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SAFETY EVALUATION OF
ASTROTECH
PAYLOAD PROCESSING FACILITY
TITUSVILLE, FLORIDA

AUGUST 1990

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ASTROTECH

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TITUSVILLE, FLORIDA

Prepared for:

U.S. Department of Transportation
Office of Commercial Space Transportation

and

U.S. Environmental Protection Agency

Prepared by:

ICF Incorporated
Fairfax, VA 22031-1207

and

Research Triangle Institute
Cocoa Beach, Florida 32931

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LIST OF ACRONYMS

acfm	actual cubic feet per minute
AFB	Air Force Base
AFR	Air Force Regulation
AH	Anhydrous Hydrazine
AIChE	American Institute of Chemical Engineers
AKM	Apogee Kick Motor
ASME	American Society of Mechanical Engineers
ATF	Bureau of Alcohol, Tobacco, and Firearms
BTU	British Thermal Unit
CCAFS	Cape Canaveral Air Force Station
CCPS	Center for Chemical Process Safety
CCTV	Closed Circuit Television
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CO	Carbon Monoxide
CPIA	Chemical Propulsion Information Agency
DER	Department of Environmental Regulation
DoD	Department Of Defense
DOT	Department Of Transportation
ECI	Explosive Consultants, Inc.
EED	Electro-Explosive Device
EHS	Extremely Hazardous Substance
ELSA	Emergency Life Support Apparatus
ELV	Expendable Launch Vehicle
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act

ESMC	Eastern Space and Missile Center
ESMCR	Eastern Space and Missile Center Regulation
°F	Degree Farenheit
FEMA	Federal Emergency Management Agency
gpm	gallons per minute
HCl	Hydrogen Chloride
HNO_3	Nitric Acid
HTH	Calcium Hypochlorite
HVAC	Heating, Ventilating, and Air Conditioning
IDLH	Immediately Dangerous to Life and Health
IR	Infrared
KHB	Kennedy Space Center Handbook
KSC	Kennedy Space Center
kVA	Kilovolt-ampere
kw	kilowatt
LEL	Lower Explosive Limit
LEPC	Local Emergency Planning Committee
LOC	Level of Concern
MIL-STD	Military Standard
MMH	Monomethylhydrazine
MOU	Memorandum Of Understanding
MSHA	Mine Safety and Health Administration
N_2H_4	Hydrazine
N_2O_4	Nitrogen Tetroxide
Na_2S	Sodium Sulfide
NaOH	Sodium Hydroxide
NASA	National Aeronautics and Space Administration
NFPA	National Fire Protection Association
NIOSH	National Institute of Occupational Safety and Health

NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
NRC	National Response Center
OCST	Office of Commercial Space Transportation
OSHA	Occupational Safety and Health Administration
PAM	Payload Assist Module
PKM	Perigee Kick Motor
ppb	parts per billion
PPE	Personal Protective Equipment
ppm	parts per million
psia	pounds per square inch actual
RF	Radio Frequency
RSPA	Research and Special Programs Administration
SARA	Superfund Amendments and Reauthorization Act
SCBA	Self-Contained Breathing Apparatus
SERC	State Emergency Response Commission
SOP	Standard Operating Procedure
SRM	Solid Rocket Motor
SRT	Specialized Response Team
STS	Space Transportation System
UN	United Nations

1.0 INTRODUCTION

This report has been jointly prepared by the Office of Commercial Space Transportation (OCST) of the Department of Transportation (DOT) and the U.S. Environmental Protection Agency (EPA). This joint effort provides an evaluation of the buildings, equipment, operations and procedures employed at a commercial payload processing facility owned and operated by Astrotech Space Operations (Astrotech), Limited Partnership, in Titusville, Florida. Astrotech's corporate management gave its full cooperation to the evaluation. This report provides an overview of the operations, procedures and methods employed by Astrotech to protect public health and safety, the environment, and public and private property in the Titusville area and presents a summary of the OCST/EPA evaluation team's findings regarding operating procedures, safety policies, and emergency planning and preparedness. However, the safety evaluation team did not examine operations from the standpoint of worker safety, which is regulated by the Occupational Health and Safety Administration (OSHA), nor did they perform a detailed analysis of transportation operations, which are regulated by the Research and Special Programs Administration (RSPA) of DOT. This report can also serve as a general model and guide for the evaluation of similar issues at other existing or proposed facilities that would support the commercial space launch industry.

Payloads (also called spacecraft) are satellites that are launched into space to be used in communications systems, for remote sensing, in weather systems, for planetary exploration and as scientific experiments. Before launch on an expendable launch vehicle (ELV) like the Titan, Delta, or Atlas, or on the Space Shuttle, a payload must be prepared for its mission. The preparations include such things as checking electrical circuits, testing lines or tanks for leaks, and loading liquid propellants into assist motors that will be used once the payload is separated from the launch vehicle and must move itself into a specified orbit and then maintain itself in place while performing its mission. Since these and other preparations must be done under controlled conditions in clean environments (e.g., dust and particulate free) and since some of the materials (i.e., liquid and solid propellant and explosives) that are handled or loaded are hazardous, special facilities were developed by the National Aeronautics and Space Administration (NASA) and the Air Force for these operations. With the growth of the commercial space industry, the ability to process payloads in commercially available facilities is important and Astrotech is the first such commercial payload processing facility.

1.1 Background

The safety evaluation was performed in response to a request by the Lieutenant Governor of the State of Florida, the Honorable Bobby Brantley. In his letter to OCST, dated October 24, 1989, he indicated that a unique industrial facility existed in Titusville, Florida, owned and operated by Astrotech. This facility provides for the processing and checkout of spacecraft prior to their delivery and launch at either Kennedy Space Center (KSC) or Cape Canaveral Air Force Station (CCAFS). Processing of spacecraft involves a variety of operations as described in Section 4.0.

Under the Commercial Space Launch Act of 1984, as amended (Public Law 98-575, 100-657), the U.S. Department of Transportation (DOT) is responsible for licensing and regulating U.S. commercial space launch activities in a manner that protects public safety, safety of property, and U.S. national security and foreign policy interests, and encourages development of a viable domestic commercial launch industry. When questions arose concerning the safety of Astrotech's activities, the Lieutenant Governor of Florida requested OCST to conduct an impartial and focused review of the payload processing facility and operations. Because activities at Astrotech could affect safety of licensed launch operations, OCST agreed to undertake the safety evaluation.

OCST conducted an initial fact-finding visit and interviewed individuals from Astrotech, the City of Titusville, Brevard County, the Florida Department of Environmental Regulation (DER) and the Air Force to identify the potential issues involved with the safety evaluation. As a result of this visit, OCST determined that many of the safety evaluation issues involved areas in which EPA has recognized expertise. Since EPA has an on-going chemical safety audit program that addresses emergency planning and preparedness requirements, inclusion of EPA in a joint OCST/EPA effort has provided a more thorough and insightful review and evaluation.

1.2 Overview

In the early 1980's, with the growing opportunity for commercial access to space via the NASA's shuttle program and various ELVs, it was believed that the capacity for launch services support provided by the Government was inadequate to meet the growing needs of the commercial spacecraft community. Astrotech designed and built a commercial facility near KSC and CCAFS, which would provide state-of-the-art payload processing and support capabilities to those payload customers that had been using the NASA-owned facilities at KSC. NASA and Astrotech entered into a formal Memorandum of Understanding (MOU) whereby NASA agreed to accept payloads processed at Astrotech as long as they complied with NASA safety and other requirements. Astrotech also compiled and presented site selection information, services to be offered, design concepts and contracting considerations to spacecraft manufacturers, owners and contractors to elicit comments. The responses were then used, as appropriate, in designing, developing and constructing the Astrotech facility in Titusville, Florida.

The Astrotech complex in Titusville contains six major buildings located on approximately 37 acres in an industrial park, 2.75 miles from the Gate 3 entrance to KSC. The facility provides space and limited support for payload customers (U.S. and foreign) to perform the final assembly, checkout, fueling, and telemetric control of their spacecraft. The buildings are physically separated into hazardous and non-hazardous operations areas, based on the materials handled during the operations. Building 2, the Hazardous Processing Facility, is located several hundred feet from the rest of Astrotech's buildings and is constructed to meet Department of Defense (DoD) and Bureau of Alcohol, Tobacco, and Firearms (ATF) explosives siting standards.

Astrotech provides, through a fixed-price agreement with a payload customer, approximately the same support services as those provided by NASA through its Space Transportation System (STS) Optional Services Package. Services include ancillary support to the payload customer, local transportation of propellants to and from KSC/CCAFS for spacecraft fueling, transportation of the processed payload to the launch site, and off-load and on-load of spacecraft parts and other support equipment, as needed. All hazardous operations performed at Astrotech are directly supervised by the Astrotech Safety Officer. In order to provide comprehensive services, Astrotech subcontracts with NASA to provide limited routine support including propellant storage, cold soak and x-ray of rocket motors and chemical analysis of liquid propellants.

The payload customer is responsible for, and performs all hands-on work related to the assembly, processing, and fueling of the spacecraft; all of which requires highly trained, specialized personnel. The payload customer conducts these activities because the investment in the spacecraft is so great (on the order of $100 million or more) that stringent control measures are required. The value of a typical spacecraft may be five to ten times greater than that of the entire Astrotech facility, estimated to cost approximately $15 to $20 million.

1.3 Data Gathering and Analysis

This evaluation involved a visit to the Astrotech Titusville payload processing facility to examine buildings and equipment, to assess policies and procedures encompassing the overall safety program at Astrotech, and to evaluate the protection afforded to the public by the program in place. Specific information was gathered concerning the following:

- Buildings
- Operations and equipment
- Hazardous materials handled on-site
- Safety systems and equipment (including detection and monitoring systems)
- Emergency preparedness and planning

The on-site visit allowed the OCST/EPA team to examine buildings, equipment, and safety systems used for hazardous operations as well as the chance to view hazardous operations, interview key Astrotech safety personnel and to review relevant documents, reports, design drawings, regulatory permits, and other pertinent information. The visit also afforded the OCST/EPA team members the opportunity to meet with the local emergency response authorities, the local emergency planning committee (LEPC), and the Brevard County Emergency Management Agency to discuss the status of the emergency response and planning activities for the Astrotech facility and to identify and characterize the strengths and weaknesses of Astrotech's specific safety and accident prevention programs.

Following the data gathering phase, the team members analyzed data, evaluated safety systems, performed hazard analyses and determined risk to the public from various potential accident scenarios. Additional questions were asked of Astrotech personnel on an as needed basis, and Astrotech reviewed selected draft sections of this report to ensure that the safety evaluation team had accurately represented the facility's features and operations.

1.4 Evaluation Report

The results of the extensive data gathering and evaluation processes are presented in this report. While this safety evaluation will not ensure that an accident never happens at Astrotech, this process can help to identify any potentially hazardous situations that may exist, and highlight areas within the facility where operational or safety system improvements might significantly reduce hazards to the public. This report may also provide state and local emergency response agencies with guidance for dealing with safety issues concerning these and other space-related activities, as well as an approach to learning about and sharing technologies, techniques, and management practices dealing with safety and emergency preparedness.

The remainder of the report is organized into the following sections:

Section 2.0	Executive Summary
Section 3.0	Site Overview
Section 4.0	Buildings and Operations
Section 5.0	Safety Policies and Requirements
Section 6.0	Emergency Preparedness and Planning
Section 7.0	Hazard Analyses and Risk Assessment
Section 8.0	Findings, Recommendations and Guidance

Several appendices are also included with more detailed information regarding items such as Astrotech's Florida DER air permit, safety equipment specifications, references for information on performing hazards analyses, and the Brevard

County Hazards Analysis.

2.0 EXECUTIVE SUMMARY

This document presents the results of a safety evaluation of a commercial payload processing facility owned and operated by Astrotech in Titusville, Florida. The evaluation was performed by a team of experts from the Office of Commercial Space Transportation (OCST) and the Environmental Protection Agency (EPA). Under the Commercial Space Launch Act of 1984, as amended (Public Law 98-575, 100-657), the U.S. Department of Transportation (DOT) is responsible for licensing and regulating U.S. commercial space launch activities in a manner that protects public safety, safety of property, and U.S. national security and foreign policy interests, and encourages development of a viable domestic commercial launch industry. When questions arose concerning the safety of Astrotech's activities, the Lieutenant Governor of Florida requested OCST to conduct an impartial and focused review of the payload processing facility and operations. Because activities at Astrotech could affect safety of licensed launch operations, OCST agreed to undertake the safety evaluation.

The approach used in the evaluation was first to identify the major concerns of the state and local regulatory, planning and emergency preparedness officials, Astrotech, and the community. These concerns focused on the operations, procedures and policies in place at Astrotech to protect public health and safety and the environment. Issues included building safety design and siting, operating policies and controls, safety systems, training, and emergency preparedness and planning.

The next step was to visit Astrotech to gather specific information concerning the buildings, operations and equipment, hazardous materials handled on-site, safety systems and equipment, and emergency preparedness and planning. The visit allowed the evaluation team to see the safety and control systems; view some hazardous processing operations; interview key Astrotech safety personnel; review relevant documents, design drawings, and permits; and interview local emergency response and planning officials.

After the data gathering phase, the team analyzed the information, evaluated safety systems, performed hazards analyses, and identified potential risks to the public posed by credible accident scenarios that result in worst case releases at the facility. The final step was to make recommendations for changes or additions to procedures, policies, equipment, or facility design that could help prevent future problems or mitigate anticipated impacts on public health and safety of possible accident scenarios; in addition, the evaluation team prepared guidance to assist in evaluating other industrial facilities where public health and safety concerns may arise.

This report presents the findings and recommendations of the safety evaluation team, with emphasis on public health and safety risks that could arise from operations at the Astrotech facility. The team did not perform a transportation risk assessment; nor did the team evaluate issues of worker safety, either during routine operations or during accidents.

Site Overview

Astrotech is a commercial payload processing facility located in an industrial park in the city of Titusville, Florida. The site is about 3 miles from the Kennedy Space Center (KSC) and is near an airport, offices, a manufacturing plant and a residential housing development. The site covers approximately 37 acres and is divided into hazardous and non-hazardous work areas. Operations are conducted in the work area appropriate for the nature of the materials involved.

There are six buildings on the site. Buildings 2 and 3 are in the hazardous area and house the operations that involve the handling, storage, and transfer of solid rocket propellant, liquid rocket propellant and explosive material. (Note: no liquid propellants are allowed in Building 3.) The remaining buildings (1, 1A, 4, and 5) are in the non-hazardous work area. They contain space for offices and administrative activities as well as for storage of support equipment, and for functional testing, leak checking, and assembly of spacecraft prior to hazardous operations. Hazardous operations involve handling of solid rocket motors; transport, transfer and loading of liquid propellants; and lifting, spin balancing and transporting of fueled spacecraft to a launch pad at KSC or Cape Canaveral Air Force Station (CCAFS). Operations are carefully scheduled between the hazardous and non-hazardous work areas to minimize risks to processing personnel and sensitive spacecraft equipment and to maximize efficient processing flow.

Since Astrotech is located in an industrial park, there is some separation between the site and residential areas. However, concerns regarding accidents and potential impacts on nearby populations have focused public attention on the facility and its operations.

Facility Features

Astrotech provides a specialized facility and limited facility support under contract to payload customers who perform the final assembly, inspection and processing of their payloads prior to launch. The activities involved in preparing a payload for flight typically include assembly, leak testing of propellant systems, installation of other equipment, functional testing, cleaning, propellant loading, pressurization of tanks, spin balancing (if required), and mating the satellite with assist motors. These operations require special "clean room" conditions (with specific limits on the amounts of dust and particles in the air) and stringent controls on hazardous activities. Astrotech is one of the newest payload processing facilities in the U.S. and the only fully integrated one owned and operated by a commercial entity. Thus, Astrotech has taken advantage of the experience and knowledge gained by the National Aeronautics and Space Administration (NASA) and the Air Force over the last three decades of space launch activities to build and operate a state-of-the-art payload processing facility.

Since Astrotech is a commercial concern it is subject to federal, state and local regulatory requirements concerning such things as fire and building safety, worker safety, emergency response and preparedness planning, waste handling and disposal, transportation of hazardous materials, environmental emissions, and notification of accidental releases. The safety evaluation team found that Astrotech complied with all applicable safety, environmental, and emergency preparedness regulatory requirements.

The buildings in the hazardous work area of the facility were designed, sited and constructed to meet Department of Defense (DoD) and Bureau of Alcohol, Tobacco, and Firearms (ATF) explosives safety standards because solid and liquid rocket propellants and explosive materials (e.g., ignition and separation devices) are routinely handled, transferred, and installed during payload processing operations.

Building 3 is used for the long- and short-term storage of payloads, solid rocket motors (containing solid propellant classified by DoD as mass-fire) and any other ordnance-containing flight hardware, and other environmentally sensitive flight hardware, as required. No liquid propellants are handled or stored in Building 3.

Building 2 is used for performing operations considered to be hazardous, including loading and transfer of solid and liquid propellant, and is designed to be a total containment facility to prevent the release of propellant vapor or liquid into the environment from a small release during normal operations. The building can effectively be sealed to trap propellant vapors inside until treated. In constructing one of the newest facilities of its kind, Astrotech was able not only to incorporate lessons learned from the years of operation at NASA and DoD facilities, but also to identify the best technologies available, some of which had been developed for use in other industries or applications, and to transfer and apply these technologies to improve payload processing operations safety.

The special features and systems that were incorporated by Astrotech and that the safety evaluation team found to be an improvement over older processing facilities are briefly described below.

Vapor Containment

Building 2 was designed and built to contain a propellant leak or spill, should one occur inside during normal operations. The only exhaust from the building is through a scrubber that treats any propellant vapors generated as part of the fuel/oxidizer containment and neutralization system (see below). Also, a recirculation fan is installed inside Building 2 for agitation of air and to aid in diluting and breaking down of propellant vapor in the event of a major spill in the building.

Electrostatic Dissipation

The floor in the high bays and North Airlock in Building 2, where hazardous processing operations are performed, is covered with vinyl tiles, impregnated with graphite and bonded to the concrete with conductive mastic. This dissipates static electricity to the building grounding grids, reducing the threat of electrostatic discharge that might ignite SRMs or flammable liquid propellants. This technology was originally developed for use in hospital operating rooms where static electricity created severe potential safety hazards in dealing with sensitive instruments.

Spill Collection and Containment

Propellant loading operations are conducted on "fueling islands," which are in the center of a work area and are surrounded by a stainless steel collection trench that slopes underground and drains to the containment and neutralization tanks outside the building (described below). If a spill occurs, it is directed into the trench drainage system, confining the spill and making cleanup easier. In the event of a fuel spill involving a fire, the trench system would also serve to confine the fire to the fueling island and help prevent its spread to other areas.

Fuel/Oxidizer Containment and Neutralization

There is a containment system, consisting of oxidizer and fuel holding tanks, separated by appropriate valving and manually-switched piping connected to a vapor scrubber. The scrubber is operated under a permit from the Florida Department of Environmental Regulation (DER) for anhydrous hydrazine, monomethyl hydrazine and nitrogen oxides. Following a complete processing operation, the contents of the tanks are neutralized, and after testing by the city, are discharged to the city of Titusville sewer.

Remote Visual Access To Hazardous Operations

Since Astrotech monitors all hazardous operations that are performed by its payload customers, explosion-proof observation windows were installed between the control rooms and bays in Building 2 to reduce the number of personnel in the bay during propellant sampling and loading. This allows safety and quality control personnel required to observe and monitor hazardous operations to do so without being physically present in the bay.

Pre-Action Suppression System

A computer-controlled fire suppression system was installed that has compressed air in the lines, maintaining a "dry pipe" condition. Activation of this pre-action system requires two independent events: first, smoke/heat detection alarm signal from any of the detectors mounted in the bays, airlocks, or the heating, ventilating and air conditioning (HVAC) system or from a manual pull station; and second, sufficient heat to melt the fusible link in the sprinkler head. The first opens a valve releasing the water to the sprinkler system; the second releases the water from the sprinkler head to wet the area. This system design provides some special protection for sensitive payloads and other equipment in case there is a false alarm or other problem.

Computer Monitoring of Alarms

Alarms are automatically sent to the guard house at the front gate via computer link for various parameters and systems including: temperature and humidity (HVAC system), loss of air pressure in the pre-action fire suppression system, toxic vapor detector alarm, toxic vapor detector status problem such as low battery or a tape break, generator failure, and an automatic or manual fire alarm. The alarm panel indications displayed to the guard allow prompt identification of potential problems and notification of appropriate personnel.

Vapor Detectors

Astrotech monitors atmospheric conditions in Building 2 using state-of-the-art portable toxic vapor detectors to supplement the more conventional vapor analysis techniques used (Draeger tubes). Vapor monitoring is done at all times that liquid propellant is in the building. These detectors are extremely sensitive and are microprocessor-controlled for speed, accuracy and specificity. The detectors are encased in special explosion-proof clear plastic boxes for use in flammable/potentially explosive atmospheres.

Safety Policies and Requirements

Astrotech has strict safety policies and operating procedures for the use of its facility and support equipment by its payload customers. Because of the high value of their satellites, Astrotech's payload customers also have stringent internal safety requirements. So there is to some extent a system of safety redundancy and crosschecks between Astrotech and its payload customer, with each having considerable interest in ensuring safe and efficient processing operations.

Payload customers are required to provide detailed technical data and operating procedures for all hazardous operations. Astrotech reviews and approves these procedures prior to initiation of operations. Additional Astrotech safety requirements include such things as training and certification of propellant handling teams, scheduling and coordinating all hazardous operations through Astrotech, and safety monitoring by Astrotech and customer safety and quality control personnel of all hazardous operations scheduled for a specific payload.

Astrotech's safety requirements are detailed in two operating documents, Safety Policy and Safety Standard Operating Procedures, which identify what is required of the payload customer by Astrotech in terms of information concerning support equipment (e.g., pressure systems, electrical systems, tanks and lines); certification standards; operating procedures and safety requirements for performing hazardous operations (e.g., ordnance checkout and installation, propellant loading); baseline weather conditions for conducting operations; requirements for lifting and transporting spacecraft; and accident reporting.

Emergency Preparedness and Planning

Astrotech has a written emergency plan that addresses emergency response procedures for incidents that may occur either at the facility or while transporting liquid propellant from and returning any excess to the storage facilities at KSC and CCAFS. The plan was updated in 1988 and is considered an adequate document for dealing with emergencies that could occur. Since it began operations in 1984, Astrotech has never had a release in which reporting to or alerting of emergency response agencies has been necessary.

Astrotech has worked closely with local, county and state emergency response and planning officials in familiarizing them with the facility, its safety systems, the types of operations that are performed, the materials that are handled and their hazards, and the personal protective equipment necessary for personnel responding to emergency situations. The public safety officials interviewed by the evaluation team gave Astrotech high marks for their efforts in these areas.

Hazards Analyses and Risk Assessment

The overall goal of this evaluation was to identify potential risks to the public from accidents that could occur at Astrotech. The hazards analyses were performed by reviewing the facility design, operations and procedures and then defining possible accident scenarios that could produce a hazard to the public. In this evaluation, a scenario leading to a fire and explosion in Building 2 was the baseline for defining accident scenarios that could potentially affect the public. For each accident scenario that could produce impacts on the public an estimate of the probability of its occurrence was made and the potential consequences described. For each potentially hazardous condition, those facility design features and operating procedures that could mitigate the hazard and reduce the associated risk were also considered in making the probability estimates. Any residual risk to the public was then identified.

In performing this assessment, the evaluation team determined credible accident scenarios, regardless of how unlikely, which could result in the largest potential negative impact on the public. If these scenarios produce no significant negative impacts on public health and safety, any lesser accident can also be assumed to have no negative impacts. Hazards analyses and risk assessments require assumptions and data inputs to models which attempt to predict the results of physical phenomena like fires, explosions and the release and dispersion of toxic gases in the atmosphere. The evaluation team made "conservative" assumptions and used conservative or worst case data inputs for these analyses. This means that the assumptions and data inputs err on the side of protecting public health and safety. Therefore, the actual impacts, if an accident were to occur, would likely be considerably less than those predicted.

The results of the analyses indicated that a worst case release is caused by a fire and explosion involving the maximum quantities of liquid propellant permitted on site (2,500 pounds of fuel; 5,000 pounds of oxidizer) and the maximum amount of solid propellant on site (24,600 pounds from the explosive safety siting analyses), that damage or destroy the walls and/or ceiling in Building 2. Gases not consumed in the fire and explosion could then disperse and diffuse in the direction of the prevailing winds.

The probability that any of the identified credible accident scenarios will occur and result in the worst case release is remote (about 2×10^{-4}), on the order of two such accidents per 10,000 complete payload processing operations. At an average processing rate of ten payloads per year, the probable frequency of such an accident is approximately once in 500 years. In Government payload processing facilities, with many years of combined operating experience, accident scenarios of the severity analyzed in this evaluation have never occurred. So, the safety evaluation team conservatively estimates that even applying an uncertainty factor, the maximum frequency of the worst case release would be once every 100 years.

The consequences associated with these accidents are extremely difficult to predict since there are no mathematical models that take into account fire and explosion inside a building, followed by damage to the building allowing release of toxic gases. Thus, conservative estimates for the amount of propellants involved in the initial accident were made. Also, conservative assumptions were made based on actual accident experience, regarding the amounts of propellant that would be available to be released (i.e., not consumed in the fire and explosion). Typical ambient temperature and humidity were assumed, along with conservative wind conditions. These estimates resulted in very conservative (protective) estimates of the concentrations of toxic gases that could result in the nearby atmosphere.

Accident consequences, including ground level concentrations of toxic gases and overpressure effects of explosions, were examined to estimate any risk to the public. The analyses indicated that no explosion effects, including primary overpressure effects and secondary effects such as glass breakage and flying debris, would occur beyond the facility boundary.

To quantify the hazard from toxic gases, it is important to use a standard measurement for airborne toxic hazards. The Immediately Dangerous to Life and Health (IDLH) concentration set by the Occupational Safety and Health Administration/National Institute of Occupational Safety and Health (OSHA/NIOSH) was selected for this analysis. An IDLH, set at a specific value for a particular chemical, is the maximum concentration that one could inhale for thirty minutes, and still not experience escape-impairing symptoms or irreversible injury. Thus, both exposure **concentration** and **duration** are important considerations in evaluating effects. EPA uses the IDLH as a basis for performing hazards analysis for community planning, but in order to be protective of the general population has defined a "Level of Concern" (LOC) for a chemical as 10% of its IDLH.

The safety evaluation team compared the predicted ground level concentrations of all resulting toxic vapors (hydrazine; nitric acid, from dissociation and reaction of oxidizer; and hydrochloric acid, from the burning of a solid rocket motor [SRM]) to their IDLH values. The hydrazine concentration outside the facility boundary is never predicted to be above the 10% IDLH level. Nitric acid and hydrogen chloride concentrations outside the facility boundary are never predicted to be above the 50% IDLH levels, and their concentrations will diffuse to below the 10% IDLH levels within approximately 860 feet and 1,225 feet of downwind travel, respectively. At all locations outside the facility boundary, even with a conservative assumption of low wind speed, the exposure duration would be less than a minute. There would be no adverse impacts on the public from exposures at these concentrations for such brief durations.

Thus, a worst case release, which has only a remote possibility of occurring at the facility, would have no adverse impacts on public health and safety.

Findings

Overall Astrotech appears to have taken every reasonable precaution in designing and constructing a facility which is safe for those living and working nearby and in implementing the policies and operating procedures that have been successfully used by DoD and NASA for many years. The owners commissioned several safety studies, both to site the buildings on the property initially and before design and construction changes for modifications were approved. Astrotech has also tried to identify and incorporate effective safety, monitoring, and detection features into the facility.

Findings Regarding the Buildings and Operating Procedures

The buildings where hazardous materials are handled are separated from the public and from the non-hazardous work areas by distances determined using DoD and ATF explosives siting criteria.

The buildings and equipment are state-of-the-art design and quality.

Building 2 is designed and operated to minimize the risk to the public from any potential releases of propellant vapor or liquid that could result from a spill occurring inside the building. The containment and scrubber systems provide protection to the public from any incidental exposures during routine operations.

The physical facility and equipment compare favorably with Government facilities that serve similar functions.

Prior to and during operations, policies and procedures are in place to ensure safety. These include attention to all aspects of operations, equipment maintenance and certification, personnel training, and safety systems.

The formal, documented procedures for processing payloads meet all accepted standards as applied by industry, DoD and NASA.

No reportable accidents or incidents have occurred at Astrotech since it began operations in 1984.

Astrotech has continued to update equipment and is committed to minimizing the generation of hazardous waste, as evidenced by the recently ordered closed-loop still for processing and recycling contaminated freon.

Findings Regarding Emergency Response and Preparedness

Astrotech has an adequate written emergency response plan.

Astrotech has been cooperative and interactive with local and county emergency response and preparedness officials.

Procedures and equipment are in place to protect workers in hazardous situations, to assemble the facility emergency response team should it be necessary, and to call for off-site assistance as required.

Results of Hazards Analyses

If an explosion were to occur in Buildings 2 or 3, the public would not be exposed to any primary explosion effects from overpressure, flying fragments, or fire.

The worst case accident scenarios, which involve a fire and explosion in Building 2, result in no adverse impacts on public health and safety.

Recommendations

In this section, the evaluation team outlines areas needing additional evaluation and attention by Astrotech to further enhance the safety of its facility and operations. These recommendations can be generally divided into those directed at the systems, equipment, and operations; those dealing with policies and procedures; and those dealing specifically with emergency preparedness and planning:

Systems, Equipment, and Operations

Evaluate the feasibility and safety of modifying the sequence of processing operations dealing with loading liquid propellants, lifting and mating the satellite with the SRM, pressurizing tanks, and spin balancing operations so that the operations sequence minimizes the chance of a worst case release.

Provide additional communication capability for cart storage rooms (e.g., telephones or direct connection to the guard house).

Policies and Procedures

Include operational sequencing limitations for propellant loading in the Safety Standard Operating Procedure (SOP).

Develop written guidelines for necessary activities following an "uncontrollable" spill including a definition of incident(s) that initiate an uncontrollable spill, activities that need to be done to mitigate and evacuate the area, and the steps and requirements for re-entry.

Specify with more detail the criteria considered for proper training and certification of customer personnel.

Emergency Preparedness and Planning

Provide additional clarification of personnel assignments, especially regarding an assigned back-up to the Safety Officer.

Expand the emergency contacts list to include critical contacts beyond the 911 system (e.g., the county emergency management director), and the phone numbers and contact person for the nearest industrial neighbors.

Add the Superfund Amendments and Reauthorization Act (SARA) Title III reporting requirements for information to be furnished in the event of a release to the plans and procedures.

Perform a simulated exercise of the emergency response plan with emergency responders, even if only a table-top exercise.

Guidelines

The safety evaluation team found that in the process of evaluating the Astrotech facility, there were generic guidelines that could be outlined in order to assist communities and local response and planning authorities in evaluating the overall safety of industrial facilities. It must be noted that these guidelines are not aimed at the Astrotech facility itself; in fact, in many of the areas identified, Astrotech can provide a model for proper implementation.

