Skylab1980
Operations Manual

September, 2008
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Reality
Section 1

BRINGING SKYLAB DOWN

In early 1970, three-and-a-half years before Skylab's launch, NASA Administrator Thomas Paine called for a review of the reentry hazards. The resulting study considered the Saturn V's S-II second stage, the four segments of the payload shroud which would be jettisoned after reaching orbit, and the Skylab station itself. Because of Skylab's high orbital inclination the booster, shroud and station could pass over 90% of the Earth's population, but the NASA study concluded that the risk of a person being hit would be very low, and the cost of bringing all these pieces down in a controlled fashion would be very high. Retro rockets and control systems for the S-II and Skylab would weigh 18,000 kg, cost more than 20 million dollars, and delay the program several months. It was simply too late in the process to do anything. The study concluded that NASA should accept the small risk for Skylab, but also recommended that reentry risk assessment and mitigation be made a standard part of the early planning for future programs.

Later in the same year a Lockheed Martin study for the Marshall Space Flight Center came to similar conclusions. The Lockheed study anticipated that 306 pieces of the Skylab cluster would survive reentry, including the film vault weighing half-a-ton. But Lockheed's estimate of the risk for human injury did not differ significantly from NASA's.

Reassured that the risks were negligible, at the end of 1970 NASA headquarters accepted the study recommendations. The problem of Skylab's reentry was reduced to a public relations issue. NASA's offices of Public Affairs and International Affairs were directed to make a plan. The problem was swept from view.

By late 1972 final assembly of Skylab was underway at Cape Canaveral - without provisions for controlled reentry. During that same time, NASA issued a request for proposals to design and construct the Space Shuttle's launch system. Following the recommendations of the 1970 Skylab study, NASA Deputy Administrator George Low directed that the request for proposals include requirements for bidders to assess the reentry hazards posed by the external fuel tank. At the same time, and in the same vain, Low ordered the Office of Manned Space Flight to come up with suitable means to deorbit the S-IVB second stage of the Saturn B1 rockets that would launch the Skylab crews in 1973.

All this talk of falling orbital debris weighed on the mind of James Fletcher, NASA's new Administrator, who took over in 1971, after the decision was made to launch Skylab without controlled reentry provisions. The question of Skylab's fall to Earth was reopened in early 1973 when Fletcher directed MSC and Marshall to study the possibility of using the Apollo spacecraft's main engine to deorbit Skylab just before the last crew undocked.

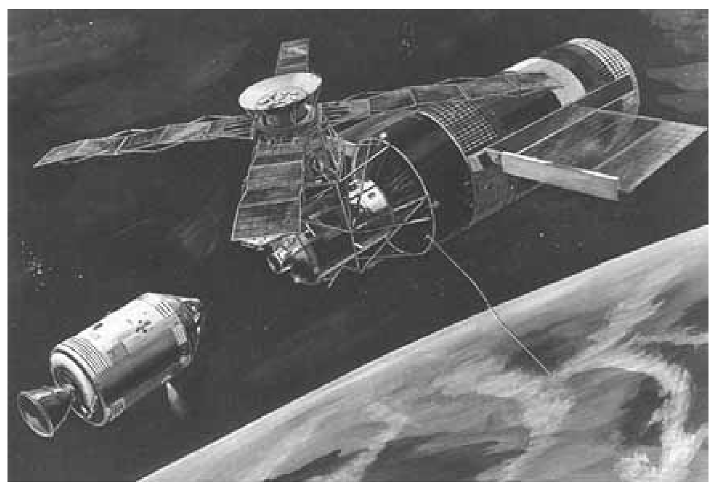


Figure 1-1 Skylab and the Apollo CSM

Both space centers were dubious. The Apollo drogue and probe docking system had never failed in flight, but it was troublesome often enough to cause concern. If the Apollo Command Service Module had difficulty undocking after the deorbit burn the astronauts would be in serious trouble. Even if the CMS undocked smoothly the subsequent maneuvers would be unforgiving. After the deorbit burn both Skylab and the CSM would be on identical reentry trajectories. The CSM would have to reliably distance itself from Skylab to make its own safe reentry. Furthermore, the docking system might be subject to excessive impact and torque loads by the ignition of the unthrottled SPS engine against Skylab's high mass - the system was designed to push a light-weight Lunar Module. Just conducting the necessary studies and identifying the problems to be worked would take six months, leaving little time to make the necessary changes before the last crew launched.

Nevertheless, NASA administrators persisted in their request and the studies got started. The effort came to nothing. The loss of the micrometeoroid shield and damage to the solar arrays during Skylab's launch introduced too many engineering uncertainties to deal with in the time available. Studies on controlled reentry were terminated.

Before undocking from Skylab in February, 1974 the last crew burned the CSM attitude control thrusters for three minutes, increasing the station's apogee 11 km, extending its on-orbit lifetime as best they could. It was a small upward nudge for the space station, but it also marked a trajectory change in thinking about Skylab's reentry.

KEEPING SKYLAB UP

When the Skylab program concluded in 1974 there seemed to be plenty of time to deal with the reentry problem. Based on calculations made during the mission, Skylab was expected to remain in orbit until about March of 1983. If all went according to plan, the new Space Shuttle would begin flying in 1979. One of the new ship's early missions could attach a propulsion module to Skylab and boost it into a higher orbit (or bring it down in an ocean).

Nothing went according to plan. From 1974 through 1977 NASA's budget shrank to record low levels, delaying Shuttle development. By 1977, as the next cycle of solar flares approached maximum, it became clear that the sun would be much more active than predicted three years earlier. The higher-than-expected solar activity would expand the Earth's atmosphere, increase drag on Skylab, and bring the station down much earlier than originally predicted. The revised estimate for reentry was now late 1979 or early 1980. The projected overlap between the Shuttle's early launches and Skylab's orbital lifetime was shrinking to zero.

Meanwhile, some institutional momentum was building toward keeping Skylab aloft, rather than controlling its fall. In late 1974 NASA commissioned Martin Marietta Corporation to study an alternate mission for the Apollo-Soyuz Test Program including a rendezvous with Skylab and temporary reactivation of the station. The station's systems and subsystems were evaluated, with very favorable theoretical predictions about Skylab's condition. The alternate ASTP mission never took place, but NASA and MMC got interested in the possibilities of reusing Skylab - not just reactivating the station but reoccupying it. Early in 1977, a small NASA/MCC in-house study for reusing Skylab concluded that the station could support a crew of 3 to 7 astronauts and perform significant missions.

By late 1977 the Skylab reentry problem was becoming critical. In November, NASA awarded a design contract to Martin Marietta Corporation for the Teleoperator Retrieval System (TRS), a free-flying booster system with an Apollo docking probe. The TRS would be delivered to Skylab on the fifth Shuttle flight. It would be flown and docked to Skylab via remote control by the Shuttle astronauts. In December, MCC also got authorization to conduct a complete Skylab reuse study. The previous studies convinced NASA administrators that Skylab might be a 2½ billion dollar asset worth saving.

NASA's charge to Martin Marietta outlined a four-phase approach for Skylab's rescue and reuse:

> Phase I - Ground Interrogation and Reboost. To begin immediately (early 1978) by establishing a radio telemetry link with Skylab, checking the health of it's systems and regaining attitude control. This phase would conclude with the TRS reboosting Skylab into a higher orbit by late 1979.
>
> Phase II - Refurbishment. Add interface modules to Skylab including an airlock for crew transfer between the Shuttle and the station, and multiple docking ports to permit further station growth. Refurbish Skylab's systems to working order and replenish the consumables.

Phase III - Operations, Tended by Shuttle. Add a 25kw solar cell Power Module (PM) to the Skylab cluster. Skylab serves as living quarters and work space for Shuttle crews. Provide film for the ATM telescopes and resume solar observations. Use the PM to extend the Shuttle's on-orbit time and to power experiments mounted in the Shuttle's cargo bay.

Phase IV - Operations, Untended. Add a Logistics Module to the Skylab cluster, with provisions for extended missions. Add Ku band radio equipment. Add experiment pallets with instruments needing long-term exposure to a space environment. Station is continuously occupied, receiving only occasional Shuttle visits for crew rotation and for exchanging Logistic Modules and experiment pallets

While Martin Marietta began studying Skylab reuse, and planning the TRS, NASA sent engineers to Bermuda to established contact with Skylab. Kindley Naval Air Station was the only tracking station left with UHF transmitters that could communicate with Skylab's obsolete telemetry equipment. First contact was made in March, 1987, but the station was rolling at 10 revs per hour, able to transmit only when its solar panels were facing the sun and generating electricity. Working for only a few minutes during each orbital pass, it took the engineers a week to recharge Skylab's batteries, determine its attitude and ascertain that the on-board computer could be used to help control the spacecraft. Next, the two working control moment gyros (CMG) were spun up - Skylab's third gyro quit working before completion of the manned missions. The attitude sensing gyros were turned on and the thruster attitude control system (TACS) was activated. Skylab was reoriented into a low-drag attitude which would definitely extend its fall to Earth from late 1979 to early 1980.

