Skylab1973 v2.0
Operations Manual

September 2008
by
Scott Conklin (Usonian)

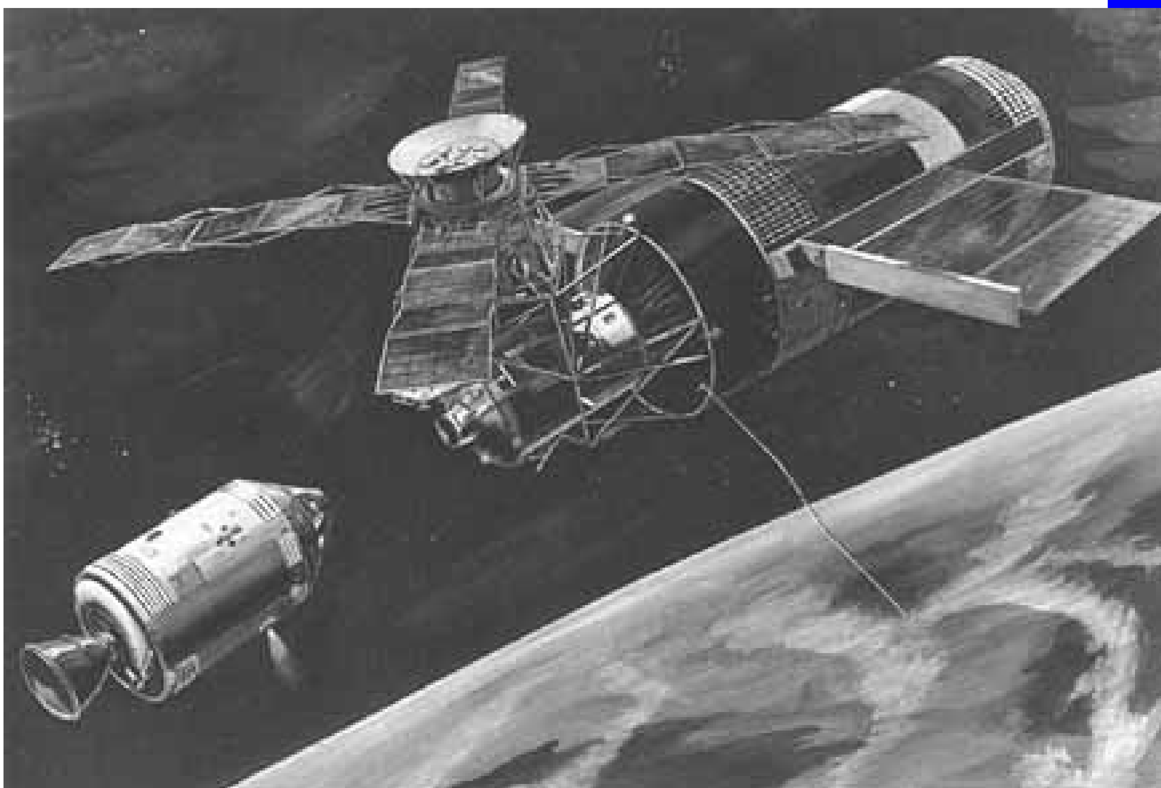


TABLE OF CONTENTS

Introduction

Section 1

BACKGROUND

From the earliest days of the Apollo program some NASA visionaries wondered what would come next. How would the exploration and exploitation of space proceed after achieving the immediate (and largely political) goal of landing a man on the Moon and returning him safely to the Earth? As Saturn/Apollo development progressed it also became apparent -- to practical people as well as visionaries -- that the program was building up a huge store of specialized expertise, organizational structures, manufacturing systems, hardware and personnel that would very likely dissolve soon after the Moon was reached.

An Apollo Extension Support Study identified new flight projects using launch vehicles, spacecraft and components originally developed for Apollo lunar landing missions. These early efforts evolved into a permanent organization when NASA opened the Apollo Applications Office in 1965. Using modified Apollo spacecraft and Saturn rockets, the Apollo Applications program envisioned long-term Earth orbital missions to conduct various scientific and engineering experiments.

Among the earliest ideas considered was a scheme for placing small telescopes in the Service Module of an Apollo spacecraft. The astronauts would operate and maintain this Apollo Telescope Mount (ATM), and then return the exposed film to Earth. In time, the idea of a small cluster of telescopes, deployed and operated from the CSM, grew into a large canister holding ten telescopes, powered by its own solar array, and mounted to the bottom of a Lunar Module ascent stage. The LM would serve as the control room for the ATM and would permit the telescope canister to be launched separately and maneuvered independently with the LM's attitude control thrusters.

