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**MANNED SPACE PROGRAMS ACCIDENT/INCIDENT
SUMMARIES (1970 - 1971)**

**Cranston Research, Inc.
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16. Abstract This document is a compilation of 223 mishaps assembled from company and NASA records covering the Accident/Incident experience in 1970-71 in the Manned Space Flight Programs. It is the companion volume to NASA CR-120998 which covered the years 1963-1969. The objectives of this summary is to make available to Government agencies and industrial firms the lessons learned from these mishaps. Each accident/incident summary has been reviewed by description, cause and recommended preventive action. The summaries have been categorized by the following ten systems: Cryogenic; Electrical; Facility/GSE; Fuel and Propellant; Life Support; Ordnance; Pressure; Propulsion; Structural; and Transport/Handling.			
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PREFACE

The objectives of the NASA Aerospace Safety Research and Data Institute (ASRDI) are:

- (a) To support NASA, its contractors and the aerospace industry with technical information and consulting on safety problems.
- (b) To identify areas where safety problems and technology voids exist and to initiate research programs both in-house and on contract in these problem areas.
- (c) To author and compile state-of-the-art and summary publications in our areas of concern.
- (d) To establish and operate a Safety Data Bank.

In pursuing these objectives, ASRDI has assumed the responsibility for publishing two documents resulting from an effort initiated and supported by the NASA Headquarters Safety Office (DY).

The first of these documents is:

General Electric Co., Daytona Beach., Manned Space Programs Accidents/Incidents Summaries (1963-1969), March 1970, NASA, Director, Manned Space Flight Safety, NASW-410 (Safety Task), NASA-CR-120998.

This document is being reprinted to fill current needs.

The second of these documents is:

Cranston Research Inc., Manned Space Programs Accident/ Incident Summaries (1970-1971), April 1972, NASA Headquarters Safety Office, Charles W. Childs, Program Manager, NASW-2225, NASA-CR-120999.

This is the initial printing of this report.

Frank E. Belles
Director of Aerospace Safety
Research and Data Institute

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FOREWORD

This document has been compiled to update the Manned Space Programs accident/incident experience information presented in NASA Safety Program document, Manned Space Programs Accident/Incident Summaries, dated March 1970. It should be used in conjunction with the March 1970 document to obtain full visibility of the ways of preventing repetition of accidents/incidents in future programs.

The March 1970 document is based on accidents/incidents experienced in the calendar years 1963 through 1969. This document is based on accident/incident experience in the calendar years 1970 and 1971.

The statistical information in this document includes a restatement of the significant statistical information in the March 1970 Summaries for comparison with the new information; and an integration of the total information to provide statistical summaries covering some nine (9) years of Manned Space Program activities.

As with the March 1970 document, the compilation of this document was made possible through the understanding and support provided by management and safety personnel of NASA Headquarters, NASA Field Centers, and NASA contractors.



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PART I, INTRODUCTION

A. Purpose and Objective

This compilation of accident/incident information relative to space programs has been prepared as part of the NASA Manned Space Flight Safety Program. The basic documentation of this information is contained in NASA Safety Program Document, Manned Space Programs Accident/Incident Summaries, March 1970, on experience through the calendar years 1963-1969. This document is an update of the basic document to add accident/incident experience gained during calendar years 1970 and 1971. The objective of this compilation is to contribute to safety by making available to government agencies and industrial concerns the significant lessons learned from the accident/incident experience of Manned Space Flight Programs. No reference has been made in the summaries as to location, facilities, companies, organizations, products, programs, or individuals involved. The document has been prepared primarily for the use of management, supervisory, engineering, and safety personnel on space programs. For most effective use in future programs, the individual accidents/incidents recorded herein must be interpreted by program specialists for application to potential hazards of the particular program or systems involved. For the assistance of management in evaluating the potentially hazardous phases of a program, statistical summaries of cause factors and other significant

information pertaining to accident prevention in future programs has been provided.

B. Information Sources

The summaries contained herein were compiled from existing documentation of accidents or incidents on Manned Space Flight Programs. In compiling the basic document, approximately 10,000 case documents were reviewed, from which a total of 509 summaries was selected. Records reviewed included existing records of NASA Headquarters, NASA Field Centers concerned with space programs, and eighteen (18) contractors, associate contractors and subcontractors on space programs. In compiling the information for this document, over 5000 case documents were reviewed at NASA Headquarters, NASA field centers, and five (5) major contractors, resulting in the selection of an additional 223 summaries. No attempt was made to summarize anomalies which occurred during manned space flight missions. The majority of the accidents/incidents selected occurred during various phases of the Apollo Program with the remainder selected from other manned space programs.

C. Criteria Used

Each accident/incident summary contained in Part III has been summarized by description, cause and recommended preventive/corrective action. The criteria used for each of these summary segments are defined below:

1. Descriptions

Accidents/incidents were selected from records on the basis of the following criteria:

- a. An occurrence which reflected a significant lesson of importance to future programs.
- b. The occurrence involved space programs (flight vehicle systems, hardware or ground support equipment and facilities providing direct support to space programs).
- c. The occurrence resulted in personnel fatality/injury, and/or caused damage to program systems, hardware, GSE and facilities or resulted in a potentially hazardous condition.

The description for each accident/incident relates what happened; how it happened; the phase of the program activity involved; hardware, equipment and/or facilities damaged; personnel injuries and fatalities incurred or potential hazards created.

The description of what happened has included the event that caused the accident/incident to occur. For example, "a gage blew up and injured one person during development test of an engine, due to inadvertent cross connection of high and low pressure systems." Here, the first order cause factor was included as part of the description of what happened and permits concentration in the cause section on the second order of causes related to why it happened. This was done because

it is believed that too often cause factors have not been identified in sufficient depth to provide guidelines for management or supervisory corrective programs.

2. Causes

The causes identified in the "Cause" sections reflect the judgment of the reviewing teams based upon information provided in the accident/incident records. In many cases, the reports were supplemented by discussions with key people to more accurately identify cause factors. The second order cause factors considered were hardware or software deficiencies, as determined by the following criteria:

a. Hardware Deficiencies

- o Material Failure - Material failure as used in cause determinations was defined as any failure of materials or components in development tests at less than design specification or failure under operational conditions.
- o Design Deficiency - This cause factor was defined as any design specification inadequacy, resulting in deficient hardware which contributed to the occurrence of an accident/incident. Factors considered were omission of essential information, failure to specify safety devices or warnings, failure to determine stress/fatigue and other operational/interface factors, errors in material selection, or clerical errors in drawings and specifications.

- Materials Incompatibility - Materials incompatibility was defined as any cause in which incompatible materials were brought together through a design error, installation error, or procedural error.
 - Malfunctions - Malfunctions were defined as any anomaly where a system, subsystem or component failed to function as intended, resulting in conditions which contributed to accidents/incidents.
- b. Software Deficiencies
- Procedural - A procedural deficiency was defined as any case in which formal procedures contributed to accident/incident causes as a result of failure to prepare procedures, failure to follow procedures, deviations from procedures during a test, failure to coordinate concurrent tests, omissions of essential information in procedures, clerical errors in procedures, use of wrong procedures, or failure to update procedures.
 - Planning - A planning deficiency was defined as any case where the cause of an accident/incident was due to failure to properly plan prior to an event. Included in these considerations were lack of or inadequate test planning, failure to perform pre-operations hazard analysis, deficiencies in planning for transportation, handling and storage, and failure to determine necessary equipment and personnel resources for an operation.

- Work Control - Work control deficiency was defined as any condition contributing to an accident/incident during installation, maintenance, storage, cleaning, repair, and fabrication of systems. Factors considered as work control deficiencies were inadequate records, inadequate area control, failure to exercise proper control over materials, failure to properly mark and identify equipment and failure to define work requirements.
- Management/Supervisory - This cause factor was defined to include errors in decisions, policies, or directives which contributed to the occurrence of accident/incidents. Included was failure to perform management or supervisory responsibilities for planning; training and certifying personnel; and failure to perform personnel surveillance of critical activities.
- Training - This category was defined as any deficiency in workmanship or duty performance in which lack of training, briefing, certification or specific work instructions contributed to an accident/incident.
- Inspection - An inspection deficiency was defined as any condition contributing to an occurrence in which inspection was involved through failure to verify, failure to maintain inspection records or errors in inspection records.

3. Recommended Corrective/Preventive Action

In this part, an effort was made to reflect all recommendations included in the reports reviewed. In many cases, recommended corrective/preventive actions in individual reports were keyed solely to the one event, and not necessarily broadly applicable to other similar events. In those cases, the recommended corrective actions were evaluated and extrapolated for application generally to like systems on future programs. Also, since cause factors were considered in terms of hardware or software deficiencies, the recommended corrective/preventive action was generally oriented to these cause factors.

PART II, STATISTICAL SUMMARY

A. Approach

The statistical information presented in this document is designed to present graphically that information considered to be of value to management. The charts at the end of this Part show the distribution of accidents by system categories, cause factors and program activities. The information provided in these charts represents accident/incident statistical information over an approximate nine (9) year period. In each chart, a bar-graph is presented to show accident/incident experience over:

1. The 1963 through 1969 period (March 1970 Summary period)
2. The 1970 and 1971 period (update period)
3. The 1963 through 1971 period (total period)

B. Findings

By the method of display, management is provided with a basis for relating program events to accident/incident data for the time periods shown. Some of the more significant information shown in the charts is summarized below. Although the accidents/incidents in the 1970-71 period generally followed the same distribution as the 1963-69 period, there were some significant changes over the last two (2) years.

1. Distribution by Systems

Of the ten (10) system categories shown in Chart 1, Pressure Systems and Facility/Ground Support Equipment were the two

systems having the highest percentage involvement over the total period; although there was a significant decrease (23% to 9%) in Pressure Systems involvement, and a significant increase (18% to 35%) in Facility/Ground Support Systems involvement in the 1970-71 period. The percentage involvement over the total period for these systems were:

- a. Facility/Ground Support Systems 24%
- b. Pressure Systems 19%

Ordnance Systems continued to show the lowest involvement, with no recorded accident/incident in the 1970-71 period.

2. Distribution by Causes

The distribution of accidents/incidents by cause factors is shown in Chart 2. Software deficiencies were a greater contributor to accidents/incidents than Hardware deficiencies; and procedures, work control and inspection were the most significant Software cause factors.

a. Hardware Deficiencies

Hardware deficiencies were, for the most part, related to design deficiencies. The number of cases in which design deficiencies contributed to or caused accidents/incidents was significantly higher than those caused by material failures or malfunctions, although there was a significant decrease (37% to 17%) in design deficiency causes in the 1970-71 period. In 31% of the

732 cases, a design deficiency was identified, whereas only 5% of the cases involved material failure as a cause and only 6% involved malfunctions. Material failure causes increased (3% to 8%), and malfunction causes decreased (8% to 1%) in the 1970-71 period. Cases involving malfunctions occurred mostly during operational tests and manufacturing checkout. Likewise, the number of cases where material incompatibility contributed to the cause of accidents/incidents was relatively small, only 3% of the 732 cases; however, some very serious accidents occurred as a result of this factor.

b. Software Deficiencies

The number of cases involving procedural deficiencies was significantly high and constituted the single largest contributor to accidents/incidents causes with 49% of the 732 cases. Likewise, the number of related work control deficiencies was quite high. This area was a very significant factor in accident/incident causes and constituted the second largest contributor with 38% of the 732 cases.

Management or supervisory deficiencies were involved in 7% of the 732 cases. Six percent (6%) of the cases involved planning deficiencies and 9% of the accidents/incidents involved training deficiencies. In many

cases, training deficiencies pertained to inadequate knowledge of the total operation. Individuals were not well enough informed of other work going on concurrently and/or what the previous shift had done as shown by the fact that 3% of the accidents/incidents involved failure to transfer essential information during shift changes. Although inspection deficiencies were not the primary cause of accidents/incidents, inspection was a major contributing factor since many accidents/incidents could have been prevented had there been sufficient and timely inspection and verification. For example, in 3% of the cases, there were cross connections of lines or cables which could have been prevented by inspection. Twenty-three percent (23%) of the accidents/incidents involved inspection deficiencies.

3. Distribution by Program Activity

As records were reviewed, the accidents/incidents were identified to a program activity. The results of this compilation are shown in Chart 3. As shown in the chart, more of the 732 accidents/incidents occurred during operational test and checkout than in any other program activity, accounting for 45% of the total. Manufacturing was also a significant source of accidents/incidents, with 34% of the cases occurring during this activity.

4. Distribution by Accidents vs. Incidents

The distribution of accidents/incidents was based on NHB 1700.1 definitions (Type A, Type B, Incident) and the identifications in the case documents reviewed. The distributions are:

<u>Period</u>	<u>Accidents</u>	<u>Incidents</u>
1963-1969	17%	83%
1970-1971	13%	87%
1963-1971	16%	84%

5. Distribution by Work Shift

The statistical summary of accidents/incidents by work shifts revealed a rather direct relationship to the level of activity or the number of people involved in each shift. With most of the work done on the day shift, as would be expected, the majority of cases occurred on the first shift. Although risks may have been higher, per level of activity, on second and third shifts, data was not available to make this correlation. Distribution of cases by shift was as follows:

<u>Period</u>	<u>First Shift</u>	<u>Second Shift</u>	<u>Third Shift</u>
1963-1969	65%	26%	9%
1970-1971	81%	12%	7%
1963-1971	70%	22%	8%

6. Distribution by Calendar Quarters

The seasonal distribution of accidents/incidents by calendar quarters was compiled as follows:

	<u>1963-69</u>	<u>1970-71</u>	<u>1963-71</u>
First Quarter (Jan., Feb., Mar.)	29%	30%	29%
Second Quarter (April, May, June)	24%	24%	24%
Third Quarter (July, Aug., Sept.)	27%	22%	25%
Fourth Quarter (Oct., Nov., Dec.)	20%	24%	21%

This distribution could not be correlated to any particular factor, and the variation in distribution was not enough to be significant.

7. Injuries/Fatalities/Damage

Records compiled on percentage of accidents/incidents which involved injuries, fatalities, or damage showed the following:

	% OF THE TOTAL		
	<u>1963-69</u>	<u>1970-71</u>	<u>1963-71</u>
Injuries	15%	20%	17%
Fatalities	1%	< 1%	1%
Damage (hardware, facilities, equipment)	68%	66%	67%

In a number of the cases, personnel injury or fatality, as well as damage, occurred. A number of incidents were included in the summaries where there were no injuries, fatalities, or damage, but the incident created a high hazard potential. For

these reasons, the percentages shown do not cumulatively represent all the accidents/incidents summarized.

8. Human Error

Separate emphasis was not given to human error in identifying cause factors unless it was apparent in a report, because human error would be present to some degree in most unplanned events. Emphasis was placed, however, upon determining what caused or contributed to the human error and, as the accident/incident records were reviewed, a notation was made as to whether or not human error was directly involved in the cause of the accident. Based upon a simple yes or no determination of direct or indirect human error involvement, the following percentages of cases involved human error as a factor to the cause of accidents/incidents. The majority of these cases involved second-order causes. Human error involvement could probably have been identified in the remainder of the cases had more information been available:

1963-69	74%
1970-71	72%
1963-71	73%

The following percentages of cases, where an individual act of carelessness or irresponsibility at the time of the occurrence was the only cause, were identified:

1963-69	< 1%
1970-71	9%
1963-71	~ 3%

In practically all the cases there were indications that management and supervisory deficiencies were indirectly involved in accident/incident causes even though deficiencies were not specifically identified in the reports and documents reviewed.