It is helpful to coordinate early in the design process with local planning officials, recognized safety experts, and other facilities with similar functions, so that the original construction can incorporate as many safety features as possible. For example, because the Astrotech facility is sited to meet explosive safety distance siting criteria, the public is protected from the primary effects of explosions.

A comprehensive safety program should include operating and maintenance controls, training, documentation and record keeping, and internal audits and inspections. Because the safety program is a key factor in protecting the public and the environment, the community may want to consider establishing a monitoring program, where an external expert regularly inspects a facility and observes operations to ensure that all aspects of the safety program are implemented.

Along with community emergency planning officials, it is important for facilities to establish an emergency response plan. In order to increase the effectiveness of such a plan, the community and facility should work together to identify facility hazards, determine likely accident scenarios, implement procedures that minimize the likelihood and severity of such accidents, and finally plan how to respond in the event of an accident. Because hazardous materials are necessary for many aspects of industrial processes, it is important that facilities and communities work together to prevent or minimize accidents.

3.0 SITE OVERVIEW

This section provides an overview of the facility layout and security measures, and details background regarding the site location, including the local geography, weather patterns and community demographics.

The Astrotech facility is located in the southernmost part of the City of Titusville, Florida at 28° 31' 30" North Latitude and 80° 49' 12" West Longitude, approximately 3,000 feet south of State Road 405 and adjacent to State Road 407. See Exhibit 3-1.

3.1 Facility Profile

The buildings that comprise the Astrotech facility are divided into non-hazardous and hazardous work areas. It is common industrial practice to localize and segregate operations involving activities in which hazardous materials are handled, to minimize any potential exposure outside of a limited area and to control and limit access. At Astrotech, operations are scheduled to take place in the work area appropriate for the materials being transferred or loaded.

There are 11 permanent employees at Astrotech (including janitorial staff), most of whom have been at the facility since its opening. Security guards are provided to Astrotech under contract.

This section will present a general overview of the buildings that comprise the facility as well as a general description of the safety design features of the buildings in both the non-hazardous and hazardous operations areas. Detailed descriptions of the buildings can be found in Section 4.1.

3.1.1 Buildings

The Astrotech facility opened in April 1984 after a ten month construction period. After the original design and construction, Astrotech identified the need to provide more processing space and to facilitate processing larger spacecraft, and additions were made to Buildings 1 and 2. These additions were completed in May 1989, after a ten month construction period. Additional studies were conducted to ensure that the expansion of Building 2 met explosive siting criteria (See Section 7.1.1). Astrotech also requested and obtained a modification of its Florida DER air permit to allow the handling of larger quantities of liquid propellants on site (See Section 7.1.2).

The facility consists of six buildings and a free standing antenna tower. Buildings 1 and 1A, 4, and 5 are located in the designated non-hazardous area of the site and Buildings 2 and 3 are in the hazardous operations area. See Exhibit 3-2 for a layout of the buildings on the property.

EXHIBIT 3-1 MAP OF ASTROTECH SITE

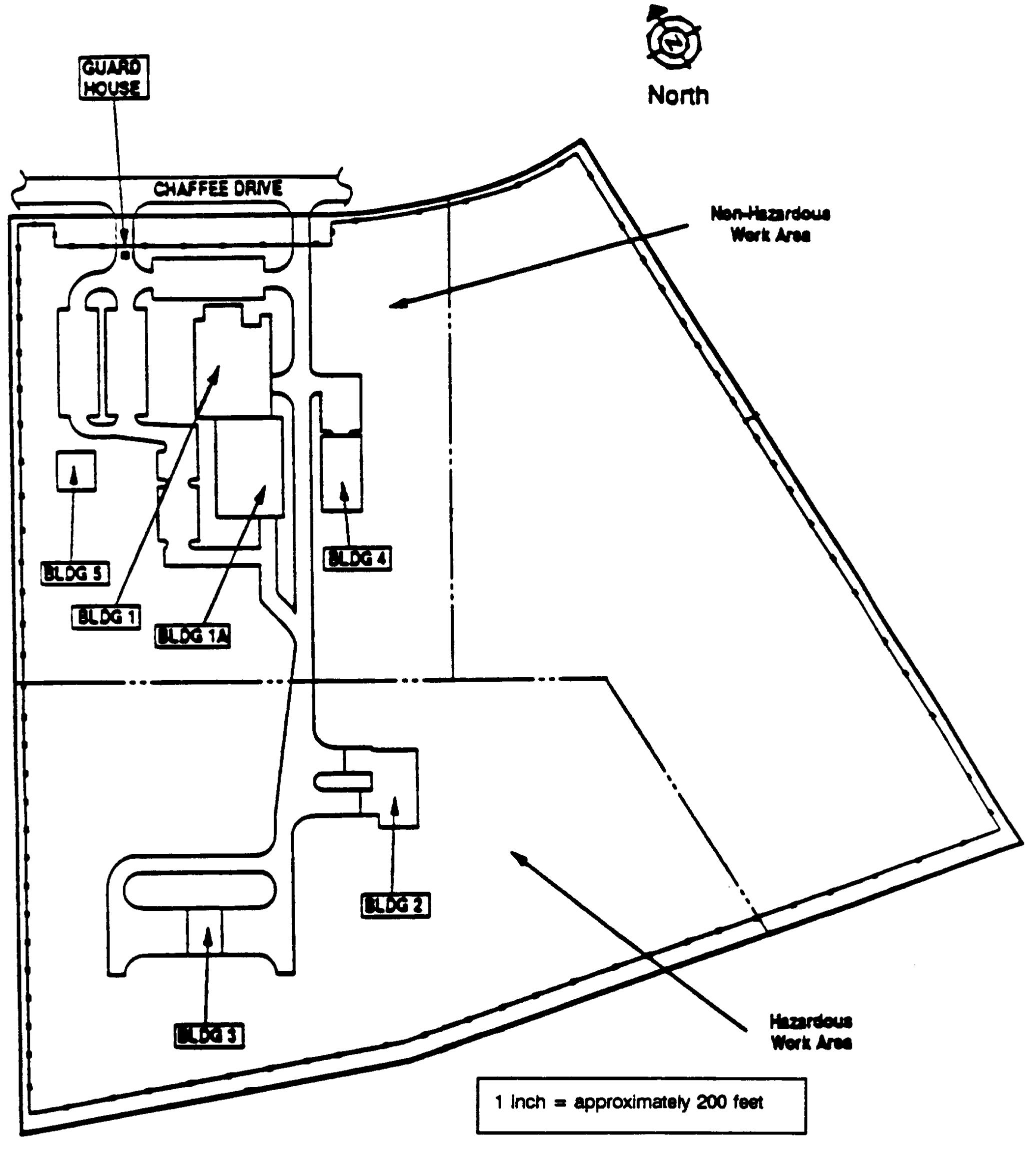
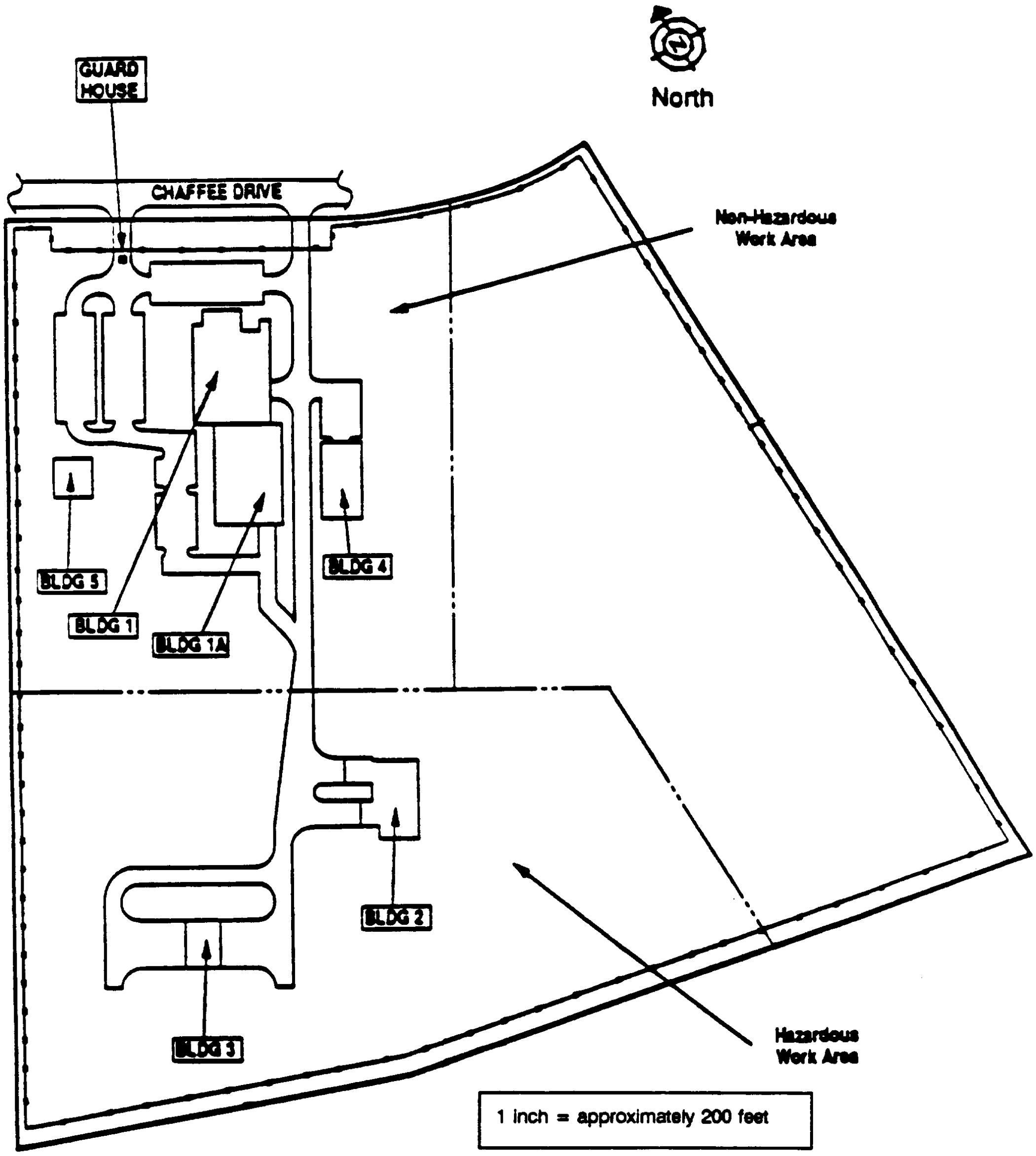


EXHIBIT 3-2 LAYOUT OF BUILDINGS AT SITE



3.1.2 Overview of Facility Design Safety Features

Buildings in the hazardous operations area (Buildings 2 and 3) are constructed with special design features based on the materials and operations that are allowed in each. These are detailed in Section 4.4 and are only briefly mentioned here.

Building 3 is sited and constructed to DoD and ATF explosives safety criteria for storage of solid rocket motors and any other ordnance-containing flight hardware, as required. No liquid propellants are stored in Building 3.

Building 2 is designed to contain a release of propellant vapor or liquid into the environment. The building has a sealed design, which, in the event of a propellant spill, would trap all toxic vapor inside the building and its containment system until it was neutralized into harmless materials. Also, the building is designed to minimize the possibility of igniting propellants. For example, extensive lightning protection, consisting of lightning rods and grounding grids, prevents accidental ignition of materials and damage to equipment. In the unlikely event of a fire or explosion, there are fire protection systems designed and installed to meet strict National Fire Protection Association (NFPA) code requirements. Safe operations are also enhanced by having backup power for critical functions like facility lighting, the fire protection system, and vapor monitors.

3.2 Site Conditions[1]

In performing the safety evaluation, it is important to understand the topography, hydrology, weather, and atmospheric conditions in the vicinity of the site in order to evaluate the effectiveness of the safety features of the facility and also to identify and evaluate operations that may be sensitive to site specific phenomena, such as storms and floods.

3.2.1 Soil, Topography and Hydrology

The soil is predominantly sugar sand with some sea shell fragments to a depth of approximately 100 feet. No shell is evident at the surface, and none was encountered in excavation to approximately ten feet. The upper region of the soil is moderately porous and because of the gently rolling slope, moderately well drained. Vegetation ranges from low grasses to sparse palmetto.

The site is located outside of the one hundred year flood plain, and flooding due to either excessive rainfall (i.e., thunderstorms or hurricanes) or tidal surges is unlikely. The terrain is nearly flat, with a slightly rolling slope of less than ten feet. Because of the site's gently sloped topography and its natural water table of approximately eight feet, rainwater is rapidly absorbed into the ground. Swales or slight depressions in the ground located throughout the facility site also contribute to the rapid absorption of rainwater.

Tidal surge flooding, although possible, is unlikely because the site is more than twenty feet above mean sea level and approximately fourteen miles from the nearest Atlantic beach.

3.2.2 Weather Patterns

There are two major weather seasons: May to October is the wet season and November to April is the dry season. Rainfall, temperature, wind direction and atmospheric stability all vary depending on the season.

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[1] Most of the data in Section 3.2 was taken from Final Environmental Impact Statement for the Kennedy Space Center NASA, October 1979 except for site specific details concerning soils, topography and terrain.

Especially in the wet season, hurricanes and lightning are likely weather patterns, so the facility must carefully monitor the weather before scheduling hazardous payload operations.

Seasonal Temperature and Wind Patterns

The dominant weather pattern in the May to October wet season is characterized by southeast winds that travel around the Bermuda Anticyclone, bringing moisture and warm air, leading to almost daily thundershowers. This season also has the greatest potential for hurricanes. Approximately 70 percent of the average annual rainfall occurs during the wet season. The monthly precipitation average is four inches, with the greatest amount of rainfall in September.

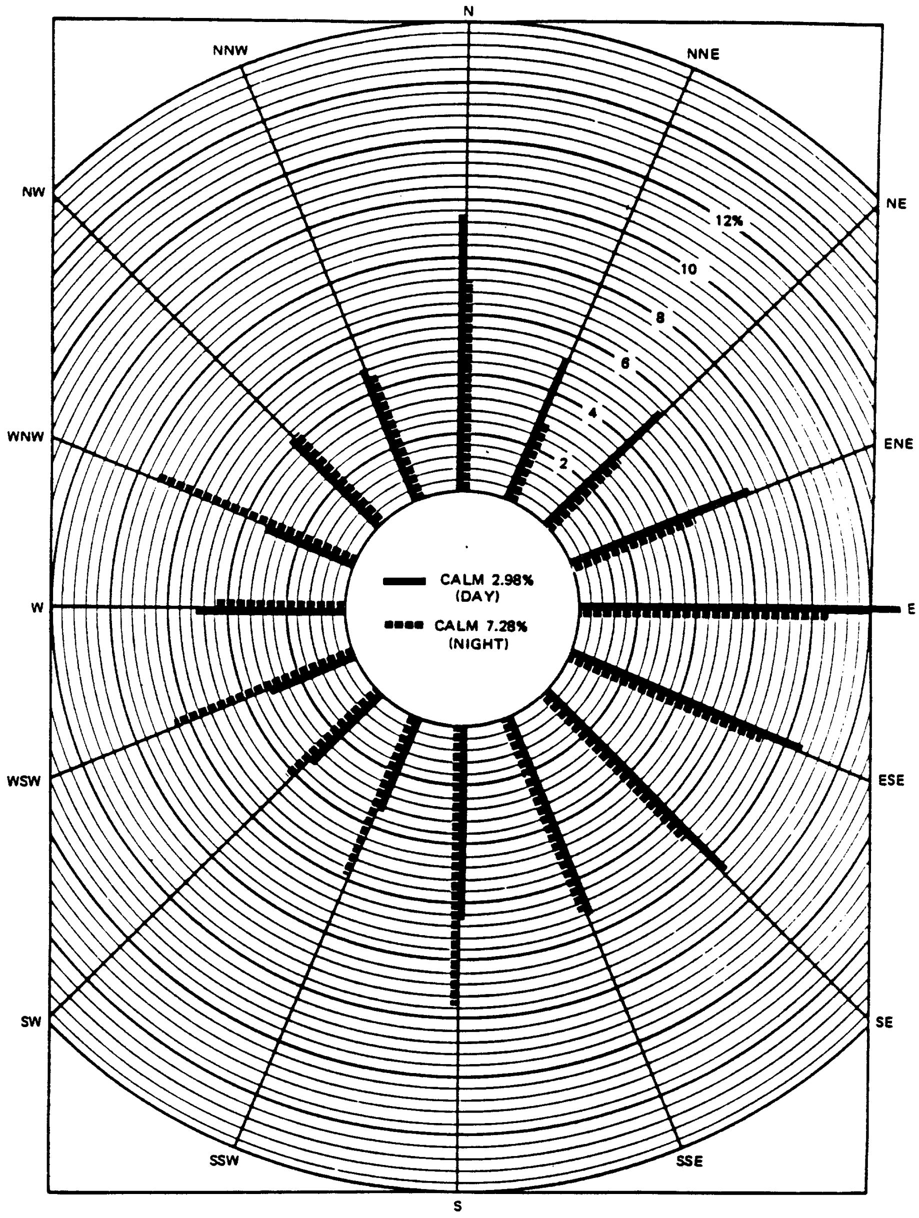
Temperatures during the wet season average 79 degrees Fahrenheit (°F) and rarely exceed 90°F. Relative humidity averages 90 percent in the early morning hours and generally declines to approximately 70 percent by early afternoon.

Weather patterns in the dry season (November to April) are influenced by cold continental air masses that cause rain when they move over the Florida peninsula and meet warmer air. In contrast to the localized, heavy thundershowers of the wet season, rains during the dry season are light and steady, and tend to be uniform in distribution. Total rainfall averages 15 inches for a monthly average of approximately 2.5 inches.

Dry season temperatures average 64°F, but have sharp gradients when the cold air masses move over the area. In the past decade, the temperature has usually not gone below 32°F, and recent winters have had longer cold periods than previously. Relative humidity during the dry season averages 55 percent.

Weather patterns originate from both daily and seasonal wind patterns. Wind directions are influenced by seasonal meteorological conditions and by the thermal differences between the Atlantic Ocean and the Cape Canaveral-Merritt Island-Titusville land masses. Cool air always replaces rising warm air so that during the night offshore (from land to ocean) breezes predominate and during the day onshore (from ocean to land) breezes are most frequent. Exhibit 3-3 illustrates day and night mean wind direction patterns. Onshore breezes can be 3,300 feet and higher, and reach farther inland during the wet season.

EXHIBIT 3-3 DAY AND NIGHT MEAN WIND DIRECTION PATTERNS



Seasonal wind directions are influenced primarily by continental temperature changes. In general, the fall winds occur predominantly from the east to northeast. Winter winds occur from the north to northwest shifting to the southeast in the spring and finally to the south in the summer months. Exhibit 3-4 presents seasonal wind direction distributions.

Atmospheric stability is an indicator of air turbulence, inversely related to the dispersion of gases and particles, and is an important factor in determining the concentration of gases and particles in the air as well as how long they might be present. Stable conditions can result in poor dispersion (e.g., a plume of pollutants would not diffuse and disperse as quickly) and are most likely to occur during the evening hours; unstable conditions provide rapid diffusion and removal of gases and particles from an area. Exhibit 3-5 illustrates the frequency distribution of stability classes by hours of the day. Exhibit 3-6 presents seasonal distribution of atmospheric stability detailing both the wind speed and the percent of time that it occurs. In general, atmospheric conditions are most stable during the winter months.

EXHIBIT 3-6 SEASONAL DISTRIBUTION OF ATMOSPHERIC STABILITY*

		Summer June-Aug		Winter Dec-Feb		Annual Average	
Atmospheric Turbulence	Stability Classification	1/	2/	1/	2/	1/	2/
	Extremely Unstable	1.8	6.3	0.6	4.9	1.1	6.5
High	Unstable	4.4	8.3	1.9	9.2	2.8	9.2
	Slightly Unstable	19.4	10.3	12.9	11.4	15.2	11.2
Moderate	Neutral	44.9	9.6	40.4	11.4	44.9	11.0
	Slightly Stable	21.4	6.9	28.9	9.6	24.6	8.5
Low	Stable	7.3	4.7	12.9	6.7	9.8	6.0
	Extremely Stable	0.8	3.6	2.6	5.8	1.6	5.1

1/ Percent of the time
2/ Miles per hour (wind speed)

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* Final Environmental Impact Statement for the Kennedy Space Center, NASA, John F. Kennedy Space Center, October 1979.

EXHIBIT 3-4 SEASONAL WIND DIRECTION DISTRIBUTIONS

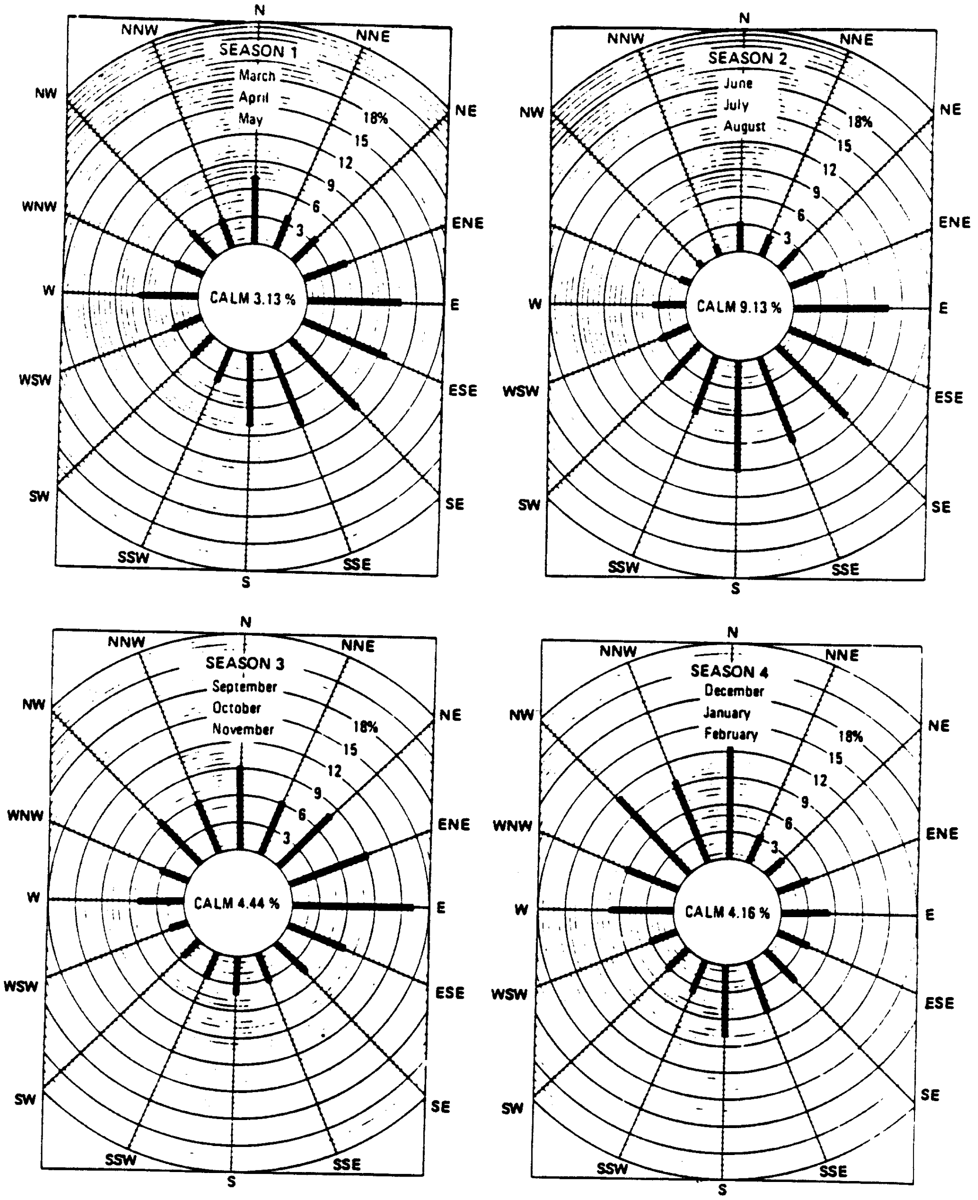
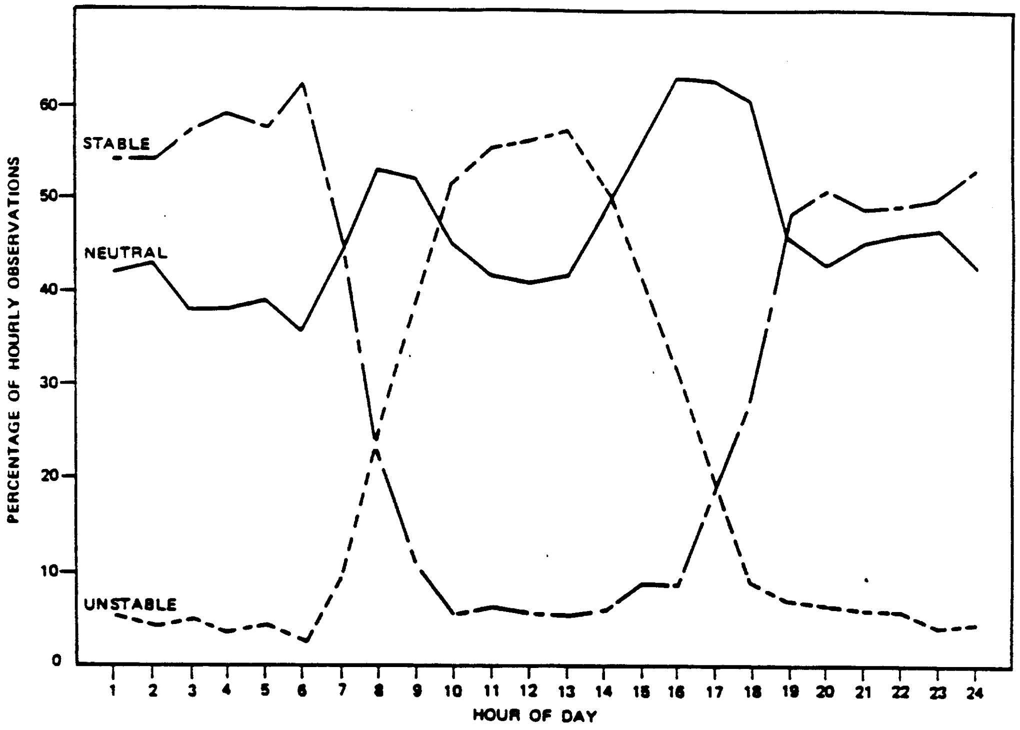


EXHIBIT 3-5 FREQUENCY DISTRIBUTION OF ATMOSPHERIC STABILITY BY HOUR OF THE DAY



3.3 Site Access and Control

All site access routes are publicly maintained roads. The immediate access to the Astrotech site is via Chaffee Boulevard from Grissom Parkway, which is off State Road 405, which extends to the east directly into the NASA Causeway leading to KSC. State Road 405 intersects US Route 1 on the east and joins State Road 50 to intersect with Interstate 95 on the west. Grissom Parkway is the major artery into the Spaceport Florida Industrial Park. See Exhibit 3-1.

Perimeter access is restricted by a chain link fence topped with barbed wire. Access through the main entrance gate is controlled 24 hours a day in order to regulate employee, customer, and visitor traffic through conventional sign in, verification, and numbered badge assignment procedures. Access to operations buildings is restricted by cipher/key locks on all personnel doors and all visitors must be escorted. Other special access restriction could be provided upon customer request. An additional badge exchange guard station limits access to the entire hazardous work area when certain operations are taking place in Building 2.

Liquid propellants are transported to Astrotech from CCAFS/KSC, and, therefore, the transport route is a short one. See Exhibit 3-7. Propellants are transported from the CCAFS Liquid Propellant Supply Depot to Astrotech for fueling payloads, and fueled payloads are transported from Astrotech to launch pads at KSC and CCAFS.

3.4 Demographics of the Vicinity

It is useful to know the population pattern in the immediate vicinity of the Astrotech facility as a baseline for risk analysis. After quantifying specific distance relationships in a hazards analysis, the safety evaluation team can determine the population affected, if any.

The safety evaluation team has made separate estimates of residential and industrial populations within one mile of the Astrotech facility, and has surveyed that area for any specialized concerns, such as ecologically sensitive zones or sensitive facilities (e.g., hospitals, nursing homes, and schools). The one-mile radius was selected to be conservative in evaluating whether the public would be affected (i.e., be more protective of the public), based upon the results of the Brevard County hazards analysis (see Appendix A).

Because the facility is located within the existing Spaceport Florida Industrial Park, there are a substantial number of offices and light industries within a one-mile radius. Daytime office and light industrial population is estimated to be 1,500 individuals, and the evening estimate is 150 individuals.

Based on the 1985 actual data[2], the residential population by quadrant (see Exhibit 3-8 for quadrant locations) is projected for years 1990, 1995, and 2000 in Exhibit 3-9. Each quadrant has a one mile radius. The closest residences to the facility are in Windover Farms, approximately one quarter of a mile west of the facility across State Road 407. No residences are located in the east quadrants.

If a hazardous situation were to arise, certain specialized populations could require additional attention by emergency responders. EPA guidance recommends that a community identify facilities, such as hospitals, nursing homes, schools and parks, so that the community can incorporate their protection into its emergency preparedness planning. No schools, hospitals,

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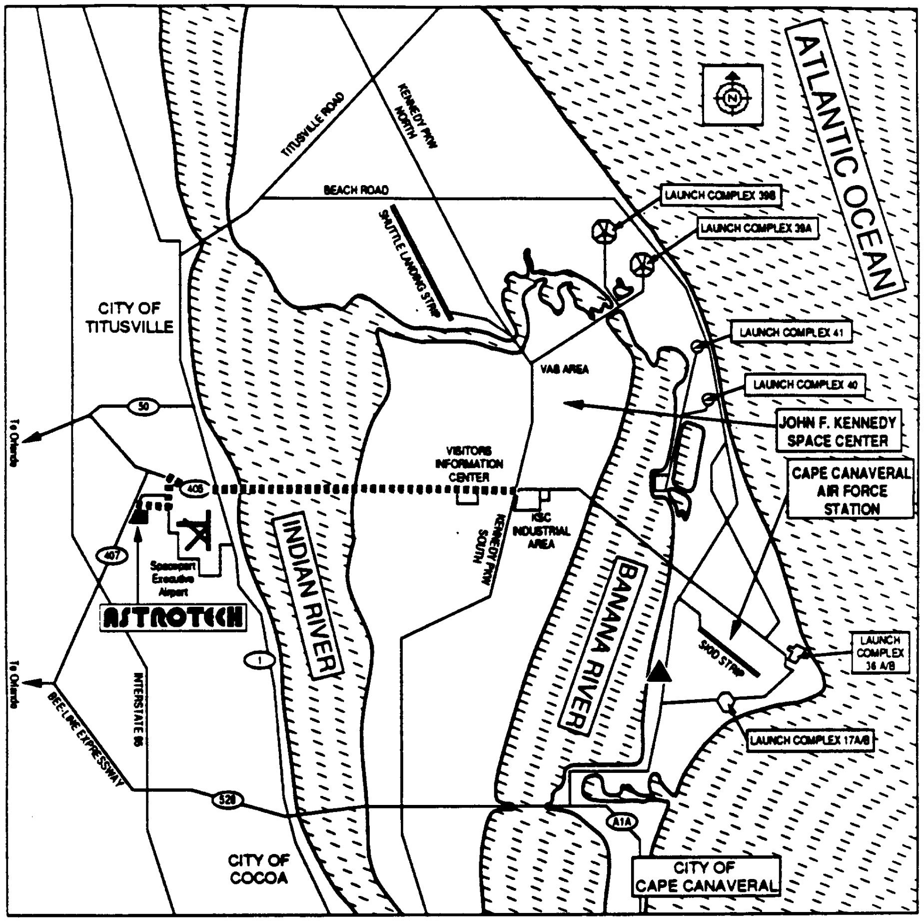
[2] Brevard County Projections, Populations and Occupied Dwellings, Brevard County Geographic Research Division, August, 1987.

nursing homes or environmentally sensitive areas are known to be within a one mile radius of the Astrotech facility.

