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BROWN ENGINEERING

TECHNICAL LETTER ASD-ASTN-20102

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FROM: Human Factors Engineering Branch
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Aerospace Support Division

SUBJECT: Final Crew System Corollary Experiment
Input to the Skylab Final Mission Evaluation
Report

DATE: February 15, 1974

In response to AVO No. 140, dated February 8, 1974, and in partial fulfillment of Technical Directive S-3-500, paragraph I. D. 1, the subject report is enclosed.

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MISSION EVALUATION REPORT
SKYLAB COROLLARY EXPERIMENTS

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February 9, 1974

13.22 COROLLARY EXPERIMENTS

13.22.1 General - - The corollary experiments involved three major categories of experimentation consisting of; the scientific, with objectives to acquire photographic data of solar and stellar phenomena; the technological, with objectives to measure contamination levels surrounding the Orbital Assembly; and the operational, with objectives to assess technological innovations which assist the crew in performing space related tasks.

Performance of the corollary experiments during the three Skylab missions achieved most of the designed and planned functional objectives. The knowledge obtained from their operation and the acquired data have provided insight that will be implemented into the design and operational requirements of future manned spacecraft.

Significant information has been acquired as a result of the corollary experiment activities performed during Skylab. The following are some conclusions derived from the on-orbit corollary experimentation that is applicable to future spacecraft hardware designs and operations.

- An adequate maintenance workstation with appropriate tools and restraints should be included in future spacecraft design.
- Crew manipulation of large experiment equipment caused no problems. Multiple, small items were

found to be difficult to constrain and handle. It is recommended that handles be provisioned on all large mass items to facilitate their manipulation. Also, a system is required to control the manipulation of multiple, small items.

- Of the experiments requiring extension/retraction through the Scientific Airlock (SAL) to space, it was found that the retraction forces were somewhat higher, as anticipated, and that a warm-up period was required prior to final retraction and removal of experiments from the SAL to prevent formation of condensation/ frost.
- Through operations of M509 and T020 the feasibility of a one-man maneuvering unit was successfully demonstrated.
- Corollary experiment T013 demonstrated that crew motion within a large spacecraft does impact its stability and guidance control and should be considered in future designs.

13.22.2 Scientific Experiments

13.22.2.1 S009 - Nuclear Emulsion

a. Operations - Experiment S009 was scheduled to be performed throughout the SL-2 mission to investigate aspects of cosmic radiation. Prior to experiment initiation, the S009 detector package was to be removed from the OWS film vault, transferred to the MDA and installed in the S009 experiment housing. The crewman was then to initiate experiment operation by setting the proper beta angle and activating the open-close cycle for the experiment. S009 was to operate automatically throughout SL-2 with the crew making periodic checks and/or corrections to the experiment beta angle and open-close cycle. At the completion of the experiment, the S009 detector package was to be removed from the experiment housing and stowed in the CM for earth return.

b. Usage/Anomalies - The S009 experiment was conducted on SL-2 despite a concern of possible S009 detector emulsion degradation due to the high OWS temperatures present during the beginning of the SL-2 mission. During the S009 detector package installation considerable difficulty was encountered. It was determined that due to the high OWS temperatures, the emulsion package had expanded thereby reducing the tolerances between the package and experiment housing.

After two weeks of operation the door on the S009 experiment housing began to bind and finally would not close properly. The crew performed

malfunction procedures and concluded that the motor/drive train for the experiment door had failed. As a result the S009 door was left open, the automatic open-close cycle was inhibited and manual pointing was maintained throughout the duration of the SL-2 mission for data collection.

At the end of SL-2 the S009 detector package was stowed in the CM and returned to earth. On ground analysis of the package revealed that the emulsion layers had been fused together due to the high OWS temperatures and the data was of little use.

On SL-3 a new S009 door motor was launched for replacement but replacement was not accomplished due to scheduling reasons.

On SL-4 a new emulsion package was launched. During malfunction procedures the crew replaced the defective door motor (an hour operation) and installed the resupplied detector package. S009 was then activated and performed satisfactorily throughout the remainder of the SL-4 mission. Upon completion of the experiment, the detector package was stowed in the CM and returned to earth.

c. Assessments/Recommendations - Experiment S009 operations, including malfunction procedures, were straightforward and no crew interface problems were experienced. The hardware unstowage and experiment activation was a one-man operation and the restraints

provided in the MDA for S009 operations were considered adequate. No problems were encountered during the SL-4 S009 motor replacement and resupply of the detector package.

13.22.22.2 S019 - UV Stellar Astronomy

a. Operations - The S019 UV Stellar Astronomy experiment was scheduled to be performed during 12 selected night orbits in each of the first two missions, SL-2 and SL-3.

The equipment to be used was an optical canister and the Articulated Mirror System (AMS), launched in individual stowage containers, and the film canister, launched in the OWS film vault. One crewman was to be required to set up and operate the experiment hardware in the Scientific Airlock (SAL) to obtain a total of 150 slides of data from a minimum of 36 starfields. Three starfields, with three exposures per starfield, were to be photographed during each operation. To maximize the scientific return of S019, the astronaut was to be allowed as much flexibility in the choice of starfields and exposure times as possible.

b. Usage/Anomalies - During the initial activation of the AMS a problem occurred in the operation of the tilt mechanism. As a result, this S019 operation was aborted and no data was acquired. Through extensive malfunction procedure checkout and finally, disassembly of the AMS tilt mechanism, the crew discovered an Allen screw binding on a

small gear of the tilt mechanism. This was corrected and the unit functioned properly during the remainder of the experiment's data acquisition operations.

During the repair of the AMS tilt mechanism, the mirror was inadvertently touched leaving a finger print on the mirror. At the request of the Principle Investigator (PI), no corrective procedure was implemented to remove the finger print. This was to prevent possible additional damage to the mirror surface. Trying to clean the mirror could have been more degrading to the mirror's viewing function than the imposed finger print.

During SL-3 operations of S019 it was reported that the luminescence had come out of the digits on one of the rotation dials. However, by close inspection, the operator could still distinguish the engraved impressions of the digits to permit proper operation of the rotational dial.

The S019 spectrometer mechanism jammed during retraction following a SL-3 pass. Retraction was eventually accomplished some 30 hours subsequent to the initial failure and normal operations were restored. Due to this S019 experiment retraction failure, warm-up procedures for all experiments placed in the SAL were observed prior to exposure of their mechanism to OWS environment for all subsequent experiment operations.

During a SL-3 S019 pass the crew reported that the film advance/ shutter lever stopped at the carriage retracted position, and could not be moved on to the slide retracted position. This film canister was replaced with the new canister and the remaining exposures were taken as scheduled during SL-3. The failed canister was taken to an area of subdued light (the head, with lights out and door closed), the cover was removed, and the sliding film hatch was opened. Inspection by feel was performed on part of the carriage and shutter mechanism. The crew identified no apparent damage or discrepancy that could be corrected by their action. Consequently, the film canister unit was returned to earth for malfunction analysis.

It was found from the review of acquired data that during performance of the S019 experiment, the system was extremely sensitive to motion and some blurs occurred on one S019 slide. It was felt that this could have been caused when the canister was used as a writing surface. The PI requested that the S019 system not be touched when taking data. This was necessary to the acquisition of clear photography. The crew had no difficulties complying with this request except when opening or closing the shutter. At this time momentary jiggling of the S019 system could not be prevented.

Although S019 operations were not originally scheduled for SL-4, the

SL-4 mission extension created additional crew experiment time and allowed assignment of S019 to SL-4. New S019 film canisters and a replacement S019 mirror were launched. During replacement of the S019 AMS mirror the crew reported the new mirror was dusty and had three very narrow white streaks. The new mirror was touched by the crewman leaving a 3/4 inch long smudge which extended 3/16 inch in from the edge. This was caused by the gloves being packed under the mirror and the crewman having to remove the mirror bare handed.

Numerous problems were experienced with the S019 canisters jamming during SL-4. The canister would not go into the slide retract position and the problem was believed to be with the nylon sleeve on the film slides. The first canister to jam was placed in stowage however when the second canister jammed the crew decided to use brut force to put the lever in the slide retract position. The canister then operated normally except higher forces were required on the operating mechanism. This canister eventually jammed again and broke when the crewman forced it into the slide retract position. Malfunction procedures were performed but the canister was considered completely broken. The first canister was operated using excessive force but the crew felt it could jam at any time. Both canisters were returned for evaluation.

There was a continual gradual degradation in the indicator on the rotation dials of the AMS. In addition to the luminescence coming out of the units digit,the crew reported they were experiencing slippage between the mirror rotation attitude control knob and the indication dial. The belt broke and the degree indicator did not move even though the crank was turning. No repair was attempted due to the radioactivity from the luminescence in the sealed dials. For all subsequent operations the crew had to count the number of turns of the crank to determine the rotation settings. The T002 sextant was used to check misalignment of the mirror.

A failure of the S019 reticle light was identified on one S019 canister. The crew reported earlier that the reticle light was dim and it was assumed that the battery charge was too low to illuminate the bulb. The bulb and battery were not replaceable but the reticle was for reference only and no data was lost due to the failure. No corrective action was necessary except the crew turned off the reticle light when it was not required to verify pointing accuracy.

An additional S019 operation requirement was incorporated during SL-4 to reduce possible S019 data degradation due to OWS influenced disturbances on the S019 pointing accuracy. During SL-4 all ergometer and Mark I exerciser operations were prohibited during S019 operations.

c. Assessment/Recommendations - The crew recommended that the first couple of S019 pads be relatively easy to give them a chance to re-familiarize themselves with S019 operations. The crew felt that 80% of all crew errors would probably occur during the first runs of the experiment. They also stated that S019 procedures needed to be updated with more exact information concerning photography exposure times.

Differences existed between the forces required to operate the controls of the different S019 canisters. Some canister's carriage retract systems operated easily while others were quite stiff. The PI stated that this was normal as they were not all the same. The operating controls should have been designed with appropriate stop positions to eliminate the necessity of counting crank turns to the full extended or full retracted position. The crew also recommended not using the locks on the shaft rotation or extension controls as they were no longer required after placing the controls in the unlocked position.

