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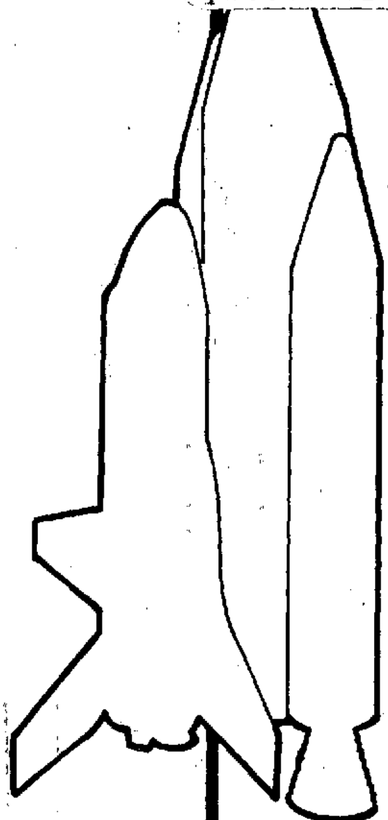
# SPACE SHUTTLE SORTIE PAYLOAD CREW SAFETY AND SYSTEMS COMPATIBILITY CRITERIA





## Volume I

## Executive Summary

15 MAY 1973

FINAL REPORT

TRW
SYSTEMS GROUP

# SPACE SHUTTLE SORTIE PAYLOAD
# CREW SAFETY AND SYSTEMS COMPATIBILITY CRITERIA

## VOLUME I - EXECUTIVE SUMMARY

Prepared for

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

Under Contracts
NAS9-12741 and NAS9-12742

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* Approval is given with respect to complete responsiveness to contractual requirements and does not, at this time, necessarily imply total NASA acceptance of all conclusions contained herein.

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## FOREWORD

Space shuttle characteristics are expected to allow selective easing of many cost-inducing criteria now required of payloads placed in orbit by expendable launch systems. Of particular interest is the prerequisite of identifying and differentiating between the minimum, mandatory design and verification criteria for sortie payloads and all other criteria for payload projects.

The TRW Systems Group under two concurrent contracts to NASA/JSC (NAS9-12741 and NAS9-12742) has performed a combined study effort entitled "Space Shuttle Sortie Payload Crew Safety and Systems Compatibility Criteria" for the express purpose of addressing the determination of mandatory and discretionary design and verification criteria applicable to sortie payloads from operational space shuttle management viewpoint. The study projects were performed during the period from 16 May 1972 through 15 May 1973.

The studies were sponsored jointly by NASA Headquarter's Mission and Payload Integration Office of the Office of Manned Space Flight, and the Lyndon B. Johnson Space Center's Engineering and Development Directorate. Study direction was provided by Mr. Earle M. Crum of the Future Programs Division, Payloads Engineering Office. He was assisted by a NASA Management Team representing NASA Headquarters, Johnson Space; Kennedy Space; Langley Research; Lewis Research; and Marshall Space Flight Centers.

The results of these studies are documented in the following three volumes:

Space Shuttle Sortie Payload Crew Safety and Systems Compatibility Criteria Documentation

| Volume | Title | Document No. |
|---|---|---|
| I | Executive Summary | 22214/22215-H013-R0-00 |
| II | Crew Safety Design and Verification Criteria | 22214-H014-R0-00 |
| III | Systems Compatibility Design and Verification Criteria | 22215-H014-R0-00 |

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X73-10413

# 1. INTRODUCTION

NASA is currently examining shuttle payload costs in an effort to predict more accurately and reduce such costs. History indicates that the criteria applied by NASA to previous space payloads caused them to be quite expensive. This practice was acceptable considering the costs associated with the launch and the necessity for a high probability of mission success. However, when these costs are used to estimate the cost of future shuttle payloads, it is evident that there would soon be a cost factor limiting the use of the shuttle.

Fortunately, the shuttle characteristics will allow selectively easing many of the cost-inducing criteria now placed on expendable launch system payloads. Relaxing these criteria is expected to greatly reduce the cost of space payload development.

Central to those cost-reducing efforts must be the capability to identify and differentiate between the minimum, mandatory design and verification criteria for shuttle sortie payloads and all other candidate criteria for payload projects. Accordingly these two studies will contribute to lower sortie payload costs by producing a methodology capable of defining the minimum mandatory criteria required for crew safety (NAS9-12742) and systems compatibility (NAS9-12741) of sortie payloads. The resulting criteria will form the basis of future specifications to be developed when quantitative space shuttle data are available.

