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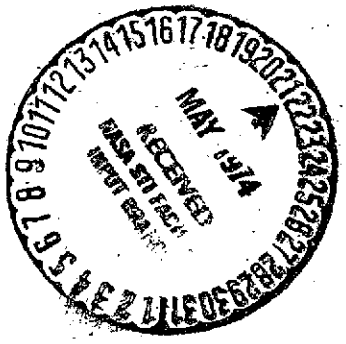
NASA TECHNICAL MEMORANDUM

NASA TM X-64839

RETENTION AND APPLICATION OF SKYLAB EXPERIMENT EXPERIENCES TO FUTURE PROGRAMS

By Nancy Milly and Victor G. Gillespie
Quality and Reliability Assurance Laboratory

May 1, 1974



NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
NASA TM X-64839		

4. TITLE AND SUBTITLE
RETENTION AND APPLICATION OF SKYLAB EXPERIMENT EXPERIENCES TO FUTURE PROGRAMS

5. REPORT DATE
May 1, 1974

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Nancy Milly and Victor G. Gillespie

8. PERFORMING ORGANIZATION REPORT #

9. PERFORMING ORGANIZATION NAME AND ADDRESS
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

10. WORK UNIT NO.

11. CONTRACT OR GRANT NO.

13. TYPE OF REPORT & PERIOD COVERED
Technical Memorandum

12. SPONSORING AGENCY NAME AND ADDRESS
National Aeronautics and Space Administration
Washington, D. C. 20546

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This document has been prepared to consolidate into one listing certain outstanding problems encountered on Skylab Experiments in order that these experiences and associated recommendations might help to prevent similar problems on future programs. The criteria for selection of the data to be utilized in this document was to identify the problem areas within the Skylab Program which it was felt would be of major significance with respect to future programs. Also, the problem had to be unique in that it would help identify to a designer/manufacturer an unforeseen or unanticipated occurrence which could cause failures, delays, or additional cost. This would not include the multitude of run-of-the mill anomalies which are normally encountered in the design, manufacture and test of an aerospace experiment system. This document addresses only those unexpected problems that may occur due to the nature of aerospace experiment environmental and operational requirements.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
	Unclassified-unlimited

Nancy J. Milly

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	52	NTIS

For sale by National Technical Information Service, Springfield, Virginia 22151

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SUMMARY

In order to prepare this handbook for the use of experimenters on future programs, approximately 7,000 Skylab Experiment Discrepancy Reports were reviewed. A total of 38 problems are included in this handbook, most of which include more than one occurrence of the same problem.

The problems are indexed into five major types as follows:

A	Materials & Processes	8
B	Environmental	5
C	Design	10
D	Procedural	8
E	Human Error	7

Of the Materials & Processes Problems, six were concerned with materials which were not suited for the particular application for which they were used. Four of these concerned degradation of material over a period of time. The other two concerned a bonding material which was unsatisfactory and a cleaning fluid which reacted unfavorably with cable jacket material causing deterioration and flaking. The two special processes used which caused problems indicate the need for a more thorough engineering evaluation of the necessity for special processes prior to their use.

The five environmental problems stress that thermal vacuum testing of space hardware is essential as early in a test program as possible. If feasible, such testing should be performed at the component level prior to subsystem or system testing under thermal vacuum conditions.

The problems categorized under Design indicate the need for design reviews early in a program. These design reviews should emphasize the astronaut-experiment interface.

Procedural problems include lack of or inadequate procedures which resulted in the noted discrepancies. A careful review of all phases of inspection and testing to which space hardware will be subjected should be performed to assure that adequate procedures document the requirements and performance for each phase. This should be done as early in a program as possible.

The last group of problems were attributed to human error. Procedures were available for performing various operations, however, personnel did not follow the procedures. These problems emphasize that all inspection and test personnel should be thoroughly and continuously trained to use applicable procedures associated with space hardware.

INTRODUCTION

This document has been prepared to consolidate into one listing certain outstanding problems encountered on Skylab Experiments in order that these experiences and associated recommendations might help to prevent similar problems on future programs. The criteria for selection of the data to be utilized in this document was to identify the problem areas within the Skylab Program which it was felt would be of major significance with respect to future programs. Also, the problem had to be unique in that it would help identify to a designer/manufacturer an unforeseen or unanticipated occurrence which could cause failures, delays, or additional cost. This would not include the multitude of run-of-the mill anomalies which are normally encountered in the design, manufacture and test of an aerospace experiment system. This document addresses only those unexpected problems that may occur due to the nature of aerospace experiment environmental and operational requirements.

