts to dock. They buttoned up their suits again, depressurized, opened the hatch, and went to work on the docking probe, partially dismantling it. Whatever they did worked, and they were finally able to dock successfully with *Skylab*. They had had a very busy day, and would have a sleep period before entering *Skylab*.

The air aboard *Skylab* had been expelled and replaced, but astronaut Weitz still donned a gas mask to enter it. He carried detection equipment that showed that the air was now safe to breathe, so the other two astronauts joined him aboard, and all turned to the task of making *Skylab* more habitable. It was still 130° inside, but “it was a dry heat” and therefore marginally tolerable. They immediately went to work deploying the parasol as trained. It unfurled as planned (except for one corner), and the effect it had on the temperature was immediate. After a few hours, it was cool enough to re-orient *Skylab* for maximum solar power from the observatory panels. Temperatures were still high, and the astronauts slept the next few nights in the docking adapter, which was more comfortable, until *Skylab* had cooled off further.

The crew quickly settled into their work routine, but their plans were affected by the loss of solar power from the now-missing workshop panel and the one not yet deployed. The rate they could conduct experiments had to be slowed to accommodate the power situation, and six planned experiments had to be canceled because they were to use the same hatch that was now more-importantly occupied by the parasol sunshield. Everything was OK for now, but they really needed to get the one solar panel remaining on the workshop section into action.

Ground control had a pretty good view of the strap blocking the panel deployment from the fly-around, and were developing a plan that would allow the astronauts to cut it with the tools and materials they had at hand. Apollo 9 veteran Rusty Schweickart tested several methods in the Wet-F, and the pry bar, bone saw, and cable cutter all worked. On June 7, Conrad and Kerwin tried to free the panel during an EVA, with Schweikart coaching them from the ground. They assembled a 25' pole from five sections, attached the cable cutter to one end, and then maneuvered the pole until the cutter's jaws could engage the obstinate strap. The tied their end of the pole to the observatory truss structure. Conrad then worked his way hand-over-hand to the beam supporting the partially deployed panel, and confirmed that the cutter was in the correct position. After taking a break for orbital night, Kerwin pulled hard on the cable that should have actuated the jaws and cut the strap.

Nothing happened. At first, anyway.

Conrad moved back out the pole, hand-over-hand as the day before. But as he reached the cutter end, the jaws succumbed to the pressure on the cable that controlled them and cut the strap, sending Conrad tumbling away. Good thing he was tethered to *Skylab*! The panel immediately sprang partially free, an eventuality that had been planned for. Conrad had previously hooked a tether an antenna support truss and its other end to the beam supporting the panel. They heaved; nothing moved. Conrad moved to get more leverage. Both heaved, and the clevis bracket broke, freeing the beam and its panel. Both astronauts tumbled away this time from the sudden movement, but both were tethered in and got back to *Skylab* safely. Meanwhile, the panel beam slipped into its full -open position, but the accordion-like panels did not unfurl. The astronauts began preparations to end their EVA. The panels were now in full sunlight, and as they warmed up, the unfurled themselves into a full-open position. *Skylab* was now generating all the electricity it was ever going to.

The crew had lived up fully to their boast that they could fix anything. As only NASA can!

However. The environmental control that cooled the EVA spacesuits by running cool water through a special undergarment (now common on Earth for race car drivers, fire fighters, and other personnel who have to operate in high temperature conditions). The 210-minute EVA had caused clogs in the heat exchangers connected to their suits, freezing the fluid in places and preventing the suits' temperature control from operating properly. The cooling system problems worsened, but close coordination with trouble-shooters on the ground cleared up the problems within a few days.

When they weren't fixing problems, the crew managed to explore free-fall in a larger volume of space then possible before (the workshop was a 27' long, 22' diameter cylinder). They quickly mastered movement, including flips and other maneuvers impossible under gravity. They also enjoyed Earth-watching immensely. And best of all, the Space toilet worked!