EXHIBIT 3-9 PROJECTIONS OF RESIDENTIAL POPULATION BY QUADRANT

	YEAR 1990	1995	2000
NE Quadrant	0	0	0
NW Quadrant	750	1065	1344
SW Quadrant	180	327	480
SE Quadrant	0	0	0
Population Total	930	1392	1824

EXHIBIT 3-7 HAZARDOUS MATERIALS TRANSPORTATION ROUTES

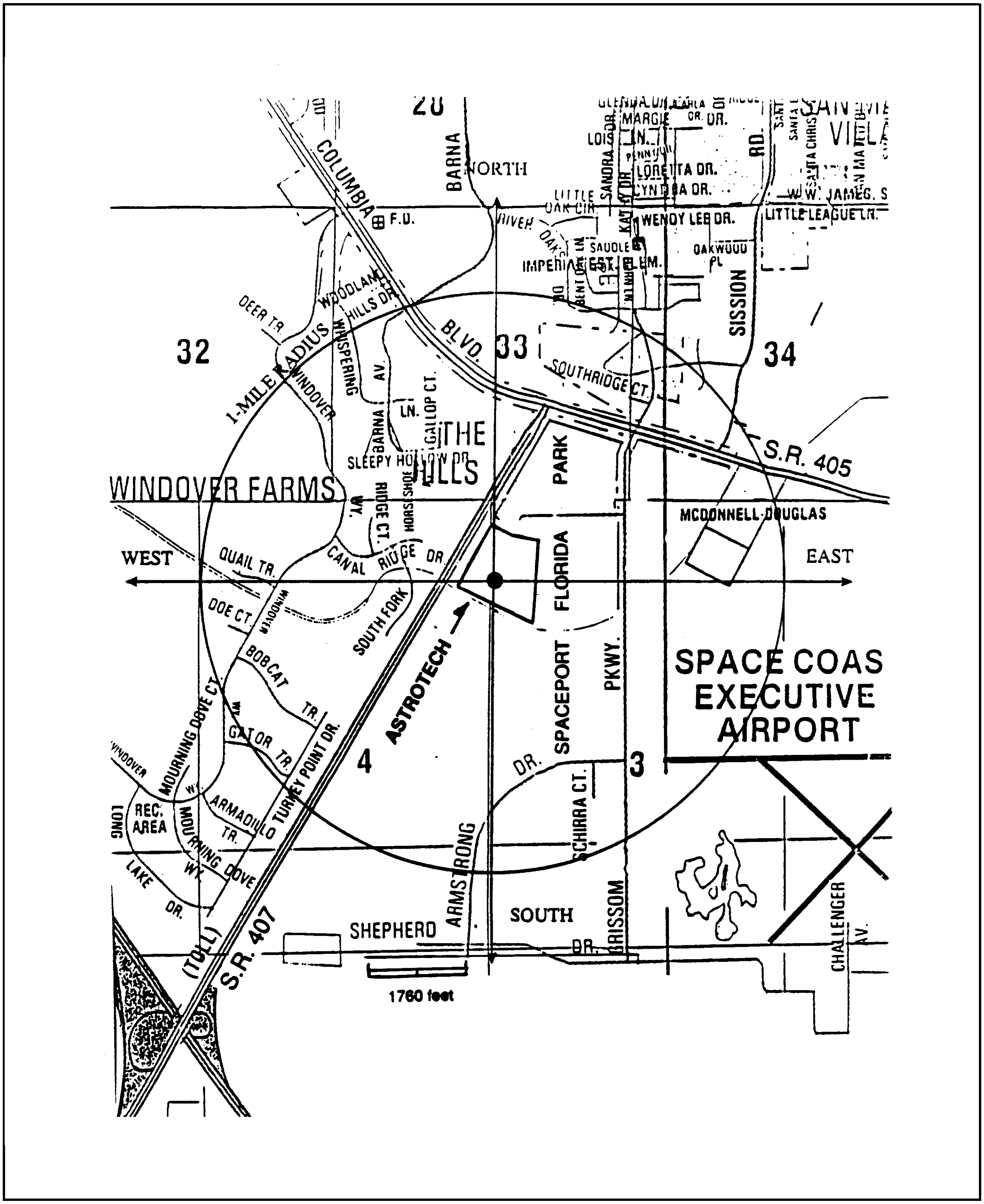


▪▪▪▪▪▪▪▪▪ = Hazardous Materials Transportation Routes

▲ = Liquid Propellant Supply Depot

1 inch = approximately 3½ - 5 miles

EXHIBIT 3-8 RESIDENTIAL POPULATION QUADRANTS



4.0 BUILDINGS AND OPERATIONS

This section provides a more detailed description of the site buildings (Section 4.1), an overview of the operations that take place within those buildings (Section 4.2), a listing of the materials handled on site and their characteristics (Section 4.3) and details regarding the safety design features of Building 2 (Section 4.4).

Astrotech provides facilities and limited facilities support for the final assembly, inspection, and processing of payloads prior to launch. Payloads can be grouped into four generic classes of satellites based upon their function: communications satellites, remote sensing satellites, weather satellites, and scientific experiment satellites. Payload processing begins at Astrotech once the satellite and its specific ground support equipment arrive at the site.

The activities which comprise the preparation of the payload for flight can be grouped into non-hazardous and hazardous operations. The non-hazardous activities generally include:

- Final assembly or buildup of the spacecraft;
- Leak tests and initial checkout of propellant systems before propellant loading;
- Installation of solar panels, antennas, insulation and other equipment;
- Payload function testing;
- Inspection and cleaning;
- Monitoring and checkout of payload electronic systems via hardlines and microwave communication.

Operations are designated as hazardous by NASA and the Air Force when significant amounts of potential energy are present and loss of control could result in injury to personnel or equipment; a significant change (i.e., increase or decrease) in the ambient conditions of temperature, pressure, or oxygen content could occur; or the presence of hazardous materials presents the potential for personnel exposure.[1]

The procedures and operations that are considered to be potentially hazardous to personnel or to pose potential damage hazards to critical spacecraft equipment and/or systems, generally include:

- Transport, short-term storage, sampling and loading of liquid propellants (anhydrous hydrazine, monomethyl hydrazine, and nitrogen tetroxide);
- Installation of explosive devices used in space to ignite motors and to separate the payload from the vehicle;
- Final assembly, lifting, and mating of solid rocket motors and liquid propellant motors with the payload;
- Dynamic spin balancing of the assembled payload or the fueled parts of the payload; and
- Transport of the fueled spacecraft from Astrotech to KSC (See discussion of transport in Section 5).

Payloads have various types of motors that are fueled with either solid or liquid propellants. See Section 4.2.1 for a discussion of the functions of various motors. The orbit position control propulsion system in the spacecraft itself can use either a single liquid fuel referred to as a monopropellant (i.e., anhydrous hydrazine) or a combination of liquid fuel and liquid oxidizer referred to as bipropellant (i.e., monomethyl hydrazine and nitrogen tetroxide) depending on the requirements of the spacecraft. Generally, both the perigee kick motor (PKM), when required, and apogee kick motor (AKM) contain solid propellant. Monopropellant spacecraft usually use a solid propellant AKM; however, in bipropellant spacecraft the AKM often utilizes the same liquid bipropellants as the orbit control propulsion system. Thus, a fueled spacecraft can have, in addition to solid propellant, combinations of liquid fuel and liquid oxidizer: (1) anhydrous hydrazine only, or (2) monomethyl hydrazine plus nitrogen tetroxide.

4.1 Payload Processing Buildings

The buildings in the hazardous and non-hazardous work areas on the Astrotech site are physically separated by a distance of approximately 335 feet. See Exhibit 4-1. This physical separation ensures that the hazardous work areas are located beyond the distance required by explosive siting criteria. See Section 7.1.1. A typical spacecraft is located first in Building 1, the non-hazardous processing facility, for operations such as electrical systems checkout and leak check and then moved to Building 2, the hazardous processing facility, for operations such as propellant loading.

4.1.1 Building Descriptions - Non-Hazardous Areas

Buildings 1 and 1A

Buildings 1 and 1A are separate but adjoining buildings that comprise the non-hazardous processing facilities. Building 1 with dimensions of 136 feet x 193 feet x 53 feet (including roof top air conditioning equipment) contains three payload processing high bays, a common clean room airlock and

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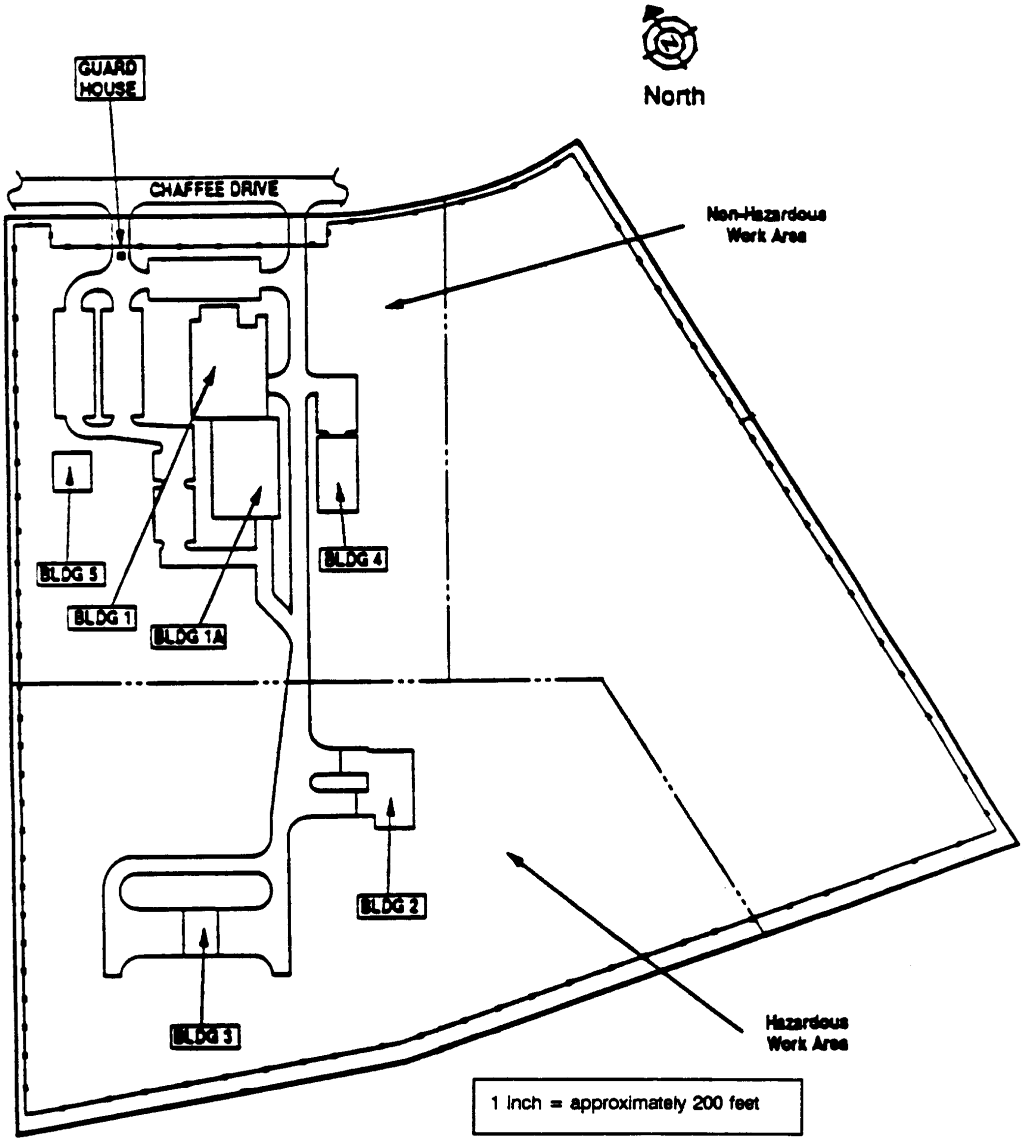
[1] Space Transportation System Payload Ground Safety Handbook, SAMTO HB S-100, KHB 1700.7, November 1982, p 4-2.

associated support office space. The building has three antenna towers on the rooftop, 96 feet above ground, that enable direct line-of-site air links with nearby launch complexes at KSC and CCAFS.

EXHIBIT 4-1 SEPARATION BETWEEN HAZARDOUS AND NON-HAZARDOUS FACILITIES



Building 1A, the later addition, contains one clean room high bay with its own clean room airlock. The overall building dimensions are 95 feet x 170 feet x 60 feet. Both buildings are constructed of steel columns and beams with metal stud framing, except for the office and support sections of Building 1, which are of concrete masonry block.

Overhead cranes within Building 1 provide hoisting capability in each high bay, and those within Building 1A provide hoisting capability in and between the high bays and airlock. In addition to the high bays and airlocks, each of the two buildings contains garment change rooms, office areas, conference rooms, break rooms, and an administrative area.

Building 4

Building 4 is the warehouse storage facility. It is used for storage of equipment not requiring a controlled environment, such as shipping containers and certain ground support equipment. Dimensions are approximately 62 feet x 125 feet x 30 feet. It is constructed of corrugated steel sheeting, interspersed with translucent corrugated fiberglass.

Building 5

Building 5 is the customer office building. It is primarily used for client office space during operations. The building is pre-engineered of structural steel and has approximate dimensions of 60 feet x 60 feet x 16 feet.

4.1.2 Building Descriptions - Hazardous Operations Area

Building 2

Building 2, the hazardous processing facility, is used for activities such as liquid propellant transfer operations, installation of ignition and separation ordnance, spin-balancing, and mating of the spacecraft with its upper stage (perigee kick motor or both perigee and apogee kick motors). Since these hazardous operations are the major focus of this evaluation, more details about Building 2 are presented in this evaluation than for other buildings on the site.

Building 2 (approximately 120 feet x 120 feet) contains clean room high bays and airlocks. A system of overhead cranes provides lifting capacity through the building such that a lifted load can be transferred or passed off between cranes and moved between the high bays. The major areas of the building include two airlocks (the North has a ceiling height of 65 feet and the South 43 feet), three clean room high bays, two propellant cart storage rooms, two garment change rooms, and two control rooms. See Exhibit 4-2 for the general layout of Building 2 and Exhibit 4-3 for the room specifications.

EXHIBIT 4-2 LAYOUT OF BUILDING 2

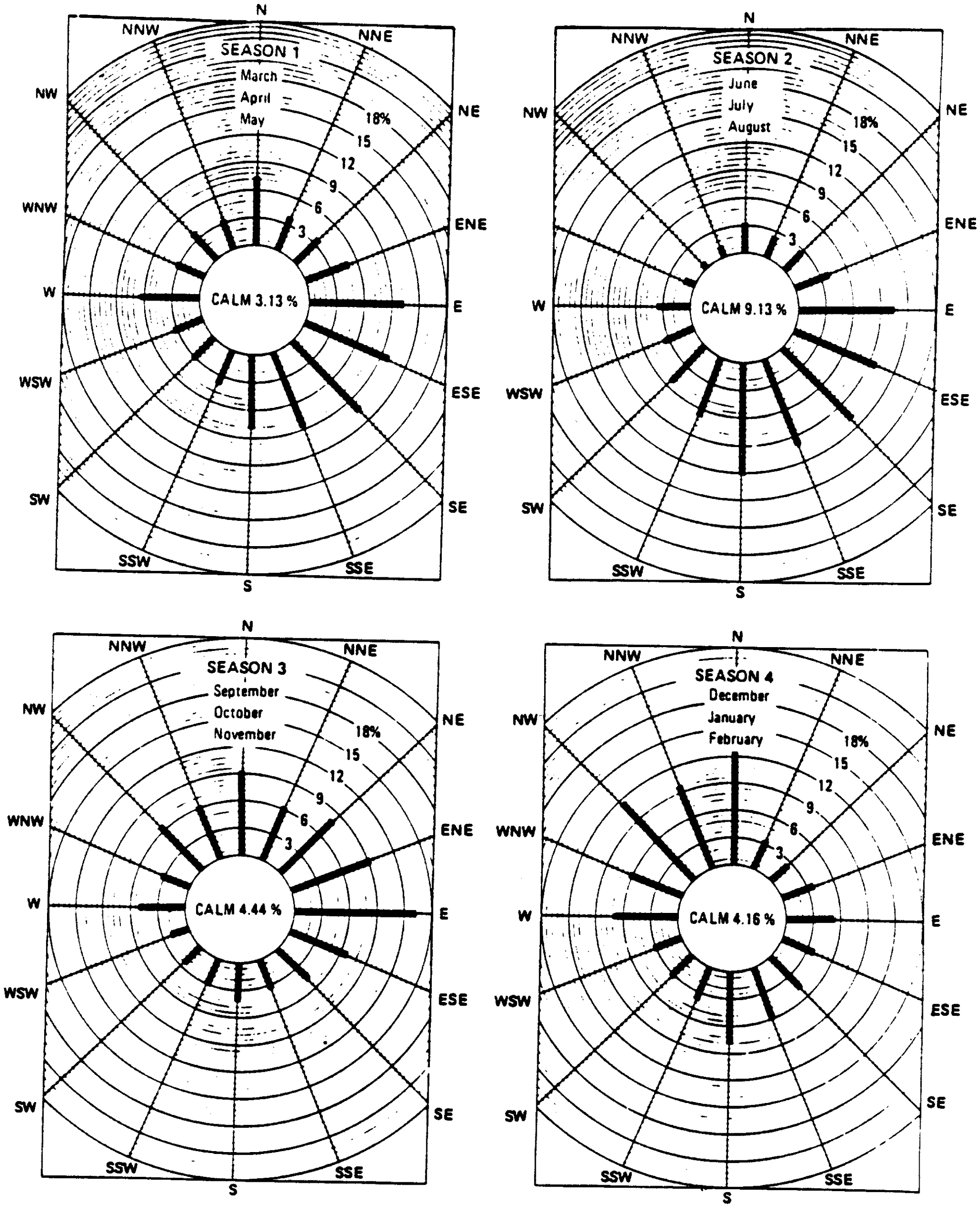


EXHIBIT 4-3 BUILDING 2 ROOM SPECIFICATIONS

RM	FUNCTION	LENGTH	WIDTH	HEIGHT	LARGEST DOORWAY	FLOORS	WALLS	CEILING
101	South Airlock	38	29	43	20x40	Vinyl	GWB	GWB
102	South High-Bay	60	37	43	20x40	Vinyl(c)	GWB	GWB
103	Center High-Bay	48	27	43	20x40	Vinyl(c)	GWB	GWB
104	North High-Bay	60	37	43	20x40	Vinyl(c)	GWB	GWB
105	Office	12	11	9-4	3x6-8	Vinyl	GWB	ACST
108	North Control Room	30	25	9-4	8x8	Vinyl	GWB	ACST
109	North Change Room	20	10	9-4	3x6-8	Vinyl	GWB	ACST
110	Corridor							
111	Women's Restroom							
112	Janitor							
113	Men's Restroom							
114	South Change Room	19	14	9-4	3x6-8	Vinyl	GWB	ACST
115	South Control Room	25	15	9-4	8x8	Vinyl	GWB	ACST
116	Balance Control Room	15	10	9-4	6x6-8	Vinyl	GWB	ACST
118	Corridor							
119	Oxidizer Cart Room	20	20	9-4	10x10	Vinyl	Concrete	GWB
121	Fuel Cart Room	20	20	9-4	10x10	Vinyl	Concrete	GWB
123	North Airlock High-Bay	55	40	65	20x50	Vinyl(c)	GWB	GWB

Notes:

1) All dimensions are shown as feet or as feet-inches

2) Vinyl(c) - Conductive Vinyl

3) GWB - Gypsum Wallboard

4) ACST - Acoustic Tile

Building 2 is sited, designed and constructed to meet explosives safety criteria standards[2,3,4] and permitted to contain up to 2,500 pounds of liquid fuels, 5,000 pounds of liquid oxidizer and sited for 24,600 pounds of solid propellant. The high bays and airlocks are constructed of structural steel column and beams with steel reinforced concrete-filled masonry block. The walls have integral horizontal concrete tie beams and the roof is framed with steel joists and decked with corrugated steel sheeting. The entire building is covered on the exterior by insulation sealed with plasticized cement/stucco for an impact resistant and airtight exterior. The upper surface of the roof has an attached layer of rigid insulation material covered by a heat sealed plastic membrane for thermal and moisture protection. The temperature and humidity inside the clean room (100,000 Class) high bays are monitored and controlled.

There are two grounding grids, one outside the building and one inside, consisting of structural steel ground bars connected to a steel grate in the floor. All lights and intercoms are purged by positive air flow out of each device to prevent the possible ignition of any flammable vapors that might be present in the high bays. All other electrical equipment in the high bays is explosion-proof.

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[2] Bureau of Alcohol, Tobacco, and Firearms, Department of the Treasury, ATF P 5400.7 (11/82).

[3] DoD Directive 6055.9, DoD Ammunition and Explosives Safety Standards, July, 1984.

[4] Department of the Air Force, AFR 127-100 CHANGE 1, 24 December 1984, Chapter 8 - Site Plans, Construction, and Utilities, Section A - Explosives Site Planning and Section B - Construction Considerations.

Building 3

Building 3 is a storage facility designed for short- or long-term storage of payloads, SRMs, flight hardware, ground support equipment or other sensitive equipment. Any stored payloads are, in general, waiting for processing. The building contains six identical storage bays which are environmentally controlled but are not clean rooms. Since this building is used for the storage of SRMs, it is designed to DoD and ATF explosives safety criteria and sited in the hazardous work area of the Astrotech site, remote from the other buildings.

Building 3 was designed to store three PKMs called Payload Assist Module (PAM) solid rocket motors (Thiokol Star 48 or Star 63) and three smaller unspecified solid rocket AKMs (typically Thiokol Star 15) all using DoD Class 1.3 (mass-fire) solid propellant. Total propellant quantity limit is 24,600 pounds. No liquid propellants are permitted in the building.

4.2 Hazardous Operations

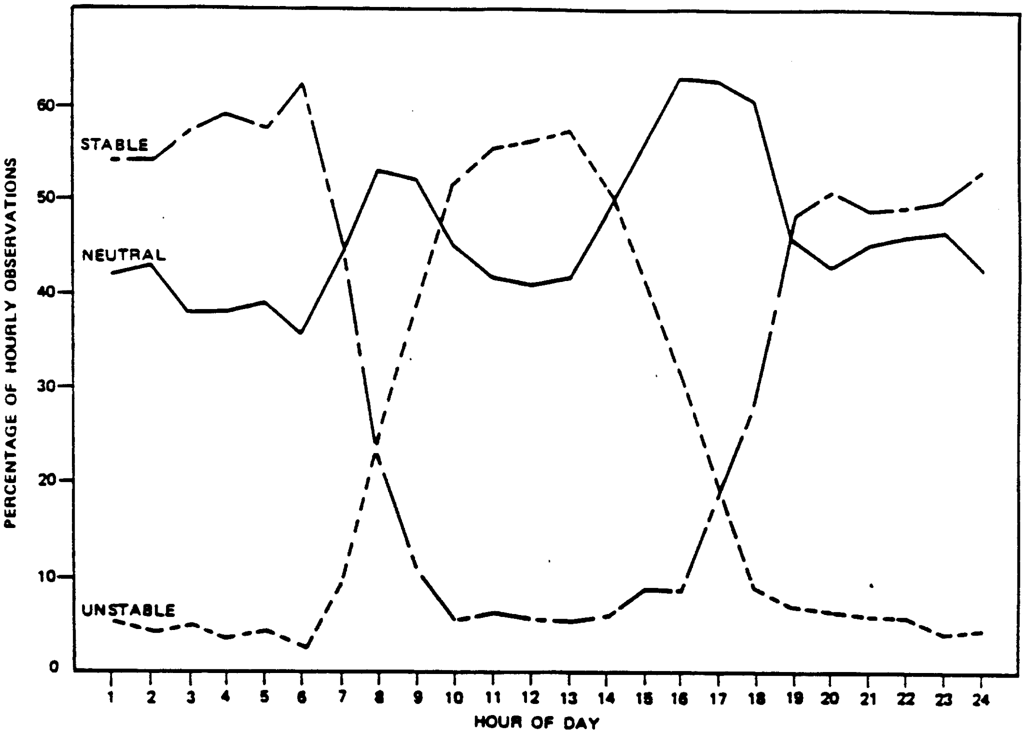
Payload processing operations are comprised of a set of activities that are performed on a spacecraft or satellite and assist motor(s) to ensure that the payload is flight-ready before it is mated with the launch vehicle at the launch pad. Most payloads processed at the Astrotech facility have similar functional characteristics but vary in size and appearance. Variations in size and appearance may mean that the sequence of operations differs somewhat for each payload processing operation. Under typical processing conditions, a spacecraft will be located in the non-hazardous work area (Buildings 1/1A) for 6-10 weeks and in the hazardous work area (Building 2) for 3-4 weeks. Liquid propellant loading is one of the last operations performed. The discussion below describes the "typical" sequence of operations.

4.2.1 Functions of Payload Motors

A typical payload is a communications satellite that needs to be placed in a geostationary orbit 22,000 miles above the earth. Launch vehicles provide only enough energy to boost a satellite into a lower orbit, either a circular one with a diameter of approximately 130 miles, or an elliptical orbit with its low point at about the same altitude. To be fully operational, a typical satellite requires additional energy for three functions: first, to raise the orbit to the 22,000 mile high geosynchronous altitude; second, to circularize the orbit at that altitude; and third, to maintain the precise orbit positioning (i.e., station keeping) throughout the seven to fifteen year operational life of the satellite.

The substantial energy initially required to raise the orbit to the geosynchronous altitude is normally provided by a PKM, which is generally an SRM ranging in size from 4 to 8 feet in diameter. As shown in Exhibit 4-4, the PKM is a separate section of the spacecraft, designed to separate from the remainder of the payload after the PKM's energy is expended. The fairing is a shroud used to surround and protect the spacecraft during ascent through the

EXHIBIT 4-4 SCHEMATIC DIAGRAM OF A TYPICAL PAYLOAD



atmosphere and is typically jettisoned prior to achieving orbit as soon as the launch vehicle has escaped the dense atmosphere.

When the satellite arrives at the required apogee altitude, the additional energy required to circularize the orbit and to adjust the equatorial inclination to place the satellite into its operational orbit is provided by an AKM, generally solid propellant, and sometimes augmented by small motors using liquid propellant(s). Because during its typical operational life of 7 to 15 years a satellite will drift slightly out of the required precise orbit, energy is needed to reposition the satellite periodically. This energy is provided by the small liquid propellant(s) motors. To improve operational efficiency and reliability, the tendency in recent years has been to design liquid propellant rocket systems that can perform both the AKM function and the orbital position control function. Although this design avoids the need for a solid rocket AKM, the amount of liquid propellants required increases significantly.

4.2.2 Typical Payload Processing Operations

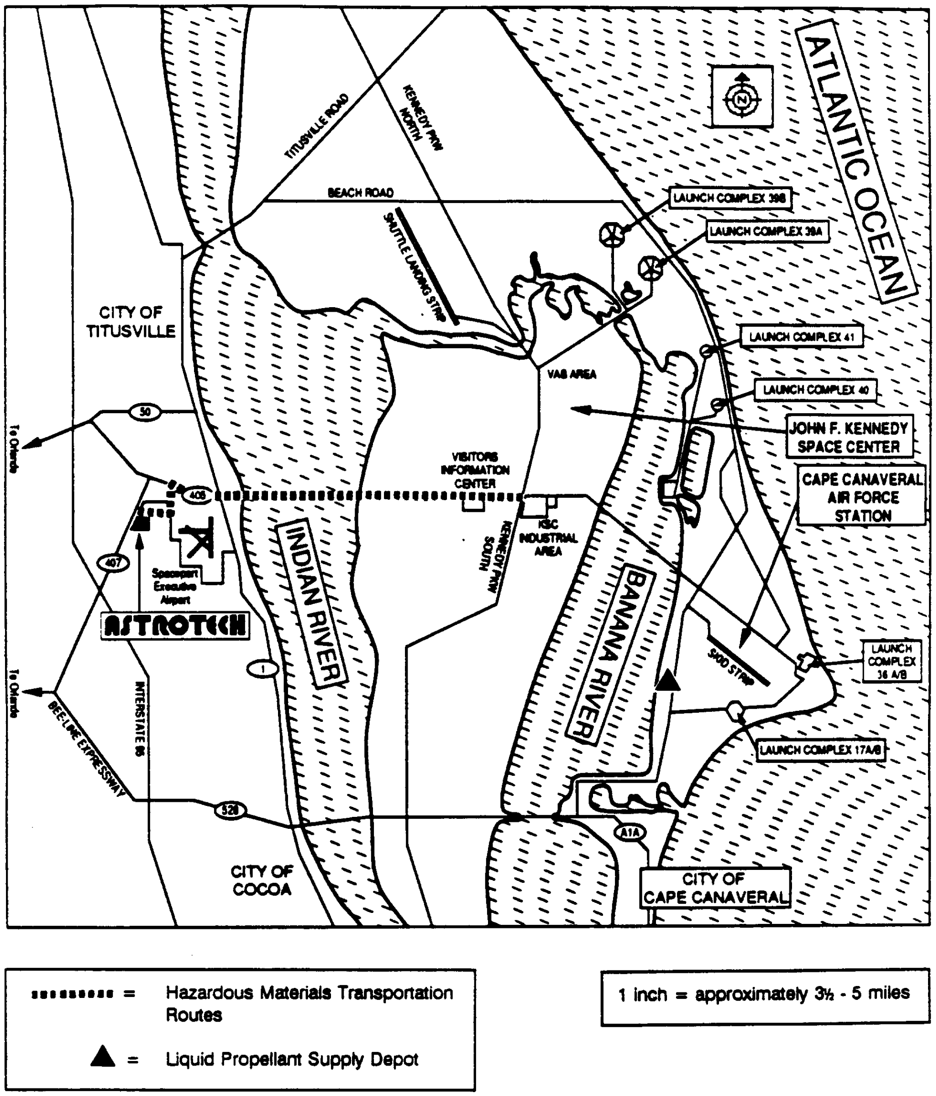
Because the PKM is essentially separate from the rest of the payload, operations at Astrotech can be performed independently on the PKM and the remainder of the payload. Because the PKM has solid propellant and igniter systems, PKM operations are considered hazardous and performed in Building 2. In the typical sequence shown in Exhibit 4-5, the PKM operations begin approximately two weeks before the spacecraft operations and take approximately six weeks to complete. Upon completion of the PKM processing, it either remains in a high bay separate from that used for the spacecraft operations, or it is moved to Building 3 for temporary storage. Simultaneous to the PKM operations, the satellite undergoes approximately four weeks of non-hazardous final assembly and checkout in Building 1, including tests to verify the proper functioning of all electrical systems and leak checks.

