Contract NAS10-8676

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LAUNCH SITE PROCESSING OF HAZARDOUS PAYLOADS

FINAL REPORT

VOLUME 1

EXECUTIVE SUMMARY

MAY 1975

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FOREWORD

This document constitutes Volume 1 of a seven volume final report prepared by Teledyne Brown Engineering, Huntsville, Alabama under NASA Contract NAS10-8676, Launch Site Processing of Hazardous Payloads. This study required a thorough analysis of the impact on the launch site and its operations by hazardous Space Shuttle Payloads.

The seven volumes of the final report are as follows:

Volume 1. EXECUTIVE SUMMARY: This volume presents a concise review of the results of the study and summarizes the principal conclusions and recommendations.

Volume 2. HAZARDOUS PAYLOADS SURVEY AND ANALYSIS: This volume presents the results of a survey and an analysis of proposed Shuttle payloads to identify hazardous payloads and to define the characteristics of materials and systems that make them hazardous. This task included the development of hazardous payloads ranking technique and recommendations for processing analysis on selected payloads.

Volume 3. NORMAL PROCESSING ANALYSIS: This volume presents preliminary normal processing flow plans for three Shuttle cargoes selected as a result of the Hazardous Payloads Survey and Analysis Task:

- Spacelab with Advanced Technology Laboratory
- Tug, Solar Electric Propulsion Stage, and Synchronous Earth Observatory Satellite
- Interim Upper Stage, and a Pioneer Jupiter Probe with a Fluorine Propulsion Unit

The preliminary processing flow plans include identification of unique facilities and GSE, processing hazards, and payload safety related design criteria.

Volume 4. CONTINGENCY PROCESSING ANALYSIS: This volume presents preliminary alternate processing flow plans for contingency situations for the three Shuttle cargoes analyzed in the Normal Processing Analysis Task.

Volume 5. CURRENT PAYLOADS SURVEY AND ANALYSIS: This volume presents the results of a survey and an analysis to determine payloads that are currently flying and that may also fly on the Shuttle vehicle when it becomes operational. The analysis determines hazardous materials/systems for each of these current payloads and recommends design and operational safety criteria for each hazardous current payload to minimize its impact on the Shuttle Transportation System.

Volume 6. ENVIRONMENTAL IMPACT STATEMENT POTENTIAL REQUIREMENTS: This volume presents the results of an evaluation of the probable environmental impact of Shuttle payloads hazardous materials and includes recommended KSC Environmental Impact Statement Potential Requirements.

Volume 7. ADVANCED TECHNOLOGY REQUIREMENTS: This volume presents a list of special problems identified in the study that require advanced technology study or technology development.

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1.0 INTRODUCTION

Payloads containing hazardous materials associated with space vehicle launch operations have been recognized and dealt with on previous R&D space programs. However, when compared to the Shuttle Program, these R&D space programs involved relatively few launches with considerable time between launches. The Shuttle operational program will have a high launch rate and in many cases individual launches will have several independent payloads for accomplishment of separate missions. Some of these payloads by intent will be recoverable for purpose of reuse, and all must be recoverable in the sense that possible abort situations prior to deployment have to be recognized.

Present processing schedules have been derived assuming nominal passive payloads and nominal payload flow time. A number of specifically safety oriented studies on Shuttle payloads have been performed in recent years. However, relatively few of these have treated ground operations in depth, and the overall impact of Shuttle payload hazards on launch and landing site processing and procedures has not been documented. In order to fill this gap, this 10 month study was initiated in July 1974.

The purpose of this report is to present an overview of the entire study and summarize the major results. In section 2.0, a summary of the principal study conclusions are listed. In section 3.0 the study results are presented on a task by task basis. Section 4.0 presents the highlights of the study results on a cargo related basis. Finally, recommendations for further study and advanced technology developments are presented in sections 5.0 and 6.0.

1.1 STUDY OBJECTIVES

The overall objectives of this study were to identify hazardous systems and materials in Shuttle payloads and to develop safety oriented normal and contingency launch site processing plans for selected payloads. The impact on the existing KSC Environmental Impact Statement by Shuttle hazardous payloads was determined as well as the need for further studies and advanced technology development.