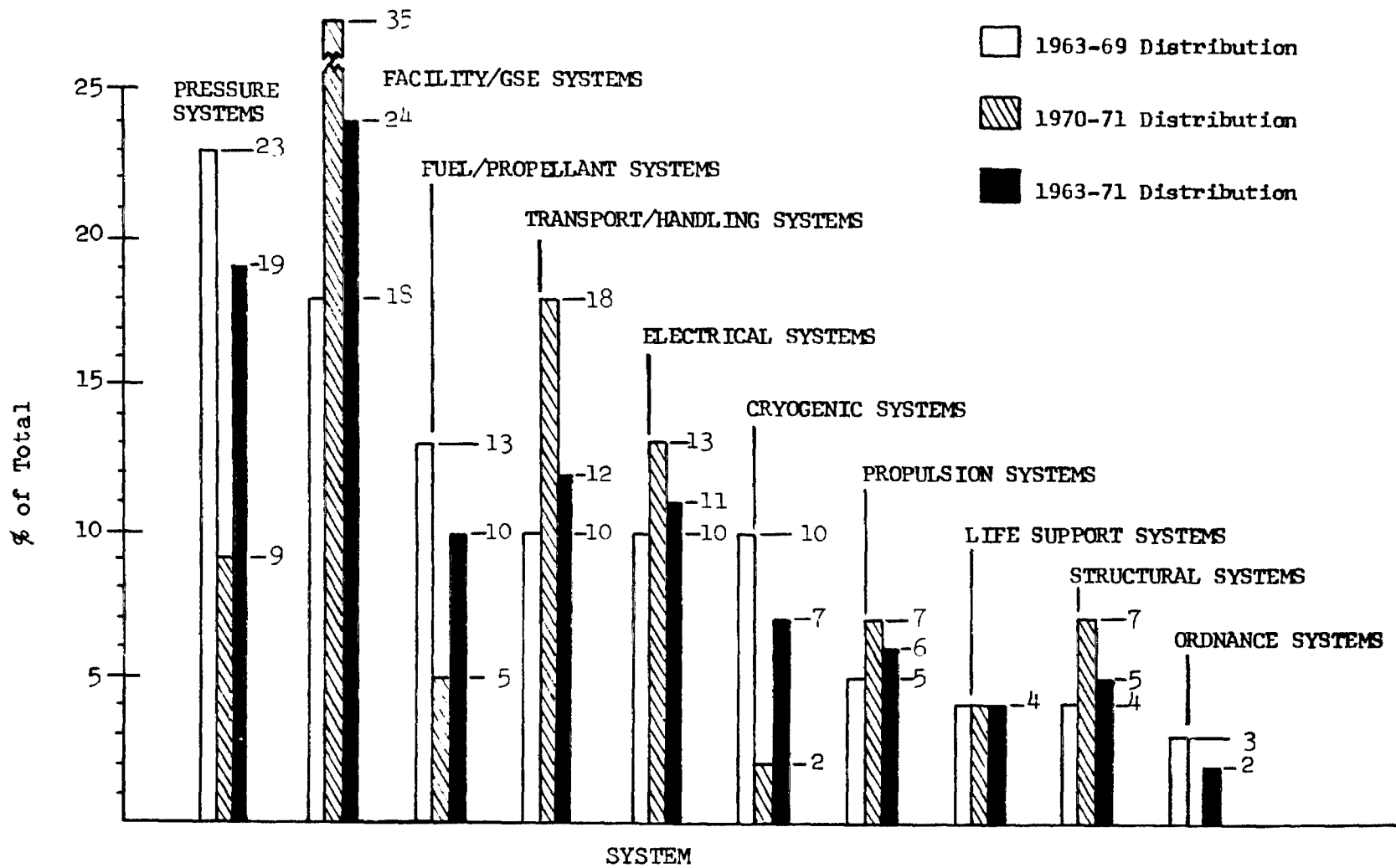


CHART 1 - DISTRIBUTION OF ACCIDENT/INCIDENTS BY SYSTEM

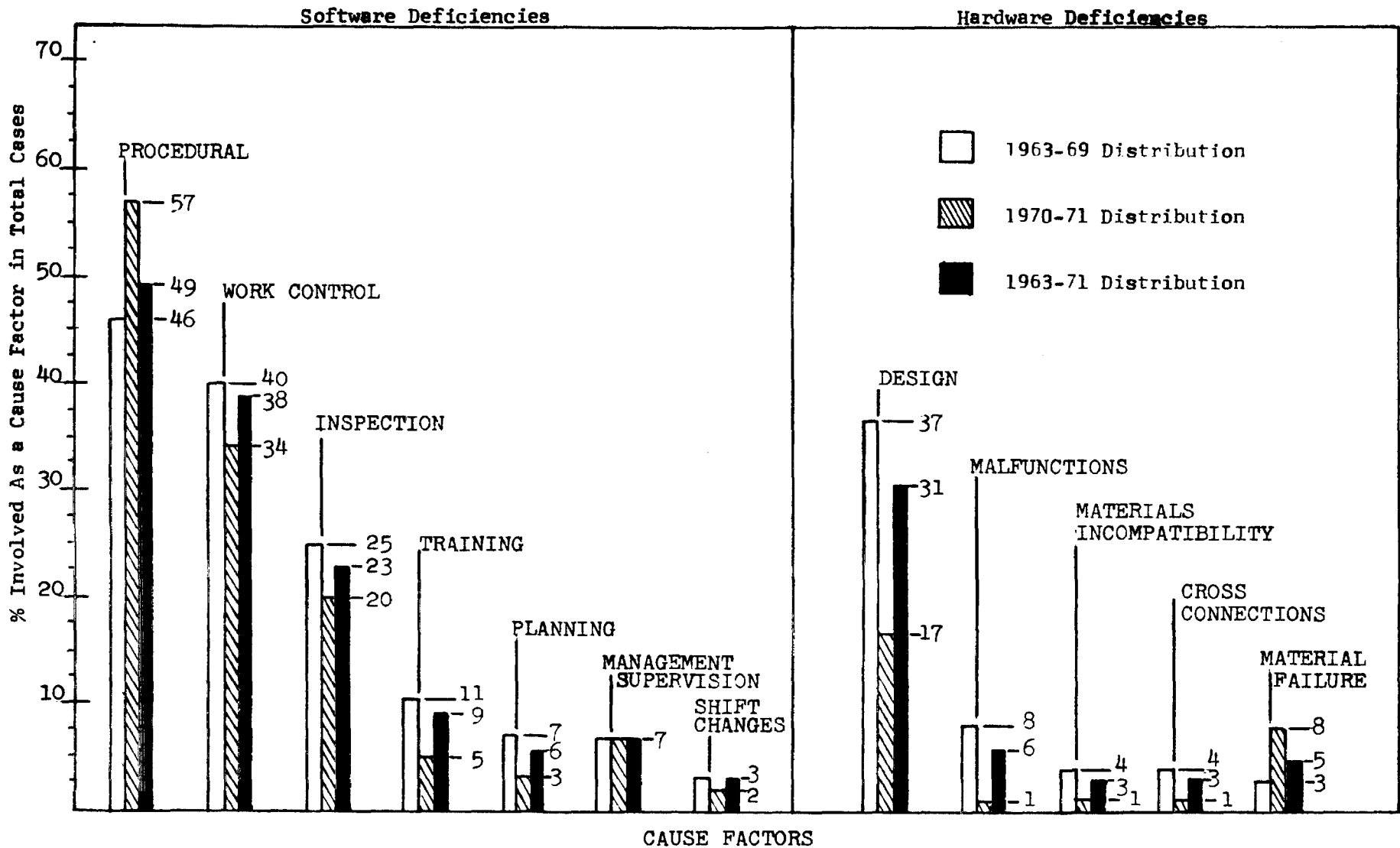
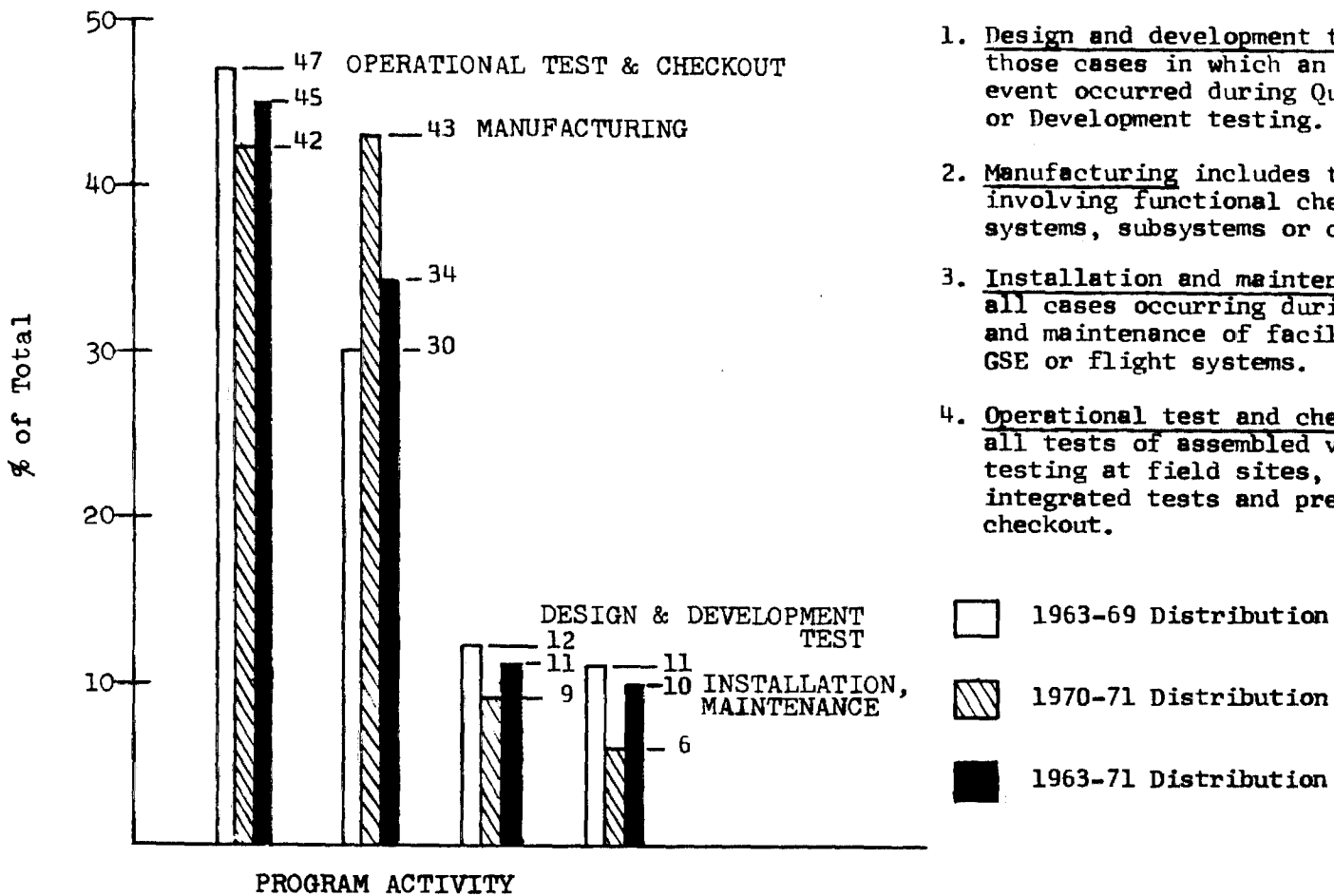


CHART 2 - DISTRIBUTION OF ACCIDENT/INCIDENTS BY CAUSES

Note: Several Cause Factors Could Be Involved in the Same Accident/Incident



NOTES:

1. Design and development tests are those cases in which an unplanned event occurred during Qualification or Development testing.
2. Manufacturing includes those cases involving functional checkout of systems, subsystems or components.
3. Installation and maintenance includes all cases occurring during installation and maintenance of facilities, systems, GSE or flight systems.
4. Operational test and checkout includes all tests of assembled vehicles and all testing at field sites, including integrated tests and pre-launch checkout.

CHART 3 - DISTRIBUTION OF ACCIDENT/INCIDENT BY PROGRAM ACTIVITY

**SECTION I
CRYOGENIC SYSTEMS**

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
50. During LOX tanking from barge-mounted storage tanks, the replenish pump on the barge caught fire internally and exploded, resulting in a fire and damage to the barge and adjacent barge and dock area.	Failure of monitoring personnel to note and report abnormally low pump radial bearing temperature. Contributing were material failure in that the pump shaft thrust bearing failed due to an oil seal leak at 50 psi pressure; and inadequate design in having no automatic signal to warn of abnormal pump conditions.	Designate all LOX handling operations as hazardous and require training and certification of all personnel. Require use of welded stainless steel oil seals rated at 150 psi for LOX pump applications. Require all LOX-handling equipment monitoring instrumentation to provide automatic warning of abnormal operating temperatures.
51. During planned LOX discharge from a storage tank into a drainage ditch three automobiles in the area caught fire and were destroyed. One driver narrowly escaped severe injury.	Personnel error in that employees who were handling the road block operations, during the LOX discharge, drove autos into an area where LOX vapor clouds were present. Contributing were inadequate controls and procedures governing movement or activity in areas where LOX vapor clouds can be anticipated.	Designate LOX discharge operations as hazardous and require safety inspection and approval prior to any discharge. Ensure the placement of area caution and warning devices prior to LOX discharge operations and/or institute positive traffic control procedures around LOX discharge areas.

SECTION I
CRYOGENIC SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
52. While a H ₂ sample was being prepared for analysis one of two cryogenic sample bottle discs ruptured and the gas ignited, injuring one employee.	A material deficiency in that the disc was extensively corroded and failed under working gas pressure. Contributing causes were inadequate quality control which failed to detect the corroded disc, and a test set-up which aimed the disc end of the bottle toward technicians.	Ensure periodic inspection and certification of all cryogenic sample bottles. Ensure that test equipment configurations provide adequate protection to personnel from hazards of pressurized sample bottles.
53. During manufacture check-out of a spacecraft cryogenic shelf, metallic chips were detected in the cryogenic disconnect and in the ground half pressure operated disconnect (POD) of tank 2 vent line. Chips also were found in tank 1.	Inadequate work control in that cryogenic vent lines were not properly cleaned after trimming as required. Contributing was QC failure to detect the contaminated parts.	Ensure that personnel are trained and certified for their job. Require strict QC during each step of the cryogenic system assembly and installation.

SECTION II
ELECTRICAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
52. During operational testing and checkout of a spacecraft vacuum pump electrical unit, 28 volt circuitry was subjected to 115 volt main supply due to cross connections and sustained irreparable damage to several circuit components.	Inadequate quality control during manufacture of the unit in that the wiring harness of the unit had been erroneously assembled and permitted 115 volts supply to flow into circuits designed to accept only 28 volts.	Require development and use of circuits continuity checkout procedures for post-assembly verification of electrical units. Ensure that such procedures receive review and concurrence by competent engineering authority.
53. While a set of nickle-cadmium batteries was undergoing trickle charge in the course of a charge-discharge cycle, one of the cells shorted, overheated and caught fire.	Deficient battery conditioning procedures in that the charge-discharge cycles used were too severe for the batteries being employed.	Designate battery conditioning operations as hazardous. Require safety review/analysis of conditioning procedures to ensure procedures compatibility with the batteries being processed.

SECTION II
ELECTRICAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
54. During a training flight, a space flight training vehicle lost its primary electrical system and crashed when the attitude control system (ACS) failed. The vehicle was destroyed and the pilot received minor injuries during ejection.	A design deficiency in that the ACS could not be switched from primary to emergency electrical power with the engine at flight RPM. Contributing causes were inadequate check-out procedures which failed to verify emergency switchover functions at engine flight RPM, and the need for multiple relays to operate simultaneously to switch in emergency ACS.	During design of complex flight systems ensure that hazard analyses are performed on all electrical circuits controlling switch over from one system to another to determine integrity of relays under all power settings. Require all flight control systems to be tested and certified for actual flight conditions.
55. While performing PM on an electric main breaker panel, a workman using a wire brush to clean inside the panel made contact with energized stabs, receiving second and third degree burns.	Failure to follow required procedures in that the panel was not de-energized prior to beginning maintenance operations. Contributing was the use of improper equipment; wire brushes were prohibited for cleaning electrical system components. Also, inadequate training in that the workman incorrectly used a test instrument to verify the panel was de-energized.	Ensure positive verification of circuit deactivation prior to allowing electrical work. Ensure that all tools used with electrical consoles are non-conductive or are specifically certified for use. Require training of all personnel assigned to work on electrical systems.

SECTION II
ELECTRICAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
56. During a manufacturing checkout of a spacecraft module caution-and-warning system power supply unit, a signal input lead was disconnected from the test oscilloscope, as part of the test sequence, and was accidentally grounded, causing an arc and burning the C&W power supply.	Test set-up design deficiency in that the test lead between the oscilloscope and the power supply unit contained no over-current protective devices. Contributing was personnel error in that the oscilloscope was connected with its chassis ungrounded and electrically "hot"; and procedural deficiency since no detailed circuit hook up instructions were provided the technicians performing the work.	Require that circuit-protective current-limiting devices be installed in test leads used on spacecraft electrical systems. Ensure that technicians used to test flight systems are trained and certified for the work. Require the use of formal procedures and checklists with QC verification in making test set-ups.
57. During assembly electrical insulation resistance test of cables installed on a flight unit, a power supply and two control accelerometers were severely damaged due to the application of reverse polarity.	Inadequate procedures in that the inspection verification of the set-up configuration prior to test was incomplete. Contributing was human error in misreading test set-up engineering drawings during test set-up.	Require formal QC inspection verification of test configurations prior to initiating test of critical components.

SECTION II
ELECTRICAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
58. During assembly cell-matching sequence test on a number of flight batteries, a battery cell explosion occurred, due to excessive internal pressure generated by major cell overcharge/over-temperature, resulting in minor damage to test equipment and the test facility, and destruction of the battery.	Deficient test assembly procedures in that verification of the proper test set-up was not made prior to test initiation. An installation error in assembling the test set-up was made which inhibited automatic test shut down when battery over-temperature was encountered. Contributing cause was failure to communicate test information (over-temperature conditions) during shift change.	Require QC inspection and verification of proper test configuration prior to initiation of cell sequencing tests. Establish procedures/checklists for transfer of essential test information at shift changes.
59. During battery charging in a launch operations battery shop, a battery cell overheated and ruptured destroying the battery.	Inadequate inspection procedures in that a weak cell had gone undetected, and it overheated at standard charge rate.	Require inspection and test of battery cells for cell condition before starting charging cycle.
60. During manufacturing assembly of an electrical wiring harness for a spacecraft, the harness cover pressed a deep indentation into a wire bundle cover, necessitating replacement of the bundle cover.	Inadequate work control in that there was improper storage of wire harness when the harness cover was installed.	Ensure that procedures for electrical harness cable assembly include a cautionary note to verify proper storage of wire harness before installing cover.

SECTION II
ELECTRICAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
61. During nickle cadmium battery conditioning at a test facility, a cell overheated resulting in emission of smoke and fumes and necessitating area evacuation. The battery had to be replaced.	Material failure in that the battery failed internally while under normal charge conditions.	Designate battery conditioning areas and operations as hazardous and ensure that all area personnel are instructed in emergency evacuation procedures.
62. During manufacturing checkout of an O_2/H_2 burner sparks system, a short occurred on one burner spark circuit, resulting in excessive current to the circuit and burnout of the spark exciter and ancillary circuitry.	Personnel error in that the connector to the spark exciter had been assembled with a misaligned pin, which shorted to the connector shell; and inadequate monitoring of meter panels in the test control center during the trial run.	Require QC certification after assembly or installation of electrical components or flight hardware circuitry. Establish procedures for megger- pre-testing high voltage circuit sections for potential grounding. Assure that control center monitoring procedures during test runs are adequate. Where possible, equip safety critical or operationally critical meters with overcurrent alarms.

SECTION II
ELECTRICAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
63. During manufacturing assembly of a spacecraft, an engine gimbal electrical switch toggle was broken off its panel due to an unknown impact.	Inadequate assembly procedures in that protective covers for the switch toggles were not provided.	Require use of protective covers/caps for flight electrical equipment during assembly to avoid inadvertent damage.
64. During certification testing of a power supply unit, the unit and a launch vehicle data adapter being used in the test were damaged due to an electrical fault.	Failure to follow required procedures in that test set-up cables were modified to accommodate test conditions without engineering approval and without inspection, resulting in misconnection of test power.	Require that all modifications of test set-up configurations and test procedures which involve critical hardware be approved by competent engineering authority. Require QC inspection of approved test equipment changes prior to testing.
65. During acceptance testing of a command decoder unit, the unit was damaged when it was electrically shorted between terminals of a digital voltmeter being used to conduct the test.	Inadequate test procedures in that the shorting link between the voltmeter terminals was not removed prior to proceeding with the test.	Require formal procedures and checklists to verify proper test set-up conditions prior to beginning test. Conduct hazard analyses of test procedures to identify and prevent potentially hazardous events.