Along with the Apollo Telescope Mount, ideas evolved for an Orbital Workshop. Early plans involved using the spent second stage (S-IVB) of the Saturn IB rocket that boosted the Command Service Module into orbit. The hydrogen tank of the S-IVB would be purged of residual fuel and then filled with a breathable atmosphere. The CSM, and the separately launched LM/ATM, could be joined to the S-IVB workshop by an intermediate airlock module with multiple docking ports (the cluster concept). The S-IVB "wet workshop" would provide a

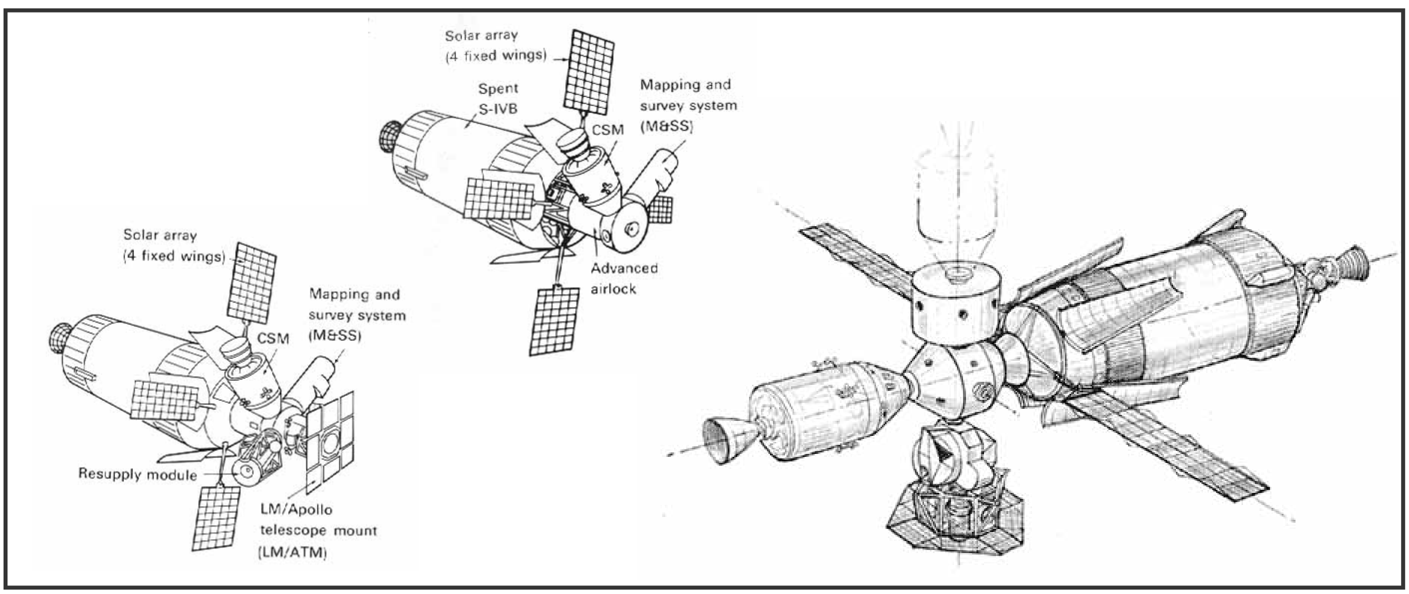


Figure 1-1 Some early cluster concepts

large enclosed environment for astronauts to test devices for maneuvering and working in weightlessness. Over time, this limited view of the workshop grew to include additional experiments, partitions, living quarters for the astronauts, and its own solar panels. In July, 1969 the wet workshop notion was dropped. With the Moon landing accomplished a surplus Saturn V booster was available for Apollo Applications. By using the powerful Saturn V, the S-IVB stage could be fully prepared for habitability prior to launch -- a "dry workshop." It would not start out full of fuel, nor have its own engine.

None of these schemes received much attention or funding while the Moon landing program was underway. Firm commitments, planning and production for Apollo Applications began only after the success of Apollo 11. As NASA turned its attention toward developing the Shuttle the idea of multiple Saturn V launches, and fleets of modified Apollo spacecraft conducting a variety of missions, faded away. The entire Apollo Applications Program would consist of a single station called Skylab, manned by three successive crews, and the Apollo-Soyuz Test Program. Skylab would be in use for only eight months and fall from orbit about ten years after launch.

The downsizing of Apollo Applications can be attributed to lack of funding, of course, and NASA's commitment to the Shuttle. But it was also true that the Apollo spacecraft were specifically designed to carry out Moon landings. For the most part, modifying these machines to perform other missions was impractical, costing about as much as developing new vehicles from scratch.

SPACECRAFT DESCRIPTION

Skylab was launched on May 14, 1973 by a two-stage version of the Saturn V called Saturn INT-21. Skylab's Orbital Workshop (OWS) took the place of the Saturn's S-IVB third stage. The OWS was, in fact, a heavily modified S-IVB stage with engines removed and interiors fully up-fitted for long-term human occupation. Above the OWS were the Air Lock Module (ALM), Multiple Docking Adapter (MDA) and the Apollo Telescope Mount (ATM), all of which were covered by a payload shroud during launch and until orbit was achieved.