## 2. OBJECTIVES

The prime objective of these studies was to identify the minimum, mandatory design and verification criteria necessary to insure that sortie payloads are safe (from a flight personnel standpoint) and compatible with the space shuttle system. These mandatory criteria must be distinguished from all other criteria related to payload mission success, configuration choices or management approaches which are, therefore, discretionary to payload management as variables in cost-benefit trades. Specific study objectives are tabulated in Table 2-1.

Table 2-1. Specific Study Objectives

- Research, identify, and analyze past practices in analogous payload situations to establish a historical perspective and to utilize available experience.
- Establish categorizing processes for distinguishing between shuttle mandatory and discretionary design and verification criteria.
- Identify the mandatory design and verification criteria that are required by shuttle management to insure crew safety and systems compatibility of sortie payloads with the space shuttle system.
- Identify the design and verification criteria that are discretionary to payload management as variables in cost-benefit trades.

# 3. STUDY SCOPE

The scope of these studies is bounded by the sortie payload philosophy shown in Figure 3-1. A shuttle sortie payload may consist of one or more major payload elements. These elements remain attached to the orbiter at all times and therefore do not include propulsion systems or free-flying satellites. A given sortie payload may interface with the shuttle mission specialist station (MSS) or payload specialist station (PSS) and excludes a remote manipulator system. Several pallets of experimental equipment may reside in the payload bay as well as piggy-back package(s). Additionally, as in Skylab, some experiment equipments may also be included in the shuttle crew compartments.

Accordingly, the design criteria derived by these studies are applicable to sortie payload elements carried in the shuttle payload bay or in the crew compartments.

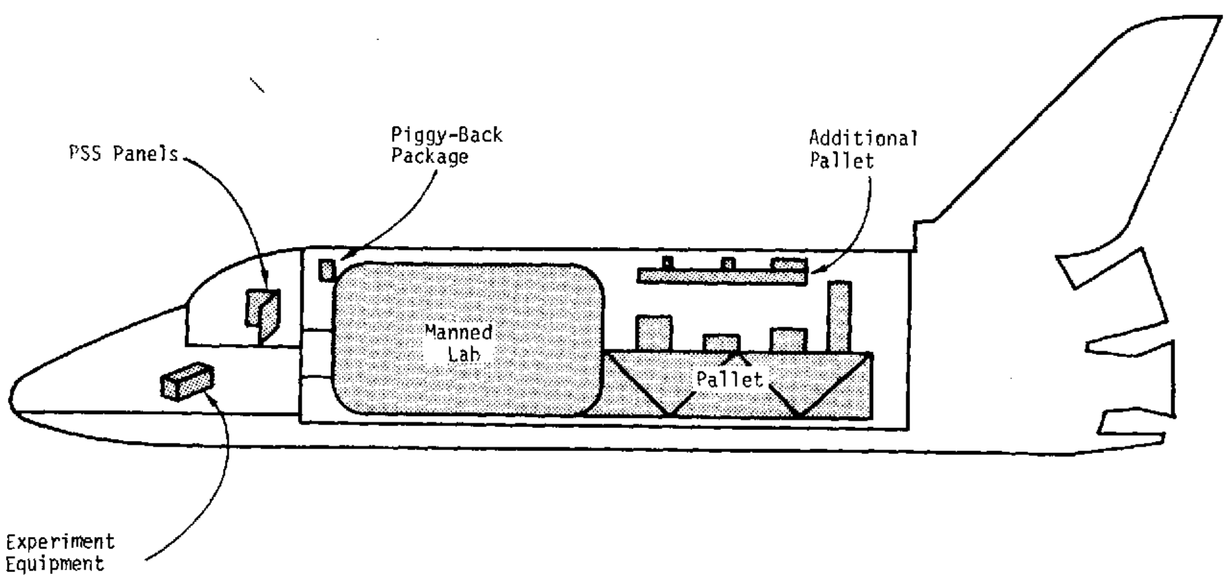



Figure 3-1. Shuttle Sortie Payload Elements

Because, in general, sortie payloads are pre-phase A in development, a generalized sortie payload was conceived against which a preliminary hazard analysis and an interface design analysis were made. This generalized payload model contained the subsystems and considerations known to be included in a representative sortie payload and is summarized below in Table 3-1.

Wherever possible, items are listed under their usual subsystems (mechanical, controls and displays, thermal, pneumatics, instruments, pointing/aiming, pyrotechnics, and electrical/electronic) for interface study purposes. Because crew safety analyses treat hazard considerations that stem not only from these subsystem considerations, but other space flight factors also, various non-subsystem considerations were included (material, energy sources, agents, crew involvement and environment) to complete the model. Note that entries are not redundantly listed in Table 3-1. For example, a pressure vessel appears as a pneumatic subsystem component and is not duplicated as an energy source although it would be so considered in a hazard analysis. Likewise, payload nuclear particle sources (radioactive) outweigh their possible high temperature characteristics for Table 3-1 purposes.