[The back-up craft for *Skylab* has been for years a mainstay exhibit in the National Air and Space Museum's National Mall Building. The most-asked question – by far – we'd get from visitors is "How do the astronauts go to the bathroom?" We even had to get a display mock-up!]

They *Skylab* crew even had a shower of sorts. Weitz was the guinea pig on that one and found it worked reasonably well.

One of the things that can be troublesome in free-fall is the tendency for small bits of debris to get to undesirable places, so the astronauts would take turns running a vacuum cleaner. There was also a gentle breeze in the workshop caused by forced air circulation for temperature control, so wayward nuts, bolts, tools, etc. would end up on an air filter intake. They even got to working next to one of the larger intakes because the air sucking through it would hold tools and equipment in place on its filter, making them easy to find.

After making the necessary repairs and setting up housekeeping, the astronauts could turn to their experiment schedule. Kerwin was a Scientist Pilot, in charge of the Apollo Telescope Mount, an array of solar telescopes in the observatory section. Not all of their experimentation was scientific, they also tested a wide array of equipment for use on further Space missions.

Some of the remedies they used to fix minor problems were decidedly not high-tech. One of the observatory's solar panels suffered a failed electrical conditioner, due to a contactor getting stuck in an open position. The problem had been encountered during testing on the ground, and was solved when a technician rapped the housing of the contactor with a hammer. That's right; NASA fixed a balky machine by hitting it with a hammer. The astronauts on *Skylab*, however, had to make an EVA to try the same technique on their problem. They went out, rapped in the exact spot directed, and bingo, the contactor released and operated properly.

A lot of attention was also paid to the medical side of long-duration spaceflight. After a few weeks, they found that they had gained an inch or more in height (as the pads in their spine adjusted to a no-work situation), and they had become visibly fatter, as the water balance was affected by the lack of gravity.

All too soon it was time to return to Earth. They'd been on orbit for a total of 28 days, far longer than anyone before them. They acquired a lot of experimental data, but most importantly, the proved that people could live and work in Space for an extended period. That's good, for the next two crews were scheduled to be on *Skylab* for twice as long!

The first crew put *Skylab* in its low-power, unmanned mode, and returned to Earth on June 22. *Skylab* telemetry and ground control was still in full operation, as was the solar telescope equipment. The station was ready for the …

SECOND CREW

The *Skylab 1* mission was the launch of the station itself. *Skylab 2* was the launch of the first crew, and *Skylab 3* would be the launch of the second crew.

The second crew was led by veteran astronaut and Moonwalker Alan Bean. Owen Garriott. the scientist pilot, had been an electrical engineering professor at Stanford. Jack Lousma was the mission pilot; he had served as CapCom for the Apollo 13 mission.

They launched to *Skylab* on the morning of July 29, 1973. The launch date had been advanced, because the gyroscopes *Skylab* used to control its orientation in Space were degrading faster than expected (a similar problem has affected the *Hubble Space Telescope* over the years). The second crew was taking replacement gyros, a second parasol sunshade, and other supplies and equipment with them to *Skylab*. They also had a number of small animals along to see how they adapted to free-fall, including two spiders, Anita and Arabella. How would free-fall affect their web-making? [I don' know where Arabella ended up, but Anita, last time I looked, was in a glass jar in a display case located aft of Space Shuttle *Discovery* at NASM's Udvar-Hazy Center, in the same case as a proximity fuse developed by James Van Allen in WWII.]

The launch and orbit insertion worked perfectly, and they rendezvoused with *Skylab* eight hours later. On approach, ground controllers noted a pressure drop in one of the four thruster assemblies that allowed the Apollo CM/SM to maneuver. At the same time, Commander Bean noticed glowing particles. There was a leak in the thruster, so it was shut down, making the docking process more difficult, but not impossible. The crew docked safely, entered *Skylab,* and began transferring gear.

