AEROSPACE REPORT NO.
ATR-72(7316-01)-1, VOL. II-2

N73-11879

Advanced Missions Safety

Volume II: Technical Discussion

Part 2, Experiment Safety - Guidelines

CASE FILE COPY

Prepared by
SYSTEMS PLANNING DIVISION

15 October 1972

Prepared for
OFFICE OF MANNED SPACE FLIGHT
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C.

Contract No. NASw-2301

Systems Engineering Operations
THE AEROSPACE CORPORATION

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VOLUME II - TECHNICAL DISCUSSION

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PREFACE

This study on Advanced Missions Safety has been performed as Task 2.6 of Contract NASw-2301, entitled "Advanced Space Program Analysis and Planning." The task consisted of three subtasks.

Subtask 1 —	Space Shuttle Rescue Capability
Subtask 2 —	Experiment Safety
Subtask 3 —	Emergency Crew Transfer

Each subtask is an entity not related to or dependent upon any activity under either of the other two subtasks.

The results of Task 2.6 are presented in three volumes.

<u>Volume I</u>: <u>Executive Summary Report</u> presents a brief, concise review of results and summarizes the principal conclusions and recommendations for all three subtasks.

<u>Volume II</u>: <u>Technical Discussion</u> is in three parts, each providing a comprehensive discussion of a single subtask.

<u>Part 1</u> provides an assessment of Earth Orbit Shuttle (EOS) capability to perform a rescue mission. It treats several concepts for augmenting this capability and increasing EOS rescue mission utility.

<u>Part 2</u> presents an analysis of potential hazards introduced when experimental equipment is carried aboard the EOS. It identifies safety guidelines and requirements for eliminating or reducing these hazards.

Part 3 discusses the applicability and utility of various means of emergency crew transfer between a disabled and a rescuing vehicle.

Volume III: Appendices is in two parts, each devoted to an individual subtask. Part 1 contains detailed supporting analysis and backup material for Subtask 1, and Part 2 contains similar material for Subtask 2. Volume III is of interest primarily to the technical specialist.

Since the reader is not necessarily interested in all three subtasks, each part of Volumes II and III is a separate document.

All calculations were made using the customary system of units, and the data are presented on that basis. Values in the International System of Units (SI) are also given. Data taken from reference sources are presented in the system of units employed in the original reference.

The Advanced Missions Safety Task was sponsored by NASA Headquarters and managed by the Advanced Missions Office of the Office of Manned Space Flight. Mr. Herbert Schaefer, the study monitor, provided guidance and counsel that significantly aided the effort. Mr. Charles W. Childs of the Safety Office, NASA Headquarters, and Miss Ruth Weltmann of the Aerospace Safety Research and Data Institute, NASA-Lewis, also provided valuable contributions by reviewing results of the Experiment Safety Study and making positive suggestions for improving visibility of the results.

SUMMARY OVERVIEW

In contrast to safety considerations in experiment ground facilities, which emphasize experimenter safety first, an experiment laboratory in space has to give prime safety considerations to the operational functioning of the Orbiter to enable a safe crew return.

In ground facilities, hazardous experiments are separated from other experiments and personnel. For space operations, experiment equipment of a hazardous nature may be densely packed, because flight costs are high. For this reason, special attention has to be given to potential interferences and interactions such as overheating, permeating fields, spurious signals, high voltage potential, etc. Such interaction between experiments could lead to a malfunction of otherwise safe equipment and might influence the safe operation of the Orbiter.

Many hazardous materials on board the Orbiter, such as cryogenics, storable propellants, etc., will add to the hazards of some of the experiments and the crew. The location of such materials in relation to any experiment or Orbiter equipment, as well as the access and egress routes for the experimenters, require serious consideration.

In contrast to most ground laboratories, the Orbiter structure outside the crew compartment can withstand a pressure difference of only a few psi. Therefore, experiments with components of a potential high pressure or explosive source have to be constrained, shielded, or safed to prevent inadvertent activation by other experiments.

Toxic and hazardous materials (especially in gaseous or powder form), which present a health hazard to men or which can damage materials or equipment, may have to be double-contained with special environmental conditioning systems, as complete cleanup of contaminants in zero gravity might be impossible to achieve.

Venting of effluents into space, even in small amounts, will create a thrust that has to be counteracted if the Experiment Module or the Orbiter are to remain in a given orbit and to be prevented from tumbling. Thus, effluent outlets should be designed and located so that any undesired thrust is compensated by a counteracting thrust. If this cannot be achieved in an emergency, sufficient Orbiter thrust should be available to keep the Orbiter on course, even if all effluent has to be vented by emergency relief in one direction. Similar considerations apply also to the case of rotating equipment producing reaction torques.

Many of the experiments being considered for shirtsleeve operation will require venting of one or more fluids because the experiments are conducted in an artificial environment that has to be maintained for crew life support. Different fluid lines require prominent marking, ready accessibility for repair, and arrangement to permit convenient access or egress. All fluid lines require markings and connectors that are unique to any one fluid.

Many of the experiments being considered have high voltage components with the potential of fire, shock, etc. which could result in injury to the crew and damage to the Orbiter. The clear indication of the operational status of such components is required. In case of emergency, provisions for automatic shutdown and rapid discharge after shutdown are required. Ground circuits should be avoided.

Emergency situations resulting from experiment equipment and/or its operation that could lead to Orbiter damage and/or loss require immediate assessment by the Orbiter crew. This can be accomplished by providing warning signals in the crew compartment which indicate the hazard, severity, location, etc. Normal procedures provide the commander with the authority to determine actions necessary to save the Orbiter and crew. This may involve sacrificing an experiment, an Experiment Module, and perhaps even a crew member, if the emergency warrants such drastic means and the Orbiter and most of the crew can be saved by such an action.

Radiation sources, such as radioisotopes, X-rays, lasers, etc. which can cause injury to men and damage to materials, equipment, experiments, and the operation of the Orbiter, should be clearly marked, monitored, shielded, and located so that no interference is possible under normal operating conditions. Emergency procedures and plans should be prepared and executed, if an emergency or malfunction is indicated by the monitoring system.

In ground facilities, the safety plan for any complex experiment usually identifies start-up, operating, and normal and emergency shutdown procedures. For the case of an Orbiter, where a number of experiments might be operated simultaneously, safety procedures should consider not only single experiments but also the interactions of all experiments to be operated at any one time. A certain shutdown procedure might be safe for one experiment but might create an emergency situation in another experiment, thus endangering the Orbiter and crew. Such procedures might indicate, for example, that if an emergency occurs in experiment A, experiment B has to be shutdown prior to taking action on experiment A. In another situation, the Orbiter may be required to make a certain maneuver before shutdown action can be taken on either experiment, in order to ensure the safety of the Orbiter.

In the case of hazardous experiment equipment such as lasers and X-rays, there should be a trade-off study made to determine whether the experiment should be conducted within or exterior to the Experiment Module or Orbiter. If located within the Experiment Module, the experimenter can closely supervise the experiment operations and assure compliance with all safety procedures. If located exterior to the Module or Orbiter, docking or EVA may be required. Such operations also have safety implications, such as collisions and EVA hazards.

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1. INTRODUCTION

1.1 BACKGROUND

A major NASA objective is to utilize manned space flight capability for the benefit of our nation and mankind. To further this objective, a number of experiment programs have been defined. These experiments are described in the "Reference Earth Orbital Research and Applications Investigations" (Blue Book), Ref. 1. This broad-based experiment program definition encompasses the disciplines of astronomy, physics, earth observations, communications/navigation, materials science and manufacturing, technology, and the life sciences.

Present plans place complete dependence on the Space Shuttle for transporting such scientific and application payloads into space and returning them (where appropriate) from earth orbit. Additionally, the Orbiter element of the Shuttle is required to deploy and retrieve payloads in some instances; in other cases, the Orbiter functions as a primary base of operations for an attached experimental payload. In all cases, the nature of the experiment payloads and their potential for introducing or precipitating hazards which endanger the safety of experimenters and/or the Orbiter and its crew are of obvious interest. Therefore, this study was undertaken to investigate the safety aspects of in-space experiments performed in connection with the Space Shuttle.

1.2 STUDY OBJECTIVES

The objectives of the study were:

a. Analyze the potential emergency situations created by carrying experiment equipment aboard a Space Shuttle.

b. Identify safety guidelines and requirements for eliminating or reducing hazards to the Space Shuttle and its crew which may be introduced by the experiment equipment and its operations.

1.3 STUDY SCOPE

The safety analysis considered all mission phases from the launch pad through to deployment, free flight (where applicable), experiment operations, retrieval, and final disposition. Also considered were the interactions of the experiment equipment and experiment operations with Experiment Modules (Pallet, MSM, RAM, Sortie Module, etc.) and the Space Shuttle, other payloads within the Orbiter cargo bay, and associated satellites.

2. PRIMARY PARAMETERS AFFECTING EXPERIMENT SAFETY

The parameters affecting safety during experiment activities conducted on or near the Space Shuttle Orbiter are functions of:

a. The nature and operation of the Experiment

b. The experiment and support equipment

c. The accommodation mode of the Experiment Equipment within the Shuttle Orbiter

The following sections briefly discuss significant aspects of these Shuttle/ Experiment interactions and give a summary of some of the primary parameters affecting experiment safety.

A detailed treatment of Experiment Equipment, support requirements, experiment operations, and hazards analyses is presented in Vol. III, Part 2.

2.1 EXPERIMENT EQUIPMENT AND SUPPORT REQUIREMENTS

This safety effort is based on Experiments and Experiment Equipment identified as Space Shuttle payloads in the "Blue Book" (Ref. 1) and the SOAR study (Ref. 2).

Seven scientific disciplines with related first level functional program elements (FPEs) are identified in the "Blue Book." Experiment categories of these disciplines are shown in Table 2-1. Specific Experiment Equipment, support equipment, and materials used for performing the Experiments are discussed in Vol. III, Part 2.

Several operational modes of Experiment Modules will be involved. These include a module attached to a Space Station or a Space Shuttle Orbiter (Shuttle-Sortie mission mode) or a free-flying module. Figure 2-1 shows a schematic of various Experiment Modules in deployed configuration.