Table 3-1. Generalized Sortie Payload Subsystems and Considerations

| | | | |
|---|---|---|---|
| MATERIAL<br>-Metal<br>-Plastic<br>-Composite Material | THERMAL<br>-Conduction<br>-Liquid Loop/ Cold Plate<br>-Heaters<br>-Insulation<br>-Radiation | INSTRUMENTS<br>-Data Circuitry<br>-Transducers<br>-Electrical Instruments<br>-Sensors | ELECTRICAL/ELECTRONIC<br>-Power Circuitry<br>-Batteries<br>-Power Supplies<br>-RF Transmitters |
| MECHANICAL<br>-Hatch<br>-Structures<br>-Cryogenic Cooler<br>-Extendable Booms<br>-Antenna<br>-Gyros<br>-Shields<br>-Hydraulics | PNEUMATICS<br>-Pressure Vessels<br>-Extending Mechanisms<br>-Valves & Lines<br>-Compressors | AGENTS<br>-Reagents<br>-Pathogens<br>-Fuels & Oxidizers<br>-Fluids & Gases<br>-Corrosive Fluids | CREW INVOLVEMENT<br>-EVA/IVA<br>-Control Display Interface<br>-Direct Operation |
| CONTROLS & DISPLAYS<br>-Control Stimuli<br>-Display Responses<br>-Computer Operations | ENERGY SOURCES<br>-X-Ray<br>-Magnetic Flux<br>-Radio Frequency<br>-Payload Generated Nuclear Particles<br>-Laser | POINTING/AIMING<br>-Gimballed Platforms<br>-CMG<br>-GN&C Data | ENVIRONMENT<br>-Pressure<br>-Vibration<br>-Acceleration<br>-Thermal<br>-Humidity<br>-Acoustical<br>-Gravity<br>-Natural Radiation<br>-Contamination<br>-Meteoroid |
| | | PYROTECHNICS<br>-Devices | |

The basic guidelines employed in the studies are summarized in Table 3-2.

Table 3-2. Study Guidelines

- These studies address the post R&D, operational shuttle era assuming a mature, fixed-design, "shuttle airlines" flight operations capability oriented to low-complexity, low-cost operations.
- Design and test considerations include only those imposed by the space shuttle for mission purposes and are confined within the limits from terminal countdown through a normal landing.
- Whether payload equipment is from the civilian sector or GFE should not alter the applicability of the shuttle imposed mandatory criteria. The payload should be given maximum possible latitude.
- Extravehicular activity (EVA) requirements are not excluded from a sortie payload. However, shuttle EVA equipment are excluded from assignment to the payload.
- Study definitions:
  - Criteria are general rules by which the acceptability of shuttle payloads may be determined.
  - Specifications are the translations of criteria into explicit, usually quantitative, statements suitable for detailed design and test purposes. A criterion may translate into several specifications.
  - Requirements may be criteria or specifications which have been imposed by appropriate administrative authority.
  - Crew safety involves those payload design features that must be satisfied so that any credible hazard (i.e., believable as proven by experience or analytical techniques) is eliminated or its expectancy reduced to acceptable limits of risk.
  - Hazards are events or conditions that could cause death or serious injury to one or more of the orbiter personnel through either direct means or indirectly via propagation of vehicle hardware damage (other non-crew-hazard hardware safety considerations are treated as systems compatibility).
  - Mandatory crew safety design criteria and verification levels are defined, levied and controlled by shuttle management and are obligatory to all sortie payload elements.
  - Orbiter/payload interface is a point (or area) where a physical relationship exists between the orbiter and payload, or between major payload elements, wherein physical and/or functional compatibility is required.
  - Systems compatibility involves those payload interface design features that must be satisfied so that the payload elements and the orbiter can function together within acceptable degrees of mutual tolerance. Compatibility between payload elements is defined to encompass the same considerations as those between the payload and the orbiter.
  - Mandatory systems compatibility design criteria and verification levels are defined, levied and controlled by shuttle management and are obligatory to all sortie payload elements. However, certain of these criteria that affect only the payload may be controlled by payload management.
  - Discretionary design criteria make up all other criteria. Implementation and verification of these criteria are subject to payload project management prerogatives.

# 4. SIGNIFICANT RESULTS

## 4.1 CATEGORIZING METHODOLOGY

Using a logic tree approach, categorizing methodology was devised that has resulted in three different categorizing processes; crew safety design criteria; systems compatibility design criteria; and a design criteria verification process. The logic tree technique was chosen for its objectivity in determining mandatory criteria now -- and in future use. Associated with each categorizing process are basic study guidelines as listed in Section 3 and specific assumptions outlined in Volumes II and III.