Approximately 7,000 discrepancy documents were reviewed with 38 separate types of items being selected as meeting the above criteria. Each item contains one or more examples for that type of problem. Each item is considered unique and different from every other item.

Each individual entry referenced in the index contains an index number, title, explanation as to cause of the problem, and a recommendation or description of action taken. It is our intention that this document will be of benefit to the reader in avoiding the pitfalls encountered in our prior experiences in designing, building, testing, and using complicated aerospace experiment equipment in new and different applications and under extreme environmental conditions.

CONCLUSIONS

It is the intent of this handbook to present Skylab Experiment experiences in such a manner that the data may be used in future programs to minimize occurrence of similar problems. This document, used in conjunction with design standards that have evolved over the years of space activity, can have broad application in future space experiment activities--from the designer making a part selection for a specific application to the test engineer or technician in the identification of a particular failure cause. Use of the document will also allow greater management emphasis to be placed upon potential problem areas.

SECTION A

MATERIALS AND PROCESSES

TITLE:	Inadequate Material
DESCRIPTION:	During testing of the Nitrogen System of the Human Vestibular Function Experiment (M131), the low pressure trip level to actuate the pressure switch under decreasing pressure conditions indicated zero inches H_2O. The specification requires that the switch actuate at 0.25 inches H_2O minimum under decreasing pressure conditions.
CAUSE:	Test and evaluation indicated that the pressure switch diaphragm was the cause of failure. The material used was selected because of its helium diffusion characteristics; however, the material takes a slight set.
CORRECTIVE ACTION:	Pressure switch diaphragm material was changed from ethylene propylene to SE4404 silicone rubber in all units.
RECOMMENDATIONS:	A thorough engineering analysis of the physical properties should be made prior to selection of any material for aerospace usage.

A2

TITLE:	Deformation of Seal During Storage
DESCRIPTION:	Safety valve assembly of the Lower Body Negative Pressure Experiment (M092) leaked external to internal during functional and leak test.
CAUSE:	Leakage was caused by valve inlet seal deformation during storage so that when the seal is first installed into the valve, it does not conform perfectly with the seat.
CORRECTIVE ACTION:	An Engineering Order to the drawing instituted the use of a "set-in" procedure, through a heat application process, to conform the seal to the seat.
RECOMMENDATIONS:	A thorough engineering evaluation of all soft goods used should be made to predetermine the effects of anticipated special environments and long term storage on the materials.

A3

TITLE:	Improper Manufacturing Process
DESCRIPTION:	The top thermal sensor of the Thermal Control Coatings Experiment (M415) was bead blasted on one side per a marked up drawing. This caused the sensor to curl from .060" to .090". The sensor was made from aluminum alloy 6061-T6, .020" thick.
CAUSE:	Design deficiency
CORRECTIVE ACTION:	Part was scrapped and requirement was deleted.
RECOMMENDATIONS:	Engineering should evaluate the applicability of special processes to the physical dimensions as well as to the material itself.

A4

TITLE:	Effects of Long-Term Storage on Camera Film
DESCRIPTION:	During prelaunch testing of the White Light Coronagraph (S052), the camera operate light malfunctioned and erroneous frame counts were received. Film was not advancing properly.
CAUSE:	Cause was a "set" in the film due to long-term storage. Film had been stored 7 months.
CORRECTIVE ACTION:	Flight Operations at Johnson Space Center and the astronauts were informed that this condition might occur as a result of long-term storage of film during the Skylab mission. Such an occurrence should not be cause for alarm as problem disappeared after five frames were advanced.
RECOMMENDATIONS:	Engineering should not overlook the effects of long-term storage on materials to be used in space experiments.

A5

TITLE:	Deterioration and Flaking of Cable Jacket Material
DESCRIPTION:	Blue outer jacket material of the Vectorcardiagram (M093) umbilical cables was flaking off during normal usage and handling.
CAUSE:	Discussion with the vendor revealed that all production cables had been submerged in freon during the cleaning process. A chemical reaction between the freon and the teflon-fiberglass braided jacket resulted in the deterioration and flaking.
CORRECTIVE ACTION:	All cables were returned to the vendor for jacket replacement.
RECOMMENDATIONS:	Cleaning materials and processes should be evaluated prior to use on production items to prevent damage and costly delays.