1.2 SCOPE

This study has involved a thorough analysis of the potential impact of hazardous Space Shuttle payloads on the launch site and processing operations. This has included an analysis of the hazards associated with launch site operations from receipt of the payload through launch, landing, and refurbishment. The study consisted of the following tasks:

- Task 1: Hazardous Payloads Survey and Analysis
- Task 2: Normal Processing Analysis
- Task 3: Contingency Processing Analysis
- Task 4: Current Payloads Survey and Analysis
- Task 5: Environmental Impact Statement Potential Requirements Study
- Task 6: Advanced Technology Requirements

Requirements for special Ground Support Equipment (GSE) items and facilities, safety and operational requirements, and areas of payload design that can favorably affect safe and efficient launch site processing operations were identified as part of these tasks.

1.3 STUDY APPROACH

The six basic tasks in this study and their interrelationships are depicted in Figure 1. Task 1 involved surveying and analyzing all Shuttle payloads to determine those materials and systems that are hazardous. This task entailed extensive contact with the scientific community and a thorough search of existing documentation.

The payloads identified as hazardous were then grouped into feasible cargoes. From this group, three cargoes were selected and approved by KSC for processing analysis based on processing coverage, hazardous materials coverage, unique hazards, and payload hazard potential.

Next, normal processing analysis (Task 2) was conducted on each of the three cargoes selected. This analysis included a detailed breakdown of each operation sufficient to identify all hazards, GSE and facility requirements, and to establish time lines.