### 4.1.1 Crew Safety Design Criteria Process

Figure 4-1 shows, in conceptual form, an overview of the detailed categorizing methodology for crew safety design criteria presented in Volume II of this report.

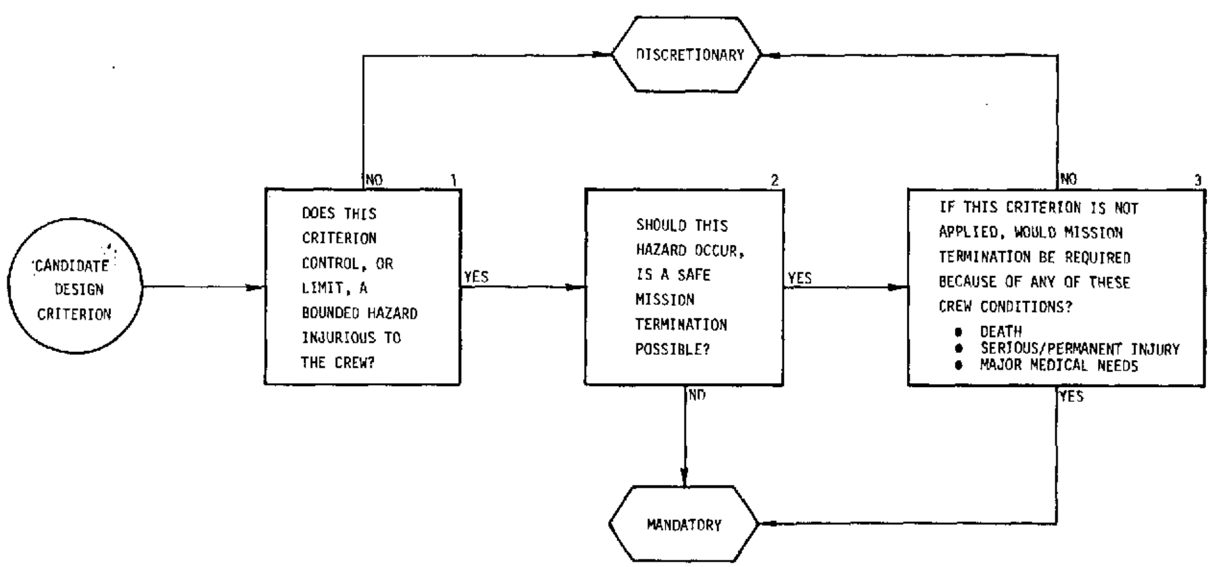



Figure 4-1. Crew Safety Categorizing Process Concept

This process is designed to determine whether a candidate safety design criterion is a member of the mandatory or discretionary sets. The philosophy around which the crew safety process is built demands that a subject hazard be credible and that it threaten crew safety rather than solely hardware. An unsafe mission termination is a major factor affecting crew safety as in block 2 of Figure 4-1. Block 3 defines the degree of potential seriousness resulting from the hazard under design consideration by the candidate criterion. Thus, mandatory crew safety design criteria can be separated from all other criteria that address cost-benefit factors such as payload mission success, configuration choices and other project management prerogatives.

### 4.1.2 Systems Compatibility Design Criteria Process

An overview of the detailed categorizing methodology for systems compatibility design criteria, presented in Volume III of this report, is depicted in conceptual form by Figure 4-2. Using a similar methodology, this process is designed to determine whether a candidate systems compatibility design criterion is a member of the mandatory or discretionary sets.