Six days later, another of the thruster assemblies showed a pressure drop similar to that of the first thruster malfunction. This could be serious, as the CM needed to be able to orient itself properly for a safe reentry. There was an Apollo capsule held in reserve, modified so it could rescue a stranded trio of astronauts if need be. Mission planners began reviewing how it was used. Telemetry suggested that the two affected thruster assemblies were suffering problems unique to them, and not indicative of a design or construction flaw, so the mission proceeded cautiously.

The first order of business was to erect the new parasol sunshade they had brought with them, and the two-pole cover built but not installed by the first crew. Garriott and Lousma installed them both, loaded film cannisters into the observatory solar telescopes, installed panels to record micrometeoroid impacts, and inspected the wayward thrusters for damage, all in one EVA that lasted for six-and-a-half hours, much longer than any previous EVA ever.

The crew settled into routine operations, carrying out many scientific and engineering studies. One of the areas they worked on was using *Skylab* as a platform to look downward, rather than outward, as part of their Earth resources experiment program. They acquired 16,000+ photographs and recorded data on 18 miles of magnetic tape in the process (ah, the wonderful technology of a half-century ago…). They were pioneering great strides in multi-spectral remote sensing for direct terrestrial applications, such as land use planning, agricultural assessment, vegetation health/insect infestation management, and more.

Observations of the Sun proceeded apace with the Apollo Telescope Mount and its instruments, all but one of which could not operate through Earth's atmosphere. Sounding rockets had and a few early satellites had made a few similar, but highly-temporary, observations, but *Skylab* had a more modern suite of instruments and a lot of time over which observations could be made. A burst of solar activity provided *Skylab* instruments to measure details of the corona, solar flares, and other solar features than previously possible.

Arabella was doing her thing, too, but poorly. Her early web attempt looked rather goofy, but she apparently became accustomed to free-fall conditions, and started spinning a more normal-looking web. Anita tried later, and had no problem with hers, either. The public was quite interested in their adventures.

Of course, there was a lot of attention paid to the response of the astronauts' bodies to life on *Skylab*. They had all suffered motion sickness early in the mission, but after a few days they felt fine, and were even stimulated by free-fall conditions, able to work long hours on relatively small amounts of sleep. They were so pumped that they got ahead of the heavy work schedule and even started requesting additional things to do.

The problem with solar heating and climate control had been solved, but now the gyro problem started getting worse. The six-pack of new gyros they brought up needed to be installed, and that would require another EVA. The fix required disconnecting the present gyros, so if the fix failed for any reason, the mission was terminated. But the oft-practiced installation went well, and the nav/guidance system was restored to full operation.

The second crew had performed extremely well, conducting more experiments and acquiring far more data than originally planned. They had some time to enjoy the comforts of life in free-fall, too. And Owen Garriott got to play a cool trick on ground control. Near the end of the second crew's mission, a radio call came in to ground control from *Skylab*. It was clearly a woman's voice. She called twice asking if Mission Control was reading her transmission. The perplexed CapCom said they were reading her OK but did not recognize the voice. The voice claimed she was Helen and had come up to *Skylab* to cook a home-style dinner for the crew. The sound of a woman's voice coming from *Skylab* began to attract an audience. "Helen" made a few general statements about what she was seeing from Space, then she quickly bade farewell, saying the boys were coming into the CM and "she wasn't supposed to be talking to Houston." Her final "Good bye" elicited a meek "bye, bye" from the CapCom. The next thing he heard was the second crew laughing loudly, along with CapCom's companions. Garriott had made a recording of his wife for him before the launch for use to play a trick on Mission Control. It worked!

The second crew returned to Earth safely on September 25, 1973, after 59 days in Space, a new record of endurance. The astronauts had some physiologic changes, and would need a few days to re-acclimate to one-g, but were otherwise healthy and unharmed.