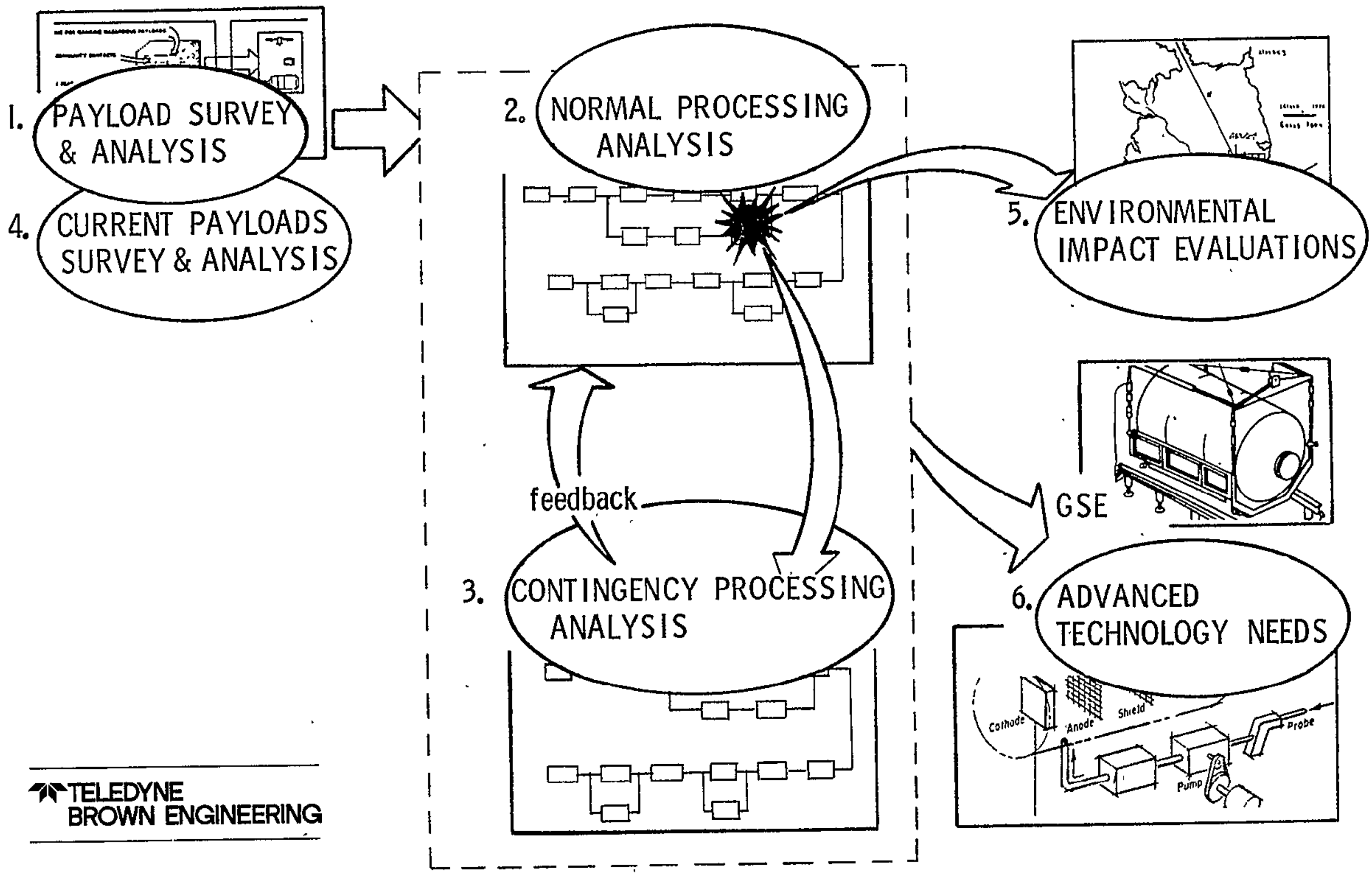

FIGURE 1. TASK RELATIONSHIP

Each of the hazardous conditions uncovered in Task 2 became a candidate for the development of a contingency plan for Task 3. A group of such contingencies was developed into work-around processing plans that would help minimize the impact of accidents or unplanned events in the Shuttle processing. Sixteen contingency plans were developed for the three cargoes.

Task 4 involved analyzing payloads that are currently flying and may also fly on the Shuttle to determine their hazardous systems and materials. Operational and design safety criteria and requirements were developed for the hazardous systems on these payloads. Twenty one current payloads were identified and the appropriate criteria and requirements were specified for each payload.

Those hazards that were not addressed by the current KSC Environmental Impact Statement were identified in Task 5 and evaluated for their potential effects on the environment. Methods for providing environmental protection were recommended.

Task 6 identified advanced technology requirements.

1.4 RELATIONSHIP TO OTHER NASA EFFORT

This study, which was dedicated to safety implications concerning ground operations of hazardous Space Shuttle payloads and cargoes, relates essentially to any future ground operations efforts for Shuttle payloads, Spacelab, Interim Upper Stage (IUS), and Space Tug. KSC inhouse efforts will profit by its results as will contracted efforts, such as ongoing and impending studies like:

- Launch Site Integrated Operations
- Launch Site Payload Accommodation Handbook
- Multiuse Mission Support Equipment
- Payload Ground Operations Requirements
- Post Landing Payload Support

The study will also be beneficial to the validation efforts by the U. S. Air Force for the Interim Upper Stage (IUS), which are planned to start early next year.

2.0 SUMMARY OF STUDY CONCLUSIONS

- This study has shown that the processing of fluorinated oxidizers is the most difficult from a safety viewpoint and will have a significant impact on ground processing operations. A dedicated loading facility and GSE for control and monitoring are required. Of special concern is the consequence of the release of highly reactive F_2 in the presence of fuels and organic materials. Special procedures and trained personnel are required.

- Mercury containing payloads can be processed safely without significant impact on processing operations. Of primary concern in processing mercury containing payloads is contamination and environmental pollution which can be controlled. Mercury leakage in the payload bay could result in a mission scrub because the orbiter and payload would require refurbishment.

- Microorganisms and biological hazards present unique operational problems relating to on board loading time but the hazardous aspects can be controlled with facilities such as a mobile biological laboratory and packaging.

- RTG's present special problems with cooling and radiation and require special GSE and handling and will restrict operations. Loading of RTG's at the latest available time in the countdown is the safest method and presents the least impact.

- Simultaneous leakages of hazardous fluids present potential catastrophic situations. Payload bay inerting purges, hazardous gas analyzers for detection, and pressurization in flight are required safety concerns.

- Vertical payload mating and vertical installation at the pad are recommended for hazardous cargoes (exception of Spacelab and passive payloads).

- Payload access in the cargo bay is a problem area and may impose severe design constraints on payloads.

- A change in the cargo checkout philosophy sequence on some payloads is required because of the relatively small amount of time allocated for the Orbiter at the pad.

3.0 SUMMARY OF TASK RESULTS

3.1 HAZARDOUS PAYLOADS SURVEY AND ANALYSIS

The purpose of this task was to select representative hazardous cargoes for detailed processing analysis.