Table 2-1. Blue Book FPE Experiment Categories

Astronomy

- X-Ray Astronomy (A-1)
- Advanced Stellar Astronomy (A-2)
- Advanced Solar Astronomy (A-3)
- Intermediate Size UV Telescopes (A-4)
- High Energy Stellar Astronomy (A-5)
- IR Astronomy (A-6)

Physics

- Space Physics Research Laboratory (P-1)
- Plasma Physics and Environmental Perturbations Laboratory (P-2)
- Cosmic Ray Physics Laboratory (P-3)
- Physics and Chemistry Laboratory (P-4)

Earth Observations

- Earth Observations Facility (ES-1)

Communications/Navigation

- Communications/Navigation Research Facility (C/N-1)

Materials Science and Manufacturing

- Materials Science and Manufacturing in Space (MS-1)

Technology

- Contamination Measurements (T-1)
- Fluid Management (T-2)
- Extravehicular Activity (EVA) (T-3)
- Advanced Spacecraft Systems Tests (T-4)
- Teleoperations (T-5)

Life Sciences

- Medical Research Facility (LS-1)
- Vertebrate Research Facility (LS-2)
- Plant Research Facility (LS-3)
- Cells and Tissues Research Facility (LS-4)
- Invertebrate Research Facility (LS-5)
- Life Support and Protective Systems (LS-6)
- Manned System Integration (LS-7)

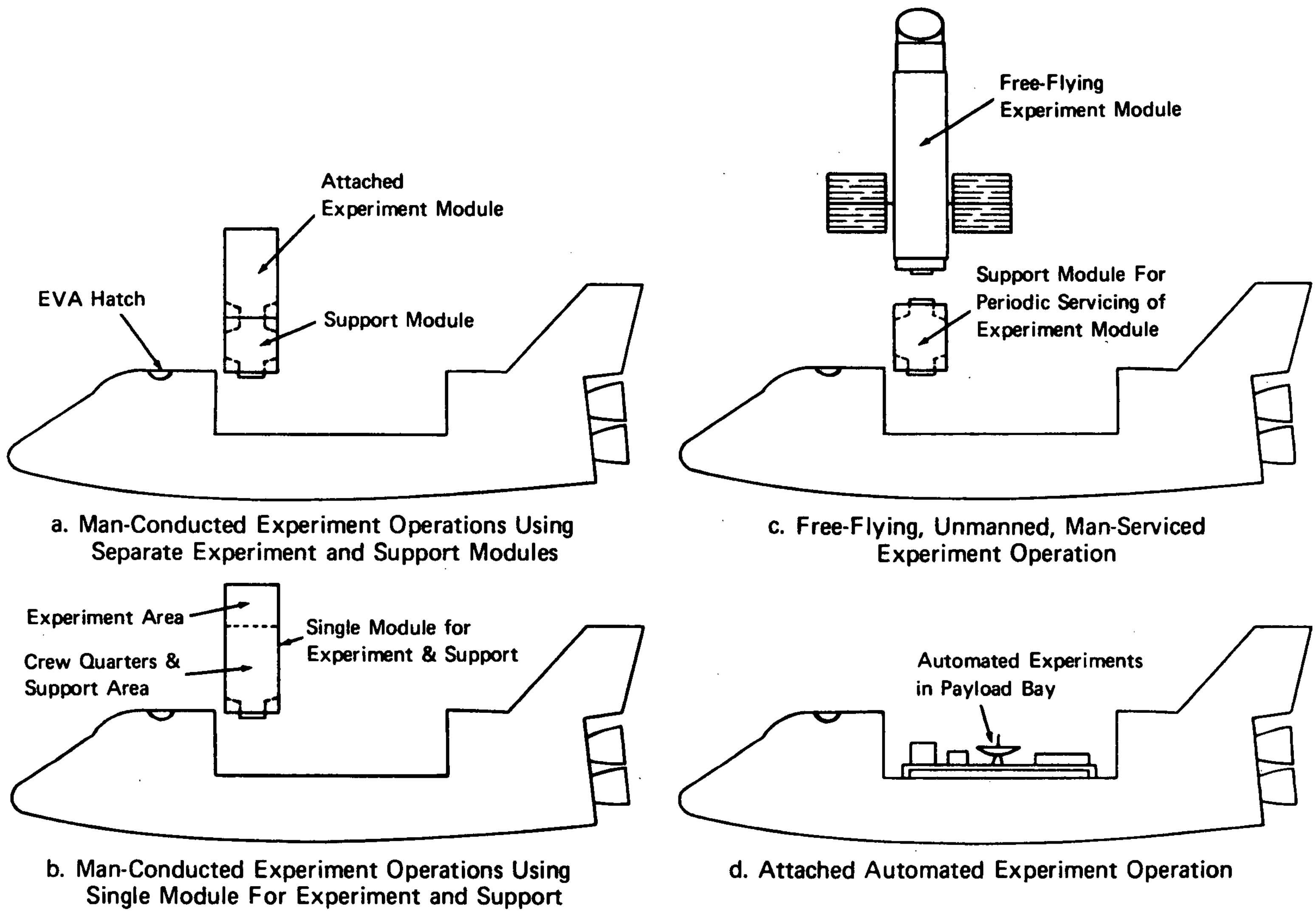


Fig. 2-1. Several Operating Modes for Space Shuttle Orbiter-Sortie Operations (Ref. 1)

Sortie missions may have the Experiment Equipment either mounted on a Pallet or contained within or attached to a manned Mission Support Module (MSM). Figure 2-2 shows the arrangement within the Orbiter cargo bay of several mission classes.

The SOAR study further divided the experiments into 56 Sub-FPEs or payload elements (see Table 2-2). That study also addressed delivery, service, and retrieval of automated spacecraft, four of which are shown in Fig. 2-3.

2.2 SUMMARY OF PRIMARY PARAMETERS AFFECTING EXPERIMENT SAFETY

The primary parameters which affect experiment safety are summarized in Table 2-3. Emphasis is directed to the inherent characteristics of Experiment Equipment and its operations which can cause a potential hazard due to a change in environmental conditions and/or energy. Also given are the principal hazards directly associated with the Experiment Equipment and its operation.

Many of the Experiments involve high voltage equipment, such as TV, imaging tubes, inverters, pulsers, etc. Such equipment can cause personnel injury due to shock, burns, etc., and/or fire due to high voltage arcing if combustible materials are present.

A number of Experiments are designed for operation under vacuum conditions. These require either EVA or a compartment that can be pressurized for set-up, deployment, calibration, etc. Other equipment requires a pressurized compartment for normal operations with the capability for reducing pressure to space vacuum for certain experiment activities. Some Experiments require high pressure gases which could become explosive sources.

Temperature extremes associated with the space environment as well as cryogenics can cause structural and environmental hazards, including

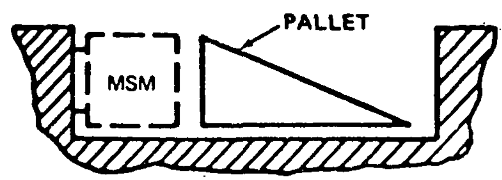
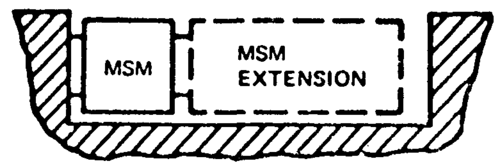
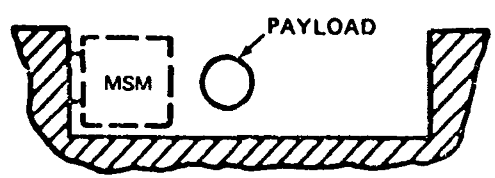
MISSION CLASS	DESIGN OPTIONS	FEATURES
SORTIE	 	PALLET-MOUNTED EQUIPMENT SHUTTLE-MOUNTED CONTROLS AND DISPLAYS OPTIONAL MSM SUPPORT
	 	PRESSURIZED MSM INTERNAL EXPERIMENTS MSM EXTENSION MODULE GROWTH VERSION
AUTOMATED SPACECRAFT	 	AUTOMATED SPACECRAFT FREE-FLYING RAM'S SHUTTLE-MOUNTED CONTROLS AND DISPLAYS OPTIONAL MSM

Fig. 2-2. SOAR/Shuttle Mission Classes (Ref. 2)

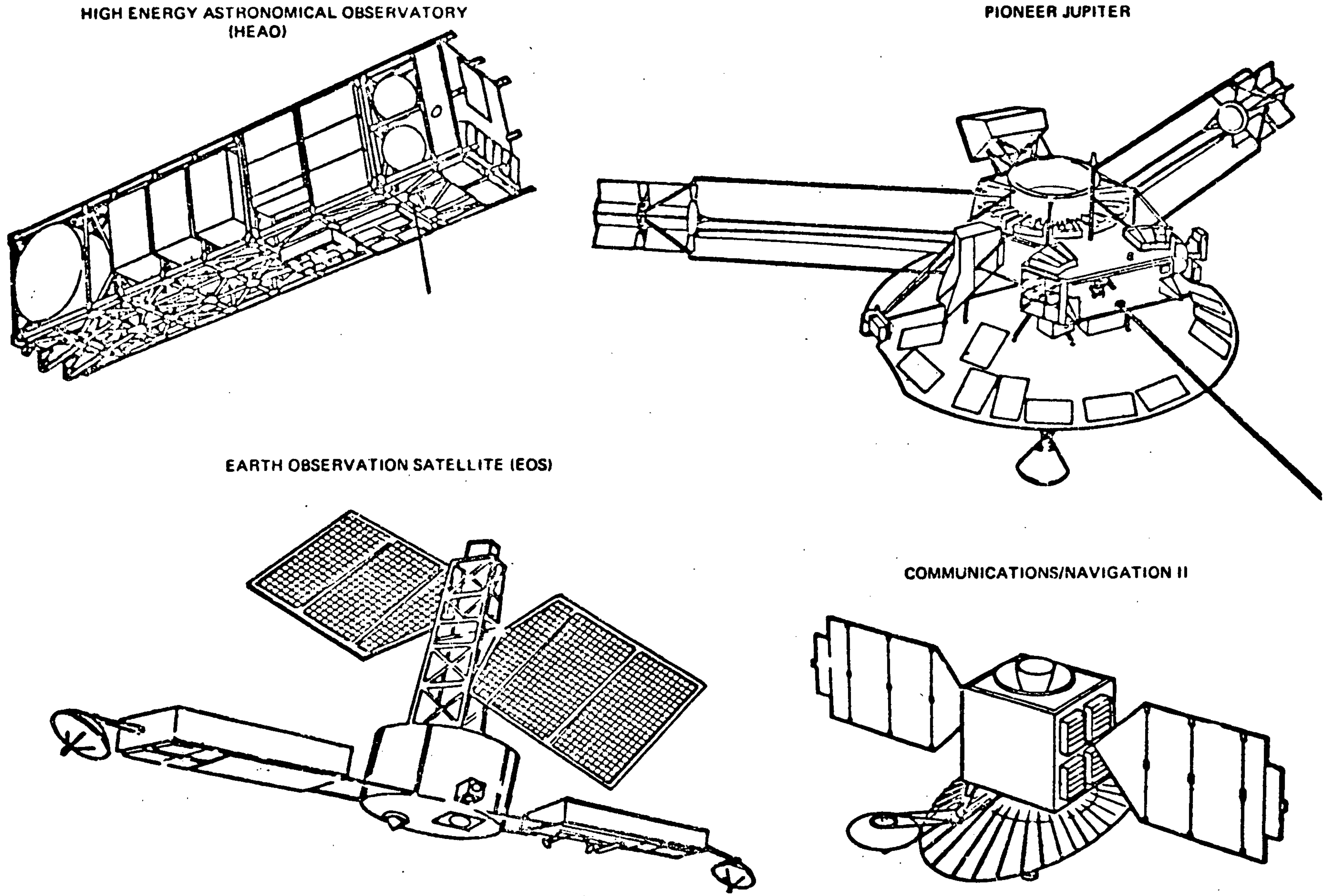


Fig. 2-3. Selected Representative Satellite Payloads (Ref. 2)

Table 2-2. FPE-Sub-FPE Relationships (Ref. 2)