SECTION II
ELECTRICAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
66. During vibration testing of a launch vehicle digital computer (LVDC), the LVDC was excessively vibrated due to incorrect mounting location of a test control accelerometer, resulting in damage to the LVDC.	Deficient design of test set-up in that the mounting location of the control accelerometer on the test fixture was not identified with any markings or reference designation, and there was an additional unmarked and unused mounting hole on the fixture.	Designate vibration testing of flight equipment as safety critical. Ensure that set-up drawings provide positive identification of mounting location of test hardware. Require QC inspection and approval of test configurations prior to test.
67. While spacecraft systems were being tested in an assembly and checkout facility, output voltage on the 28 VDC test power supply rose to approximately 50 VDC, subjecting the spacecraft MN bus A and B to a voltage level of approximately 45 VDC for 43 seconds.	Random material failure, since a transistor in the power supply regulator circuitry failed. Contributing was the lack of over-voltage sensing and protecting circuitry which would shut down the power supply in the event of an over-voltage condition.	Provide over-voltage sensors in electrical test set-ups which will cause the output of the power supply to be interrupted if the output voltage reaches established limits at any time.

SECTION II
ELECTRICAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
68. A technician crawled under a cathode ray tube unit at a test facility to perform routine adjustments with the power on and his shoulder came into contact with a 14 KV terminal and received an electrical shock.	Personnel error in not shutting off power prior to work. Contributing were lack of procedures for specifying conditions for work performance and a design deficiency in that adjustment controls were not easily accessible.	Ensure that for all high capacity electrical units, procedures are established specifying safety requirements for maintenance and operation. Ensure that adjustment controls are placed in accessible locations.
69. During work on a 28V power supply a technician's metal watch band shorted out against an electrical terminal and burned his wrist.	Personnel error in wearing a metal watch band while working on an energized circuit.	Ensure that personnel working on energized circuits do not wear metal watch bands, bracelets or other objects which can inadvertently come into contact with power sources. Ensure that hazards and safety precautions in working on energized circuits are adequately covered in training courses.

SECTION II
ELECTRICAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
70. While doing work in an ordnance storage facility a workman plugged a portable power saw into an extension cord and received minor electrical burns when severe arcing occurred.	Personnel error in that the workman failed to inspect and maintain his equipment properly, since a set screw was missing from the male plug, causing a short circuit and arcing.	Ensure that procedures provide for inspection of electrical plugs and connections prior to issue and use of electrical hand tools. Require safety certification of electrical hand tools to be used in ordnance and flammable material storage areas.
71. During test operations at a test facility a power supply panel being inserted into a panel rack on a test set contacted a 110VAC circuit breaker terminal in an adjacent panel and sustained minor arc damage. Circuit breaker action prevented major damage.	Improper handling in which the technicians allowed the panel to tip out of position. Contributing was procedural in that rack power was not switched off prior to initiation of installation work.	Ensure that electronic technicians are trained in proper equipment handling procedures and certified for their job. Ensure that work procedures specify turning off rack electrical power prior to inserting additional units in panel racks.

SECTION II
ELECTRICAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
72. During an electrical "trouble" test in a test support facility, a technician received electrical burns on both hands while handling a 480V, 3 phase cable and receptacle.	Material failure in that the receptacle had an electrical short.	Require low voltage continuity check of high voltage cables/receptacles prior to applying load during maintenance or "trouble" testing.
73. During routine on-site maintenance a technician was blowing corrosion from the top of a bank of electrical storage batteries with an air hose when the air stream entered a battery wall via a vent and blew caustic alkaline solution into his eyes.	Inadequate maintenance procedures. The technician had to use unregulated air of 60 psi which created sufficient internal pressure in the battery to spray the solution out. Contributing was personnel error in that the technician was not wearing eye protection equipment.	Forbid the use of air over 15 psi pressure for battery corrosion cleaning. Supply pressure regulators for all air hoses used in battery maintenance operations. Ensure that eye protection equipment is available and its use enforced at field sites as well as in shops.

SECTION II
ELECTRICAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
74. Seventeen of 27 nickel-cadmium batteries in an unattended emergency lighting cabinet in a facility mechanical equipment room were ruptured, due to internal overpressure or externally ignited hydrogen explosion, resulting in blowing the door off the cabinet and strewing pieces of plastic cell case over the facility floor. It was evident that an explosion of considerable magnitude had occurred without smoke or soot deposits.	The exact cause of the explosion is unknown. Probable cause was inadequate maintenance procedures/techniques which allowed a contaminated electrolyte chemical reaction to plug battery vent caps, permitting a hydrogen pressure build-up. Another possible cause was deficient operating procedures which failed to recognize the possibility of an accumulation of hydrogen gas in a confined area which could be ignited by a spark.	Ensure that facility maintenance personnel are instructed in the procedures/techniques necessary to prevent contamination of battery electrolyte in emergency lighting systems. Require inspection of battery vent caps for plugging at each service interval. Require positive circulation of ambient air around battery areas in facility emergency lighting systems.

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ELECTRICAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
75. In a test laboratory, the wet cell battery of a wall mounted emergency light exploded, sending a spray of acid into a hallway, which at the time contained no people. No injuries.	Maintenance had inadvertently replaced vented battery caps with a non-vented type. During automatic "trickle charge" the battery could not vent the hydrogen produced and exploded.	Ensure that maintenance procedures for wet cell batteries preclude inadvertent substitution of non-vented caps. Ensure that personnel handling servicing and maintenance of wet cell batteries are trained.
76. During normal operations of an environmental simulation laboratory, outdoor switchgear circuits triggered an explosion in their enclosure, resulting in extensive damage to the switch gear, transformer and electrical cables.	Defective electrical cables provided an ignition source and triggered explosion of unexplained accumulation of gas in the area. Contributing was inadequate inspection of electric cables and lack of a hazard analysis to determine potential gas accumulation in the system.	Ensure that a hazard analysis is performed on any enclosed electrical control system for the possibility of gas accumulations. Establish preventive maintenance and inspection procedures for checking condition of electrical power cables in switch gear installations.

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ELECTRICAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
77. During operation of an electric bridge crane at a vehicle stage manufacturing facility, an electrical fire occurred at the plug-in unit serving the crane causing minor damage to the unit.	Malfunction. Inadequate contact of spring loaded plug pins with plug-in unit bus bar caused over-heating and fire. Four over-current protective devices failed to operate. Contributing were maintenance policies which did not call for periodic inspection/adjustment of contact mechanisms or over-current protective devices.	Establish maintenance and calibration/inspection schedules for electrical plug-in units and over-current protective devices used on equipment handling end item hardware. Ensure that maintenance schedules require checking the adjustment of electrical contact points and the time current characteristics of over-current protective devices.
78. During routine maintenance in a test laboratory, a technician attempted to close a circuit breaker, the "bat" handle of which had broken off, by inserting the tip of a ball point pen into a hole in the remaining portion of handle for leverage. When the circuit breaker closed, a flash occurred and the ball point pen disintegrated.	Inadequate laboratory operation/maintenance procedures in that the defective switch handle had not been "red-tagged" to prevent operation. Contributing was personnel error in that the technician attempted to manipulate defective electrical hardware.	Ensure that laboratory operating/maintenance procedures provide for timely "red-tagging" and reporting of defective laboratory electrical equipment, and prohibit use/operation of such hardware until repair is made.

SECTION II
ELECTRICAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
79. During routine facility maintenance of an automatic charger battery system, 6 of 27 nickel-cadmium batteries being reinstalled exploded, resulting in mild chemical burns to two workmen.	Inadequate work procedures in that a probable cause was ignition of accumulated hydrogen gas by a spark generated during the replacement work, and inadequate ventilation of the battery area; a second probable cause was stopped up vent caps, resulting from contaminated electrolyte, which permitted hydrogen pressure build-up to an explosive force in the 6 batteries.	Require positive circulation of ambient air around battery areas during maintenance/servicing of batteries. Require verification of battery vent cap openings prior to initiating maintenance/servicing in battery areas. Ensure that maintenance personnel are adequately instructed in the procedures necessary to prevent contamination of battery electrolyte.

SECTION III
FACILITY/GSE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
95. During inspection of facilities' fire detection systems at a NASA center, several "fixed temperature/rate of rise" fire detectors were found defective in the "rate of rise" mode.	Material failure because a crack or other defect in the detector pressure tight dome prevents necessary pressure build-up from heat exposure which activates the alarm.	Establish periodic "inspection and replacement" schedules for automatic fire detection equipment at all facilities.
96. During welding operations of a launch facility structure on the upper level, slag fell to a lower level, striking a workman. No injury resulted, although the potential for such was present.	Failure to exercise reasonable safety precautions, in that protective devices were not used.	Designate all welding operations on launch facility structure as hazardous and require safety inspection prior to commencing operations. Enforce use of protective measures to control sparks, spatter, and dripping slag during welding operations.

SECTION III
FACILITY/GSE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
97. While undergoing contingency crew fire training under live fire conditions, 3 men received minor injuries when the portable extinguishers used malfunctioned and the trainees panicked and ran from the training area.	Failure to properly inspect and maintain extinguishers, since chemicals had formed and lodged in discharge hose, making extinguishers inoperative. Contributing were failure to familiarize trainees with escape routes prior to beginning operations and the use of a fire much larger than needed on a windy day.	Require formal procedures, for cleaning, inspection and maintenance of extinguishers, including inspection for blocked discharge hoses. Require "dry-run" of trainees prior to exposure to simulated fire fighting conditions. Ensure that wind factors are considered when determining size of training fire to be used.
98. During heat curing of materials in a 500° F. rated environmental chamber, the materials were decomposed and the chamber damaged due to an excessive rise (to approximately 1000° F.) in chamber temperature.	Failure to follow approved procedures in that the temperature sensing and control system was improperly set when the chamber was readied for operations. Contributing were a material failure and a design deficiency; a chamber pressure bleed line had failed and the chamber temperature control system was so designed that it was dependent on proper operation of the chamber pressure system to provide over-temperature shutdown.	Require the use of formal procedures and checklists in preparing test chambers for operation. Ensure that test chamber temperature sensing and control systems are independent of the proper operation of other systems, or provide fail-safe features.

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FACILITY/GSE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
99. Approximately ten minutes after a welding crew at a test site construction operation had quit work for the day, a fire occurred as a result of hot slag wedged between a scaffold board and tarpaulin wind break.	Inadequate work control procedures in that an asbestos fire blanket was not in place during the welding operations. Contributing was failure to inspect work area prior to leaving.	Ensure that work control procedures enforce use of barriers/asbestos blankets during welding operations; require at least a one hour fire watch following end of welding operations.
100. During inspection and recovery of a sample in an X-ray spectrometer, a trained and qualified technician bypassed the safety interlocks and removed a shield to recover a spilled sample and was exposed to X-ray radiation.	Failure to follow established procedures for handling samples in the spectrometer. Contributing were a design deficiency in that the spectrometer lacked adequate positive safety interlocks to ensure de-activation of the x-ray high voltage power source when the shield was removed, and a lack of hazardous condition warning devices.	Require that all x-ray spectrometry be designated as hazardous. Provide safety interlocks that will turn off the x-ray power supply when the shield is removed. Ensure that all areas where x-ray equipment is being used are designated and placarded as hazardous.