The S019 timelines were too close and the crew recommended that 30 seconds to 1 minute be allocated for the operator to perform a change in S019 pointing. They also suggested allowing 15 to 30 minutes extra to the timeline for the first running of the experiment to allow familiarization with the equipment.

The crew requested that the same crewman not be asigned to an ATM pass and a S019 pass with no time in between. Otherwise any falling behind in the ATM pass immediately impacted the S019 operations. The crewman should be allowed to go into S019 with nothing else on his mind and not cluttered with what he had just finished.

The crew suggested having a T-handle on top of the winding valve instead of the knob. The knob was very slippery when their hands were moist and a T-handle would have been better for winding the film.

Experiment S019 handling was easy on orbit compared to ground handling. The crew felt that the carrying handle for the optical canister was a necessity.

The procedures for changing the viewing coordinates due to the NU_z were very satisfactory but there was a definite source of potential error with the sign and albegraic manipulations required to compute the rotation. The crew had never trained for these calculations and felt that they should have had such training for the calculations to be apparent.

There was no problem with dark adaptation when operating experiment S019. The critical adjustments required to prevent dark adaptation problems were the position of the eye to the eye piece and the focus.

The repair work performed on the AMS tilt mechanism would have been

aided by the addition of a Skylab Inflight Maintenance facility composed of a work bench and a high intensity light. An optics cleaning kit would have been valuable to remove the finger print contamination from the AMS mirror and should be provided on future flights.

13.22.2.3 S020 - UV X-Ray Solar Photography

a. Operations - Experiment S020 was scheduled to be performed on SL-3 and SL-4 through the solar Scientific Airlock (SAL) to photograph x-ray and extreme ultraviolet spectrums of the sun in wavelength regions from 10 to 200 Å.

Two crewmen were to perform the setup and checkout of the experiment in the SAL. When notified that a solar flare might occur, the crewmen were to point the equipment at the solar disc and obtain quiet on active sun flare exposures as required.

b. Usage/Anomalies - Due to the parasol thermal shield occupying the solar SAL, additional operating methods were devised. A special EVA bracket was designed and launched on SL-3. The EVA bracket was fit checked and an operational decal was installed by the SL-3 crew. S020 was successfully performed on three SL-4 EVA's with exposures up to one hour being obtained.

During deployment of the S020 camera the crew experienced some slight difficulty in attaching the mount to the ATM truss. In screwing down the knob to tighten it the whole mount twisted. The ball joint on the mount was also difficult to adjust and the crew felt a larger ball would have made it easier to adjust.

During S020 preparation for the final SL-4 EVA the crew reported a number of pin holes in each of the two filters. Some were detected by the naked eye and others were detected with a flashlight and magnifying glass. It was felt that the size of the holes as described by the crew would not allow enough light through to cause any problems.

c. Assessment/Recommendations - The interface between the S020 equipment and the EVA bracket was well designed. The experiment hardware and procedures were adequate and experiment operations were accomplished without any anomalies being reported.

13.22.2.4 S063 - UV Airglow Horizon Photography

a. Operations - Experiment S063 was scheduled to be performed on SL-3 and SL-4 to photograph in the visible and ultraviolet (UV) spectra the earth's ozone layers and twilight airglow.

The equipment to be used included the visible and UV cameras, with related accessories, and the respective mounting structures for the related cameras at the Scientific Airlock (SAL) and wardroom windows. One crewman was to attach the cameras to the SAL or wardroom window, make appropriate exposure time and shutter settings, and perform exposures during approximately 28 selected orbits of the mission.

b. Usage/Anomalies - Some difficulty was experienced during the loading of a new Nikon camera for S063 operations. Upon investigation it was found that a bit of epoxy-like material prevented the film system from positioning properly. The crew removed this material with a knife and the camera operated satisfactorily for the remainder of the mission.

Due to solar SAL obstructions by the parasol thermal shield, the S019 Articulated Mirror System (AMS) was utilized to obtain some of the S063 data.

During initial S063 operations there was a problem with a timer malfunctioning. Analysis established that the motor drive switch was out of configuration and that the timer was being operated incorrectly. This problem necessitated the use of the crewman's wristwatch in conjunction with the timer for all subsequent S063 operations.

Additional lighting was required for S063 operations as the crewman had to use a flashlight to read the watch and timer. The crew also requested an additional 45 seconds preparation time between S063 exposures. At the request of the crew, information on how to interpret the S063 optical sight reticle was provided by the ground and posted next to the experiment for future reference by the crew.

S063 operations called for eight second exposure times but due to a problem encountered in setting the viewing equipment some exposures may have been 10 second exposures. The marker on the viewing equipment had a bright edge and light glinted off the leading edge of the marker through the window. The viewing equipment was set on this leading edge rather than the white mark. This added about two seconds to the exposure.

One visible photography portion of a S063 run was not obtained because a battery powering the visible camera had tape covering one terminal. This tape was removed and no futher problems were encountered with the battery.

The crew reported that during hand-held photography through the ward-room window they tended to point the camera so as not to view through any of the contamination on the window.

During SL-3 it was noted that an adapter between the AMS and the S063 window was missing a bolt. This missing bolt did not interfere with S063 operations but a requirement for a replacement bolt was provided for SL-4. The crew also reported fixing a looseness of the interface between the mounting shear and the optical sight of the camera. Tape was used to tighten and thus reduce the wobble in this interface. This provided better resolution than previously with the camera wiggle in the system.

During the initial SL-4 S063 operation the remote timer did not operate. This complicated the S063 operation in that the crewman had to use manual timing in addition to tracking and controlling the rotation and tilt settings. The problem with the timer occurred when the crew mistakenly used a timer without any batteries. A new battery in the remote timer fixed the problem. For subsequent operations the crew removed the batteries after each use and taped them to the timer to insure nothing in the timer would drain the batteries down.

The crew reported the ring site was looking in the wrong direction and that it should be looking more towards the axis. Part of the sight was obscured such that you could not see the whole mirror. The crewman

assumed that although his sight was getting a truncated view the camera was getting the full view,therefore he centered it in the circle and not the truncated portion of the field of view. The crewman found that by looking right below everything,straight at the AMS mirror,he could get a better field of view than looking through the sights.

A problem was experienced with the S063 reticle light not illuminating. The crew checked the prime and backup batteries and they checked out at 1.6 volts compared to a 3.1 volts preflight. The battery contacts were scraped however neither battery would illuminate the reticle light. A substitute battery pack was fabricated from two (2) spare "C" cells, tape, and two (2) multimeter leads. The substitute battery pack was installed by inserting the probe ends of the leads into the female terminals of the optical sight housing and normal reticle operation was restored.

c. Assessment/Recommendations - The S063 stowage and unstowage went as planned and the S063 procedures related to the equipment went very well. In some instances the crew had to hurry to get two photographs on the same target, but the tracking task using the hardware was reasonable. The time allocated for stowage and preparation for S063 and AMS equipment was adequate.

The stowage location of the twin filter underneath the S063 stowage container lid was inadequate because of poor lighting and visibility in

in the area. This filter stowage inadequacy was identified in training but never corrected.

The crew stated that they should have had one extra Nikon camera body and a minimum of six extra cassettes of 2485 fast film for photography of targets of opportunity. A great opportunity may have been missed to properly photograph the Aurora because these items were not on board. The crew recommended replacing the Hasselblad in the CM with a Nikon.

The crew recommended that some type of suction-cup type mount be supplied for cameras used in hand-held photography. These cameras could then be restrained at any window. Such a restraint should be light, have a shutter release, and so provisioned that it could be moved to any position.

The crew recommended that the Principle Investigator (PI) provide a small color chart identifying the different shades of gray or white that the night airglow might look like to the crew. This would make identification easier for the crew and provide a commonality point between ground and on orbit data.

Crew training for experiment S063 appeared to be inadequate as the timer was operated incorrectly and the crew had to request information on how to interpret the S063 reticle. The crewman stated that the problem with the timer was 25% incorrect configuration and 75% his error.

The SL-4 crew stressed that due to the lack of a simulator the first couple of runs with the S063 would have to be accepted as training sessions. Any operations that called for manual dexterity could not be learned by talking through them. The crew stated they had more difficulty with S063 than with other more complicated experiments which they had trained for. Even with a relatively simple task, when you encounter something new, a couple of familiarization runs are required before it goes smoothly.

There was a confusion factor in determining the frame count from the UV Nikon camera. The frame count on the top of the Nikon read differently than the frame count on the bottom of the camera. The crew decided to use only the bottom frame count indicator. There should be only one frame count indicator provided on a camera.

13.22.2.5 S073/T027 - Gegenschein Zodiacal Light and ATM Contamination Measurement

a. Operations - Experiment S073/T027 was scheduled for operation during SL-2 and SL-3. The purpose of S073 was to measure surface brightness and polarization of night glow in visible spectrum. The purpose of T027 was to determine changes in properties of optical samples due to deposition of contaminates and to measure sky brightness background due to solar illumination of contaminates.

The experiment employed the T027 Photometer canister with the automatic programmer. The combined photometer system and Data Acquisition Camera (DAC) system, which was attached to the T027 Universal Extension Mechanism (UXM), was to be mounted to and deployed through the SAL into the space environment for acquisition of data. S073/T027 was to require one crewman for operation.

b. Usage/Anomalies - During SL-2, the S073/T027 photometer system was activated and operated with no major difficulties. No hardware anomalies were identified. During one T027 retraction, the photometer system could not be lined up to effect/permit its retraction into the Scientific Airlock (SAL) and the T027 canister. This was a T027

systems operations problem in that the system had been driven hard over, past the desired alignment. After being bumped against the OWS and physically forced, the system was retracted into the SAL and T027 canister as required.

During SL-3, the first crew operations with the T027 UXM system was to retract the S149 system which had been left extended through the SAL during the unmanned period between SL-2 and SL-3. This was accomplished with some difficulty. The final extension rod lacked about one inch from full retraction and engagement of the UXM capture latch. At this point the SAL door was closed to permit warm up of the system. After warm up, the final retraction was accomplished. The T027/S149 system was removed from the SAL and stowed as required.

The SL-3 crew had performed the T027 photometer extension and data gathering for only a short time when during the retraction mode it failed to align to the required position to permit its retraction as had previously occurred during the SL-2 mission. All malfunction operations performed on the system to effect its retraction failed. Consequently, the UXM with the photometer and S073 system attached was jettisoned on MD-8 of SL-3.