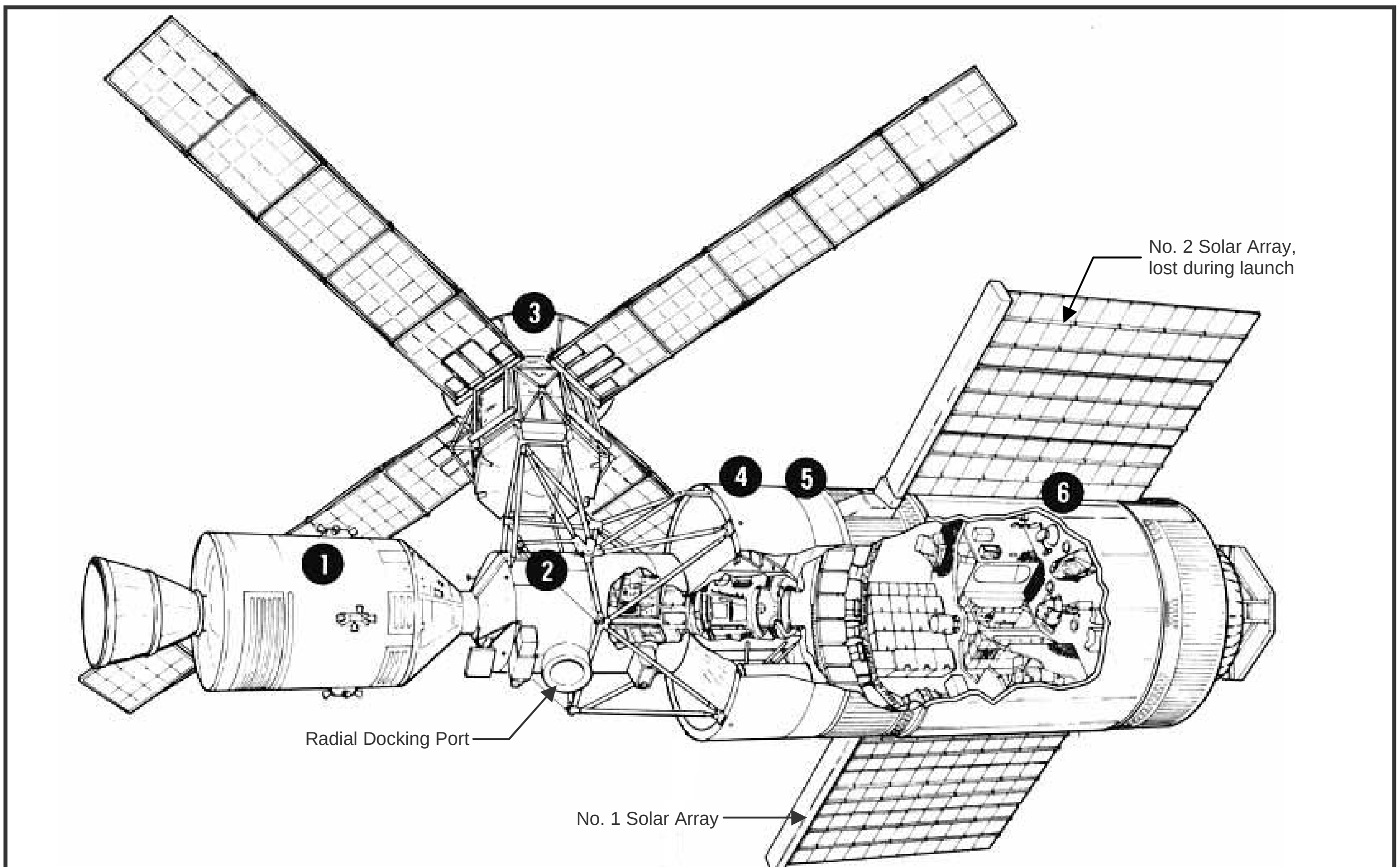


Figure 1-2 The final arrangement

The outer "skin" of the OWS, exposed and visible during launch, was composed of two moveable panels. After reaching orbit, the panels were to be extended out 6" from the wall of the workshop, forming a combination sun and micro-meteoroid shield. During assembly at Kennedy Spaceflight Center the panels could not be brought tightly against the outer wall of the OWS, but the engineers convinced themselves that the installation was good enough. A minute after launch the shields tore completely off, also removing one of the workshop's two main solar arrays.

Ground controllers received an indication that the meteoroid shield deployed prematurely, but otherwise the launch was flawless and Skylab achieved a near-perfect orbit. During the first half-hour of orbit al operations the payload shroud and a radiator cover were jettisoned as expected. The ATM swung up from its launch position, clearing the main docking port for use, and the ATM's four solar arrays extended — all according to plan. But then controllers began to receive erratic signals from the meteoroid shield and both OWS solar arrays. And the temperature inside the station began to rise. Within a few hours, after examining all the available telemetry, controllers had a fairly clear picture: The Sun/meteoroid shield and the number 2 solar array were gone. The number 1 array was present, but unable to open, presumably jammed by debris from the accident.

Launch of the first crew was delayed ten days while fixes were debated and fabricated. The first crew carried a small collection of cutting tools, hooks and ropes to free the solar array. They also brought a parasol sunshade that could be deployed from inside Skylab, through one of the two science experiment airlock ports. The second crew deployed a second, more effective screen during a day-long EVA, supported on two spars attached to the ATM.