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FACILITY/GSE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
101. While cutting a steel plate near an unused LN ₂ tank, during manufacturing operations, sparks from the cutting torch fell on the tank insulation causing it to ignite and resulting in a small fire.	Inadequate work control and failure to follow established procedures and safety precautions, in that operation was started without required approval of supervision and fire department verification.	Designate all welding operations around LN ₂ tanks as hazardous. Require safety/fire department inspection and verification before welding starts. Require use of protective shields or blanketing.
102. During the proof load-testing of a manufacturer's 10 ton bridge crane, a control panel door loosened and fell 40 ft. to the floor.	Inadequate inspection/maintenance procedures in that the holes for #4 counter sunk screws had enlarged and could no longer hold the door hinge in place.	Require maintenance inspection of counter sunk screws and screw holes for looseness or wear on overhead handling equipment being used with critical program hardware. Where possible, replace screws with bolts and lock nuts.
103. While moving a workstand being used during the assembly and checkout of a flight module, a handrail struck an antenna guard cover on an adjacent module causing minor damage to the cover.	Inadequate work control which permitted moving the work stand without assistance and assurance that proper clearance from flight hardware articles could be maintained.	Require the use of at least one observer to verify clearances during movement of workstands in program manufacturing/assembly areas.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
104. During manufacturing welding operations on an engine instrumentation line, a high frequency arc punched through the insulation of the welding head cable and burned a hole approximately 3/16 inch in diameter in the engine cross-over duct bellows.	Inadequate pre-welding inspection procedures, since inspection of the failed cable suggests several strands were cut or broken prior to initiation of the arc. Contributing was personnel failure to maintain required cable clearances from conductive surfaces.	Require pre-welding QC inspection and certification of electric arc welding cables prior to use on program essential equipment. Inspect for unacceptable insulation cuts, knicks and abrasions; prevent welding cables from touching conductive surfaces during welding. Ensure that welding personnel are trained and certified for safe conduct of the work.
105. During maintenance of a space engine manufacturing facility air conditioning unit, a solenoid valve blew up while being sweated off a unit freon line, causing minor injury to two workmen.	Personnel error. The freon line had not been cut, as required, to relieve gas pressure prior to applying heat.	Designate all welding, torch cutting and heat sweating operations on essential facility air-conditioning or refrigerating equipment as hazardous and require training and certification of workmen for their job. Require use of checklist procedures when such work is performed in vicinity of flight hardware.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
106. During a manufacturing functional check of the ladder/catwalk assembly for horizontal tank interior operations, the winch which deploys and stows the assembly failed, allowing the assembly to drop uncontrollably to its deployed position. Damage consisted of broken cables and fittings on the assembly. There were no injuries.	Inadequate tool inspection/maintenance procedures in that the manually operated winch, which had a malfunctioning safety lock and a loose drive handle, had not been removed from service. Contributing was inadequate work procedures which allowed use of defective equipment.	Require periodic (at least monthly) maintenance inspection of handling gear in manufacturing/assembly areas. Ensure that manufacturing/assembly area operating procedures require "red-tagging" of deficient handling gear, and removal from service until repair is made.
107. While a spacecraft was mounted on a workstand during parts installation a VHF in-flight antenna was damaged in an unknown manner several hours after having been installed.	Inadequate work control in that there was failure to use available antenna protective devices.	Ensure that area work procedures require installation of flight hardware protective devices during assembly operations, when they will not interfere with current work. Require formal QC inspection and verification of their installation.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
108. During first stage engine boost test of a space-craft test article, the vehicle was damaged due to failure of a bolt in a load adapter. Failure occurred at approximately 139% of a scheduled maximum load of 140%.	Inadequate work control in assembly of the test set-up in that the failed bolt had been overstressed in a previous unrelated test and was incorrect size for the boost test.	Establish supervisory/QC controls to prohibit reuse of test set-up hardware unacceptably damaged or overstressed during previous tests. Require QC inspection and buy-off of test set-up assemblies for conformance to test set-up drawings prior to initiation of test on program essential equipment.
109. During preparations to introduce a powdered chlorine compound (HTH) into drinking fountain drains, in an assembly and checkout facility, the compound ignited, releasing dense clouds of chlorine gas until extinguished with a CO ² fire extinguisher. Personnel were evacuated with no injuries.	Failure to instruct maintenance crews about the combustion and toxicity hazards of HTH. The crew used a plastic bottle apparently contaminated with some foreign material that ignited on contact with the HTH.	Ensure that all maintenance personnel are informed of the hazards and precautions in using HTH. Require hazard warnings on HTH containers. Require that containers used with HTH are washed immediately prior to use.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
110. When the doors on a flight vehicle assembly building were closed, three float scaffolds erected earlier were caught in the path of the closing doors and destroyed.	Personnel error in that verification of adequate door clearances was not made before closing. Contributing was failure by riggers to place required flags or signs to warn that scaffolds protruded into the door's path.	Ensure that obstructions near sliding doors have warning flags or signs when they protrude into clearance ways.
111. During functional test at a space vehicle assembly facility, a helium manifold controller was left inside a vacuum drying oven over the weekend and was badly charred, requiring extensive overhaul.	Malfunction of the oven power supply switch relay which kept oven power on after the oven pilot switch was turned off. Contributing were inadequate power shut-down procedures in that the facility main power supply switch was left on, and inadequate maintenance procedures in that the oven switch relay had a design life of one million cycles but was cycled 1.8 million times before it failed.	Require that procedures governing oven drying of program critical hardware include shut down of facility main power supply circuit as well as unit power switch at end of daily operations. Ensure that maintenance schedules which specify replacement of parts before end of design life are prepared and followed for all equipment which handles program critical hardware.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
112. During preparation of a pneumatic test chamber for a high pressure impact test at 9500 psig the sequencing valve was being cycled when an explosion and GOX fire occurred, destroying miscellaneous chamber equipment. There were no personnel injuries.	Material incompatibility in that the non-metallic material (Vespel 21) used for a valve seat reacted with the high pressure oxygen to cause the explosion.	Prohibit use of Vespel 21 material in applications using high pressure oxygen. Require safety review/analysis of oxygen system/component designs and specifications during their development to eliminate materials incompatibility.
113. During test of a flight experiment package in a thermal vacuum chamber, the package and associated equipment were severely damaged by internal high voltage corona discharges which occurred when a chamber vacuum pump seal failed and allowed chamber repressurization.	Deficient test procedures in that the adequacy of the test setup was not verified prior to or during the test; loss of seal was caused by improper positioning of a fan used to blow air on a LN ₂ trap-input solenoid valve to prevent ice build-up on the valve and subsequent loss of seal to the atmosphere. Contributing was deficient test setup design in that there was no provision for automatic cutoff of high voltage sources in event of pressure rise in the chamber.	Require use of formal procedures and checklists to obtain and verify proper configuration of test setup in test chambers; include periodic inspection of test system elements for proper operation during the test run. When conducting vacuum tests on a specimen having a high voltage source that is likely to arc in the corona pressure range, require installation of an automatic power interrupter to shut off the high voltage source on significant rise in chamber pressure.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
114. During manufacturing assembly of a space-craft module a drain bucket used to bleed a water glycol trim unit was entangled with an intercom extension cord in the module and tipped over, spilling water-glycol solution. There was no damage but the incident could have caused module contamination.	Inadequate work control in that the unattended drain bucket had not been secured, and area housekeeping was marginal.	Implement and maintain rigid housekeeping controls in flight system assembly areas. Require periodic QC inspection during each shift. Prohibit unattended liquid containers in work areas unless secured from inadvertent spill by a holding fixture.
115. While cutting a structural member on a launch support facility, molten slag fell on flight equipment and lines at lower level damaging fluid lines and burning electrical cables. Subsequent investigation showed that the torch was being used only 3 inches from unprotected fuel lines and a 3000 psi helium supply line. There were no injuries.	Inadequate work control in that welding operations were being performed without providing protective shields, covers, or blankets.	Designate all welding operations around flight hardware as safety critical. Require inspection and safety approval prior to welding operations. Require protective blankets or covers to prevent damage from falling welding slag.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
116. While lowering an engine service platform at a launch vehicle assembly station with four hand-operated winches, one of the winches failed at the cable drum swage connection, allowing one side of the platform to fall, striking and slightly damaging one engine.	Inadequate work control in that the failed winch was positioned so that only 3 cable turns remained on the drum at the time of failure; and the lowering method used could allow uneven distribution of the load (overload). Contributing was operator error in not requiring a halt in operations as the cable was paid out to the 3 turn condition.	Ensure that winches are so positioned in work areas that at least 3 cable turns will remain on the winch drum at maximum cable extension. Where possible avoid use of independently operated winches on the same load; use adjustable single point pick-up tool to avoid uneven distribution. Ensure that handling personnel are instructed and certified for safe use of hoisting equipment.
117. While moving an engine vertical installer from the first level of a teststand at a test facility, the left and right horizontal adjustment hand wheel struck the concrete structure of the stand, resulting in breaking of 2 spokes at hub with an additional check of one spoke at the outer ring.	Inadequate work procedure since there was a lack of attention given to the clearance needed between the installer and the teststand as the move was being made.	Require the use of at least one observer during movement of heavy equipment in test areas. Ensure that operators are properly certified for duties being performed.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
118. During lowering of an electrical cable by a mechanic from an upper level of a mobile service structure to pad level, a cable coil lying on the deck caught his foot, jamming his leg against the railing, resulting in minor injury.	Failure to exercise reasonable safety precautions in that the heavy cable was not properly secured to help control the lowering operations. Contributing was failure to provide sufficient personnel to safely lower the cable.	Require safety securing of all portable equipment when it is being raised or lowered. Ensure that sufficient personnel are assigned to safely handle raising and lowering of portable apparatus.
119. During high winds, (tornado action) two trailers in a launch pad area were overturned and destroyed. There were no injuries.	Environmental, trailers were torn loose from tie downs by tornado action winds.	Require that safety standards and precautionary measures be established for protection of high value trailers in areas subject to high winds.
120. While checking inoperative elevator doors in a launch facility structure, a workman's finger was caught between the linkage and hangers when the elevator was activated. The finger was severely lacerated.	Inadequate work control in that the doors were being checked with the elevator power on.	When working on elevator systems ensure that the elevator power source is turned off and either locked out or guarded by a co-worker.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
121. During inspection of a stage pressure regulator the inspector dropped it and it fell 4 feet to the floor, requiring component return to the vendor for reinspection and retest.	Inadequate inspection procedures in that positive component protection was not provided during inspection. A contributing cause was failure to exercise reasonable safety precautions during component handling.	Ensure that inspection procedures require positive positioning and protection of critical equipment during inspection activities.
122. During installation of a servoactuator on a spacecraft engine, a certified position and holding fixture (P&HF) failed, permitting the free end of the servoactuator to rotate and fall 3 feet, striking two technicians and a steel work bench, resulting in minor injuries to the technicians and minor damage to the servoactuator.	Design deficiency in that the P&HF was in a failed condition prior to use but the design configuration did not permit ready inspection of the failed item (a shoulder screw); and the failed condition may have been induced by a standard proof load test (150% of safe working load). Contributing was poor workmanship during P&HF fabrication.	Ensure that GSE fixtures which handle end-item hardware are designed so that critical wear points can be readily inspected prior to use, and can be subjected to rigid QC inspection during fabrication. Require handling/lifting equipment to be designed with a minimum safety factor of 5, and ensure that any components subject to repeated load stresses can be easily inspected for fatigue.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
123. A laboratory technician in a materials test facility was exposed to x-ray radiation due to failure of a safety device (lead shield) on a diffraction unit which became jammed in the open position.	Inadequate x-ray diffraction unit design in that the lead shield was internal to the unit and its open/close status was not sufficiently visible external to the unit. Contributing was inadequate procurement/receiving inspection and checkout in that the design deficiency was not detected prior to or at the time of installation.	Require positive indication/warning of position status of shields used in x-ray units or systems. Require pre-procurement radiation safety review of units design to verify adequacy of controls. Require radiation safety inspection/checkout of safety controls operability prior to operational activation.
124. During material curing operations at a test facility, a technician reached in the oven and received second degree burns.	Personnel error in reaching into hot oven. Contributing was failure to provide proper tools for reaching in the oven.	Ensure that all personnel working with curing chambers are properly trained and certified. Ensure that specific instructions are issued specifying tools to be used and procedures to be followed in curing operations.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
125. During test build-up in a thermochemical test facility, insulation on an electrical immersion type heater caught fire due to failure of gaseous nitrogen flow over the heaters, and subsequent erroneous positioning of the heater control switch.	Inadequate heating system design in that the heaters were dependent on nitrogen gas flow to keep them from overheating and there were no interlocks to automatically shut down the heaters in case of gas flow failure. Also, no heater case temperature gages to indicate over-temperature conditions; grouping and labeling of heaters' control switches in such a manner that erroneous identification of their positions could be, and was, made.	Require positive switch cutouts for control of gas flow dependent heaters, to activate in event of low gas flow. Require temperature readouts for each heater case used in test systems. Require separate positive indicating off-on switches for each heater used in test systems.
126. During maintenance operations requiring exchange of two operational mass spectrometers for malfunctioning ones situated on upper levels of a checkout facility, three units were placed into the hoisting basket at one time and, as one of the units was being offloaded, it swung over and collided with another, damaging two gages.	Inadequate work control procedures in placing more than one instrument at a time in a sling and failure to properly protect instruments prior to movement.	Require that only one high value/fragile test instrument or similar hardware item be hoisted at a time. Require QC verification of proper hardware protection and padding prior to hoisting high value/critical program hardware.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
127. During spacecraft assembly testing, a ground-support module cooling unit lost its capability to supply water-glycol cooling, necessitating test shut down and a four hour delay in operations. There was no damage to spacecraft components.	Personnel error. Failure to follow proper maintenance procedures in that the cooling unit had been only partially refilled with freon during servicing.	Require thorough post-servicing/maintenance test and functional checkout of all GSE environmental control equipment used in essential operations prior to returning to operations.
128. During clean room operations three technicians became ill from inhalation of freon fumes shortly after turning on the freon cleaning unit master switch at the start of the second shift. They were unaware that the freon pump switch had been left on by first shift personnel.	Inadequate work control procedures for coordinating information between shift changes because the freon cleaning unit was shut down at the end of the first shift by switching the master switch off and leaving the discharge hose on the floor with the pump switch on; this condition was not transmitted to second shift personnel. Contributing was that the clean room had laminar down flow into sub-flooring so that discharge of freon from the hose was not readily detectable.	Require use of shift-change checklists in clean room operations to transmit essential information on status and condition of test and operating equipment.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
129. While the system was operating, the water separator bowl on an industrial air system facility exploded. There were no injuries.	Material failure in that a crack in the bowl was undetected and constant pressure caused it to enlarge until failure occurred.	Ensure that inspection procedures provide for periodic checks of water separator bowls in industrial air systems.
130. During flight readiness test of a manned system the launch structure was struck by lightning, causing minor damage to automatic checkout equipment.	Environmental in that apparently the lightning strike traveled through the ground to the checkout equipment. There was no evidence of inadequate grounding or safety procedures.	Require post-strike/electrical storm checks for damage to essential equipment. Ensure periodic inspection and continuity checks of the grounding of lightning protection systems.
131. During manufacturing operations a non-stainless steel reducer in a cleaning tank air line failed resulting in a 30-40 gallon nitric acid spill. There was minor damage to tank plumbing and the cleaning room floor.	Unqualified workmen erroneously installed the air line directly into the side instead of over the top of the tank, allowing acid to corrode the steel reducer. Contributing was failure to inspect work for conformance with approved work drawings prior to use.	Ensure that personnel involved with installation/maintenance of hazardous assemblies are specifically certified for their job. Require QC verification of all installation work involving hazardous materials and critical hardware.

SECTION III
FACILITY/GSE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
132. During pull test of an item of ground test support equipment used in development testing, a component of the test article was broken due to excess pull force applied by use of a facility overhead crane. There were no personnel injuries.	Inadequate/deficient test procedures in that the use of the overhead crane was substituted for a malfunctioning hydroset tool assigned for pull test use, to expedite test operations.	Prohibit use of substitute test tools and fixtures for test of essential equipment unless certainty is established that safe test parameters will not be exceeded by use of such substitutes.
133. During facility modifications, a contractor performed inspection using a gamma ray source without first securing approval of the radiological safety officer, and without instituting adequate area control and warning procedures. There were no accidents or incidents.	Management failure to establish and implement policy to include radiological health procedure requirements in facility contracts governing radiographic inspection.	Require the inclusion of radiological safety and health requirements in safety and health clauses, and other pertinent clauses, of facility contracts where radiographic equipment is used.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
134. During post-assembly test of a spacecraft oxygen system, while a cap was being torqued on an oxygen simulator panel, the back-up wrench slipped off an elbow fitting resulting in damage to and replacement of an adjacent line.	Deficient simulator panel design in that insufficient clear space was provided around the elbow to allow a secure grip with assigned tools. Contributing was personnel error in not taking adequate precautions to protect adjacent hardware during torquing operations.	Require maintainability review/analysis during design of test equipment, to verify design compatibility with standard tools or to identify special tool requirements. Ensure that maintenance/test personnel are adequately trained and instructed in the precautions necessary to protect essential equipment during maintenance/adjustment operations.
135. During manufacturing checkout a "Lift-A-Loft" being operated adjacent to a vehicle stage made contact with the stage causing two gouges, one 1" x 11" and the other approximately 1" square and 3/4" deep.	Inadequate work control in that verification of clearances was not made prior to vehicle movement.	Require an observer to assist in verifying clearances to operator when using handling/lifting equipment around flight hardware.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
136. While on portable scaffolding in an assembly and checkout facility, a technician using a safety belt tethered to a trolley installed in an overhead channel inadvertently dislodged the trolley stop, allowing the trolley to fall on him, causing minor head injury.	Personnel error. The workman, by repeated yanking on the harness, forced the trolley beyond the stop. Contributing was design deficiency since the stop should have been immovable when struck by the trolley.	Ensure that the design of all trolley stops will prevent inadvertent trolley dislodgement. Ensure that workmen are instructed on any limitations on equipment being used.
137. During use of a prepositioned TV set-up, a remotely controlled flood light was activated while lying face down and ignited a tar paper roof near the LOX pad. The light was disconnected and the fire was extinguished with minor damage to the roof.	Inadequate work control since the light was left connected to the remotely controlled power source after its pedestal had been removed for maintenance.	Prohibit the use of electrical lamps near flammable materials unless equipped with adequate safety devices. Require safety inspection and certification of all high intensity and heat lamps installed near LOX, fuel, or ordnance areas. Ensure that maintenance procedures require positive disconnecting of all electrical equipment prior to beginning maintenance work.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
138. During painting of a static test tower at the 150 ft. level, a contractor painter was using a boatswain's chair and associated rigging for support. While the painter was being hoisted in the boatswain's chair, a manila rope in the block-and-tackle broke causing the painter to fall out of the chair and sustain fatal injuries.	Material failure in that the rigging rope failed. Contributing causes were inadequate work control over contractor activities and failure to require inspection and certification of the contractor's rigging prior to use, and failure of the contractor to use required safety restraints.	Require safety inspection and tagging of all rope rigging lines to be used for personnel prior to each use, whether contractor or government owned.
139. During operational test of a spacecraft, a water glycol cooling circulation unit lost electrical power, resulting in test shut down for 29 minutes. There was no damage to spacecraft components.	Inadequate design in that a 28 VDC cable plug dropped out of the facility receptacle causing the shut down.	Require that power and control circuitry on critical test support equipment connectors be equipped with positive retention/restraining devices.

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FACILITY/GSE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
140. While a block-and-tackle rigging in an assembly and checkout facility was being used to lift a bundle of test cables, the snap hook sliding bar failed, allowing the block and tackle to fall, striking a hard-hat-wearing workman on the head, causing minor injury.	Inadequate work control procedures in that lifting operations commenced without a QC or safety validation of rigging proof loading/capacity.	Require inspection and validation of special rigging setups prior to use. Ensure that all workmen using or rigging lifting gear are qualified and certified for their job.
141. During flush line servicing, trichlorethylene (TRIC) vented into a mobile launcher work compartment, necessitating personnel evacuation. No damage or injury.	Material failure in that a valve failed in the mobile flush and purge servicer, allowing TRIC to leak.	Designate all TRIC flushing operations as hazardous. Perform hazard analysis of all flush line servicing operations to identify potential personnel hazards and emergency actions in case of TRIC vapor release.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
142. During checkout work on a spacecraft, a cast aluminum support fitting on a scaffold failed while a technician was climbing up. There were no injuries.	Material failure in that the support fitting broke under normal service conditions as a result of fatigue.	Require periodic safety inspection by supervision of scaffold fittings and supports to detect signs of incipient failure, such as thread cracks.
143. During furnace brazing an R&D engine injector was destroyed when the furnace temperature increased from the normal 1900° F. to 2400° F. and melted copper parts of the injector. There was also moderate structural damage to the furnace.	Malfunction of the temperature control thermocouple circuit which gave an erroneously low temperature reading due to an electrical short circuit between the temperature recording instrument inner door and wire of the thermocouple filter circuit. Contributing were faulty installation procedures and poor QC inspection which led to the short circuiting, and inadequate design which did not allow for monitoring furnace temperature along with the temperature of the item being heated.	Ensure QC inspection of all electrical circuit installation and maintenance in electrical furnaces to be used with critical R&D and end item hardware prior to use. Ensure furnace brazing and heating specifications and procedures require monitoring of furnace temperature as well as item temperature on all furnaces used with program essential hardware.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
144. During torch cutting operations in a launch facility, molten slag fell to a lower level, igniting plastic film being used in conjunction with a drain set-up. The fire caused only minor damage and no injuries.	Failure to follow required procedures in that blanketing of the area around the cutting operation was inadequate and permitted hot slag to fall on the plastic film; and the cutting operation was undertaken without prior safety clearance.	Ensure that all welding operations in a launch facility are safety inspected prior to beginning work. Require safety training and certification of welders for work in hazardous areas.
145. During work on an upper level of a mobile launcher, a hold down arm hood pivot bolt, which was being removed, was forced out and fell to ground level. No injury or damage resulted, but a similar mishap could cause severe injury or damage to flight hardware.	Failure to follow required procedures in that the pivot bolts were removed without a sling and crane being attached to the hood to relieve pressure.	Ensure that procedures and/or checklists are followed during all work on flight systems and support structures. Wherever possible, provide safety netting around upper level operations.

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FACILITY/GSE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
146. Several ordnance-activated vent valves received minor damage when loose packing material in the store room caught fire from sparks of welding operations in an adjacent room. There was severe damage to storage area. No injuries.	Inadequate work control of welding operations in failing to inspect for nearby combustibles. Contributing cause was housekeeping policy which permitted storing flammables near ordnance items.	Designate all welding operations as hazardous. Require pre-operational area inspection and safety clearance, and the use of a spark barricade/blanket for all welding operations. Enforce housekeeping policies which prohibit storing combustibles with ordnance items.
147. During assembly of a multiple adapter unit, a rivet bucking bar was dropped and impacted a coaxial cable connected to a switch box, pulling the cable out of its connector on the switch. There was minor damage to the connector.	Inadequate work control in that program essential equipment was not protected from inadvertent damage during assembly operations.	Require protective covers over program equipment when work is being performed adjacent to or above the items. Require that all hand tools be restrained when being used above essential equipment. Require screens or netting around work platform areas located above essential equipment.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
148. During handling operations, a slide wire cable drum was scarred and bent when a locking pin lodged in the locking frame.	Failure to follow required procedures in that the drum was put into motion while the locking pin was being removed. Failure to coordinate simultaneous operations.	Where possible require all cable drums with safety lock mechanisms to be placarded with warning notices to prevent operation prior to releasing the lock.
149. While the high rise elevator at a launch and checkout facility was in operation, bolts on the stabilizer bar failed, allowing pieces to fall to lower levels.	Material failure in that two of four bolts failed, probably due to metal fatigue. Contributing was failure to perform daily inspection of bolts when normal 5 day work week was extended to 7 days.	Ensure that facility "daily" inspection procedures are carried out when normal work week is extended.
150. During assembly operations in a clean room, a fan being used to circulate air into a unit of flight hardware caught fire, due to an electrical short resulting from previous impact damage to the motor housing.	Procedural in that existing mishap reporting procedures did not require reporting of the mishap which damaged the motor housing. Contributing was a design deficiency in that the fan did not have an overheat protection device.	Require that all electrical GSE/facility motors used during assembly of flight hardware be equipped with overheat protection devices. Establish procedures for immediately reporting and documenting all mishaps and corrective actions which involve any damage to GSE/facility equipment used during assembly of flight hardware.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
151. A technician was opening a one pound can of finishing compound at a test facility when the lid blew off and the compound blew out into the air.	Material failure in that the compound had chemically decomposed from old age and formed a gas which created sufficient pressure to blow off the lid of the can when it was partially loosened.	Develop a program to identify all materials subject to hazardous decomposition and establish procedures for their routine removal from stock before critical age is reached.
152. During assembly of a flight system module a workman fell from a platform, receiving minor injuries.	The primary cause was that supervisory personnel allowed workmen to use an unstable platform. Contributing were failure to make a temporary fix with rope, a two-month delay in fulfilling a repair work order, and a non-approved structural change in the platform.	Designate work on overhead platforms as hazardous. Ensure that supervisors prevent use of unsafe work platforms. Require prior approval and post-change safety inspection of all structural modifications. Establish procedures to expedite repair of hazardous personnel support structures.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
153. While performing circuit etching operations during manufacturing, a technician was exposed to toxic fumes.	Inadequate capacity of the exhaust system which did not adequately carry away fumes. Contributing was failure to check and monitor system for toxic fumes.	Ensure that all operations involving toxic fumes have been checked and certified for safety. Require all exhaust systems to be safety verified for adequacy.
154. During modification work on an elevator in a launch structure, a mechanic apparently inadvertently activated a portable elevator control switch, moving the elevator downward and trapping his arm between elevator and shaft structure, resulting in serious injury and subsequent amputation of the arm.	Personnel error due to poor work area practices and procedures by placing switch where it could be inadvertently activated. Contributing was design deficiency in that the portable switch could be inadvertently struck by some object or stepped on thereby activating the elevator movement.	Require that elevator portable control switches be designed to preclude inadvertent switching. Ensure that elevator mechanics are properly trained on methods and procedures required to maintain a safe work area.