The *Skylab* cooling system was still not working quite right, loosing pressure even though the second crew could not find a leak. Engineers fabricated a kit with the materials the astronauts would need to recharge the coolant loop, a service not originally planned for in the mission requirements. The gyros showed some anomalies, too. Otherwise, solar telescope operations continued automatically. Another activity taking place between the second and third crews being aboard was the creation of teams that would go out and get "ground truth" from areas being imaged by *Skylab*'s Earth-monitoring instruments, helping investigators calibrate what the remote sensing data was seeing with what was actually on the ground being imaged. Simlilarly, NASA sent out a request to ground-based solar astronomers to get them to make measurements in concert with those being made from *Skylab*.

The third crew was deep in training for their turn on *Skylab*, and NASA decided to lengthen the planned mission duration to get a better handle on how longer flights would affect the astronauts. There were to be on *Skylab* for 84 days!

A few minor problems with the Saturn 1B rocket that would take the *Skylab 4* mission to LEO were found and corrected, and the new crew was rarin' to go. Three rookie astronauts had been thoroughly been trained for their mission: Mission Commander Gerald Carr, Science Pilot Edward Gibson, and Pilot William Pogue. The Apollo CM was loaded with a lot of supplies, additional food, more film for the telescope cameras, and other gear. Time for launching!

THIRD CREW

Skylab 4, with the third crew aboard, launched safely on November 16, 1973. Once again, the lift-off and orbit insertion at LEO went smoothly, as did the rendezvous with *Skylab*. The crew took preventive medicine to counteract the motion sickness experienced by the second crew. This time only Pilot Pogue, a veteran of the Air Force Thunderbirds flight demonstration team, was so affected. Go figure.

The unloading process was longer than on the previous missions because there was more food, equipment, and supplies to off-load and stow properly. Further, many items had been added to the crew's work list late in the preparation period; the crew did not have a lot of time to train on them, and that slowed the process down, too. The crew was falling behind schedule, and felt that Mission Control was pushing them too hard. Mission Control was comparing the third crew to the second's work ethic. Not good. The situation was such that morale dropped, and unforced errors were being made.

The crew and Mission Control had frank talks about the task list, the work load, and how things were going. The outcome was adjustments all around. The situation improved and the rate of assignment completion soared. We were learning how best to work on a long-duration mission!

Another factor that might affect crew morale was coming up, however. They were going to spend Thanksgiving and Christmas on *Skylab*, away from their families. Thanksgiving Day started with Pogue and Gibson performing a long EVA, replacing film cannisters in the Apollo Telescope Mount and repairing a malfunctioning antenna. The latter task required a lot of skill and effort on the part of P and G, but they got it done. Back aboard, it was time for dinner.

The astronauts were on a very strict and controlled diet, for medical research reasons, so the meals were rather bland. But they were well-received, indeed!

The minor glitch in the gyro system noted at the start of the mission soon grew into a mission-threatening problem. The *Skylab* thruster system had been in heavy use for some time, and was low on fuel, creating a greater dependence on the squirrely gyros. The star tracker system also began acting up, too, and failed completely in the middle of the third crew's mission. In spite of the problems and the heavy workload, the third crew found time to really enjoy free-fall. They enjoyed using the physical fitness gear aboard *Skylab* regularly.

When Christmas came, the astronauts' families came to Mission Control to exchange messages with their loved ones via teleprinter. Their wives had arranged for small presents to be concealed aboard the Apollo CM prior to launch; clues in the teleprinter messages led the astronauts to find them.

Holidays aside, the most favored relaxation for the astronauts was looking at Earth, especially noting the changes they could see with the changing of the seasons. The also got an opportunity to look at Comet Kohoutek, a much-ballyhooed event that for many on Earth turned out to be a bust. But from LEO, Kohoutek was pretty amazing.

And after 84 days on *Skylab*, they came home.