3.1.1 Payload Survey

A comprehensive documentation search and review were conducted and communications with NASA and the scientific community were used in the survey and identification of the various Shuttle payloads for hazardous materials/systems. This survey identified 219 potential payloads that may fly on the Shuttle and assessed the hazard potential of each payload. (The hazard potential is a function of the likelihood of occurrence of an undesired event and of the impact of such an occurrence.) Weighting factors were developed to estimate impacts of undesired events for all hazards. Approximately 50 different systems/materials were found to be hazardous. Table I shows the categories, hazardous materials/systems in each category, and a summary of the characteristics that make them hazardous.

TABLE I. HAZARDOUS MATERIALS/SYSTEMS SUMMARY

Category	Hazardous Characteristics	Hazardous Materials/Systems
Cryogenics	Asphyxiants, explosive, flammable, contamination sensitive, toxic, personnel injury/equipment damage from extreme cold.	LH_2, LO_2, LHe, LHeII, LNe, LN_2 and LF_2
Hypergolics	Flammable, corrosive, toxic, contamination sensitive, explosive.	Hydrazine and its methyl derivatives, nitrogen tetroxide, fluorine, and Inhibited Red Fuming Nitric Acid (IRFNA).
Toxic/Asphyxiant	May act as asphyxiants by displacing air and/or vapor may be toxic.	Ammonia; gaseous argon, helium, neon, krypton, xenon, nitrogen; Freon 113 and related chlorofluoro compounds; mercury; silicate esters (cooling fluid).
Radiological	Burns, injury, equipment damage, high temperature.	RTG's, RHU's, laser, UV, microwave, RF, barium, americium, X-ray, ion source.
High Temperature	Burns, ignition source.	Heaters, RTG's, RHU's
High Pressure	Injury, damage, explosive.	-
Electrical	Shock, sparking, overheating, burns, ignition source.	-
Microbiological	Pathogenic hazards.	Microorganisms, bacteria, viruses.
Fire/Explosives	Flammable, explosive, sensitive to RF, spontaneous ignition in air.	Solid propellants; pyrotechnics, batteries, methane and homologous hydrocarbons; and flammable metals such as rubidium, cesium, and lithium hydride.

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3.1.2 Candidate Cargo Selection

Candidate cargoes were developed using the 727 cargoes given in the Shuttle traffic model as well as those scheduled for the first 20 missions. In addition to these, tentative cargoes comprised of other payload groupings that could be flown were developed and tested for compatibility (orbital requirements, size, weight, etc.) to select feasible candidate cargoes. A cargo selection rationale consisting of hazard potential, hazardous materials and quantities, systems coverage, unique materials and processes, and number of flights was devised as a second series of tests to obtain a manageable number of cargoes. Fourteen candidate cargoes resulted from this activity.

3.1.3 Final Cargo Selection

The final step was to select cargoes to be analyzed in the normal and contingency processing analysis tasks. Rationale for final selection included high hazard potential, high number of flights, broad coverage of hazardous materials, and a payloads processing scenario to ensure that all major launch site processing paths would be covered.

3.1.4 Results

Three Shuttle cargoes consisting of nine payloads were selected and approved by KSC for processing analysis in this study.

- A Spacelab with an Advanced Technology Laboratory (ATL) and an Integrated Real Time Contamination Monitor (IRTCM).
- A cryogenically fueled Tug carrying a Solar Electric Propulsion Stage (SEPS) and a Synchronous Earth Observatory Satellite (SEOS).
- A conceptual Interim Upper Stage (IUS) carrying a Pioneer Jupiter Probe (PJP) with a Fluorine Propulsion Unit (F_2PU).

3.2 NORMAL PROCESSING

The purpose of this task was to develop and analyze normal launch site processing flows for each of the three cargoes selected. These normal processing flows were developed to the level necessary to identify all processing hazards, waterfall/time lines, unique facility and GSE requirements, safety requirements for launch site protection, and payload safety related design criteria.

3.2.1 Results Summary

3.2.1.1 Cargo Hazards

The three cargoes normal base line processing flows and functional event descriptions resulted in the identification of 28 different types of hazards distributed throughout 237 operational events. An analysis of each event, of the operations involved, and of the hazardous systems was performed to determine the effect of the hazard on personnel, facilities, payloads, Orbiter, and the environment. To reduce or eliminate the effects of the payload hazards, 87 payload design recommendations were made, 125 safety related operational requirements were identified, and 57 items/requirements for support equipment were generated. The hazards that were identified for each of the three cargoes, the frequency of occurrence, and the final hazard categorization are shown in Table II.