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FACILITY/GSE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
155. During routine test work at a laboratory work table configured with an RF induction heater, a research assistant received electrical shock resulting in arm burns, due to contact with an exposed RF outlet.	Inadequate design of warning devices in that although a blinking red light was activated when the RF power was on, it was so located that the technician could, and did, fail to notice it. Contributing was inadequate shielding on the RF outlet.	Require safety review/verification of laboratory warning systems and RF power outlets for adequacy and compatibility with laboratory operations.
156. Following operational checkout of an electromagnetic interference (EMI) test set-up in an RF anechoic chamber, a fire occurred in the RF absorber, resulting in minor damage to the absorber.	Design deficiency in that the RF absorber was not grounded, permitting arcing between the RF coax cable and the absorber when the cable was in close proximity to the absorber.	Establish a standard for EMI test set-up in an RF anechoic chamber, including a requirement for minimum one foot separation between absorber and cable. When RF cables carry more than 10 volts, additional grounding, adequate to prevent cable jacket RF voltage build-up must be provided.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
157. During development testing, the sight gage of a steam generator on a laboratory autoclave sterilization unit failed, releasing steam and water. An employee attempting to clear the area, received minor injury when he slipped and fell. Only the gage was damaged.	Inadequate inspection/checkout procedures in that the unit had been damaged during shipment and there was no record that the unit had been inspected and checked out at the time of activation (approximately 1 month prior to the mishap.)	Require formal inspection and verification of pressure units damaged in shipment prior to operational activation.
158. During post operational testing, personnel in a facility laboratory were exposed to toxic Beta-propiolactone (B-P) vapors emanating from a broken 1 Kg. bottle of crystallized E-P stored in a cabinet. B-P was not used in the lab and lab technicians had no knowledge that it was present or how it had gotten there. No serious injury resulted.	Inadequate work control in that the B-P apparently had been stored in the cabinet a long time without having been discovered or inventoried. Contributing was inadequate storage procedures in that B-P should be stored at + 5° to + 10° C.	Require, as a minimum, quarterly safety inspections of laboratories to ensure that any hazardous chemicals or conditions are identified. Implement formal procedures for requisitioning and control of hazardous chemicals in laboratories.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
159. During manufacturing operations, a worker who was standing on the catwalk of a space vehicle support fixture, fell through a 12"-14" access opening between the end of the handrail and end of the catwalk and landed on the vehicle. The worker sustained a concussion and other injuries. There was no damage to the vehicle.	Inadequate work area procedures in that there was no protective barrier or warning placard at the opening to prevent personnel from inadvertently falling through.	Ensure that work procedures require safety inspection of catwalks/workstands at completion of initial assembly and when changing their configuration to verify the adequacy of barriers and warning placards.
160. After working hours, a fire occurred in a warehouse due to ignition of oil-saturated cardboard boxes by radiated heat from a heat sealer, destroying 20 pieces of electronic equipment and causing first and second degree burns to a night watchman who attempted to extinguish the fire.	Inadequate work control in that an electrical heat sealing device located among the cardboard boxes was left on at the end of the working day. Contributing was inadequate housekeeping of the packing area in that flammable material was stored in the packing area.	Require procedures/checklists for supervisory inspection of packaging areas for hazards at end of work shift. Develop procedures and checklists for identification of flammable materials and store them in areas separate from packing operations.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
161. During maintenance operations a technician was disconnecting a mercury-filled vacuum gage from a hypobaric test chamber when the gage broke, causing mercury to splash on his face and into his eyes.	Personnel error. The technician bumped the gage with sufficient force to break it while attempting to remove a flexible connection which attached the gage to the chamber.	Instruct and certify technicians in proper procedures for protecting delicate/hazardous instruments during maintenance operations. Whenever possible, replace mercury-filled gages with a satisfactory mercury-free substitute, such as a capacitance manometer.
162. During equipment maintenance in a thermo-chemical test laboratory, chilled Freon 22 splashed on a technician from an uncapped line he had previously disconnected, causing extensive first degree burns.	Inadequate procedures in that the technician did not install a cap on the open tube to prevent the liquid Freon 22 from escaping when the pressure built up due to gas vaporization.	Ensure work procedures require that the open ends of all fluid/gas lines be capped during maintenance/modification operations.
163. During installation of a large vacuum testing chamber, workmen using a cutting torch dropped slag onto freon line insulation, starting a fire.	Procedural in that no asbestos fire blanket was used and no fire watch set. Also, the required "Hazardous Operation Work Permit" had not been obtained.	Designate all welding and cutting torch operations as hazardous. Require safety inspection and verification prior to beginning all such operations. Stress the necessity for supervisory personnel to closely monitor welding and cutting operations.

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FACILITY/GSE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
164. Following testing operations in a laboratory, a nitrogen valve in a mass spectrometer was left on resulting in split water lines and damage to the facility floor.	Inadequate work control in that the nitrogen valve was not shut off at the end of the day.	Develop checklists for daily activation and shutdown of laboratories and ensure their use by all laboratory personnel.
165. During maintenance welding and cutting operations in a flight simulation laboratory hot slag fell on an air duct and ignited the insulation, resulting in minor damage.	Procedural in that no asbestos fire blanket was used. Also, the required "Hazardous Operation Work Permit" had not been obtained.	Designate all welding and cutting torch operations as hazardous. Require safety inspection and verification prior to beginning all such operations. Stress the necessity for supervisory personnel to monitor welding/cutting operations.

SECTION III
FACILITY/GSE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
166. During crew training in astronaut rescue procedures, the test subject suffered a back injury while being removed from the test chamber.	Inadequate work control. The trainees were allowed to pull the test subject from the chamber while the bulk of his weight was still suspended from an overhead rail. Possibly contributing was failure to report a previous similar injury which may have left test subject's back in a weakened condition.	Ensure close supervision of rescue training procedures by qualified personnel. Require periodic medical examination and qualification of all research and training test subjects.
167. While performing routine maintenance on the rail of a non-rail hoist near the ceiling of a hypobaric chamber, a workman received a severe electrical shock when his hand came in contact with the 480 VAC bus bar channel in the rail. He fell off the hoist but was caught by other workers.	Inadequate work control. The workman used the hoist as a work platform instead of using a ladder or portable scaffolding, and also was not using a safety harness.	Establish positive work control procedures to ensure the briefing of workers on job requirements, restrictions and potential hazards. Require the use of safety belts for all overhead work where there are no railings or other positive safety restraints. Require electrical power to be shut off and locked out on hoisting equipment when not in use.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
168. While relocating a work platform during spacecraft manufacturing operations, a welding machine on top of the platform fell to the floor resulting in extensive damage to the machine. There was no personnel injury or damage to flight hardware.	Personnel error in that there was failure to secure the welding machine in accordance with established procedures. Contributing was inadequate work control procedures in that there was no requirement to verify the safe configuration of the platform area prior to movement.	Require safety inspection and verification that tools and equipment on work platforms are removed or secure prior to platform movement.
169. During post assembly flushing and drying of spacecraft plumbing, the flushing cart pump motor overheated and caught fire, resulting in damage to the motor.	Inadequate design since the motor was not equipped with a thermal overload protection device.	Require that all GSE/facility equipment motors used during assembly/test of flight hardware have thermal overload protection devices installed.
170. During assembly inspection of a stage from an upper level work platform, a workman dropped a 110 VAC portable work light onto the stage forward bulkhead protective cover. The cover prevented any flight hardware damage.	Inadequate work control in that the work light was not tethered. Contributing was personnel error in that the employee failed to exercise adequate precautions when working on flight hardware.	Require tethering of equipment/tools used on work platforms above flight hardware. Require that personnel working above and around flight hardware be certified and instructed in work procedures to prevent tool/hardware droppage.

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FACILITY/GSE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
171. During manufacturing assembly of a flight module, a clevis pin fell from an upper work level into an uncovered section of the module and did minor damage to installed equipment.	Inadequate work control in that there was no protective barrier in place to catch the falling clevis pin. Contributing was personnel error in that an employee at the upper level failed to exercise adequate precaution when working on flight hardware.	Require installation of barriers and/or catch nets when work is being performed above flight hardware. Require that personnel working above and around flight hardware be instructed and certified in work procedures to prevent tool/hardware droppage.
172. During the installation of a kick plate on a work platform in a stage manufacturing area, the stage side-wall insulation was struck by the kick plate resulting in indentation in the spray foam approximately 4" long by $\frac{1}{2}$ " wide. Stage move was delayed $1\frac{1}{2}$ hours.	Failure to exercise adequate supervision and maintain proper work control.	Require that personnel working around flight hardware be instructed and certified in work procedures to prevent flight systems damage. Where possible, install removable work platform items prior to positioning platform at work station.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
173. *During structural modifications on top level of a mobile service tower, molten slag from a cutting torch became imbedded in the styro-foam sandwich wall of the environmental enclosure causing delayed ignition of the wall while the workers were absent for lunch. Fire hydrants were not connected at that level and CO ₂ extinguishers failed to put out fire. After burning for half an hour, the fire was extinguished by station firemen after hoses were pulled up from a ground level hydrant. This mishap resulted in major damage to the facility.	Inadequate work control procedures in that the contractor failed to enforce adequate fire preventive procedures during welding/cutting operations and failed to provide proper training for his workers. Contributing were contractor failure to station a watchman in the work area when the torch cutting operations were suspended and management failure in not ensuring that the service tower water system had been connected to the station water supply prior to operations on the tower.	Designate all operations which use welding/cutting torches or electrodes as hazardous. Require fire safety inspection of all welding operations prior to commencement. Ensure that work control procedures provide for implementation of fire safety precautions, such as use of asbestos blankets to catch sparks and molten slag, and/or briefing and/or certification of workers on hazardous operations. Require a fire watchman to be posted during breaks and lunch period and for a minimum of one hour following operation shut down in all areas where welding/cutting operations are underway near flight systems.

*This mishap was not associated with manned space programs; however, it was considered significant enough in terms of amount of loss and lessons learned to include in this summary.

SECTION IV
FUEL/PROPELLANT SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
65. During fueling of a space vehicle at a test facility, hydrazine fuel was inadvertently pumped from the storage tank through the waste pond rather than into the vehicle's fuel tank.	Personnel error in which a technician failed to close the fuel dump valve in accordance with operating procedures although he and QC verified that it was closed on the work sign-off sheet.	Implement safety training and awareness programs to motivate all personnel to be especially attentive to comply with all work control procedures in hazardous operations.
66. While using an acetylene torch to loosen rusted strap hold-down nuts on a hydrogen trailer, workmen discovered two H ₂ cylinders still held over 2000 psi pressure. No mishap occurred, but the risk of explosion was great.	Personnel error. Cylinders were inspected and erroneously tagged as inert. Contributing was inadequate work control in that during a subsequent inspection, the torch was allowed to be used before inspection was completed.	Require formal safety approval before torches may be used near flammable gas producing or storage facilities and equipment. Require depressurization, purging and certification prior to placing inert tags on H ₂ cylinders.
67. During a manufacturing leak check of a fuel system ball check valve, leak test compound was drawn into the ball valve's actuating cylinder through a vent port, resulting in removal, cleaning, reinstallation and retesting of the valve.	Personnel error in that technician failed to exercise proper care in carrying out leak test procedures.	Ensure that leak test technicians are adequately trained and instructed in leak test procedures and means to avoid contamination of test articles.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
68. During manufacturing and while performing LH ₂ propellant valve purge flow checks on an O ₂ H ₂ burner, a portable flow meter ruptured and was destroyed when inadvertently subjected to excessive pressure due to sealed flow meter discharge ports. Three workers sustained minor injuries.	Personnel error in that technician failed to check the flowmeter discharge ports, which were sealed with threaded B-nut caps. Contributing was a design deficiency in that no inlet low pressure relief valve was provided in the flowmeter configuration.	Require that portable flowmeter installation and checkout procedures include caution and warning notes about removing seals or caps from discharge ports; require checklist verification of test set-up prior to initiation of test. Where possible, provide for and require the use of relief valves in portable flowmeter installations.
69. During torque wrench tightening of a "B" nut on a GSE fill/drain/feed line attached to a spacecraft oxidizer fill/drain/feed line, the feed line buckled due to overstress caused by leverage of the torquing operation.	Deficient assembly procedures in that off-vehicle assembly of the GSE fill/drain line could have been accomplished prior to connection to flight hardware.	Avoid assembly of GSE lines after attachment to flight systems; require a bench assembly to the point of GSE/flight hardware interface.

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FUEL/PROPELLANT SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
70. Five personnel were exposed to toxic nitrogen tetroxide fumes when a vapor cloud was inadvertently released without warning during oxidizer loading operations in an adjacent work area 150 feet directly upwind of their work area.	Inadequate work control procedures in that there was lack of coordination of safety responsibilities between the two work areas; and no "on-site" procedures for local evacuation of individual work areas.	Establish procedures for assignment of responsibility for overall safety of all hazardous operations between all potential hazard areas. Ensure that all hazardous areas have an effective evacuation plan consistent with the type or types of emergency potential.
71. During checkout of fuel vent quick disconnect hose assemblies, a fuel weigh tank top was blown off and attached flex hoses, tubing, and gage were destroyed. There were no injuries.	Personnel error in that a test valve was incorrectly positioned (opened) causing overpressurization. Contributing was an inadequate checklist which permitted bypassing a sequence check, and resulted in tank being pressurized due to the open valve.	Designate all fuel system checkouts as hazardous. Require safety review/analysis of procedures and checklists to ensure adequacy of caution and warning notes, and to identify safe sequence of operations. Require that checklists be followed without deviation whenever fuel tanking and detanking operations take place.

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<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
72. During preparation for test firing of a spacecraft system engine, a fuel (helium saturated aeroxine-50) auxiliary conditioning unit (ACU) electrical heater assembly on the test stand ruptured, due to auto-ignition of fuel vapor within the heater case, resulting in minor ACU and test stand damage, and inhalation by nearby workmen of toxic fuel vapor created by the rupture. The rupture occurred after the heater unit had been turned on but prior to start of fuel flow.	Deficient test GSE design in that the heater used (calrod immersion type) permitted direct contact between the heater elements and a flammable liquid; the heater orientation within the ACU created a high point vapor trap thus exposing some of the heater elements to fuel vapor; the design provided no electrical interlock to preclude energizing the heater prior to starting the fuel circulating pump; the heater controls were placed in such a configuration that they did not reflect the true temperature within the heating unit. Contributing was a deficiency within the test procedures that permitted energizing heater coils before circulation of fuel was established in the test sequence.	Require the use of a non-hazardous intermediate heat transfer fluid such as water to separate hazardous fluids from direct contact with heating elements. Require safety review/analysis of hazardous test procedures to verify compatibility between procedures and test set-up, and to identify safe procedural sequencing.

SECTION IV
FUEL/PROPELLANT SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
73. During replacement of a millipore teflon filter in an aeroxine-50 fuel system, the element burst into flame as it was placed on the filter plate. The resulting fire was extinguished with water spray. No personnel injury.	Inadequate QC because a non-compatible filter was used with aeroxine-50, resulting in ignition of the element and the residual fuel in filter bowl assembly. A contributing cause was the nearly identical part numbers of the correct and incorrect filters.	Require QC verification of replacement parts, prior to installation, on any fuel system to ensure compatibility.
74. During fuel conditioning operation at a test facility when the fuel inlet line to the pump was opened toxic fuel spilled onto the ground through the outlet valve which was in an indicated closed position. Seventy gallons of fuel were pumped out onto the ground before the inlet line could be closed by "scape" suit procedures.	Inadequate laboratory maintenance procedures which made the valve handle indicate closed when the orifice was actually open.	Ensure that indicating valve maintenance procedures require functional/visual check of valve for proper indication prior to release for installation.

SECTION IV
FUEL/PROPELLANT SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
75. During removal of a spacecraft module fuel tank assembly from a holding fixture during manufacturing, the assembly contacted the fixture and sustained damage to fuel line and bellows, due to close clearances between the tank and the holding fixture.	Inadequate work planning in that a hoist was selected and used to remove the tank from a close tolerance fixture. Contributing was deficient fixture design due to lack of consideration for parts removal and handling clearance.	Require the use of "hydraset" control with hoists when removing parts from close tolerance fixtures. Require manufacturing operations review of holding fixtures designs to assure compatibility with parts removal operations.

SECTION V
LIFE SUPPORT SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
19. During purging and inspection of a life support system, an employee entered a spacecraft cabin with oxygen deficient atmosphere and was rendered partially unconscious.	Personnel error in that the cabin atmosphere had been improperly certified as breathable. Contributing was the erroneous classification of the inspection procedure as "no safety hazard involved."	Designate all life support system purging operations as hazardous. Train and certify all personnel involved in these operations for their jobs. Require safety clearance prior to opening and entering sealed spacecraft hatches.
20. During verification test of a life support system the test was prematurely terminated due to failure of an oxygen circulation fan/motor within the system to start up, caused by corrosion seizure of a fan/motor bearing. Subsequent investigation revealed that the corrosion was caused by water which had been introduced unknowingly into the life support system oxygen loop during a previous spacecraft/life support system compatibility test.	Deficient compatibility test procedures in that a design limitation of the life support system was not recognized during procedures development. This limitation allowed water to be introduced unknowingly through a closed water shut-off valve (leakage) in the system, under conditions of test pressure/time span. As a consequence, available oxygen loop dry-out procedures used when water was knowingly introduced into the loop were not implemented.	Require safety review/analysis of safety critical systems test procedures during their development, to make certain that the test operations will provide timely removal of all system contaminants that may be introduced by the test conditions.