Astronomy		
A-1	X-Ray Stellar Astronomy	
A-2	Advanced Stellar Astronomy	
	A-2A	Intermediate Stellar Telescope
A-3	Advanced Solar Astronomy	
	A-3A	1.5m Photoheliograph/0.25m XUV Spectroheliograph/0.5m X-Ray Telescope
	A-3B	Solar Coronagraph
	A-3C	Photoheliograph
	A-3D	X-Ray Spectroheliograph
	A-3E	UV Long Wave Spectrometer
A-4	Interemdiate Size UV Telescopes	
	A-4A	0.5m Narrow Field UV Telescopes
	A-4B	0.3m Wide Field UV Telescopes
	A-4C	Small UV Survey Telescopes
A-5	High Energy Astronomy	
	A-5A	Lower Energy Experiment.
	A-5B	Higher Energy Experiment
A-6	IR Telescope	
Physics		
P-1	Space Physics Research Lab	
	P-1A	Atmospheric and Magneto Science
	P-1B	Cometary Physics
	P-1C	Meteoroid Science
	P-1D	Thick Material Meteoroid Penetration
	P-1E	Small Astronomy Telescopes
P-2	Plasma Physics and Environmental Perturbation Lab	
	P-2A	Wake Measurements from Station and Booms
	P-2B	Wake Measurements from Subsatellites
	P-2C	Plasma Resonances
	P-2D	Wave Particle Interactions
	P-2E	Electron and Ion Beam Interaction
P-3	Cosmic Ray Physics Lab	
	P-3A	Lab Without Total Absorption Device
	P-3B	Lab With Total Absorption Device
	P-3C	Plastic/Nuclear Emulsions
P-4	Physics and Chemistry Lab	
	P-4A	Airlock and Boom Experiments
	P-4B	Flame Chemistry and Laser Experiments
	P-4C	Test Chamber Experiments
Earth Survey		
ES-1	Earth Observation Facility	
	ES-1A	Meteorological and Atmospheric Science
	ES-1B	Land Use Mapping
	ES-1C	Air and Water Pollution
	ES-1D	Resource Recognition
	ES-1E	Natural Disasters
	ES-1F	Ocean Resources
	ES-1G	Minimum Payload
COM/NAV		
C/N-1	Communications/Navigations Facility	
	C/N-1A	COM/NAV Subgroup A
	C/N-1B	COM/NAV Subgroup B
Materials Science and Manufacturing		
MS-1		
	MS-1IA	5-Day Group, Biological
	MS-1IB	5-Day Group, Levitation
	MS-1IC	5-Day Group, Furnace
	MS-1ID	5-Day Group, Small and Low Temp
	MS-1IIA	30-Day Group
	MS-1IIB	30-Day Group
	MS-1IIC	30-Day Group
	MS-1IIIA	Space Station Group
	MS-1IIIB	Space Station Group
	MS-1IIIC	Space Station Group
	MS-1IIID	Space Station Group
	MS-1IIIE	Space Station Group
Technology		
T-1	Contamination Measurements	
	T-1A	Contamination Package 1
	T-1B	Contamination Package 2
T-2	Fluid Management	
	T-2A	Long Term Cryogenic Storage
	T-2B	Short Term Cryogenic Storage
	T-2C	Slosh Propellant
	T-2D	Non-Cryogenic Storage 1
	T-2E	Non-Cryogenic Storage 2
T-3	EVA	
	T-3A	Astronaut Maneuver Unit
	T-3B	Manned Work Platform
T-4	Advanced Spacecraft Systems Test	
	T-4A	Long Duration Systems Tests
	T-4B	Medium Duration Tests
	T-4C	Short Duration Tests
T-5	Teleoperations	
	T-5A	Initial Flight
	T-5B	Functional Manipulation
	T-5C	Ground Control
Life Science		
LS-ST/A	Minimal Medical Research Facility (Station)	
LS-ST/B	Minimal Life Science Facility (Station)	
LS-ST/C	Interim Life Science Facility (Station)	
LS-ST/D	Dedicated Life Science Facility (Station)	
LS-SH/A	5-Day Life Science Facility (Shuttle)	
LS-SH/B	10-Day Life Science Facility (Shuttle)	

Table 2-3. Primary Parameters Affecting Experiment Safety (Sheet 1 of 3)

	Experiment (FPE*)	Inherent Characteristics									Associated Hazards					
		Mass (Wt) kg (lb)	Volume $m^3 (ft^3)$	Power kW	Voltage	Pressure	Temperature	Permeating Fields	Hazardous Materials	Ignition Source	Fire	Explos./Implos.	Decomp./Over-Pressure	Contam. (Incl. Toxicity)	Radiation	EVA
Astronomy	X-Ray	4240 (9350)	72 (2540)	0.53	High	Space Vacuum	Low (Cryogen.)	--	Cryogen.	(1)	√	√	√	Imaging Tubes	--	--
	Stellar	5930 (13200)	75 (2620)	0.86	High	Space Vacuum	--	--	Film & Processing Chemicals	(1)	√	--	--	Chemicals; Imaging Tubes	--	--
	Solar	3470 (7340)	71.5 (2500)	0.97	High	Space Vacuum	--	--	--	(1)	√	--	--	Imaging Tubes	--	--
	Intermediate Size UV Telescope	1680 (3370)	11.5 (395)	0.63	High	Space Vacuum	--	--	Film & Processing Chemicals	(1)	√	--	--	Imaging Tubes; Chemicals	--	--
	High Energy Stellar	3400 (7510)	24 (845)	0.49	High	Space Vacuum	Low (Cryogen.)	--	Solid Cryogen.; Methane	(1)	√	√	√	Imaging Tubes; Argon, Methane	--	--
	IR	1500 (3300)	74 (2614)	0.3	High	Space Vacuum	Low (Cryogen.)	--	Cryogenics (LNe, LHe)	(1)	√	√	√	Imaging Tubes	--	--
Physics	Space Physics Research Lab.	2648 (5800)	3.6 (127)	1.0	High	Pressurized Compartment (14.7 psia)	--	--	Film; NH_3, ICN	(1) Heaters; Battery	√	√	Sub-Satellite Collision (2)	NH_3, ICN; Imaging Tubes	--	--
	Plasma	550 (1210)	1.4 (50)	0.3	High	Hi-Press. Cold Gas for Sub-Satellite	--	VLF RF X-Ray	Sub-Satellite Propellant	(1) Battery	√	√	Sub-Sat. Collision; Balloon Inflation (2)	Imaging Tubes; Propellants	VLF RF X-Ray	--
	Cosmic Ray	15700 (34500)	137 (5720)	0.71	High	Hi-Press. Gases for Spark Chamber	Low (Cryogen.)	Magnetic	Plastic & Nuclear Emulsions; LHe	(1) Spark Chamber	√	√	√	Argon, Methane; Emulsions	Magnetic	--
	Physics and Chemistry	2700 (6200)	10 (350)	9.6	High	Hi-Press. Gases for Gas Jets	Low (Cryogen.)	Magnetic; Laser	Propel.; Chemicals; LHe; Film	(1) Heaters; Gas Jets; Laser	√	√	(2)	Imaging Tubes; Chemicals	Laser; Magnetic	--

Notes: (1) High-Voltage Arcing
(2) Open or Leaking Scientific Airlocks
* Functional Program Element

Table 2-3. Primary Parameters Affecting Experiment Safety (Sheet 2 of 3)

	Experiment (FPE*)	Inherent Characteristics: Mass (Wt) kg (lb)	Volume $m^3 (ft^3)$	Power kW	Voltage	Pressure	Temperature	Permeating Fields	Hazardous Materials	Ignition Source	Associated Hazards: Fire	Explos./Implos.	Decomp./Over-Pressure	Contam. (Incl. Toxicity)	Radiation	EVA
Earth Obs.	Earth Observations Facility	(3490 (7720)	26 (930)	4.5	High	Pressurized Compartment (0-15 psia)	Low (Cryogen.)	--	LN_2; Film & Process. Chemicals	(1)	√	√	√	Imaging Tubes; Chemicals	--	--
Comm/Nav	Comm/Nav Research Lab.	756 (1670)	5.2 (184)	2.64	High	Pressurized Compartment (0-14.7 psia)	--	RF (SHF & VHF); Laser	Film	(1)	√	√	Sub-Satellite Collisions (2)	--	RF; Laser	--
MS/MS	Materials Science Research Lab.	215-3700 (4750-8300)	22.3-38.2 (788-1350)	5.0	High	Pressurized Compartment (0-15 psia)	High Temp. Process. (Casting Melting)	--	Toxic Serums; Liquid Metals & Glasses	(1) Furnaces; Hot Liquids	√	√	√	Biological Serums; Vaporized Substances	--	--
Technology	Contamination Measurements	190 (420)	0.68 (24)	0.7	High	Space Vacuum	--	--	Film	(1)	√	--	(2)	Imaging Tubes; Collected Contaminants	--	--
Technology	Fluid Management	63-2393 (140-5250)	0.6-59 (22-2095)	0.17 to 4 Max.	High (TV)	Pressurized Propellant Tanks	Low (Cryogen. LO_2, LH_2)	--	Film; Cryo and Storable Propellants	(1) Battery	√	√	√	Storable Propellants	--	-
Technology	EVA: Astronaut Maneuvering Unit	2 Units 120 (265)	6 (20)	0.37 Max.	--	Pressurized GO_2 Bottle	--	--	GO_2	Battery	√	√	(3)	--	Space Radiation	√
Technology	EVA: Maneuverable Work Platform	2 Units 1448 (3200)	60 (200)	2 kW-h per Mission	--	Pressurized GN_2 Tanks	--	--	N_2H_4 Propellant; Film	Battery	√	√	Docking Collisions	N_2H_4	Space Radiation	√
Technology	Advanced Spacecraft Systems Test	670 (1500)	1.3 (46)	2.8	--	Vacuum "Glove Box" Operations	Fire Sensing and Suppression Experiments	--	Propellants; Combustible Gases	Electrolysis Cell; Combustion	√	√	(2)	Propellants; Gases	--	-
Technology	Teleoperations	670 (1500)	4.4 (155)	0.3	High (TV)	Pressurized GN_2 Tanks	--	--	--	(1) Battery	--	√	S/C Collisions (3)	--	--	--

Notes: (1) High-Voltage Arcing
(2) Open or Leaking Scientific Airlocks
(3) Open or Leaking EVA Airlocks
* Functional Program Element

Table 2-3. Primary Parameters Affecting Experiment Safety (Sheet 3 of 3)

	Experiment (FPE*)	Inherent Characteristics									Associated Hazards					
		Mass (Wt) kg (lb)	Volume $m^3 (ft^3)$	Power kW	Voltage	Pressure	Temperature	Permeating Fields	Hazardous Materials	Ignition Source	Fire	Explos./Implos.	Decomp./Over-Pressure	Contam. (Incl. Toxicity)	Radiation	EVA
Life Sciences	Medical Research	3010 (6675)	44 (1560)	3.55	--	Lower Body Negative Pressure Chamber	--	--	Noxious or Poisonous Reagents; Radio-isotopes	(4)	√	--	√	Reagents; Radio-isotopes	Nuclear	--
	Vertebrate Research	1063 (2345)	38 (1340)	4.07	--	--	Low (Cryogen.)	--	Chemicals; Cryogenics	(4)	√	--	Cage Rupture	Feces; Debris; Chemicals; Insects	--	--
	Plant Research	2232 (4920)	16 (565)	3.42	--	--	--	--	Chemicals	(4)	--	--	Cage Rupture	Pollen; Debris; Chemicals	--	--
	Microbiology Research	2081 (4600)	14.3 (515)	3.31	High (TV)	--	--	--	Isotopes; Chemicals; Bacteria	(1)(4)	--	--	Incubator Rupture	Isotopes; Chemicals; Bacteria; Biologicals	Nuclear	--
	Invertebrate Research	2044 (4520)	14 (495)	3.28	--	--	Low (Cryogen.)	--	Chemicals	(4)	--	--	Cage Rupture	Debris; Chemicals	--	--
	LSPS (Life Support and Protective Systems)	3339 (7360)	25 (883)	3.66	--	Space Vacuum	--	--	Toxic & Caustic Liquids, Gases; Flammable Gases	(4)	√	√	(3)	Toxic & Caustic Liquids & Gases	Space Radiation	√
	MSI (Manned System Integration)	2668 (5900)	31.4 (1110)	3.71	--	Space Vacuum	--	--	--	(4)	--	--	Centri-fuge Mal-function (3)	--	Space Radiation	√
Satt. Pay-Loads	HEAO, EOS, Pioneer-Jupiter, COMM/NAV II	--	--	--	High (TV)	Pressurized Propellant Tanks (GN_2, GHe)	Low (Cryogen., LO_2, LH_2)	--	N_2H_4, LO_2, LH_2, Solid Propellants, Isotopes	(1) Battery, Pyrotechnics	√	√	√	Propellants	Nuclear (5)	--

Notes:
(1) High-Voltage Arcing
(3) Open or Leaking EVA Airlocks
(4) Electrical Equipment Arcing in Laboratory (Lower than "High" Voltage)
(5) Radioisotope Thermal Generator (RTG) in Pioneer-Jupiter Satellite
* Functional Program Element

pressure changes which might cause explosions or implosions. High temperature processing operations, such as metal melting, casting, etc., combustion experiments, and the fire sensing and suppression experiment could produce not only hazardous environmental temperature changes but could also become a fire source if not properly contained.