TABLE II. CARGO HAZARDS SUMMARY

Hazard Types	Frequency of Occurrence			Final Hazard Categorization
	Spacelab	Tug	IUS	
High Pressure	7	18	15	Catastrophic
Cryogenic F_2 Overpressure			5	1 Catastrophic and 4 Critical
Hydrazine & Methyl Derivatives		6	5	Critical
Mercury		2		Critical
APS Thruster Firing - Toxic Gas		2	2	Critical
Cryogenic O_2		3		Critical
Cryogenic H_2		4		Critical
GF_2			1	Critical
Cryogenic F_2			2	Critical
N_2O_4			2	1 Critical and 1 Controlled
GN_2 Purge	1	15	6	Controlled
Electrical Power	6	26	13	Controlled
RF Emissions		4	3	Controlled
Laser	2	1		Controlled
High Temperature		1	1	Controlled
Moving Equipment		1		Controlled
Freon	3			Controlled
Pyrotechnics - Safed		5	2	Controlled
Pyrotechnics - Armed	2	2	1	Controlled
Batteries		4	1	Controlled
Hydraulics		1		Controlled
Purge with Hot GN_2		1		Controlled
Radar	2			Controlled
Steam Generator	2			Controlled
Microbiological	3			Controlled
Cryogenic N_2			5	Controlled
Radiological			2	Controlled
Krypton 85			2	Controlled

3.2.1.2 Interface Hazards

Those operational events containing more than one hazard and those operations where hazards were continued from previous events were examined for possible interface hazards.

In the Spacelab/ATL/IRTCM cargo, two events were found to present an interface hazard potential and both of these involved electrical power application checks that could lead to the inadvertent activation of other hazardous sources such as laser, radar, or steam generator.

The major interface hazards for the IUS/F_2PU/PJP cargo are centered around fluorine and other hypergolic materials such as hydrazine and N_2O_4. The potentially catastrophic effect of a water leak from the Radioisotope Thermoelectric Generator (RTG) cooling jackets combining with a fluorine leak is also an interaction hazard. Fluorine leakages could adversely affect critical electronics, and control circuits.

In the Tug/SEPS/SEOS cargo, the 10 events found to present an interface hazard potential had as their common causative or accessory hazard the application or use of electrical power. Electrical power application usually involves checks, tests and/or verifications of various communications networks, control systems and interfaces. The electrical power application can lead to the inadvertent activation of other hazardous sources, such as RF generating systems, lasers, heaters or thruster gimbals. Mercury leakage could also cause electrical shorts, arcing, and affect critical circuits.

In all cargoes, the application of electrical power or malfunction in an electrical system could lead to the ignition of spilled or leaking fuels. Similarly, inadvertent power application to pyrotechnic devices could result in the ignition of other fuel sources. Finally, the presence of propellant reactants (LO_2, LH_2, LF_2, N_2O_4, and N_2H_4) presents a potentially catastrophic situation if simultaneous leakages should occur.

3.2.1.3 Time Line Analysis

The time line analysis conducted revealed that no Orbiter constraints are imposed. For safety reasons, it was necessary to perform off-line loading of fluorine in the F_2PU. This operation involves passivation, loading, stabilizing, and monitoring, which is a 31 hour operation. Obviously, without off-line fluorine loading the Orbiter processing would have been impacted.

3.2.1.4 GSE/Facility Identification for Normal Processing

Fifty seven items of GSE/facility were identified for the normal processing of all three cargoes. The items that may cause a significant impact on KSC are as follows:

- GSE

  -- IUS/F_2PU Cargo Transporter (LN_2 Dewar and Monitoring System)
  -- Portable Fluorine Disposal Unit and LN_2 Dewar for use at:

    - Fluorine Loading Facility
    - SAEF #1
    - Launch Pad

  -- Personal Life Support Equipment Compatible with Fluorine
  -- Fluorine Sensing Systems
  -- Mercury Servicing Unit
  -- Mercury Sensing Systems

- Facilities

  -- Dedicated Fluorine Facility
  -- Hydrazine APS Dedicated Loading Area in SAEF #1
  -- Mobile Biological Holding Facility
  -- Laser Test Facility

3.3 CONTINGENCY PROCESSING ANALYSIS

The purpose of this analysis was to provide a method of returning operations to normal or near normal with a minimum loss of time, minimum damage to facilities, and minimum exposure of personnel to hazards after an accident or unscheduled event occurred. In this study, 16 contingency plans were developed for the three cargoes. Table IV lists the contingency plans developed for each cargo.