SECTION V
LIFE SUPPORT SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
21. During a rehearsal of a simulated altitude chamber test, a ribbon antenna atop a mobile life support system was cracked halfway through.	Design deficiency in that the life support system thermal cover flap was inadequate to protect the stowed antenna from being damaged during the couch change-out exercise.	Assure that design of protective covers over life-support systems provide shielding against damage for protruding parts of ancillary system components.
22. During manufacturing de-soldering operations on ECS plumbing, Methyl Ethyl Ketone (MEK) used as a solvent caught fire. No damage or injury.	Procedural in that flammable MEK was not prohibited for use in soldering operations. Contributing was personnel error in using a soldering iron before the solvent was completely dry, and supervisory failure to prevent use of a flammable solvent near a heat source.	Avoid use of MEK during soldering operations.
23. During the removal of an environmental control unit from a flight module, a water-glycol line on the unit was bent and subsequently broke while being straightened.	Inadequate work control procedures in that the water-glycol line was not adequately protected.	Require training and certification of personnel assigned to remove/install equipment in spacecraft, to emphasize avoidance of equipment damage. Require installation of protective barriers/blankets and warning placards during equipment installation and removal.

SECTION V
LIFE SUPPORT SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
24. While attaching a 3/8" water glycol line during installation of a flight fuel cell simulator, the line twisted out of blueprint configuration before reaching torque value on attaching "B" nut, resulting in removal and replacement of the line.	Material failure in that the B-nut rotated freely, but its sleeve was frozen to the tube. Contributing was inspection failure to identify the defective line prior to installation operations.	Designate flight systems lines safety critical items, requiring QC tagging and validation during receiving/issue actions and prior to installation operations.
25. During assembly leak test of an ascent stage water system, contamination fluid from a leak meter was pulled into the water system lines due to omission of a step in the test procedure that required leak meter disconnection.	Inadequate work control of test operations that led to a momentary lapse in attention by an experienced test team. Contributing could have been the lack of a caution note in the procedure at each step where leak meters were scheduled to be disconnected.	Require the use of formal procedures/checklists during leak test of program essential equipment to verify proper test sequencing. Require safety review of leak test procedures to provide caution and warning notes.

SECTION V
LIFE SUPPORT SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
26. During a space suit fan functional checkout, as a result of an unscheduled test shutdown, a fan designed for use at 10 psia was inadvertently run for 1½ minutes at full atmospheric pressure and potentially damaged. There were no injuries.	Personnel error in that there was a failure to follow approved, written procedures to cut electric power to the fan before shutting off the test system vacuum pump.	Require use of checklists in conjunction with written procedures to ensure completion of essential steps in test sequence of flight systems.
27. During post leak test disassembly of an oxygen purge system oxygen regulator a damaged "O" ring seal and "delta" ring were found; the damage was due to their improper installation at the time of regulator assembly.	Deficient procedures governing regulator assembly/ inspection in that there was no requirement to verify the proper installation of the seals during assembly operations.	Require formal manufacturing QC procedures to control assembly of non-metallic seals and parts; require inspection to verify their proper installation during assembly.

SECTION V
LIFE SUPPORT SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
28. During manufacturing one sector of a space-craft sun sensor was broken loose during removal of its protective cover preparatory to painting the sensor supporting structure.	Inadequate work control. Workman removing the cover was not authorized or trained to do so.	Ensure that only trained and certified workmen are used to install and remove flight hardware and related protective covers.

**SECTION VI
ORDNANCE SYSTEMS**

**Accident/Incident
Description**

Causes

**Recommended
Preventive/Corrective
Action**

No Accidents/Incidents pertaining
to Ordnance Systems recorded in
the 1970-1971 period.

SECTION VII
PRESSURE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
120. While being proof tested to 6000 psig, a stainless steel braided flex hose in a test fixture line ruptured at 3000 psig. No injuries.	Personnel error. The hose was incorrectly tagged for test to 6000 psig, which was above its burst rating. Contributing was inadequate inspection procedures which allowed the incorrectly tagged hose to be set up for test.	Ensure that hose part numbers are checked against listed pressure ratings prior to tagging. Require that pressure rating tags be checked against part numbers and validated prior to proof testing.
121. During laboratory test evaluation of a regulator, a flowmeter exploded, injuring two technicians.	Personnel error because the flowmeter outlet diameter had been reduced from 1-1/2" to 1/4", restricting flow, thus causing meter to exceed its design pressure and explode. The modification was not authorized by approved procedures.	Require standards/procedures for laboratory modification of high pressure equipment. Require inspection of high pressure equipment modifications prior to operation.
122. While being proof tested to 6000 psig, a flex hose ruptured at 4000 psig. One employee sustained minor injury.	Personnel error. The hose was incorrectly tagged with a proof pressure that was actually above its burst rating. Contributing was inadequate inspection procedures which allowed the incorrectly tagged hose to be set up for test.	Ensure that hose part numbers are checked against listed pressure ratings prior to tagging. Require that pressure rating tags be checked against part numbers and validated prior to proof testing. Ensure that personnel protective equipment is adequate in pressure proof testing areas; barriers should be installed to isolate the test set-up.

SECTION VII
PRESSURE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
123. During development and qualification testing, a facility high pressure air line operating at a normal 3400 psig pressure failed at an elbow swagelock fitting and caused minor damage to the building fixtures from consequent whipping action.	Improper assembly in that a reused swagelock fitting did not match the type of tubing used and was improperly fitted. Contributing were a design deficiency in that the assembly drawings used were not approved by qualified engineers; QC failure to inspect for proper fittings and workmanship; and inadequate tie-down of the air line.	Require certification of personnel assigned to assemble and maintain high pressure systems. Ensure that design of high pressure systems is performed by qualified and experienced personnel. Require formal QC inspection of high pressure systems for compliance with design specifications prior to system activation. Ensure that all high pressure hydraulic and air lines are secured at 6-foot intervals.
124. During operational testing of a space flight simulator, a 3000 psi hydraulic line pulled out of its "B" nut connection and sprayed hydraulic fluid over a portion of the facility. No damage or personnel injury.	Improper installation of the line assembly in that the "B" nut was loose, allowing pressure on the line to straighten out the tube flare causing the line to blow out from the simulator unit.	Require formalized procedures to inspect and verify pressure connections for program simulator equipment prior to test commencement.

SECTION VII
PRESSURE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
125. During operational check-out of a test equipment modification in a down flow clean room, a 50 psig air line was inadvertently connected to a vacuum gage port, resulting in destruction of an absolute pressure gage.	Procedural due to lack of detailed checkout/activation procedures and checklists and lack of QC certification. Contributing were test system design deficiencies in lack of positive identification of inlet and outlet ports and lack of an absolute gage pressure relief valve.	Require that formalized test set-up and operational procedures be established for activation/testing of pressure systems which include precautionary warnings and QC verification. Inlet and outlet ports should be clearly marked, and designed to prevent inadvertent cross connections. Require installation of pressure relief devices on all pressure gages.
126. During visual inspection of a high pressure system in a facility supplying gas to test cells, desiccant particles were found, resulting in a shut-down of the system for investigations and repair.	Inadequate supply system design in that one of the drying filters ruptured, caused by a normal rapid pressure drop on the downstream side of the filter, creating a venturi, or vacuum, effect.	Require that pressure systems used in test of flight hardware be designed with sensing and relief devices to detect pressure variations and protect critical filters in the system; support design development with system safety analyses/reviews.

SECTION VII
PRESSURE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
127. While operating the purge and vacuum console during pre-launch checkout, the operator turned the regulator clockwise instead of counter-clockwise, resulting in overpressurization of the system. No damage resulted.	Personnel error in that the technician turned the regulator in the opposite direction from that called out in the test procedure.	Ensure that test operators are certified and trained in pressure system adjustment techniques. Require caution and warning notes in test procedures governing pressure control adjustments. Use directional decals/placards on test consoles to indicate proper adjustments.
128. During vehicle assembly at a launch facility, a helium control system solenoid valve on an engine was found to have four radial scratches across the outlet port sealing surface. The valve was rejected from service.	Personnel error. Failure to carry out the required complete inspection of the valve during source inspection.	Require the use for formal checklists during source inspection of program critical equipment to verify completion of all elements of the inspection sequence.

SECTION VII
PRESSURE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
129. During oxygen sampling of the crew umbilical system of an altitude chamber, a GOX hose was erroneously disconnected, pressurizing the hose to 173% of design burst level. The hose did not fail and there was no damage or injury.	Design deficiency in that interconnect hose fittings contained a self-sealing valve which caused the hose pressure to increase above design burst level following inadvertent disconnect. Contributing was a procedural error in disconnecting the line while still pressurized.	Review design standards for LOX and GOX hose connections to ensure the prevention of hose overpressurization following inadvertent disconnect. Require check-off verification of depressurization prior to all hose disconnects.
130. While investigating apparent nonoperation of a gas generator blade valve during system check-out, employee had finger amputated when the valve was suddenly activated by an operator at a remote location.	Failure to follow approved safety precautions in that the employee had not informed the engineer in charge of valve activation that he was working on the valve; there was no continuing communication between the remote operator and the workman, and no lock-out procedures to prevent valve activation.	Require that system troubleshooting operations be approved by the engineer with functional control authority over the system prior to commencement. Ensure that system controls are "locked out" either mechanically or with warning tag while the system is being worked on. Ensure positive communication between employees working on systems at remote locations and operators and engineers in charge of system activation.

SECTION VII
PRESSURE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
131. During leak check of a test pressure container, the burst disc of the container ruptured due to overpressure caused by incomplete closing of the manual test gas valve, resulting in minor injury (ear drum damage) to three workmen.	Inadequate test set-up design in that the test gas system contained no relief valve or pressure regulation within the safe working pressure of the test article. Contributing was the failure to follow procedures in that closure of the test gas valve was not verified.	Require installation of pressure regulators and relief devices in test pressurization systems when source pressure exceeds safe working pressures of pressurized containers. Require positive verification of pressure application/isolation valves positioning during application of test pressures through QC and/or supervisory checklists.
132. During pressure adjustment to reseal a mercury sealed piston in a flow rate calibrator, a pressure gage on the test bench exploded due to inadvertent application of overpressure from the supply source, resulting in injury to a test technician (shattered tempered glass dial cover showered face and upper body with glass fragments).	Inadequate test bench design in that there was no automatic pressure relief device between the exploded gage and the supply source; the exploded gage had no safety shield; and there was no pressure gage to indicate the amount of pressure applied to the calibrator. Contributing was inadequate work control in that pressure valve/regulating devices on the test bench were positioned without authorization during the resealing operations.	Require installation of pressure relief devices on all pressure gages and at other critical locations in test pressure systems. Require installation of pressure gages in maintenance/test set-ups to indicate applied pressures at work stations. Require installation of safety lenses on test bench pressure gages. Placard test pressure systems for operation by authorized personnel only.

SECTION VII
PRESSURE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
133. A helium cylinder located in a K-bottle facility storage rack suddenly burst and released all of its contents as a result of a ruptured disc in the valve assembly.	Inadequate storage procedures in that the K-bottle storage rack was located under a translucent sheet roof which allowed sun's rays to overheat/over-pressurize the cylinders.	Ensure K-bottle storage procedures require sheltered storage to protect bottles from over-pressurization from heat sources.
134. During operational test and checkout of a spacecraft, a water glycol quick-disconnect (QD) was mated to the wrong port. There was no damage since the system was not pressurized. The spacecraft was tested for contamination and the flight half of the QD was changed.	Inadequate procedures due to the lack of warning notes in test and hook-up checklist. Contributing was inadequate design in that the QD configuration was such that it could be mated to a wrong port.	Provide warning notes in procedures and checklists where it is possible to make wrong connections. Require QC verification of all flight systems test set-ups. Ensure that adjacent connectors are properly coded, marked, or sized to avoid mismatching.

SECTION VII
PRESSURE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
135. During run-in of a high pressure air compressor used for laboratory testing of flight hardware, the fifth stage oil separator of the compressor exploded, due to autogenous ignition of an oil/air mixture in the exit pipe, propelling fragments of the separator throughout the building and through the walls and roof. No one was injured.	Deficient design of air compressor system in that automatic cut-off temperature sensors were so located that they could not detect the temperature of the discharged air at the area of the explosion. The temperature approached 400°F under run-in conditions, the approximate autogeneous point of the mineral based lubricating oil used in the compressor system under maximum stage discharge pressure.	Require hazard analyses to be performed on laboratory/facility pressure equipment which is used with flight hardware prior to operations and require safety approval. Specify use of synthetic lubricants in place of mineral base oils when potential operating temperatures may exceed 350°F.

**SECTION VII
PRESSURE SYSTEMS**

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
136. During preparation for an underwater test in a test facility, a sealed battery box containing two lead-acid batteries was being pressurized to approximately 10 psi from a 110 psi source when the box blew up due to overpressurization, resulting in battery breakage. There was no personnel injury or unacceptable tank contamination.	Inadequate design of pressure source system in that there was no pressure regulating or relief device between the 110 psi supply and the connection to the battery box. Contributing was management failure to implement formal design control of the battery box in that the box was a "locally fabricated item" with no identification of safe working pressures. Also contributing was a procedural error in that, although the box was equipped with a shut-off valve and a gage, the valve was either open when the 110 psi source was connected or it was opened too fast during pressurization.	Require installation of pressure regulators and automatic relief devices in source lines when source pressures exceed safe working pressure of pressure receivers in test pressurization systems. Require formal design control of all pressurized containers used in tests. Label pressurized containers with safe working pressures and periodic proof pressure test requirements. Require the use of formal procedures/checklists for the proper sequencing of operations in pressure applications.

SECTION VII
PRESSURE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
137. During proof pressure testing of a coolant servicing unit, a flowmeter within the unit ruptured due to overpressure and showered glass fragments within the enclosed test area. There were no injuries or other damage.	The test procedures required application of 460 psig pressure even though the flowmeter was rated for a safe maximum working pressure of only 230 psig.	Require checklist verification that test pressure requirements are within safe operating limits of test equipment. Limit proof pressure tests to 1.5 times maximum safe working pressure of test equipment. Ensure that proof pressure requirements for an assembly are compatible with assembly components during development of test procedures.
138. During operational test and checkout flow testing of a spacecraft reaction control system engine, pressurization of the system caused leakage in an oxidizer isolation valve, which went unobserved until the oxidizer propellant tanks were pressurized to 20 psig, approximately 44% of design burst. There was no damage and no injuries.	Inadequate test procedures in that the procedures failed to sufficiently recognize the possibility of pressure leakage through the oxidizer isolation valve and overpressurization of the oxidizer tanks during the test sequence.	Identify all tests requiring pressure applications to flight systems as hazardous; require safety review/analysis of test procedures during their development, to ensure entry of required caution and warning notes, and safe test sequencing.

SECTION VII
PRESSURE SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
139. During acceptance testing of an APS module, the module bellows assembly was permanently distorted due to the application of test pressure approximately 130 psi above the maximum allowable. The bellows assembly had to be replaced.	Personnel failure to properly position valves as required by the test procedure. Contributing was lack of requirements for positive verification and communication of correct positioning of valves during the test sequence.	Designate flight hardware pressure testing operations as hazardous. Require safety review and analysis of such operations to identify potential hazards. Institute positive communication and verification procedures for all configuration changes required during test operations. Require a "dry run" to validate proposed pressure test procedures for critical flight hardware.

SECTION VIII
PROPULSION SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
27. During a manufacturing check-valve verification leak test on a space vehicle propulsion system, a technician working on the vehicle, using a drill motor, slipped and nicked a fuel line which was under test.	Inadequate work area control. The leak test was being performed in a limited access area and test procedures required no work on the vehicle during test operations. Contributing was personnel error in use of the drill.	Require supervisory and QC verification of work area clearance prior to initiation of test operations in limited access test areas. Ensure that using personnel are trained and instructed in the proper use and positioning of drill motors in the vicinity of pressurized lines and tanks.
28. During cleanup of a minor fuel leak from a pressure regulator in a propulsion system valve box, several polypropylene felt clean-up pads were slightly charred. No damage or injuries resulted.	Personnel error in that technician failed to follow established procedures, since clean-up pads were not sufficiently water-dampened prior to being used to absorb fuel.	Designate all fuel clean-up operations as hazardous. Require all personnel involved in fuel clean-up to be trained and certified for their job.

SECTION VIII
PROPULSION SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
29. During removal of engine from test stand after completion of development test firings, three technicians inhaled toxic aeroxine-50 fuel vapors that had been entrapped in the engine and discharged at the engine connect point.	Inadequate work control procedures in that the technicians were not wearing proper protective clothing for this type activity in which residual fuel and oxidizer vapors can be expected even after engine purging operations.	Establish work control procedures which define the proper protective clothing to be worn for removal of liquid propellant engines from test stands after they have been operated.
30. While removing an engine LOX inlet duct during manufacturing assembly operations, water in the bellows convolutions poured into the LOX turbo pump, necessitating removal and reconditioning of the pump.	Inadequate inspection since the weep holes of the inlet duct and the shroud of the pump bell housing had not been covered and sealed as required, thus the collar area of the inlet duct permitted water to remain trapped below weep holes of the duct.	Require use of checklists in performance of assembly inspections to record and verify that all inspection steps have been carried out.

SECTION VIII
PROPULSION SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
31. During installation of a spacecraft propulsion engine, the railing of the engine stand pressed up against a fuel vent line and dented it.	Procedural deficiency in that there was failure to communicate essential information concerning change in engine configuration to installation personnel; this particular engine had its fuel ventline routed 5 inches lower than in previous engines, and the pneumatic-tired stand raised up when part of working load was removed.	Ensure that installation/test procedures used in conjunction with pneumatic-tired work stands provide cautionary warnings to make allowances in stands' height due to load.
32. During instrument modification work on a spacecraft engine, a welding machine operator misinterpreted a voice communication from the interstage area and applied power to the tube welding head while it was in contact with the engine work platform, shorting the head to the platform. No damage to the engine; however, the potential existed.	Inadequate work control in that there was a failure to provide adequate communications between the interstage and the welding operator.	Require hardline voice/visual communications among welding team members on flight systems. Require review of communication techniques prior to start of welding operations. Require safety approval of welding setup. Ensure that welding machine operators and technicians are certified and instructed in procedural communication techniques.