Several Experiments involve the use of RF transmitters, X-ray machines, high powered magnets, and lasers which have permeating fields. These fields are a potential source of personnel injury (radiation effects), and by producing spurious noise signals may also adversely affect the operation of sensitive equipment, including Orbiter operational and control equipment or instrumentation. Strict control of the periods of operation for such Experiments may have to be imposed in order to eliminate such potential hazards.

The nature of some of the Experiments involved introduces a wide range of hazardous materials. These materials include cryogenics, propellants, film, processing chemicals, plastic and nuclear emulsions, toxic serums, radioisotopes, etc. They are a potential source of personnel injury, contamination, fire, explosion, control instrument malfunction, etc.

Other potential ignition sources are spark chambers, heaters, batteries, gas jets, lasers, hot liquid metals and glasses, etc. The location of these sources on board the Orbiter relative to combustible materials must be a prime safety consideration for each Orbiter mission configuration.

Sub-satellites represent a potential for collisions which can result in spacecraft decompression and critical structural damage.

A comprehensive list of specific hazard sources, causative events, factors, and conditions leading to potentially hazardous results is presented in Vol. III, Part 2. The principal implications arising from the interactions between Experiments and Experiment Equipment, the Orbiter, and Experiment Modules (Pallet, MSM, RAM) are addressed in Section 3.

3. EXPERIMENT INTERACTION SAFETY CONSIDERATIONS

Performing experiments in connection with the Space Shuttle Orbiter could result in emergency situations of well-recognized categories. The presence and operation of Experiment Equipment do not cause hazards that are significantly different from previously known space hazards. They do, however, introduce an extremely broad range of specific hazard sources which are additive to the hazards inherent in space operations.

The number of discrete hazards that can occur due to equipment or operation of any experiment class (FPE) is related to the nature of the Experiment. Materials Science and Manufacturing Experiment Modules, for example, have more equipment of a hazardous nature than Earth Survey Experiment Modules. However, this class-to-class differentiation loses significance when multiple experiment categories are integrated into any one Experiment Module. The definition of hazards with their resultant potential emergency situations have to be based on the equipment that will actually be used. The synergistic effects and the interactions between Experiment, Module, and Orbiter equipment and instrumentation must be considered in order to reach a complete definition of potential hazards and emergency situations attributable to a specific Experiment.

The discussions in Section 2 regarding primary parameters affecting experiment safety were necessarily directed to first-order effects because the Experiments and their interfaces are not completely defined at present. Equally important, from a safety standpoint, are the hazards arising from less well defined potential interactions due to the integration of the diverse Experiment Equipment. This section discusses interactions involving an Experiment and related operational equipment that could have an impact on the safety of the crew and the Orbiter.

3.1 EXPERIMENT-TO-EXPERIMENT INTERACTIONS

Within a given scientific discipline, such as Astronomy, the number and characteristics of hazard sources varies as a function of the accommodation mode (Pallet, MSM, or RAM). The number and types of scientific equipment which can be carried and operated depend upon the available volume, weight limitation, capacity for pressurization, thermal control, contamination control, etc. For multiple-experiment missions, there is also the variation in scientific and supporting equipment required for the different Experiments.

The hazards associated with the Experiments and their equipment, as shown in Table 2-3, lead to a formidable list of potential emergencies. The less demanding Experiments (in terms of both experiment and support equipment) produce fewer hazards, while more complex or multiple-experiment combinations produce a greater number of potential hazards.

In addition to the hazard sources that exist for any discrete scientific Experiment Equipment, interference with other scientific or operational equipment can endanger safety. For example, field-coupling effects (magnetic, RF, nuclear, etc.), which could produce synergistic interactions, and thus could activate or deactivate sensors, detectors, or control loops of other Experiment Equipment, could result in:

a. Hazardous component/subsystem malperformance
b. Erroneous sequencing of hazardous equipment operation
c. Requirement for manual experiment operator control (to avoid hazardous occurrence) at a time when an operator is not available for such control
d. Overloading of electrical power system
e. Inadvertent start-up and/or shut-down of multiple Experiment Equipment

3.2 EXPERIMENT-TO-MODULE INTERACTIONS

Emergency situations could also be produced by interactions which are related to equipment configuration and placement within the Experiment Module (Pallet, MSM, RAM, etc.) in which the equipment is carried and operated.

Therefore, consideration must be given to:

a. The density of packaging of Experiment Equipment within a Module

b. The environment within the Module (i.e., pressurized or unpressurized)

c. Placement relative to Module (i.e., whether "inside" Module or attached "externally")

d. Degree of reliance on sensors, detectors, control loops, etc. which are "experiment-specific" equipment, or which are central equipment provided by the Module or the Orbiter

e. Effects of special remedial means included in the Module (e.g. special fire detection and suppression equipment)

f. Start-up and shut-down procedures

The conduct of scientific experiments in ground laboratories devoted to a variety of experiments generally allows separation of the different Experiment Equipment, provisions for protective enclosures or walls between equipment and operators, and isolation of caution and warning detectors as well as control loops from the primary power source and experiment control systems and stations.

The comparatively small volume available for Experiment Equipment within a Module aboard the Space Shuttle Orbiter suggests centralization of auxiliary equipment, such as central power conditioning and control units, data processing units, caution and warning detectors and alarm systems, etc., in order to maximize the number of experiment packages and equipment for any Module and mission. Such an approach is justifiable because it minimizes costs and maximizes the scope of experiment activity that can be undertaken during any one space mission. However, it could lead to a safety problem because of interactions. Wall-to-wall experiment and control equipment, with its potential for hazardous interactions and synergistic effects, suggests that a careful and systematic systems integration approach for Modules housing Experiment Equipment should be followed.

3.3 EXPERIMENT-TO-ORBITER INTERACTIONS

The hazard-causing potential of Experiment Equipment can also provide interactions with the Orbiter operational equipment and cause direct hazards due to potential synergistic effects on diverse equipment within a Module or the Orbiter.

All of the subsystems essential for the safety and well-being of the Orbiter and its crew can be detrimentally affected by Experiment Equipment either directly or indirectly, regardless of the location of the equipment. For example, the electrical power system could be overloaded or rendered inoperable; communications with other spacecraft and the ground could be interrupted or cut; the Orbiter guidance and navigation system could be rendered inaccurate or ineffective, etc.

During experiment operations, the orientation of the Experiment Module and Experiment Equipment with respect to the Orbiter is of importance. For example, the efflux from overboard vents could contaminate the cargo bay and/or sensitive Orbiter elements (lenses, sensors, etc.).

3.4 INTERACTION SUMMARY

The experiment program foresees a large variety of Experiments aboard the Space Shuttle on any one flight. The multitude of interactions between the Experiment Equipment, experiment operations, Accommodation Modules, experimenters, and Shuttle Orbiter operational equipment and crew creates many potential hazards. Malfunctioning Experiment Equipment presents discrete hazard sources; the potential hazards created could propagate to other Experiment Equipment and supporting equipment and to operational equipment of the Accommodating Module and the Orbiter.

Implementation of effective preventive or remedial measures to eliminate or reduce to an acceptable level the safety risk of such experiment-related hazards requires an integrated system approach. Such an approach demands the preparation and coordination of failure mode and effect analyses and

4. EXPERIMENT SAFETY GUIDELINES

4.1 GUIDELINE SELECTION AND FORMULATION CRITERIA

The Safety Guidelines listed in this chapter are expressed as brief summary statements or expressions. The guidelines are intended to be used as safety inputs into design, integration, and planning activities for all phases of the Space Shuttle related experiment program and they can also be used as safety checklists.

The judicious application of these Guidelines will be a step toward accomplishing "Man-Compatibility" between Experiment Equipment and Experiment operation with the Space Shuttle Orbiter. The term, "Man-Compatibility," implies that man-rating safety criteria shall be applied to those systems and functions of a payload and its contents which could create a hazard to the Orbiter and its crew, while the payload is within the cargo bay, during its deployment, and while it is in the vicinity of the Orbiter.

Vol. III, Part 2 describes how the Safety Guidelines were developed.

4.2 THE HAZARD REDUCTION PRECEDENCE SEQUENCE

The Safety Guidelines are not presented in order of absolute value as safety measures. However, generally accepted safety practice indicates that the order of precedence that should be followed in applying them is:

a. Design features to eliminate the hazard
b. Design features to control the hazard
c. Use of protective safety devices
d. Use of warning devices
e. Implementation of operational procedures

4.3 USE AND INTERPRETATION OF THE SAFETY GUIDELINES

4.3.1 Format of the Guidelines

Figure 4-1 illustrates the guideline format and gives the explanation for the abbreviated headings and codes used.

4.3.2 General Remarks

Many of the general Safety Guidelines (Table 4-1) apply to all Experiments and Experiment Equipment; their applicability should be considered before considering the specific Guidelines (Table 4-2). The latter include only Guidelines which either:

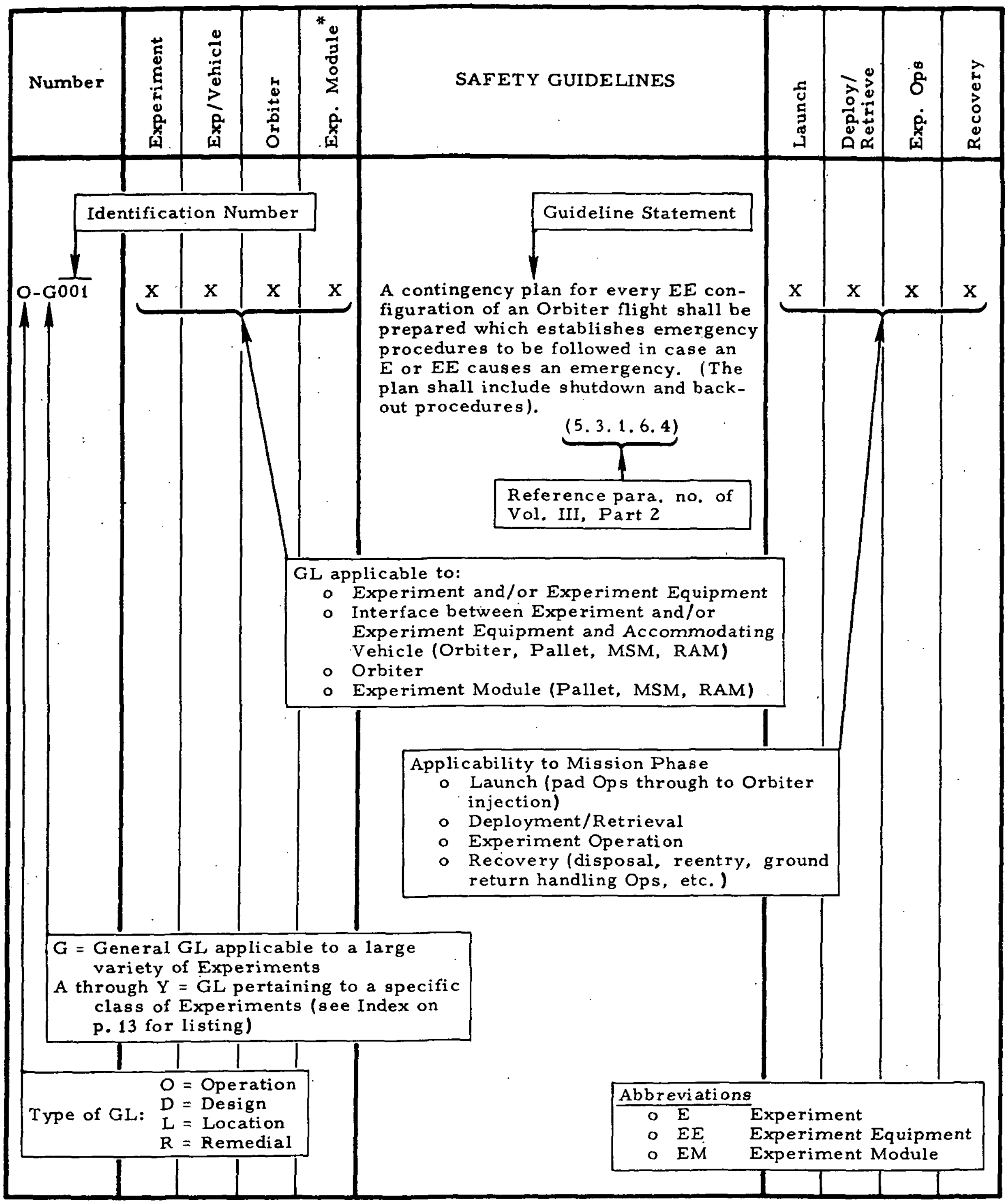
a. Are only applicable to the specific Experiment or equipment group, or