A6

TITLE:	Failure of Epoxy Coating to Adhere to Potting
DESCRIPTION:	The conductive epoxy (Ablestix Adhesive 369-3), that was used to coat the housing of the pressure transducer preamp assembly of the Lower Body Negative Pressure Experiment (M092), had begun to crack and flake away from the housing.
CAUSE:	Engineering analysis concluded that this epoxy is more rigid than the pliable Sylgard-186 potting of the assembly and has only marginal adherence to the Sylgard.
CORRECTIVE ACTION:	Epoxy coating was replaced with an electrical conducting silver silicon coating which is flexible and will bond to the Sylgard.
RECOMMENDATIONS:	A laboratory experiment should be made to check the physical properties and degree of adherence prior to actual usage of materials in any similar application.

A7

TITLE: Inadequate Piece Part Process

DESCRIPTION: During Skylab Medical Environmental Altitude Test (SMEAT) of the Experiment Support System, the heart rate indicator "hung up" after calibration and indicated properly only after the panel was given a tap.

CAUSE: Failure of the oscillator was caused by a bad solder joint on the tuning fork in the oscillator which is the clock for the heart rate system. The bad solder joint was caused by inadequate piece part process in which a copper flash had been used over the silver plating on the piezoelectric crystal for the purpose of indicating polarity. The copper flash served the purpose of a shop aid only. The copper flash had not fused to the silver plating and repeated vibration followed by repeated temperature cycles caused intermittent, and eventually permanent, separation.

CORRECTIVE ACTION: The oscillator was replaced with one which was reworked to assure an adequate bond by partially removing the copper flash. Retest was performed to assure proper operation after rework.

RECOMMENDATIONS: Engineering should weigh carefully the advisability of using difficult and costly special processes which serve no function in the operation of the system.

A8

TITLE:	Switch Contact Failure After Long Term Non-Use
DESCRIPTION:	Microwave Radiometer (S193) failed to achieve nadir (lowest point) alignment.
CAUSE:	The "X-mit Inhibit" signal was erroneously generated by the Electrical Test Set as the result of a high-resistance normally-closed contact in the "cal-mode" switch. This contact is required to pass a logic zero (1 ma) to prevent the generation of the "X-mit Inhibit" signal. The switch has silver contacts which tend to develop high resistance after long periods of non-use. The high resistance resulted in the generation of a logic 1 (> 2.7V)
CORRECTIVE ACTION:	Switches with silver contacts were replaced with gold over brass contact/epoxy-sealed switches.
RECOMMENDATION:	Switches with silver contacts are not recommended for controlling logic functions or other dry circuit applications.

SECTION B

ENVIRONMENTAL

B1

TITLE:	Failure Due to Differential Pressure
DESCRIPTION:	During post thermal vacuum testing of the targeting telescope (H-Alpha 1), the frames remaining counter indicated erroneous readings of 30 to 40 counts.
CAUSE:	This problem was caused by the magazine not being vented to ambient pressure after being subjected to thermal vacuum conditions, leaving a pressure differential which adversely affects the operation.
CORRECTIVE ACTION:	Magazine was reloaded and tested successfully. Test procedure was changed to require magazine be vented after thermal vacuum tests.
RECOMMENDATION:	Design engineering should carefully evaluate enclosed and unvented components which are to be operated in both ambient atmosphere and vacuum conditions to assure that pressure differentials do not affect their operation.

B2

TITLE: Camera Photo Plates Fogged

DESCRIPTION: When operated in a vacuum the SC5 photographic plates used in the Ultraviolet Panorama (S-183) Camera were sensitized by a parasitic light.

CAUSE: The light was caused by an electrostatic discharge which was caused, in turn, by the rubbing, under vacuum, of the plates' Delrin chassis on the black anodization of the magazine's aluminum parts.

CORRECTIVE ACTION:

1. The Delrin chassis was covered with a gold coating, deposited under vacuum by vaporization, to a thickness of 0.1 μ.
2. The black anodization on those pieces rubbing on the chassis was replaced by an Iridite treatment.
3. The Delrin ring was replaced with the same ring with a Polymet AG material, 80% silver and 20% plastic.

RECOMMENDATIONS: This problem emphasizes the necessity of performing tests on experiment hardware under vacuum conditions as early in the program as possible.

B3

TITLE:	Desiccant Swelling
DESCRIPTION:	During manned altitude test of the Multispectral Photographic Camera (S190A) Experiment, the spare desiccant outer packages in the stowage container swelled to such an extent as to cause difficulty in restowing the desiccant and closing the container lid.
CAUSE:	The outer packages for the spare desiccant containers were sealed under conditions of sea level pressure. As a result, when exposed to ambient pressure of less than one atmosphere, the packages swelled because of the pressure difference.
CORRECTIVE ACTION:	Desiccant packages were repackaged under evacuated conditions.
RECOMMENDATIONS:	The effects of a space environment on various materials being used in space experiments should always be considered and properly compensated for.