By mid-1978 three more stations were added to Skylab's UHF tracking network and the conditions of Skylab's systems and sub-systems were known. To everyone's surprise the station had changed very little during 4½ years of orbital abandonment. When the workshop was briefly pressurized the leakage rate was no more than the engineers could attribute to deterioration of the hatch seals alone. In all likelihood, after more than five years in orbit, the workshop was not punctured even once by a micrometeoroid. The elaborate expanding metal shields that nearly killed Skylab during its launch had been unnecessary. This was valuable confirmation for a growing feeling within NASA that the micrometeoroid threat to spacecraft had been overstated. The effort to reboost and reuse Skylab was already returning dividends.

Martin Marietta published the final draft of their study on schedule, in September, 1978. By then it was firmly established that Skylab could be reboosted, refurbished and made useful. The study presented solid arguments for the utility and economy of reviving and reusing Skylab. Within NASA, enthusiasm for the project was growing.

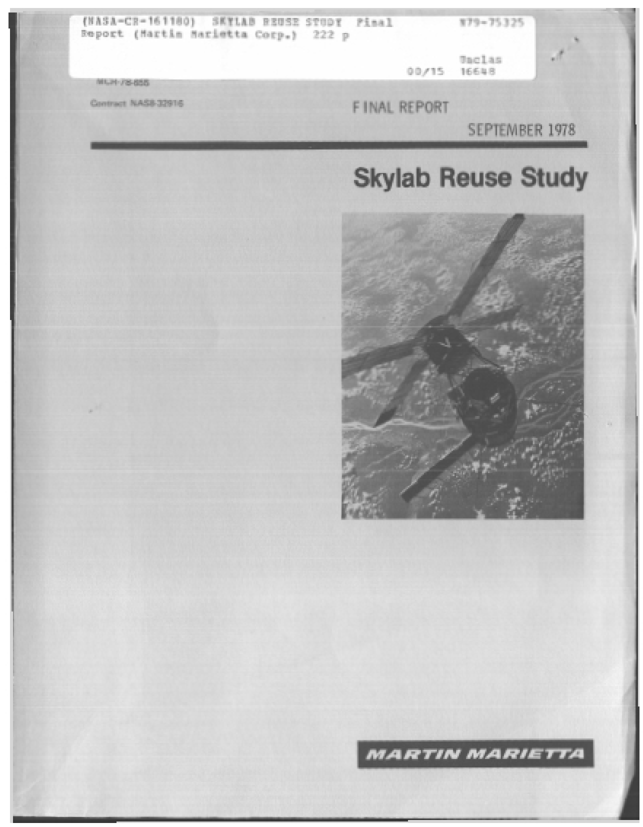


Figure 1-2 Cover, Skylab Reuse Study

Some opposition was starting to grow, too. Skylab was seen by some as a potential drain on resources that should go to the Shuttle. Others saw the station, with its array of powerful solar telescopes and its spacious living quarters, as a threat to development of the Shuttle's own extended missions using its Spacelab module. All the critics worried that Skylab would chain NASA to the past.

The inescapable argument in favor of doing *something* with Skylab was simply the fact that it existed; a 2½ billion dollar, 77,000 kg asset already in orbit. In the course of constructing the International Space Station, twenty years later, it would take three Shuttle launches, two Russian Proton-K and a Soyuz-U to bring ISS up to an equivalent mass. Even now, in mid 2008, the ISS has no instrumentation as powerful and useful as Skylab's ATM.

DEFEAT

But the debate over Skylab's reuse never got rolling. NASA called off the year-long effort to keep Skylab aloft in December, 1978. The Teleoperator Retrieval System was ready for final assembly, but there would be no Shuttle in 1979 to deliver it. Martin Marietta Corporation proposed launching the TRS on a Titan III rocket, but nothing came of the suggestion.

Skylab was now reoriented to a high drag attitude to hasten its end. Keeping it up was getting expensive and there was no longer any point in delaying its unavoidable demise. NASA was confident that by the last three orbits they could estimate the location and time of its impact. In its last orbit, at about 140 km altitude, the controllers would send the station into and end-over-end tumble. By advancing or delaying timing of the tumble maneuver the controllers could lengthen or shorten Skylab's orbital track. Skylab was certain to come down on July 11 and NASA began the tumble maneuver at 148 km to bring it down in the Indian Ocean.

But Skylab was not finished confounding the engineers. They expected the station to begin breaking up over the east cost of North America, but Bermuda radar detected a single image when it passed the mid-Atlantic. Over Ascension Island, NORAD imaging radar clearly detected the delicate solar panels still attached. The late breakup meant that the heaviest pieces would fly further down range and would likely reach Australia. NASA soon received word that an area southwest of Perth was showered with debris. Residents reported a spectacular light show, sonic booms and whirring noises as debris passed overhead. NASA anxiously awaited reports of injuries or property damage, but none were received. In its last moments Skylab had finally gotten lucky.

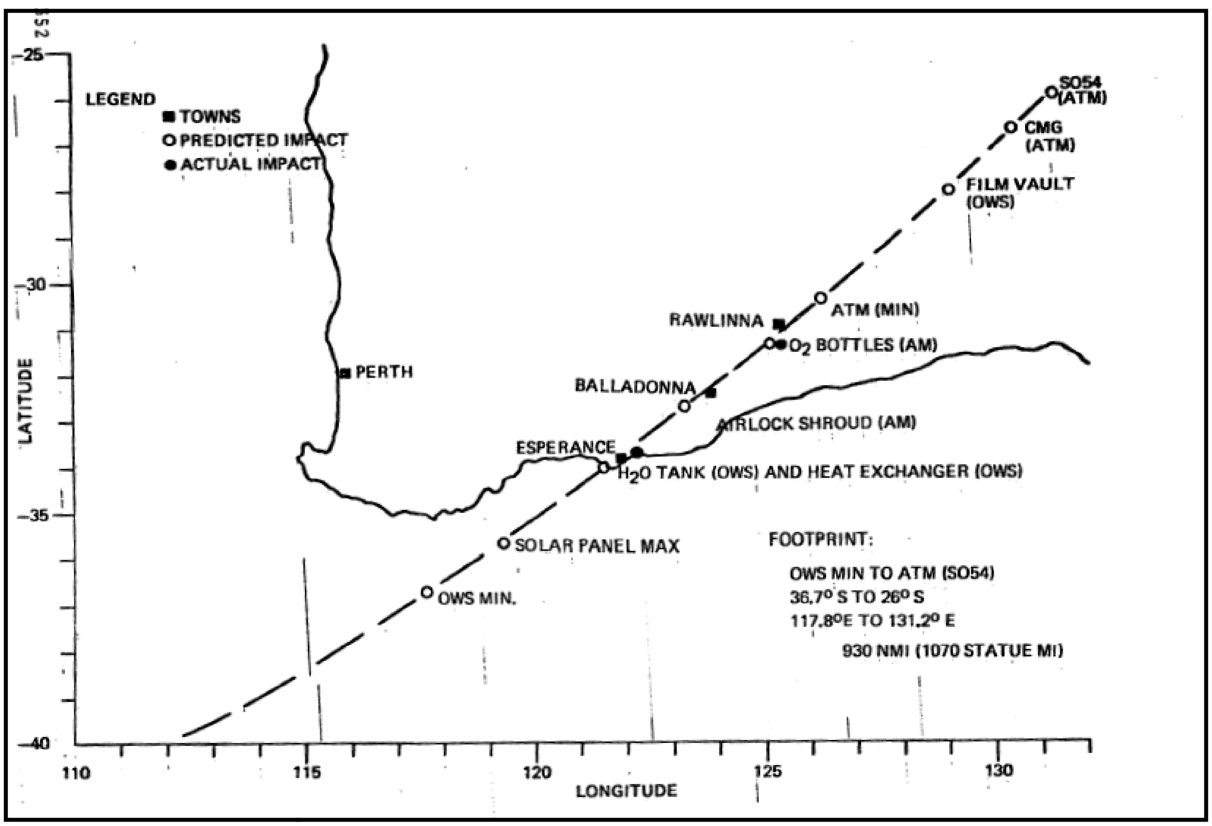


Figure 1-3 Detail of debris footprint from Skylab Reactivation Report

Alternate Reality
Section 2

WHAT IF?
At the end of 1978 the Teleoperator Retrieval System (TRS) was ready for final assembly. Astronauts Fred Haise and Jack Lousma were training to operate it. Because of Shuttle development delays, the October 1979 reboost mission had slipped from the fifth Shuttle flight to the third. What if just a little more money had been devoted to Shuttle program all along and the schedule slipped no further? It is all but certain that STS-3 would have rendezvoused with Skylab. Surely, the STS-3 mission would have been to reboost Skylab, not to bring it down. A final decision on reuse could be made later.