b. Require wording sufficiently different from a general guideline statement to communicate a particular safety measure desired for the Experiment or equipment group, or

c. Deserve particular emphasis for the Experiment or equipment group addressed.

The Guidelines in a given area, such as Design (D) are not always independent and may also require considerations as to Location (L) and Operations (O). For example, for an item to be jettisoned, location of the item within the Module or the Orbiter and the required operations for safely jettisoning that item under emergency conditions require considerable attention. In some cases, the application of a Guideline to several areas has been indicated by adding one or more type identification letters. The Location (L) has received emphasis in the Guidelines because contrary to usual space practice, the integration effort establishing the location of Experiment Equipment within a Module or the Orbiter may not occur until long after the equipment proper has been designed.

It is also emphasized that a Guideline may consider only one of several possible approaches to enhance safety in a given potentially hazardous situation.



*Pallet, MSM, RAM, etc.

Figure 4-1. Illustration of Guideline Format

Furthermore, under certain conditions, some Guidelines may be conflicting with respect to each other or Experiment requirements. Trade-off analyses would have to be performed to determine the most satisfactory solution in each instance. These trade-off analyses are beyond the scope of the present study.

The level of detail in the preventive measure assessment is in many cases sufficient to overlap to a certain degree with generalized spacecraft safety criteria, even though the present analysis was restricted to identifying Experiment-related safety criteria. Typical overlap areas are:

a. Electrical systems (cable insulation, connectors, grounding, power distribution paths, redundancy, shielding, routing, etc.)
b. Airlocks (mechanical design, materials, sealing provisions, etc.)
c. Vent systems (valves, regulators, location, pressure-relief, etc.)
d. Pressurized containers storing gases or liquids (valves, regulators, pressure-relief, vents, etc.)
e. Batteries (electrolyte containment, venting, etc.)
f. Solid propellants (safing, arming, etc.)
g. Minimum number of egress ports in a manned habitable compartment
h. EVA

The Guidelines within this report are intended to be supplementary to the generally accepted safety guidelines for manned space flight equipment and operations and the types of areas listed above are referred to in the general sense only.

4.4 SUPPLEMENTARY INFORMATION

Some of the results of recent studies conducted for NASA are directly applicable to experiment safety. They should also be considered during experiment design, experiment integration, mission planning, etc. These include:

a. The Prevention of Electrical Breakdown in Spacecraft (Ref. 4)
b. Safety in Earth Orbit (Ref. 5, 6, 7, 8)
c. Manned Space Flight Nuclear System Safety (Ref. 9)
d. Space Station Safety (Ref. 10)
e. Space Station Study, Experiment Safety (Ref. 11)

Four other documents, even though not specifically safety oriented, should also be of value:

a. Space Shuttle Baseline Accommodation for Payloads (Ref. 12)

b. Shuttle Orbiter/Payloads Monitor and Control Interface (Ref. 13)

c. Assessment and Control of Spacecraft Electromagnetic Interference (Ref. 14)

d. Shuttle Orbiter Applications and Requirements, Phase II (SOAR)(Ref. 15)

Table 4-1. Safety Guidelines – General Application (Sheet 1 of 11)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-G001 L O	X	X		X	The field strength (magnetic, RF, nuclear radiation, etc.) of any single EE or combination of EEs shall not cause any injury to the crew or interference with the operation of or damage to other EE and/or any EM or Orbiter systems or crew. (5.1.6.1)	X	X	X	X
D-G002	X	X		X	EE shall be designed to withstand rapid ΔP changes without causing a hazardous condition. (5.1.12.13)	X	X	X	X
D-G003	X	X		X	Fluid and electrical components of EE shall fail safe. (5.1.7.2)	X	X	X	X
D-G004	X	X		X	EE and other subsystems within an EM shall be configured and packaged for retention of integrity and containment of contents during the load and temperature environments of all mission phases, including all intact aborts. (5.1.12.10)	X	X	X	X
D-G005	X	X		X	Provisions shall be made to prevent EE and EMs from crushing the Orbiter cabin during an Orbiter crash landing which would not otherwise have resulted in catastrophic damage to the cabin.				X
D-G006	X	X		X	Failure of any subsystem within an EE or EM shall be contained and shall not propagate to the Orbiter. (5.1.12.11)	X	X	X	X
D-G007	X	X		X	All EE shall consider the number and types of hazard sources within the limited volume of an EM and their potential interactions and synergistic effects. (5.1.12.12)	X	X	X	X

*Pallet, MSM, RAM, etc.

Table 4-1. Safety Guidelines – General Application (Sheet 2 of 11)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-G008	X	X		X	E and EE integration in an EM shall include provisions for monitoring EE so that the crew can assess emergencies and take action. (5.3.5.1)			X	
D-G009	X	X		X	EE or combinations of EE shall be automatically shut down to prevent overheating. (5.1.4)			X	
D-G010	X	X		X	Fluid line connectors shall have connect/disconnect features which ensure fast operation, cleanliness of the connection, and positive locking. (5.1.7.2)	X		X	X
D-G011	X	X		X	Fluid connectors shall be individually marked and keyed to identify the nature of the fluid involved and to prevent mixing. (5.1.12.9)	X	X	X	X
D-G012	X	X		X	Fluid piping and connectors in an EM shall be accessible. (5.1.12.14)			X	
D-G013	X	X	X	X	Overboard vent systems shall be provided for those EE susceptible to pressure buildup or the accumulation of flammable, toxic, or noxious substances (e.g., batteries, dewars, gas bottles, furnaces, etc.) (5.1.1.1)	X	X	X	X
D-G014	X	X		X	Connectable vent provisions in an EM shall include a vent terminal board. (5.1.1.1)	X	X	X	X
D-G015	X	X	X	X	The overboard vent system shall have a capacity for venting individual and all EE, including separate vent lines as required by the fluid vented. (5.1.1.1)	X	X	X	X

*Pallet, MSM, RAM, etc.

Table 4-1. Safety Guidelines – General Application (Sheet 3 of 11)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-G016	X	X	X	X	Overboard vent systems shall be configured to: a. Avoid common or adjacent exit ports for combustible or reactive effluents. (5.1.1.2)	X	X	X	X
D-G017	X	X	X	X	b. Prevent vent efflux from entering the Orbiter cargo bay. (5.1.1.2)	X	X	X	X
D-G018	X	X	X	X	c. Prevent vent efflux in the vicinity of sensitive equipment (e.g., telescopes, camera lenses, gaskets, etc.) (5.1.1.2)			X	
D-G019		X	X		For flammable gases venting over-board, an igniter at the Orbiter venting port shall be considered for post landing ignition to assure that no flammable gas can envelop the Orbiter on the ground.	X			X
D-G020	X	X		X	Means shall be provided to permit controlled venting during critical operations (e.g., EVA, docking, etc.) which also permits a quick pressure relief of the vent system in case an emergency should arise during a no-venting period. (5.1.1.3)		X	X	
D-G021	X	X		X	Provisions shall be made to prevent EE operation in case of vent system malfunction. (5.1.8.1.1)			X	
D-G022 O			X	X	Electrical discharge means shall be provided to establish equipotential between the Orbiter and satellites or EMs to be retrieved. (5.1.8.5)		X		
D-G023	X	X		X	Automatic means shall be provided to discharge high-voltage EE after shutdown. (5.1.8.5)	X	X	X	X

*Pallet, MSM, RAM, etc.

Table 4-1. Safety Guidelines – General Application (Sheet 4 of 11)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-G024	X	X		X	The operation of high voltage EE shall be indicated prominently on the master experiment monitoring panel. (5.1.12.8)			X	
D-G025 L	X	X	X	X	No equipment whose malfunction could obstruct free passage shall be located, internally or externally, near crew access and egress passageways through airlocks, tunnel, and docking ports (e.g., pressure bottles, batteries, etc.). (5.1.12.15)		X	X	
D-G026	X	X	X	X	Whenever an Orbiter flight carries EE aboard which could cause a hazard for which the normally carried emergency equipment is not suitable, appropriate emergency equipment shall be provided (e.g., appropriate fire extinguishers, decontaminants, protective gear, antidotes, etc.). (5.1.8.8)		X	X	
D-G027 L O	X	X		X	Jettisoning of malfunctioning EE which might cause a major hazard to the crew or the Orbiter shall be considered (e.g., EE or EMs which cannot be fully retracted into the Orbiter, propellant tanks, subsatellites, etc.). (5.1.9)	X	X	X	X
D-G028 O	X	X		X	Provisions for dumping hazardous fluids in case of an emergency shall be considered. (5.1.9)	X	X	X	X
D-G029	X	X		X	If emergency dumping of fluids is determined to be a requirement, provisions shall be made so that dumping can be done during any phase of the mission, including the phase of aerodynamic flight of the Orbiter and on the ground.	X	X	X	X
D-G030	X	X		X	A modular approach shall be considered for the design of hazardous EE components to enable remote deployment and operations, and retrieval. (5.1.10)		X	X	

*Pallet, MSM, RAM, etc.

Table 4-1. Safety Guidelines — General Application (Sheet 5 of 11)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-G031 O	X	X		X	Special work areas shall be provided for Es which require containment of spills, disposal of wastes, venting of toxic gases, prevention of contamination, etc. such as glove boxes, double containment, etc. Such areas may require separate environmental control. (Applicable to Es such as film processing, biologicals, animal handling, toxic serums, radioactive materials, etc.) (5.3.1.4)		X	X	
D-G032	X	X		X	Manual interlocks shall be provided which require a knowledgeable act to operate EE. (5.1.8.1.2)			X	
D-G033	X	X		X	Safing shall be provided to prevent inadvertent actuation of EE that could result in a hazardous situation (e.g., equipment containing solid propellants, squibs, etc.). (5.1.3.1)	X	X	X	X
D-G034	X	X		X	Means for positive holding and securing of transportable equipment shall be provided. (5.1.11.1)	X	X	X	X
D-G035	X				EE containers for hazardous fluids, such as toxic liquids, emulsions, etc. shall have handles and lids with positive closures to prevent spills and contamination. (5.1.12.6)	X	X	X	X
D-G036	X				EE containers with removable lids containing hazardous materials (e.g., toxic fluids, serums, etc.) shall be prominently and permanently marked as to their contents and with warning and handling notes (which include antidote information). (5.1.12.9)			X	

*Pallet, MSM, RAM, etc.