B4

TITLE: Effects of Vacuum on Cold Cathode Ion Gage

DESCRIPTION: During thermal vacuum testing of the Ultraviolet Scanning Polychromator/Spectroheliometer (S055) Experiment, the cold cathode ion gage failed to actuate when commanded. There was a delay from one minute to one hour before gage would begin to indicate pressures.

CAUSE: Tests indicated that this was normal operation for the gage as lower levels of vacuum were obtained.

CORRECTIVE ACTION: Modifications were made to provide a higher operating voltage to the cathode which resulted in greatly improved turn-on characteristics. Vacuum levels below 10^{-6} torr at which this condition exists were not expected during mission operation. The vacuum level was monitored by ground telemetry to inform the astronauts when to activate the gage.

RECOMMENDATIONS: This problem stresses the necessity for thermal vacuum testing of hardware prior to use in space. All hardware which will operate at vacuum conditions should undergo such testing.

B5

TITLE:	Motor Failure Under Vacuum Conditions
DESCRIPTION:	During thermal vacuum testing the Dual X-ray Telescope Camera (S-056) failed to complete its timed sequence of operation. Subsequently, the override was activated and the operation reinitiated. After approximately 30 frames the film drive motor stalled again.
CAUSE:	The torque equalizer spring and bearing on the film drive motor caused increasing friction under hard vacuum conditions which stalled the motor.
CORRECTIVE ACTION:	Torque equalizer spring and bearing were removed from the system. Subsequent tests indicated camera operated satisfactorily without this hardware.
RECOMMENDATIONS:	This problem again stresses the importance of thermal vacuum testing for hardware which will be used under vacuum conditions during a mission.

SECTION C

DESIGN

C1

TITLE:	Improper Camera Operation
DESCRIPTION:	During thermal vacuum testing and post-vibration testing of the Dual X-ray Telescope (S056), the film camera stopped operating.
CAUSE:	The cause was a loose screw retaining the decoding magnet on the idler shaft. As a result the magnet oscillated, giving false signals to the decoding "reed" switch.
CORRECTIVE ACTION:	The type of screw being used was replaced with a different type which contains a nylon insert as a locking device.
RECOMMENDATIONS:	Any retaining hardware which will be subject to vibration should contain a locking device to prevent loosening, especially where it can cause loss of operation of a system or component.

C2

TITLE: Improper Operation Due to Transients

DESCRIPTION:

1. During Thermal Vacuum Testing of the Extreme Ultraviolet Spectrograph (S082B), several measurements were found to be fluctuating.

2. During Post Vibration Testing of the X-ray Spectrographic Telescope (S054), the camera started operating although no command signal had been given.

CAUSE: The above conditions were caused by susceptibility to transients.

CORRECTIVE ACTION:

1. Isolation amplifiers were installed in the circuit to prevent picking up transients from the vehicle skin.

2. Camera was modified by adding a gated circuit that required the start command signal to be as long as one clock pulse thus limiting noise transients from generating camera starts.

RECOMMENDATIONS: The two examples cited here are not the only ones that occurred on Skylab experiment hardware. Although the presence of electrical transients cannot be predicted, the probability of occurrence is high in anything as large and complex as Skylab. The designer should, therefore, reduce susceptibility as much as possible through isolation and circuit design.

TITLE: Design of Experiment Hazardous to Astronaut

DESCRIPTION: Several instances of non-safe conditions were disclosed with the Foot Controlled Maneuvering Unit (T-020) during astronaut evaluation:

1. Beaded chain was used on connector covers for restraints. Beads and wire from broken chains could cause problems in valves, fans, etc.
2. Foot plates had exposed screw edges which could cause possible damage to suit, footwear, or feet.
3. Quick release handles on restraint harness were too large making harness subject to inadvertent release.
4. Electrical and propellant gas umbilicals were of such a length as to leave a large loop of umbilical below and behind the crewman. This loop is susceptible to entanglement during experiment operation.
5. Restraint system had loose ends of straps for the crewman to contend with. Unrestrained loose strap ends could become entangled in hardware thus presenting a serious operational problem.
6. Lower latches were galling which could easily produce free metallic particles that could get into electrical connectors or other hardware and cause damage.