The SL-3 and SL-4 crews utilized the T025 hardware to perform some S073 Gegenschein and Zodiacal light photography. The equipment was installed upside-down in the anti-solar SAL and the occulting disc was moved out of the cameras view. No anomalies were reported with this mode of operation.

c. Assessment/Recommendations - Experiment T027 handling was a one man operation and was facilitated by the canister handle's proper location through the center of gravity. On movable items of large volume and mass (i.e. T027, S183) handles were definitely required. These handle(s) should be located such that the crewman would have complete control of the object during maneuvering operations.

No problems existed during photometer head changeout/maintenance even with the compressed operational envelope caused by the parasol canister/tripod protrusion. Instead of restowing T027 in its launch container between operations, the crew recommended that leaving the photometer attached to the launch container lid become the nominal stowage procedure.

As T027 operations progressed, the crew noticed that the photometer UXM rods became increasingly difficult to screw together. This was thought to be caused by a buildup of moisture and contamination. Also, during rod retraction, the crew reported that the thermal gloves were indeed required and did not hinder the crewman's rod retraction operations. The SL-3 crew indicated that the T027 system should have been checked out completely and possibly operated inside the OWS prior to its use.

13.22.2.6 S149 - Particle Collection

a. Operations - Experiment S149 was scheduled to be performed in four different exposure periods; during SL-2, the unmanned period between SL-2 and SL-3, during SL-3, and the unmanned period between SL-3 and SL-4. Its design objective was to acquire data to assist the determination of mass distribution of micrometeorites in near-earth space.

On orbit, the S149 Motor Drive/Cassette Support Unit (MD/CSU) was to be unstowed, fitted with the detector cassettes, and attached to the T027 Photometer Universal Extension Mechanism (UXM). The T027 canister was to then be installed in the anti-solar SAL and the S149 MD/CSU extended into space. Power was to be applied to the experiment and switches configured for ground activation of cassette exposure. In the event of a ground command failure, the experiment had a manual control capability which could be operated by the crew.

At completion of the exposure time, the crew was to be notified and was to retract, remove, and stow the hardware. The S149 detector cassettes were to be removed from the MD/CSU and stowed in the CM for earth return.

b. Usage/Anomalies - During SL-2 the first of four sets of S149 detector cassettes was deployed through the anti-solar SAL. Prior to crew return to earth, ground commanded the MD/CSU to "Open" for cassette exposure and subsequent data collection between missions.

A problem was reported by the SL-3 crew during retraction of the SL-2

deployed S149 MD/CSU. During retraction operations by the crew, the UXM tended to extend back out to space by itself. The crew had to maintain a continuous retraction force on the UXM rod while the SAL door was closed (this involved a two man effort). Once the SAL door was closed the system still lacked full retraction. The final extension rod lacked about one inch from full retraction and engagement in the UXM capture latch. After allowing the system to warm up, the full retraction and engagement of the capture latch was accomplished. The T027 UXM system canister containing S149 was then removed from the SAL, dismantled and stowed.

Prior to the SL-3 deployment of the second set of S149 detector cassettes, the T027 Photometer/UXM malfunctioned and was jettisoned, thereby losing the hardware required to nominally deploy and expose the S149 detector cassettes. As a back-up method for S149 deployment, hardware had been fabricated and launched on SL-3 for EVA deployment. Therefore, during the first SL-3 EVA, the crew mounted the S149 MD/CSU and bracketry on the ATM thermal shield lip and manually exposed the detector cassettes. It was later retrieved by EVA on SL-3 and the two sets of detector cassettes were stowed and returned to earth.

On SL-4 the third set of cassettes was deployed and later retrieved by EVA. During retrieval the crew reported that the small discs on S149

were debonding and popping off. Several discs were lost and the others were peeling up due to their bonding not holding. The experiment was stowed and no further action was taken. The fourth set was deployed during the final SL-4 EVA and has been scheduled for possible retrieval during the Apollo-Soyuz Test Program (ASTP) in 1975.

c. Assessments/Recommendations - S149 hardware, for both nominal and contingency operations, was well designed and operated as planned. The contingency hardware used in EVA deployment of S149 functioned well during EVA. The bracket used in mounting the MD/CSU on the ATM thermal shield was a little loose but caused no problems. The ATM thermal shield paint was scratched as the mounting clamp was attached but this was not considered to be detrimental.

Concern was stated that proper precautions be taken to mark the return container that housed the exposed cassettes to assure that the CM returned cassettes were those that had been exposed.

13.22.2.7 S183 - Ultraviolet Panorama

a. Operations - The S183 experiment was scheduled for performance during each of the Skylab missions to obtain photographs of a wide field of view of individual stars and extended star fields in the ultraviolet.

Prior to activation of S183 for operation, the crewman was to be required to prepare the S183 support hardware; the Scientific Airlock (SAL) and

the S019 Articulated Mirror System (AMS). Once the SAL was prepared, the S019 AMS, used for S183 pointing, was to be inserted. The S183 experiment was to be unstowed and attached to the S019 AMS. The S183 film carrousel was to then be removed from the OWS film vault and installed into S183 along with a 16mm Data Acquisition Camera (DAC) for comparison photographic data. The crewman was to then power up S183, open the SAL door and extend the AMS mirror. The S019 AMS mirror was to be aligned to the desired starfield and S183 photography was to commence as outlined by the checklist. Once this photographic sequence had been completed, the S183 experiment was to be deactivated, the S019 AMS retracted and the SAL closed. The experiment hardware was to be dismantled, removed from the SAL and stowed.

b. Usage/Anomalies - Throughout the entire Skylab mission all crew comments and other related data to on-orbit operations of S183 experiment identified no operational/handling anomalies. Problems experienced with the S183 system were of a mechanical nature. After two nominal SL-2 performances with S183, the film plate jammed and the operations were discontinued. Malfunction procedures were performed and the problem was isolated to the film carrousel. Due to this problem all subsequent photographic data for the SL-2 and SL-3 performances was obtained through use of the 16mm DAC. One other anomaly was

reported and involved a focus problem with the 16mm DAC. Changing to another DAC did not alleviate the problem but indicated that the S183 DAC optic system was the problem.

On SL-4 a replacement DAC optic system was launched and interchanged with the original. This corrected the focus problem associated with the S183 DAC. In conjunction with the optics replacement, the crew performed additional malfunction procedures and were successful in correcting the S183 film carrousel anomaly. This permitted the experiment to be operated as scheduled throughout the mission to acquire S183 photographic data as originally planned. Both DAC optic systems were returned for evaluation.

Upon removal of the carrousel from the spectrograph during the second S183 operation on SL-4, a fragment of the SC-5 glass film plate was discovered. It was reported that the carrousel was misaligned 45° from the "00" position. A plate was protruding and the crewman pushed it into the carrousel and stowed the carrousel. Prior to the next operation an alignment procedure was performed with no problems or loose glass being reported. Pliers were used to rotate the carrousel 45° to the "00" position. During the fourth operation of the spectrograph an additional fragment of the SC-5 plate was discovered. It was concluded that the glass was jamming the carrousel. A malfunction procedure to remove the plate was unsuccessful. In addition, an "E" clip retaining a spring

used to force the carrousel into the indexing detents was lost. This did not eliminate the use of the carrousel but it did require that the crewman check the orientation marks prior to each usage. Extreme care had to be used when inserting the carrousel into the spectrograph as any sudden torquing around the cylindrical axis would misalign the unit and cause difficult if not impossible installation.

The SL-4 crew experienced sequence problems with the logic counter and the carrousel index due to hardware problems and procedural mix-ups. The SL-3 crew had failed to reset the logic counter. The SL-4 crew cycled the plate advance reset switch and returned the reading to 01. However the logic counter is completely independent of the carrousel indexing and the film carrousel rotated to plate 33 and not back to plate 1. This resulted in plate 34 becoming detached from the carrousel and thus being exposed to cabin light. The extent of the anomaly appeared to be the loss of one plate and degradation of two others. The operation of S183 spectrograph and film carrousel was not affected. In an effort to eliminate the condition which caused the film plate to slip out of place a malfunction/synchronization procedure was done to sychronize the carrousel with the logic counter.

The SL-4 crew experienced a jamming problem with the DAC camera and S183 magazine 04. After performing trouble shooting procedures the

problem was isolated to a blown fuse inside the S183 spectrograph assembly. The malfunction was duplicated on the quality test unit in France and the French experiment developer recommended a workaround procedure which would bypass the blown fuse by connecting an existing wire from a DAC connector on the spectrograph assembly to an adjacent connector. The procedure was successful and S183 operations were resumed with the carrousel.

c. Assessment/Recommendations - The S183 experiment activation and manipulation was easily a one-man operation. The latching technique and decals on the experiment launch stowage structure were adequate. The crew stated that for maneuvering the large mass of S183, the handholds supplied were a definite necessity. In addition, the crew recommended that on large masses (i.e. S183, T027) it would be best to have handles provided to facilitiate two-handed manipulation for better control during large mass handling/maneuvering. The maneuvering technique used was to stabilize one's body and carefully push the mass in front of oneself. Then let the mass and oneself move to the terminal location making positional corrections while in flight. Braking was not considered a problem. This maneuvering technique was documented by experiment M151, Time and Motion Study.

The S183 operations timeline did not allow enough time between exposures. One minute was added to these times to allow for crew adjustments

in pointing and timing for the upcoming exposure. The crew also complained about being rushed between an ATM pass and S183 operations. The timeline did not allow enough time to debrief the ATM pass and then get started on the S183 operations. During S183 operations, the crew reported no problems associated with the OWS lighting levels.

13.22.2.8 S201 - XUV Electronographic Camera

a. Operations - Experiment S201 was scheduled to be performed on SL-4 to photographically collect Extreme Ultraviolet (XUV) imagery data on comet Kohoutek.