Skylab's primary missions were biomedical testing to determine the long-term effects of weightlessness, photographing the Sun with the ATM, and making Earth resources observations. Because Skylab was a solar observatory, the attitude control system had to be extraordinarily precise. Conventional RCS thrusters could not be used; they were not delicate enough and their exhaust gasses might interfere with the telescopes. Primary attitude control was furnished by three control moment gyroscopes (CMG) mounted on the ATM. The ATM canister also had gimbal mounts to further refine the aim. Gross attitude control was furnished by the Thruster Attitude Control System (TACS), a cold gas system working off of compressed nitrogen.

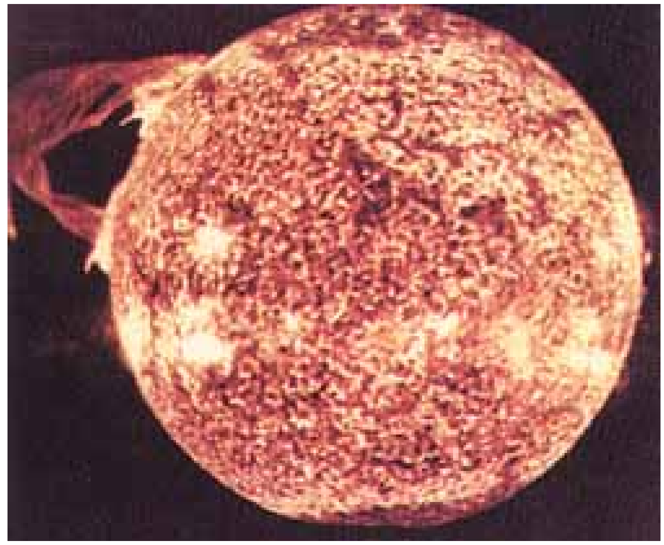


Figure 1-3 Solar flares recorded by the extreme-ultraviolet spectroheliograph, experiment S082A.

Digital imaging was in its infancy in 1973. The advantage offered by Skylab was photographs taken on film which could be returned to earth for processing. Changing film was done via EVAs during the course of each mission.

Flight Operations
Section 2

ORBITER CONFIGURATION

Skylab1973 v2.0 is configured with Vinka's *Multistage2* and *Spacecraft3*. Version 2 includes Saturn V launch scenarios using *Multistage2*. There are also two sets of Saturn IB launch scenarios for the crew missions. One set uses *NASSP,* patched through V6.4.3, for the Saturn IB and the Command Service Module. The other set uses *Velcro Rockets*' Saturn IB to launch the *AMSO* CSM. See Section 3 for the *NASSP*, *Velcro* and *AMSO* add-ons. All launch scenarios are configured with autopilots. Launch and orbit insertion are completely automatic.

Version 2 also has a revised mesh for Skylab with a smoother appearance, somewhat lower polygon count and a substantially lower vertex count. The mesh and configuration also include new animations for use with the separate Skylab rescue and reuse add-on, *Skylab1980.*

Skylab1973 CUSTOM KEY COMMANDS

Keyboard key presses are shown in square brackets [THUS]. On-screen MFD button clicks are shown italicized and in rounded parenthesis *(Thus)*

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

Launch Operations:

[P] Activate *Multistage* Autopilot at T-10 sec

[O] Activate *Velcro* Autopilot—immediate launch

[F] Jettison Skylab's launch fairing

[J] Jettison radiator cover

Orbital Operations:

[G] Initial Deployments - ATM swing-up, ATM solar arrays and UHF discone antennae.

[K] Fold up ATM solar arrays No. 1 and 2 (for use with *Skylab1980* add-on)

[LShift]+[0]numpad
Deploy/retract parasol sun shade [1]

[LShift]+[1]numpad
Deploy main solar array No. 1 [1]

[LShift]+[2]numpad
Turn on/off running lights

[LShift]+[3]numpad
Turn on/off EVA lights

[LShift]+[4]numpad
Open/close EVA hatch

[LShift]+[5]numpad
Deploy/retract twin pole sun shade [2]

[LShift]+[6]numpad
Open/close ATM aperture doors for White Light Coronagraph, Helium Alpha telescopes and Fine Sun Sensor

[LShift]+[7]numpad
Open/close ATM aperture doors for X-ray telescopes and Ultraviolet telescopes

[LShift]+[8]numpad
Open/close ATM aperture door for Ultraviolet telescope film retrieval

[LShift]+[9]numpad
Start/Pause/Resume Deployment of wrap-around sun shade (for use with *Skylab1980* add-on)

1 Deployed by the first crew. (Retract for *Skylab1980*)

2 Deployed by the second crew. (Retract for *Skylab1980*)

Skylab1973 NAV/COM

Skylab I is configured with a transponder (XPDR) frequency of 111.10

There are no instrument docking system frequencies (IDS). Docking is performed visually, using the docking target and CSM reticule. *Skylab1973* was originally designed to work with *NASSP*. The docking reticule on the *AMSO* CSM does not align properly with Skylab's docking target. Use the Docking MFD with *AMSO*.