As late as possible in the schedule, the liquid propellants are transported from KSC to Building 2, where they undergo thermal conditioning and helium saturation for several days. Operations are sequenced carefully so that completion of PKM operations occurs several days before completion of the non-hazardous satellite processing operations, leaving Building 2 available for liquid propellant conditioning. After the propellants are conditioned and thoroughly saturated with helium, the satellite is moved from Building 1 to Building 2, where the liquid propellants are loaded and any solid propellant AKM installed. (For the "typical" sequence illustrated in Exhibit 4-5, no separate AKM is installed in the satellite.) If the laoded satellite requires dynamic balancing, a spin balance operation is performed at this point. The final step in assembling the payload is to mate the satellite with the PKM. Before transporting the flight-ready payload to the launch pad, the payload is either encapsulated in the launch vehicle fairing or placed in a special container designed to protect the payload during transport.

4.2.3 Transport of Fueled Spacecraft

The transport of the fueled and processed spacecraft from Astrotech to KSC may be considered a hazardous operation. It is performed under strict requirements: a convoy of law enforcement officials accompanies the shipment

EXHIBIT 4-5 TYPICAL SEQUENCE OF PAYLOAD PROCESSING OPERATIONS



in a rolling roadblock (one vehicle is ahead of the transporter and one is behind); the highway intersections are closed to the public ahead of the transport vehicle; transport only occurs at night; and a maximum speed of 5 mph is maintained while en route.

During the course of gathering data on the various processing operations at Astrotech, the evaluation team identified the transport of fueled spacecraft as an area where, despite the fact that it is beyond the scope of this evaluation, additional coordination was indicated between Astrotech and RSPA to ensure compliance with all requirements of the Hazardous Materials Transportation Act. Astrotech acted quickly on the verbal recommendation of the team to coordinate with RSPA and provided all technical information identified by RSPA to obtain the transportation approvals called exemptions for the transport of not only the fueled spacecraft but also propellant carts, when needed, propellant samples, and the oxidizer filter assembly.

Astrotech transports fueled spacecraft under this approval from the U.S. DOT. Prior to transport, Astrotech obtains an oversize load permit from the Florida DOT, and a Florida DOT officer inspects the transport equipment, procedures, and driver licensing records to assure full compliance with all applicable federal and state laws and regulations. This Florida DOT officer also accompanies the transport convoy. Refer back to Exhibit 3-7 for transport routes.

4.3 Characteristics of Hazardous Materials

The hazardous materials handled at the Astrotech facility of most interest are chemicals used in the propulsion system(s) of the spacecraft (both liquids and solids) and ordnance (electroexplosive devices [EEDs]) used to ignite SRMs and to separate the spacecraft from assist motor(s).

The liquids used as propellants are two types, fuels and oxidizer. These chemicals are stored and handled at ambient conditions without elevated pressures or reduced temperatures. They are very volatile and when they come into contact with one another they spontaneously ignite, liberating large quantities of heat and gas. Because they undergo this reaction (referred to as a hypergolic reaction), these chemicals are extremely useful as rocket propellants. The fuels used at Astrotech include anhydrous hydrazine (AH) and monomethyl hydrazine (MMH); they are also referred to as hydrazine fuels. The oxidizer is nitrogen tetroxide (N_2O_4). A particular spacecraft may require only fuel (i.e., monopropellant system) or both fuel and oxidizer (i.e., bipropellant system).

As detailed below, these chemicals are used in other industries besides the space industry and have been manufactured, transported, stored, and handled safely for many years. For an overview of releases of hydrazines and nitrogen tetroxide reported to the National Response Center (NRC) over an 8-year period, see Appendix B. In the eight year period, there were 77 separate releases of hydrazine and 66 of nitrogen oxides. Of the hydrazine releases, 35% were attributable to public utilities and only 9% were space industry related. Of the nitrogen oxide releases, 74% were attributable to manufacturing industries and only 10.6% were space industry related. Although there have been space industry related releases, the safety evaluation team is not aware of any occurring from payload processing operations.

The major hazards from propellants result from their flammable and reactive characteristics. However, propellants have properties similar to other hazardous chemicals which are routinely transported throughout the U.S. on the nation's highways and are manufactured and used in a variety of industrial operations. For example, liquified natural gas and propane pose similar flammability hazards, and are commonly used for home heating and electricity generation. A typical industrial pressurized spherical propane storage tank contains approximately 475 tons of propane with a chemical energy of 19 x 10^9 BTU. By comparison, a Titan III ELV, one of the largest users of liquid propellants in the spacecraft industry has a roughly equivalent weight, 414 tons, but lower chemical energy, 1.7 x 10^9 BTU. In fire situations, the greater the chemical energy available, the greater the potential hazard. The payloads processed at Astrotech have a much lower quantity of propellants than ELVs, and hence much less chemical energy. Other industrial chemicals, such as chlorine, ammonia, and sulfuric acid pose similar short-term exposure hazards.

4.3.1 Hydrazines[5]

The hydrazine chemicals most commonly used at Astrotech are MMH and AH. Both are clear, oily, water-white liquids with a fishy odor. They are slightly less dense than water. Vapors from these fuels are more dense than air and therefore tend to hug the ground.

The largest manufacturers of hydrazine in the U.S. are Olin Chemicals (approximately 21 million pounds per year), Mobay (14 million pounds per year) and Fairmont Chemical (1 million pounds per year). Total U.S. production averages around 36 million pounds annually, of which 29 million is sold commercially. The remainder is retained for use by the manufacturer or produced directly under contract. Only 5% of all hydrazine produced in the U.S. is used by the space industry. The greatest consumer of hydrazine is the agricultural chemical industry which uses 40% of the total hydrazine output.

Hydrazine is a key ingredient in a variety of agrochemicals, including many common pesticides, fungicides, algaecides, bactericides and herbicides. Some blowing agents also contain hydrazine, particularly those used in the production of foam rubber and plastics (including certain types of vinyl flooring and automotive cushions). This accounts for another 28 percent of the hydrazine consumed in the U.S.

Only 15% of the hydrazine that is produced in the U.S. is used as pure hydrazine. In this form, it is effective as an industrial water treatment chemical to remove chromates and is also used by electric utilities and other industries to scavenge oxygen from feed water and reactor cooling waters. The remaining 12% that is produced is used as a chemical intermediate in a variety of products and processes. It is a key component of an experimental drug for sickle-cell disease and is also found in the antituberculant drug Isonoizoid. It is used when plating electrolytic metals onto glass and plastics, as an intermediate in textile dyes, as a polymerization catalyst, and as a reducing agent in the extraction of plutonium from reactor wastes. Estazolam, a sedative, and hydrazide salts used in soldering fluxes are also manufactured from hydrazine.

Monomethyl hydrazine is manufactured in the U.S. by Charkit Chemical Corporation in Darien, CT and the Olin Corporation in Stanford, CT. The latest available records show that at least 100,000 pounds were produced in the U.S. in 1977. Since 1982, however, monomethyl hydrazine has not been sold on the commercial market. Monomethyl hydrazine is used as a chemical intermediate, as a solvent, and in the synthesis of the antibiotic cesftriaxone.

Further information on the properties of the hydrazine fuels can be found in the Chemical Propulsion Information Agency (CPIA) Publication 394, Hazards of Chemical Rockets and Propellants, Volumes I, II, and III, Applied Physics Laboratory, Johns Hopkins University, September 1984 and in Hydrazine

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[5] Hypergolic Propellant Hazard Response Guide, Cape Canaveral Air Force Station (CCAFS), Draft Volume I, ICF Technology Incorporated, July 1, 1988.

and Its Derivatives Preparation, Properties, Applications, Eckart W. Schmidt, Wiley-Interscience Publications, USA, 1984.

The hydrazines are volatile chemicals that react readily with carbon dioxide and oxygen in the air and will also decompose on contact with some metals. If hydrazine vapor is released into the air in sufficient concentration, it may ignite or react to form ammonia and oxides of nitrogen (NO_x). Further oxidation will form ammonia-based nutrients and the NO_x will ultimately return to earth as nitric acid rains.

The hydrazines are flammable liquids that can present fire and explosion hazards, if sufficient quantities are handled improperly. A vapor phase is readily formed at ambient conditions (the vapor pressures are roughly that of water) and the vapor can be ignited by spark, open flame, or contact with an oxidizer. Exposure of MMH or AH to air from a large surface, such as saturated rags, may result in spontaneous ignition due to the heat evolved from contact with oxygen in the air.

The hydrazines are also corrosive, poisonous, and can present serious health hazards if direct contact is made with sufficient quantities of either the liquid or vapor. The most severe exposures occur through dermal (i.e., skin) contact with liquid and inhalation of vapors. Contact of the chemical on the skin can cause severe burns and the chemical can enter the bloodstream leading to similar effects caused by inhalation. These effects may include damage to the central nervous system such as tremors, convulsions, or death in the case of extremely high concentrations of the chemical involved. Hydrazine is also a suspect human carcinogen, according to the American Council of Industrial and Government Hygienists. However, since hydrazine decomposes quickly upon release into the atmosphere, it is unlikely that vapor concentrations will remain high enough to cause serious health effects. See Exhibit 4-6.

4.3.2 Nitrogen Tetroxide[6]

Nitrogen tetroxide is a thick, heavy, greenish liquid that is very volatile (its vapor pressure is about 50 times that of water and 5 times that of acetone). Its yellowish to reddish brown vapor, which is due to the nitrogen dioxide (NO_2) resulting from the N_2O_4-NO_2 equilibrium mixture, has a pungent odor similar to bleach. Nitrogen tetroxide is manufactured by a single source in the U.S., Cedar Chemical Corporation in Vicksburg, MS. Based on data from the U.S. Air Force Directorate of Energy Management, Kelly AFB, the annual production capacity for N_2O_4 is estimated to be 3 million pounds per year.[7] Nitrogen tetroxide is produced by oxidation of nitric oxide which is an intermediate stage in the production of nitric acid from ammonia. N_2O_4 is used in the manufacture of other chemicals (e.g., nitric acid and ammonia fertilizer), as a chemical manufacturing intermediate, a nitrating agent, an oxidizing agent, as a polymerization inhibitor for acrylates, and as a catalyst. In air, nitrogen tetroxide liquid will vaporize and dissociate to form gaseous phases of nitrogen tetroxide, nitrogen dioxide, and nitric acid (mist).

Propellant grades of nitrogen tetroxide, which is mixed with nitric oxide, are known as MONs (mixed oxides of nitrogen) and are identified by percent weight of nitrogen tetroxide with no more than 0.17 percent by weight of water. N_2O_4 dissociates into NO_2 which is rapidly photochemically

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[6] Ibid.

[7] Post Accident Procedures for Chemicals and Propellants, AFRPL-TR-82-031, Report F04611-80-C-0046, Systems Technology Laboratory, Inc., September 1982.

decomposed to nitrogen oxide (NO) and oxygen. The typical half life for NO_2 in sunlight is about 2 minutes.[8] Nitrogen oxides react with atmospheric moisture to form nitric acid rain which can be returned to the land during precipitation.

Though not flammable itself, nitrogen tetroxide will support the combustion of most fuel sources. In addition, N_2O_4 may ignite organic materials such as wood or rubber on contact. Nitrogen tetroxide will react with water in a vigorous reaction that will produce nitric and nitrous acids and NO_2.

Contact with corrosive N_2O_4 liquid or vapor may lead to burns of the skin and eyes. Inhalation of a sufficient quantity of N_2O_4 vapor to cause adverse health effects may initially occur without great discomfort; however, a few hours later more severe symptoms of tightness in the chest, coughing, and breathing difficulty may begin and could result in pulmonary edema and death in severe cases.

4.3.3 Solid Rocket Motors

Solid rocket motors (SRMs) contain solid propellant; those handled at Astrotech include PKMs and AKMs. The description below of a "typical" SRM illustrates how it releases energy to perform the perigee and apogee kick, orbital adjustment functions. A typical SRM is mainly rubber-like propellant surrounded by a thin-walled case constructed of heat-treated steel, titanium or glass filament. The forward internal section of the motor consists of a ring of propellant around a star-shaped hollow area. This star configuration greatly increases the available surface area, allowing for easy ignition triggered by the igniter ordnance. The central internal section of the motor has a hollow, smooth circular core. On the end of the aft closure is the nozzle where hot gases exit the motor.

The solid propellant burn travels from forward to aft instantaneously and then from the core outward to the steel casing. Since the propellant burns at over 6,000°F, the thin-walled case must be insulated from the heat. Initially, the unburned propellant contributes to this insulation. For end-of-burn insulation, a layer of insulative material is used between the propellant and the case.

The primary hazard from solid propellant in the SRMs processed at Astrotech is due to its flammability. Solid propellant is classified by the DoD as a Class 2, Division 1.3 (non mass-detonating, mass-fire hazard).[9] The material itself is not explosive; however, a solid propellant produces large volumes of gas upon burning, which can lead to rupture and/or propulsion of the motor. Additionally, the burning of an SRM generates hydrochloric acid, a toxic combustion product.

There are several ways to ignite solid propellant, including: 1) hard impact, caused either by a motor dropping onto a hard, sharp surface from several feet or by an object falling onto exposed propellant or its steel case, 2) direct contact of propellant grain with a flame, 3) extreme heat, 4) an electro-static energy discharge or other large electrical discharge, such as lightning, and 5) activation of explosive destruct charges or the motor ignition system. Inadvertent ignition of solid propellant is difficult when

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[8] Hazards of Chemical Rockets and Propellants, Volume III, Liquid Propellants, CPIA Publication 394, Chemical Propulsion Information Agency, The Johns Hopkins University, Chapter 14 - Nitrogen Oxides, September, 1984.

[9] DoD Directive 6055.9, DoD Ammunition and Explosives Safety Standards, July 1984.

standard safety practices are used. In fact, SRMs segments are regularly transported both by rail and highway carriers, illustrating that they are routinely safely handled in the normal transport environment.

4.3.4 Ordnance

Ordnance is defined in ESMCR 127-1 as all electroexplosive devices, detonators, squibs, primer, pyrotechnic devices, initiators, igniters, solid propellants, explosives, warheads, ammunition, fuzes and energy transfer systems (e.g., linear shaped charges and Primacord). All initiating ordnance items, for example, EEDs, are classified as Category A (hazardous)[10] or Category B (non-hazardous) for pre- and post-installation handling situations. ESMCR 127-1 details safety requirements for EEDs in Section 3.13.4, ranging from design, connection, and environmental criteria (shock, vibration, temperature). The hazards from ordnance are the potential for ignition or detonation.

4.3.5 Other Hazardous Materials

Other hazardous materials used at the Astrotech facility for various industrial support operations (e.g., degreasing parts, paint thinners, and solvents) include isopropyl alcohol, 200 proof alcohol, Freon-113, gaseous helium, high pressure liquefied nitrogen, gaseous nitrogen, and methyl ethyl ketone. The use of these products at Astrotech does not pose a danger to the public.

One Astrotech customer has a leak check procedure that uses helium containing a small amount of krypton-85, a gas that is a source of ionizing radiation. All use of ionizing radiation sources must comply with any necessary requirements, specifically the Nuclear Regulatory Commission's Title 10 Code of Federal Regulations (CFR) and Florida Statute 10D.56 and must be used under the supervision of a state qualified radiation protection officer.

All leak checking using the helium containing the krypton-85 gas takes place within Building 1 in a sealed tent to preclude exposures within the building. The majority of the krypton is recovered and the remainder is vented out through an exhaust duct above the roof. The exhaust concentration is limited to 3×10^{-7} millicuries per liter of air, which rapidly diffuses in the atmosphere and dissipates before reaching the facility boundary. The maximum amount of krypton-85 that could be released to the atmosphere, conservatively assuming a full day of leak checking with a continuous release at the maximum allowable concentration, corresponds to a dose of less than 2 millirems of radiation.[11] Therefore, there are no adverse health effects posed to the public. No other radiation sources have been or are scheduled to be used at the Astrotech facility.

4.4 Building 2 Features

The fueling operations at Astrotech by their nature require engineering controls and personal protective equipment that reduce any risk to systems and personnel within the facility to as low a level as is reasonably achievable. Although this safety evaluation does not focus on the risk to personnel within Building 2, controls that protect personnel also minimize risk to the general

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[10] Category A electro-explosive devices are those which, by expenditure of their own energy or because they initiate a chain of events, may cause injury or death to people or damage to property (Eastern Space and Missile Center, Range Safety, ESMCR 127-1, 30 July 1984, Section 3.13.2.2)

[11] This dose can be compared with radiation doses from other activities, e.g., flying from Los Angeles to Paris - 4.8 millirems; getting a chest x-ray - 22 millirems; getting a full-mouth dental x-ray - 910 millirems; and getting a mammogram - 1,500 millirems.

public and are therefore relevant. As described in this section, the controls include the design and construction of Building 2 as a "self-contained" facility, the spill containment system to preclude any release of liquid propellant from reaching the environment, and the scrubber system to reduce any point source propellant vapor emissions from normal operations. The containment and scrubber system work together to ensure that all vapors from the system are reduced to acceptable levels as detailed in Astrotech's Florida DER air permit. Standardized work practices and procedures (see Section 5), similar to those required at KSC and CCAFS, provide additional protection against unanticipated accidents or releases.

4.4.1 Propellant Containment and Scrubber System

It is essential while performing fueling operations to minimize the release of propellants. Astrotech has included special design features and operations procedures which can confine spilled propellant vapors within Building 2, continuously monitor vapor concentrations, and collect all fugitive and point source emissions (vapors and liquids) to chemically treat them. In the event of a spill (with no associated fire or explosion), Building 2 is designed to contain all propellant vapors and liquid and to prevent any release to the environment.

Containment Facility

Building 2 was designed and built from the very beginning to be a containment facility in case a release of propellant liquid or vapor should occur inside the building during routine operations. In the event of a large fuel spill, defined as a spill of greater than one gallon, the personnel in the high bay would evacuate the building, the personnel in the control room would turn off all power (effectively sealing the building) before evacuating, and no one would reenter until the ambient concentration of the propellant vapors decreased sufficiently to allow reentry.[12]

The rate of decrease of fuel vapor concentration can be predicted using the hydrazine "half-life" concept that is based on laboratory studies and detailed by Schmidt in a book titled Hydrazine and Its Derivatives. Hydrazines react with oxygen, carbon dioxide and water in the air aided by agitation and recirculation. Half of the initial volume of anhydrous hydrazine and monomethyl hydrazine breaks down into non-toxic constituents in roughly 1 hour and 3 hours, respectively, as presented in Exhibit 4-6. The evaporation rates are also listed in Exhibit 4-6 as relative indicators of the volatility of the fuels.

EXHIBIT 4-6 HALF-LIFE TIME AND EVAPORATION RATES

A recirculation fan inside Building 2 can circulate any vapors within the building to promote agitation and evaporation and therefore, a more rapid decay. The self-contained recirculation fan disperses and dilutes vapors and, in instances of releases of fuel, will assist in the natural "half-life" deterioration of the fuel vapors. Vapor circulation can be further assisted by opening internal doors between the high bays and airlocks, thus allowing greater volume of air within the sealed facility to mix with the vapor and break down the concentration of fuel vapor (see discussion below).

Vapor Monitoring

At all times that liquid propellants are in Building 2, vapor detectors

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[12] Communication with Astrotech, 1990.

Compound	Evap. Rate (mg cm^{-2} min^{-1})	Half-Life Time* Air (hours)	 Water (days)
Anhydrous Hydrazine	0.49	1.1	7
MMH	1.7	2.7	10

* Ch. 4 "Hydrazine Handling," p. 600, Hydrazine and Its Derivatives, Schmidt, 1984, Wiley and Sons, Inc.

are in use. During propellant loading operations, toxic vapor detectors and visual inspection of equipment are used to monitor the area. If a release is indicated (either by elevated concentrations of propellant [100 parts per billion {ppb} of anhydrous hydrazine; 200 ppb of monomethyl hydrazine; 3 parts per million {ppm} of nitrogen dioxide] or by visual observation of a liquid spill), the fueling team would turn off valves to stop propellant flow and to minimize damage to the spacecraft and other equipment.

Astrotech has recently obtained state-of-the-art toxic vapor detectors to supplement and ultimately replace a less sophisticated vapor analysis system (Draeger Tubes) traditionally used, and has incorporated their use in revised operating procedures. The increased sensitivity of the new detectors will improve safety by alerting personnel more quickly of elevated vapor concentrations. The detectors combine the use of special detection tape keyed to the material being monitored and microprocessor control for speed, accuracy and specificity. These detectors are portable and are encased in special explosion proof clear plastic cases. A concentration alarm is indicated by a continuous tone and steady alarm light emitting diode (LED). Instrument problems (e.g., bad battery, tape break) are indicated by a flashing red indicator and an intermittent beep, and the alarm relay will be activated. These detectors have factory set alarm levels available of 200 or 400 ppb for MMH, 100 or 200 ppb for N_2H_4, and 3 ppm or 6 ppm for NO_2[13]. Astrotech monitors at the lower concentrations. More general instrument specification information on the new MDA portable toxic gas detector can be found in Appendix C.

Trenched Fueling Islands

Propellant transfer and loading operations take place in the center of the high bays on a 25 feet by 25 feet "fueling island" created by a stainless steel trench which surrounds a center portion of the floor. The trench is covered by stainless steel grating and slopes to a common point where it drains into the containment system located underground immediately outside the building. The trench drainage system would confine a spill and facilitate cleanup operations. In the event of a spill of fuel that resulted in a fire, the trench system would also confine the fire to the fueling island and prevent spread of the fire to any other area of the high bay or the adjoining rooms.

Containment and Neutralization System

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[13] Guide To Operation, TLD - 1 Toxic Gas Detector, MDA Scientific, Inc., 1989.

The Astrotech waste containment and neutralization system serves both oxidizer and fuel propellant loading operations. Any propellants (liquid or vapor phase) released or spilled in Building 2 are processed through this system. This containment system is comprised of two underground holding tanks and a vapor scrubber (see discussion below). These tanks collect any liquid spillage which could occur during propellant sampling and transfer operations. Each tank (one dedicated for oxidizer and one dedicated for fuel) has a capacity of 6,100 gallons and contains approximately 500 to 1,000 gallons of water mixed with the appropriate neutralizing agent before the start of a propellant loading operation. A common piping system leads from the fueling island trenches to a T-valve upstream from the holding tanks. The piping drawing, examined by the evaluation team, showed that the drain line is a 4 inch, 110 cubic feet per minute (i.e., 50 gallons per minute [gpm]) line. The valve must be manually operated to connect the trench with either the fuel or oxidizer tank, depending on the propellant operation. Floor drains in the propellant cart rooms also drain into the holding tanks, either directly (in the case of oxidizer) or via the trench drain (for the fuel).

The tanks are constructed of fiberglass reinforced polyethylene with an inert lining. No secondary containment or monitoring wells are required around the tanks or lines. Hunter/ESE (an environmental engineering consulting firm) performs annual leak checks on the tanks. In addition, the City of Titusville can sample the tanks at any time to confirm that no hazardous substances are stored. Recently, the City has been sampling the tanks regularly and has never found a problem with Astrotech's use of the tanks. The tanks are buried in the ground by tying them to underground concrete pads, to keep them from "floating" in the buoyant soil. DOT placards indicating hazards of the contents are posted above each of the tanks.

After loading operations are completed, hose lines are aspirated clean using suction to draw any vapors or residual liquid into the containment/scrubber system. Then, the hose lines are capped and bagged for transport and decontamination by the customer. Any excess fuel or oxidizer is returned to CCAFS. The propellant loading carts which are used to condition propellant and then to load the spacecraft are cleaned on-site or the customer may send the entire cart off-site for cleaning once he has demonstrated full compliance with all applicable DOT transport requirements. The filter system used for the transfer of nitrogen tetroxide is cleaned with freon.

Any hazardous waste that must be disposed is packaged and labelled in accordance with EPA hazardous waste regulations and manifested for transport according to DOT regulations. Installation of a closed-loop distillation system is planned. This system will further minimize the generation of hazardous waste by allowing the freon to be recycled.

The waste propellant vapor and liquid aspirated into the underground containment tanks are then neutralized into non-toxic products in preparation for discharge to the sewer. Anhydrous hydrazine and monomethyl hydrazine are neutralized with calcium hypochlorite (HTH) and the neutralized liquid in the tank is checked for approximately 1% residual chlorine as an indication of destruction of all hydrazine. N_2O_4 is neutralized with sodium hydroxide (NaOH) to a pH of 10 to 12.

The neutralized liquid is pumped to the scrubber agitator tanks before discharge to the Titusville city sewer. The city first samples the material and tests for biological oxygen demand, chemical oxygen demand, and extraction procedure toxicity parameters (mostly metals and pesticides). When the city determines that the waste water presents no hazards to the treatment facility, the waste water is allowed to be discharged and is then processed through the sewage treatment system, commonly known as a Publicly Owned Treatment Works. The average amount discharged per spacecraft processing operation is about

5,000 gallons. A discharge is made after every complete spacecraft loading operation. The current annual processing rate of six payloads results in six discharges per year.

Vapor Scrubber

The scrubber functions during normal operations as an air pollution control device by treating any fugitive or point source emissions of propellant vapor, so that the emissions to the environment meet the Florida DER air quality permit requirements. Stray vapor is drawn out of the building through flexible hoselines and goes through the containment tanks into the scrubber columns. The propellant reacts with the scrubber liquid and is removed (or "scrubbed") from the vapor phase. The scrubber is not designed to handle a catastrophic spill or accident but rather to treat point source and fugitive emissions generated within Building 2 during normal propellant transfer, sampling and loading operations.

The scrubber consists of two 40 foot packed bed towers that operate in series using counter-current flow with an approximate 10 inch drop. In each bay there are two 2½ inch ports (facility vents) located on opposite walls (north and south). During sampling or fueling operations, a dedicated flexible hose (for either oxidizer or fuel) is attached to the nearest port and directed in the close vicinity of the operation to remove any stray vapors. These vapors are first drawn by a fan to the holding tanks and then the tank vapor is taken through the scrubber. The centrifugal fan in the scrubber system, which was activated while the evaluation team was inspecting it, draws a vacuum through the tanks and to the ports in the high bays. The vacuum draws any fugitive or point source emissions out of the building to be treated. Once the vapors are scrubbed, the exhaust is discharged into the atmosphere through a five inch diameter stack 60 feet above grade.

The scrubber stack parameters[14] include:

Exhaust flow rate	400 actual cubic feet per minute (acfm)
Exhaust temperature	70.7 degrees Fahrenheit (annual average)
Scrubber efficiency	90%
Stack diameter	0.42 feet
Standard conditions	68 degrees Fahrenheit; 29.92 pounds per square inch actual (psia)

The scrubber is located within the lightning protection of Building 2 as detailed in Section 4.4.2. Because there is no back-up power supply to the scrubber system in case of a power outage, the scrubber would automatically be turned off, sealing the building. In the event of a large spill, the building would be evacuated and the power to the building including the scrubber would be turned off from the control room, sealing the building.

The scrubber is designed to handle normal propellant loading operations involving either fuel or oxidizer. Scrubber liquors are sodium hydroxide in a 10% solution at a pH of 10-12 with sodium sulfide (Na_2S) for oxidizer and water for hydrazine fuels. Different liquors are needed depending on the vapors present, because the vapor undergoes a chemical reaction with the scrubbing liquor. The scrubbing liquor can be considered a sponge; just as a sponge can absorb a large, but limited amount of moisture, the liquor can absorb (i.e., react with) a limited amount of vapor. The treatment capacity of the scrubber liquor is more than adequate to handle normal propellant loading operations. The system can handle a total of 300 pounds of oxidizer

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[14] Satellite Fueling Operation Response to FDER Completeness Summary, Hunter/ESE, No. 3901-010010-0400-3160, July 1989.

and 100 pounds of hydrazine fuel without recharging the respective scrubber liquor.[15] This translates into approximately 25 gallons of oxidizer and about 12 gallons of fuel, which would be extremely large releases.

The vendor has further indicated that the scrubber exhausts approximately 100 ppm or less of NO_x vapors and has an average efficiency of 90%; therefore, an approximate 1,000 ppm charge of NO_x vapors can be scrubbed. Astrotech has indicated that the system can effectively handle a charge of approximately 200 ppm of fuel vapor and remain functional at maximum efficiency. If fuel vapor concentrations rise above 200 ppm, the scrubber could handle the higher concentration over a longer period of time. If a spill of sufficient magnitude occurs such that the scrubbing liquor became saturated, reducing its capability to react with propellant vapors, the liquor would be recharged and the scrubbing process resumed. It is important to note that the scrubber is not designed to handle emergency releases of propellant nor for use in decontaminating the building in the event of a spill although over a long enough period of time this could be effected.

The approximate magnitude of anhydrous hydrazine spilled that could reach 200 ppm depends on the air volume in the high bay or combination high bay(s) and airlocks available for dilution of the concentration within Building 2.[16] For example, in the south high bay (approximate volume of 95,460 cubic feet of air), it would take about 0.18 gallons (about 3 cups) of anhydrous hydrazine spilled to reach 200 ppm in the bay; however, in the event of a spill, the south airlock could also be opened, making an additional 42,920 cubic feet of air available. Then, approximately 0.25 gallons (about a quart) of anhydrous hydrazine would be required to be released to reach a concentration of 200 ppm. However, it must be noted that given the total capacity of the scrubber system, while it would take about 4 hours to process the 95,460 cubic feet of air containing the fuel vapor (or about 5.75 hours for the larger volume) at maximum efficiency, the system could obviously handle a larger release over a much longer time period before reaching saturation.

As a benchmark, the lower flammable limit (the vapor concentration which will ignite and burn in the presence of an external ignition source) of anhydrous hydrazine in air is 4.7 percent on a weight percent basis or 4,700 ppm; this limit for MMH is 2.5 percent or 2,500 ppm. At these levels in the high bay, fire would be the most serious hazard. The scrubber is not designed to handle releases of this magnitude.

4.4.2 Static Electricity Protection

Because flammable liquids and vapors can be present in Building 2 and because SRMs and EEDs are extremely sensitive to electrical discharge, significant design features and detailed operations procedures are in place to minimize the opportunity for spontaneous electrostatic discharge (i.e., sparks).

Electrostatic Dissipating Floor Tile

The floor covering in the high bays and North Airlock is made of a static dissipating, graphite impregnated, vinyl tile. The tile is bonded to a substrate with an electrically conductive mastic and connected to the

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[15] Correspondence with Tri-Mer Corporation, Air Pollution Control Systems, manufacturer and supplier of the Astrotech scrubber system, August 1, 1990.