SECTION VIII
PROPULSION SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
33. During removal and replacement of booster engine LH ₂ prevalves, a prevalve spacer was scratched in three places.	Inadequate maintenance and installation procedures. Contributing causes were inadequate supervision and personnel error.	Require that all personnel be certified for work on flight hardware and require that specific installation procedures are prepared and followed.
34. During helium system leak test pre-static engine checkout at an assembly facility, a growing bubble leak was detected at the mating flanges of the heat exchanger helium supply duct and the helium supply wrap around duct, resulting in replacement of the seal.	Personnel failure to follow established installation procedures/techniques in that 80 degrees of the seal's teflon coating had been peeled off as a result of improper installation.	Require that critical component installation procedures be understood and that personnel are trained and certified to perform such operations. Ensure that inspection procedures and checklists provide for specific check-offs, as appropriate, during installation of critical components on flight hardware.
35. During maintenance installation of a replacement O-ring on an engine igniter fuel line, four O-rings were found creased in their package, resulting in rejection for use.	Inadequate/improper packaging since procedures called for the O-rings to be packed so that they would remain in their natural shape. Contributing was inadequate inspection of packaged products.	Ensure that packaging and packaging inspection personnel are trained and certified in proper packaging techniques; and the use of approved packaging procedures.

SECTION VIII
PROPULSION SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
36. During manufacturing checkout leak test of an engine hydraulic system, the braided flex hose connected to the gimbal filter manifold supply pressure tap leaked at a severely damaged area resulting in replacement of the hose.	Inadequate pre-test inspection procedures in that the failed hose was in an incipient failure condition, that could have been detected by visual inspection (damaged braid and permanent bulge set).	Require formal QC inspection and verification of test pressure set-ups before application of test pressures to or around program essential equipment.
37. During engine development testing a circuit malfunction in the facility cutout system led to premature engine cut-off. No damage.	Personnel error. The thrust chamber exit igniter indication device was inadvertently wired into the cutout system, there was no evidence that test wire connections had been inspected.	Require formal QC inspection and verification of test wiring connections prior to application of power to program essential equipment.

SECTION VIII
PROPULSION SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
38. An engine injector became contaminated with rain water while in its storage container in a storage warehouse due to a leak in the building roof and lack of cover on the storage container.	Personnel error in that the storage container cover had been removed to inspect the condition of the container dessicant and had not been replaced. Contributing was a management deficiency in that there was a failure to have proper building inspection to detect roofing deterioration.	Ensure that program hardware inspection procedures require immediate replacement of protective coverings when inspection is completed; require use of "buddy system" and checklist verification when inspections are performed in isolated areas. Require pre-storage inspection of storage facilities for program essential equipment to ensure they will provide the required protection; and perform periodic (at least quarterly) inspection and corrective maintenance.
39. During a flight engine pre-stage checkout inspection following removal from storage, it was discovered that there was minor damage to the thrust chamber tubes, requiring repair.	Inadequate storage inspection procedures since the protective engine cover had not been installed, and the stage was damaged when struck by some sharp object.	Require formal procedures and checklists to verify installation of protective covers on flight hardware placed in storage.

SECTION VIII
PROPULSION SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
40. During a leak check procedure on a spacecraft propulsion system during assembly operation, the overhead workstand was moved while a propulsion flex line was still attached to it, causing damage to a line connector and mounting bracket.	Inadequate work control in that the workstand was not cleared of flexline connections before being moved. Contributing was personnel error since the incident was partly due to carelessness during the test procedures.	Use formal procedures and checklists during assembly/test of flight systems to verify completion of all operations prior to movement of workstands.
41. During installation of a tube assembly on a spacecraft engine, a tube weld purge could not be accomplished. Inspection revealed a piece of plastic film plugging the tube passage.	Deficient inspection procedures governing processing of plugged tube from manufacturer to point of installation, in that plastic film was used to protect tube ends, and its presence in the tube was undetected in its process through an undetermined number of shipping/receiving points; there were no procedures to verify the internal cleanliness of the tube immediately prior to installation.	Require formal QC inspection/verification of cleanliness of internal tube/piping areas immediately prior to installation in flight systems.

SECTION IX
STRUCTURAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
21. Following removal of a protective hard-floor covering during manufacture of a flight module, the module floor was found to have a one and a half inch long triangular puncture.	Most probable cause was personnel error in allowing the hinged hard floor supporting frame to fall against the module floor during either installation or removal.	Require training and certification of personnel involved in installation of protective flight module coverings.
22. During weight and balance testing of a spacecraft in a manufacturing facility, the turn buckle on the sling being hooked to the top of the craft contacted the craft and broke off a finger seal.	Inadequate work control since one leg of the sling was not pulled taut enough to prevent the sling from contacting and breaking off the finger seal. Contributing was failure to provide required protection for the finger seal.	Require any in-plant movement of flight hardware to be under the direct supervision of a designated move conductor. Ensure that required protective devices are used.
23. While performing work on top level platform of a spacecraft module, a torque wrench slipped from technician's hand, falling and striking aft bulkhead structure, causing a 1/16 inch nick.	Inadequate work control procedures in that there were no protective or restraining devices used to prevent a slipped wrench from falling.	Require the use of protective nets or restraining devices on tools being used on elevated work platforms.

SECTION IX
STRUCTURAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
24. During the lifting of a launch vehicle section, a hold-down bolt in the aft support structure over-stressed the vehicle's aft skirt section, resulting in minor damage.	Personnel error in that the bolt was not removed as required prior to lifting. Contributing was improper inspection in that several inspection teams had certified that all bolts were removed.	Ensure that inspection personnel are qualified and certified for their specific job. Ensure that hold-down bolt removal procedures and checklists identify and require verification of the number of bolts removed.
25. During manufacturing, a titanium propellant tank was undergoing final internal inspection by means of an X-ray anode tube which was left inside the tank unattended. Overnight, a leak developed at a hose connection in the X-ray tube cooling system which half-filled the tank with water, collapsing and totally destroying it.	Inadequate work procedures in that cooling system hoses were not checked for proper installation since a kinked hose caused a pressure buildup which resulted in the hose backing off the nipple. Contributing causes were a design deficiency in using adhesive tape on hose connections to restrain hose from pulling loose; and a management deficiency in that the tank manufacturer failed to follow instructions of the contractor to remove the X-ray tube from the tank whenever it was to be left unattended.	Require that QC verify proper installation of test equipment used with critical hardware. Prohibit the use of test equipment which does not use mechanical hose clamps for all hose connections. Require use of a checklist to ensure correct procedures for shutdown of test/inspection operations on program critical hardware.

SECTION IX
STRUCTURAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
26. During countdown demonstration test at a launch facility, the spacecraft boost protective cover (BPC) hatch latches did not retract prior to hatch closure, resulting in minor damage to BPC.	Inadequate procedures in that test procedures did not call for verification, visually or otherwise, that hatch latches were in open position.	Ensure that test procedures require positive verification of positioned devices during test sequence.
27. While raising the hydraulic work platform around the spacecraft, the kick plate came in contact with the spacecraft tunnel, causing a 2" tear in the lower edge of the tunnel door.	Inadequate supervision and work control in that a visual inspection for determining adequate clearances for the platform was not made before and during the raising operation.	Require that two men always be assigned to raise or lower any workstand; one man to operate the raising or lowering mechanism, and one man to assure hardware clearance.
28. During manufacturing, a spacecraft side hatch was closed on and crushed a live portable light cord, resulting in arcing which burnt two small indentations on the hatch frame ledge.	Personnel error in that a technician failed to remove the light cord before closing the side hatch.	Require supervisory or inspection approval prior to opening or closing spacecraft hatches. Install restraints on open hatch doors to prevent inadvertent closing.

SECTION IX
STRUCTURAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
29. During manufacturing assembly operations, a stage tank was subjected to possible negative pressure differential and damage, due to failure to uncap the breather port of the tank desiccant canister following canister connection to the tank.	Inadequate work control procedures since the canister was both disconnected and reconnected to the tank without documented authority or procedural instructions; as a result, the mechanic making the reconnection failed to uncap the breather port.	Require the use of formal procedures and checklists to attain and verify the proper configuration of flight equipment during all assembly operations.
30. During the horizontal paint and rolling operation on a stage tank, a temporarily secured flange became loose and fell inside the forward skirt area, resulting in minor damage to mylar on forward dome and a small ding in a thermo-conditioning system line.	Inadequate inspection procedures in that after the desiccant system had been reinstalled following tank pressurization for an engine leak check, the temporary flange was improperly stowed inside the tank.	Require accountability for all equipment and tools upon the completion of specialized operations involving flight hardware. Require inspection and certification when any item has been stowed temporarily on flight hardware.

SECTION IX
STRUCTURAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
31. During test preparation, a control handle fell off an overhead hydraulic hoist and punctured a spacecraft bulkhead, allowing approximately a gallon of hydraulic fluid to spill on the bulkhead and leak onto equipment inside. The long range effects of the fluid contamination are unknown.	Personnel error in that the hoist passed receiving inspection with an improperly installed control handle set screw. Contributing was lack of procedures requiring special inspection of flight hardware handling/lifting equipment prior to use.	Require QC receiving inspection check of control handles installation on all handling/lifting equipment. Require local QC inspection and verification of all handling/lifting equipment used with flight hardware prior to use.
32. During manufacturing test preparation, the floor skin of a flight module was torn when a workman dropped one end of a crew couch.	Inadequate work control. The workman was not experienced or qualified and had not been assigned to the job. Contributing was failure to follow required procedures since protective floor pads were not in place.	Designate all transport and handling operations involving flight equipment as safety critical and train and certify personnel for their job. Ensure that only certified personnel participate in safety critical handling operations. Require QC verification that protective pads are in place prior to moving heavy items inside flight vehicles.

SECTION IX
STRUCTURAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
33. While machining foam insulation during 360° repair of a spacecraft forward skirt at a manufacturing facility, the rotating aluminum shaft of the machining tool sheared at the base of the phenolic cutting head. The cutting head hit and damaged the insulation.	Deficient work planning in that the machining tool (aluminum shaft) selected was inadequate for the assigned work.	Avoid the use of aluminum shafts in machining tools. Require engineering design review of machining tools procurement specifications to ensure their adequacy for use with program essential hardware.
34. During manufacturing operations involving the removal of a bonded support bracket from the forward dome of a spacecraft, the dome skin was dented in three places.	Personnel error in that there was failure to follow established procedures when using a plastic scraper to separate the bond between the support bracket and the forward dome.	Require that employees be instructed on proper procedures for removing bonded items from critical flight hardware. Assure that the proper hand tools are available for employees' use when removing bonded articles from flight hardware.

SECTION IX
STRUCTURAL SYSTEMS

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
35. During manufacturing, a titanium propellant tank loaded on an automatic conveyor was damaged beyond repair when it jammed into a partially open heat-treat oven door due to failure of the door lifting mechanism.	Deficient design of the heat-treat system in that there was no provision for automatic shut-down of the conveyor if the oven door failed to less than required open position. Contributing was deficient work procedures since the door mechanism was in an incipient failure condition which could have been detected prior to start of heat-treat operations.	Designate all automatic feed operations for flight hardware safety critical. Require safety analysis/review of feed systems designs to ensure incorporation of fail-safe features. Ensure operating procedures require visual/functional check of proper systems operations prior to start of loading

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
53. During highway transport of critical program equipment a tractor-trailer interior caught fire approximately 5 hours after it was loaded. The local fire department extinguished the minor blaze. The driver continued and 1½ hours later the fire recurred, completely destroying the critical equipment. Destruction and damage amounted to over \$800,000.	Failure to enforce no smoking policies around packing and shipping areas and materials. Contributing causes were failure to inspect loading of high value equipment, carelessness of loading personnel, and failure to properly extinguish initial trailer fire.	Publicize and enforce no smoking regulations in packing, shipping, and receiving areas.
54. While towing a vertical engine installer to its storage location at a launch facility a crack developed in the installer draw-bar assembly at an area of previous repairs.	Personnel error in that proper towing vehicle operating procedures were not followed. Contributing was inadequate maintenance procedures in that multiple repair of the failed area had been made, in lieu of part replacement, which weakened the failed part.	Designate handling and transport of essential GSE as safety critical operations; require training and certification of handling personnel. Ensure that essential GSE parts replacement policies prevent multiple failure repair of the same part.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
55. During preparations for shipment of a propellant tank from the manufacturer a heat lamp was tipped against the outer tank wrapping and started a fire causing minor damage to the tank.	Procedural in that heat lamps, though not actually required, were used near flammable materials without proper protective devices to prevent ignition.	Require that all heat lamps used in presence of flammable materials be equipped with protective devices, and be specifically certified for use in each operation.
56. During maintenance work on a main stage crawler transporter, three hydraulic steering pistons and related cylinders were severely damaged when the transporter platform was lowered.	Inadequate work control in that there was no overall supervision or positive communication during maintenance operations. Contributing were personnel error since the required inspection to verify open position of manually operated isolation valves was not performed prior to platform lowering, and a design deficiency in that there was no hydraulic over-pressure warning or relief system.	Designate all maintenance and check-out operations on flight hardware transporter equipment as hazardous and certify personnel for such operations. Ensure that all maintenance operations on such equipment are controlled by one overall supervisor. Require the use of checklists and/or procedures during maintenance operations. Equip all hydraulic sub-systems capable of inadvertent over-pressurization with relief valves or warning devices.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
57. During removal of an empty tank car, a helium rail car was mistakenly moved while a pressurized hose was still connected between the car and the off-load facility manifold, resulting in damage to the flex hose and bleed panel.	Inadequate work control in that the car was moved without first being checked for connected lines; failure of the off-loading crew to set legally required warning flags, and failure to verify the identity of the car before moving it. Contributing was poor visibility due to night-time conditions.	Designate propellant off-loading operations as hazardous and certify off-load crews. Require safety approval of off-loading operations prior to commencement. Require use of a checklist and/or procedures to ensure correct railcar identification and that all disconnects have been made prior to movement.
58. A commercial tractor-trailer van hauling a NASA-owned computer system skidded off the highway into an embankment. The trailer jackknifed, causing damage to various computer parts. The driver received minor injuries.	Material failure in that an apparently good front tire of the tractor blew out under ideal highway and weather conditions. Contributing were personnel error in that the driver failed to control the vehicle after the blowout occurred, and inadequate procedures in that there was no evidence that vehicle condition or driver qualification had been determined before departure.	Designate highway transportation of high value/program critical equipment as safety critical. Require certification of drivers and inspection of highway vehicles hauling critical equipment prior to departure.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
59. During shipment of a number of space system batteries via common carrier trailer truck from the manufacturer plant to the launch center, the batteries were damaged beyond use due to exposure to excessive heat brought about by failure of the trailer temperature conditioning system and failure of an independent temperature gage/sensor assembly.	Inadequate transportation planning in that there were no procedures to verify the proper operation of the conditioning system and its temperature gage system prior to battery loading; there were no procedures to ensure adequacy of emergency actions to be taken on noticing the failure of the temperature gage/sensor assembly (the conditioning unit was heard to be running and it was assumed it was in the "cool" mode when it had actually failed into the "heat" mode due to a short circuit in the thermostat assembly).	Require verification by authorized supplier and a government representative of proper operation of essential trailer truck conditioning systems prior to loading program essential equipment for transport. Require safety/reliability review of essential trailer truck conditioning systems to establish compatibility between emergency enroute procedures and failure modes of conditioning equipment, prior to shipment of program equipment.
60. During manufacturing check-out a wheeled leak detector was damaged while being loaded on to skid, when a wheel broke off causing unit to fall backwards to the pavement.	Material failure. The wheel broke off at a weld. Contributing was possible overstressing of the wheel/weld due to rough handling.	Require training and certification of all personnel involved in handling/moving of essential hardware. Require regular maintenance inspection of wheel assemblies on trolley mounted high value/critical test and support equipment. Affix handling warning notices to critical portable equipment and ensure its movement only by certified personnel.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
61. While removing a spacecraft control unit from the mobile launcher to the high bay during the pre-launch checkout, three calibration test point connections were broken.	Personnel error since control unit was moved without protective pads or cases, in violation of established procedures.	Require QC inspection and verification of proper packaging/protection of high value test equipment prior to movement.
62. While equipment was being unloaded from a cart on the 120-foot level of a mobile launcher, a test box fell to the "0" level and was totally demolished. No other damage or personnel injuries occurred.	Personnel error in overloading the cart, intermingling flex hose with other apparatus, and unloading cart while too close to the edge.	Establish procedures and controls to prevent over-loading and hazardous handling of carts. Require that personnel handling movable carts around and on launch support structures be properly trained and certified for their jobs. Provide protective side barriers or nets on carts. Require cart loads to be secured by nets or other arresting methods before being moved across catwalks. Specify and enforce safe load limits for equipment carts.

SECTION X
TRANSPORT/HANDLING

Accident/Incident
Description

Causes

Recommended
Preventive/Corrective
Action

63. During the moving of test equipment on a cart across a catwalk, a 5-lb. test box fell from the cart over 100' to a lower level and was demolished. No personnel injuries or other equipment damage resulted.

Personnel error in that the cart was overloaded with loose, unsecured equipment. Contributing were failure to exercise proper supervision and to provide side fencing or netting on catwalk.

Establish procedures and controls to prevent over-loading and hazardous handling of carts. Require that personnel handling movable carts around and on launch support structures be properly trained and certified for their jobs. Provide protective side barriers or nets on carts. Require cart loads to be secured by nets or other arresting methods before being moved across catwalks. Specify and enforce safe load limits for equipment carts.

64. During facility modification, a 190-lb. steel heat shield panel was being hoisted by an overhead crane when the handling tool attached to the panel failed and the panel fell against a space vehicle engine, damaging 4 lines beyond repair.

Procedural error in that a handling tool not designed for the specific job was used. There was no tool for lifting the steel panel so one used for lighter ceramic panels was utilized. Contributing causes were failure to provide formal authorization of lifting tool substitution, failure to provide instructions on lifting tool limitations, failure to require safety inspection of the lift rigging, and failure to provide support for the shield while taking up cable slack.