Table 4-1. Safety Guidelines – General Application (Sheet 6 of 11)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-G037	X	X		X	Flammability requirements for materials in the EM shall be identical to those of the Orbiter except where an E requires a combustible material; in that case, precautionary measures shall be employed. (5.1.13.2)	X	X	X	X
D-G038	X	X		X	Hg shall be avoided in EE. If Hg is indispensable, accidentally escaped Hg must be prevented from entering habitable compartments (e.g. by locating it outside such compartments, double containment, etc.), as spilled Hg cannot be removed completely and will permanently poison the compartment atmosphere. (5.1.13.3)	X	X	X	X
D-G039	X	X		X	E with radioactive materials shall be performed in separate work areas which provide double containment, have environmental control, radiological monitoring and decontamination equipment, and waste storage and disposal provisions. (5.1.5.4)	X	X	X	X
D-G040	X	X		X	E and EE shall be designed for minimum EVA. (5.1.10)		X	X	
D-G041		X	X		Capability shall be provided to purge the Orbiter cargo bay in the event of accidental release of hazardous EE efflux into it. (5.3.2.2)	X	X	X	X
					Caution and Warning signals shall be provided. Their display (visual and/or aural) and location (on Orbiter flight deck or lower deck, or in EM) depends on the particular hazard condition and severity. The signals shall include:				
D-G042		X	X	X	a. changes in the EM atmosphere with regard to pressure, temperature, humidity, and incidences of fire or contamination. (5.3.4.1)	X	X	X	X

*Pallet, MSM, RAM, etc.

Table 4-1. Safety Guidelines – General Application (Sheet 7 of 11)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-G043	X	X	X	X	b. changes in EE temperature and/or pressure levels, where these parameters are indicative of EE operational safety. (5.3.4.1)	X	X	X	X
D-G044		X	X	X	c. status of EM airlock EC/LS pressure levels and door positions (5.3.4.1)		X	X	
D-G045			X	X	d. improper velocity and/or alignment of a docking spacecraft relative to the EM or Orbiter docking port. (5.3.4.1)		X	X	
D-G046			X	X	e. position and status of the Orbiter payload erection/retraction system. (5.3.4.1)		X	X	
D-G047	X	X	X	X	f. status of overboard vent system. (5.3.4.1)	X	X	X	X
D-G048	X	X		X	g. operation of hazardous EE (high voltage, strong permeating fields, etc.) (5.3.4.1)	X	X	X	X
D-G049	X	X		X	h. status of solid propellant safe-and-arm circuits. (5.3.4.1)	X	X	X	X
D-G050	X	X		X	All high pressure fluid lines shall be tied down to prevent whipping in case of a failure of the line or connections.	X	X	X	X
D-G051	X	X		X	Automatic relays for switching to back-up power shall respond also to gradual loss of primary power. (Applicable to EE for which power failure could create a hazard). (Suggested by Lunar Landing Training Vehicle Accident in 1971)	X	X	X	X

*Pallet, MSM, RAM, etc.

Table 4-1. Safety Guidelines – General Application (Sheet 8 of 11)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-G052	X	X		X	EM subsystem designs shall be based on at least a fail safe concept except for structure which shall be based on a safe life concept. Subsystem redundancy shall only be used to achieve mission success and fail safe design goals or to reduce cost. (Adapted from Sortie Lab. Guidelines and Constraints)	X	X	X	X
D-G053	X	X		X	Access shall be provided for all installed EE requiring short term periodic maintenance on the ground and on orbit. (Delays during launch or in orbit; feeding and drinking of animals, cage cleaning, etc.) (5.2.5.11)	X	X	X	X
D-G054 O		X	X	X	All docking ports shall be located so as to assure visual observation of the docking operations. (5.2.5.10)		X	X	
L-G001	X	X		X	EE producing heat shall be arranged in such a manner as to minimize thermal control requirements. (5.2.4.8)			X	
L-G002	X	X		X	Exteriorly mounted EE, such as booms, platforms, antennas, etc., shall be located away from docking ports to prevent potential collisions. (5.2.4.3)		X	X	
L-G003	X	X		X	The location of EMs and EE shall be such as not to interfere with any egress from or ingress to airlock hatches of the Orbiter tunnel (neither in the installed nor in the extended position). (5.2.5.9) (5.2.5.8)	X	X	X	X
L-G004	X	X		X	Sufficient space shall be provided when locating EE so as to allow an IVA suited man to pass by regardless of the position of movable exterior EE parts. (5.2.5.12)			X	

*Pallet, MSM, RAM, etc.

Table 4-1. Safety Guidelines – General Application (Sheet 9 of 11)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
O-G001	X	X	X	X	For each Orbiter flight, a contingency plan for its particular EE arrangement shall be prepared which outlines emergency procedures to be followed for the case of an E-related emergency. (This plan shall include shutdown and backout procedures). (5.3.1.6.4.1)	X	X	X	X
O-G002		X	X	X	One man in the Orbiter shall be responsible for implementing safety and contingency plans. (5.3.1.6.4.2)	X	X	X	X
O-G003	X	X	X	X	Schedules for loading/unloading and deployment/retrieval shall be prepared and implemented for EE. These schedules shall consider the particular safety requirements of each EE, such as environmental, structural, contamination etc. (e.g., isotope heat sources requiring thermal conditioning). (5.3.1.6.4.3)	X			X
O-G004	X	X		X	Startup and shutdown procedures shall be established for all EE. The sequencing shall minimize effects on other EE and have no adverse effects on Orbiter operating systems. (5.3.1.6.4.4)			X	
O-G005 L D	X	X		X	EE containing nuclear materials shall conform with established nuclear safety requirements. (5.3.1.6.4.5)	X	X	X	X
O-G006 D	X	X		X	Order-of-connection for EE shall be established for every fluid connection involving cryogenic, explosive, or flammable mixtures. (For example, (1) electrical; (2) H_2; (3) O_2.) Disconnection shall be analyzed on an individual basis. (5.3.1.6.4.6)			X	

*Pallet, MSM, RAM, etc.

Table 4-1. Safety Guidelines — General Application (Sheet 10 of 11)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
O-G007			X	X	Radiation dose-accumulation by the crew shall be monitored with accepted health physics equipment at all times to guard against excessive radiation from EE and natural sources. (5.3.1.1.1)	X	X	X	X
O-G008				X	Protective garments, gloves, face masks, etc., shall be worn by the crew when handling EE or contents capable of causing injury or illness by contact or inhalation. (5.3.1.1.2)			X	
O-G009 L D	X	X		X	EE posing severe risks (potential explosions, fire, open flames, release of ionizing radiation, liquid metals, release of toxic gases or vapors) should preferably be conducted on a free-flying EM. (5.3.1.2.1)		X	X	
O-G010	X	X	X	X	EE with strong RF or magnetic field sources shall not be transported on the same Orbiter flight with payloads having solid-propellant propulsive stages unless appropriate precautionary measures are incorporated. (See also D-G033) (5.3.1.5.2)	X	X	X	X
O-G011 D	X	X		X	All transportable containers in the EM shall be secured in their respective storage areas after use. (5.3.2.4)			X	
O-G012 D	X	X		X	EE and operations requiring immediate or concurrent measures to prevent hazardous situations shall be monitored and controlled on a continuous or scheduled basis (as appropriate). (5.3.5.1)		X	X	
O-G013 D			X	X	The total radiation level environment to which the Orbiter and EM have been subjected shall be monitored and controlled. (5.3.5.1)	X	X	X	X

*Pallet, MSM, RAM, etc.

Table 4-1. Safety Guidelines – General Application (Sheet 11 of 11)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/Retrieve	Exp. Ops	Recovery
O-G014 D	X	X	X	X	Es involving the use of chemicals within a pressure compartment shall be evaluated for the necessity of having their own independent environmental control system so as to prevent possible contamination of the EM or Orbiter by toxic gases or vapors. (5.3.1.5.4)			X	

*Pallet, MSM, RAM, etc.

Table 4-2A. Safety Guidelines — High-Temperature Sources

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES Gas jets, Combustors, Furnaces, Fire-sensing and Suppression Module, Liquid Metals and Glasses	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
					High temperature EE shall have available:				
D-A001	X	X		X	a. Purging and fire-suppression equipment. (5.1.2.1)	X		X	X
D-A002	X				b. Protective covers and guards. (5.1.8.2) (5.1.8.4)			X	
D-A003	X	X		X	c. Venting provisions. (5.2.3.3)			X	
D-A004	X	X		X	d. Double containment, depending on its nature.	X	X	X	X
O-A001	X	X		X	High-temperature EE shall be maintained deactivated until used for experimentation. (5.3.2.6)	X	X	X	X
SEE ALSO D-G013 D-G027 D-G030 D-G031 L-G001									

*Pallet, MSM, RAM, etc.

Table 4-2B. Safety Guidelines — Lasers

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES Laser Experiments; Laser-radar Equipment	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-B001	X	X		X	Shielding shall be provided to protect the crew and equipment from exposure to damaging laser radiation (should include absorbing material located between the laser beam target and the structure). (5.1.5.2) (5.1.8.4) (5.1.8.6)			X	
D-B002	X	X		X	Stops and interlocks shall be provided to prevent laser operation outside a shielded area. (5.1.8.3) (5.2.2.2)			X	
D-B003	X	X		X	The operation of laser EE shall be indicated prominently on the master experiment monitoring panel. (5.3.4.1)			X	
SEE ALSO:									
D-G032									

*Pallet, MSM, RAM, etc.

Table 2-4C. Safety Guidelines — Spark Chambers

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-C001	X	X		X	Spark chambers and associated A and CH_4 tanks shall be evaluated for being designed as self-contained units with the capability of remote storage and deployment, and of jettisoning. (5.1.9) (5.1.12.5)		X	X	
SEE ALSO: D-G013 D-G026 D-G027 D-G030									

*Pallet, MSM, RAM, etc.

Table 4-2D. Safety Guidelines — Permeating-Field Generators

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES Magnets, RF Transmitters	Launch	Deploy/Retrieve	Exp. Ops	Recovery
D-D001	X	X		X	The operation of RF generators and magnetic-field devices shall be indicated prominently on the master experiment monitoring panel. (5.3.4.1)			X	
D-D002	X	X		X	EE with permeating fields shall be shielded from sensitive EE, personnel and animals, and Orbiter systems, so as to preclude interference with operations or damage and injury. (5.2.4.1)			X	
O-D001	X	X	X	X	E using magnetic or RF fields may have to be scheduled to prevent interference with Orbiter operational control. (5.3.1.5.3)			X	
SEE ALSO: D-G001									

*Pallet, MSM, RAM, etc.

Table 4-2E. Safety Guidelines – Scientific Airlocks

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-E001	X	X		X	A Scientific Airlock and any associated deployment mechanisms shall permit jettisoning of hazardous objects contained within. (5.1.9)			X	
D-E002	X	X		X	An indication shall be provided for the open and closed door positions of a Scientific Airlock and for excessive leak rate of the airlock. (5.3.4.1)		X	X	
L-E001	X	X	X	X	A Scientific Airlock shall be located in the EM in such a manner that an open airlock door will not prevent Orbiter cargo bay door operation. (5.2.3.1)		X	X	X
SEE ALSO:									
D-G032									

*Pallet, MSM, RAM, etc.