The experiment consisted of a canister-enclosed XUV electronographic camera (with film-transport box), a second film-transport box, and an EVA bracket. The experiment was to be used in two operating configurations; (1) through the anti-solar Scientific Airlock (SAL) utilizing the S019 Articulated Mirror System (AMS) as support equipment or (2) bracket-mounted to the ATM truss for EVA operations. Power was to be provided by the Data Acquisition Camera (DAC) cable during the EVA and SAL operations. Experiment S201 data was to be recorded on special NTB-3 film and returned to the Photographic Technological Laboratory at JSC for post-flight processing.

b. Usage/Anomalies - While performing a S201 experiment operation through the anti-solar SAL the crew noted that the green exposure sequence indicator light was actually brownish red and very low in brightness and would probably be difficult to read during the EVA operations. During the second SL-4 EVA, three S201 data takes were

performed even though the crew could not see the comet. It was hoped that the comet would be detectable on the photographic data.

c. Assessment/Recommendations - S201 experiment operations were performed as scheduled through the anti-solar SAL and during the SL-4 EVA's. The procedures and equipment were adequate and the crew reported no significant problems in performing S201.

13.22.2.9 S228 - Trans-Uranic Cosmic Rays

a. Operations - Experiment S228 was scheduled to be performed on SL-2, SL-3, and SL-4 to obtain knowledge of the abundance of nuclei with an atomic number greater than 26 in the cosmic radiation.

A crewman was to deploy the detector module harness on SL-2 from floor to ceiling in the OWS experiment compartment using velcro straps. Thirty-six detector modules were to be launched and deployed with the harness. At the conclusion of the SL-3 mission, one module was to be removed and returned. One S228 detector module was to be launched on SL-4 and deployed during the first SL-4 EVA. It was to be retrieved during the last SL-4 EVA and returned to earth along with the remaining harness detector modules.

b. Usage/Anomalies - Experiment S228 was performed as scheduled and no anomalies were reported. During the SL-4 EVA deployment, the crew observed some expansion of the experiment package which was an indication of outgassing. This bulging was expected and was within normal limits. On the final Skylab EVA, this experiment package was

retrieved and was stowed with the remaining harness detector modules for return to earth.

c. Assessment/Recommendations - Experiment S228 deployment and retrieval went as scheduled and no crew systems assessments were reported.

13.22.2.10 S230 - Magnetospheric Particle Composition

a. Operations - Experiment S230 was scheduled for performance during SL-3 and SL-4 EVA's. Its purpose was to acquire data for measuring fluxes and composition of precipitating magnetospheric ions and trapped particles through the use of a foil collection technique.

The experiment hardware was composed of two (2) collector spools, two (2) inner collector assemblies, two (2) outer collector assemblies and two (2) return pouches. The collector spools, providing support for the inner and outer collector assemblies, were to be launched on SL-1 attached to the ATM deployment truss D2 handrail. During an EVA on both SL-3 and SL-4 the crew was to retrieve one (1) of the two remaining collector assemblies. These collector assemblies were to be stowed and returned to earth for analysis.

b. Usage/Anomalies - On the first SL-3 EVA the two (2) outer collector assemblies of S230 were retrieved and a calibration shield was installed on the forward inner collector spool. During the final SL-3 EVA the crew retrieved one of the two remaining inner collector assemblies. It was stowed in the CM with the previously retrieved outer collector assemblies and returned to earth.

On SL-4 a new inner collector assembly was launched and on the first

SL-4 EVA was attached to the empty collector spool. During a subsequent EVA for ATM film resupply and Kouhotek photography the crew reported that the S230 calibration shield was missing. Evidently, the shield had been brushed by one of the crew during EVA operations and knocked loose. On the final SL-4 EVA the remaining two (2) inner collector assemblies were retrieved. During AM repressurization operations, one of the two samples was damaged by the rush of air from equalization valve 311. The crew reported the damage to effect approximately 10% of the sample. The samples were placed in the CM stowage and returned to earth.

c. Assessment/Recommendations - The EVA procedures for the collector assembly retrievals were straightforward and no problems were reported. The crew reported that they were very careful during retrieval so as not to touch and consequently contaminate the collectors.

The calibration shield and the one (1) collector assembly deployment were performed without any reported crew interface problems. The restraint/stability provisions were considered adequate for performing the S230 crew tasks.

13.22.2.11 S232 - Barium Plasma Observations

a. Operations - Experiment S232 was scheduled to be performed on SL-4 to obtain data necessary for determining the effects of plasma conductivity and geomagnetic activity upon the motion of barium plasma.

The experiment operations involved one crewman whose objectives were to photograph the barium cloud injected to outer space by a ground launched rocket. The crewman was notified three hours prior to the scheduled launch as to the photographic settings and procedures. A Nikon 35mm camera was attached to the universal mount and then mounted to the OWS wardroom window to obtain the photographic data. A total of seven barium rocket launches were scheduled during SL-4 with the crewman obtaining a minimum of 40 photographs.

b. Usage/Anomalies - Experiment S232 was performed as planned. Due to problems involved with the rocket launches and resulting launch cancellations all premission planned photographic data was not obtained. The crew reported that the experiment set-up was a lengthy operation and took approximately two (2) hours to complete. The barium injection was visible to the naked eye and was photographed by the crew using numerous time exposures. During these photographic sessions the crew reported some difficulties with damping the oscillations of the camera/universal mount after exposure actuation. As the experiment

progressed and the crew technique improved these oscillations were reduced.

c. Assessment/Recommendations - S232 experiment photography was performed during SL-4 and photographs of the barium plasma infection were obtained. Other than the initial oscillation problem with the camera/universal mount the hardware performed satisfactorily.

13.22.2.12 S233K - Kohoutek Photometric Photography

a. Operations - Kohoutek Photometric Photography, experiment S233K, was scheduled to be performed during SL-4 to obtain a series of visible light photographs suitable for photometry and to provide a synoptic history of the comet Kohoutek.

Experiment S223K used the Nikon 35mm camera and mounting braketry to obtain photographs through the left viewing window of the CM and the STS window. The crewman was required to take a sequence of photographs every 12 hours throughout the comet acquisition periods.

b. Usage/Anomalies - S233K was performed throughout the designated periods of SL-4 and photographs of comet Kohoutek were obtained. All pre-mission scheduled photographic exposures could not be obtained by the crew due to window field of view limitations and faintness of the comet.

c. Assessments/Recommendations - The S233K operations were straightforward and were performed as scheduled. No hardware anomalies were reported.

13.22.3 Technology Experiments

13.22.3.1 D024 - Thermal Control Coatings

a. Operations - Experiment D024 sample panels retrieval was scheduled for the SL-2 EVA and for the last EVA of SL-4. The equipment for experiment D024, consisting of two thermal control coating sample and two polymeric film sample panels, was mounted and launched

externally on the AM support structure.

Experiment D024 was not to require a specific EVA for its performance as it was to be performed in conjunction with the ATM experiments film retrieval. D024 sample retrieval was to require two crewman (designated EV1 and EV2). EV2 was to retrieve two sample panels, stow them in the return container, then pass the container to EV1 who was to temporarily stow it in the AM. Upon completion of the EVA activities the sample return container was to be stowed in the CM for return to earth.

b. Usage/Anomalies - Experiment D024 sample panel retrieval was performed as scheduled on SL-2 with one thermal control coating sample panel and one polymeric film strip sample panel being returned. Due to the total time in orbit it was decided that the remaining two sample panels had received adequate exposure by the end of SL-3 and that they should be retrieved on the last EVA of SL-3 and returned to earth. To alleviate handling of multiple items the crewman placed the sample into the return container prior to removing the pip pin. It was noted that some of the samples were becoming slightly debonded, although none were actually loose or lost as the samples were put into the return containers. After the return of the remaining two samples on SL-3, two additional sample panels with return container were launched on SL-4 for deployment on the first EVA and retrieval at the end of the mission.

During deployment of the sample it was difficult for the crewman to align the snaps due to lack of visibility and lack of dexterity caused by the EVA glove. However, he was eventually able to attach the panel by touching the center samples with his finger, possibly contaminating them. The samples were retrieved on the final SL-4 EVA and returned to earth.

c. Assessment/Recommendations - The problem the crew experienced with the deployment of the sample panels could have possibly been eliminated with the addition of guide pins and alignment marks on the mounting plates and the sample panels. However, the experiment as it was originally designed, did not call for the deployment of the samples on orbit as they were launched in place.

The retrieval of the D024 samples was quite easy to perform per the checklist. The crewman was able to fold the retrieved specimen and correctly stow it in the appropriate return container slot. The crew reported no problems in retrieving and stowing the D024 samples and stated that the overall design was adequate. The crew voiced their opinion that a heel restraint would have been helpful at the D024 location to assist their stabilization when retrieving samples.

13.22.3.2 M512 (M551, M552, M553, M555) - Materials Processing In Space
M479 - Zero Gravity Flammability
M518 - Multipurpose Electric Furnace System

a. Operations - The M512 experiment facility was designed to utilize a common spacecraft interface for a group of experiments in

in materials science and technology. It was scheduled to be used on SL-2, SL-3, and SL-4.

The facility was to permit exploration of space manufacturing applications of molten metal phenomena such as metal flow, freezing patterns, thermal stirring, fusion across gaps, and surface tension. One crewman was to be required to perform the experiments. The basic functions performed were to be installation of the experiment equipment or specimen in the work chamber, systems control operation, observation, photography, and monitoring of the experiment, and removal and stowage of the equipment and specimen after experiment completion. Experiments M551, M552, M553, M555, M518, and M479 were to utilize the M512 facilities.

b. Usage/Anomalies - During initial use of the M512 facility it was believed that the electron beam gun had shifted due to loads experienced at launch. Upon later analysis the problem was found to be with a new mirror installed at KSC. The mirror was reversed so only one of two retaining screws could be fastened when mating it inside the facility.

During a performance of the M553 experiment, difficulty was experienced with the installation of the shield over the electron beam gun. This problem was caused by a hardware installation sequence error. The shield should have been installed first instead of last as performed by the crewman.

Due to M512 operational problems the crew was asked to use the main circuit breaker to shut off the M512 facility power when performing experiment M553 spherical forming. During cutting of the M553 specimen stinger, the jaw of the cutting pliers broke. Wheel number one of the experiment was completed and wheel number two had two balls that were not released and three that were released. Wheel two was returned to earth along with the released specimen balls from wheels one and two.

A long period of time was required to obtain a sufficient vacuum in the facility on orbit. To obtain the vacuum the crew had to leave the vent valve in the "Vent" rather than the "Open" position during their sleep period.