[16] This section discusses only vapor concentrations within Building 2. See Section 7 for a discussion of vapor concentration outside the facility.

grounding grid system. The fuel and oxidizer cart rooms and the South Airlock do not have conductive tile but do have fixed grounding points in each room. The conductive tile and grounding points prevent electrical sparks in Building 2.

Lightning Protection System and Operations Policy

The entire central Florida area is known for its high incidence of thunderstorm and lightning activity. The Astrotech facility is constructed with design features that ensure minimal negative effects in the event the facility is hit by lightning. (To date no building within the Astrotech facility has been struck by lightning.)

A lightning protection system surrounds Building 2 and consists of eight lightning masts approximately 100 feet high, each connected to the primary grounding grid, designed to prevent induced electrical current damage to all support equipment.

Prior to all hazardous operations, a Stormscope (a state-of-the-art, commercially available lightning detection system) is activated on site which receives radio frequency (RF) signals from electrical discharges in the atmosphere out to a distance of 200 miles from Building 2. If an electrical storm is indicated within five miles of the facility, Astrotech's policy is that no hazardous operations are initiated. Any ongoing hazardous operations may be stopped immediately or continued only until a stable stopping point is reached, depending upon the determination by the Astrotech Safety Officer and customer safety official. Because the Stormscope identifies storms out to 200 miles, the Safety Officer knows in advance of a storm's existence and can delay operations at his discretion if, for instance, a storm twenty miles away appears to be heading toward the facility. During ongoing operations, safety personnel are alerted by an audible alarm feature on the Stormscope to the presence of any lightning within 25 miles of the facility.

Explosion Proof Electrical Systems

All electrical supply and illumination systems operating in Building 2 are either explosion proof by design or are made explosion proof by purging the fixtures with an explosion preventing gas. The design requirements for these systems are in accordance with pertinent sections of the National Electric Code and NFPA Codes.[17] The codes require that conduit and outlets be sealed to preclude vapor entry, that all switching and contacting operations be in sealed enclosures and that exposed surface temperatures be limited to levels that will not produce vapor-air ignition. All electrical equipment, including lighting that cannot practicably be sealed, is purged, eliminating the possibility of vapor entry and subsequent exposure to potential electrical ignition sources.

Physical Separation of Equipment

Non-explosion proof electrical equipment must be kept at least ten feet away from any SRM assembly. Prior to starting any operations involving SRMs, the area is "safety checked" by both Astrotech and its customer. This requirement is also true for operations involving ordnance and liquid propellants.

Required Grounding Equipment

Grounding equipment, including such items as legstats, wriststats,

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[17] National Electric Code, 1987, which is Section 70 of the National Fire Codes.

conductive shoes, and shoe coverings, is required for personnel handling ordnance, working within five feet of exposed SRM propellant grain, handling propellants or working in a high bay containing a fueled cart or spacecraft. All grounding equipment is tested before each operation to ensure electrical resistance levels (i.e., between 0.01 and 1 megohm) that avoid the occurrence of sparks.

4.4.3 Personnel Protective Measures

Because the hazards associated with the handling of SRMs, PAMs, EEDs, ordnance, and propellants generally pose a danger only to personnel working in their immediate vicinity, non-essential personnel are not permitted near operations involving these items. Special design features and safety procedures protect personnel that are working in the immediate vicinity of these materials.

Area Clear Restrictions

Safety precautions and restrictions are established and enforced at Astrotech to limit the physical presence and access of non-essential personnel during hazardous operations. These physical access restrictions have been defined by Astrotech based upon operating expertise and requirements of several of their payload customers and extend to either a 10-foot radius from the activity to the entire room (high bay) in which the activity is taking place, to the entire hazardous section of the facility. In general, the relative risk associated with each operation is correlated with the size of its control area. The operations that take place within Building 2 and their control areas[18] are listed in Exhibit 4-7.

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[18] Safety Standard Operating Procedure, 1988, Astrotech Space Operations, L.P.

EXHIBIT 4-7 AREA CLEAR REQUIREMENTS

OPERATIONS	CONTROL AREA
Clampband installation	10-foot radius around operation
Solid rocket motor ordnance installation/removal	10-foot radius around SRM
Spacecraft ordnance installation	10-foot radius around spacecraft (or greater at discretion of Spacecraft Manager)
Solid rocket motor handling and transfer	Active high bay in which work is being conducted. Work may continue in adjoining high bay(s)
Solid rocket motor grain inspection	Active high bay. Work may continue in adjoining high bay(s)
Solid rocket motor leak test	Active high bay. Work may continue in adjoining high bay(s)
Activation of Shuttle or PAM cradle spin system with PAM	Active high bay and adjoining high bays
Hoisting of solid rocket motor bays	Active high bay and adjoining high
Spin balance solid rocket motor bays	Active high bay and adjoining high
Spacecraft pressurization	Active high bay and adjoining bays
Liquid propellant transfer into spacecraft	Entire Building 2 with road block manned by Astrotech
Spin balance with loaded manned propellants in spacecraft	Entire Building 2 with road block by Astrotech

The transfer and loading of propellants and operations performed on fueled spacecraft require that Building 2 be cleared of all non-essential personnel. Access to the area surrounding the building is restricted; only personnel directly involved in safety monitoring or performance of the operation are permitted within the hazardous work area of the facility.

During "building clear" operations, access to Building 2 can be restricted by closing a gate arm near the badge house located a safe distance from the building. A safety monitor is positioned at the gate to limit access to the Building 2 area. Signs on the gate indicate "Keep Clear" and "Hazardous Area." The gate arm also has a yellow flashing light activated from inside the badge house. This badge house is manned by Astrotech personnel when hazardous fueling operations are taking place; it is equipped with telephone and power, and serves as the fallback assembly area in case of emergency evacuation of Building 2. A hazard status board located near the badge house indicates the nature and location of any hazardous material present in Buildings 2 or 3.

Procedures for installation of EEDs are another example of procedures to limit personnel exposure. EEDs may not be installed until a control area has been established and cleared of nonessential personnel. These devices must not be electrically connected to the spacecraft systems until a power on and off check is made to ensure there is no stray voltage. The control area is required to be defined in the operating test procedures provided by the customer to Astrotech. All personnel in the defined control area are required to wear protective clothing and grounding equipment.

Personal Protective Equipment

All personnel working in Building 2 when release of liquid propellant (fuel or oxidizer) or vapor is a possibility are provided with personal protective equipment (PPE). PPE is designed to protect an individual from toxic vapors and/or heat generated by fires and provides an appropriate air supply and air filtering system along with protective coverings (e.g., chemical resistant suit, boots, gloves). Equipment used at Astrotech meets NASA flammability and compatibility requirements for the hazards present. Level A, B or C equipment (as defined by the EPA) is available and meets Mine Safety and Health Administration/National Institute of Occupational Safety and Health (MSHA/NIOSH) standards and approval. The level of PPE required is dependent upon the nature of the operation and the potential hazards. For example, during operations where propellant vapors may be present (e.g., the leak check, propellant sampling and start of propellant loading operations) the highest level of protection, a Level A PPE[19], is worn. However, once the closed loop fueling operation has been verified to be leak tight, personnel can change into a Level C (splash suit)[20] for the remainder of the fueling operation. If a problem is indicated, the crew can change into Level A and re-enter to monitor the situation and take appropriate actions.

Breathing Air System

In Building 2, air is purified through a compressed air purification system that removes particulates, water vapor, and carbon monoxide (CO). A downstream remote alarm system continuously monitors for CO. In addition, a reserve air system has the capacity to allow four users at least five minutes to exit and decontaminate. Further, a five minute emergency air supply is incorporated into the air line respirator apparatus, allowing the user to disconnect from the air line umbilical to exit and decontaminate with a self-contained breathing apparatus (SCBA). The emergency breathing air system can be independently connected to a 50 kVA diesel power generator as a standby power source in case of a general power failure.

During emergency escape from Building 2, individuals could also take advantage of an Emergency Life Support Apparatus (ELSA). These portable, self-contained breathing units provide air for five minutes in oxygen deficient or contaminated atmospheres and are easily accessible to workers in both the North and South high bays.

Remote Visual Observation

Remote visual monitoring enables individuals, like the Astrotech Safety Officer and customer safety personnel, who must directly observe hazardous activities to do so without being in the immediate presence of the hazard. In Building 2, explosion-proof observation windows installed between the control

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[19] Level A PPE includes a supplied air respirator with an auxiliary self-contained 5 minute emergency air supply; a SCBA with full facepiece; fully-encapsulated chemical resistant suit; chemical resistant inner and outer gloves; chemical resistant boots; and two-way OIS communications and umbilical.

[20] Level C PPE includes chemical resistant disposable overalls; chemical resistant outer gloves; and 5 minute Emergency Life Support Apparatus (ELSA).

rooms and the high bays allow Astrotech and customer payload safety officers and quality control personnel to observe hazardous operations directly. Thus, safety officers can validate compliance with procedures, but minimize risk to themselves and eliminate any potential interference with operations that their presence in the high bay might cause.

In addition, there are five closed circuit television (CCTV) cameras for remote monitoring of operations in Building 2. However, these cameras currently have no scanning or zoom capabilities. All three Building 2 high bays can be monitored by video camera. Videotapes of fueling operations are routinely made by Astrotech and offered to customers; video monitors can be set up during fueling operations. Thus, any individual that needs to see observations performed, but who does not need to provide direct feedback during those operations, can either watch a monitor located in Building 1 during the ongoing operation, or can watch a videotape later.

4.4.4 Monitoring Systems and Communications

In order to ensure that equipment is functioning properly, as well as to provide prompt response to any potential emergency, Building 2 is equipped with detection and monitoring systems that alert the control rooms and the guard house, as appropriate, of significant changes in the facility status. Communications during operations exist between the working area, the control room and the guard house.

Building 2 is also equipped with an explosion-proof paging system that can be used from either of the two control rooms. The paging loudspeakers are located in all high bays and airlocks. The emergency exits in Building 2, which shut automatically after opening, are also equipped with emergency communication equipment that sounds a local alarm when activated.

Alarms are automatically sent to the guard house via computer link for various parameters identified below (additional capacity in the computer link is available to accommodate additional monitoring system alarms in the future). The guard house alarm panel was recently installed by Honeywell.

<u>Parameters Monitored</u>

1. Temperature and humidity (HVAC systems)
2. Loss of pressure to fire protection system (i.e., compressor failure)
3. Toxic gas detectors and detector status (i.e., tape break or battery problem)
4. Generator failure
5. Fire alarm

Also, a fire alarm is sent to the Titusville fire department via automatic dialup.[21]

Non-hazardous situations can cause alarms. For example, item 2 on the above list would alarm if the compressor failed. At that time, there would be no immediate danger to the facility. However, the pre-action fire suppression system (see description below), if needed, would require monitoring for loss of pressure. Similarly, equipment problems with the gas detectors would not in themselves be a hazard; however, their malfunction would limit the ability of safety personnel to detect a hazardous atmosphere. If such an alarm occurred during hazardous operations, operations would be brought to a stable stopping point, personnel evacuated and the source of the alarm investigated.

Temperature and Humidity

Both temperature and humidity are monitored in the high bays to ensure safe levels and effective functioning of the HVAC system. The typical control settings are 70°F and 50 percent humidity with alarms at 60 percent relative humidity and 75°F. The target levels and alarm settings for temperature and humidity are designed to protect sensitive spacecraft equipment from damage and can be specified by individual customers, as required. However, Astrotech will not allow hazardous operations to take place if the relative humidity is below 30% due to electrostatic hazards at humidity lower than this level.

Vapor Monitoring System See Section 4.4.1

Fire Alarm and Sprinkler System

The pre-action fire protection system[22] is a computer-controlled system designed to quickly extinguish any fire within Building 2 while protecting spacecraft and other valuable equipment from inadvertent system activation or malfunction. The high bays and airlocks have a dry-pipe solenoid actuated system.[23] The piping between a valve and the sprinkler heads is pressurized and the pressure level monitored to ensure no loss of pressure. In order to get water to the sprinkler head two things must occur: a smoke/heat detector (see description below) must indicate a problem or a manual pull station must be activated and the fusible link on a sprinkler head must melt due to an intense heat source (the link melts at approximately 155°F).

For areas of the Astrotech facility where immediate danger of damage to equipment from inadvertent wetting is not as great (i.e., non-high bay, non-airlock rooms in Buildings 1 and 2 and all other buildings), there is a wet-pipe system with automatic sprinklers connected directly to a water supply, that discharges water immediately upon melting of the fusible link at the sprinkler head.

All water is supplied from the Titusville municipal system and is assisted by a diesel boost pump, located in the pumphouse at the front of the property, that upon system activation automatically provides 1,500 gpm of water at 150 psi pressure. The North and South high bays in Building 2 each have 28 sprinkler heads with 5/16" orifices and fusible plug activation temperature of 155°F; the smaller center spin bay has 15 sprinklers; the airlocks each have 12 sprinklers. Rough estimates of flow from each sprinkler

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[21] Safety Standard Operating Procedure, Astrotech Space Operations, L.P., 1988.

[22] For additional information on fire protection systems see NFPA Fire Protection Handbook, 14th edition.

[23] The high bays and airlocks in Building 1 have a similar pre-action fire suppression system.

range from 40 to 50 gpm. If all 28 heads in a Building 2 high bay were open, the total flow would be approximately 1,260 gpm.

All areas in Building 2 have ceiling-mounted infrared (IR) smoke/heat detectors that detect rate of heat/rate of rise. There are six detectors in each high bay and two detectors in each of the return lines of the HVAC system. There are also thermo-couples mounted on the tanks of the propellant loading cart and in the spacecraft to monitor temperature during fueling.

There are portable fire extinguishers of both halon and dry chemical types located throughout the facility.

Generator Failure See Section 4.4.6

Communications During Operations

There is a manually activated intercom (i.e., push-to-talk) for communication between the control room and the fueling team during propellant loading operations. Also, hand-held communication boards that can be written on are available. As mentioned above, Building 2 is equipped with an explosion-proof area paging system that can be used from either of the two high bay control rooms.

The guard house is the focal point for the communications and alarm detection system as described above. There is a cellular telephone and eight UHF radios available at Astrotech for use by staff. In the event of an incident, the guard has a list of personnel (with phone and pager numbers) to be notified. See Section 6.0 for additional detail on emergency communications.

4.4.5 Hurricane Potential and Restrictions

The potential for hurricanes during the wet season is well known; the facility continuously monitors the likelihood of hurricanes approaching, and implements hurricane preparation procedures whenever necessary. In addition to implementation of specific procedures, buildings on the Astrotech site are designed and constructed to withstand sustained winds of 125 miles per hour. Since 1887 only 24 hurricanes have passed within 100 nautical miles of KSC and CCAFS. None have entered the Cape Canaveral area. However, hurricane precautions are taken seriously, not only to protect valuable flight hardware elements and operations facilities but also to ensure worker and public safety.

Weather tracking, specifically hurricane prediction, for the immediate vicinity is meticulously performed by the U.S. Air Force meteorologists at CCAFS with support from the National Weather Service. In its MOU with NASA, Astrotech can contact NASA by telephone at anytime for weather information. In addition, contractor teams stationed at the facility are automatically alerted by the Air Force of potential hurricanes.

Astrotech's hurricane precautions are patterned after those used at CCAFS and KSC.[24] They include successive steps of preparations for the strong winds and heavy rains. For example, building evacuation and sandbagging of entrances begins 24 hours before winds of 50 knots (57 miles per hour) are expected to reach the area. In addition, all "unhardened" temporary or portable structures are generally secured by anchors or removed and stowed, as are any loose construction materials.

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[24] Hurricane Preparedness Implementation Plan, NASA/KSC, KHB-1040.2

4.4.6 Backup Power

Florida Power and Light is the prime provider of power to Astrotech. In case of an unanticipated power failure, each building has a sensing device and power automatically switches over to a 25 kVA propane-powered generator. The backup power to Building 2 is fueled by an external propane tank mounted outside the generator room. The automatic power supply initially goes only to emergency lighting in the high bays. This light level was tested during the on-site visit and found to be sufficient for any kind of emergency operation. The cranes and the airlock roll-up doors can also be powered from the backup generator, so that if a spacecraft was being lifted during a power failure, the lift could be completed. Manual relays must be thrown in the generator room to direct power to the cranes or to the doors.

There is also a 55-kw diesel generator that can be plugged in and used during count-down and for power up during ground stations and spacecraft checkout. (A 50 hertz source is available for European satellites). There are also several uninterruptable power supplies available to prevent software crashes during system testing and checkout.

Building 2 has battery backup for the fire protection system and the portable toxic vapor detectors; however, there is no backup power provided for the scrubber system. This could negatively impact ongoing fuel operations in the event of a power failure, especially during sampling operations, allowing vapors to build up in the bay. It could also impact emergency response activities since access to the building could be restricted because of dangerous concentration levels with no system to remove the vapors. However, since the scrubber was not meant to serve as an emergency system and is not designed to handle large spills, the fact that it receives no power in the event of a failure caused by a catastrophic accident is a protective measure to ensure that no untreated vapors are exhausted directly to the atmosphere from a scrubber system not designed or intended to treat them.

5.0 SAFETY POLICIES AND REQUIREMENTS

Astrotech has strict safety policies and operating requirements for the use of its facility and support equipment. This section begins with a discussion of overall management policies and requirements (Section 5.1), describes operation and maintenance requirements (Section 5.2), and concludes with specific personnel training requirements (Section 5.3).

Because Astrotech only provides the use of the facility and limited support equipment to their customers and performs no hands-on processing of a spacecraft, Astrotech requires that customers provide detailed technical data and supply operating procedures for all hazardous equipment and operations. Astrotech's schedule for submissions, allowing time for review and approval prior to initiating operations, is outlined below (see Section 5.1.1). Additional requirements include such things as training and certification of propulsion teams, scheduling and coordinating of all hazardous operations through Astrotech, and safety monitoring by Astrotech and the customer of all hazardous operations scheduled to take place for a specific spacecraft.

When hazardous equipment or operations have been or are to be used at KSC or CCAFS, the customer's detailed technical data and operating procedures are also reviewed and approved by NASA and/or the Air Force. The general safety standards against which these plans and procedures are scrutinized are Air Force Regulation AFR 127-100 Explosive Safety Standards, Eastern Space and Missile Center Regulation ESMCR 127-1 Range Safety documents and Kennedy Space Center safety requirement documents KHB 1700.7 and KHB 1710.2. The responsibilities of all parties involved in the processing of a payload at ESMC are detailed in ESMCR 127-1. The safety evaluation team compared Astrotech's safety policies and procedures to these requirements for Government facilities.

Further, the safety of operations at the Astrotech facilities is a partnership between Astrotech and its customers and each has compelling financial incentives to maintain the highest standards of safety during payload processing operations. The customer is bringing in a satellite that may be worth in excess of $100 million. At the same time, Astrotech has an investment of approximately $15 to $20 million in the facilities and facilities support equipment which it must protect. In addition Astrotech wants to maintain its ability to process payloads to ensure future business and revenues.

Astrotech also commissioned detailed technical analyses, both before the initial facility construction and before the facility modifications. These safety analyses are discussed in Section 7.1.1.

5.1 Management Policies and Requirements

The document Safety Policy prepared by Astrotech delineates corporate policy regarding desired levels of safety and the safety criteria against which the customers' hazardous operations safety plan are assessed. It outlines the documentation required of customers to meet Astrotech's safety requirements for customer required support equipment, operating procedures, and personnel certification and training; safety requirements for performing payload operations including ordnance checkout and installation, propellant loading, meteorologic baseline conditions for conducting operations, allowable hazardous atmosphere work levels (25% LEL)[1]; safety requirements for handling, lifting and transporting spacecraft; and accident reporting requirements.

5.1.1 Documentation Requirements

Astrotech requires certain documentation from its customers to ensure that its own safety criteria and standards are met. These include:

- At least 90 days prior to processing, data on flight hardware and safety critical subsystems, an operations schedule, a list of technical operating procedures and designation of whether hazardous or not, and a list of safety and emergency equipment and procedures;

- Certification that each individual performing operations has been trained and certified, if appropriate, and is medically able to perform assigned hazardous tasks;

- At least 30 days prior to processing, detailed step-by-step procedures for hazardous operations; and

- Any necessary federal and state licenses to handle radiation sources, data on the sources, and documentation on testing, packaging, transport and transfer of the sources.

The customer must comply with all Astrotech safety requirements or request a waiver from Astrotech, detailing what system or equipment is involved, why a waiver is being sought, any potential hazards created and rationale for acceptance. No waivers have been requested as of August 1990. Astrotech will then either approve or deny the waiver. The customer is also responsible for obtaining any waivers or variances from federal regulation and must provide these to Astrotech.

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[1] 25% of the Lower Explosive Limit (LEL). The LEL is the volume percent concentration of a flammable material in air at which the material will ignite, propagate flame, and in a confined area an explosion can occur. Using 25% of the LEL provides a four-to-one margin of safety.

5.1.2 Safety Requirements

Written operating procedures are required for all hazardous operations that are performed at the Astrotech facility and are reviewed and approved by Astrotech prior to the operations. Simultaneous hazardous operations in the same hazard control area are prohibited. Joint safety inspections by both Astrotech and customer safety representatives are generally performed prior to and immediately after payload and ground support equipment installation at the facility, before initiation of hazardous operations, and after <u>any</u> modification to the facilities or equipment. Specific requirements are identified below for:

- Payload and ground support equipment
- Environmental conditions
- Handling and transport

<u>Payload and Ground Support Equipment</u>

Propellant systems and systems ground support equipment (usually provided by the customer) must meet the requirements of either Air Force Manual AFM 127/161 or Kennedy Space Center Handbooks KHB 1700.7 and KHB 1710.2. These requirements are outlined in the Astrotech safety policy handbook[2] and apply to all operations at Astrotech. Before any new, modified or repaired propellant subsystems, storage or transport systems can be used at the Astrotech facility, the customer must validate and certify that they meet the requirements. Materials used in propellant systems must meet compatibility and use standards as detailed in either AFM 161-30 "Chemical Rocket Hazards," Volume II, or the CPIA Publication Number 194, "Chemical Rocket and Propellant Hazards," Volume III. A leak check using a helium leak detector is performed on load lines, pressure lines and transfer systems prior to beginning propellant loading operations to ensure equipment integrity before introducing propellant.

In Astrotech's <u>Safety Policy</u>, specific requirements are detailed for standards that must be met by electrical equipment, electrical equipment in hazardous atmosphere areas, grounding and bonding, and maintenance operations. These are designed specifically to preclude hazardous conditions and include detailed requirements such as hazardous area distances for flammable liquid propellants, and instructions for "explosion-proofing" of electrical equipment operated during pressurization or flow of flammable propellants.

Pressure systems (e.g., pneumatic and hydraulic systems), that contain fluids above ambient pressure and include components like tanks, pipelines, gauges, fittings, valves, regulators, and relief devices are also closely scrutinized by Astrotech. Such

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[2] <u>Safety Policy</u>, Astrotech International Corporation, Sections 3.2.6.1-3.2.6.3.

things as pressure vessel American Society of Mechanical Engineers (ASME) design and marking requirements, safety factors for burst design of components, and system operating relief pressures and flow capacities are indicated. Flexible hoses, and inspection, calibration and test requirements are also discussed.

Radiation is also addressed in the safety requirements. This covers both ionizing (radioactive) radiation and non-ionizing (microwave, radio frequency, optical or laser) radiation sources. General requirements for preventing inadvertent personnel exposure, assuring fail-safe operations, and testing and maintaining equipment are outlined. As discussed in Section 4.3.5, the only use of ionizing radiation at the facility is for limited leak checks of equipment by one customer.

A significant component of the payload/ground support equipment safety requirements deals specifically with solid rocket motors, ordnance (electro-explosive devices used in destruct and separation systems) and liquid propellants, since these are considered hazardous materials and any operations involving them are closely and carefully scrutinized.[3] Other hazardous materials are also mentioned including cleaning solvents and adhesives because of potential flammability or reactivity. Astrotech is also concerned with the toxicity of the propellants and has installed a containment system to prevent releases to the environment. The system is described in more detail in Section 4.4.1.

Environmental Conditions

The major concerns addressed here are ensuring the proper meteorological conditions are adhered to in scheduling and conducting propellant handling and loading operations. No hazardous operations may be initiated if electrical storms are within five miles of the facility or if hurricanes are predicted; if operations are ongoing, safety personnel are notified of any thunderstorm activity within 25 nautical miles.

A hazardous indoor atmosphere is defined (25% of the LEL) for sampling purposes as well as a level for personnel (oxygen between 19.5 and 25% by volume) activity. This requirement assures at least a four-fold safety factor for fires because the LEL is the minimum vapor concentration at which a compound can ignite.

Handling, Transport and Storage

Requirements for hoists, slings and cranes, including safety factors and load test requirements, test frequency, and inspection details for each type of lifting equipment are

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[3] Safety Policy, Astrotech International Corporation, Section 3.2.

outlined; compliance with applicable OSHA 29 CFR and American National Standards Institute (ANSI) B30 sections is required[4]. Transport of fueled spacecraft to the launch pad is not allowed to begin when electrical storms are within five miles, and general vehicle and safety system checks are required prior to embarking.

Astrotech requires SRMs to be handled and stored in accordance with the requirements of their hazard classification and storage compatibility group. The storage compatibility group is the group for explosives, propellants or other hazardous materials which can be stored together without significantly increasing the probability of accident, or for a given quantity, the magnitude of the effects of such an accident. The compatibility groups are based on the system recommended for international use by the United Nations (UN) as adopted by the DoD. The hazard classification system is also based on the recommended UN international system and distinguishes between mass-detonating and non mass-detonating explosives (including propellants)[5].

All explosive materials used at Astrotech are required to be stored, inspected and tested in approved areas only and in accordance with the hazard classification and storage compatibility grouping of the material. Ordnance must be stored in the high bay ordnance lockers (Hoffman boxes), and work on Category A[6] EEDs must be performed only in Building 2. Work on Category B[7] EEDs requires a 20 foot clear area.

Ordnance and associated flight items are required to be the natural color of the devise, while non-flight items require color coding and submittal of the coding key to Astrotech. The color code facilitates efficient operations.

Generally, all liquid propellants are transported to the Astrotech facility from CCAFS by Astrotech personnel in DOT-approved transport containers. A maximum of one cylinder (approximately 3,600 pounds) of nitrogen tetroxide or two 55-gallon drums of fuel (approximately 925 pounds of anhydrous hydrazine or approximately 800 pounds of monomethyl hydrazine) is allowed in any one shipment. On occasions when it is necessary to load propellant into the propellant carts from the bulk

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[4] Ibid. Section 3.4.1.

[5] <u>Hazards of Chemical Rockets and Propellants, Volume II, Solid Propellants and Ingredients</u>, C.P.A. Publication 394, September 1984.

[6] Category A EEDs are those which by the expenditure of their own energy, or because they initiate a chain of events, may cause injury or death to people or damage to property. ESMCR 127-1, 30 July 1984, Attachment 1.

[7] Category B EEDs are those which will not, in themselves, or by initiating a chain of events, cause injury to people or damage to property. ESMCR 127-1, 30 July 1984, Attachment 1.

storage facility, the carts are transported to Astrotech under the protection of a security escort and in accordance with the applicable DOT transport approval. Transport of fuel and oxidizer never occurs at the same time.

Liquid propellants are present at the Astrotech facility only as long as required to condition, sample, load the liquid fuel or oxidizer into the spacecraft, and transport the spacecraft to the launch pad. No liquid propellants are stored at the Astrotech facility. Liquid propellants brought on site are placed in Building 2 either on a fueling island or in a propellant cart storage room, where they are conditioned with helium for 5-7 days until fully saturated. This saturation is done to ensure that adequate pressure is maintained in the spacecraft propellant tanks. Vapor detectors, which alarm directly to the guard house, are used whenever liquid propellants are on site so that any leaks will be detected immediately.

Only enough liquid propellant is brought on site for loading the payload with allowance for ullage in the storage cart and sampling. Following completion of a fueling operation, any residual propellant is drummed appropriately and returned to CCAFS for reuse or disposal. A maximum of three nearly empty drums, containing small amounts of residual fuel, can be transported at one time.

After nitrogen tetroxide is loaded into a spacecraft, the micropore filter used for its transfer is contaminated with a small amount of nitrogen tetroxide. This is removed using freon, which is planned to be distilled in a closed-loop distillation system. After the small amount of oxidizer in the freon has been neutralized, the contaminated freon is run through the unit which recovers the freon for reuse. Because the closed-loop distillation system has not yet been installed, the cleaning solution, which is classified as "waste oxidizer" and is 99% freon, is currently drummed and treated as a hazardous waste according to EPA regulations.[8] Any other residual chemicals classified as hazardous waste are shipped off site to an EPA approved Treatment, Storage, and Disposal facility within 90 days of their generation. During six years of operation, only one drum of hazardous waste has been generated that required off-site disposal.

The largest propellant transfer operation to take place at the Astrotech facility occurred in 1990 with the processing of INTELSAT. Approximately 4,000 pounds of oxidizer and 2,400 pounds of fuel were loaded into the spacecraft. Payloads of this size are rare, and typical payloads are somewhat smaller, generally requiring about 1,000-1,500 pounds of propellants (fuel

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[8] Resource Conservation and Recovery Act (RCRA), Subtitle C, 40 Code of Federal Regulations (CFR), Part 262 - Regulations Applicable to Generators of Hazardous Waste.

and oxidizer) to be brought on site at any one time, depending on the requirements of the spacecraft. This typical liquid propellant quantity on site is about twenty percent of Astrotech's design criteria and DER permit allow; 5,000 pounds of oxidizer and 2,500 pounds of fuel. These maximum permitted quantities are 240-650 times less than the amount of propellants used to fuel a Titan ELV at CCAFS.

5.1.3 Accident Reporting

In the event of an accident, Astrotech has established reporting requirements so that it can evaluate accident causes and initiate preventative measures. All customers are required by Astrotech to prepare a formal written report of any accident involving serious injury or death to personnel or substantial damage to equipment or facilities within five working days. Minor incidents can be reported verbally; however, minor incidents with high accident potential must be formally reported. In over six years of operations, there have been no accidents requiring formal accident reporting. In addition, Astrotech is subject to accident reporting requirements under SARA Title III and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as outlined in Section 6.4.

5.1.4 Insurance Inspections

An additional external safety inspection is performed by an inspector representing Astrotech's insurance company to ensure that the facilities meet the insurance company's safety standards. Prior to entering into a contract with Astrotech, each potential customer may have an agent representing his insurance carrier inspect the facilities to ensure that his own safety and operating standards are met. The inspections are performed approximately twice a year.

5.2 Operation and Maintenance Requirements

Astrotech provides continuous safety monitoring during all hazardous operations by the Safety Officer and he is empowered to stop an operation if he deems it unsafe or problems are indicated. Most hazardous operations can be completed in one 8 hour shift and that shift is scheduled during normal business hours to maximize personnel alertness. At least one shift separates operations involving fuel and operations involving oxidizer, during which time the trench drain system is flushed and reconfigured to prevent any possibility of contact between fuel and oxidizer.