FLIGHT PORCEDURES

SKYLAB 1

The Skylab launch vehicle was a two-stage version of the Saturn V call the Saturn INT-21. The launch is completely automatic, simply press [P] to start the Multistage2 autopilot at T minus 10 seconds. Upon reaching orbit:

- Jettison the spent S-II stage by pressing [J]
- Yaw to retrograde orientation and jettison the payload fairing [F]
- Jettison the radiator cover [J]
  This also spawns the Spacecraft3 vessel named *Skylab-I*. Focus shifts automatically to *Skylab-I.*
- Pitch and roll to a "solar inertial" attitude, meaning that the solar panels and ATM (when deployed) will be facing the Sun. In Orbiter terms, your Y+ axis will be pointed toward the Sun.

NOTE

> The thruster attitude control system (TACS) is modeled as realistically as possible. The fuel supply is limited, so maneuvers are best made with short bursts. The TACS nozzles are accurately shown, but you will not see any exhaust flame. The TACS was a "cold gas" system discharging compressed nitrogen.

- Deploy the ATM [G]

The ATM swings up into its working position, its windmill solar arrays extend, the UHF "discone" antennae unfold, and the "clothes line" boom deploys. (The boom was used to move film canisters between the EVA hatch and a film retrieval door on top of the ATM.)

Because of the loss of its micrometeoroid/sun shade, Skylab began to severely overheat in its solar inertial attitude. On the other hand, with its surviving main solar panel jammed shut, the station was underpowered; keeping the station in solar inertial attitude maximized power generation from the ATM array. Ground controllers eventually settled on a compromise attitude about 45° off of the solar inertial. An extraordinary volume of TACS nitrogen was expended during the first couple of days to find and maintain a favorable attitude.

During normal operations, which were restored by the first crew, the station would typically have its long axis parallel with the station's orbital plain. It could then roll and pitch to solar inertial attitude for ATM work, or to a "local level" attitude for the Earth resources experiments.

SKYLAB 2 3 & 4

The remaining scenarios are for the three manned missions. For the Saturn IB booster and CSM these scenarios require a separate download and installation of either *Project Apollo NASSP*, or a combination of *Velcro Rockets/Velcro Saturns* plus *AMSO*.

SATURN IB LAUNCH AND ORBIT INSERTION

Pre-Flight

All S-IB launch scenarios begin at about T minus fifteen minutes. For *NASSP* scenarios, the essential, functional switches are pre-set to their correct launch positions.

Launch

- *Velcro/AMSO* scenarios have a ground elapsed time (GET) display. When the count reaches 00:00:00 press the letter [O] key to immediately ignite engines and activate autopilot.
- *NASSP* will ignite the engines automatically at the correct time.

After Orbit Inserion

- For *NASSP* jump to the cockpit view [F8] and set the CMS ATTITUDE switches Roll, Pitch and Yaw to their ON positions. Separate the CSM from the S-IVB second stage by opening the switch guard (right mouse click) and pushing the CSM/LV SEP button.
- For *Velcro/AMSO* press [J] to jettison the S-IVB.

Orbital Plane Alignment

- For *NASSP* only: In the virtual cockpit view, set SPS Thrust Direct switch to ON
- Switch to generic cockpit view [F8] and open the Alignment MFD (Generic view makes the on-screen MFD buttons available.)
- Set target for "Skylab-I"
- Note the Relative Inclination (RInc) and whether it is positive or negative
- As you approach the next orbital node indicated on the MFD turn the CSM to the appropriate Normal or Anti-normal attitude as shown in the following table:

At Ascending Node

- Use Anti-Normal thrust to decrease a POSITIVE Rinc toward zero.
- Use Normal thrust to increase a NEGATIVE Rinc toward zero.

At Descending Node

- Use Normal thrust to decrease a POSITIVE Rinc toward zero.
- Use Anti-Normal thrust to increase a NEGATIVE Rinc toward zero.
- Use 10% RCS thrust to fine tune orbital alignment. The relative inclination must be 0.00°

<u>RENDEZVOUS</u>

Skylab is orbiting at a 50° inclination and an altitude of 432± km. The CSM is now on an identical inclination and an altitude of 200 to 255 km. Following is my preferred rendezvous procedure.

<u>Transfer Orbit Insertion (TOI)</u>

- Switch to generic cockpit view [F8]
- Open NavCom MFD and set NAV 1 to Skylab's transponder frequency: 111.10 kHz
- Open the Transfer MFD
- Activate hypothetical transfer orbit mode *(HTO)*
- Set target to 'Skylab-I" *(TGT)*

  Green circle = CSM current orbit.

  Yellow circle = Skylab current orbit.

  Solid green line = CSM current position.