Experiment M479 was performed at the end of SL-4 with the only anomaly reported being with the water quench system. The lower nozzle appeared to be completely plugged and the upper nozzle emitted only a dribble. The crewman completely reserviced the system but it still did not function properly. In order to get any spray at all the crewman had to grab the accumulator knob and pull sharply on it to force water through the system. There was no time for extensive trouble shooting but the problem was believed to be with a water supply valve not being turned on.

While burning sample number three the crewman stated there was an operator error in that he left the chamber repress valve in the open

position. The only effect was the sample burned slightly longer.

c. Assessment/Recommendations - M512 experiment performance on orbit was similar to on-ground training with exception of the times required to heat or cool the experiment specimen and to obtain a sufficient vacuum in the facility. The crew stated that the training unit was excellent, just like the flight unit, but they never experienced pumping the facility to a vacuum during their training. Consequently, the first time the vacuum gauge was used on orbit the crew thought that the slow bleed down time indicated a faulty gauge. As experienced,a longer time than expected was necessary to obtain an acceptable operational vacuum in the facility.

During M553 operations in the M512 facility no problem developed with the facility or the accessory equipment. However, pressure build up in the facility chamber during the firing of the electron beam gun occurred more rapidly on orbit than experienced during training. In some instances the balls on the M553 experiment wheel stings formed a pear shape or did not release. The crew experienced no problems in handling the specimens as long as they observed proper cool down times.

The crew enjoyed performing the M518 Multipurpose Electric Furnace experiment because it was new and different. The equipment worked as designed and was easily installed into the M512 facility chamber. The specimen cartridges were numbered (identified) in an excellent manner to permit their insertion and coordination. The operations

were clearly defined and no problems were experienced performing the M518 series in the M512 facility.

The M551 experiment welds looked basically the same as during training with the exception of a non-round dwell pattern on the stainless steel specimen. The welds built up quicker in flight than on the ground. No high external chamber temperatures were experienced during any of the facility operations.

All M479 specimen samples were in excellent condition and the burning had no effect on the view ports. The view ports remained clean throughout the experiment performance.

Restraints associated with M512 were no problem. The foot restraint grid was used only in the beginning of the experiment and was later discarded. Handholds were adequate.

The M512 chamber hatch did not appear to have proper friction hinges as per the experiment design requirements. No detrimental crew comments were received but during video downlink of M512 facility operations the hatch was observed to be floating free

13.22.3.3 T002 - Manual Navigation Sightings

a. Operations - Experiment T002 was scheduled to be performed on SL-2, SL-3, and SL-4 with batteries for the sextant and stadimeter being resupplied on SL-3 and SL-4. Sightings were to be distributed uniformly throughout the mission on a non-interference basis.

The crewmember performing the experiment was to remove and stow the wardroom window shield, obtain and install the T002 hood over the wardroom window and obtain the sextant or stadimeter from locker W740. The batteries for the sextant and stadimeter were to be installed by the crewmember during experiment activation. Wardroom lights near the wardroom window were to be dimmed and the reticle light adjusted before the crewman proceeded with the experiment sightings.

b. Usage/Anomalies - Experiment T002 was performed on all three Skylab missions and was satisfactorily completed. Due to a residue pattern formed on the wardroom window during SL-3 and SL-4, the operator had to move around during his sightings to avoid viewing through this residue. He was concerned that his moving may have affected his sightings.

The SL-4 crew emphasized the importance of body position and posture in obtaining accurate sightings with the T002 sextant. During an early operation the crewman developed muscle cramps in his arms and legs. The crewman devised a restraint system to hold him over to the window using a long strap hooked over the S063 bar. The crewman felt this improved the accuracy of his sightings. The crewman also stated that there was a distinct difference in ease, ability and accuracy you get whether the stars were located up and down relative to your body posture or left to right.

c. Assessment/Recommendations - The T002 window hood which was used to shield the wardroom window from internal reflection was considered a definite necessity. The crewman found it difficult to hold the sextant steady during sightings and also felt it would be extremely helpful to have the sextant readout inside the reticle so you would not lose sight of the star while taking readings. The stowage configuration and location in locker W740 was excellent and the foot restraint provisions at the wardroom window were considered adequate.

The crew stated it was difficult to remove their fingers from the pointing control knobs on the sextant without moving it. They could get a good alignment but when they released their fingers the knob would move slightly. This created some mediocre scatter in the system. The control knobs should have been easy to move but not so sensitive that they could not remove their fingers without moving it. The crew also stated the knobs on the filters were poorly designed in that they could not tell whether they

were in or out.

The crew experienced pointing difficulties due to the shape of the case and the location of the strap. This made it difficult to hold the sextant in the proper position at the window. The crew stated they needed phosflorescent alignment marks to get the line of sight directed between two stars. They also suggested the use of a colored filter so that they would not lose track of which star they were sighting. This was a problem when holding the sextant at odd angles. The system should have been designed so that all controls could be operated without the crewman removing his eyes from the reticle sight.

13.22.3.4 T003 - In-Flight Aerosol Analysis

a. Operations - Experiment T003 was scheduled to be performed on SL-2, SL-3, and SL-4. Multiple measurements were to be taken daily to determine the concentration and size distribution of particles suspended in the OWS atmosphere.

A crewman was to transport the portable self-contained aerosol analyzer throughout the OWS observing the readout and recording the data on the T003 data cards. At the completion of each mission the data cards and the filter impactor unit from the aerosol analyzer were to be returned to earth.

b. Usage/Anomalies - Operation of experiment T003 went as scheduled with all functional objectives being accomplished. Results

showed that the OWS was cleaner than most hospital operating rooms with a particle count of 3000 per cubic foot. The crew reported that T003 readout time was adequate for recording the data on the data cards. The only anomaly reported was a filter change which was missed due to a tardiness of the detailed pads up-linked from the ground.

c. Assessment/Recommendations - Experiment T003 operations were straight forward and no problems were experienced in stabilizing at the various sample stations. The crew did report that the data cards were not large enough to allow sufficient area to record all the information.

13.22.3.5 T025 - Coronagraph Contamination Measurement

a. Operations - Experiment T025 was scheduled to be performed on SL-2, SL-3, and SL-4 through the solar Scientific Airlock (SAL) to determine the existence and presence of any changes in particle atmosphere due to transfer firings, waste dumps, vehicle orientation, and time decay of such atmospheric concentrations.

The T025 experiment equipment to be used was the coronagraph canister including the occulting discs and extension boom assembly with the photographic equipment. One crewman was to set up the experiment apparatus in the SAL and complete a 27 photographic exposure sequence during five (5) non-consecutive orbits.

b. Usage/Anomalies - T025 was not performed as scheduled because the solar SAL was occupied by the parasol thermal shield. All T025 operations were cancelled for SL-2 as alternate performance methods had to be developed. The SL-3 crew utilized the T025 hardware to obtain some experiment S073 Gegenschein and Zodiacal light photography. The equipment was installed upside-down in the anti-solar SAL and the occulting disc was moved out of the camera's view. During this operation the crew used their finger to control the Data Acquisition Camera (DAC) shutter release. This was difficult and fatiguing. In readiness for subsequent operations the DAC was prepared for operation with the DAC push button cable. However, the SL-3 crew was not asked to repeat the experiment.

As an alternate method of performing T025 and viewing the Kohoutek comet, an EVA bracket was designed and launched on SL-3. The SL-3 crew fit checked the bracket to the T025 experiment and attached operational decals in readiness for EVA deployment on SL-4.

Problems occurred during the first SL-4 EVA operation of T025 which prohibited the acquiring of all planned data. Five photographs out of a planned 40 were obtained. The view finder on the camera was loose and the shutter speed knob came off during operation. The crewman was able to replace the knob but it did not engage enough to permit use. During

EVA trouble shooting with the T025 equipment, the thermal blanket cover was removed. The T025 hardware was stowed in the AM to permit further trouble shooting at a more opportune time in the OWS. After completion of the EVA, the crew successfully repaired the shutter speed knob and the T025 hardware was utilized during subsequent EVA's to obtain ultraviolet and visible photographs of the Kohoutek comet. All subsequent T025 experiment performances were without incident.

c. Assessment/Recommendations - The T025 experiment was performed from the SAL without any problems. The T025 hookup with the extension rod worked very well and the procedures/checklists and hardware used for night photography were adequate. Pad updates for the experiment should remind the crew to inhibit the fire sensors prior to experiment initiation. The fire alarm was initiated on SL-3 when the SAL was opened with T025 installed.

T025 was not originally designed for EVA use but with the addition of the specially designed EVA bracket ultraviolet and visible photographs of the Kohoutek comet were obtained.

13.22.3.6 T027 - Sample Array

a. Operations - The T027 Sample Array (SA) experiment was scheduled to be performed during SL-2 to acquire data for determining the change in optical properties of various transmissive windows, mirrors, and defraction gratings, caused by deposition of contaminants found

about the orbital assembly.

The experiment equipment included a canister system with one extension rod, an ejection rod, and a launch stowage container. One crewman was to prepare the T027 SA experiment and then install it through the anti-solar Scientific Airlock (SAL) for exposure to the space environment. Upon completion of the exposure the SA was to be retracted, removed from the SAL and restowed in its launch container for return to earth.

b. Usage/Anomalies - The T027 SA experiment was installed in the SAL and deployed as planned. Due to the parasol deployment and resulting requirements for usage of the anti-solar SAL by other experiments, the T027 SA exposure time was reduced. It was then removed from the SAL, stowed in its launch container and returned for earth analysis.

The only problem identified during operation of the T027 SA occurred during closing of the array valve prior to retraction and removal of the SA system from the SAL. When the crewman closed the array valve, by turning the vane control, the valve did not seat completely. Force in excess of that recommended during training was applied to the vane control, and the valve was closed. The problem was attributed to the low temperature of the system, forming frost, preventing the normal closure of the array valve.

c. Assessments/Recommendations - For some reason the requirement to let the T027 SA system warm up prior to its removal from the SAL had been crossed out of the checklist and omitted from the experiment pad. This procedural information concerning warm up prior to removal was required, and should not have been omitted, as indicated by the minor problem which occurred as a result of its omission.