Safety procedures and plans for all hazardous operations must be submitted by the customer to Astrotech for review and approval. In addition, Astrotech regularly inspects and tests all equipment that it provides. As detailed below for specific equipment, the daily visual checks are common as are semi-annual to annual system-wide verifications.

There are three Astrotech safety personnel who are always available to respond to incidents or accidents during critical periods of handling SRMs, ordnance or liquid propellants. They all have pagers and can be reached at anytime during the day or night. All three individuals are intimately familiar with payload processing operations and have worked at Astrotech since the facility opened. If a problem arises after work hours, the guard has a full set of notification procedures to follow, that include calling the appropriate Astrotech personnel.

<u>Personnel safety equipment</u> (e.g., static dissipating devices, safety glasses for EEDs or propellant grain inspection, gloves and cartridge respirators) supplied by the customer must be approved by Astrotech. Astrotech provides personal protective equipment (see Section 4.4.3), flame retardant coveralls, legstats, emergency escape units with a 5-minute air supply, and Scott air packs with a 30-minute air supply. See Section 4.4.3.

<u>Overhead cranes and hoists</u> are inspected prior to use each shift visually and by activating the pendant emergency power kill switch under simulated load conditions. All cranes, hoists and hooks are proof tested at least yearly at 125% of their rated load per OSHA requirements (29 CFR 1910) and ANSI B30. All hooks are magnafluxed yearly. Proof load data are attached to each crane pendant. Transfer of spacecraft from high bay to high bay in Building 2 entails the use of the Javelin feature on the overhead crane, and is only performed by fully trained Astrotech personnel[9]. The roll-up doors in Building 2 are also restricted to operation by Astrotech personnel.

The <u>conductive floors</u> of Building 2 are checked at least annually by Astrotech per NFPA 56A to verify that the static dissipation capacity is 1 Megohm or less. This safety check ensures continuing dissipation of any electrical sparks. Equipment is bonded or grounded when attached to any device containing hazardous materials. Grounding straps are inspected prior to use and daily when in use, and if the integrity of the cable is suspect for any reason, the cable is checked to ensure proper functioning (e.g., a resistance of less than 10 ohms).

Prior to beginning operations, <u>area safety checks</u> are performed by both Astrotech and the customer, if ordnance, solid motor or liquid propellant are present. Each shift that propellants are on-site, toxic vapor checks (sniff checks) are made and the results marked on the high bay door. Once propellants have been brought into Building 2, continuous monitoring using the MDA toxic gas detectors is performed. See Section 4.4.1.

<u>Fire protection equipment</u> in Building 2 is checked visually at the start of each shift. The entire system is tested on a semi-

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[9] <u>Safety Standard Operating Procedure 1988</u>, Astrotech Space Operations, L.P., pp 11-14.

annual basis (every 5 to 7 months depending upon operational schedules). See Section 4.4.4 for a more detailed description of the fire protection system.

Security is provided for the high bays by key and cipher control available only to the customer and Astrotech. The cipher control may be changed at any time interval specified by the customer.

5.3 Personnel Training Requirements

The Astrotech Safety Officer is responsible for ensuring that Astrotech employees have adequate training in dealing with hazardous materials. Employees who have responsibility for handling hazardous materials, and who are assigned to response duties, have training equivalent to that required by NASA personnel who perform similar duties at KSC. This training exceeds the requirements of Training Standards for Hazardous Technicians Level III and Level IV as designated under OSHA, Title 29 CFR Section 1910 and EPA, Title 40 CFR Part III, and applicable to a wide variety of industries that use hazardous materials.

Customer personnel coming to Astrotech, who participate in hazardous operations (e.g., propulsion teams), must each have certification from the employer noting the individual's training and qualification as well as physical fitness for his assigned hazardous task. Astrotech provides safety briefings for customer employees that include:

- NASA propellant handling safety video
- Facility specific safety/emergency features
- Safe operating procedures and checklists
- Safeguards and safety devices
- Personal protective equipment
- Monitoring and warning devices
- Emergency and contingency procedures

After such training, customer personnel are familiarized with the Astrotech facility and prepared to implement the safety procedures effectively.

6.0 EMERGENCY PREPAREDNESS AND PLANNING

Astrotech has a written emergency plan that covers emergency response actions for incidents that may require action by emergency responders including medical and fire personnel and evacuation of buildings and nearby areas. This plan was updated in 1988 and is supported by other Astrotech documents.[1,2]

In the Titusville area, emergency planning and response capabilities benefit from the planning and working relationship between the City of Titusville and Brevard County. The officials have worked together during other activities requiring public safety duties, specifically the responsibility for thousands of spectators and visitors that are present in the area before, during and immediately following space launches.

Astrotech takes its safety responsibility seriously as evidenced by its concern for safety design features during facility construction and modification as well as its safety record to date. Astrotech has never had a major spill or a release of toxic vapors from its facility, so the alerting of emergency response agencies has never been necessary. On one occasion in connection with sampling anhydrous hydrazine during the fueling of a satellite, less than a teaspoon of liquid was spilled. The tank and scrubber systems totally contained this small spill. Even though no notification was required, Astrotech reported the incident to local officials.

6.1 Emergency Response Equipment and Personnel

Astrotech officials are extremely knowledgeable in the use of and requirements for safety equipment. The facility is designed with ready access to personal protection and fire prevention equipment. For an overview of emergency equipment available in Building 2, see Exhibit 6-1. Local and county emergency responders are nearby and, as detailed below, experienced in the operations and materials handled at the facility.

6.1.1 Personnel Protection and Medical Response

Astrotech has provided personal protection and safety equipment up through Level A for use by those who work in the hazardous operations area. This equipment is also available, if needed, for emergency response personnel. See Section 4.4.3. Astrotech has also supplied PPE to emergency response personnel from both the city fire department and the county specialized response team.

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[1] Safety Standard Operating Documents, Astrotech Space Operations, L.P., 1988.

[2] Safety Policy, Astrotech International Corporation, 1988.

EXHIBIT 6-1 BUILDING 2 EMERGENCY EQUIPMENT

EQUIPMENT	LOCATION	CAPABILITIES
Scott Air Packs (2)	South Control Room	30 Minute SCBA
ISI Ranger Air Packs (2)	Hallway by Spill Response Equipment	30 Minute SCBA with Airline QD
Splash Coveralls (20)	Balance Machine Control Room	Chemical Resistant Suits
Level A Airline Hazmat Suits (6)	Balance Machine Control Room	Encapsulated Fullbody Chemical Resistant
Level A SCBA Hazmat Suits (4)	Balance Machine Control Room	Encapsulated Fullbody Chemical Resistant
Disposable Nitrile Gloves (12dz)	Balance Machine Control Room	Chemical Resistant Wide Range Application
ISI Full Face Pressure Demand Airline with 5 Min. Escape	Balance Machine Control Room	ISI Airline System for Extended Hazardous Operations
Emergency Life Support Apparatus (ELSA) (6)	North & South Bays	5 Minute Emergency Escape Units
MDA TLD-1 Monitors (4)	Placed in Areas Containing N_2H_4, MMH, & N_2O_4	Continuous Monitoring System that Alarms Locally and at Guard House
Spill Control Station	Hallway	Contains 2 Tyvek Total Body Coveralls, 2 Splash Goggles & Gloves, Sorbent Pads, 15 Polyzorb Spill Control Pillows and Disposable Bags
95 Gallon Poly-Overpack Drums	Fuel Cart Room	Twist Top Salvage Drum
Drum Repair Kit	Hallway by Spill Response Equipment	Repair of Most Common Container Leaks, Contains Barrier Tape
Absorbent Booms and Dam Kit	Fuel Cart Room	Spill Control
Emergency First Aid Kit	Balance Machine Control Room	Emergency First Aid Trauma Kit, O_2
Open Top Drums (2)	Cart Rooms, 1 Each	Contaminated Materials, Rags, Booms. 20 Gallon Capacity x 2
Wilden Pump (2)	Mechanical Room	Pneumatic Diaphragm Pump, 60 GPM Capacity
Drum Skid (1)	Scrubber Pad	4 Drums
Water Broom	Fuel Cart Room	35 psi Water Outlet to Wash Down Spill Areas

Should emergency medical attention be needed, the plant has emergency medical technicians on site during liquid propellant operations. Injured individuals requiring additional medical attention would be transported to the Jess Parrish Hospital in Titusville, where the staff has been trained to deal with the types of injuries that could occur at the Astrotech facility.

6.1.2 Fire Protection Equipment and Personnel

Astrotech relies upon an automatic sprinkler system (both dry and wet pipe) activated by heat/smoke detectors located throughout the facility. See Section 4.4.4. Additional facility fire protection equipment includes portable fire extinguishers, both halon and dry chemical types. The facility has fire hydrants placed at strategic locations that would be used by public responders.

In the event of a fire in Building 2, an automatic dialer, triggered by activated smoke/heat detectors, calls the Titusville Fire Department. Additional available response personnel include the Brevard County Fire Department Station # 22, located approximately 2¼ miles or 5 minutes away, and the county hazardous materials specialized response team (SRT) based approximately 20 miles or 25 to 30 minutes from Astrotech. On Exhibit 6-2, the locations of fire stations are indicated; the SRT is not on the map. All emergency access routes are over publicly maintained roads.

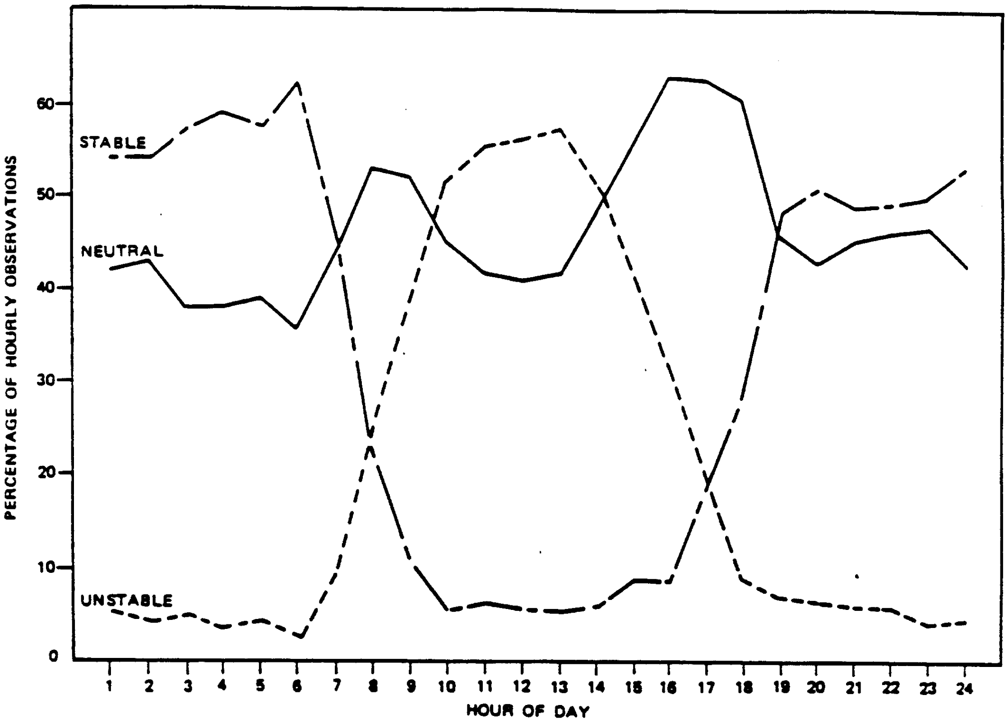
The Brevard County SRT is an experienced hazardous materials response unit that is well trained and equipped. This team has a large hazardous materials response and communications van that can serve as a command post. This team responds to approximately 50 hazardous materials calls per month, but as noted earlier, has never needed to respond to an incident at Astrotech.

6.1.3 Familiarity of Emergency Responders with Facility

The Astrotech Safety Officer, named by the company as emergency response coordinator, has made the facility emergency plan available to local planning officials and has fully cooperated with emergency planning and response leaders in on-site explanations of the company's hazardous materials operations. Members of the county SRT and county emergency medical technicians have been invited to and have attended satellite fueling operations. Additionally, the Titusville Fire Department has been invited to Astrotech for familiarization with and training in the fire control system at the plant. Various types of PPE have been donated to the county SRT by Astrotech.

Coordination between Astrotech and emergency responders began even before the facility was built. Local fire, building and planning staff, and NASA officials were consulted during design and construction phases of the facility and their recommendations were solicited, many of which were incorporated into the facility.

EXHIBIT 6-2 LOCATIONS OF EMERGENCY RESPONDERS



The Brevard County emergency management agency has a staff person, who is fully aware of hazards at the facility, assigned to deal with distributing public information. Public information regarding the Astrotech operation is generally disseminated from the Astrotech Maryland office. However, the general manager at the facility is assigned to work directly with Brevard County emergency management to furnish emergency information should there be a release.

6.2 Emergency Response Communications

Astrotech procedures require that when propellants are on-site, a senior spacecraft propulsion engineer must be available in the local area and on call twenty-four hours each day.

The key person in both emergency planning and response for Astrotech is the Safety Officer. He continuously observes <u>all</u> hazardous operations through the explosion-proof window in the control room and ensures compliance with approved procedures. He is also involved in the transportation of fueled satellites from Astrotech to KSC. When he is away from the facility, he is available through pager and cellular telephone.

Astrotech considers a spill of hydrazines or nitrogen tetroxide in excess of one gallon to be an uncontrolled release.[3] Should such a spill occur during working hours, the procedures states that a call for outside assistance be made by the Safety Officer using the emergency telephone number 911.

Should conditions preclude this action by the Safety Officer, procedures are in place for any workman involved to contact the front gate guard who would then report the accident to public authorities, also by dialing 911. Under such circumstances, the following information concerning the spill would be furnished to the front gate guard:[4]

1. Exact location
2. Estimated quantity
3. Time and duration
4. Media or medium into which the release occurred
5. Direction of vapor movement if release is outside of the Building 2[5]
6. Number of personnel involved.

Also, the guard house would be alerted of problems by the alarm system as described in Section 4.4.4.

Astrotech's emergency response plan has a roster for contacting and calling to duty critical response personnel when they are off duty. The roster lists the names and pager numbers of the Safety Officer and the deputy general manager and the telephone numbers of three response team members. All Astrotech employees have in their possession a card listing telephone numbers of these and additional plant personnel considered critical in emergencies.

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[3] Spills of that amount of fuel could bring the vapor concentration level in the bay to the lower explosive limit for hydrazine.

[4] <u>Emergency Spill Response Plan</u>, Astrotech Space Operations, L.P., 1988.

[5] A wind sock is located near the hazardous materials working and storage area to identify wind direction should evacuation become necessary.

Should an incident occur at night or when Astrotech is not in operation, the front gate guard, after calling 911, would contact the Safety Officer, the vice president and the general manager.

Procedures for inter-communication and coordination of company response operations are in place. Astrotech has a close-knit staff of eleven individuals, many with long tenure. Contractors servicing satellites bring with them only four to eight persons involved in handling propellants, so the total number of individuals in Building 2 during propellant operations is small. Astrotech has a plant-wide telephone system and has posted the number of the front gate guard by each telephone. There is an intercom system in the spacecraft processing areas, including communications capability to and from personnel working in full protective clothing. Eight of Astrotech's eleven employees have one-watt portable radios with plant wide coverage. One radio is maintained at the desk of the administrative assistant in the administration building.

6.3 Emergency Response Planning

6.3.1 Brevard County Hazards Analysis Study

The Brevard County Emergency Management Agency has performed hazards analyses (including risk and vulnerability analyses) for the Astrotech facility as detailed in the EPA guidance document for emergency planning[6] under SARA Title III. The results showed that there was "very slight" possibility of release of anhydrous hydrazine or monomethyl hydrazine from this facility; that state-of-the-art containment, scrubber and neutralization systems are in-place to deal with any problems; that the training and safety program at the facility is "excellent"; and that the emergency response program is "comprehensive."

The results of the analyses of releases for these chemicals, including maps of the identified EPA vulnerable zones, are presented in Appendix A. The analysis is based on an release scenario where the maximum quantity of fuel allowed on-site by the Florida DER air permit, is instantaneously released outside the building. County emergency officials stated that they view this scenario to be unrealistic given Astrotech's transport and operating procedures, and believe that a more realistic, but still unlikely accident scenario would be a release initiated within the building with exposure confined to the facility and its immediate vicinity.

6.3.2 Building and Area Evacuation

In the event that a spill in excess of one gallon occurs in Building 2, all personnel would evacuate the building through designated evacuation routes. See Exhibit 6-3 for these routes. Portable emergency life support apparatus, if needed for emergency egress, is readily available in hazardous operations areas. The affected area would be secured, outside help would be called as detailed above and a command post would be established at a pre-determined point based on location of the exposed area and the wind direction. Before evacuation, control room personnel would turn off all power to the building including the scrubber, and therefore all vapors would be contained within the building, unless there was a fire or explosion.

Astrotech continuously monitors vapor concentrations in the interior of

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[6] Technical Guidance for Hazards Analysis, *Emergency Planning for Extremely Hazardous Substances*, U.S. Environmental Protection Agency/Federal Emergency Management Agency/U.S. Department of Transportation, December 1987.

the building when liquid propellants are present. However, they have no fixed monitoring around the perimeter of their property. Should an internal release occur as described above, portable monitoring equipment would be used to measure ambient vapor concentrations. From information thus obtained, Astrotech officials would evaluate any toxic vapor levels and determine safe areas.

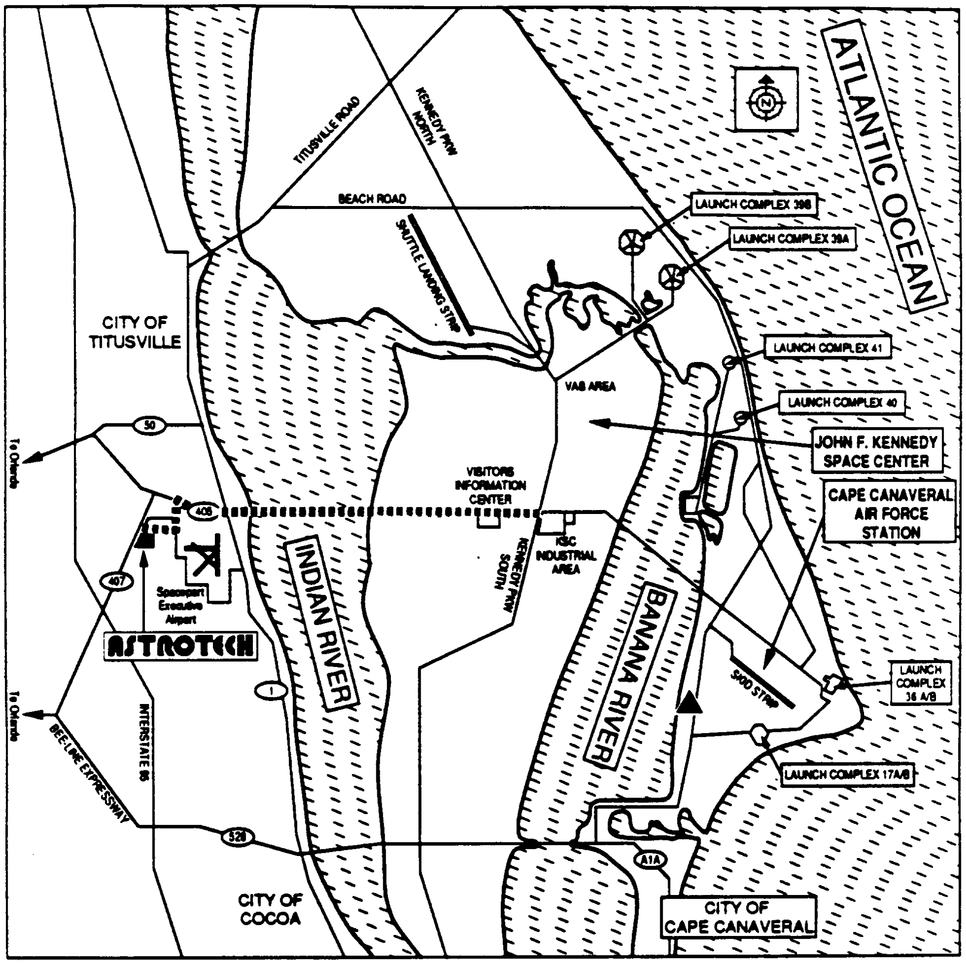
Brevard County has provisions for evacuation of areas surrounding the facility, if necessary. Should there be a release at Astrotech potentially affecting an off-site population, alerting and evacuation would be effected by public safety agencies through door-to-door contact, supported by emergency broadcasts using pre-determined radio stations. There is no public alerting device at Astrotech. Neither does the city of Titusville have a public alerting system maintained in the area surrounding the Astrotech facility.

No formal exercises of the emergency plan involving local emergency response agencies have been conducted, but the plan has been distributed and reviewed with the local fire department, the county SRT and emergency agency heads. The absence of a simulation exercise has been due to logistical problems in scheduling such an exercise with local agencies. Both local emergency management agencies and Astrotech stated that they view conducting the exercise as a high priority.

6.4 Title III Reporting

In 1986, SARA Title III, also known as the Emergency Planning and Community Right to Know Act (EPCRA) of 1986, was enacted so that local government could become aware of inventories of potentially hazardous chemicals and could plan with the facility to protect the public should a release occur. Under Section 302 (a) of SARA Title III, chemicals that are acute toxics are listed as Extremely Hazardous Substances (EHSs). The list contains three hundred and sixty substances, including commonly used chemicals

EXHIBIT 6-3 EVACUATION PLAN FOR BUILDING 2



▪▪▪▪▪▪▪▪▪ = Hazardous Materials Transportation Routes

▲ = Liquid Propellant Supply Depot

1 inch = approximately 3½ - 5 miles

such as ammonia and chlorine. For each listed chemical, a planning threshold is identified, and any facility having an amount on site at or above that level must report its presence to the state, LEPC and fire department(s) serving the facility. Additionally, SARA Title III identifies reportable quantities for each EHS. If a release at or above the reportable quantity extends beyond the facility boundary, the owner or operator must report the release to local government officials and to the State Emergency Response Committee (SERC).

Monomethyl hydrazine (Chemical Abstracts Number [CAS #] 60-34-4) and anhydrous hydrazine (CAS# 302-01-2) are listed as Extremely Hazardous Substances (EHS). Quantities of anhydrous hydrazine or monomethyl hydrazine exceeding the planning thresholds of 1,000 pounds and 500 pounds, respectively, are periodically present at Astrotech (i.e., when satellites are being fueled). Therefore, Astrotech is subject to SARA Title III reporting requirements. The reportable quantity for releases is ten pounds for monomethyl hydrazine and one pound for anhydrous hydrazine.

Nitrogen tetroxide, another chemical that is used during satellite fueling at Astrotech, is not on the Section 302 (a) Title III EHS list; however, it is on a list of chemicals, as are anhydrous hydrazine and monomethyl hydrazine, that is regulated by CERCLA. Any facility releasing this chemical into the environment in quantities of ten pounds or more must immediately report the release to the NRC. See Appendix B for a summary of releases of hydrazines and nitrogen oxides reported to the NRC over an eight year period.

Under Section 304 (b) of Title III, facilities having releases of reportable quantities of chemicals listed as EHSs must furnish the following information, to the extent it is known, to the SERC and to a local emergency answering point designated by the LEPC:

- Chemical name or identity
- Presence of the chemical on list of "Extremely Hazardous Substances"
- Quantity released
- Time and duration of release
- Released into air, land, surface water, ground water
- Anticipated acute or chronic health risks
- Medical attention requirements
- Precautions
- Evacuation information
- Name and telephone number of person to be contacted for further information

Astrotech's plan and procedures do not specifically indicate that these items of information are to be furnished when reporting a release.

Inquiries made by the safety evaluation team of the Florida SERC, the LEPC covering Titusville and local emergency planning and response officials, revealed Astrotech management has filed all required reports and is in compliance.

7.0 HAZARDS ANALYSES AND RISK ASSESSMENT

The overall goal of this assessment is to identify risks to the public that may result from accidents that could occur at the Astrotech facility. The risk assessment was performed by reviewing the facility design, operations and procedures and then defining possible accident scenarios that could produce a hazard to the public.

In Section 7.1, evaluations performed previously by other experts are discussed. In Section 7.2, the flammable and explosive properties of liquid and solid propellants are reviewed and scenarios that could cause an explosion capable of breaching Building 2 are determined.

In Section 7.3, the accident scenarios capable of producing a fire and explosion and possible venting of toxic vapors are described. These scenarios include:

- Explosion resulting from liquid propellant operations
- Explosion resulting from a dropped payload
- Explosion of a high pressure tank
- Explosion resulting from spin balance accidents
- Ignition of an SRM

For each accident scenario described in Section 7.3 the probability of occurrence has been calculated in Section 7.4. A detailed fault tree has been constructed that indicates contributing events that must occur for the accident scenario to result, the probability of each contributing event has been estimated and the overall accident scenario probability calculated. For each potentially hazardous condition, the facility design features and the operating procedures that minimize the hazard have been considered as part of the basis for the assessment.

The severity of the consequences for each accident scenario would depend primarily on the quantity of fuel, oxidizer and solid propellant involved, leading to three worst case release conditions:

- Explosion of a payload/fueling cart containing the maximum quantity of fuel permitted on-site (2,500 pounds)

- Explosion of a payload/fueling cart involving the maximum quantity of fuel (2,500 pounds) and the maximum quantity of oxidizer (5,000 pounds) permitted on-site

- Explosion of a payload/fueling cart with the maximum quantity of fuel and the maximum quantity of oxidizer permitted on-site and the amount of solid rocket propellant used in siting analyses (24,600 pounds).

For these worst case release conditions, the toxic gas concentrations at ground level were calculated. The calculated concentrations were then compared to a vapor concentration called the level of concern (LOC) used by the EPA in hazards analyses for community emergency planning.

Any risk to the public health was determined by evaluating the results of the accident scenarios leading to the worst case release conditions. These were then compared qualitatively with other similar public risks and some observations were made.

7.1 Site Evaluations and Modeling Studies

Both before initial construction and before the building modifications, Astrotech commissioned studies to evaluate whether the proposed facility and modifications complied with applicable safety criteria and regulations. The studies, performed by independent consultants, included evaluation of compliance of the facility with DoD quantity distance criteria and quantification of the potential air emissions to support the renewal of the Florida DER air permit. These prior studies have concluded that the Astrotech facility is in compliance with all applicable standards and represents a minimal safety hazard to the surrounding community.

7.1.1 Site Distance Criteria Studies

The siting and construction of Building 2 on Astrotech's property was done in accordance with DoD siting criteria[1] specifically to control and limit the effects of any explosions to within the facility boundaries. A special report was commissioned by Astrotech as part of the design engineering prior to construction of the facility to identify the siting criteria and validate the design, given the proposed operations, and to ensure that these requirements would be met.[2] The evaluations used applicable siting criteria from DoD Directive 5154.4S (as updated by DoD Directive 6055.9 dated July 1984, DoD Ammunition and Explosives Safety Standards); fragment size and velocity analyses based on analyses previously performed on similar satellites by ESMC (TM5-1300, Chapter 8 - equation to determine wall resistance to fragment penetration); secondary fragment analyses based on Chapter 2 Figure 2-33 of the CPIA <u>Hazards of Chemical Rockets and Propellants</u>, Vol I, Explosive Effects and Damage; and sympathetic detonation analysis using the results of the prior fragmentation analyses.

The conclusions of the commissioned report indicated that the proposed siting of the buildings on the property met DoD explosives quantity distance criteria, and that Buildings 2 and 3 with their respective siting and design should not present a hazard to the general public outside of the facility boundary "...greater than that normally presented from any DoD hazardous facility site containing similar hazardous liquid and solid propellants."

An additional safety analysis was conducted when the new high bay hazardous staging airlock was proposed for addition to Building 2.[3] The results showed that the 45 foot high reinforced masonry walls would stop the primary fragments of an explosion involving the liquid and solid propellants installed in an INTELSAT-sized spacecraft (approximately 6,400 pounds of liquids and 16,000 pounds of Class 1.3 solid propellant[4]). The secondary building fragments would not be thrown beyond 500 feet. The analysis also concluded that adequate distance was available to the boundaries and inhabited non-ordnance buildings to meet the requisite quantity distance requirements specified in the DoD Directive. An addendum to this study was performed

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[1] Department of the Air Force, <u>AFR 127-100, CHANGE 1</u>, 24 December 1984, Chapter 5 - Principles and Application of Explosives Quantity-Distance Criteria and Related Standards.

[2] <u>Astrotech Satellite Assembly and Checkout Facility Explosives Quantity Distance Siting</u>, BRPH Report No. 1-83, Louis J. Ullian, Explosives Ordnance Consultant, January 9, 1983.

[3] <u>Hazard and Quantity Distance Siting Analysis of Astrotech Hazardous Staging Airlock Addition to Building 2</u>, ECI Report No. 1-88, Explosives Consultants Inc., February 9, 1988.

[4] Class 1.3 class propellant is defined in AFR 127-100 as an item which burns vigorously, and the fires are difficult to extinguish. Explosions are usually pressure ruptures of containers and do not produce propagating shock waves or damaging blast overpressure beyond a safe distance between two explosives storage facilities.

shortly thereafter to analyze the potential for sympathetic detonation in the event of dual payload processing in Building 2 (specifically to address the SKYNET 4 and JCSAT satellites that required processing for a Commercial Titan III launch).[5] This analysis showed no risk of sympathetic detonation as long as the payloads are separated from one another by at least one reinforced wall (in Building 2, the separation is made by two reinforced walls).

These hazards analyses have all been concerned mainly with the effects of explosion (e.g., blast overpressure and flying debris) on surrounding buildings and public areas, but did not address or analyze toxic vapor hazards. In fact, one of the recommendations of the Explosives Consultants, Inc. (ECI) Report 1-88[6] stated "...An analysis should be made of the potential toxic hazards in the event of an explosion in the bay which caused sufficient damage to allow vapor release to the outside atmosphere." Therefore, while these analyses do adequately assess the siting and design criteria for handling explosive materials on the site, additional effort is needed to assess the potential for exposing the public to toxic gases given an accident involving fire and explosion.

7.1.2 Study to Support Florida DER Air Permit

Astrotech also used an environmental engineering consulting firm to estimate emission rates from Building 2 during normal propellant loading operations. The study supported renewal of the Florida DER air permit that Astrotech holds to operate their scrubber system.[7] A copy of the most recent version of the air permit is attached as Appendix D. The emission rate estimates were made by reviewing processes at Astrotech and comparing them to operations at other facilities handling hydrazines (specifically the Olin anhydrous hydrazine manufacturing facility in Lake Charles, Louisiana). The scrubber efficiency (90%) as provided by the vendor (Tri-Mer Corporation) was also a component of the analysis. The resulting fugitive emission estimates were then input to the Industrial Source Complex Short-Term dispersion model to project the maximum 8-hour ground level ambient concentrations for the materials of concern in the permit. The modeling results showed that the maximum ambient concentrations for all pollutants will be below the DER's Acceptable Ambient Concentrations. The ISCST model has been approved by both the Florida DER and the EPA for use in determining compliance with Ambient Air Quality Standards.[8]

Although this study confirmed that there are no risks to public health and safety during normal operations, it did not examine risks during an accident.