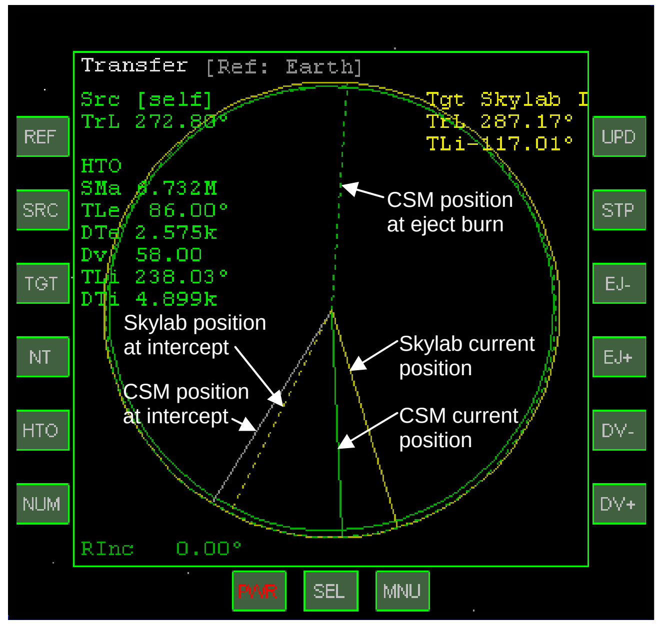
  Solid yellow line = Skylab current position.

  Dotted green line = upcoming position of the CSM transfer orbit eject burn. The MFD will be displaying the message "No Intersect."
- Increase Dv just enough to make two more lines appear *(DV+)* These will be:

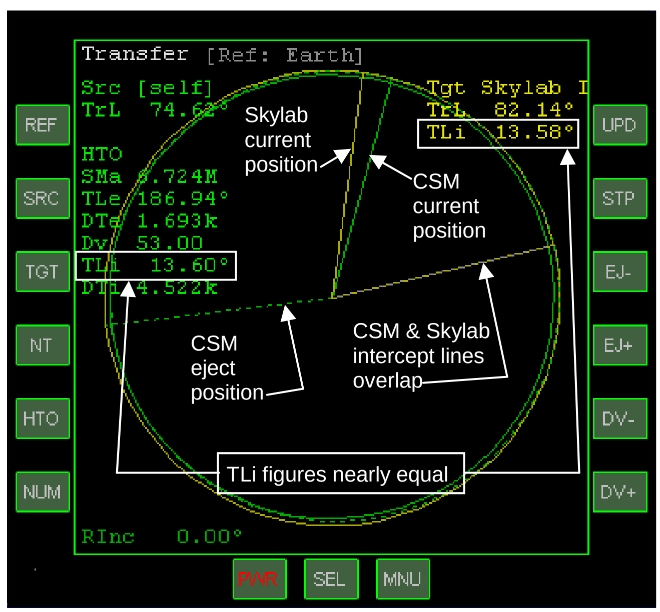
  Solid gray line = Intercept position (where CSM's orbit will intercept Skylab's orbit).

  Dotted yellow line = Skylab's position at time of intercept (where Skylab will be when CSM intercepts Skylab's orbit).

  Dotted Green Circle = CSM transfer orbit.
- Rotate the eject position line *(EJ+)* or *(EJ-)* until the gray and yellow lines overlap. If the position lines will not overlap (see Figure 2-1A) wait for the CSM to draw closer to Skylab and try again. When the lines overlap compare the TLi (location of intercept line) shown for CSM and for Skylab. Adjust eject line further to minimize the difference between the two TLi figures. (see Figure 2-1B)
- Turn CSM prograde, then lock spacecraft into prograde attitude.
- When DTe (Δ time to eject) = 0 seconds ignite the main engine thrust [+]numpad
- As Dv nears zero shut down engine [*]
- Fine tune Dv to zero with 10% RCS thrust [CTRL] + [6]numpad or [9]numpad



A Initial setup. CSM will fall short of Skylab when CSM intercepts Skylab's orbit.



B Final setup. CMS and Skylab will arrive at the same place at the same time.

Figure 2-1 Transfer MFD for Rendezvous

Mid-course Correction (MCC)

- Close MFD on right side (power OFF)
- Set HUD mode to Docking
- Open Docking MFD on left and set target to Skylab-I.
- *Perform MCC 1 at 40km distance to Skylab*:
  - Turn toward Skylab in direction indicated by Docking HUD. From a prograde attitude this should be a right yaw. Docking HUD will mark Skylab with a square target box. The HUD's retrograde crosshairs should be close by.
  - Aim the CSM at the retrograde crosshairs and kill rotation [5]numpad
  - Turn on translation RCS [/]numpad
  - "Drive" the retrograde crosshairs into the target box by firing X-axis RCS thrusters [1]numpad or [3]numpad
  - Fire Y-axis thrusters to drive the crosshairs "up" or "down" if needed.
- *Perform MCC 2 at 20km distance to Skylab*.
- Repeat the MCC1 procedure.

Braking Phase

At 10km distance to Skylab the closing velocity should be 20 m/sec. Closing velocity will most likely be higher and "braking" will be required.