13.22.4 Operations Experiments

13.22.4.1 M487 - Habitability/Crew Quarters

a. Operations - Experiment M487 was scheduled for operation on each of the three Skylab missions and was charged with evaluating and reporting on the OWS habitability provisions.

The methods of M487 data collection were to depend primarily on the crewmen. Where possible the experiment task was to augment or coincide with the operational activity to be observed. When the activity was not scheduled or predictable, the elements of the activity were to be grouped into a staged demonstration to optimize time and effort. First the crewman was to obtain, calibrate as required, and position the various monitoring devices throughout the OWS. The crewman was to then obtain, position, and operate the various equipment that was required for photography and data collection.

b. Usage/Anomalies - M487 was performed as planned throughout each Skylab mission, accomplishing all pre-mission requirements.

One hardware problem occurred during the SL-2 mission. During the initial calibration of the sound level meter/frequency analyzer the crewman could not obtain the correct calibration factor. A second calibration was attempted at a later time and the correct factor was obtained. The cause of the problem encountered during the first calibration attempt was undetermined.

c. Assessment/Recommendations - The hardware supplied by this experiment to supplement the crews' observations was considered unnecessary as was shown by its lack of use throughout the Skylab missions. For this reason, few comments concerning the M487 hardware were available. It was reported that both the ambient and digital thermometers required a lengthy time to stabilize when measurements were made where a large change in temperature was involved. Both the digital and ambient thermometers were used over the three Skylab missions in support of other hardware evaluation and the 10' tape was used in several science demonstrations. These items should be included on future missions as operational support hardware.

Some crewmembers expressed their dislikings toward the lengthy and time consuming on-board debriefings. They felt that this orbit time

could be better utilized and that the debriefings could be conducted post-mission.

It was felt that the data compiled from M487 would form the basis for verifying existing spacecraft habitability criteria and would establish requirements for more advanced spacecraft.

13.22.4.2 M509 - Astronaut Maneuvering Equipment

a. Operations - Experiment M509 was scheduled to be performed on SL-2 and SL-3. Each test pilot was to perform four runs with the Automatically Stabilized Maneuvering Unit (ASMU) while an observer assisted. Runs 1, 2, and 4 were designated to be performed unsuited whereas run 3 was to be performed while wearing the Skylab Extravehicular Mobility Unit (EMU).

Prior to the experiment performance, the M509 hardware and support hardware was to be unstowed and reconfigured for operation, including Propellant Supply System (PSS) bottle and battery charging. Once the experiment preparation was completed and the OWS forward experiment area was cleared of equipment not required for the experiment, the observer was to assist the test pilot in donning the ASMU. The test pilot was to then undock from the donning station and perform the designated M509 maneuvers. Upon completing these maneuvers, the subject was to return to the donning station and dock the ASMU, thereby concluding the experiment performance.

b. Usage/Anomalies - The M509 experiment performance for SL-2 was limited to operational configuration and checkout. Due to the OWS meteoroid shield problem and resulting high temperatures it was concluded that a hazardous condition might exist if the M509 batteries were discharged. If the batteries were used an internal short might have occurred resulting in a possible explosion. The ASMU, PSS bottle rack and AM N_2 recharge station were reconfigured to their inflight usage configurations and the PSS bottles were recharged. After reconfiguration/checkout of the M509 ASMU and the PSS bottle installation, the unit was powered up from OWS power while still in the docking station and the backpack and Hand-Held Maneuvering Unit (HHMU) thrusters were fired.

Between missions, onground testing determined that the flight M509 batteries were acceptable for use and on SL-3 and SL-4 the experiment was successfully operated. The unit was flown in all four modes, both suited and unsuited.

One modification was made to the planned M509 activities after the first suited performance. During this performance the test pilot noted that the Life Support Umbilical (LSU) imparted undersirable dynamic forces on the ASMU during maneuvering. In hopes of reducing/eliminating these dynamic effects the crew stripped the LSU of all wiring and

insulation, leaving only the 0_2 line. This modified LSU was then used on all subsequent M509 and T020 suited runs not utilizing the Secondary Oxygen Packs (SOP).

During a SL-4 suited run battery problems arose causing the experiment run to be shortened. The batteries were being depleted much faster than anticipated due to time consuming delays during the M509 run. One delay was experienced when the crewman encountered problems attaching the AM recharge station quick disconnect to the PSS bottle connector. An additional delay was experienced when the SOP was depleted and had to be replaced by the LSU. During both these delays the ASMU was on battery power thus draining the battery. These delays drained both M509 batteries to the 26 volt minimum and the M509 run was terminated after completing only 2/3 of the run's objectives. M509 was performed throughout the remainder of SL-4 and no anomalies were reported.

c. Assessment/Recommendations - The M509 ASMU was well designed and easy to fly. Intuitive skills, common to all astronauts because of their flight training, was all that was required to navigate M509. Ground based training for this experiment using the Denver simulator was not necessary. This was verified during an unscheduled M509 performance by a crewmember who had never trained for M509 nor had ever used the training simulator. His flight was performed with ease and was considered a complete success.

During the M509 maneuvers four potential flying modes were evaluated and, in order of preference, were DIRECT, CMG, RATE GYRO and HHMU. The DIRECT mode was far the easiest and the more intuitive to control. The CMG and RATE GYRO modes were very good but the precesion inherent to these modes was unnecessary for a future EVA maneuvering device. The HHMU was given a poor rating and was recommended by the crew to be deleted from consideration as an EVA maneuvering mode. The difficulty with the HHMU was in locating the center of gravity which turned out to be an important factor in this maneuvering mode. In future testing of a maneuvering unit the HHMU should be eliminated from consideration because it was not an intuitive device to operate, as it required unique and undeveloped skills.

In flying M509 actual EVA conditions were simulated to evaluate all phases of maneuvering. Suited operations were conducted using both the LSU and SOP. The SOP configuration was preferred over the LSU configurations because of the dynamic effects present with the LSU. The LSU, due to its mass and elastic characteristics, imparted an inertia on the M509 ASMU which proved to be an annoyance to the test pilot, in that guidance corrections to the unit were constantly required.

Safety was a principle concern in pre-mission design and planning of M509. But due to the ease of operations and maneuverbility of the

ASMU the pre-mission concern of inadvertant and possible catastrophic collisions was shown to be invalid. The ASMU, though very large and heavy, was not bothersome or incapable of being handled by the test pilot. The test pilots were confident that even with the large ASMU mass and a maximum maneuvering velocity of 3-4 ft/sec that they could, in the event of a thruster failure, reposition themselves and absorb the energy of an impact without bodily or hardware damage.

The M509 hardware and supporting equipment was well designed both from a functional and integration standpoint with one exception. The ASMU had too many controls located in too many diverse and remote positions. If possible these controls should be relocated on a common panel to facilitate crew operations. The safety goggles and ear plugs were required and were used by all crewmen. The unstowage/stowage of the M509 hardware was straightforward with no problems occurring. PSS bottle charging required the crew to translate to and from the AM recharge,station with the bottles. This entire procedure,including recharge,took less than 10 minutes to perform and it was reported that the bottles during recharging only reached a temperature of approximately 100^{o}F. Translation with the bottle was accomplished by the crewman holding the bottle ahead of him, pushing off and then following along behind the hardware. Prior to reaching his destination, through a mental integrative process, the crewmember could reposition himself between the hardware and contact

point for a safe landing.

The ASMU was a good translational device but was found to be severly limited in its use as a workstation/platform for performing work related tasks. In performing relatively easy tasks, the crewman's body torques would over saturate the ASMU gyros and cause a loss of stability. To perform EVA tasks the ASMU, as designed, would have to be docked/restrained at the designated work area to achieve the necessary stability required to perform the task.

The next generation EVA maneuvering device should be back mounted with the pilot-to-backpack restraint system providing a tight, secure and comfortable (seat padding recommended) fit. Backpack donning/doffing should be designed as an one man function. The backpack must have six degrees of freedom, with the propulsion thrusters located around the center of gravity of the pilot/backpack combination, and should be hand controlled. The hand controllers should have the capability of being relocated/moved during flight to allow multiple working postures for the pilot. The DIRECT mode should be selected as the maneuvering mode with a capability of a 3-4 ft/sec velocity. Restraints/docking provisions (i.e. manipulative arms) must be provided to adequately stabilize the pilot and permit him to perform the designated task. A backpack spotlight should be incorporated to provide the pilot with an illumination source at his work area. Separate isolation valves/circuit breakers for each

thruster or set of thrusters should be provided to insure against a single point failure. The backpack should contain all systems required for EVA such that no umbilical or LSU is required. The unit should contain a pressure control system, oxygen system and maneuvering system with all system monitoring displays/readouts being illuminated. With such a system the pilot could suit up, don and plug in the maneuvering unit and perform an EVA as a free entity.

13.22.4.3 T013 - Crew/Vehicle Disturbances

a. Operations - Experiment T013 was scheduled to be performed on SL-3 to measure the effects of crew motions on the dynamics of manned spacecraft.

Two crewmen were required for T013 operations; one designated as the subject and the other as the observer. A third crewman was required during performance of the worst case control system input task. Data was to be collected employing the 16mm Data Acquisition Camera (DAC), mounted in the OWS forward compartment. The Limb Motion Sensor (LIMS) suit assembly including the LIMS data cable was to be removed from stowage. The subject was to don the LIMS suit and then connect the experiment data cable between the LIMS and the Experiment Data System (EDS). Prior to start of the experiment performance, the observer was to don a communications headset and turn on the AM tape recorder and cameras for data collection. The Force Measurement Units (FMU) were to then be uncaged and calibrated. During the experiment performance of body and limb motions and free soaring activities, the observer was to assist in securing the subject to and releasing him from FMU No. 1 at appropriate

times during the experiment. Upon conclusion of the experiment performance, the cameras, AM tape recorder and the EDS were to be turned off and the FMU's caged and pinned. The EDS data cable was to then be disconnected and stowed together with LIMS suit assembly in the T013 stowage container.

b. Usage/Anomalies - T013 was performed on SL-3 as designated by the experiment checklist. Upon completion of the experiment performance the crew reported that the experiment had functioned as planned.