It is far from certain that Phases II through IV of the Skylab Reuse Program would have been carried out. But this add-on would not amount to much if it stopped at the TRS reboost mission. Let's imagine that the Skylab Reuse Program went forward very much according to Martin Marietta's plan.

SPACECRAFT DESCRIPTIONS & ORBITER CONFIGURATIONS
All vessels included in *Skylab1973* and *Skylab1980* are configured with Spacecraft3.dll. See Section 3 of this manual for flight operations.

Skylab
The *Skylab1980* add-on requires a separate installation of *Skylab1973 v2.0*. Version 2 includes some new animations needed for the reuse scenarios. Also, the v2.0 Skylab mesh has a smoother appearance, improved textures and a lower vertex and polygon count.

Space Transportation System
Skylab1980 is designed to work with Orbiter's Stock Atlantis, Space Shuttle Ultra and Shuttle Fleet. Scenarios are provided for all three launch systems. Autopilots are configured for the SSU and Fleet launch scenarios. *Skylab1980* makes no changes to the Shuttle meshes or configurations.

APAS-75
The Androgynous Peripheral Attach System is a Russian docking apparatus that replaced the earlier male/female probe and drogue systems. The APAS features identically arranged spade-shaped guide plates on both units. The system currently used on the Shuttle, the APAS-95, has inward tilting guide plates. On the APAS-75 the plates spayed outward (Figure 2-1). The APAS-75 flew on several Soviet spacecraft and was used in actual dockings on the Apollo-Soyuz Test Project and Soyuz 19. Its use is depicted in the 1978 *Skylab Reuse Study* but the system was never actually flown on the Shuttle.

In *Skylab1980* the APAS-75 is configured with one child attachment point that joins to the Shuttle's single cargo bay attachment point. The APAS-75, in turn, has five parent attachment points to permit attaching multiple payloads in the Shuttle's cargo bay. The APAS-75 mesh fits over and conceals the Shuttle's modern APAS-95. In the *Skylab Reuse Study* all depictions of the Shuttle show the APAS-75 extended *outside* of the cargo bay (Figure 2-2). Apparently, the early plan for the Orbiter Docking System was to mount the docking apparatus on a telescoping extension of the Shuttle's cargo bay airlock. Presumably this was done to increase clearances between the Shuttle and the docked spacecraft. This telescoping action is animated in *Skylab1980*.

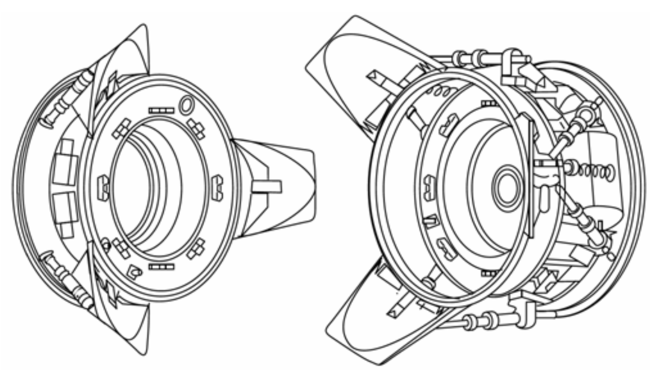


Figure 2-1 APAS docking apparatus

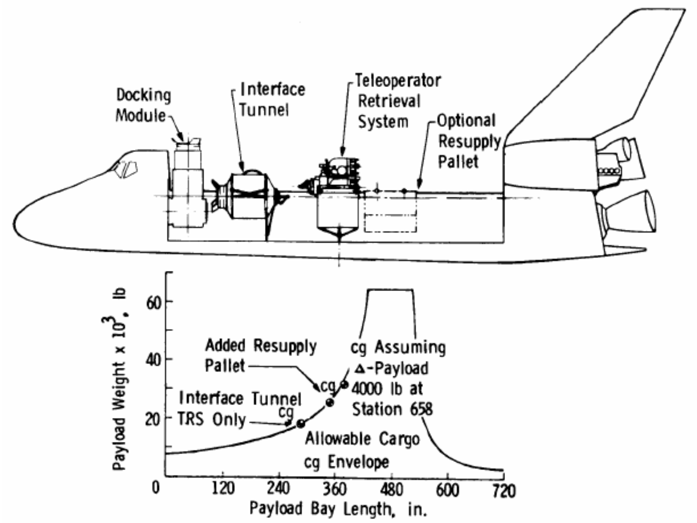


Figure 2-2 Skylab Refurbishment Mission 1 - Payload Arrangement and Center of Gravity from Skylab reuse Study, showing APAS-75 deployed above cargo bay. Note also the TRS and is support pallet.

Attachment Fittings and Bridges

These hardware items are used to secure payloads in the Shuttle's cargo bay. They are included in *Skylab1980* to give the various payloads a more complete and realistic appearance.

Teleoperator Retrieval System (TRS)

The TRS had to be designed, built and launched very quickly (in less than two years). Therefore, to the greatest extent possible, it would be built from already existing hardware. The main propulsion was thirty-two 100 Newton thrusters, with enough fuel to burn them continuously for over 30 minutes.

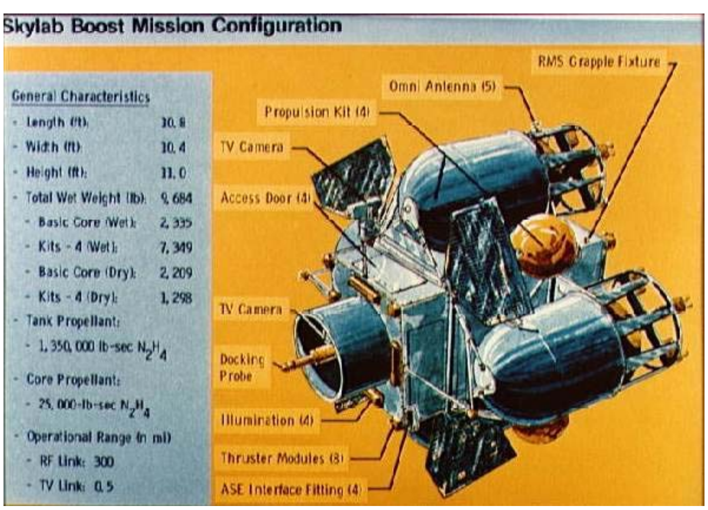


Figure 2-3 NASA rendering of the TRS

The only information I could find about the TRS is contained in a low resolution artist's rendering from the NASA Technical Report Server (Figure 2-3) and a half-paragraph mention in *Living and Working in Space* (see Section 4 for sources). The *Skylab Reuse Study* makes several references to TRS mission functions but offers no structural details about the craft. The rendering's label, "Skylab Boost Mission Configuration" implies that other configurations were imagined. The "retrieval" in its name suggests future mission beyond reboosting Skylab. It appears that the Apollo docking apparatus could be replaced with other hardware - perhaps a grasping device permitting the TRS to retrieve other spacecraft and bring them to the Shuttle.

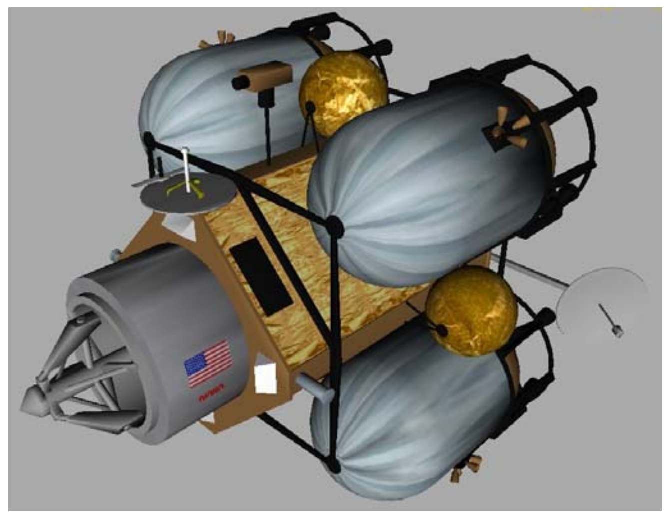


Figure 2-4 TRS for Skylab1980 add-on

Skylab1980 takes some liberties with the design of the TRS. The spacecraft is rotated 45° and the RCS thrusters are arranged differently (simply because I liked the way it looks); it has a dish antenna for long-range ground communications (in case a user would like to launch it on a Titan III as Martin Marietta desperately proposed); its TV camera is retractable to assure that it will not be struck by the Shuttle's RMS when the craft is deployed and retrieved; the small solar panels are deleted (again, my aesthetic preference). Spacecraft3 supports a maximum of 16 main engine exhausts, so where the rendering shows 16 *paired* exhaust nozzles (for a total of 32), the TRS for *Skylab1980* has 16 single nozzles.