CAUSE: Design oversight

CORRECTIVE ACTION: The following actions were taken for the noted discrepancies:

1. Design changes to callout approved teflon covered wire.
2. Footplate was redesigned to eliminate exposed screw edges.

3. Design of quick release was changed to eliminate possibility of inadvertent release.
4. Design was changed to eliminate umbilical loops.
5. Design change provided a method for stowing straps.
6. Design was changed to incorporate rollers thereby eliminating galling.

RECOMMENDATIONS: In designing an experiment, special consideration should be given to whether or not the design could constitute a safety hazard for the astronauts while they operate it. This would be particularly important where the experiment is actually in bodily contact with the astronaut.

C4

TITLE:	Malfunction Due to Resistance Change
DESCRIPTION:	The minus 10 VDC power supplies in the Experiment Support System required an input of -10.00 $\pm$ .10 VDC. Readings were below specification.
CAUSE:	In the design of the -10 VDC output circuitry a $\pm$ 5% carbon resistor, which is additionally subject to an on-the-shelf drift of 20%, was used to provide a reference voltage for an amplifier. The resistance values had drifted on the subject power supplies causing their -10 VDC outputs to be out-of-tolerance.
CORRECTIVE ACTION:	Resistor was changed to a satisfactory type and retest was satisfactory.
RECOMMENDATIONS:	Part application review should be included in the design review for critical circuits.

C5

TITLE:	Malfunction Due to Limited Life
DESCRIPTION:	Several proportional counter tubes in the Dual X-ray Telescope (S-056) failed to detect x-rays.
CAUSE:	These proportional counter tubes have the inherent characteristic of a loss of gain over a period of time (limited life.)
CORRECTIVE ACTION:	The proportional counter tubes were replaced and retest was successful. Enough tubes were obtained so that tubes with a gain sufficient to last through the flight period could be selected. Exposure times to high counts were kept to a minimum during preliminary testing.
RECOMMENDATIONS:	The use of limited life items should be kept to a minimum; however, when it is necessary to use them, they should be identified, tracked and replaced prior to exceeding operational life limitation.

C6

TITLE:	Improper Mounting of Transistor
DESCRIPTION:	During post-manufacturing checkout of the Metabolic Activity Experiment (M-171), a high voltage reading was exhibited. The collector of a transistor in the power supply regulator of the Metabolic Analyzer was shorted to the chassis.
CAUSE:	Disassembly disclosed that a split ring lock washer had been used to mount the transistor stud to the heat sink. When the nut was put on, the split ring washer pierced the mylar insulation and shorted the collector to the chassis.
CORRECTIVE ACTION:	The transistor was replaced using a flat washer and retest was successful.
RECOMMENDATIONS:	When lock washers are used to fasten stud-mounted transistors, a flat metal washer should also be installed between the lock washer and the insulation to prevent this type of problem. Design engineering should become aware of acceptable configurations for the fastening of stud-mounted transistors as outlined in ALERT MSFC 74-01.

TITLE: Lack of Identification, Alignment Marks, Position Indications, etc.

DESCRIPTION: During astronaut evaluation of the Foot Controlled Maneuvering Unit (T-020), the following were noted:

1. There were no instructional labels or nomenclature on the various connectors, components, quick disconnects, etc. Labels and nomenclature are required to inform the crew of various mechanical and electrical operations as well as to identify items of hardware.
2. Alignment marks were not provided on several pieces of hardware where they are necessary for ease of installation and the prevention of inadvertent damage.
3. Neutral position of foot controls is required during suited operations; however, no indication of neutral position was provided.

CAUSE: Design oversight.

CORRECTIVE ACTIONS: The following actions were taken:

1. Instructional, identification and nomenclature labels were added to the experiment hardware. Appropriate labels were added to mechanical and electrical interfaces.
2. Alignment marks were provided as required.
3. Adjustments were made to the operational travel of the foot pedals to improve the crewman's "feel" for the neutral position.

RECOMMENDATIONS: In the design of an experiment, ease of usage by the crew should always be a major consideration.

TITLE:	"HALO" Effect on Developed Film
DESCRIPTION:	Several field flattener lenses were the source of a "halo" effect on developed film from the White Light Coronagraph (S052) Camera.
CAUSE:	The cause was at first thought to be the lens coating, but using a coating with a different wave length did not resolve the problem. The cause was finally attributed to stray light interfering with the main path light rays.
CORRECTIVE ACTION:	The lens coating was changed to a coating of a different wave length and a lens holder with a smaller aperture at the rear of the lens was provided.
RECOMMENDATIONS:	Design of camera should be such as to preclude the occurrence of a "halo" effect, if possible. Also, tests should be run prior to camera acceptance to assure that no "halo" effect is present on exposed film.