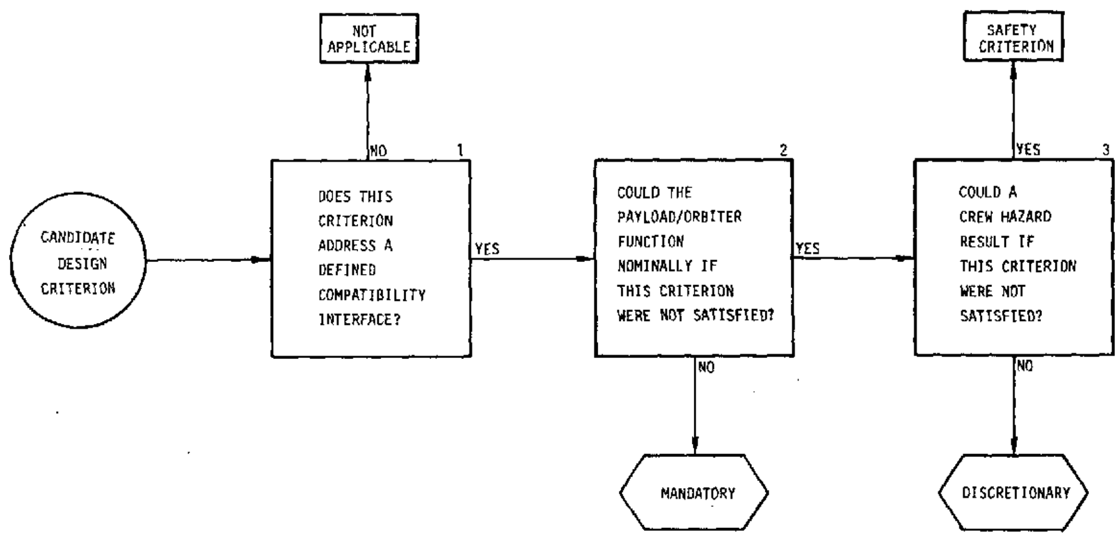



Figure 4-2. Systems Compatibility Categorizing Process Concept

The compatibility study determined that compatibility design criteria involve system interfaces and interactions between the orbiter, payload and the environment. Therefore, this process philosophy demands that a candidate design criterion address a real hardware interface or interaction between systems rather than an operating procedure. As emphasized in block 2, the ability to function nominally on both sides of the orbiter-payload systems interface is mandatory. Finally, block 3 shows that the degree one considers contingency, or non-nominal, interface situations is clearly a matter of discretionary cost-benefit trades; or, a safety matter originating from a possible incompatibility consequence.

### 4.1.3 Design Criteria Verification Process

A single process to determine the need for mandatory testing has resulted for the verification of a crew safety or a systems compatibility mandatory design criterion. This common process, oriented to a design criterion, is presented in Figure 4-3.

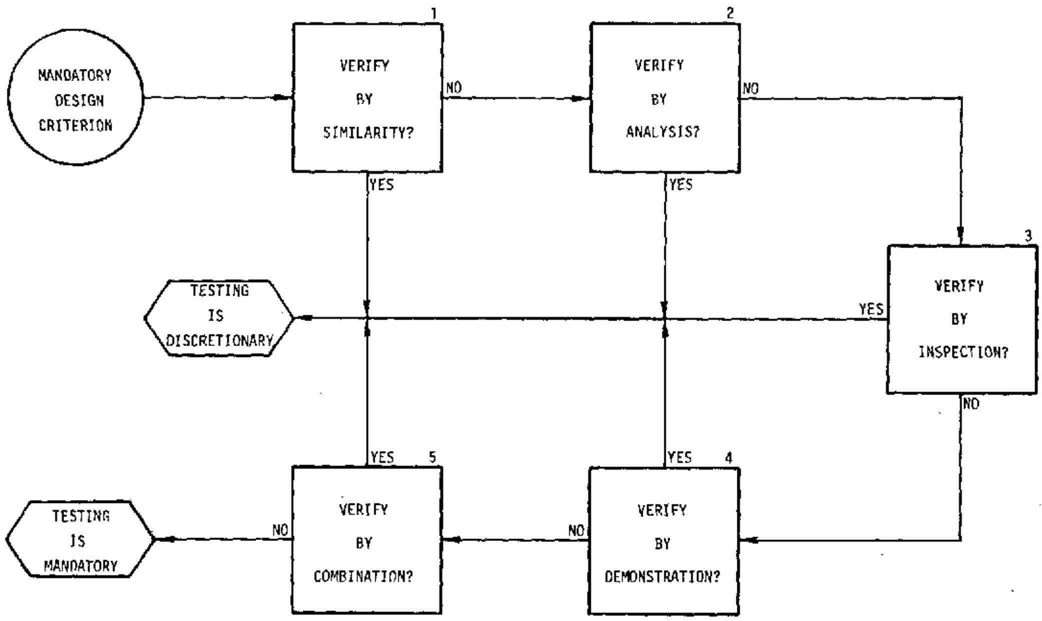



Figure 4-3. Design Criterion Verification Process Concept

The process contends (in blocks 1 through 5) that commensurate with the accumulated NASA manned spaceflight experience, verification techniques other than testing should be emphasized to reduce payload costs. Additionally, since orbiter program management has commissioned two, minimum, mandatory sets of design criteria sufficient to assure crew safety and systems compatibility, it follows that only these criteria require obligatory, shuttle-defined verification (for orbiter management overview purposes). All other criteria (discretionary) may be verified at a cost level according to the same cost-benefit factors that guided their implementation.