Skylab1980 includes a second TRS mesh with an APAS-75 docking unit for later reboost missions after the new modules are added to Skylab.

Interface Modules

Because the Shuttle and Skylab have differing docking apparatus and cabin pressures, interface modules would be needed to connect the two spacecraft and transfer crew between them. The *Skylab Reuse Study* presents several options. The baseline concept is a two-piece interface composed of separate airlock and docking modules. A one-piece interface option provides both functions in a single module. The one-piece approach had the advantage of lower total cost, but the entire cost would fall in a single budget year. The two-piece module would have spread out the cost. *Skylab1980* uses the baseline two-piece approach.

Airlock Module

The Shuttle cabin was pressurized to 14.7 pounds per square inch - normal Earth pressure at sea level. Skylab was pressurized to 5 psi. The *Skylab Reuse Study* examined three options for crew transfer:

1 Make no modifications to either spacecraft and operate both at their design pressures. This would require the astronauts to perform 2 hours of oxygen pre-breathing in the airlock when transferring into the low-pressure Skylab.

2 With very slight modifications to both craft the Shuttle's pressure could be lowered to 12.6 psi and Skylab's raised to 6.3 psi. Transfers would require no pre-breathing.

3 With slight modifications to Skylab alone, its pressure could be raised to 7.3 psi and the Shuttle could stay at 14.7 psi. This would reduce the safety factor on Skylab's window seals to 3.0 which was considered acceptable. Again, transfers would require no pre-breathing.

The *Reuse Study* makes no positive recommendation between these options, but it is clear that crew transfers through an airlock could be accomplished without significant delays or inconvenience.

The Airlock Module was also to have connections for refilling Skylab's oxygen and nitrogen tanks. The *Reuse Study* details systems of permanent external piping, to be installed by EVA, running from a manifold on the Airlock Module to the various fill port locations on Skylab. Quick connect inlets on the manifold would permit fill hoses to run between the Airlock Module and the re-supply tanks to be brought up by subsequent Shuttle missions.

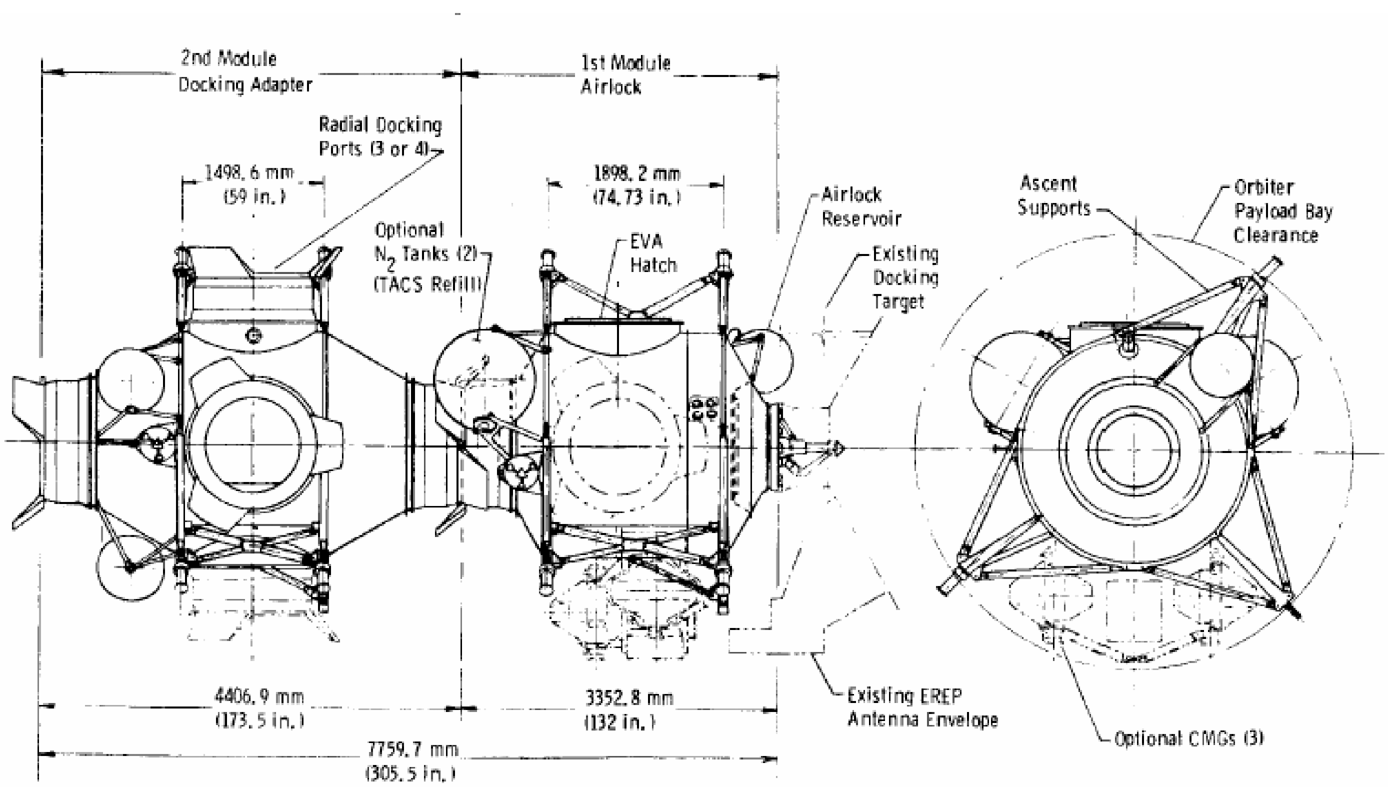


Figure 2-5 Two-piece Interface Module

The *Reuse Study* recommended the optional addition of three control moment gyros to the Airlock Module to take over from Skylab's own failing CMGs, and two small nitrogen tanks to perform an immediate partial refill of Skylab's thruster attitude control system (TACS).

The TACS nitrogen tanks and fill port was located at the aft end of Skylab. There were no handholds or framework to restrain EVA astronauts. The piping would need to be installed with a Manned Maneuvering Unit (Figure 3-3). The Airlock Module was scheduled to be launched 2½ years after the reboost mission - there would be time, presumably, to construct and test the equipment needed to carry out these audacious EVA procedures.

Docking Module

The Docking module would furnish up to six docking ports for subsequently attaching the Power Module, Logistics Module, instrument pallets and future items not yet conceived. The Airlock and Docking Modules were also to be equipped with their own air, water and food supplies to act as an emergency shelter during a major malfunction. It is hard to imagine that the completed station would not have an escape capsule, relying instead on a quickly launched Shuttle rescue mission. But that was actually the plan in this overconfident time before Challenger and Columbia!

Skylab1980 includes Airlock and Docking modules as they are shown in the study. See Figure 2-5.

Power Module

The *Reuse Study* implies that the Power Module was being developed separately as a free-flying spacecraft to which the Shuttle could dock for support of long duration missions. See Figure 2-6. The PM would have two large solar arrays producing 25kw of electricity, heat rejection radiators and three CMGs. Adding these CMGs to the three on the Airlock Module, the completed cluster would have five CMGs for attitude control and one spare. There was also an option to add a Ku band antenna to the PM. The idea was to shut down the Shuttle's fuel cells and use the PM to power the entire cluster, permitting the Shuttle to remain in orbit a month or more. That was the plan before the Shuttle actually began flying, but in reality, NASA has never allowed a complete fuel cell shut down for fear that they might not restart.