T013 was performed on SL-3 but during the first pushoff of the soaring activities a malfunction occurred in the load cells of FMU No. 2 causing a partial loss of data. Malfunction procedures were performed on both FMU's and deformation of the load cell flexures was uncovered. As part of the malfunction procedures a FMU calibration was performed and the results indicated that load cells 4 and 5 of FMU No. 2 had failed and were considered lost.

To satisfy the experiment mission requirements, a rerun of the T013 soaring activities was performed, but the crew failed to activate the T013 Experiment Data System (EDS) and no experiment data was received.

Again, in attempt to satisfy the experiment requirements, a third run of T013 was performed by the SL-3 crew and all ATM and photography data was successfully gathered. This performance satisfied all T013 requirements.

During performance of the T013 worst case input task only two crewmen participated instead of the three required. Since the third man, designated as observer, did not contribute to the data input and was required only for safety reasons, the omission of his participation had no effect on the experiment results.

c. Assessments/Recommendations - Other than the FMU anomaly, experiment T013 operations were straightforward and easy to perform. Stowage/unstowage was simple, the LIMS suit fit well and the camera positioning was no problem. Soaring between the FMU's was quite easy, in fact, the FMU's could have been placed much farther apart without effecting the crewman's soaring accuracy. The FMU's placed as they were, were so close that it was difficult for the performing crewman to soar between them and land feet first.

During the worst case task, the second performer could not soar between the film vault and the food lockers. He had to soar between the food lockers and the lockers adjacent to the film vault. During the simultaneous soaring both crewmen performed their push-offs together but due to the differences in soaring distances their impacts were not simultaneous.

13.22.4.4 T020 - Foot Controlled Maneuvering Unit

a. Operations - Experiment T020 was scheduled to be performed in the OWS forward compartment area during SL-3 and SL-4. A total of 5 runs by each test pilot was scheduled with the Foot Controlled Maneuvering Unit (FCMU) while a second crewman acted as observer, OWS cameraman and safety man. Of the 5 performances conducted by each test pilot three were to be operated in shirtsleeves and two while suited.

Prior to the experiment performance, the T020 hardware and support hardware were to be unstowed and reconfigured for operation, including M509 PSS bottle and battery charging. Once experiment preparation was completed and the OWS forward experiment area was cleared according to the T020 checklist, the observer was to assist the test pilot in donning the T020 maneuvering equipment. The test pilot would then undock from the T020 docking station and perform the required maneuvers. Upon completion of these maneuvers, the subject, with aid from the observer, would return to the docking station and dock the FCMU, thereby concluding the experiment performance.

b. Usage/Anomalies - Experiment T020 was performed as planned on SL-3 with the test pilots operating the FCMU five times. The first three runs were performed in shirtsleeves while the last two runs were flown suited. The two suited runs were conducted utilizing both the Life Support Umbilical (LSU) and Secondary Oxygen Pack (SOP) configurations. On SL-4, T020 was performed twice. The first run was performed suited whereas the second was performed in shirtsleeves.

Two modifications were added to T020 during its performance on SL-3. After the first maneuvering operation with T020 it was evident that a better restraint system was needed. A modified system was devised on ground and then information was uplinked to the crew. This restraint system provided the added stability sought by the test pilot and was used throughout the remaining SL-3 T020 performances.

The second modification was performed by the SL-3 crew on the LSU in hopes of reducing or eliminating the dynamic effects it imparted on the maneuvering units. Using a scapel and sissors, the LSU was stripped of all wiring and insulation, leaving only the 0_2 line. This LSU was used on all subsequent M509 and T020 suited runs not utilizing the SOP configuration.

Because of the lack of rigidity experienced with the T020 restraint system during SL-3 a new rigid restraint system was designed and fabricated between missions. This rigid restraint system was launched on SL-4 and used by the crew in their T020 operations.

The first SL-4 T020 run was performed suited and utilized the new rigid restraint system. The crew reported that the system worked extremely well and reduced practically all body/backpack motions.

The second T020 performance was conducted in shirtsleeves. The crew operated T020 with both the rigid and original restraint systems. Again,

the rigid system was considered highly effective whereas the non-rigid system was considered extremely poor.

This was the last evaluation of experiment T020 as scheduling considerations prohibited any additional performances.

c. Assessment/Recommendations - T020 stowage/unstowage was fairly simple, although between operations it was left stowed in such a manner that would not require much time to reactivate...a casual type of stowage.

The T020 restraints and harness were not satisfactory. Also, seat padding was improvised and is definitely required. The restraints did not give the operator a secure or tight feeling in the unit. The harness, due to its unusual design, was difficult to don and connect. The backpack assembly was not contoured correctly and was too loose when donned. Incorporation of the required restraint system removed most of the sloppiness between the backpack and FCMU and gave the pilot a more secure fit with the T020 hardware.

The shoe plates seemed to work well although it was easy to kick your foot/shoe plate out of the FCMU. Also the shoe plate forces for the thrusters were too high. These seemingly high shoe plate forces could be attributed to a possible deconditioning of the crew's leg muscles due to the zero gravity environment.

T020 must have six (6) degrees of freedom to be fairly evaluated. As designed, it is completely unacceptable as a maneuvering vehicle and the crew sees no advantage in its concept of foot-controlled maneuvering.

13.22.5 Student Project Experiments

13.22.5.1 ED 23 - Ultraviolet from Quasars

a. Operations - Student experiment ED 23 was scheduled to be performed on SL-3 as an additional data pass of baseline experiment S019 to obtain spectrographic data of selected quasars.

The crew was to use experiment S019 as support equipment for ED 23. With S019 mounted in the Scientific Airlock (SAL), ultraviolet photographs were to be taken of pre-designated galaxies. ED 23 data was to be recorded in the S019 portion of the log book and photographs were to be returned in the S019 film canister.

b. Usage/Anomalies - Student experiment ED 23 was performed as scheduled and no anomalies were reported.

c. Assessment/Recommendations - The crew felt that experiment training was good but that a decision needed to be made as to experiment operational priority so as to better appropriate crew training requirements.

13.22.5.2 ED 25 - X-Rays From Jupiter

a. Operations - Student experiment ED 54 was scheduled to be performed on SL-3 to detect x-rays from Jupiter.

The experiment was to be performed with the use of ATM experiment S054 under Joint Observation Program (JOP) 13. The vehicle was to be maneuvered so that the ATM could observe celestrial bodies away from the sun.

b. Usage/Anomalies - Student experiment ED 25 was performed during the ATM performance of JOP 13 as scheduled and no anomalies were reported.

c. Assessment/Recommendations - The crew felt that the procedures were adequate and that the hardware performed satisfactorily.

13.22.5.3 ED 26 - Ultraviolet From Pulsars

a. Operations - Student experiment ED 26 was scheduled to be performed on SL-3 as an additional data pass of baseline experiment S019 to search for pulsars in ultraviolet wavelengths.

The crew was to use experiment S019 as support equipment for ED 26. With S019 mounted in the SAL, ultraviolet photographs were to be taken of designated galaxies. ED 26 data were to be recorded in the S019 log book and the photographs were to be returned in the S019 film canister.

b. Usage/Anomalies - Student experiment ED 26 was performed as planned and no anomalies were reported.

c. Assessment/Recommendations - Student experiment ED 26 used only film and S019 experiment hardware, therefore all crew interface assessments are included with the assessment of S019.

13.22.5.4 ED 31 - Bacteria and Spores

a. Operations - Student experiment ED 31 was scheduled to be performed on SL-3 to determine the effects of weightlessness and space radiation on the survivability, growth rate, and mutation of several vegetative bacterial species.

A crewman was to inoculate the 15 petri dishes containing nutrient agar. Nine cultures were to then be incubated in the Inflight Medical Support System (IMSS) incubator and the remaining six at OWS ambient temperature. Observation and photography of these cultures were to take place at 12 hour intervals until the colony growth was attenuated by cooling in the OWS and chiller. The petri dishes were to be returned at the end of the mission for laboratory study.

b. Usage/Anomalies - Due to the degradation caused by the SL-2 launch delay and the elevated OWS temperatures, ED 31 was investigated and a decision was made to perform the experiment on SL-2, assess the data, and consider performance on SL-4, if necessary. The 15 ED 31 petri dishes were inoculated, incubated and photographed on

SL-2. Petri dishes one through four had water drops but no visible growth. Photographs were not taken of dishes one through four but were taken of dishes five through fifteen. Only dishes number 7 and number 9 showed any growth and they had three and one colonies respectively. The experiment was completed using reduced mission protocol and the 15 dishes were returned on SL-2. The 15 plates were not chilled and they were returned in a food overcan because the IMSS resupply container was not on board SL-2. Ground studies indicated that the high temperatures experienced on SL-2 had possibly affected the experiment results and it was decided to repeat the experiment on SL-4. ED 31 was repeated on SL-4 as planned and successfully completed.

c. Assessment/Recommendations - The crew was satisfied with the experiment hardware performance and reported no difficulty in inoculating the petri dishes in a zero-gravity environment.

13.22.5.5 ED 32 - Invitro Immunology

a. Operations - ED 32 was scheduled to be performed on the SL-3 mission to determine the effects of zero gravity on the antigenicity.

To perform ED 32, a crewman was to inject each of the three (3) immuno diffusion plates with antigen and was to then periodically photograph the plates throughout the incubation period. To photograph the plates, the crew was to attach them to OWS light number 1 using the photo clip

supplied in the ED 32 hardware.

b. Usage/Anomalies - Antigen injection of the three diffusion plates was accomplished early in the SL-3 mission. Ten days later, the plates were attached to the OWS light and photographed with the 35mm Nikon camera. This constituted completion of the ED 32 experiment requirements.

c. Assessment/Recommendations - No assessments or recommendations were received from the crew concerning ED 32. Therefore it was assumed that the experiment hardware, procedures and interfaces were well designed and all functioned as planned.

13.22.5.6 ED 41 - Motor Sensory Performance

a. Operations - ED 41, Motor Sensory Performance, was scheduled to be performed on SL-4 to obtain motor sensor performance data which could be used in planning, training, and equipment development for future manned space missions.