## 4.2 CRITERIA OVERVIEW

### 4.2.1 Organization

To gain from past experiences and recommend safety and compatibility precedent practices applicable to the operational shuttle era, sixteen previous space programs and five recent safety studies were analyzed and are presented in Table 4-1. A majority of the design criteria synthesized from these studies evolved from nearly 600 safety and 350 compatibility specifications, requirements, guidelines and criteria derived from the precedent practices analysis. However, to provide assurance that the shuttle/sortie payload general interfaces and hazard considerations were as complete as possible, a preliminary hazard analysis and an interface design analysis were conducted which produced additional design criteria.

Table 4-1. Historical Perspective Baseline

MANNED ELEMENTS

- APOLLO SIM
- ALSEP
- SKYLAB
- MOL
- P&F SUBSAT.

AIRBORNE ELEMENTS

- ARC ASP (990/LEAR)
- JSC ERAP

UNMANNED ELEMENTS

- SCOUT
- DELTA
- CENTAUR
- TITAN IIIC
- PIONEER F&G
- HEAO
- VELA
- OGO
- M35

NASA SAFETY STUDIES

- Advanced Mission Safety (HQ/AC)
- Preliminary Hazard Analysis of Space Shuttle Payloads and Payload Interfaces (JSC/BC)
- Safety in Earth Orbit (JSC/RI)
- MSF Nuclear Safety (MSFC/GE)
- System Safety Guidelines for New Space Operations Concepts (MSFC/LMSC)

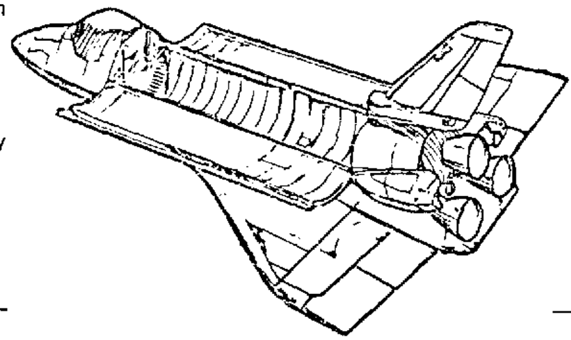
4.2.2 Results

Figure 4-4 depicts the hazard and interface areas found applicable to these shuttle/sortie payload studies within the guidelines presented in Section 3. The hazard areas listed in Figure 4-4 are aligned to the standard areas for safety analyses and stem from NASA/Headquarters Safety Program Directive No. 1A. To assure similar usability of the compatibility criteria, the compatibility interface areas were defined to be congruent with the shuttle development approach and assignment of subsystem managers by JSC. Figure 4-4 also shows the number of minimum mandatory design criteria identified by these studies.

CREW SAFETY DESIGN CRITERIA BY HAZARD AREA

9 - Contamination/Toxicity
3 - Electric Shock
15 - Energy Source Isolation
20 - EVA/IVA
9 - Explosive Devices
8 - Fire
2 - Fuels and Oxidizers
13 - Ionizing Radiation *
4 - Materials Compatibility
14 - Pressure Vessels
6 - Structural
5 - Systems Interactions

108 Minimum Mandatory Criteria



COMPATIBILITY DESIGN CRITERIA BY INTERFACE AREA

4 - Communications
1 - Cryogenics
1 - Data Processing & S/W
1 - Displays & Controls
4 - Electrical Power
1 - EC/LS
1 - EVA/IVA
2 - GN&C
1 - Instrumentation
1 - Onboard Checkout
1 - Payload Environment
1 - Pyrotechnics
9 - Structures
2 - Thermal Control
4 - General

34 Minimum Mandatory Criteria

Figure 4-4. Design Criteria Organization and Results

* Includes nuclear devices

4.2.3 Summary

Unlike design activities, the verification of design criteria compliance is performed by a well-defined set of techniques (similarity, analysis, inspection, demonstration, test). Therefore, to aid clarity of presentation the following crew safety and systems compatibility design criteria summaries do not include the selected verification levels which can be found in Volumes II (Crew Safety) and III (Systems Compatibility) of this report.

Presented in Table 4-2 is a summary of the 132 crew safety design criteria contained in Section 6 of Volume II. Table 4-2 shows the criteria subject that is addressed within each of the 12 hazard areas.

Table 4-3 presents a summary of the 41 systems compatibility design criteria contained in Section 5 of Volume III. The specific design considerations that were addressed within each interface area are itemized in Table 4-3. Certain Volume III systems compatibility criteria (that specifically address the orbiter) must also be considered to assure total safety of the flight crew and passengers from hazardous hardware incompatibilities. Volume III criteria also reflect, to a limited degree, certain hardware safety items. Thus, both volumes together comprise a systems safety approach.

These crew safety and systems compatibility criteria may form the basis for future sortie payload specifications to be developed when quantitative shuttle data are available.