- If closing velocity is fairly close to 20 m/sec aim the CSM at the Docking HUD retrograde crosshairs and fire Z axis translation thrusters [6]numpad or [9]numpad to achieve CVEL of 20 m/sec.
- If closing velocity is significantly greater than 20 m/sec (which is most likely) turn the CSM to aim at the Docking HUD ***prograde*** marker and ignite main engine at minimal thrust [CTRL] + [+]numpad
- Shut down main engine when closing velocity reaches 20 m/sec [*]numpad
- Fine tune closing velocity with Z-axis thrusters as needed.
- Turn CSM back to aim at Skylab
- As CSM closes on Skylab use Z axis thrusters to decrease the closing velocity as follows:

DST	CVEL
2000 m	9 m/sec
1000	6
500	3
150	1.5
50	0

- Maintain station-keeping at 50m distance until lighting conditions are favorable for docking.

DOCKING

Historically, only the main axis docking port was used. But both ports are configured in *Skylab1973* and you may dock with either one.

- Jump to Skylab and turn the station to a solar inertial attitude. This is historically correct and gives favorable lighting to Skylab's docking target. Kill rotation [*]numpad.
- Jump back to CSM. Use the docking MFD, if you wish. For greater realism (if using NASSP) shift to the reticule view [CTRL] + [Left Arrow] and establish the correct alignment with the reticule and docking target.

THE END OF SKYLAB

The last crew left Skylab on February 8, 1974. Ground controllers vented its atmosphere and shut down most of its systems. By the end of manned operations, one of Skylab's three Control Moment Gyroscopes was inoperative, and a second one was ailing. Two coolant loops were misbehaving and several power supply modules were nearing the end of their expected life spans. The TACS fuel supply was very low. At that time, Skylab was considered a used-up hulk. There were no plans for renovation and re-use.

The station was expected to remain in orbit until about March of 1983. It was always known that Skylab's reentry could pose a hazard to people on the ground, though the probability of a "hit" was very low.

By the end of the last Skylab mission development on the Shuttle was well underway. If that project went smoothly one of the Shuttle's early missions would be to attach a propulsion module to Skylab and boost the station into a higher orbit or bring it down in an ocean.

But funding for NASA was cut and Shuttle development lagged. On top of this, the next cycle of maximum sunspot activity began earlier and was more vigorous than NASA predicted. The increased activity on the Sun expanded Earth's atmosphere, increased drag on the station and shortened its orbital life. Ironically, results from Skylab's own data, not immediately available in 1974, refined later predictions of solar cycles.

The end came July 11, 1979 when Skylab reentered, broke up and scattered debris across the eastern India Ocean and western Australia.

The *Skylab1980* add-on provides more information on Skylab's reentry, and some very serious efforts to keep it aloft, refurbish and reuse the station.