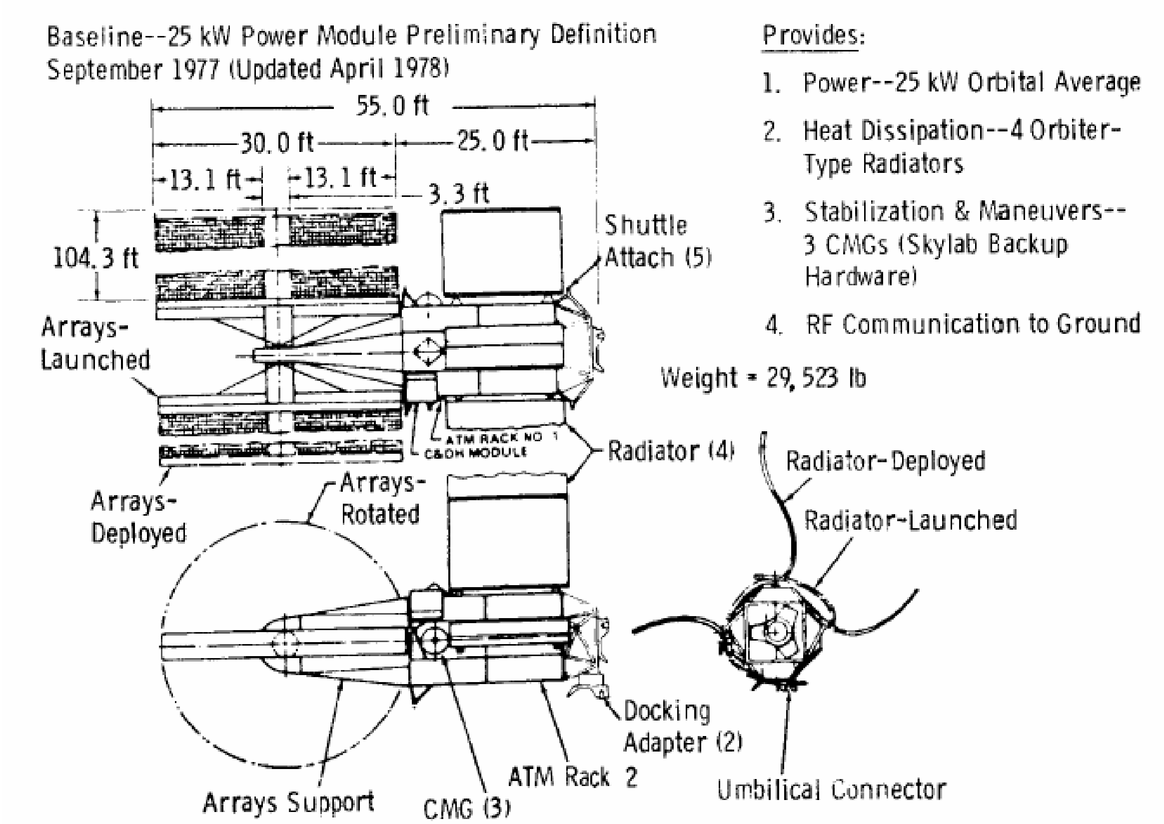


Figure 2-6 25kw Power Module

The *Skylab1980* Power Module has animated solar arrays, radiator panels and Ku band dish antenna. The PM is 55 feet long, so the mission should be flown without the Shuttle's ODS, if your preferred Shuttle add-on provides that option. The *Reuse Study* shows "Shuttle-type" radiators (an economy measure?) that conflict with two of Skylab's ATM solar panels, so the study also describes methods and tools needed for EVA astronauts to fold up ATM arrays 1 and 2. (A procedure expected to take less than 2 hours.) *Skylab1980* changes the radiators are to conventional accordion fold panels, like those on the ISS. They still conflict with the ATM arrays and *Skylab1973* includes a new animation to fold them up. The *Skylab1980* PM has RCS thrusters, mimicking the CMG attitude control system. The PM vessel should be used to perform all attitude changes after it is added to the cluster.

Supply Pallet and Logistics Module

The *Reuse Study* considered various schemes for re-supplying Skylab with consumables. In the long run, a custom designed Logistics Module (LM) docked to the station was expected to be the least expensive approach (Figure 2-7). For the initial refurbishment missions, the Airlock and Docking Modules could be packed with enough non-perishable food, clothing and hygiene materials to support up to 320 man-days. Nitrogen, oxygen and water would be carried on pallets in the shuttle's cargo bay. The *Reuse Study* also explored the possibility of converting a Spacelab module into a supply carrier, but this turned out to be the most expensive method.

Skylab1980 includes both a supply pallet to be carried on Refurbishment Mission 2, and a Logistics Module to be docked to the station at the start of Phase IV - Untended Operations.

Instrument Pallets

The *Reuse Study* furnishes detailed information on the habitability and usefulness of a refurbished Skylab. The condition and utility of the existing ATM is discussed. In addition, several new instrument packages were considered. These included: solar

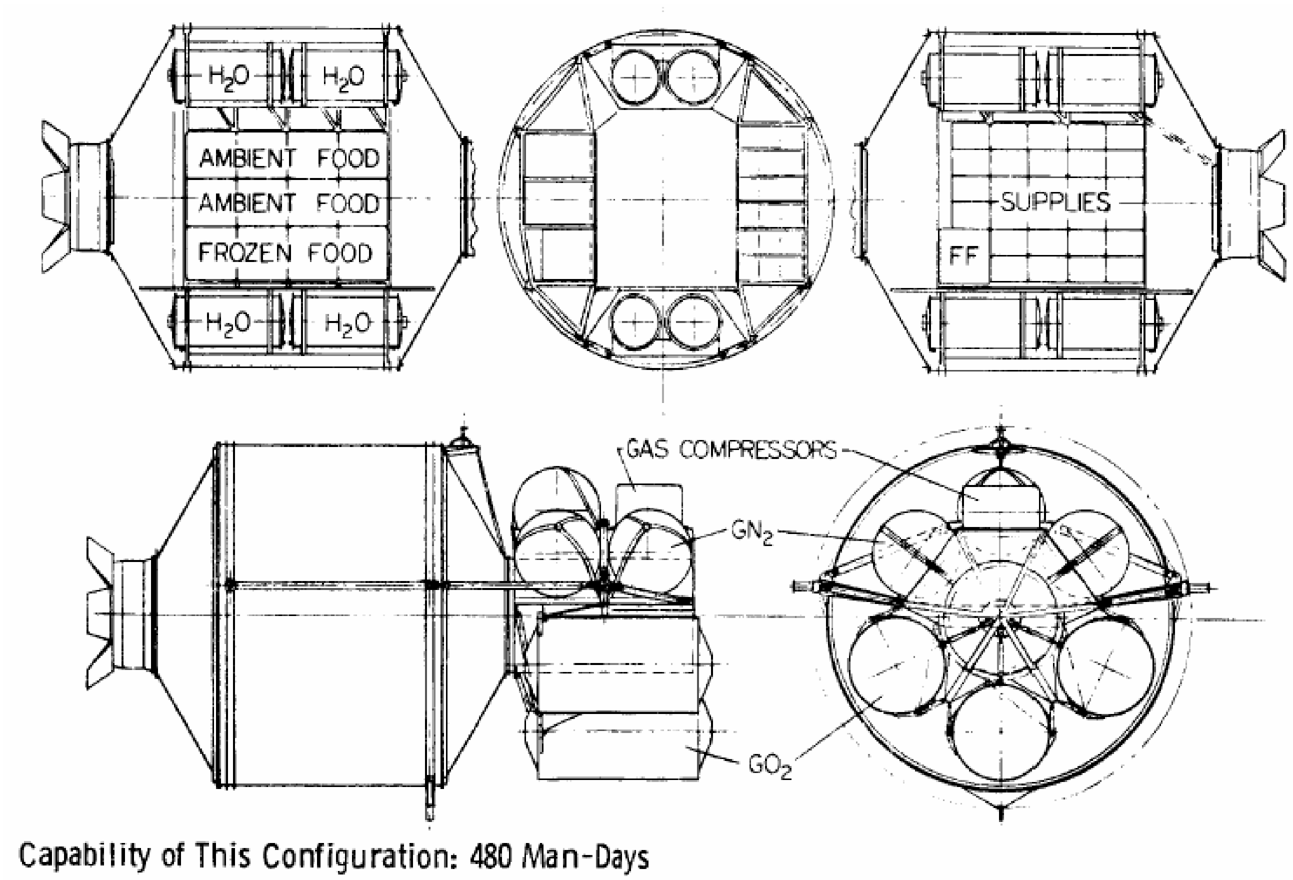


Figure 2-7 Logistics Module

physics, astrophysics/astronomy, Earth resources, communications and solar power. Of particular interest was the Solar/Terrestrial Observatory. As the ATM observed activity on the Sun, the pallet mounted Atmospheric/Magnetospheric instruments would make simultaneous observations of the Earth's electromagnetic and atmospheric responses. These observations could be made continuously, for months or even years, with the instruments ready to collect data whenever the Sun acted up.

Skylab1980 includes an instrument pallet with various animated Atmospheric/Magnetospheric instruments.

Sun Shield

The sunshields installed during the first two manned mission were still functional in 1978, but they were effective only while Skylab maintained a "solar inertial" attitude, with ATM and solar panels facing directly at the Sun. To achieve the complete freedom of movement needed by other instruments, the *Reuse Study* details replacing the existing sun shield with a new wrap-around fabric screen. Installed by two astronauts, one using the MMU, the study estimated that the job would take a day-long EVA. See Figure 2-8 and rendering at Table of Contents.

Skylab1973 includes a new animation with the wrap-around screen.

Gravity & Money

In addition to all the foregoing hardware items, the *Reuse Study* includes detailed comparisons of cluster configurations - the different orientations by which the Shuttle could be joined to the various Docking Module ports. Altering the cluster's configuration would change the gravitational torque and the amount of CMG activity needed to maintain various attitudes. The configuration also effects power generation, spacecraft thermal performance, and the clear fields of view for instruments attached to the station, or inside the Shuttle's cargo bay. All these factors had to be balanced. Figure 2-9 shows the preferred configuration and attitude for the cluster while the Shuttle was docked.

The study concludes with mission schedules, construction work schedules and cost estimates. See Figure 2-10 for the baseline program schedule.