Table 4-2. Crew Safety Design Criteria Summary

| EXPLOSIVE DEVICES | (10) |
|---|---|
| • Inadvertent firing | 3M, -- |
| • Misfire | 4M, 1D |
| • Device Size | 1M, -- |
| • Byproduct Containment | 1M, -- |

| ELECTRIC SHOCK | (3) |
|---|---|
| • High Voltages | 1M, -- |
| • Isolation, Grounding | 2M, -- |

| ENERGY SOURCE ISOLATION | (21) |
|---|---|
| • Batteries | 1M -- |
| • Short-Circuit Protection | 6M,1D |
| • Overload Protection | 2M,1D |
| • Open-Circuit Protection | --,2D |
| • EMI | 1M,2D |
| • Arcing | 1M,-- |
| • Redundancy | 1M,-- |
| • Safing Mechanisms | 3M,-- |
| • Thermal Extremes | --,2D |
| • Contamination | --,1D |

| EVA/IVA | (22) |
|---|---|
| • Thermal Extreme | 1M,-- |
| • Inadvertent Actuation | 3M,-- |
| • Handling | 3M,-- |
| • Leak Detection | 1M,-- |
| • Safing | 2M,-- |
| • Failure Identification | 1M,-- |
| • Restraint/Tethers | 2M,1D |
| • Lighting | 1M,-- |
| • Isolation Protection | 2M,-- |
| • Containment | 2M,1D |
| • Emergency Life Support | 1M,-- |
| • Sound Pressure Level | 1M,-- |

| MATERIALS COMPATIBILITY | (4) |
|---|---|
| • Galvanic Corrosion | 1M, -- |
| • Stress | 1M, -- |
| • Incompatible Materials | 1M, -- |
| • Oxidizing or Insulating | 1M, -- |

| IONIZING RADIATION* | (17) |
|---|---|
| • Containment | 1M, -- |
| • Activation | --, 1D |
| • Cooling | 1M, -- |
| • Coolant Leaks | 2M, -- |
| • Fire | 1M, -- |
| • Radiation | 3M, -- |
| • Monitor/Control | 3M, -- |
| • Jettison/Recovery | 1M, 3D |
| • Decontamination | 1M, -- |

M = Mandatory D = Discretionary

*Includes nuclear devices

Table 4-2. Crew Safety Design Criteria Summary (Concluded)

| CONTAMINATION/TOXICITY | (9) | FIRE | (9) | FUELS & OXIDIZERS | (2) |
|---|---|---|---|---|---|
| • Leak/Spill Prevention & Detection | 2M, -- | • Source Limiting | 1M, -- | • Leak/Vent | 1M, -- |
| • Gas/Vapor Generation | 1M, -- | • Self Extinguishing | 1M, -- | • Cleanliness | 1M, -- |
| • Isolation | 2M, -- | • High Temp. Isolation | 1M, 1D | | |
| • Outgassing | 1M, -- | • Open Flame | 2M, -- | | |
| • Particulates | 1M, -- | • Suppression | 3M, -- | | |
| • Micro-Biology | 2M, -- | | | | |

| PRESSURE VESSELS | (22) | STRUCTURAL | (8) | SYSTEMS INTERACTIONS | (5) |
|---|---|---|---|---|---|
| • Relief Capability | 5M, 1D | • Fragmentation | 1M, -- | • Monitoring/Control | 5M, -- |
| • Fastening | 1M, -- | • Manned Volume Walls | --, 1D | | |
| • Quick Disconnect | --, 1D | • Extension/Jettison | 1M, 1D | | |
| • Valves | 1M, -- | • Securing | 2M, -- | | |
| • Pressure Integrity | 5M, 5D | • Container Integrity | 1M, -- | | |
| • Monitoring | 1M, -- | • Meteoroid Environment | 1M, -- | | |
| • Dumping | 1M, -- | | | | |
| • Overpressure | --, 1D | | | | |

M = Mandatory D = Discretionary

Table 4-3. Systems Compatibility Design Criteria Summary

| COMMUNICATIONS | (4) |
|---|---|
| • Commands | 1M,-- |
| -Uplink | |
| -PCDS | |
| -Onboard | |
| • TV Payloads | 1M,-- |
| -Hardware | |
| -Signal Characteristics | |
| • Voice | 1M,-- |
| • Carrier Frequencies | 1M,-- |

| CRYOGENICS | (1) |
|---|---|
| • Reactants | 1M,-- |
| -Purity | |
| -Cleanliness | |

| DATA PROCESSING & SOFTWARE | (1) |
|---|---|
| • Computation Support | 1M,-- |

| DISPLAY & CONTROL | (1) |
|---|---|
| • Panels | 1M,-- |
| -Hardware | |
| -Electrical Characteristics | |