7.2 Potential Fire and Explosion Hazards

In developing accident scenarios that could result in exposure to the public, the safety evaluation team first determined which propellants or combinations of propellants would be capable of causing an accident that could breach Building 2.

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[5] Sympathetic Detonation Analysis for Dual Payload Processing in Building #2, Addendum 1 to ECI Report No. 1-88, Explosives Consultants Inc., March 26, 1988.

[6] Hazard and Quantity Distance Siting Analysis of Astrotech Hazardous Staging Airlock Addition to Building #2, ECI Report 1-88, Explosives Consultants Inc., February 9, 1988.

[7] Satellite Fueling Operation Response to FDER Completeness Summary, Hunter/ESE, No. 3901-010100-0400-3160, July 1989.

[8] Ibid.

7.2.1 Fire Hazards

The Astrotech facility is equipped with a fire suppression system that would quickly extinguish most fires (except those involving SRMs or large quantities of liquid propellants) that could occur. Moreover, the safety procedures required at Astrotech are designed to avoid situations that could lead to a fire. However, because an accident in which the public could be exposed would likely begin with a fire, a brief description of the flammable characteristics of the hazardous materials handled at the facility is provided below.

As discussed in Section 4.3.1, the hydrazines are volatile, flammable chemicals which may present fire and explosion hazards if present in sufficient concentrations under certain conditions. Nitrogen tetroxide (see Section 4.3.2) is not flammable but will react with combustible materials. Since Astrotech limits the presence of combustible materials in operational areas, any fire or explosive hazard associated with nitrogen tetroxide would most likely result from unintentional contact with the hydrazine fuel itself, as would be the case in a dual propellant spill.

The most severe fire hazard at the Astrotech facility would be posed by an accidentally ignited SRM, which although difficult to ignite once ignited, could not be extinguished by the sprinkler system. It would continue to burn until all the solid propellant was consumed. The burning of an SRM generates intense heat and certain ignition modes may lead to the potential rupture of the motor case. If its case ruptures, other fuels in close proximity would then likely become involved in the fire.

7.2.2 Explosion Hazards

Even if a fire occurred, no public exposure would result if Building 2 remained intact and sealed. Public exposure could only result if, as the result of a fire, an explosion occurred that breached the walls and/or the ceiling of the building, allowing vapors to be released.

Solid Rocket Motors

The SRMs processed at Astrotech contain solid propellant that has been classified by DoD as non-detonable Class 1.3 propellant[9]. Therefore, severe explosions of these propellants are not feasible. If an SRM was ignited while the motor was mounted on fixtures that block the motor exhaust, an internal pressure-caused explosion could occur. This type of pressure rupture would produce low overpressures that might result in some limited facility venting. Fragments generated by such an event would be retained inside the facility[10,11,12].

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[9] Hazards of Chemical Rockets and Propellants, Vol. II, Solid Propellants and Ingredients, CPIA Publication 394, September 1984, Appendix D.

[10] Astrotech Satellite Assembly and Checkout Facility Explosives Quantity Distance Siting, BRPH Report No. 1-83, Louis J. Ullian, Explosives Ordnance Consultant, January 9, 1983.7

[11] Hazard and Quantity Distance Siting Analysis of Astrotech Hazardous Staging Airlock Addition to Building 2, ECI Report No. 1-88, Explosives Consultants Inc., February 9, 1988.

[12] Sympathetic Detonation Analysis for Dual Payload Processing in Building 2, Addendum 1 to ECI Report No. 1088, Explosives Consultants Inc., March 26, 1988.

Liquid Propellants[13]

Most combustion type reactions are classified as deflagrations and would represent only minimal explosion hazards. However, if large quantities of liquid propellants were involved or the reaction products were confined in some way the explosion hazard increases.

Therefore, several conditions would generally be necessary to create an explosion severe enough to destroy the containment of Building 2:

- Ignition of confined hydrazine or hydrazine-air vapors, which leads to a rapid increase in vapor pressure,
- Direct contact of significant amounts of fuel and oxidizer (without confinement).

The explosions as described above could produce peak blast wave overpressures sufficient to cause upper side wall and roof failures in Building 2. Reaction zone overpressures of 125-150 psi could result from hydrazine or hydrazine-air mixtures and range up to 430 psi for fuel and oxidizer reactions. During such a fire and explosion event, some of the fuel and oxidizer would be consumed and the rest would be released. See Section 7.5.

In summary, spills and fires within the Astrotech facility are not likely to produce any public exposure, unless a severe explosion occurs and the building is breached. The events that could potentially produce public exposure require a fuel/air or fuel/oxidizer explosion. Therefore, the safety evaluation team determined combinations of events that could lead to an explosion in order to construct credible accident scenarios.

7.3 Accident Scenarios

A qualitative description of credible accident scenarios is provided in this section. The accidents described were determined to have potential to create a condition that could result in the release of liquid propellant to the atmosphere. A more quantitative discussion of each of these scenarios, including probabilities of specific events and conditions that would need to occur and calculations of the overall accident probability, follows in Section 7.4. The consequences of these accidents, including vapor concentrations and exposure durations, are detailed in Section 7.5.

Major events involving only the liquid propellants would most likely start as small spills which despite several means to terminate the flow, could not for some reason be stopped (Section 7.3.1). Major events which involve both liquid and solid propellants would likely start with one of several scenarios: dropping of a fueled spacecraft (Section 7.3.2), rupture of a high pressure gas tank (Section 7.3.3), explosion resulting from a spin balance accident (Section 7.3.4), or ignition of an SRM (Section 7.3.5).

7.3.1 Explosion Resulting from Liquid Propellant Operations

Spills or leaks of liquid propellants are most likely to occur during sampling and transfer operations. All propellants are sampled and tested for purity prior to loading. The quantity of fluids taken for each of these samples is approximately one-quarter of a gallon and the transfer pressure on

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[13] Fire, Explosion, Compatibility and Safety Hazards of Hydrazine, M.D. Pedley, et. al., RD-WSTF-0002, NASA, Johnson Space Center, White Sands Test Facility, February 20, 1990.

the fluid in the tanks and lines is less than 10 psi. Under these conditions it is unlikely that large quantities could leak or be spilled directly. The most likely cause of an uncontrolled leak would be from mechanical puncturing of lines or tanks by dropped tools or other equipment.

The hydrazine fuels are extremely flammable liquids and a large spill or leak would likely result in a fire. The most likely sources of ignition are:

- Electrical equipment that is not powered down before vapor concentrations exceed the flammability limits at the electrical equipment location;
- Contamination in the drainage system that reacts with fuel and creates autoignition temperatures; or,
- Electrostatic discharge caused by uncontrolled fluid flow.

The heat released by the burning of these fuels in the bay may overheat fluids/vapors remaining in payload tanks or fueling drums, thereby, causing autoignition in the vessels. However, heating rate estimates are inconclusive. The sprinkler system might activate before the tanks were hot enough to autoignite and detonate.

Alternately, the NASA White Sands Test Facility has reported[14] that small leaks from transfer lines, if ignited, have propagated to larger events through a series of small detonations in the lines until eventually the tank exploded. Shrapnel from the small line explosions may be sufficient to breach fuel and oxidizer tanks in a bipropellant payload and result in an explosion, that will likely blow out the roof and/or walls, breaching the building. Since anhydrous hydrazine and MMH are highly combustible in air, very little unreacted gas is likely to escape to the atmosphere, even if the building undergoes major structural damage. Rather, any escaping gases will consist largely of gaseous nitrogen and water vapor.[15]

Nitrogen tetroxide does not undergo decomposition reactions that produce rapid heat release in the atmosphere. Also, combustion type reactions are possible only in the unlikely event that the released oxidizer comes into contact with a fuel source. Since combustible materials such as paper, cloth, and wood are not allowed in the processing area during propellant transfer, any spilled or leaked oxidizer will enter the trench-containment system and be diverted to a holding tank for dilution and neutralization. Since nitrogen tetroxide dissociates predominantly into nitrogen dioxide on evaporation, the major result of a large oxidizer spill or leak will be high concentrations of nitrogen dioxide in the bay involved.

7.3.2 Explosion Resulting from a Dropped Payload

All payloads prepared at Astrotech must be lifted at least once for loading onto the transporter for movement to the launch pad. However, payloads are typically lifted several times after fueling (e.g., between high bays, in preparation for spin balancing). If a payload was dropped during lifting operations, it would likely be seriously damaged and liquid propellants would likely be released. Because large quantities of liquid propellant would be involved, an explosion resulting from such a release would

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[14] Personal communication with F. Benz, Project Director at the NASA White Sands Test Facility.

[15] Ibid.

generally be worse than one which could occur during fueling. If a payload was dropped, fire and explosion would be likely; major facility damage, and possible release of unburned propellants could occur. Although payloads have been damaged during lifting and crane operations, none has ever been damaged to the extent necessary to cause this type of accident.

7.3.3 Explosion of a High Pressure Tank

High pressure gases are used on payloads as a source of pressure to pump liquid propellants. The pressure tanks are usually filled with gaseous nitrogen or helium and pressurized as high as 6,000 psi using high pressure gas bottles. This operation is normally performed after spacecraft fueling operations have been completed, and the spacecraft has been mated to the SRM; and just before encapsulation and transport. Most payloads contain high pressure tanks that are designed to leak rather than burst. However, in the unlikely event that a high pressure tank should burst as the result of overpressurization or material flaw, its fragments could penetrate nearby propellant tanks. Although there have been several instances of failures in high pressure tanks or lines, no failure has resulted in the severe accident described in this section. The damage caused by such an event, however, could result in an explosion, loss of building containment and possible release and dispersion of toxic vapors.

7.3.4 Explosion Resulting from a Spin Balance Accident

A spin balance table is used to measure precisely the center of mass and moments of inertia of the major elements of a payload. Normally the spacecraft is attached to the table and spun at a slow rate to make these measurements before propellants are loaded. Some customers request a subsequent spin balance after propellants are loaded. At another time in the processing flow, the solid rocket motor(s) is (are) attached to the table mated with their upper and/or lower adaptor (mating) sections, as required by the specific design. Attachments are pretested and attach forces precisely set prior to each operation.

Fire could result from hydraulic oil leaks under the table if an ignition source were present. The potential for oil leaks is minimized by overall inspection prior to each use, frequent detailed scheduled inspection and maintenance, and on line redundant leak detection measurements. The drive motor is located in a separate pit, not directly under the spin table, and is totally encased and purged by two-way air flow.

The spin rates are low, so stress loads do not approach design limits and no self damage is ever to be expected. The bearing function is provided by a fully hydraulic system backed up by roller bearings, so bearing seizure probability is minimized. Dangerous out-of-balance situations are detected automatically. Visual and audio signals are activated and shutdown is automatically activated at pre-set limits.

7.3.5 Ignition of a Solid Rocket Motor

An SRM can be ignited accidentally by dropping it from a height of several feet onto a hard sharp or pointed surface, applying electrical energy directly to the motor's initiators, electrostatic discharges[16], heating the motor to autoignition temperatures, or penetrating it with high energy fragments from nearby explosions. The solid propellant motors processed at

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[16] Electrostatic Ignition of X-248 Rocket Motors, Technical Report CAL No. DM-1934-EZ-1a, Cornell Aeronautical Lab, March 1965.

Astrotech are classified as fire hazards, but they cannot be detonated even when exposed to fires or explosions of the type possibly resulting from a payload processing accident.

Ignition of a motor by external heating or penetration of its outer case by a destruct charge will normally produce external low pressure burning of the solid propellant contained in the motor. Destruct charges of the type that could penetrate Building 2 walls if accidentally initiated are not permitted at Astrotech. Destruct charge initiators are protected by safe-arm devices. The solid propellant used in these motors contains both fuel and oxidizer and once ignited cannot normally be extinguished until all solid propellant is consumed. If initiated while attached to the payload, the heat released is likely to cause failure of the liquid propellant tanks, leading to involvement of liquid propellants in a fire and possible explosion.

Internal ignition of an SRM can occur from electrostatic discharge or stray current introduced into the ignition circuits and will cause internal pressurization of the motor. At Government launch sites, several SRMs that had sensitive initiators not protected by safe-arm devices have been ignited by electrostatic discharge and lightning induced current. However, all SRMs processed at Astrotech are protected by safe-arm units and use insensitive initiators which meet ESMC and NASA standards, and significantly reduce the possibility of ignition from electrical discharge. Ignition of a motor on a stand with the payload attached may result in the restrained propulsion of the SRM and fueled payload within the building and explosion on impact. Overpressurization and failure of the motor case due to restricted flow from the nozzle can also occur in this type of event. Fragments generated by this type of explosion would not penetrate the walls; however, severe damage could occur to a payload.

Unrestrained motors ignited during preparations or during lifting operations can become propulsive and accelerate into the walls or ceiling. Because of the limited distance to a wall or the ceiling, impact velocities will be low and escape from the facility is unlikely. Motor case failure and fragmentation could occur due to impact of the motor with facility equipment or walls. Any damage would most likely be confined to the bay where the ignition took place.

7.4 Estimation of Accident Probabilities

The likelihood of an accident that can produce a public exposure for each of the accident scenarios described in Section 7.3 will be evaluated in this section. The methodology used in developing these accident probabilities includes evaluation of the systems involved, past accident histories for similar operations and systems, the measures taken to minimize the likelihood of failure or procedural error, and if a failure occurs, the likelihood that it could worsen and lead to a severe event.

The method used to estimate the probability of the occurrence of an event is based on use of both qualitative and quantitative data as shown in Exhibit 7-1. This method was developed by Sverdrup[17] and allows a reasonable correlation to be made between the MIL-STD-882B definitions and a probability range (See Appendix E). Exhibit 7-1 is a modification of the Sverdrup methodology that is more appropriate for estimating and combining event probabilities shown in the fault trees developed in this analysis. The quantitative probability ranges represent the number of anticipated event

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[17] Combinational Failure Probability Analysis Using MIL-STD-882B, P.L. Clemens, Sverdrup Training Notes 6000-8i, 3rd Edition, December 1984.

occurrences in a given number of operations. For example, 8 x 10^{-2} means 8 occurrences in 100 operations and 8 x 10^{-3} means 8 occurrences in 1,000 operations, so a descriptive word "probable" means the event is likely to occur between 8 times in 100 and 8 times in 1,000 operations.

Fault tree analysis is a method for estimating the frequency of a hazardous accident (top event on the tree) from a logic model of the failure mechanisms of a system. A fault tree for each accident scenario identifies a series of contributing events that must occur and their estimated probability of occurrence. A fault tree is arranged to represent the logical combinations of various system states (e.g., contributing events) which can lead to a particular event at the top of the tree. In fault trees, alternative contributing events are presented that can independently lead to the same

EXHIBIT 7-1 DEFINITIONS AND DESCRIPTIONS OF PROBABILITY RANGES

PROBABILITY RANGE LIMITS		DESCRIPTIVE DEFINITIONS	
Lower Limit	**Upper Limit**	**Descriptive Word**	**Definition**
8 X 10^{-2}	8 X 10^{-1}	Frequent	Likely to occur frequently
8 X 10^{-3}	8 X 10^{-2}	Probable	Will occur several times in life of item
8 X 10^{-4}	8 X 10^{-3}	Occasional	Likely to occur sometime in life of item
8 X 10^{-5}	8 X 10^{-4}	Remote	Unlikely but possible to occur in life of item
8 X 10^{-6}	8 X 10^{-5}	Improbable	So unlikely it can be assumed occurrence may not be experienced

accident outcome; these events are connected by OR gates and their probability is summed. If two are more contributing events are combined by an AND gate, then each event must occur to lead to the accident; their probabilities are multiplied.

On each fault tree, formulas are given for the multiplication and addition of event probabilities that leads to the overall accident probability. Each fault tree is supported by an exhibit that identifies each contributing event in the fault tree, the assigned probability value, the descriptive qualitative probability and the justifications for the probability assigned. Assigned probabilities estimated are based on accident histories, past experiences at the Government ranges in processing thousands of payloads and launch vehicles, and subjective judgment on the applicability of such past experience to Astrotech's operations.

7.4.1 Explosion Resulting From Liquid Propellant Operations

The contributing events leading up to an accident involving a major spill, fire, and explosion of liquid propellants are depicted in Exhibit 7-2. This fault tree identifies the events that must occur and their estimated probability of occurrence, and illustrates the sequence of events needed to cause a fire that results in a fuel tank explosion.

Fault trees are evaluated from the bottom up. As can be seen in the exhibit, events 1, 2, and 3 are alternative contributing events that can initiate a major spill. The sum of the probabilities of these three events is the probability of event 4, a major spill. Events 4, 5 and 7 all occur before a spill can lead to an explosion. Thus, the probabilities of events 4, 5 and 7 are multiplied to determine the probability of top event 8, an explosion.

Exhibit 7-3 identifies each contributing event in the liquid propellant spill fault tree, the assigned probability, and the justification for the probability assigned. A fuel spill that resulted in a fire and explosion involving a payload has never occurred in the many thousands of payload operations conducted at the various federal ranges, so the overall probability of improbable is supported by actual operations experience.

7.4.2 Explosion Resulting From A Dropped Payload

The majority of payloads processed at Astrotech require one to two lifting operations. However, if a fueled payload is spin balanced, the present sequence of operations may require as many as four lifting operations. Dropping a fueled payload from any significant height is likely to damage the payload sufficiently to cause liquid propellant leaks. The events required to create an explosion are depicted in the fault tree in Exhibit 7-4.

The fault tree indicates that any of the contributing events numbered 1 through 5 can result in a dropped payload. For a drop to cause major damage to the payload, either the drop must be from a height of at least 5-6 feet or the entire payload must tip over. Most payload lifts do not exceed 1-2 feet and a drop from this height is not likely to cause major damage or a tip over. Conditional events 7 and 8 are also necessary for a fire and explosion that breaches the building.

The conditional event probabilities and justifications are shown in Exhibit 7-5. Although there have been payloads damaged during lifting operations on rare occasions, none have been damaged to the extent necessary to cause the accident described, supporting an overall accident probability of improbable.

7.4.3 Explosion of A High Pressure Tank

The failure of high pressure tanks used on payloads to pump propellants can present a serious accident threat. The fault tree describing the necessary events for this accident is shown in Exhibit 7-6.

There have been rare failures of high pressure components on launch vehicles during pressurization. To date, no such failures have occurred during payload pressurization. The probability of damage to propellant tanks is lessened because many of the current payloads isolate the high pressure gas tank from the propellant tanks. These facts support an accident probability of less than improbable. Exhibit 7-7 shows the event probabilities for the explosion of a high pressure tank leading to explosion of the propellant tanks.

7.4.4 Explosion Resulting from A Spin Balance Accident

Exhibit 7-8 shows the fault tree events necessary to have a major explosion accident during spin balance operations. Payloads flown on the Delta launch vehicle are spin balanced before propellant loading and a few are re-balanced after loading. The SRMs are spin balanced separately and thus would not be involved in a payload accident or explosion. Some payloads are fueled prior to balancing and some are flown without spin balancing (e.g., payloads flown on the Titan and Atlas Centaur).

EXHIBIT 7-2 FAULT TREE FOR EXPLOSION RESULTING FROM LIQUID PROPELLANT OPERATIONS

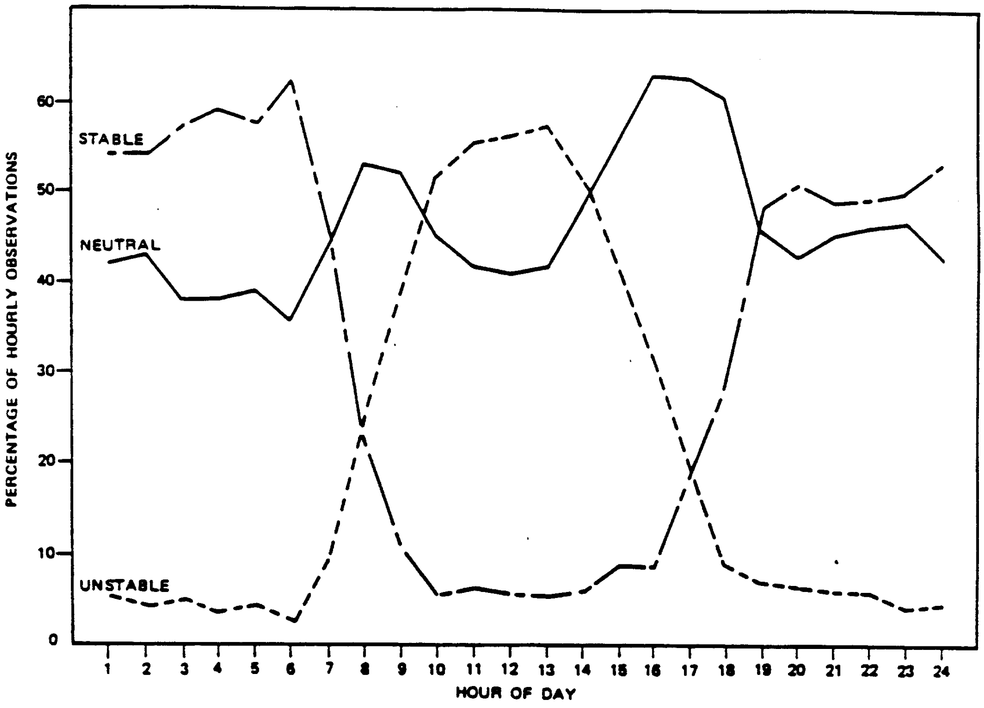


EXHIBIT 7-3 EVENT PROBABILITIES FOR EXPLOSION RESULTING FROM LIQUID PROPELLANT OPERATIONS

CONTRIBUTING EVENT	PROBABILITY DESCRIPTION/VALUE	JUSTIFICATION
1. Fill and drain time valve failure	Improbable/10^{-5}	Mechanical valve for one use, seals not likely to fail Failure for valve to seal is detectable by operator and therefore a preventable condition Lines can be capped and therefore a leak can be sealed by the operator by cap installation if a leak occurs No failures of fill and drain valves have resulted in a serious spill
2. Line/tank failure of two due to overpressur- regulators ization of payload or payload equipment	Improbable/10^{-5}	Requires failure pressure Operator failure to detect first regulator failure
3. Tank/line damaged by equipment tethered equipment or tools after loading	Occasional/10^{-3}	Tools and Tanks and lines not generally exposed to these hazards
5. Ignition of fuel	Probable/10^{-2}	No auto-ignition temperatures available Facility powered down in large spill conditions Electrostatic discharges possible
7. Sprinklers fail to localized activate or control	Frequent/10^{-1}	Heating could be and insufficient to act

The probability of a major accident during this operation is improbable. There has never been major damage to a payload or SRM during the spin balancing operation. There was one accidental ignition of an SRM after balancing. The SRM had sensitive initiators unprotected by a Safe/Arm device from electrostatic energy, which built up and ignited the motor. Current requirements, detailed in Section 7.3.5, essentially eliminate this type of accident. See Exhibit 7-9 for the event probabilities for a spin balance accident.

7.4.5 Ignition of a Solid Rocket Motor

The accidental ignition of an SRM is depicted in the fault tree in Exhibit 7-10. Three typical events are characterized: SRM fragmentation from ignition and overpressurization, a propulsive SRM, and a burning SRM that generates sufficient heat to autoignite the propellant tanks.

With the current design requirements for ignition and destruct systems, accidental ignition of an SRM is a very improbable event. See Section 7.3.5 for additional discussion. Initiators for these systems are isolated from their explosive trains by mechanical Safe/Arm units that prevent propagation even if accidental initiator firing takes place. Additionally, initiators are designed to be essentially impervious to electrostatic and RF energies which could activate them. The event probabilities and their justifications are shown in Exhibit 7-11.

EXHIBIT 7-4 FAULT TREE FOR EXPLOSION RESULTING FROM A DROPPED PAYLOAD

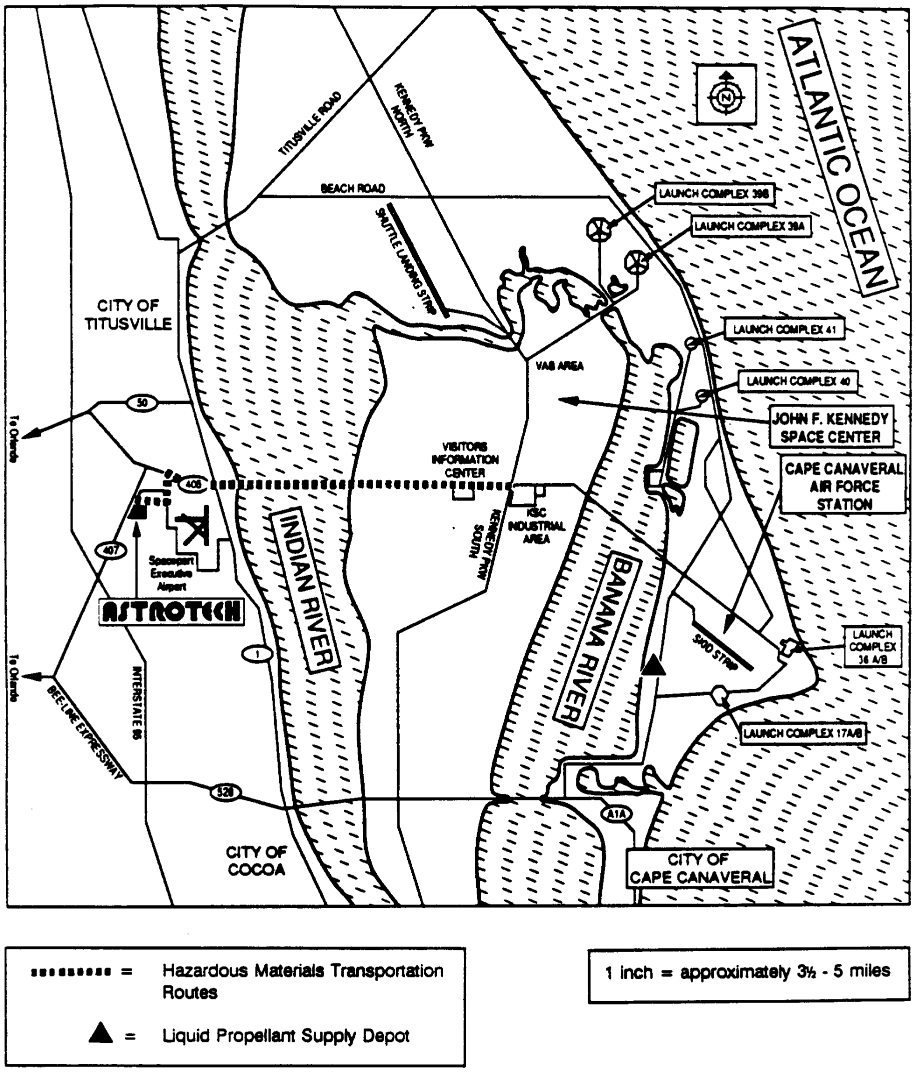


EXHIBIT 7-5 EVENT PROBABILITIES FOR EXPLOSION RESULTING FROM A DROPPED PAYLOAD

CONTRIBUTING EVENT	PROBABILITY DESCRIPTION/VALUE	JUSTIFICATION
1. Wire rope fails	Remote/10^{-4}	Cables inspected before each lift Replaced if 3 strands broken Astrotech crane technician monitors all lifts and activates kill switch if cross-reeving occurs
2. Brakes fail	Improbable/10^{-5}	Brakes are redundant Brakes tested during semi-annual load testing
3. Sling fails	Remote/10^{-4}	Slings 100% load tested before all lifts
4. Hook fails	Improbable/10^{-5}	Hooks magnafluxed annually and load tested semi-annually
5. Operator error	Remote/10^{-4}	Operators are trained and certified by Astrotech The Astrotech crane technician monitors all lifting operations and can prevent errors by using the kill switch
7. Drop height enough to cause failures/ignition	Frequent/10^{-1}	Generally, at least one lift of sufficient height may occur for most payloads
8. Sprinklers fail to control	Frequent/10^{-1}	Heating could be localized and insufficient to activate sprinklers Sprinklers may not control tank heating even if

EXHIBIT 7-6 FAULT TREE FOR EXPLOSION OF A HIGH PRESSURE TANK

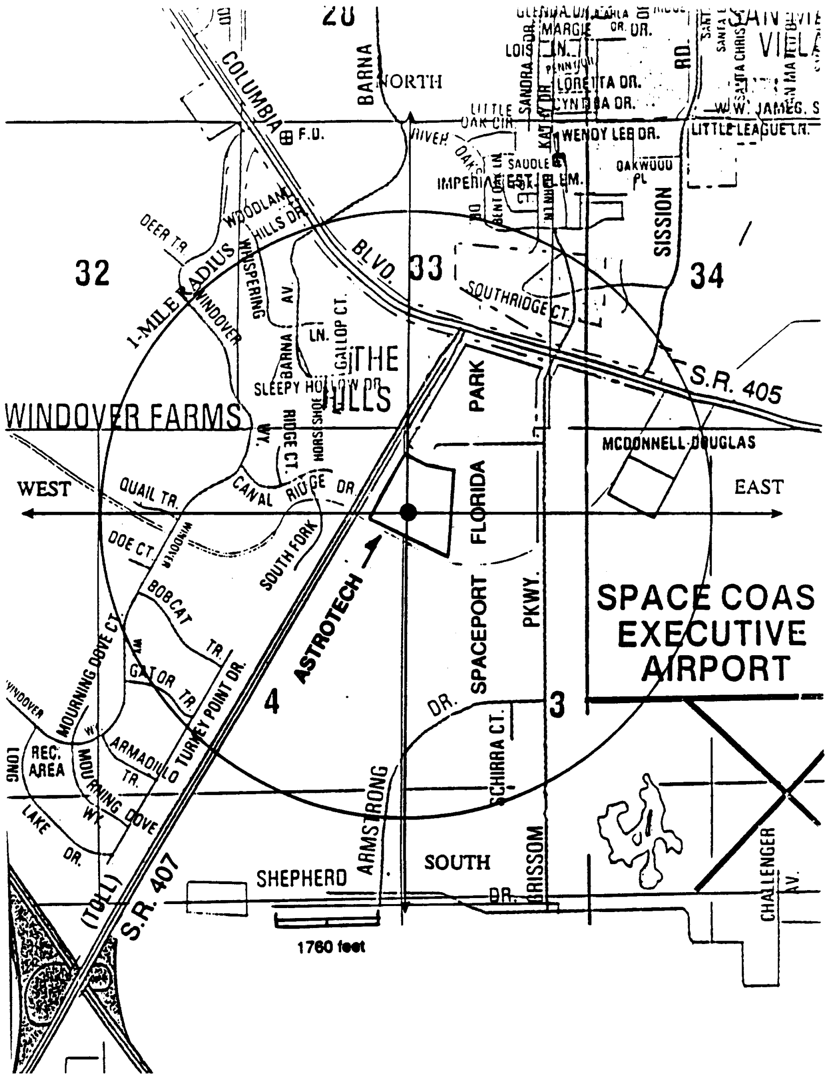


EXHIBIT 7-7 EVENT PROBABILITIES FOR EXPLOSION OF A HIGH PRESSURE TANK

CONTRIBUTING EVENT	PROBABILITY DESCRIPTION/VALUE	JUSTIFICATION
1. Material flaw in tanks or lines	Improbable/10^{-5}	Tanks are designed with safety factor of 1.3
		All tanks and lines proof tested to greater than operating pressures
		Most tanks designed to leak rather than burst
2. Tank overpressurized	Remote/10^{-4}	Tanks protected by relief valves
		Operator must disable protective limits and violate procedures
		Difficult to achieve with tanks used
4. Fragments penetrate fuel tank and ignite fuels	Probable/10^{-2}	Fragments penetrating fuel tank have sufficient energy/heat to ignite
fuels		
		Pressure tanks are not always in close proximity to fuel tanks