TABLE IV. CONTINGENCY PLANS

	SPACELAB/ATL	TUG/SEPS/SEOS	IUS/F_2PU/PJP
• MISSION ABORT	X	X	X
• VERTICAL CHANGEOUT AT THE PAD	X	X	X
• BACKOUT OPERATIONS	X	X	X
• CRASH/SHOCK CONDITION LANDING AT KSC	X	X	
• CRASH/SHOCK CONDITION LANDING AT CONTINGENCY SITE	X	X	
• NORMAL LANDING AT CONTINGENCY SITE	X	X	
• ACCIDENT (LOSS OF RTG COOLING)			X

3.3.1 Results Summary

A summary of the significant requirements for proceeding through the alternate processing situations is shown in Table V. Cargo/payload safing requirements, Orbiter/payload interface requirements, payload design requirements, and special GSE requirements are included. The requirements/conclusions/recommendations listed in the table are related to the applicable contingency plan and cargo.

TABLE V. CONTINGENCY PLAN REQUIREMENTS

	REQUIREMENTS/CONCLUSIONS/RECOMMENDATIONS	CONTINGENCY PLAN				
		BACKOUT, VERTICAL CHANGEOUT	MISSION ABORT	LAND AT ALT. SITE	CRASH/SHOCK LAND AT KSC	CRASH/SHOCK LAND AT ALT SITE
1	Shuttle/Orbiter Safing and Open Pad.	A, B, C				
2	Payload High Pressure tanks must be vented through the Orbiter vent system Orbiter or Ground Control is required.	A, B, C	A, B, C			
3	Access to all payload pyrotechnics from the PCR is required Platforms, ladders, etc must be provided for access	A, B, C				
4	Orbiter/payload fluid umbilicals should be designed to limit leakage at disconnect	A, B, C				
5	Orbiter control of pyrotechnics safing and verification is required		A, B, C			
6	Ground umbilicals for payloads hazardous fluids must provide fill, drain, flush, and purge capability.	B, C				
7	A hazardous gas analyzer system is required for the payload bay at the pad	B, C				
8	Payload design should provide access capability for disconnect and removal in the vertical while in the payload bay	B, C				
9	Payloads hazardous fluids dump capability through Orbiter control is required Dump should be through the Orbiter vent system.		B, C			
10	GSE for ground purge of payload cryogenic tanks is required at the landing sites.		B, C	C	C	C
11.	A portable hazardous gas analyzer will be required to monitor the payload bay atmosphere at the landing strip and alternate sites.		B, C	C	C	C
12	A high flow rate GN_2 purge system for the payload bay should be provided at the landing strip.		B, C	B, C	C	C

LEGEND:

A - Spacelab/ATL/IRTCM
B - IUS/F_2PU/PJP
C - Tug/SEPS/SEOS

These additional conclusions are not included in Table V because they apply to only one cargo.

- If the backout or vertical changeout for the IUS cargo contingency is initiated by the liquid fluorine oxidizer system, pad venting and safing of the fluorine system will first be required. The design of the pad vent system and fluorine oxidizer system should allow gas and liquid to be dumped. If the integrity of the fluorine oxidizer system is sound, dumping at the pad is not recommended.

- Unless present NASA studies related to inflight dumping indicate differently, fluorine vent/dump provisions should be provided in the Orbiter that can also be used for controlled ground and flight dumping and venting.

- A mobile water cooling system is required at the landing strip to supplement the 15-hour supply of onboard RTG cooling since 24 hours are required to gain access to the cargo in the Orbiter Processing Facility (OPF).

- Fluorine handling provisions are required in the OPF in case of an abort with the IUS cargo. If the fluorine has not been dumped in space, a portable LN_2 cooling supply will be required to maintain the thermal/pressure balance until the F_2PU can be removed.

- An alternate to removing the aborted IUS/F_2PU/PJP in the OPF is safing at the landing strip or other facility. A portable fluorine disposal system and a heated GN_2 servicer to aid in residual boiloff is required. A fluorine tank horizontal drain provision for draining residuals would reduce disposal time.