Table 4-2F. Safety Guidelines — Subsatellites

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-F001	X	X		X	Consideration shall be given to the design of subsatellites which provides the capability for remote storage, deployment and jettisoning. Remote deployment can avoid the need for deployment through airlocks. (5.1.9) (5.1.10)		X	X	
L-F001	X	X		X	Subsatellites shall be located outside of habitable EM compartments. (5.2.1)		X	X	
SEE ALSO: D-G022 D-G023 D-G027 D-G030									

*Pallet, MSM, RAM, etc.

Table 4-2H. Safety Guidelines – Rotating Equipment

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES Scientific Centrifuges, Manned Centrifuges, Ergometer, Rotating Litter Chair	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-H001	X	X		X	Shielding shall be provided around rotating components for containment in case of breakup due to overspeed. (5.1.5.1)			X	
D-H002	X				A non-hazardous mode of failure which occurs prior to a potential catastrophic breakup of rotating components due to overspeed shall be incorporated. (5.1.7.1)			X	
D-H003 O	X	X	X	X	Means shall be provided to prevent the operation of rotating equipment unless the Orbiter attitude control system is operational. (5.1.8.1.1)			X	
D-H004	X	X		X	Means shall be provided to shut off rotating EE when its design speed is exceeded. (5.3.4.1)			X	
D-H005	X	X		X	A backup locking device shall be provided for rotatable EE in case of failure of the primary locking mechanism. (5.1.8.9)			X	
O-H001	X	X		X	Human centrifuge operations shall be monitored and controlled on a continuous basis. (5.3.5.1)			X	
SEE ALSO: D-G032 L-G004									

*Pallet, MSM, RAM, etc.

Table 4-21. Safety Guidelines — Telescopes

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES Optical, IR, UV, X-ray	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-I001	X			X	All direct viewing telescopes shall have means (such as a fast acting filter) to protect the viewer's eyes in case the field of view is inadvertently exposed to direct or reflected sunlight. (5.1.8.2)			X	
D-I002	X	X		X	All telescopes shall be provided with remotely operated lens covers so that they can be covered during non-use periods. (No EVA for routine covering and uncovering shall be permitted). (5.1.8.2)		X	X	
L-I002	X	X		X	Sufficient room shall be provided at the viewing end of a telescope so that the operator has free egress with the telescope locked in any position. (5.2.2.1)		X	X	
SEE ALSO:									
L-G004									

*Pallet, MSM, RAM, etc.

Table 4-2J. Safety Guidelines — Extendable/Retractable Devices

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES: Booms/Platforms/Antennas, Erection/Retraction Mechanisms	Launch	Deploy/Retrieve	Exp. Ops	Recovery
D-J001	X	X		X	Extendable EE shall be evaluated for the necessity of being jettisoned. (5.1.9) (5.3.3.1)		X	X	
D-J002	X	X		X	Means shall be provided to indicate operation of EE extension mechanisms. (5.3.4.1)		X	X	
SEE ALSO:									
D-G027									

*Pallet, MSM, RAM, etc.

Table 4-2K. Safety Guidelines – Balloons

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
O-K001 D	X	X		X	Balloons and balloon inflating devices shall be maintained in a deactivated state until use. The balloon and the inflating device shall not be connected until inflation. (5.2.4.4) (5.3.2.6)	X	X	X	X
SEE ALSO: D-G032 D-G033									

*Pallet, MSM, RAM, etc.

Table 4-2L. Safety Guidelines — Negative Pressure Source

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES Lower Body Negative Pressure Chamber (LBNPC)	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-L001	X	X		X	Attachment of a vacuum source to the LBNPC shall be impossible without having appropriate control provisions in the connecting line. (5.1.6.1)		X	X	
D-L002	X	X		X	Automatic means shall be provided for a controlled shutdown of the LBNPC experiment in the event the vacuum decreases below the permissible level. (5.1.8.1.1)			X	
O-L001	X	X		X	The LBNPC shall be maintained in a deactivated status until time for the experiment. (5.3.2.6)	X	X	X	X
SEE ALSO:									
D-G032									

*Pallet, MSM, RAM, etc.

Table 4-2M. Safety Guidelines – EVA-Use Devices

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES Astronaut Maneuvering Unit (AMU), Maneuverable Work Platform (MWP), Teleoperated Spacecraft	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-M001	X	X		X	Failure modes shall be non-thrusting for EVA EE propulsion systems. (5.1.7.1)		X	X	
D-M002	X	X		X	The EM shall be provided with external attach and holding means for EVA, EE and EVA men. (5.1.11.3)	X	X	X	X
L-M001	X	X		X	EVA EE shall be located exterior to habitable EM compartments, except for small devices which can be easily carried through an airlock. (5.2.1)	X	X	X	X
L-M002	X	X		X	Externally-mounted EVA EE shall permit unimpeded egress and access through an EVA hatch by men. (5.2.5.5)		X	X	
O-M001	X	X		X	AMU and MWP operations shall be conducted in the tethered mode unless the performance of an E requires otherwise. (5.3.1.6.2.1)			X	
O-M002	X	X		X	AMU and MWP propulsion subsystems shall be continuously monitored during E operations and deactivated upon indication of a malfunction. (5.3.1.6.2.2)			X	
SEE ALSO: D-G027 D-G030 D-G032									

*Pallet, MSM, RAM, etc.

Table 4-2N. Safety Guidelines — Solid Propellants

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES Solid Rocket Motors, Pyrotechnics, Squibs, Spin-up Rockets, etc.	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-N001	X	X		X	Safing mechanisms shall be provided to prevent inadvertent activation of solid-propellant-containing EE units. (5.1.3.1)	X	X	X	X
O-N001	X	X		X	All solid-propellant-containing systems shall be safed prior to ground installation or retrieval. (5.3.2.5)	X	X		
SEE ALSO: D-G032 D-G049									

*Pallet, MSM, RAM, etc.

Table 4-20. Safety Guidelines – Radiation Sources

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES X-ray Machines, Radioisotopes, Lasers, RF Transmitters, Radioisotope Thermal Generators (RTGs)	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-O001	X	X		X	Monitoring systems shall be provided for EE with radiation field sources. (5.3.4.1)	X	X	X	X
D-O002	X	X		X	Provisions shall be made for the storage and/or disposal of radioactive waste or other materials contaminated by isotopes,etc. (e.g. excreta of animals injected with tracer isotopes, biological samples, etc.). (5.1.5.4)			X	
SEE ALSO: D-G001 D-G027 D-G031 D-G032 D-G033 D-G039 D-B001 O-G005									

*Pallet, MSM, RAM, etc.

Table 4-2P. Safety Guidelines — Cameras and Equipment

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES Cameras, Film, Film Vault, Film Processor, Processing Chemicals	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
L-P001	X	X		X	Film, photochemicals, and film vaults shall be located away from potential ignition sources and remote from open habitable EM compartments. (5.2.5.2)	X	X	X	X
SEE ALSO: D-G031 D-G032									

*Pallet, MSM, RAM, etc.

Table 4-2Q. Safety Guidelines – Batteries

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
SEE D-G013									

*Pallet, MSM, RAM, etc.

Table 4-2R. Safety Guidelines – Electrically-Powered Equipment

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES TV, Inverters, Pulsers, Furnaces, Accelerators, Transmitters, etc.	Launch	Deploy/Retrieve	Exp. Ops	Recovery
<u>SEE</u> D-G001 D-G023 D-G024 D-G032									

*Pallet, MSM, RAM, etc.

Table 4-2S. Safety Guidelines – Biologicals/ Animals/Insects/Plants (Sheet 1 of 2)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES Cages, Cells and Tissues, Organisms and Cultures, Animals, Insects, Plants, Nutrient, Waste, etc.	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-S001	X	X		X	Holding and rearing cages containing a potentially hazardous atmosphere shall have provisions for controlled emergency venting in the event of a malfunction of the pressure regulating system of the cage. (5.1.1.1)	X	X	X	X
D-S002	X	X		X	Animal cage pressure shall be kept below that of the EM to avoid possible contamination of the EM atmosphere. The cage atmosphere return flow shall not pass through a habitable compartment unless the air has been cleaned. (5.1.4.2)	X	X	X	X
D-S003	X	X		X	Means shall be provided to prevent excreta of animals from floating in the cages, and to facilitate their removal and storage. (5.1.12.1)	X	X	X	X
D-S004	X	X		X	Cages shall have means, preferably automatic, for animal feeding and drinking on the ground as well as in orbit. (5.1.10) (5.1.12.1)	X	X	X	X
D-S005	X	X		X	Means shall be provided to permit cleaning animals and animal cages from excreta, vomit, lice, fleas, etc., both on the launch pad and in orbit. (5.1.12.1)	X	X	X	X
D-S006	X	X		X	All animal cages shall be designed with provisions to protect the inhabitants against injury from both their own movements and acceleration forces.	X	X	X	X

*Pallet, MSM, RAM, etc.

Table 4-2S. Safety Guidelines – Biologicals/ Animals/Insects/Plants (Sheet 2 of 2)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp Ops	Recovery
D-S007	X	X		X	Animal cages to be used for experiments involving radioactive tracers shall be designed to safeguard against the possibility of radiological contamination of the crew. (For example, cage isolation through an airlock, location in a double containment shell or a separate compartment, an independent EC/LS system, special means for removal and storage of animal excreta, means for decontamination, etc.). (5.3.1.4)			X	X
D-S008	X	X		X	All EM compartments containing microbiological experiments, and airlocks leading to those compartments, shall be monitored for contamination. Provisions for neutralizing microbes involved shall be considered. (5.3.1.4)	X	X	X	X
D-S009	X	X		X	Provisions shall be available for preserving and storing dead animals, insects, plant specimens, etc. (e.g., formaldehyde, storage bags, etc.). (5.1.12.2)			X	X
L-S001 D	X	X		X	All plant life shall be isolated so as to avoid contamination by pollen, leaves, etc. (5.3.1.4)	X	X	X	X
O-S001	X	X		X	Biological experimentation and uncaged animal, insect and plant handling operations shall be performed in special work areas. (See also D-G031). (5.3.1.4)			X	
O-S002	X	X		X	Animal feeding and cleaning devices shall be monitored on a scheduled basis. (5.3.5.1)	X	X	X	X
SEE ALSO: D-G013 D-G031 D-G032 D-G053 O-G005									

*Pallet, MSM, RAM, etc.

Table 4-2T. Safety Guidelines —
Fluids and Gases

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES LHe, LNe, LH_2, LO_2, ICN, NH_3, N_2H_4, O_2, N_2, He, Argon, Methane, Misc. Chemicals, Nutrients, Wastes, etc.	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-T001	X	X		X	All compartments containing E or EE which could release toxic gases, vapors, or fluids shall contain monitoring and warning equipment. Equipment for cleanup shall be provided. (5.3.5.1)	X	X	X	X
D-T002	X	X		X	Means shall be provided to purge EE containing hazardous fluids. (5.1.2.1)	X	X	X	X
D-T003	X	X		X	Containers holding non-inert fluids shall be purged at the completion of experiments or prior to return to Earth. (5.1.2.2)			X	
L-T001	X	X		X	Tanks containing fluids which can react with each other shall be separated as far as possible. (5.2.4.6)	X	X	X	X
O-T001	X	X		X	All containers to be returned to Earth shall be verified that they can safely enter the atmosphere. (5.3.2.3)			X	
O-T002	X	X		X	Containers with hazardous fluids shall be monitored while aboard the Orbiter or in its vicinity. (5.3.5.1)	X	X	X	X
SEE ALSO: D-G013 D-G027 D-G030 D-G031 D-C001									

*Pallet, MSM, RAM, etc.