TITLE: Damage Due to Lack of Handling Equipment and/or Procedures

DESCRIPTION: Several instances of damage to experiments occurred due to droppage or improperly using parts of the experiment as handholds.

The Metabolic Analyzer (M-171) was inadvertently dropped causing considerable damage. It was repaired but was redesignated as a nonflight unit as a result.

After qualification testing of the Materials Processing in Space Experiment (M-512), several damaged parts were noted; i.e., connector broken loose, crystal growth container bent and mounting screws loose, vent tube and adapter bent, battery housing scuffed.

In another instance, the Extreme Ultraviolet Spectrograph (S-082B) monitor door aluminum filter was damaged while the door and filter were being bagged.

All of these instances occurred when the hardware was being moved or handled.

CAUSE: The cause of the above problems was attributed to the lack of adequate handling and/or transportation equipment and procedures.

CORRECTIVE ACTION: In each case a special handling and/or transportation fixture was devised which would preclude a recurrence of the above problems. Also, handling procedures were written as necessary.

RECOMMENDATIONS: In designing experiment hardware, special consideration should be given to how easily it may be damaged during handling and/or transporting it. If necessary, a special fixture should be designed to prevent dropping or mishandling of the hardware. Handling procedures should always be available and complied with.

TITLE:	Lubricant Failure Due to High Loading
DESCRIPTION:	During ATM testing, several X-ray Spectrographic Telescope (S-054) Camera magazines jammed.
CAUSE:	The design of the film advance assembly included a smooth, flat film flattener driven by a cam. The cam lubricant was overloaded because the film flattener was held to the platen by air pressure.
CORRECTIVE ACTION:	The film flattener was grooved to reduce the loading caused by the vacuum effect of a flat surface.
RECOMMENDATIONS:	All high-speed or intermittent-motion mechanisms should be evaluated by high-speed photography of the mechanism in operation.

SECTION D

PROCEDURAL

TITLE:	Camera Failure due to Contamination
DESCRIPTION:	The Extreme Ultraviolet Coronal Spectro-heliograph (S-082A) film camera was loaded with a full complement of film holders in preparation for vibration testing. During the camera compliance run, the camera failed to cycle on the 58th cycle.
CAUSE:	A metal chip became lodged between the camera rail and film holder retainer. Camera stoppage occurred when the metal chip prevented proper transfer of film holders at the shuttle.
CORRECTIVE ACTION:	The metal chip was removed and a detailed inspection for other metal chips and burrs was performed.
RECOMMENDATIONS:	Foreign material and contamination of various kinds has been a well known and continuing problem in the Space Program. Procedures should provide for a continual strong emphasis on maintaining proper levels of cleanliness, along with periodic retraining and orientation of people building and handling space flight hardware.

D2

TITLE:	Arcing due to Moisture
DESCRIPTION:	During ambient temperature checkout of the Microwave Radiometers (S-193), an arc-over was heard when power was applied to the altimeter. The arcing was located in the altimeter chassis well where the traveling wave tube (TWT) high voltage wires connect to the modulator assembly. Failure of a subassembly did not occur.
CAUSE:	Excessive condensation on the TWT high voltage leads and the chassis well had not been adequately dried out after low temperature test.
CORRECTIVE ACTION:	System was thoroughly dried and retested satisfactorily.
RECOMMENDATIONS:	Always inspect interior of unsealed components for moisture after low temperature tests.

TITLE:	Overstressing of Electrical Device
DESCRIPTION:	During testing of Infrared Spectrometer (S-191) Experiment, pulse code modulated (PCM) encoder clock signal output was missing. Output driver was found to be defective.
CAUSE:	Failure analysis indicated the device had failed due to overstress which was caused by electrical potential existing between equipment chassis and test equipment.
CORRECTIVE ACTION:	Equipment was properly grounded, and procedures were revised to require such grounding of all equipment.
RECOMMENDATION:	Assure that procedures provide for adequate bonding of chassis grounds of all equipment and test devices. Provide verification that such grounding has been accomplished.