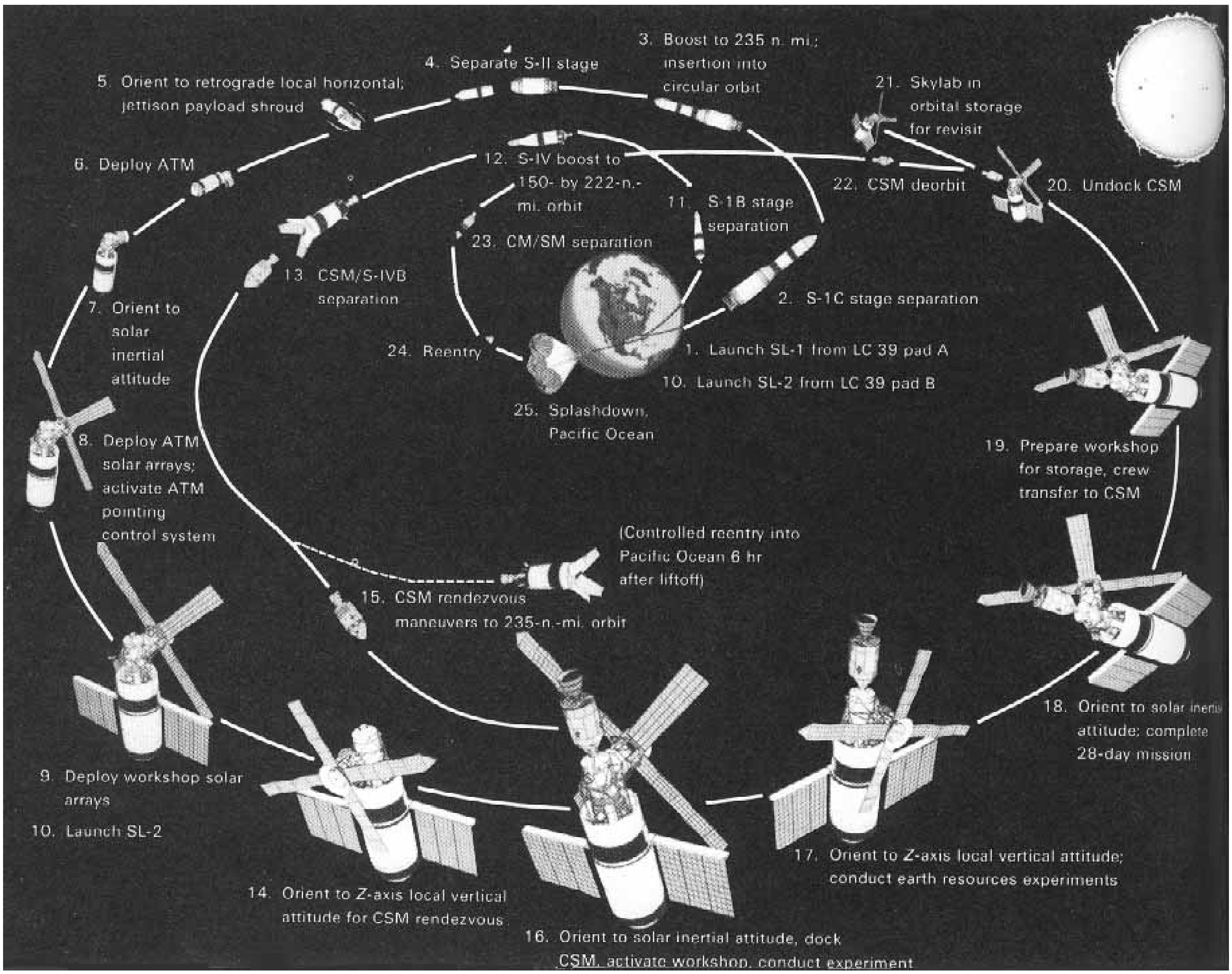


Figure 2-2 Events for Skylab missions SL-1 and SL-2. Note the aeronautical engineering convention: X axis runs fore and aft, Y axis runs side to side, and Z axis runs up and down. The note "Controlled reentry into Pacific Ocean 6 hr after launch" next to the spent S-IVB is interesting. No provisions were made to control Skylab's reentry. See the *Skylab1980* add-on for the story behind that note.

Installation and Credits

Section 3

DESCRIPTION

Skylab1973 is a stand-alone add-on for Orbiter Space Flight Simulator, Multistage2 and Spacecraft3. Skylab Saturn INT-21 launch scenario can be flown without additional add-ons. The manned mission S-IVB scenarios require installation of *Project Apollo NASSP* ***or*** Velcro Rockets/Velcro Saturns plus AMSO.

Skylab1973 v2 uses the NASSP meshes and textures for the Saturn V's C-I S-II and Interstage under the GNU General Public License. This license applies to all the files included with *Skylab1973 v2.0* except for the following:

All files pertaining to Spacecraft3 and Multistage2 by Vinka

The *Sklab1973 Operations Manual*

The public license does not extend to any other separately downloaded programs (including *Skylab1980*)

Skylab1973 installs its configuration, mesh and texture files to their own custom folders, so conflicts with other add-ons should not occur. Still, starting with a clean Orbiter installation is always a good idea. As with any Orbiter add-on, there are no guarantees of any kind.

REQUIRED PROGRAMS

Unless noted otherwise, all programs can be found at Orbithanger.com Install the programs in the order shown.

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

Multistage2 and ***Spacecraft3*** by Vinka (available at: http://users.swing.be/vinka/)
The required files are included with the installation of *Skylab1973.*

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

OPTIONAL PROGRAMS

Project Apollo - NASSP patched throurg v6.4.3 (available at: www.sourceforge.net/projects/nassp) Provides Saturn V and S-IB launch structures, S-IB rocket and Command Service Module

Velcro Rockets v1.1 and Velcro Saturns v1.11 by Erik Anderson (Sputnik) Provides S-IB rocket for launching AMSO Command Service Module.

AMSO v1.17 by ACSoft Productions (available at: http://www.acsoft.ch/AMSO/amso.html)
Provides Saturn V launch structures and Command Service Module.

SOURCES & CREDITS

Skylab scale drawings by David Weeks, 1989, 1998 available through www.realspacemodels.com
David Weeks has produced detailed scale drawings of various spacecraft, all of which appear to be very well researched.

Living and Working in Space: A History of Skylab, 1983 by W. David Compton and Charles D. Benson, NASA. This excellent history is available on line at http://history.nasa.gov/SP-4208/sp4208.htm and is the source of the illustrations in this manual.

Skylab Mission Report: First Visit, August 1973, NASA
Skylab Thruster Attitude Control System, July 1974, NASA

Skylab Reuse Study, September 1978, Martin Marietta http://www.geocities.com/bobandrepont/spacepdf.htm Manned Space Flight web page is a wonderful resource for historical add-on development.

http://orbit.m6.net/Forum/default.aspx?g=posts&t=13985 This Orbiter Forum thread, started by Saturn V, was very valuable in developing this add-on. Thanks to everyone who participated in that discussion.

Skylab: A Guidebook, 1973 by Leland F Belew and Ernst Stuhlinger, NASA. Published prior to launch with good information on Skylab's various experiments and instruments.

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