3.3.2 Contingency GSE/Facility Identification

Contingency GSE/facility requirements identified were:

- GSE
  - -- Mercury Decontamination System
  - -- Mobile Water Cooling System (RTG Cooling at Landing Strip)
  - -- GN_2 Purge System for Payload Bay (at Landing Strip)

- Facility
  - -- Emergency Fluorine Vent/Dump Capability at SAEF #1
  - -- Emergency Fluorine Vent/Dump Capability at the Pad

3.4 CURRENT PAYLOADS SURVEY AND ANALYSIS

The purpose of this analysis was to determine the safety requirements and criteria that should be applied to current payloads so that they can be flown on the Shuttle. The applicable STS safety criteria compiled and developed by this task give NASA a checklist to assist in evaluating how well the payload designer has eliminated or reduced the hazards to the STS induced by the hazardous materials and systems on their payloads.

Three classifications of safety criteria were established as follows:

- Design Safety Criteria
- General Payloads Criteria
- Operational Safety Criteria

The results of this analysis consists of listings of safety criteria that are applicable to given current payloads and are, by nature, not readily condensable. These listings are contained in Volume 5.

3.5 ENVIRONMENTAL IMPACT STATEMENT POTENTIAL REQUIREMENTS

The purpose of this task was to identify those hazards that may influence the existing KSC Environmental Impact Statement and to recommend methods for reducing their effects. Those hazardous materials that have been identified as having a possibly significant environmental impact over and above those already identified in KSC EIS's are fluorine and its reaction products, mercury and its reaction products, radioisotopes, and microorganisms.

4.0 SUMMARY OF STUDY RESULTS (BY CARGO)

This study has defined a number of potentially hazardous payload systems and operations involved in the ground processing of selected cargoes on the Space Shuttle. The majority of these hazardous operations and systems has been safely dealt with in previous launch operations at KSC. Considered individually, most of these hazards, such as cryogenics, hypergolics, high pressure gases, explosives, need not present any more of a hazard to Shuttle ground operations than on previous mission operations. An important exception to this is the processing of fluorine. However, the frequency of these hazardous operations in the Shuttle Program may increase the probability of an accident or unplanned event and the location of multihazard payloads in the confinement of the Orbiter payload bay would have a synergistic effect if an accident occurs.

4.1 IUS/F_2PU/PJP CARGO

Of the three cargoes analyzed, the IUS/F_2PU/PJP cargo is the most difficult to process safely, primarily because of the fluorine. Operational, equipment/facilities and payloads safety criteria were developed to reduce the hazards associated with processing this cargo. However, it is felt that other configurations for a fluorinated oxidizer system should be evaluated in anticipation of further reducing the hazards associated with processing a propulsion unit with fluorine as its oxidizer.

The potential hazards resulting from the use of a fluorine oxidizer propulsion unit on a Shuttle cargo are manyfold. The inherent reactivity of fluorine requires that elaborate precautions be taken to prevent an inadvertent spill or leakage of this material at any stage of the ground operations. These precautions must provide for the protection of operating personnel, the environment/ecology, and facilities and equipment. This will call for separate facilities and equipment for transfer, handling, storage, loading, and disposal of the fluorine.

A dedicated fluorine loading facility will require almost continual maintenance/service between periods of usage to maintain the facility in a condition that can safely handle F_2. This is primarily due to the reactive and corrosive nature of fluorine, which necessitates that all lines, valves, tanks, etc. be maintained in a dry, inert condition, and that after use the system be completely purged to remove the F_2 to prevent severe corrosion of the valves, pipes, etc. If there are relatively long periods between use of the facility, it may be necessary to disassemble and inspect a large part of the F_2 loading system before each use.

4.2 TUG/SEPS/SEOS CARGO

The payload in the Tug/SEPS/SEOS cargo that requires special consideration is the SEPS. The use of this mercury containing propulsion unit in the Shuttle cargo may present some potentially hazardous situations during normal ground operations. A mercury leak while in the Orbiter bay could result in a mission scrub because the Orbiter and its installed payloads would require major refurbishment. This is primarily because of the dispersive nature of mercury. The high surface tension and low viscosity properties of mercury cause it to break into small droplets upon impact. These droplets, some smaller than the eye can see, can cause electrical shorts and corrosion. A leak prior to Orbiter bay closing could also contaminate the payload changeout room with similar effects. Additional hazards arise from the possibility of operating personnel breathing mercury vapors that result from a large spill or leak, and the possibility of the mercury liquid getting into the adjacent ground water and presenting an environmental/ecological problem. It is felt that the use of the proper personnel protective equipment, mercury vapor detection and monitoring equipment, and prompt cleanup/decontamination procedures on such spills or leaks will preclude the possibility that such spills would have a significant effect on ground operations.