TITLE:	Parts Degradation due to Overtesting
DESCRIPTION:	During functional acceptance testing of the Infrared Spectrometer (S-191) Experiment, there was a gradual degradation of cooling capability of the cryogenic cooler resulting in eventual failure to achieve required temperatures within the allowable time. This condition occurred with three different cooling assemblies.
CAUSE:	Problem was traced to a deformed O-ring which had become deformed by operating at excessive temperatures for too long a time. Problem was aggravated by contaminant of refrigerant gas due to outgassing of nonmetallic materials at high temperature.
CORRECTIVE ACTION:	Buna-N O-rings were replaced by Viton O-rings, coolers were baked out and purged with clean gas. Testing plan was revised to reflect a more realistic duty cycle to preclude overtesting at excessive temperatures.
RECOMMENDATION:	Care should be taken when specifying tests on hardware that the hardware will not wear out as a result of too much testing. Also, outgassing requirements should be strictly adhered to for space flight hardware.

D5

TITLE:	Incomplete Engineering Instructions
DESCRIPTION:	A number of "O" ring seal leaks were found during both qualification and acceptance testing of the Coronagraph Contamination Measurement Experiment (T-025).
CAUSE:	Leaks were caused by contamination and lack of "O" ring lubricant. This was the result of engineering error in omitting a drawing instruction for cleaning and lubricating the "O" rings and related surfaces.
CORRECTIVE ACTION:	Cleaning and lubricating instructions were added to the drawing and parts were reworked.
RECOMMENDATIONS:	Engineering drawings should be reviewed to assure all necessary instructions are included.

D6

TITLE:	Wrong Part Installed
DESCRIPTION:	Low voltage power supply failed to turn on during low temperature testing of the Microwave Radiometer (S-193).
CAUSE:	This failure was caused by an incorrect value resistor. The resistor was a 21,500 ohm resistor instead of the required 2,150 ohm resistor. A check of the parts list and module schematic showed no requirement for a 21,500 ohm resistor, therefore, it was determined that the incorrect value part had been installed. The part was clearly marked and measured within its required tolerance.
CORRECTIVE ACTION:	Resistor was replaced with one of correct value and test was run successfully.
RECOMMENDATIONS:	In-process inspection by qualified inspectors should be imposed upon the assembly line.

TITLE:	Inadequate Test Procedure
DESCRIPTION:	The system DC power control shut off and could not be turned back on during test of the Microwave Radiometer (S-193).
CAUSE:	A transistor in the high voltage power supply (HVPS) subassembly was shorted. An improper test method had been utilized during evaluation of an engineering design change. The standby/operate switch was rapidly switched back and forth subjecting the HVPS to repeated high current surges and excessive temperature buildup, resulting in transistor shorting.
CORRECTIVE ACTION:	The transistor which was shorted, another transistor and a diode which had been overstressed were replaced and unit re-tested properly. Personnel conducting the test were instructed in correct test methods, test procedure was revised, and the test panel was modified so that there is an automatic time-delay of 30 seconds between successive switchings.
RECOMMENDATIONS:	Use only experienced personnel for this type of testing, include caution notes in test instructions where applicable, and make use of safety devices where ever a chance of making a damaging error exists.

TITLE:	Procedure Specified Inadequate Measuring Device
DESCRIPTION:	During continuity checks of the Microwave Radiometer (S-193), ground isolation points A, B, E, and F were less than one megohm.
CAUSE:	The specified test meter had inadequate input impedance to measure high resistance values.
CORRECTIVE ACTION:	Procedure was revised to specify the use of an ohmmeter with high input impedance. Test was re-run satisfactorily with this instrument.
RECOMMENDATION:	All test and installation procedures should be reviewed prior to release to ensure that specified test equipment is adequate for the particular application.

SECTION E

HUMAN ERROR

TITLE:	Film Bunching in Camera
DESCRIPTION:	During functional testing of Infrared Spectrometer (S-191) Camera the camera light did not come on when switch was turned on indicating that film was not advancing correctly.
CAUSE:	The film was found to be bunching within the magazine cavity due to improper loading of the film into the magazine. It was determined that the film had been loaded by untrained personnel.
CORRECTIVE ACTION:	This was a nonflight magazine being used for test purposes; however, such a situation could arise on flight hardware. Test procedures were updated to include verification of proper loading by trained personnel prior to systems testing.
RECOMMENDATIONS:	Assurance should be provided that personnel who will load cameras have been trained in the proper procedures. Also, assurance should be provided for verification of proper loading of film by qualified personnel.