TIMELINES AND TRAGEDY

To heighten the realism of the add-on scenarios, I decided to use actual STS mission numbers, with the corresponding Shuttle names, roughly coordinating the real timeline with the Skylab Reuse Program Schedule (Figure 2-10). Overlaying the actual Shuttle timeline onto the Program Schedule, I immediately found that the Challenger disaster occurs close to Skylab Refurbishment Mission 2 - 46 months after the STS-3 mission.

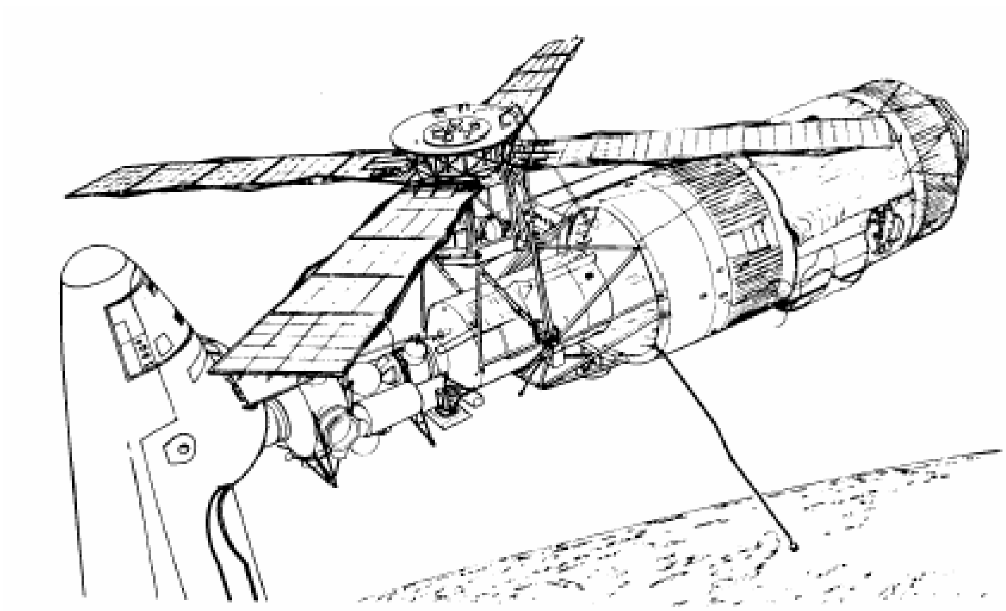
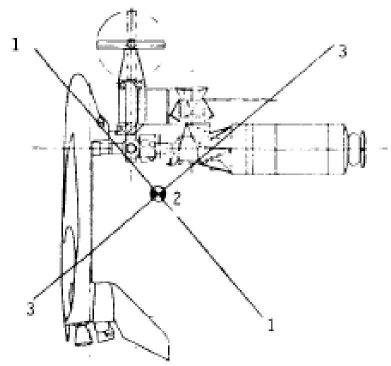


Figure 2-8 Installing the Wrap-Around Sun Screen
The astronaut with MMU is near the aft end of Skylab. Note the one-piece Interface Module shown in this rendering.

Of course, if Shuttles actually started flying in 1979 the entire train of subsequent events would have been altered. The Challenger explosion would not have happened, or not in exactly the way it happened. But in our post-Challenger/Columbia time, given what we now know about the shortcomings of the Shuttle and the weaknesses in NASA's management style and organization, it seem inevitable that disaster would have befallen one of the Shuttles, regardless of when the program got started. Truth be told, because the Skylab reuse proposal was so far ahead of its time, the outlandish efforts to refurbish Skylab might have been the very thing to precipitate a tragedy. In our alternate reality, any one of the Shuttles might have fallen victim to NASA's hubris, but it would be unfitting for *Skylab1980*'s fiction to abandon reality altogether. So, the add-on scenarios assume the loss of Challenger (on a mission unrelated to Skylab), with a 32 month interruption in the flight schedule. Because of the delay, *Skylab1980* inserts and extra reboost and station checkout scenario into its timeline. The Logistics Module and beginning of Phase IV operations is delayed from mid 1984 to March, 1987.



POWER REQUIREMENTS

	SKYLAB**	ORBITER	SPACELAB
MANNED OPS (HABITABILITY)	4.1 KW	10-14 KW	2-4 KW
UNMANNED OPS	2.9 KW	--	2-4 KW

POWER AVAILABLE

ORIENTATION & CONFIG	POWER*
3-POP	27.3 TO 31.8 KW
SOLAR INERTIAL (W/O ORBITER)	28.6 TO 30.6 KW

*BETA ANGLE DEPENDENT

ATTITUDE CONTROL

- CONTINUOUS SOLAR POINTING OF SKYLAB PANELS NOT PRACTICAL
  - APPROX 4 MINUTES POSSIBLE WITH 5 CMG's

  1-POP (-26208 nmsec) = 8.4 CMG EQUIVALENT

  2-POP (19560 nmsec) = 6.3 CMG EQUIVALENT

  3-POP (6835 nmsec) = 2.2 CMG EQUIVALENT
- CAN OPERATE SOLAR INERTIAL DURING DETACHED SHUTTLE PERIODS
- HOLD WITH ORBITER RCS:APPROX 16-18 DAYS IN 3-POP

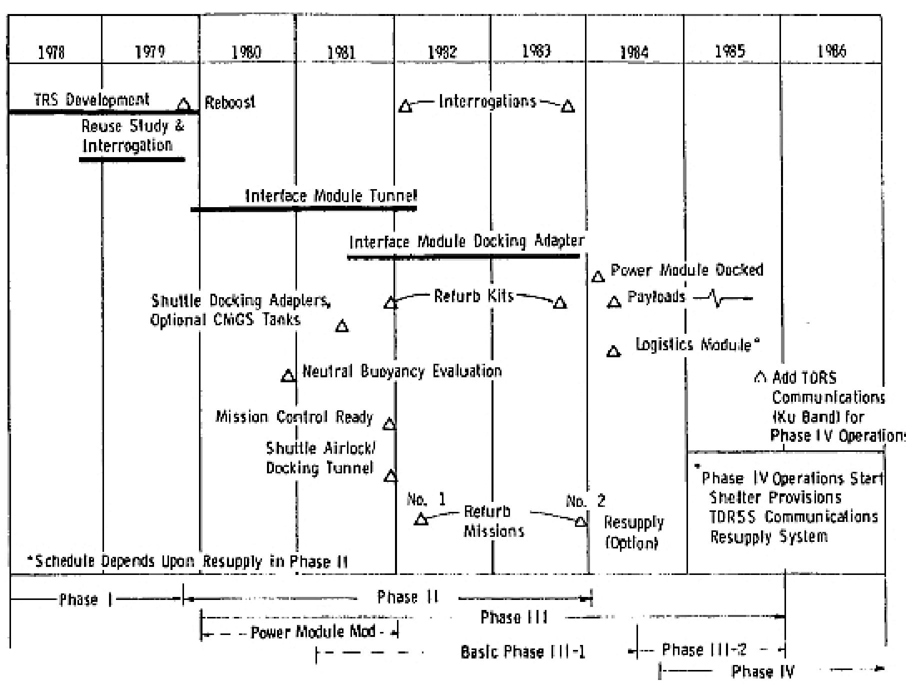
Figure 2-9 Power and Attitude Control - Baseline Configuration.

In this configuration the most efficient attitude would place Axis 3 perpendicular to orbital plane (3-POP). Axis 1 is the zenith/nadir line with the lower right end pointed toward Earth. Axis 2, pointing directly you in this perspective, is the orbital vector (the cluster is moving "sideways" along Axis 2). With the Shuttle undocked, the completed Skylab cluster would have been largely free to assume and hold any attitude.

Figure 2-10 Baseline Reuse Program Schedule.

This schedule from the *Skylab Reuse Study* indicates Phase IV operations, untended by the Shuttle, beginning in 1984. Even with a Challenger-type disaster, and subsequent 32 month delay, Phase IV could have begun in 1987. Reusing Skylab would have given NASA a 20 year head start on EVA construction techniques and permanent space station operations. If that had actually happened...

Where would we be today?



Flight Operations
Section 3

CUSTOM KEY COMMANDS

[J] means press the "J" key. [CTRL]+[/]numpad means press and hold the control key, then press the slash key on the number pad.