Table 4-2U. Safety Guidelines – Emulsions

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES Plastic and Nuclear Emulsions	Launch	Deploy/Retrieve	Exp. Ops	Recovery
D-U001	X	X		X	Emulsion sheets shall be configured with protective covers or guards to prevent chemical contact injuries. (5.1.8.2)	X	X	X	X
L-U001	X	X		X	Emulsion sheet EE shall be located for transport to orbit exterior to EM habitable compartments if the chemicals pose outgassing problems, unless special containment provisions are incorporated. (5.2.1)	X	X	X	X
O-U001	X	X		X	Deployment of emulsion sheets by remote mechanisms shall be considered. (5.3.1.2.2)		X		
SEE ALSO: D-G027 D-G030 D-G032 O-G005									

*Pallet, MSM, RAM, etc.

Table 4-2V. Safety Guidelines – Contamination – Experiment Equipment

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES The Active Cleaning Device (ACD), Contamination Sample Plates and Racks	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-V001	X	X		X	The ACD shall be provided with covers or end closures to prevent exposure of the crew to contaminants contained within the ACD. (5.1.12.7) (5.1.8.2)			X	
SEE ALSO: D-G027 D-G030 D-G031 D-G032									

*Pallet, MSM, RAM, etc.

Table 4-2W. Safety Guidelines – Recharging Systems

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES Gas Bottle and Battery Recharging	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-W001	X	X		X	Means shall be provided for gas bottle and battery recharging systems to prevent operations until positive connections are assured. (5.1.8.1.1)			X	
O-W001	X	X		X	Gas bottle and battery recharging operations shall be monitored and controlled on a continuous basis. (5.3.5.1)			X	
SEE ALSO: D-G027 D-G030									

*Pallet, MSM, RAM, etc.

Table 4-2X. Safety Guidelines – EVA Operations (Sheet 1 of 2)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-X001	X	X		X	Extendable - aid devices (e.g., lassos, telescoping rods, etc.) shall be provided to permit assistance in EVA. (5.1.8.7)			X	
D-X002	X	X		X	Emergency EC/LS umbilicals shall be provided on the EM exterior for use by an EVA man. (5.1.8.8)			X	
D-X003	X	X		X	EVA suits and PLSS units, including voice communication, shall be designed for plug-in of an emergency PLSS package. (5.1.12.3)			X	
D-X004	X	X	X	X	The EM and/or Orbiter shall be provided with exterior connections (preferably near EVA airlocks) for plug-in of EC/LS umbilicals and voice communication. (5.2.5.6) (5.1.12.4)			X	
L-X001	X	X		X	EE exterior to the EM shall be located away from EM and Orbiter EVA hatches to prevent collisions, tether entanglement, etc. (5.2.4.2)		X	X	
L-X002	X	X		X	EVA tether attach points and fixtures shall be located so as to minimize possibility of tether entanglement. (5.2.5.7)		X	X	
O-X001	X	X		X	Particularly hazardous EVA experiment operations shall be conducted by at least two EVA men, one of them performing the work and the other being a Safety Man standing by equipped for immediate emergency action. (5.3.1.6.1.3)			X	
O-X002	X	X		X	For normal EVA experiment operations two EVA men shall work as a "Buddy" team. (5.3.1.6.1.2)			X	

*Pallet, MSM, RAM, etc.

Table 4-2X. Safety Guidelines – EVA Operations (Sheet 2 of 2)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
O-X003	X	X		X	An additional crewman shall be suited and ready to go into EVA in the event of an emergency to assist any of the men already in EVA. (5.3.1.6.4)			X	
O-X004	X	X		X	Experiment EVA shall be avoided when high-voltage, RF fields, or magnetic fields are present; during Experiment Module erection or deployment, retraction or docking operations; near attitude control nozzle jets, etc. (5.3.1.6.1.8)			X	
O-X005	X	X		X	EVA operations and PLSS conditions during EVA operations shall be continuously monitored (including direct or video viewing). (5.3.5.1)			X	
<u>SEE ALSO</u>:									
D-G040									

*Pallet, MSM, RAM, etc.

Table 4-2Y. Safety Guidelines – Egress Operations

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
D-Y001	X	X	X	X	Pressure suits (including PLSS units) shall be provided for emergency EVA egress from the EM to reenter the Orbiter (via the Orbiter EVA airlock). (5.3.1.6.3.2)		X	X	
O-Y001	X	X		X	A second or safety crewman shall stand by during airlock operations in case assistance is needed. (5.3.1.6.3.1)			X	
O-Y002	X	X		X	Routine entry into an EM shall not be initiated until the EM is fully erected and secured, and interface circuits have been checked out. (5.3.1.6.3.3)		X		
O-Y003	X	X		X	All personnel shall leave the EM and enter the Orbiter prior to retraction of the EM. (5.3.1.6.3.4)		X		
O-Y004	X	X		X	Airlock and crew conditions shall be continuously monitored during airlock operations. (5.3.5.1)		X	X	

*Pallet, MSM, RAM, etc.

Table 4-3. Safety Guidelines — Remedial Application (Sheet 1 of 2)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/Retrieve	Exp. Ops	Recovery
R-G001	X	X	X	X	For combustible material, the fire of which could not be extinguished by the normally available fire-fighting equipment, special equipment for extinguishing the particular type of potential fire shall be provided. (6.2.1)	X	X	X	X
R-G002				X	Fast donning short-time life support for use under emergency conditions shall be provided in an EM commensurate with potential emergency conditions caused by Es and EE. (6.2.2)	X	X	X	X
R-G003			X	X	In addition to normal medical provisions and supplies, equipment and trained personnel shall be provided to cope with potential medical problems which are peculiar to the diverse range of experiments on board (e.g., RF field exposure, contact with emulsions or isotopes, vapor inhalation, bacterial exposure, biological diseases, etc.). (6.2.3)	X	X	X	X
R-G004			X	X	To cope with accidental equipment - peculiar contamination on board (e.g., toxic gases or vapors, isotopes, insects, bacteria, etc.), equipment and trained personnel for the specific problem shall be available. (6.2.4)	X	X	X	X
R-G005			X	X	Materials, equipment, and trained personnel shall be provided for emergency repair of the primary pressure shell of an EM. (6.2.5)		X	X	
R-G006	X	X	X	X	Tools, other equipment, and trained personnel shall be provided for removing equipment whose position prevents required Orbiter or EM operations (e.g., protuberances preventing cargo bay door closure, etc.). (6.2.6)		X	X	

*Pallet, MSM, RAM, etc.

Table 4-3. Safety Guidelines – Remedial Application (Sheet 2 of 2)

Number	Experiment	Exp/Vehicle	Orbiter	Exp. Module*	SAFETY GUIDELINES	Launch	Deploy/ Retrieve	Exp. Ops	Recovery
R-G007				X	Emergency access equipment (cutting tools, knock-out or blow-out panels, etc.) shall be provided to enable access to and the egress of crew members entrapped within airlocks or compartments of an EM. (6.2.7)		X	X	
R-G008			X	X	Transfer equipment shall be provided to enable transfer to the Orbiter of crew members stranded in EVA or from a vehicle unable to close-rendezvous or dock. (6.2.8)		X	X	
R-G009			X	X	Personnel shall be provided who are trained in the requisite operational techniques for rendering aid and assistance to injured, entrapped, and stranded crew members in the same or adjacent compartments or in EVA operations. (6.2.9)		X	X	
					Note: R-G001 through R-G007 are essentially also applicable for the launch and recovery facilities.				

*Pallet, MSM, RAM, etc.

5. CONCLUDING REMARKS

The Safety Guidelines presented in Tables 4-1 through 4-3 are initial guidelines applicable to experiment safety for experiments expected to be operated on-board Space Shuttle Orbiters.

The intent of the present effort was to focus on inherent characteristics of Experiment Equipment and its operations in order to identify safety measures. As the level of definition of such equipment and its operation increases, the Safety Guidelines presented herein can be expanded.

A number of recent studies for NASA, referenced in Section 4.4, also contain guidelines which are applicable to experiment safety.

6. REFERENCES

1. Preliminary Edition of Reference Earth Orbital Research and Applications Investigations (Blue Book), NASA NHB 7150.1, Vol. I through VIII, January 15, 1971.

2. Shuttle Orbital Applications and Requirements (SOAR) Final Report-Technical, Vol. 1, Candidate Payload Identification, McDonnell Douglas Astronautics Company, MDC G2355, July 1971, NASA Contract NAS 8-26790.

3. NASA Payload Data for Integrated Operations/Payloads/Fleet Analysis, Aerospace Corporation Report No. ATR-71(7231)-7, April 30, 1971, NASA Contract NASW 2129.

4. The Prevention of Electrical Breakdown in Spacecraft, NASA SP-208, 1969.

5. Safety in Earth Orbit Study, Vol. I, Technical Summary, Section 1.0, Hazardous Payloads, NAR Report SD-72-SA-0094-1 (MSC-04477), July 12, 1972, NASA Contract NAS 9-12004.

6. Safety in Earth Orbit Study, Vol. II, Analysis of Hazardous Payloads, NAR Report SD-72-SA-0094-2 (MSC-04477), July 12, 1972, NASA Contract NAS 9-12004.

7. Safety in Earth Orbit Study, Vol. IV, Space Shuttle Orbiter, Safety Requirements and Guidelines, NAR Report SD72-SA-0094-4 (MSC-04477), July 12, 1972, NASA Contract NAS 9-12004.

8. Safety in Earth Orbit Study, Vol. V, Space Shuttle Payloads, Safety Requirements and Guidelines, NAR Report SD72-SA-0094-5 (MSC-04477), July 12, 1972, NASA Contract NAS 9-12004.

9. Manned Space Flight Nuclear System Safety, Vol. V, Nuclear System Safety Guidelines, Part 2, Space Shuttle/Nuclear Payloads Safety, General Electric Report No. 72 SD4201-5-2, January 1972, NASA Contract NAS 8-26282.

10. Space Station Safety Study, Vol. I, Crew Safety Guidelines, Boeing Report No. D2-113070-5 (MSC-00189), January 1970, NASA Contract NAS 9-9046.

11. Space Station Study, Preliminary Systems Design Data, Vol. III, Book 4, Supporting Analysis, Section 4, Experiment Safety, McDonnell Douglas Astronautics Company, MDC G0634, July 1970, NASA Contract NAS 8-25140.

12. Space Shuttle Baseline Accommodations for Payloads, NASA MSC-06900, 27 June 1972.

13. Shuttle Orbiter/Payloads Monitor and Control Interface, NAR Report SD72-SA-004, 1 May 1972, NASA Contract NAS 9-12068.

14. Assessment and Control of Spacecraft Electromagnetic Interference, NASA SP-8092, June 1972.

15. Shuttle Orbiter Applications and Requirements, Phase II (SOAR), MDC Report, Spring 1973, NASA Contract NAS 8-28583.

7. SYMBOLS AND ABBREVIATIONS

AMU	Astronaut Maneuvering Unit
E	Experiment
EC/LS	Environmental control and life support system
EE	Experiment Equipment
EM	Experiment Module, a spacecraft element containing or housing principal experimental equipments and experimenters (when involved). Can be a Pallet, an MSM, or a RAM in configuration.
FPE	Functional program element; a grouping of experiment classes or research activities within a particular discipline of research.
LBNPC	Lower Body Negative Pressure Chamber; a medical research equipment.
MSM	A mission-support-module within which research is conducted in a pressurized environment by man.
MWP	Maneuverable Work Platform
Pallet	A structure upon which experimental equipment is mounted.
RAM	Research Application Module containing experimental equipment.
RTG	Radioisotope thermal generator
SOAR	Shuttle Orbital Applications and Requirements; a study conducted by McDonnell Douglas for NASA.
Sortie	A mission class encompassing the conduct of orbital research with the Shuttle system.
sub-FPE	Payload elements within a FPE grouping.