E2

TITLE:	Failure of Selected Resistors to Meet System Requirements
DESCRIPTION:	During functional acceptance testing of the Sleep Monitoring Experiment (M-133), the processor reading was out of limits. Trouble was isolated to two resistors in series which were on the high side of the tolerance limit.
CAUSE:	Resistors were selected using a bench power supply which did not have the same characteristics as the experiment power supply. This resulted in an incorrectly measured nominal value for the resistors. Procedure specifies use of experiment power supply for selecting resistors.
CORRECTIVE ACTION:	Hardware was reworked to requirements and personnel were notified of their error and instructed again to follow existing procedures.
RECOMMENDATIONS:	Assure that personnel performing such tasks are familiar with procedures to be used and verify that procedures are properly followed.

TITLE:	Battery Leaking Fluid
DESCRIPTION:	Batteries in two of the scientific experiments, Ultraviolet Stellar Astronomy (S-019) and Ultraviolet Airglow Horizon Photography (S-063) were found to be leaking fluid.
CAUSE:	Batteries had been left in the system for an extended period of time after being discharged which resulted in high internal pressure thus causing leakage of the electrolyte. This is a characteristic of Nickel-Cadmium (NICAD) batteries.
CORRECTIVE ACTION:	Batteries were removed and all fluid cleaned from hardware. Personnel were cautioned to remove batteries from system when not in use and to follow standard battery maintenance procedures for this type battery.
RECOMMENDATIONS:	When using this type battery assure that all users are aware of what can occur when discharged batteries are left in a system by providing proper operating and maintenance procedures and assuring that procedures are followed.

TITLE:	Incorrect Part Installed
DESCRIPTION:	A magazine assembly for the Dual X-ray Telescope (S-056) film camera was received which contained a clutch plate made of Delrin 505 material. Revision "B" to the drawing changed material to CRES-4PH material.
CAUSE:	Human error and incorrect storage procedures. Revision "A" parts had not been removed from stockroom and were mixed with Revision "B" parts. The technician picked up the wrong part.
CORRECTIVE ACTION:	Clutch plate was replaced with Revision "B" part; all Revision "A" clutch plates were removed from stock-room and the technician was cautioned to check parts removed from stock more carefully.
RECOMMENDATIONS:	Stockroom procedures and practices should be rigidly enforced to ensure that only the latest revision parts are retained in stock. Personnel should be trained to ensure that only the correct parts are checked out of the stockroom and used.

TITLE:	Non-flight Component in Flight Camera
DESCRIPTION:	Dual X-ray Telescope (S-056) camera shutter failed to close.
CAUSE:	A transistor in the motor drive assembly had failed. Investigation revealed that this motor drive assembly had undergone extensive development and qualification tests and was not of flight configuration. However, the motor drive box had not been identified as "non-flight."
CORRECTIVE ACTION:	A "flight" configured motor drive box assembly was installed in the camera and tested satisfactorily. The discrepant box was repaired with a new transistor and identified for "test only."
RECOMMENDATIONS:	Procedures should be implemented and rigidly enforced to clearly mark all "non-flight" considered hardware, and to properly identify and control all temporarily installed equipment.

E6

TITLE:	Contaminated Gasket
DESCRIPTION:	Gaskets on the Plant Growth Student Experiment (ED61) were required clean to a specified level. Magic marker pencil was used on silicone rubber which cannot be removed in cleaning operation.
CAUSE:	Cause of the problem was human error. Personnel were not aware that this type marking would not meet the specification.
CORRECTIVE ACTION:	Part was scrapped and personnel were notified.
RECOMMENDATIONS:	Personnel should be made sufficiently knowledgeable, through training and orientation, to prevent the inadvertent use of harmful materials for markings and identification. Also, appropriate means of identification should be provided to make this action unnecessary.

TITLE:	Damage Due to Inadequate Test Set-up
DESCRIPTION:	Antenna dish was damaged during electrical test of the Microwave Radiometer (S-193).
CAUSE:	Only one man was running the test. A necessary cabling change was made in the test set-up which reversed antenna travel. The antenna was operated from a remote location and as the antenna was unknowingly lowered, it hit the mount. The turntable had no mechanical stops.
CORRECTIVE ACTION:	Antenna was scrapped. Instructions were issued to operate the test set-up only with a two-man team who will verify direction and extent of turntable travel. Also mechanical stops were added to the turntable.
RECOMMENDATIONS:	Test Engineering and Safety should evaluate each operational test to determine how many people and what measures are necessary to ensure safe operations prior to actuating any system.

APPROVAL

RETENTION AND APPLICATION OF SKYLAB EXPERIMENT EXPERIENCES TO FUTURE PROGRAMS

By
Nancy Milly
and
Victor G. Gillespie

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

Eugene J. Brunauer

Deputy Chief, Quality and Reliability Engineering Division

Acting Director, Quality and Reliability Assurance Laboratory

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