Require safety approval and surveillance of facility modification hoisting operations in vicinity of flight systems; require inspection of all rigging prior to use. Establish procedures which restrict tool use to the job for which designed and require formal approval of any substitution. Require listing of proper tool use and any limitations on tool drawings, and ensure that personnel engaged in critical lifting operations are aware of this information.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
65. Two workmen inhaled toxic fumes generated by smouldering containers of oil, acid and solvent which spontaneously ignited at a test facility dump, due to incompatibility between materials being dumped.	Inadequate work planning and procedures in that the disposal operations did not provide for the identification and segregation of potentially hazardous material combinations.	Require identification and segregation of hazardous materials combinations in planning disposal procedures. Ensure that disposal personnel are adequately briefed on the potential hazards of waste materials and on the necessity for wearing protective gear.
66. During local truck transport of a spacecraft capsule at a Center, the capsule caught on and broke a fire alarm communications cable over the roadway, resulting in minor damage to 5 private vehicles parked nearby. Negligible damage to the capsule.	Inadequate transportation planning in that overhead clearances along the route were not verified beforehand.	Require route inspection and verification of adequate overhead road clearance in planning transport of flight equipment.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
67. During airport ground handling operations, a crated, pallet mounted, spacecraft oxygen tank being shipped from the manufacturer slipped off a transporter and fell 3 feet to the ground. There was no damage to the tank and only minor damage to the reusable container.	Personnel error in that the transporter operator had installed only 2 of 6 chocks designed to prevent load slippage. Contributing was failure to mark the container as critical flight hardware and failure to notify the shipper of the critical nature of the cargo.	Clearly mark all shipments of critical flight hardware as flight critical on the container and include special handling instructions. Ensure that shippers are notified of flight critical shipments.
68. While a workstand section was being moved during assembly of a spacecraft module, a wheel on the workstand caught on a floor joint, causing the workstand to pivot and strike the module propulsion system radiator.	Inadequate work control in that the workstand was being moved with the help of an electric work saver and there were no restraints employed to prevent erratic movement of the workstand.	Prohibit use of assisting equipment which cannot be controlled with required precision. Require strategic placement of adequate restraints to prevent erratic movement of workstands during their movement around flight hardware.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
69. While moving a spacecraft module control unit, a forklift went over a bump; unit bounced, breaking the pallet and fell 2-3 feet to the pavement, then rolled 5 feet in front of the forklift, resulting in damage to the unit.	Inadequate work control in that the movement of the unit was undertaken without proper securing to the pallet and forklift.	Require that forklift transport procedures on critical/high value spacecraft hardware include the equipment for tie-down before movement. Require all forklift operators handling such items to be certified.
70. During off-loading of a crated vehicle stage helium ambient sphere by forklift from a truck, the sphere crate was dropped due to imbalance and insecurity on the forklift, resulting in loss of the sphere for production use.	Personnel error in that the operator apparently misjudged the balance of the crate as it was being lifted and possibly did not use long enough forks. Contributing causes were failure to use straps or restraining devices while handling flight critical hardware, failure to clearly mark the shipment as critical hardware and to inform the shipper, and failure to properly supervise unloading of critical equipment.	Ensure that all critical program hardware shipments are clearly marked on the crate as critical equipment. Require crated critical equipment to be clearly marked with CG locations and lifting points. Require personnel involved in handling critical equipment to be trained and certified for their job. Ensure adequacy of supervisory control during forklift handling of critical equipment to ensure use of correct fork lengths and attention to load balance.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
71. During installation of an ascent stage in a work-stand, one of four hydraulic lifting jacks failed due to hydraulic leak allowing the corner of the stage to drop approximately one inch. There were no personnel injuries or flight equipment damage.	Procedural deficiency in the selection of the jacks used in that they were prone to sudden failure due to hydraulic leak. Contributing was inadequate work control in that the procedural requirement to position the jack ram locking ring to limit any stage drop to 1/8 inch was not complied with.	Prohibit use of marginal/deficient handling/positioning gear in movement of essential program equipment. Identify such gear as safety critical and establish formal design/engineering control for procurement and selection. Require supervisory review of handling/positioning procedures with handling team prior to movement of essential equipment; maintain supervisory control during movement operation.
72. While transporting 4 drums on a pallet in a manufacturing receiving area, a forklift struck and broke one corner of a fiberglass container placed in the passageway and slightly damaged spacecraft Control and Display Panel inside. There were no injuries.	Deficient receiving area procedures which failed to provide for adequate protection of in-transit program essential equipment.	Require periodic (at least quarterly) safety reviews/surveillance of receiving area/warehouse procedures and activities to ensure segregation of fragile material not requiring mechanized handling equipment from heavy bulky material; to ensure adequate passageways are provided for transit of handling equipment.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
73. While lifting a spacecraft hydraulic accumulator from its shipping container, the heavy end slipped from the mechanic's grasp and fell 6 to 8 inches, damaging an electrical connector attached to a potentiometer within the reservoir.	Personnel error due to improper handling. Contributing was failure by supervision to determine the adequacy of methods and protection being used while removing the accumulator from its shipping container.	Require that unpacking procedures for items of flight hardware and components include a step for supervision/inspection determination as to the need for use of any special handling or protective measures, prior to proceeding with unpacking operations.
74. During a helium transfer operation, the truck driver attempted to move the tube trailer, while it was still connected to the supply system, resulting in damage to the high pressure flex hose, the system manifold, the line leading away from the parking area, and the trailer discharge manifold.	Inadequate work control in that the trailer was reconnected to the system for leak checks, after it was called to be moved by the test support crew, and the driver on arrival was not so informed. Contributing was personnel error since the driver did not visually determine that trailer was disconnected.	Require that warning or caution signs/flags be placed on front and rear of trailers while connected to a transfer manifold, and permit removal only after the joint inspection by both the truck driver and the supervisor of the supply system.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
75. While slow towing a helium rail car, a trackmobile derailed, damaging a mechanical track switch and sustaining minor structural damage. The switch had to be replaced.	Inadequate design of the control levers since all three were the same color, only $1\frac{1}{4}$ " apart, and were not equipped with a positive safety lock to prevent inadvertent movement. Contributing was personnel error in that the rubber wheels were placed in the "down" position erroneously, thereby disengaging the flanged track wheels.	Require human factors/safety review/analysis of manual control systems designs during their development to ensure man/machine compatibility; provide safety locks on manual control levers. Require training and certification of transport/handling personnel.
76. During installation of portable clean rooms in a test tower, a hoist cable caught the reflector of a fluorescent light fixture, pulling loose the reflector and two 48-inch lamps. The lamps broke, scattering glass on a space vehicle. There was potential for mercury contamination of the vehicle.	Failure to follow required procedures in that workmen did not adequately monitor cable clearance during operations. Contributing was failure to provide protection for the space vehicle during hoisting operations.	Designate all hoisting and lowering operations near flight systems as safety critical and require safety inspection of rigging and system protection prior to commencing operations. Ensure that safety training and awareness programs positively emphasize the critical nature of hoisting/handling operations on or near flight hardware.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
77. During inspection of an instrumentation flight module after removal from storage, two indentations in the exterior structure were found. The damage was minor.	Improper storage and handling techniques in that the module was apparently stored with insufficient clearance between the unit and the storage station post, which caused a gash in the dust cover to be pressed into the side of the unit. Contributing was personnel error in not exercising due care in storage operations.	Require formal storage procedures and specifications for critical end items. Require QC inspection to ensure that critical end items are stored in accordance with specifications.
78. During stage rotation from vertical to horizontal position in preparation for shipment from the manufacturing facility, the protective cover of the stage feed line contacted the upper structure of a nearby forklift, resulting in minor damage to the cover.	Inadequate work control in that sufficient clearance for the stage rotation path was not established prior to movement.	Ensure that move conductors exercise rigid control of area operations during movement/repositioning of flight vehicles. Require barricading placarding of area operations prior to start of move.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
79. During transporter movement of spacecraft sub-assemblies within a plant, the transporter struck the top of a doorway, causing minor damage to the sub-assemblies.	Personnel error in that the driver did not make a visual check prior to driving through the doorway.	Require full stop visual check for adequate clearance when moving flight hardware and program equipment through doorways. Provide clearance caution and warning placards on doors and exits used by plant transport vehicles.
80. During removal of a dynamic test article from manufacturing checkout facility building, the mobile crane handling the aft end of the unit was overloaded, causing the front (tractor) end of the crane to rise off the ground and permitting several feet of uncontrolled movement of the flight unit. No damage or personnel injuries occurred. However, accident/injury potential was high.	Inadequate functional verification procedures for verifying the safe operation of the crane, which failed to consider the effect of motion on the crane's carrying capacity. Verification under load had been performed only under stationary conditions.	Ensure that procedures for all moving of critical flight hardware include requirements for pre-use functional certification of transporting equipment both under load and motion conditions. Require periodic review and certification of preparation and readiness procedures associated with "critical move" operations.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
81. During receiving inspection at a NASA Center, a mission module was found to have a high level of radiological contamination. Although no damage or injuries resulted from this incident, a similar situation could result in a serious accident.	An unauthorized modification, in that maintenance personnel replaced the 1/4" thick plastic shield on the instrumentation panel with a 1/16" thick shield which warped and, during transport, vibrated enough to rub radioactive paint off the panel. Contributing was an inspection deficiency in that the shipment was not inspected and approved by the Radiological Safety Officer prior to dispatch.	Prohibit substitution of non-standard materials in all critical hardware or flight equipment without prior approval. Require engineering hazard analysis prior to approving such material substitutions. Ensure that all radioactive shipments are labeled as hazardous and require inspection and approval by Radiological Safety Officer.
82. During Highway transport, a cargo of high-value electronic equipment broke loose from the tie-down ropes aboard a truck and the equipment fell over onto the bed of the truck and some on to the side of the road. Two fuse distribution racks were destroyed.	Procedural errors by both the trucker and the shipper. Trucking operator did not comply with procedures for proper tie-down and protection of high-value/program-critical equipment while in transit, and the shipper did not notify the trucker that the load to be transported was high-value/critical, as required. Contributing cause was material failure in that the tie-down rope broke, because it was worn and not of required working strength.	Require formal safety inspection of all packing and loading operations involving high-value/critical end-item hardware. Require safety inspection of all trucks and certification of all drivers included in transport of high-value/critical end item hardware. Ensure that truckers are notified and aware of those shipments which contain high-value/critical end item hardware. Require safety inspection and verification of adequacy of tie-down ropes and cables.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
83. During movement and positioning of a stage transporter at a manufacturing facility, the driver backed the equipment into a stanchion, damaging the access ladder to the forward truck steering cab.	Inadequate work control in that procedures requiring stanchion removal prior to moving vehicle were not followed and communications were relayed by both observer and supervisor, causing driver misunderstanding.	Require checklist verification by move conductor or supervisor that all pre-move procedures have been followed prior to moving transporter or major end item hardware. Require one observer for each side during transporter movement and ensure that only one person relays instructions to driver.
84. While guiding a hydraset to the floor in a manufacturing and assembly facility, employee's finger was caught between the load and the floor, resulting in the loss of 1-1/4" of finger.	Inadequate work control since the load was set down before ascertaining that the individual guiding the operation was clear and ready for load's contact with the floor.	Require that procedures for lowering and hoisting operations be periodically reviewed to assure they are adequate for current operations. Ensure that supervision is adequate and present during such operations.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
85. While being transported from storage on a flat four-wheeled dolly, a VHF ranging console fell off when a dolly wheel slipped into a crevice at the entrance of an elevator, resulting in minor damage to the console, and injury (broken leg) to one employee. Extensive checkout testing had to be performed on the console.	Inadequate procedures for handling and transporting high value equipment in that the load was not secured, the skid roller dolly was not an approved piece of equipment for transport of high value equipment, and clearance space between elevator and floor was not properly bridged.	Require that transport equipment be certified and approved for transport of critical hardware items and ensure periodic re-inspection. Require that formal procedures and checklists be utilized in movement of any critical hardware.
86. During assembly of a thermal systems unit (TSU), a cable assembly in the rigging hoisting tool failed when a swaged cable loop pulled loose, dropping the TSU cannister 4 feet to the floor, causing minor structural damage. No personnel injuries.	Material failure in that a swaged cable connection which had been properly proof tested 8 weeks earlier suddenly failed under load. Contributing causes were possible improper distribution of the load and possible contamination of the cable sleeve with lubricant from the wire cable.	Avoid the use of swaged cable connection in hoisting assemblies used for moving critical hardware. Require all such assemblies be designed with U-bolt wire rope clips for the cables. Establish procedures for safety inspection to verify proper condition of hoisting tools prior to each use. Determine CG for each load prior to lift and adjust rigs accordingly.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
87. During receiving operations, a vacuum pumping unit was being removed by forklift from a truck when the unit suddenly tipped toward and struck the truck bed, resulting in extensive external and internal damage to the unit.	The primary cause was inadequate handling techniques in that the forklift operator used forks which did not extend the full width of the shipping pallet and failed to detect the resulting load imbalance. Contributing causes were failure to mark the shipment as critical equipment and lack of supervision of critical handling operations.	Designate critical program equipment handling operations as safety critical and require training and certification of personnel. Require all program critical equipment to be clearly marked as such for shipment and ensure that such shipments are marked with CG locations and lifting points. Ensure adequacy of supervisory control during forklift handling of essential equipment, to ensure use of correct fork lengths and attention to load balance.
88. During manufacturing, a launch vehicle digital computer page assembly was inadvertently dropped while being hand-carried in a process laboratory, resulting in minor damage to the assembly and a non-flightworthy disposition.	The primary cause was inadequate handling techniques in that flight critical hardware was not protected from inadvertent damage during transport/handling. Contributing causes were failure to designate the page assembly as flight critical, and failure to inform personnel that the assembly was for flight use.	Require positive protection of program critical hardware during transport/handling in process laboratories/facilities; require use of padded carts in lieu of handcarry between process stations; minimize manual handling; ensure that critical hardware is identified as such.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
89. During manufacturing handling operations, the cover of a container holding a thin-walled spacecraft He tank hit the tank when a workman dropped it into the supposedly empty container. There was no damage.	Personnel error in that no visual check of the shipping container content was made before dropping in the cover. Contributing was lack of external markings indicating critical and fragile nature of contents.	Designate critical end item handling and transport operations as safety critical and require all personnel involved to be trained and certified. Require visual verification of contents prior to moving or inserting anything into equipment containers.
90. During the handling of a stage tank assembly, the forward and aft tank domes were damaged slightly by the tank handling rings.	Inadequate maintenance and inspection of handling equipment since the heads of the screws which attach the rubber protective pads to the handling rings had surfaced through the pads and caused the scratches.	Ensure adequate maintenance of specialized equipment used with flight hardware, and require a pre-use inspection.
91. During shipping preparation operations, out-gassed hydrogen/oxygen from a recently discharged silver/zinc battery in a hermetically sealed drum was ignited by a spark generated by the scraping of the battery against the side of the drum and exploded, blowing the lid from the drum, charring dessicant bags within the drum, and causing minor injury to one person.	Inadequate handling/transportation/storage techniques in that the battery was placed in the drum too soon after discharge; (it is characteristic of silver/zinc batteries to outgas both hydrogen and oxygen for several hours after discharge). Also, the battery was not secured inside the container.	Ensure silver/zinc battery shipment procedures require a delay of not less than 48 hours after discharge before sealing in shipping container. Require batteries to be secured inside shipping containers.

SECTION X
TRANSPORT/HANDLING

<u>Accident/Incident Description</u>	<u>Causes</u>	<u>Recommended Preventive/Corrective Action</u>
92. During transport operations a parked, un-attended tractor-trailer rig containing high value flight support equipment rolled down-grade through a fence, causing minor damage to the rig, but no damage to the cargo.	Personnel error in that the driver failed to secure the parked vehicle in accordance with approved procedures.	Require use of a checklist for operation and parking of transport vehicles containing program critical/high-value hardware, and establish a safety training and awareness program for drivers to motivate compliance.

APPENDIX

GLOSSARY OF ABBREVIATIONS, ACRONYMS AND TERMS

ACE	-	Automatic Checkout Equipment
ASI	-	Apollo Standard Initiator
ASME	-	American Society of Mechanical Engineers
CG	-	Center of Gravity
CO ₂	-	Carbon Dioxide
CRS	-	Cold Rolled Steel
DB	-	Design Burst
ECS	-	Environmental Control System
EO	-	Engineering Order
GH ₂	-	Gaseous Hydrogen
GN ₂	-	Gaseous Nitrogen
GSE	-	Ground Support Equipment
He	-	Helium
Hz	-	Hertz (cps)
KOH	-	Potassium Hydroxide
LH ₂	-	Liquid Hydrogen
LN ₂	-	Liquid Nitrogen
LOX	-	Liquid Oxygen
N ₂ O ₄	-	Nitrogen Tetroxide
LUT	-	Launcher Umbilical Tower
O ₂	-	Oxygen
OCP	-	Operational Checkout Procedure
PSI	-	Pounds Per Square Inch
PSIA	-	Pounds Per Square Inch Absolute
PSIG	-	Pounds Per Square Inch Gauge
QC	-	Quality Control
QD	-	Quick Disconnect
Q&RA	-	Quality and Reliability Assurance
RCS	-	Reaction Control System
R&D	-	Research and Development
RF	-	Radio Frequency
RPM	-	Revolutions Per Minute
SCAPE	-	Self Contained Atmospheric Protective Ensemble
SCFM	-	Standard Cubic Feet Per Minute
TC	-	Test Control/Test Conductor
TCD	-	Test Checkout Directive
TCP	-	Test Checkout Procedure
TPS	-	Test Preparation Sheet
TPI	-	Threads Per Inch
TV	-	Television
TVD	-	Toxic Vapor Disposal
UDMH	-	Unsymmetrical Dimethylhydrazine
VDC	-	Volts, Direct Current

APPENDIX (CONTINUED)

- Accident - A type A or B mishap as defined in the NASA Safety Manual, NHB 1700.1 (VI)
- Incident - A mishap of less than accident severity as defined in the NASA Safety Manual, NHB 1700.1 (VI)
- Cryogenics - The science of producing and the application of low temperature processes below minus 150° F and the techniques involving handling, storage and usage of liquified gases. Examples are hydrogen, oxygen and helium.
- "D" Water - Distilled water.
- Dewar - A double walled metal vessel or tank, with an evacuated space between walls, used for storing fuels and propellants in a liquid state.
- Hardware - Any program component, subsystem, system, module, stage or vehicle, plus any facility equipment and property, ground support equipment (GSE) and other used in direct support of program hardware.
- Software - Any formalized written policy, directive, procedure, plan, specification, requirement or analysis prepared as an essential tool in the conduct of program activities.
- "Hoke" Bottle - A small pressure vessel or container used in obtaining, handling and transporting gases and liquids for sampling.
- "K" Bottle - A portable pressure cylinder or tank commonly used as a pressure source.
- "Kluge" - A frequently used slang term for a temporary or unauthorized installation.
- Program Phase - The four phases of a major research and development/operations program as defined in the NASA Phased Project Planning Guidelines, NHB 7121.2, August 1968 Edition.
- Program Activities- Tasks, work, functions and responsibilities associated with program hardware development/operations as defined in NASA Phased Project Planning Guidelines, NHB 7121.2, August 1968 Edition.