Skylab

[K] Fold up ATM wings No. 1 & No. 2

[LShift]+[5]numpad
Retract and stow twin pole sun shade

[LShift]+[0]numpad
Retract and stow parasol sun shade

[LShift]+[9]numpad
Start/Stop wrap-around sun shade deploy

APAS-75

[G] Extend/retract APAS-75 docking unit

Teleoperator Retrieval System (TRS)

[G] Deploy/Stow TV camera and dish antenna

[K] Turn head lights on/off

[LShift]+[1]numpad
Start/Stop dish antenna pitch down

[LShift]+[CTRL]+[1]numpad
Start/Stop dish antenna pitch up

[LShift]+[2]numpad
Start/Stop dish antenna yaw left

[LShift]+[CTRL]+[2]numpad
Start/Stop dish antenna yaw right

TRS Pallet

The TRS Pallet must Detach/Attach the TRS in order to deploy and retrieve it, using Spacecraft3 attachment keys:

[A] Activate/Deactivate attachment controls

[L Shift]+[4] or [6]
Cycle thru available attachment points

[L Shift]+[5]
Display/Hide attachment points

[L Shift]+[0]
Attach/Detach child vessel

Power Module

[LShift]+[0]numpad
Deploy radiator panels

[LShift]+[1]numpad
Start/Stop solar array No. 1 deployment

[LShift]+[2]numpad
Start/Stop solar array No. 2 deployment

[LShift]+[3]numpad
Rotate solar arrays toward aft

[LShift]+[CTRL]+[3]numpad
Rotate solar arrays toward forward

[LShift]+[4]numpad
Deploy Ku band antenna

[LShift]+[5]numpad
Start/Stop dish antenna pitch down

[LShift]+[6]numpad
Start/Stop dish antenna yaw left

Atmospheric Instrument Pallet

[LShift]+[1]numpad
Extend/Retract IR Telescope/Cryo Limb Scanner

[LShift]+[2]numpad
Start/Stop telescope yaw right

[LShift]+[CTRL]+[2]numpad
Start/Stop telescope yaw left

[LShift]+[3]numpad
Start/Stop telescope pitch up

[LShift]+[CTRL]+[3]numpad
Start/Stop telescope pitch down

Payload Attach Fittings

You may wish to retrieve certain payloads, such as the Logistics Module and Instrument Pallet. Jump to the appropriate Fittings vessel [F3] and set its attachment point to FREE using the Spacecraft3 attachment keys (see TRS Pallet at left). When the payload is within range use the [L Shift]+[0] command to attach the module to the Fittings.

NAV/COM FREQUENCIES

To aid rendezvous, the free flying vessels are configured with transponders:

Skylab I Transponder Frequency - 111.10
TRS Transponder Frequency—111.20

There are no instrument docking system frequencies (IDS). Docking is performed visually, using Skylab's docking target and Docking HUD marker (Figure 3).

SCENARIOS

Skylab1980 includes three complete sets of scenarios, tailored for each of the three Space Shuttles currently available in Orbiter: *Space Shuttle Ultra*, *Shuttle Fleet* and *Orbiter's* stock Atlantis. Launch autopilots are configured for the SSU and Fleet scenarios. Relative Inclination will be 0.00° to 0.01 ° degrees for SSU launches , and 0.01° to 0.03° for Fleet launches.

Skylab1980 is intended to work "as is" and attempts to minimize the number of additional required downloads needed to make it work. The launch scenarios are configured to use Orbiter's stock launch structures. You will need to edit the scenario files to use a launch structure add-on such as *LC39-EAFB*.

The scenarios are organized into the four program phases. Each mission has three related scenarios:

(a) Starting at T minus 1 hour, 15 minutes. Furnishes time for ground operations (should you wish to employ one of the elaborate Shuttle launch structure add-ons) and to perform SSU's complete switch flipping pre-launch check list, if that is your preference.

(b) Starting at T minus 5 minutes. For the impatient user who just wants to get started. (The SSU scenarios start with the pre-launch checklist completed.)

(c) On-orbit Station Keeping. For the *really* impatient user. The initial mission rendezvous is complete, the Shuttle's cargo bay doors are open and the RMS is deployed. (SSU's post-launch checklist is completed.) Everything ready to begin the mission's orbital operations.

The scenarios are listed in order of their Skylab mission numbers, starting with SL-5 for the initial reboost mission. (SL-1 was Skylab's launch in 1973. SL-2, SL-3 and SL-4 were the three manned missions.) The Orbiter Launchpad window gives a brief description of each mission and the correct time to ignite the Shuttle's engines.

Skylab Reuse Program Launch Times

Skylab Mission	Space Shuttle Mission	Launch Date	Engine Ignition (UT)*
SL-5	STS-3	21 OCT 79	15:53:12
SL-6	STS-41-C	9 JAN 82	10:36:38
SL-7	STS-61-B	16 OCT 83	20:31:07
SL-8	STS-26	3 JUL 86	03:26:48
SL-9	STS-29	8 JAN 87	14:59:46
SL-10	STS-30	6 MAR 87	11:15:40

****Engine ignition time***. Liftoff occurs 6 seconds later.

MISSION DETAILS

Following are some useful notes for each mission. Detailed flight instructions for the Space Shuttle are beyond the scope of this manual. An excellent video tutorial is available at OrbitHangar for Shuttle rendezvous procedures - see Section 4 of this manual.

The TRS and modules are configured with attachment points located at the RMS grapple fixtures. Some of the larger, more awkward pieces have multiple grapple fixtures. The grapple fixtures are easily seen 2 foot diameter plates with a braced projecting stem and an alignment target (see Figure 2-4 for an example).

Refer to page 3-1 for spacecraft Custom Key Commands.

SL-5 Skylab Reboost

Use the RMS to extract the TRS from the cargo bay. (The craft's RCS thrusters would scorch the Shuttle if it were flown directly from its pallet.) Deploy the dish antenna and TV camera. Fly the TRS to Skylab and use the marker on the Docking HUD to align with Skylab's docking target. See Figure 3-1 on the following page.

Figure 3-1a TRS Docking - cockpit view. Note how the green Docking HUD marker aligns with Skylab's docking target. The red portion of the target concealed, indicating proper alignment.

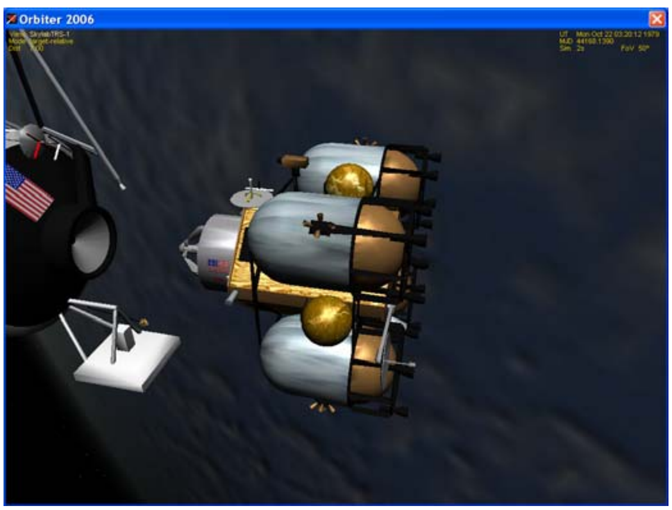


Figure 3-1b TRS Docking - external view. The extended TV camera (above and aft of the grapple fixture) lines up with the docking target.

After docking to the TRS jump to Skylab [F3] and turn it to a ***retrograde*** attitude. Perform this maneuver manually, in short bursts, to save fuel. Use the retrograde button to lock in the attitude. (Note: The TRS attitude thrusters are too weak to turn Skylab or hold its attitude - use Skylab's thrusters.) The TRS will now be face prograde. When ready, ignite the TRS main thrust and lock it on [+]numpad + [CTRL]. The TRS thrust is very low. The first burn will last about 15 minutes Cut off the main thrust when the TRS fuel level drops to ~52%. Skylab's apoapsis altitude will now be ~330 km.

Begin a second burn at about 420 seconds prior to reaching this new apoapsis to circularize the orbit.

Rendezvous again with Skylab, undock the TRS and retrieve it with the Shuttle's RMS. Immediately after the reboost burn, the Shuttle will be in a lower, faster orbit. Depending on how you look at it, the Shuttle is now either slightly ahead of Skylab, or nearly a full orbit behind. The easiest rendezvous procedure (though time consuming) is to simply wait about three days for the Shuttle to catch up to Skylab. Then perform a conventional rendezvous maneuver from below and behind.

SL-6 Refurbishment Mission No. 1
Reboost and Airlock Module

Because 2½ years have passed since the initial reboost mission, Skylab has dropped to an orbit of ~300 km. Begin the first Refurb Mission by again boosting Skylab with the TRS to a 425 km altitude.

Redezvous again with Skylab. Retrieve the TRS and deploy the Airlock Module. Use the RMS to extract the Airlock Module from the cargo bay and place the appropriate end of the module onto the APAS-75. The RMS must be twisted in a particular way. This may take some trial and error. It can be done with SSU, and presumably with other Shuttles (see Figure 3-2). Do not forget to first extend the APAS-75 to its working position. Use the Shuttle to dock the Airlock Module to Skylab's main docking port.