DECOMMISIONING

Skylab still had a lot of provisions aboard, enough to support another crew visit. NASA's initial planning was to have the Space Shuttle flying in the late 1970s, and they had made extensive plans for its use for boosting *Skylab* higher and serving future crews, but that goal was slipping. No further operational Saturn/Apollo rockets were available, so getting the crew there and back would require the use of the Apollo rescue hardware. There were a lot of good reasons to extend the Skylab program, but …

Skylab's orbit was slowly decaying. We knew it would; the Earth's atmosphere was extremely tenuous at the height of the orbit, but it induced enough drag to slowly lower *Skylab*'s orbit. The third crew had given *Skylab* a boost with the station's thrusters before the left, raising *Skylab*'s orbit by 11 km in an orbit 433 by 455 km. NASA calculated that the station would not re-enter the atmosphere until March, 1983.

Two problems arose. NASA had not quite done the drag calculations the way they should, and the Sun became more active that typical for that part of its sunspot cycle. An active Sun heats the upper atmosphere, increasing drag on LEO objects. *Skylab* was not going to last until 1983.

The USSR was flying nuclear-powered (not an RTG, a *reactor*) radar ocean reconnaissance satellites at this time. One of them, *Kosmos 954*, malfunctioned and came down over Canada, scattering highly-radioactive debris in the Northwest Territories, on January 24, 1978. It was an environmental disaster, a political debacle, and a major news story for weeks. The Canadian government embarked on Operation Morning Light, a multi-year program that cleaned the mess up as well as it could be, and billed the USSR government $6 million Canadian for the cost of the effort. The USSR demurred initially, but eventually paid half the cost.

Kosmos 954 was, therefore, on the public's mind when NASA revised its estimates of *Skylab*'s demise. When it became apparent that NASA wasn't sure of the re-entry time and place, and couldn't really affect *Skylab*'s orbit much, public concern spiked. *Skylab* had a number of pieces and structures that were big and massive enough to survive re-entry and hit the ground. Hard. Even though they were not radioactive, those pieces could cause serious damage on impact.

NASA's estimate that the odds of a person being hit by falling debris was 1 in 152, and the odds of any city larger than 100,000 people getting hit by debris was 1 in 7 did not lower public concern.

The re-entry watch became quite a media event. Some folks had fun with it, some made bets on the time and place, and some made a few bucks selling T-shirts and "*Skylab* Repellent."

NASA could make more and more precise calculations of the impending re-entry as the time approached. There was a lot of ocean beneath the orbital ground tracks, but there was a lot of inhabited land, too. When things got close to the end, *Skylab* controllers adjusted the station's attitude (therefore, drag), to aim for the nearest safe landing place, which turned out to be SSE of Cape Town. On July 11, 1979, the gallant *Skylab* hit atmosphere thick enough to bring it down, with much of the resulting debris overshooting the target point landing east of Perth, Australia, in a very-sparsely populated region. Nobody was hurt at all, but NASA did get fined A$400 for littering.

LEGACY

The Skylab Project was successful in meeting/exceeding all of its objectives. A great deal was learned about long-duration spaceflight, its enabling technology, and its biomedical issues. Large amounts of valuable data on both the Sun and the Earth were obtained.

Skylab was one of the first efforts made by NASA to take advantage of the educational engagement value of Space exploration. Of course, getting to the Moon was hugely inspirational, but there was not as much direct support for students throughout their educational process as there is today, just see the resource items in the Education section on the A+StW website!

NASA sponsored a contest for high school students during the planning for *Skylab*, challenging them to propose experiments to be conducted by the *Skylab* crew. A large number of proposals were received, including mine; nineteen were accepted (Anita and Arabella were one of them). I only got a Certificate of Participation, but the proposal process and the thought of working with NASA were a significant inspiration for my educational path. NASA has been inspiring STEM education in America's youth ever since. As only NASA can.

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Wikipedia has a good summary of *Skylab* missions: https://en.wikipedia.org/wiki/Skylab

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