| ELECTRICAL POWER | (4) |
|---|---|
| • Power Sources | 1M,-- |
| -Hardware | |
| -Voltage | |
| -Transients | |
| -Impedance | |
| -Grounding | |
| • EMC and RF | 1M,-- |
| -Conducted | |
| -Radiated | |
| • P/L-Induced Characteristics | 1M,-- |
| -Load Impedance | |
| -Transients | |
| -Capacitance | |
| -Feedback | |
| • Corona | 1M,-- |

| ECLS | (1) |
|---|---|
| • Atmospheric Maintenance | 1M,-- |

| EVA/IVA | (1) |
|---|---|
| • Astronaut Capabilities | 1M,-- |
| -Reach | |
| -Visibility | |
| -Torque/Force | |
| -Transferables | |

| GN&C | (2) |
|---|---|
| • Realtime Data | 1M,-- |
| -Data Characteristics | |
| • Pointing/Stabilizing | 1M,-- |
| -Accuracy | |
| -Stability | |
| -Deadband | |

| INSTRUMENTATION | (6) |
|---|---|
| • Downlink | 1M,-- |
| -RAU | |
| -Hardware | |
| -Signal Characteristics | |
| • Transducers | --,1D |
| -Operating Range | |
| -Resolution | |
| • Telemetry | --,4D |

| ONBOARD CHECKOUT | (2) |
|---|---|
| • Go/No-Go Criteria | 1M,-- |
| -Checkout Command Decoder | |
| -Stored Program Processor | |
| • Payload Viewing | --,1D |

| P/L ENVIRONMENT | (1) |
|---|---|
| • Natural Environment | 1M,-- |
| -Low-g & Pressure | |
| -Space Radiation | |
| -Space Thermal | |
| -Meteoroid | |
| -Space Magnetic Fields | |
| -Humidity | |
| -Solar Illumination | |
| -Contaminations | |

| PYROTECHNICS | (1) |
|---|---|
| • Generated Environment | 1M,-- |
| -Contamination | |
| -Shock | |
| -Thrust | |

| STRUCTURES | (10) |
|---|---|
| • Mounting Provisions | 1M,-- |
| -Location, Attachment | |
| • Orientation & Alignment | 1M,-- |
| • Orbiter-Induced Environ. | 1M,-- |
| -Acceleration | |
| -Shock | |
| -Vibration | |
| -Acoustical | |
| -Thermal | |
| -Nuclear Radiation | |
| -Magnetic Fields | |
| -Contamination | |
| -Structural Distortion | |
| • P/L Envelope & Mass Properties | 1M,-- |
| • Boom-Mounted Equipment | 1M,-- |
| • Fields-of-View | 1M,-- |
| • Materials | 1M,-- |
| • Flaking | 1M,-- |
| • Service Panels | 1M,-- |
| • Decompression | --,1D |

| THERMAL CONTROL | (2) |
|---|---|
| • Heat Transport | 1M,-- |
| -Coldplate Hardware | |
| • Temperature Limits | 1M,-- |

| GENERAL | (4) |
|---|---|
| • Orbiter Support Limits | 1M,-- |
| • P/L-Induced Forces, Impulses | 1M,-- |
| • P/L Induced Environments | 1M,-- |
| • Waste Storage | 1M,-- |

M = Mandatory D = Discretionary

# 5. RECOMMENDATIONS

As a result from these two, concurrent study efforts, TRW Systems submits the following recommendations for NASA consideration:

1. An investigation should be made of policies and requirement-type documents that impact spacecraft and payload design. These studies revealed that this category of documents strongly reflect only past practices. Therefore, their impact on the operational shuttle era philosophies, in terms of costs and schedule, should be analyzed and corrective action outlined.

2. Other classes of shuttle payloads, such as kick-stages and free-flying satellites, should be studied in terms of minimum safety and systems compatibility design criteria. The basic categorizing methodology developed via these studies could provide the initial basis for an expanded methodology capable of treating any shuttle payload criteria.

3. Other aerospace disciplines (i.e., reliability, quality assurance) have traditionally provided obligatory impact to payload development for manned spacecraft. A better determination of their roles in the shuttle operational era should be undertaken with specific emphasis on shuttle payloads.

4. NASA/JSC has produced a substantial set of safety requirements and guidelines. These data should be compiled into one source document to improve the efficiency of contractual levying and to reduce the frequency of detailed hazard analyses except where new designs are being implemented.

5. An additional study should be undertaken to provide a Systems Safety approach for shuttle sortie payloads that combines both the crew safety criteria and the appropriate systems compatibility criteria into one set. This study should also take into consideration the safety aspects of payload operations.

6. Requirement specifications should be developed from these crew safety and systems compatibility criteria and incorporated, as applicable, into all sortie payload development programs.