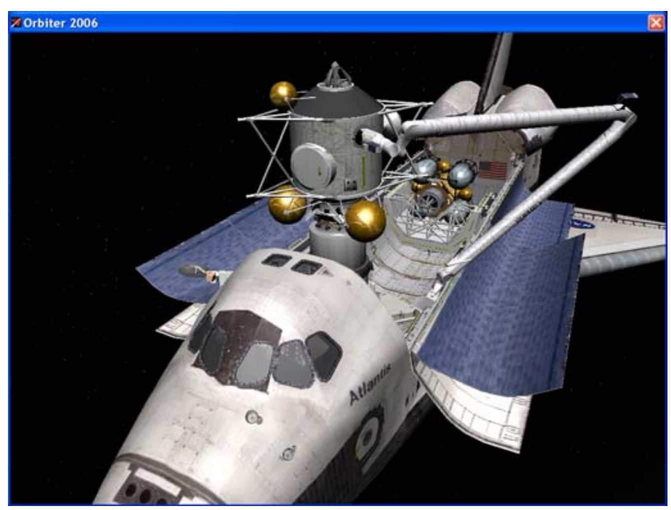


Figure 3-2 Docking the Airlock Module to the APAS-75

You can partially refill Skylab's TACS nitrogen using Fuel MFD, or simply save the scenario and edit it to increase Skylab's fuel to 30%.

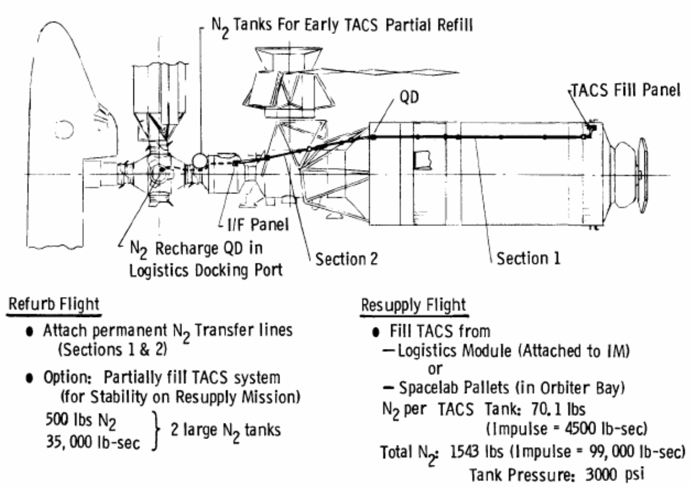


Figure 3-3 TACS Re-supply Concept
Showing piping that would need to be installed with the MMU.

SL-7 Refurbishment Mission No. 2 Docking Module and Supply Pallet

Similar to SL-6, but no reboost will be needed. Use the Shuttle's RMS to extract the Docking Module form the cargo bay. Dock *Port 1* to the APAS-75. *Port 5* must be facing forward. See Figure 3-4.

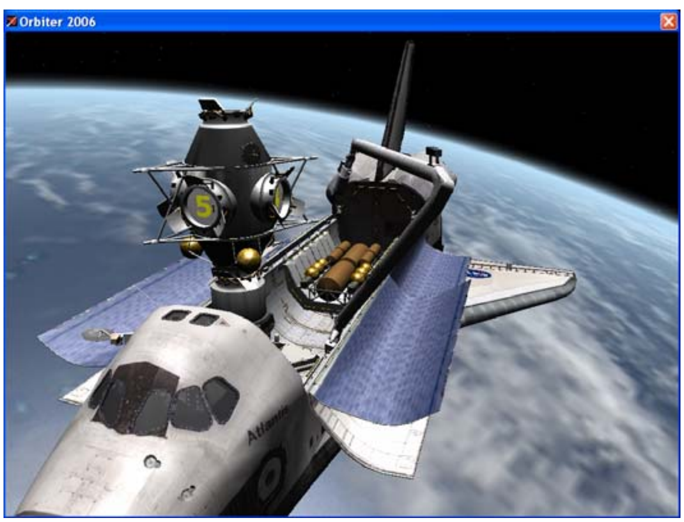


Figure 3-4 Docking Module joined to APAS-75
Docking Module *Port 1* is joined to the APAS-75, and *Port 5* is facing forward.

Skylab's ATM solar arrays 1 and 2 should be folded up during the second Refurb Mission, in anticipation of the Power Module to be installed next. The *Skylab Reuse Study* states that the wrap-around sun screen would not be need until Phase IV operations. But rendezvous and installation of the Docking Module, folding the solar panels, moving supplies from the Docking Module into Skylab and connecting hoses from the Supply Pallet to the manifold on the Airlock Module would, at most, consume four days of Refurb Mission 2. This seems like a good time to perform the day-long EVA with the MMU to install the wrap-around shade. Although, you may also choose to wait until SL-10 to install the new sunshade.

SL-8 Reboost and Assess

Skylab1980 imagines that the Challenger disaster, Shuttle mission STS-51-L, takes place soon after the second Skylab Refurb Mission. Shuttle launches are suspended for 32 months, during which time Skylab would have again lost significant altitude, down to about 375km. This is nowhere near critical, and Skylab begins this period with three healthy CMGs on the Airlock Module, and a fair supply of TACS gas. The station is in good shape to maintain a solar inertial attitude to generate electricity and continue sending telemetry to the UHF ground stations.

It seems realistic to insert an extra mission into the Reuse Program Schedule to inspect Skylab after this long interruption and to reboost the station back to its working altitude of 425 km.

SL-9 Power Module

The Power Module (PM) takes up the entire Shuttle cargo bay, so there would be no Orbiter Docking System on this flight. Use the RMS to extract the PM from the cargo bay and hold it at full extension from the Shuttle. Use Shuttle translation thrusters to join the PM to Docking Module *Port 5*. Deploy the PM solar arrays, radiators and Ku band dish antenna. PM should now be used exclusively to control and change the station's attitude.

SL-10 Logistics Module and Atmospheric/Magnetospheric Instrument Pallet

Dock the Shuttle to the station, then use the RMS to join the Logistics Module to Docking Module *Port 4* and the Instrument Pallet to *Port 2*.

Installation and Credits

Section 4

DESCRIPTION

Skylab1980 has been tested only on "clean" installations of Orbiter, with only the required add-ons listed here. However, *Skylab1980* installs its configuration, mesh and texture files to their own custom folders, so conflicts with other add-ons should not occur. As with any Orbiter add-on, there is no guarantee of any kind.

REQUIRED PROGRAMS

Unless noted otherwise, all programs can be found at Orbithanger.com Thank you, Martin and Vinka - your programs make mine possible!

Orbiter Space Flight Simulator 2006-P1 (Base) (available at: www.orbitersim.com) (Orbiter060929) by Martin Schweiger.

Spacecraft3 by Vinka (available at: http://users.swing.be/vinka/)
The required files are included with the installation of *Skylab1980*.

Skylab1973 by Scott Conklin (Usonian). Copy the contents of the .zip file into your Orbiter *Skylab* directory, preserving the directory structure.

Skylab1980 by Scott Conklin (Usonian). Copy the contents of the .zip file into the same *Skylab* directory. *Skylab1980* and *Skylab1973* use the same textures, so overwriting them will not harm *Skylab1973*.

OPTIONAL PROGRAMS

Follow the installation instructions that come with these add-ons. *Skylab1973* and *Skylab1980* can be installed after the Shuttle add-ons, if you wish.

Space Shuttle Ultra v1.06 by Siamescat et. al. Special thanks to Urwumpe, Donamy and DaveS who have been invariably generous with their time and knowledge on all things to do with the Shuttle.

Shuttle Fleet v4.0.1 by David413

Atlanits to ISS Tutorial by Reverend. An excellent video tutorial for Shuttle rendezvous and docking procedures.

SOURCES & CREDITS

Skylab Reuse Study, September 1978 by J. Allison; D. Allayaud; R. Barry; R. Champion; R. Farris; R. Haefeli; E. Karnes; R. Kruger; E. Littler; M. Winter, Martin Marietta Corporation.

This fascinating report is the source for all reuse hardware and technical matters, and for all of the line drawings in this manual (except Figure 2-1, APAS-75, from Wikipedia)

The *Skylab Reuse Study* is available through The Manned Space Flight web page: http://www.geocities.com/bobandrepont/spacepdf.htm which provides links to a huge number of technical papers. It is a wonderful resource for historical add-on development.

The following two publications were the sources for the history of Skylab re-entry and reboost efforts:

Living and Working in Space: A History of Skylab, 1983 by W. David Compton and Charles D. Benson, NASA, pp 127-129, p 212 & chapter 19. This excellent history is available on line at http://history.nasa.gov/SP-4208/sp4208.htm

Skylab's Untimely Fate, by James Oberg, first appeared in *Air & Space*, February/March 1992, pp. 73-79. Available at http://ww.astronautix.com/articles/skyyfate.htm A very interesting magazine article, apparently well sourced, with direct quotes from several of the people involved in the Skylab reuse effort.

Special Thanks to Mustard for creating a nice gold foil texture, and 4th Rock for an improved white blanket texture.