Another potentially hazardous situation, resulting from the use of mercury containing stages, is the possibility of a fire and/or explosion occurring during an abort or similar situation that could conceivably release a large cloud of mercury vapor into the atmosphere. Studies of expected downwind distances under various wind/weather conditions, etc. would help to define the potential effects and provide the criteria/conditions under which such an accident could be prevented from developing into a major hazard to the local populace.

4.3 SPACELAB/ATL/IRTCM CARGO

The handling, transfer and storage of microbiological/biological materials relative to the Spacelab cargo present operational problems but do not present a significant hazard potential. There will be a need for a Mobile Biological Laboratory to facilitate handling and storage of the containerized specimens to maintain them under controlled temperature and atmospheric conditions during ground operations at KSC. Also, trained and suitably equipped microbiological decontamination personnel should be available at all times during the ground operations involving these materials in the event that an accident should provide the possibility of the release of these organisms into the environment. Other cargoes, not included in this task, that may use animals, or particularly virulent or pathogenic organisms, may require more elaborate facilities for transfer, handling and holding during ground operations.

5.0 RECOMMENDATIONS FOR FURTHUR STUDY

The principal recommendations for further study effort are as follows:

- The reaction of fluorine with atmospheric moisture is unpredictable and sometimes violent. A study should be made to determine the conditions under which violent reactions would not occur and establish the atmospheric condition limits for processing fluorine containing spacecraft.

- A study should be performed to establish the maximum allowable concentrations of fluorine and hydrogen fluoride for the general public, since the limits now established are for exposure of personnel under controlled working conditions.

- A study should be made to evaluate the safety related processing characteristics of different payload concepts containing fluorine oxidizer systems to determine those concepts that would optimize processing and flight safety. This study should also develop new design approaches that would minimize the safety problems associated with fluorine.

- A study should be made to evaluate the impact on the environment of dumping fluorine in near space. In-flight dumping of fluorine could be required during an abort situation.

- A study should be made to evaluate the effects on the environment of dumping mercury in near space. In-flight dumping of mercury could be required during an abort situation.

- An accidential fire or explosion at KSC could result in the injection of large quantities of mercury vapor into the atmosphere. A study should be made to assess the effects on the environment of such an accidential release of mercury.

- A study should be conducted to identify the requirements for an all purpose carrier aircraft of the Boeing 747-type to transport special equipment to the alternate landing site and to ferry the Orbiter back to KSC.

- A cargo bay access and payload interface study should be made to identify requirements to allow individual payload changeout.

6.0 ADVANCED TECHNOLOGY REQUIREMENTS

Areas that require an advanced technology development are:

- Although some fluorine sensors are currently available, a satisfactory fluorine and hydrogen fluoride detector for low concentrations in the air does not exist. The development of a reliable fluorine sensor for use in both ground and flight operations is mandatory if fluorine fueled stages are to be safely processed and flown on the Shuttle.

- There is a requirement for the disposal of fluorine gas during loading operations and potentially for the disposal of relatively large quantities of fluorine during emergency situations. Although numerous methods for fluorine disposal have been studied none are completely suitable for KSC operations and it is recommended that a portable fluorine disposal system be developed.

- The various consequences of fluorine or other hazardous materials leakage requires that the integrity of tanks and plumbing systems be verified with a high degree of confidence. Thermal imaging systems could be used in a variety of applications for determining temperature profiles, thermal insulation degradation, and cryogenic gas leakage. The application of such systems to launch site processing problems should be investigated.

- A program should be conducted to evaluate existing personnel protective systems and to develop new systems including protective and life support systems as required for complete protection from fluorine. The existing KSC "SCAPE" systems are not compatible with fluorine and its reaction products.

- Since relatively low levels of mercury can cause personal injury and result in corrosive attack on various metals and electronic components, and most mercury vapor detectors/monitors are intended for field or laboratory use, the need exists for the design/development of a multichannel flight weight mercury monitoring system for use on the Space Shuttle.

- The development of a hazardous gas analyzer is recommended for pad operations and at the landing site to detect any hazardous fluid/gas leakages.