The method of measuring motor sensory performance used in ED 41 was a standardized eye-hand coordination test using a maze with a 119-hole aiming pattern, stylus, and cable assembly. During operation the unit was attached to the wardroom window shelf by velcro strips and the cable was connected to the speaker intercom assembly connector. The experiment was performed once early and again late in the mission by the same astronaut and no activities imposing either intense physical exertion or mental/

emotional strain preceded performance of the experiment. Inflight performance was compared with pre-flight and post-flight tests performed by the same subject.

b. Usage/Anomalies - Student experiment ED 41 was performed as scheduled by all three crewmen and no anomalies were reported.

c. Assessment/Recommendations - Procedures for ED 41 were straightforward and the hardware performed satisfactorily.

13.22.5.7 ED 52 - Web Formation

a. Operations - Student experiment ED 52 was scheduled to be performed on SL-3 to observe the web building process of the Araneus diadematus (cross) spider in a zero-gravity environment and compare this process with one performed in a one "g" earth environment. A prime and backup spider were to be launched.

The crewman performing the experiment was to deploy the experiment enclosure which permits observations of spider activity. The spider was to be released from her vial into the experiment enclosure and allowed to spin her web. During the experiment performance a crewman was to periodically provide food and water for the spider. Still photographs were to be made with the 35mm Nikon camera and correlated

to Ground Elapsed Time (GET) by voice recorded comments. Movie photographs were to be made with the DAC 16mm camera utilizing the automatic camera actuator which detected spider motion to start/stop the motion picture camera. Upon completion of the experiment the spiders were to be disposed of through the trash airlock.

b. Usage/Anomalies - Prior to releasing the prime spider, Arabella, the crew reported a problem with the automatic camera actuator. Malfunction procedures were conducted on the automatic camera actuator with no results. The actuator was considered failed and therefore the web forming photography objective was not met. Photographs were taken periodically by the crew using the hand-held camera. Due to the actuator failure some additional crew time was spent taking hand-held photographs. Both the prime and backup spiders died in orbit and were returned to earth along with web samples.

c. Assessment - Other than the actuator failure and resulting increased time requirement for the crewman the experiment was performed as scheduled.

13.22.5.8 ED 61/62 - Plant Growth/Plant Phototropism

a. Operations - ED 61/62 was scheduled for performance during SL-2 to observe difference in root and stem growth of rice seeds germinated in the Skylab environment.

Eight seed groups were to be implanted by the crewman with the seed planter into a compartmental container filled with clear agar. This container was to be fitted with neutral density filters to enable a variation in the total light impinging on the eight separate seed groups. Following implantation, the crewman was to photograph the seed groups daily for 14 days using the 35mm Nikon camera.

b. Usage/Anomalies - Due to the high OWS temperatures after launch, and subsequent on ground testing, the ED 61/62 performance was cancelled for SL-2. Resupply and performance of ED 61/62 was accomplished during SL-4. Prior to seed implantation the experiment was relocated because existing light levels were felt to be too low for adequate growth. In addition, the portable light was incorporated to provide additional lighting to insure good growth. Finally the seeds were implanted and photographed as scheduled with no anomalies reported.

c. Assessment/Recommendations - No assessment or recommendations were received from the crew concerning ED 61/62. Therefore it was assumed that the experiment hardware, procedures and interfaces were well designed and all functioned as planned.

13.22.5.9 ED 63 - Cytoplasmic Streaming

a. Operations - Experiment ED 63 was scheduled for operation on the SL-3 mission to observe the effects of zero gravity on cytoplasmic streaming in plants.

Crew activation operations for ED 63 were to consist of restraining the ED 63 transparent container, containing the elodea water plants, near a specific light in the OWS wardroom to maintain photosynthesis during the mission. Then, once early in the mission and again late in the mission, the crew was to detach a leaf from the elodea plant and, with use of the Inflight Medical Support System (IMSS) microscope and associated hardware, examine the leaf for cytoplasmic streaming. The 16mm Data Acquisition Camera (DAC) was to be used to document the data.

b. Usage/Anomalies - ED 63 was performed as scheduled on SL-3. During the first performance the crewman reported that all three plant vials had a sulphurous smell and that the leaves from the three plants showed no resistance when detached. Two slides were prepared from one of the plants and no cytoplasmic streaming was observed.

In conjunction with this in-flight performance of ED 63, a ground based performance was conducted. A sample slide was prepared on each of the three plants and observed under a microscope. Two of the three elodea plants appeared to be totally dead, the third appeared normal and exhibited good cytoplasmic streaming. The vials containing the two dead plants smelled of hydrogen sulfide and the leaves showed no resistance when detached. Based on this, it was considered probable that one or more of the plants in orbit were dead.

From a later on ground performance of ED 63 it was discovered that a previously considered dead plant had exhibited some cytoplasmic streaming. Therefore, the crew were requested to prepare slides on all three plants and examine for possible streaming. The crew complied and no streaming was observed. This resulted in a termination of the experiment for SL-3 and an eventual resupply for a SL-4 performance.

During the SL-4 performance of ED 63, a hardware anomaly was reported concerning the DAC camera/IMSS microscope adapter. The crewman examining for cytoplasmic streaming could not acquire a full field of view. It was his assessment that the adapter was the cause of the problem.

The SL-4 performance of this experiment approximated the results obtained from SL-3. During the first cytoplasmic streaming observation one plant provided some evidence of streaming. In subsequent observations the elodea plant leaves showed no resistance when detached, there was a sulphurous smell present and no cytoplasmic streaming was observed. It was decided that the plants were dead and the experiment was terminated. The plants were removed from their vials and placed in the trash airlock.

c. Assessment/Recommendations - Other than the DAC camera/IMMS microscope adapter anomaly, the ED 63 performances were conducted as planned. The crew reported that the experiment

procedures and hardware functioned well and felt that everything possible was done on their part to acquire usable data. From the results of this experiment, it was concluded that zero-gravity has an undesirable effect on cytoplasmic streaming in plants.

13.22.5.10 ED 72 - Capillary Study

a. Operations - Student experiment ED 72, Capillary Study, was scheduled to be performed on SL-4 to demonstrate capillary action as a liquid pumping mechanism.

The experiment hardware consisted of two separate capillary tube modules and an additional capillary wick module. Each capillary tube module contained a reservoir, lever valve system and three transparent capillary tubes of graduated sizes. One module contained water, the other Krytox oil. The capillary wick module contained three capillaries of twill and mesh screens. The crewman was to activate the lever valve of the capillary tube modules and photograph the capillary action of the fluid. The entire experimental sequence was to be photographed, beginning with the actuation of the capillary valve and ending with the time that the slowest fluid volume reached the end of the capillary tube.

b. Usage/Anomalies - The wicking segment of student experiment ED 72 was successfully performed as scheduled with photographic data and crew sketches being obtained for data.

The capillary segment of ED 72 was unsuccessful. During preparation of this portion the crewman observed that both the oil and water had leaked from their reservoirs. When the lever valves were operated no capillary action was observed. The failure was attributed to the reservoir

leakage. The ground later suggested attempting to refill the reservoirs but the crew had already disposed of the modules through the trash airlock. The leakage was documented on film.

c. Assessment/Recommendations - The wicking portion of ED 72 was successfully completed with the hardware functioning as designed. However, the capillary segment was unsuccessful due to the hardware failure resulting in the leakage of the capillary modules.

13.22.5.11 ED 74 - Mass Measurement

a. Operations - Experiment ED 74 was scheduled to be performed on SL-3 to demonstrate the use of harmonic motion to measure the mass of an object.

To operate ED 74, a crewman was to first remove ED 74 from launch stowage in the OWS film vault and then bolt it to the film vault. The device was to then be calibrated using the calibration weights included with the ED 74 hardware. Next the mass of four (4) small objects was to be determined through use of the ED 74 hardware. This was to conclude the ED 74 performance.

b. Usage/Anomalies - During SL-3, ED 74 was performed twice instead of only once as scheduled. It was decided that this experiment was a good candidate to be downlinked by real time TV coverage.

c. Assessment/Recommendation - During both performances the hardware functioned as planned and no anomalies were reported. The crew stated during the final performance that ED 74 worked very well.

13.22.5.12 ED 76 - Neutron Analysis

a. Operations - Student project experiment ED 76 was scheduled for operation during all three Skylab missions. Its purpose was to acquire data for measurement of the ambient neutron flux at Skylab orbital attitudes.

The hardware for ED 76 was comprised of ten (10) neutron detectors and stowage containers. During SL-2 the ten neutron detectors, consisting of chemically coated films, were to be deployed on the inboard surfaces of the OWS. At designated times during SL-2 and SL-4 the crew was to deactivate certain detectors and stow them for ultimate return to earth.

b. Usage/Anomalies - During SL-2 the ten (10) neutron flux detectors were deployed as planned. At the end of this mission four (4) detectors were deactivated, stowed and returned. The remaining six detectors continued data collection throughout the Skylab missions and were deactivated and stowed in the CM by the SL-4 crew just prior to their return.

The SL-4 crew stated that dector Bravo 3 was poorly placed in that as they came through the hatch from the forward compartment to the experiment compartment it was in a very natural place to grab. If touching degraded it, it was definitely degraded as it was touched numerous times.

c. Assessment/Recommendations - No assessments or recommendations were reported by the Skylab crews concerning ED 76. Therefore it was assumed that the experiment hardware, procedures and interfaces were well designed and all functioned as planned.

13.22.5.13 ED 78 - Liquid Motion

a. Operations - Experiment ED 78 was scheduled to be

performed on SL-3 to study the dynamic response of a liquid/gas interface when subjected to an impulse in zero gravity.

The crewman was to excite a gas bubble, surrounded by a liquid, by activation of the calibrated force supplied by the ED 78 piston/spring mechanical system. Photographs were to be supplied to the student investigator to provide ED 78 data interpretation.

b. Usage/Anomalies - Experiment ED 78 was set up and initiated during SL-3 but the hardware did not operate properly. The piston/spring mechanism did not function when activated. Several corrective procedures were attempted with no success. It was determined that the diaphram in the piston/spring mechanism was ruptured and that no corrective actions were possible. The ED 78 hardware was terminated and stowed.

During SL-3 and SL-4, liquid motion scientific demonstrations were performed and data from these demonstrations were provided to the ED 78 student investigator. This data provided sufficient information to satisfy the requirements of ED 78.

c. Assessment/Recommendations - Other than information concerning the ED 78 hardware anomaly, the crew made no comments concerning the assessments/recommendations for this experiment.