EXHIBIT 7-8 FAULT TREE FOR EXPLOSION RESULTING FROM A SPIN BALANCE ACCIDENT

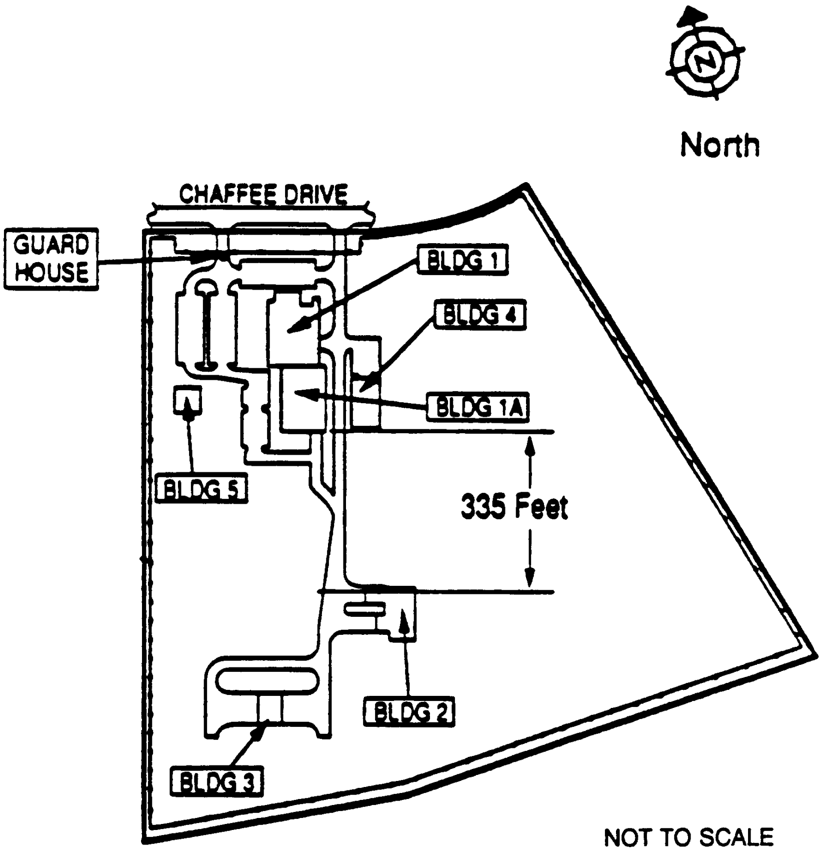
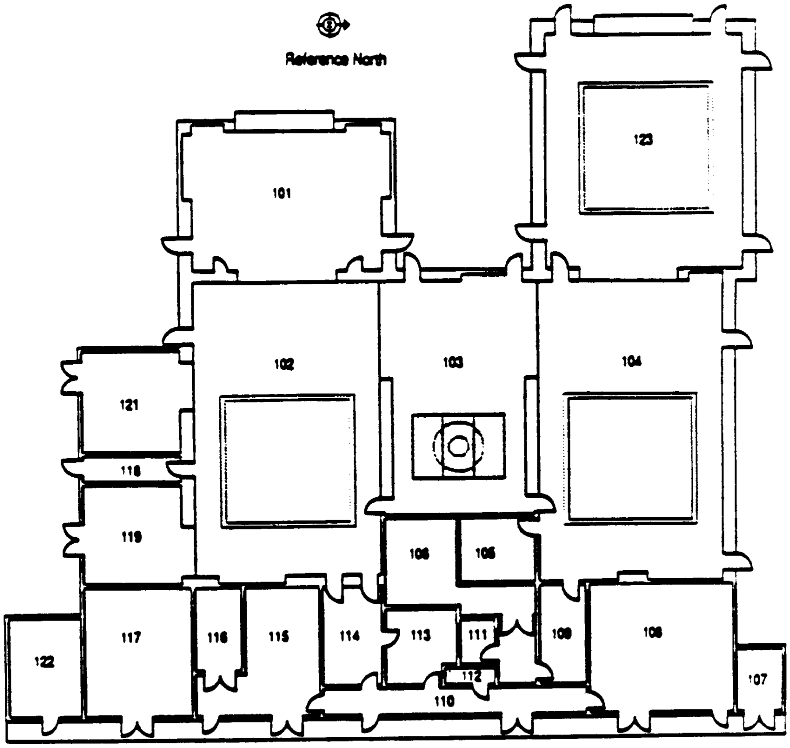


EXHIBIT 7-9 EVENT PROBABILITIES FOR EXPLOSION RESULTING FROM A SPIN BALANCE ACCIDENT

CONTRIBUTING EVENT	PROBABILITY DESCRIPTION/VALUE	JUSTIFICATION
1. Spin table fire	Improbable/10^{-5}	Motor isolated from table
		Motor protected by circuit breakers
		No other fire source available
2. Major fuel leak/spill	Improbable/10^{-5}	Fuel tanks have little pressure
		Spin loads are small
		Leak, if any, small and fire unlikely
4. Sprinklers fail to control	Frequent/10^{-1}	Heating could be localized and insufficient to activate sprinklers
		Sprinklers may not control tank heating even if activated
5. Severe imbalance loads	Improbable/10^{-5}	Payload static balance performed before dynamic spin balancing
		Spin machine shuts down automatically if imbalance limits exceeded
		Spin rates are low, 1-2 cps
		Loads not likely to exceed payload attachment strength
6. Spin table seizure	Improbable/10^{-5}	Does not appear feasible for machine design due to hydraulic bearings with roller bearing backup
8. Sprinklers fail to control	Frequent/10^{-1}	Heating could be localized and insufficient to activate sprinklers
		Sprinklers may not control tank heating even if activated
9. Severe damage and fire	Frequent/10^{-1}	Spin table recessed in floor and drop height small, however tip over is likely to cause sufficient damage to produce leaks

EXHIBIT 7-10 FAULT TREE FOR IGNITION OF SRM



101 South Airlock
102 South High-Bay
103 Center High-Bay
104 North High-Bay
105 Office
106 Mechanical Room 2
107 Motor Generator Room
108 North Control Room
109 North Change Room
110 Corridor
111 Women's Restroom
112 Janitor
113 Men's Restroom
114 South Change Room
115 South Control Room
116 Balance Machine Control Room
117 Mechanical Room 1
118 Corridor
119 Oxidizer Cart Storage Room
120 Not Assigned
121 Fuel Cart Storage Room
122 Electrical Vault
123 North Airlock High-Bay

EXHIBIT 7-11 EVENT PROBABILITIES FOR IGNITION OF SRM

CONTRIBUTING EVENT	PROBABILITY DESCRIPTION/VALUE	JUSTIFICATION
1. SRM ignited internally	Improbable/10^{-5}	Initiators protected by Safe/Arm units Initiators insensitive to electrostatic and RF energy
2. Nozzle blockage or sealed adaptor	Frequent/10^{-1}	In some cases, systems do not provide adequate venting to preclude SRM overpressurization, if ignited
3. SRM ignited internally	Improbable/10^{-5}	Initiators protected by Safe/Arm units Initiators insensitive to electrostatic and RF energy
4. No nozzle blockage or adaptor	Frequent/10^{-1}	Most systems provide adequate venting to preclude SRM overpressurization, if ignited
5. SRM ignited externally	Improbable/10^{-5}	Fire, dropping or destruct charge initiation improbable Electrostatic ignition possible but unlikely for current motor designs
6. SRM in same bay as	Frequent/10^{-1}	SRM mating and

7.5 Consequences of Worst Case Releases

The reason behind defining and using worst case releases is to determine whether there is any risk posed by the facility to the public and to quantify that risk. Not all accidents pose health or safety threats to the public. For example, Building 2 was designed to contain accidental releases of liquid propellant that might occur during normal operations. Any propellant vapors from fuel spills or from incidents involving only nitrogen tetroxide that do not involve explosive breaching of the Building 2 would be handled and treated using the established scrubber/containment system and would not pose any threat to the public. However, even well-designed facilities have their limits. Therefore, by identifying and evaluating the consequences of worst case releases and determining their impacts, if any, on the public health and safety, the safety evaluation team has estimated the maximum risk. If the maximum risk is minimal, then any release with less severe consequences, but a higher predicted frequency, will also pose minimal risk.

As indicated previously, the worst case releases are defined as resulting from fire and explosion accident scenarios involving various combinations of up to approximately 25,000 pounds of solid propellant, 5,000 pounds of oxidizer and 2,500 pounds of fuel. The evaluation team has verified the conclusions of the analyses previously carried out by ECI on the overpressure and fragmentation hazards that could occur from an explosion involving a large payload with fuel, oxidizer and an SRM. Because these analyses support the conclusion that there are no hazards to the public from overpressure and fragmentation explosion effects, in this evaluation, only the potential for exposure to toxic vapors and glass breakage hazards have been analyzed.

It must be noted at this point that there are virtually no mathematical models which accurately describe the physical phenomena that could cause a release from a closed facility. Because there are no precise models to address such an event, the approach used in this analysis produces a very conservative estimate of the concentrations that could result from an actual accident. The conservative assumptions, which lead to a conclusion that is more protective of public health, are both noted in context and summarized with the conclusions.

7.5.1 Vapor Releases

The maximum release of gas for an incident involving only liquid propellants would result from an explosive reaction of the fuel with air or with an oxidizer. These explosions could create the force necessary to penetrate the walls or ceiling and thus breach the building containment system. Astrotech is permitted by the Florida DER to have a maximum quantity of 2,500 pounds of anhydrous hydrazine or monomethyl hydrazine on-site. For events involving liquid fuels, the maximum quantity of unburned fuel that could be released to the atmosphere is conservatively estimated at 25%[18] of the quantity involved (since most will be consumed in the fire and explosion itself). On this basis it is estimated that the maximum quantity of fuel released is 625 pounds (~75 gallons). The molecular weights of anhydrous hydrazine and MMH are 32 pounds/mole and 46 pounds/mole, respectively, and therefore a maximum of 19.5 moles of anhydrous hydrazine or 13.6 moles of MMH could be released to the atmosphere. Since payloads normally contain a much larger volume of anhydrous hydrazine than MMH, and anhydrous hydrazine produces a greater concentration per pound of liquid released than MMH,

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[18] Personal Communication with ESMC/SE on Martin Marietta study of hypergol Fuel/Oxidizer concentrations resulting from the Titan 34D explosion.

anhydrous hydrazine has been conservatively selected as the fuel in the release calculations.

If a payload requires N_2O_4, Astrotech is permitted to have a maximum of 5,000 pounds on-site. Only about 20%[19] of the oxidizer is estimated to be consumed by the fire and explosion. Therefore, approximately 80% or 4,000 pounds could be released to the atmosphere as gaseous nitrogen dioxide. The molecular weight of NO_2 is 46 pounds/mole, indicating that about 87 moles could be released.

If the incident were to involve a large SRM, the hydrogen chloride (HCl) generated during the burning of the solid propellant (approximately 21 percent of the weight of solid propellant)[20] would also be released. Of the approximate 25,000 pounds of solid propellant, about 5,250 pounds of HCl is generated; since the molecular weight of HCl is 36.5 pounds/mole, approximately 144 moles of HCl could be released to the atmosphere.

7.5.2 Initial Cloud and Stem Characteristics

In a fire and explosion, smoke and hot gases are generated that rise due to buoyancy and form a ball, called a cloud, which stabilizes at the top of a stem of gases. In the releases considered in this evaluation, the cloud is primarily comprised of gas products resulting from a fire or explosion. The components of a typical cloud and stem are depicted in Exhibit 7-12. The evaluation team calculated public exposure concentrations for vapors contained in both the cloud and the stem.

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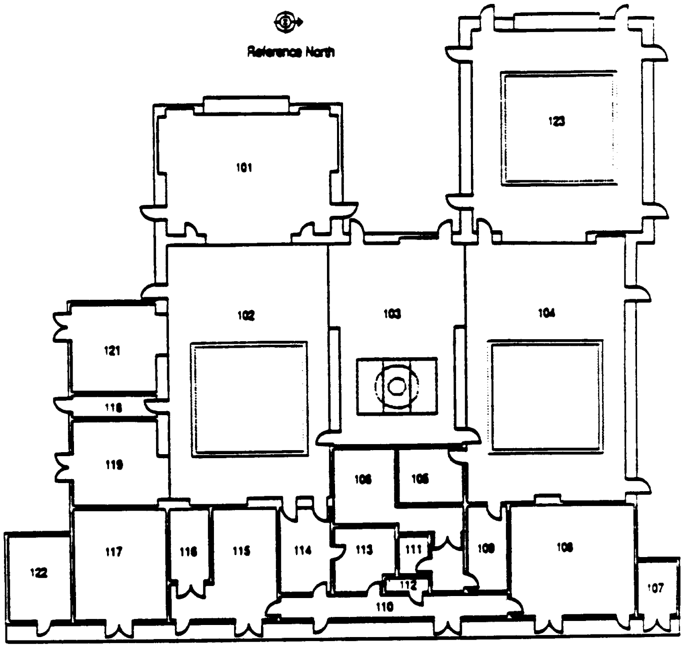
[19] Ibid.

[20] Parametric Studies with an Atmospheric Diffusion Model that Assesses Toxic Fuel Hazards Due to Ground Clouds Generated by Rocket Launches, R. B. Stewart and W. L. Grose, NASA Technical Note TN D--7852, May 1975.

EXHIBIT 7-12 COMPONENTS OF A TYPICAL CLOUD



101	South Airlock
102	South High-Bay
103	Center High-Bay
104	North High-Bay
105	Office
106	Mechanical Room 2
107	Motor Generator Room
108	North Control Room
109	North Change Room
110	Corridor
111	Women's Restroom
112	Janitor
113	Men's Restroom
114	South Change Room
115	South Control Room
116	Balance Machine Control Room
117	Mechanical Room 1
118	Corridor
119	Oxidizer Cart Storage Room
120	Not Assigned
121	Fuel Cart Storage Room
122	Electrical Vault
123	North Airlock High-Bay

Studies have shown that for conditions in this region, clouds tend to rise to altitudes in the range of 1,900 to 3,500 feet.[21] Since the concentrations of gases in the stem will be greater for the lower stabilization altitude, 1,900 feet was conservatively selected as the stabilization height.

The size of the cloud is proportional to the total weight of the propellants involved in the explosion. Using weights of 2,500 pounds for fuels only, 7,500 pounds for fuel plus oxidizer and 32,500 pounds for all three propellants, cloud diameters of 125, 175 and 280 feet were estimated using relations developed by NASA for a variety of propellants and propellant combinations.[22] The cloud volumes corresponding to these diameters are 1.0×10^6, 2.8×10^6, and 11.5×10^6 cubic feet, respectively. The clouds are depicted in Exhibit 7-13. The stem volume in each case is approximately 21×10^6 cubic feet.

The cloud rises essentially intact and most of the released gases will be contained within the cloud, not in the stem. Models of the cloud and stem concentrations indicate that a Gaussian distribution may be used for the vertical distribution of the gases.[23] The percentage of gases near the surface will be very low and increase to a maximum at the stabilization height. The effect of the building on the vertical distribution of the gases is unknown, but to be conservative, it is assumed that 20 percent of the gases emitted will be uniformly distributed in the stem and 80 percent in the cloud.

7.5.3 Initial Cloud and Stem Concentrations

The ground level toxic vapors near the Astrotech facility will primarily be from gases initially in the stem, and not from gases buoyed upward by the heat into the cloud. We have assumed that 20 percent of the vapor products will remain in the stem volume. Involvement of an SRM in the fire and explosion will tend to ensure that all of the anhydrous hydrazine is burned and that all of the N_2O_4 is buoyed up to the stabilization height of the cloud. The stem diameter was assumed to be 120 feet, the largest overall approximate dimension of Building 2 at Astrotech. On the basis of these

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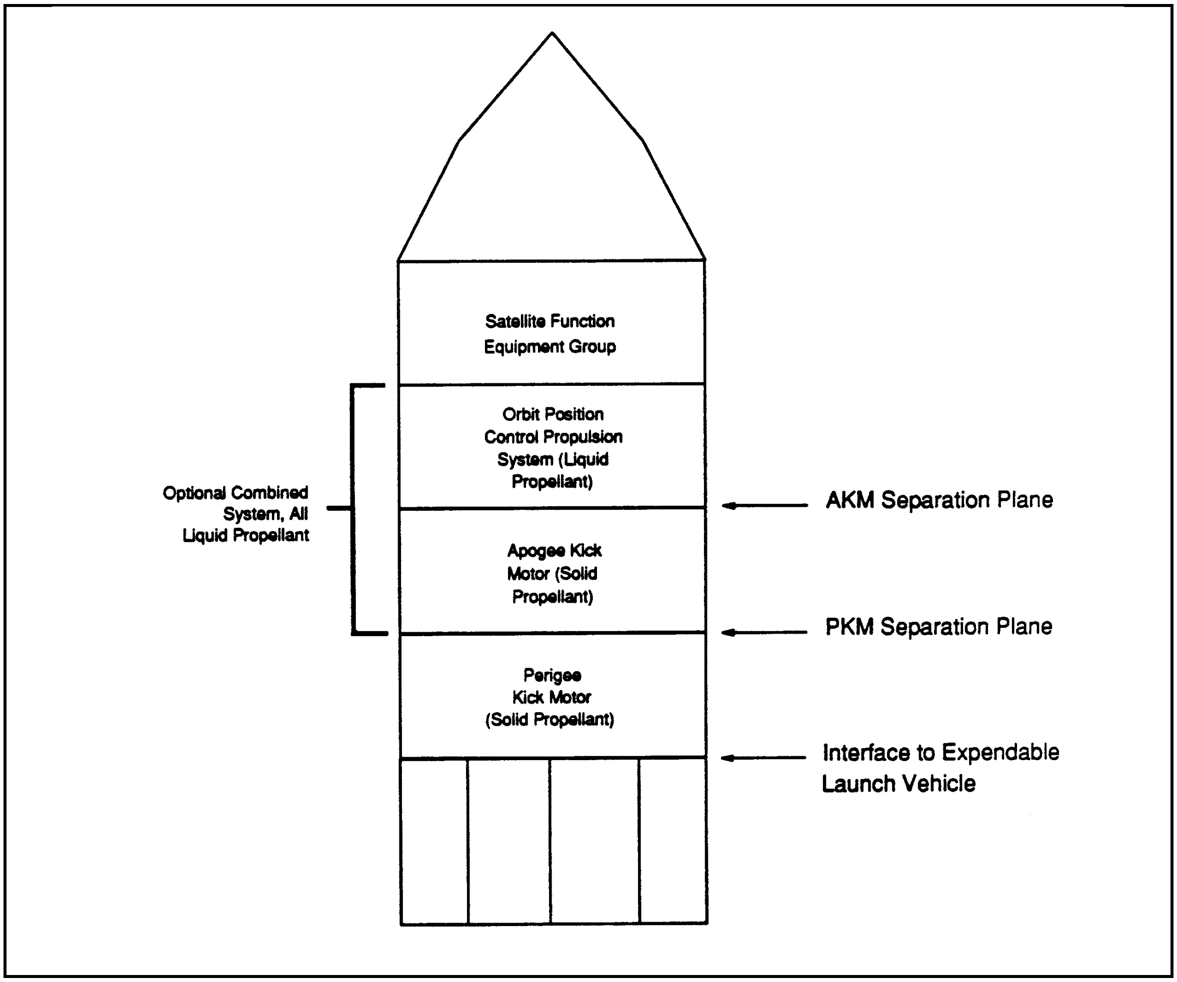
[21] Ibid.

[22] Size and Duration of Fireballs From Propellant Explosions, J. B. Gayle and J. W. Bransford, NASA-George C. Marshall Space Flight Center, Technical Memorandum X-53314, August 1965.

[23] Ibid.

EXHIBIT 7-13 DIMENSIONS OF CLOUDS FOR PROPELLANT EVENTS



conservative assumptions, the concentrations of the various gases generated and contained in the cloud and its stem are estimated as follows:

Monopropellant Event

* Stem-(N_2H_4)-19.5 moles x 0.2 = 3.9 moles
* Cloud-(N_2H_4)-19.5 x 0.8 = 15.6 moles
* Parts/million-Stem-(N_2H_4) = 3.9 moles/53,400 moles air = 73 ppm
* Parts/million-Cloud-(N_2H_4) = 15.6/2440 = 6,393 ppm

Bi-propellant Event

* Stem-(NO_2)-87 moles x 0.2 = 16.4 moles
* Stem-(N_2H_4) = 3.9 moles
* Cloud-(NO_2)-87 moles x 0.80 = 69.6 moles
* Cloud-(N_2H_4)-15.6 moles
* Parts/million-Stem-(NO_2) = 326 ppm
* Parts/million-Stem-(N_2H_4) = 73 ppm
* Parts/million-Cloud-(NO_2) = 9,870 ppm
* Parts/million-Cloud-(N_2H_4) = 2,213 ppm

Solid Rocket Motor(SRM) Event

* Stem-Hydrochloric Acid (HCl)= 490 ppm
* Cloud-(HCl) = 3,600 ppm

For the SRM event, the concentrations of anhydrous hydrazine and nitrogen dioxide will be less than those shown in the mono- and bipropellant events because of the increased burning which consumes the hydrazine and larger cloud size which dilutes the nitrogen dioxide. The largest concentration for each of the toxic vapors from the above events will be used as the worst case release in the subsequent analyses.

For an event involving an SRM, the actual stem and cloud volumes will be greater and therefore, the toxic vapor concentrations lower, than those used in this analysis. This is because the burning of solid propellant occurs over a period of time and is not an almost instantaneous reaction like the fuel and oxidizer reaction. Hence, in the SRM event, the concentrations of all toxic products will be lower than calculated.

7.5.4 Fate of Toxic Gases in Atmosphere

The safety evaluation team predicted the ground level concentrations of three toxic vapors: anhydrous hydrazine, nitric acid (HNO_3) from release of N_2O_4 and hydrochloric acid from the burning of solid propellant.

Any anhydrous hydrazine involved in a fire or explosion will be substantially consumed. The amounts of unreacted vapors that escape to the atmosphere, will be diffused by wind and will gradually dissipate by reacting with oxygen and moisture in the air.

However, nitrogen tetroxide exists primarily as a liquid that, as it vaporizes, disassociates into nitrogen dioxide. Nitrogen dioxide then reacts with moisture and oxygen in the atmosphere and forms HNO_3. Therefore, the evaluation team analyzed vapor concentrations of nitric acid.

$$4NO_2 + 2H_2O + O_2 \text{ ---> } 4HNO_3$$

Other reactions are possible but ultimately, almost all of the nitrogen dioxide released to the atmosphere is converted to nitric acid mist. The rate at which this conversion takes place is very rapid[24,25]. Virtually all of the relevant data concerning reaction rates for NO_2 in the atmosphere were obtained at or near ambient temperature whereas any release preceded by an explosion would raise the temperature of the escaping gases by several hundreds of degrees. Since the rates of most chemical reactions increase with an increase in temperature, it is likely that the rate of conversion will be limited only by the availability of moisture in the air.

For the typical relative humidity conditions, approximately 20,000 pounds of moisture is available in the cloud and stem volumes produced. Since only about 800 pounds of moisture would be required to react with 4,000 pounds of nitrogen tetroxide (the estimated amount which could be released as NO_2 in an accident), there should be ample moisture present to convert all of the nitrogen dioxide in the cloud to a nitric acid mist. The 5,250 pounds of hydrogen chloride gas generated by the SRM burning will also be rapidly converted to hydrochloric acid by the excess water vapor available.

Both the nitric acid produced from nitrogen dioxide and the hydrochloric acid from the solid propellant will gradually dissipate and ultimately be removed in the form of dilute acid rain. The quantities of acid potentially produced by such an event are significantly less than those discharges produced by fossil fuel fired power plants in the area. It is estimated that these plants emit approximately 20,000 pounds of sulfur dioxide each day that eventually contributes to acid rain. The toxicity of sulfuric acid is similar to that of both nitric and hydrochloric acids.

7.5.5 Analysis of Vapor Concentrations in the Stem

The initial plume generated by the fire and explosion will form a stem and cloud at the stabilization altitude that drift with the prevailing wind at the time of the accident. The stem footprint size in the downwind direction will be 120-200 feet and the resulting exposure duration less than a minute, even with a conservative assumption of very low wind speeds (approximately 2.5 mph[26]). As the stem drifts it will grow both laterally and in the downwind direction. This growth will increase the volume thereby diffusing the toxic vapors. Based on data from ESMC at Patrick AFB, Florida, the average daytime standard deviation of wind direction is 14-degrees (1-sigma) and the average night standard deviation is 10-degrees. Although fueling operations at Astrotech are normally conducted only during the daytime, the nighttime standard deviation of winds was used in the analysis to be conservative. This variability in wind direction will cause the stem footprint to grow with a Gaussian distribution laterally around the average downwind direction. Wind speed variations or gustiness will produce growth of the stem in the downwind direction. The downwind growth models indicate this growth is probably less than 1/4 the lateral growth.[27] For this analysis, the downwind growth used is 1/5 of the growth of the stem in the lateral direction to be conservative. The combination of these assumed wind effects will result in a rapid increase in footprint area and volume as illustrated in Exhibit 7-14.

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[24] Analysis and Model Data Comparisons of Large Scale Releases of Nitrogen Tetroxide, T. G. McRae, Lawrence Livermore National Lab, Report NO. TR-85-06, June 1985.

[25] Air Pollution and Its Effects, Second Edition, Volume 1, AIR POLLUTION, Academic Press, 1968.

[26] See Exhibit 3-6 on Atmospheric Stability. All of the annual average wind speed figures are greater than 2.5 mph.

[27] Parametric Studies with an Atmospheric Diffusion Model that Assesses Toxic Fuel Hazards Due to Ground Clouds Generated by Rocket Launches, R. B. Stewart and W. L. Grose, NASA Technical Note TN D--7852, May 1975.

The toxic vapors will be distributed in the percentages shown in Exhibit 7-14 and will be diffused by the increased volume of each sector. The highest concentrations will be contained within +/- 1-Sigma of the average wind direction. The concentrations in the +/- 1- Sigma sectors resulting from the initial release conditions are plotted as a function of downwind distance in Exhibit 7-15.

In order to interpret the data contained on Exhibit 7-15, the safety evaluation team compared the predicted concentrations of toxic vapors to their respective IDLH values, established by the OSHA/NIOSH[28], and defined as the maximum concentration allowed for short-term exposures. The IDLH values for the gases of concern are shown in Exhibit 7-16. These values represent a maximum concentration from which one could escape within 30 minutes without any escape-impairing symptoms or irreversible health effects.

To be protective of the general population, EPA has defined 10% of the IDLH as an LOC in performing hazards analyses to calculate the vulnerable zone resulting from an unconfined spill for community planning purposes. The safety evaluation team has compared the ground level concentrations from the worst case releases to the 10% IDLH values.

Exhibit 7-15 illustrates the rapid diffusion and reduction in concentration of the toxic gases that occur under the assumed meteorologic wind conditions. As shown, any unreacted hydrazine will fall below 10% of the IDLH (8 ppm) by approximately 200 feet downwind. The hydrochloric and nitric acid concentrations will have diffused to below 50% of the IDLH within the first several hundred feet of downwind travel. The nitric acid and hydrochloric acid concentrations are below the 10% IDLH level in approximately 860 feet and 1,225 feet, respectively. Concentrations at the nearest Astrotech boundary are less than 5 ppm for hydrazine, 20 ppm for nitric acid

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[28] NIOSH Pocket Guide to CHEMICAL HAZARDS, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, September 1985.

EXHIBIT 7-14 STEM FOOTPRINT DISPERSION

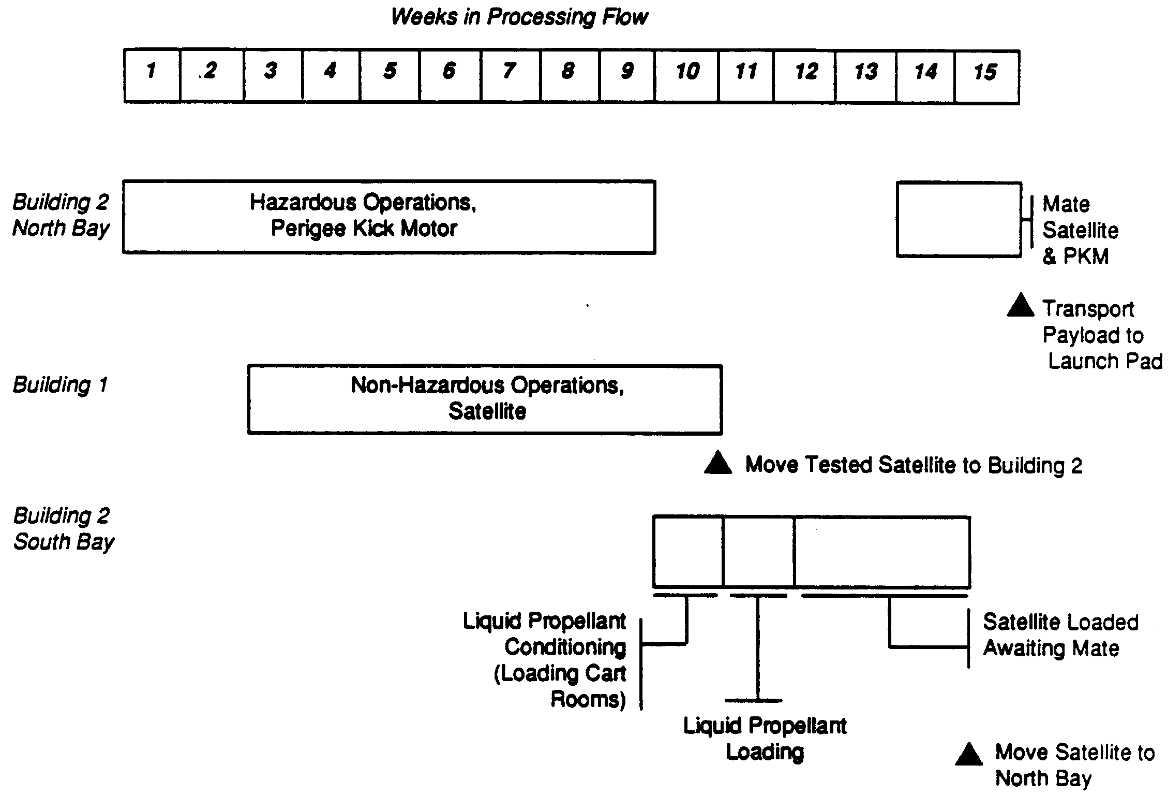
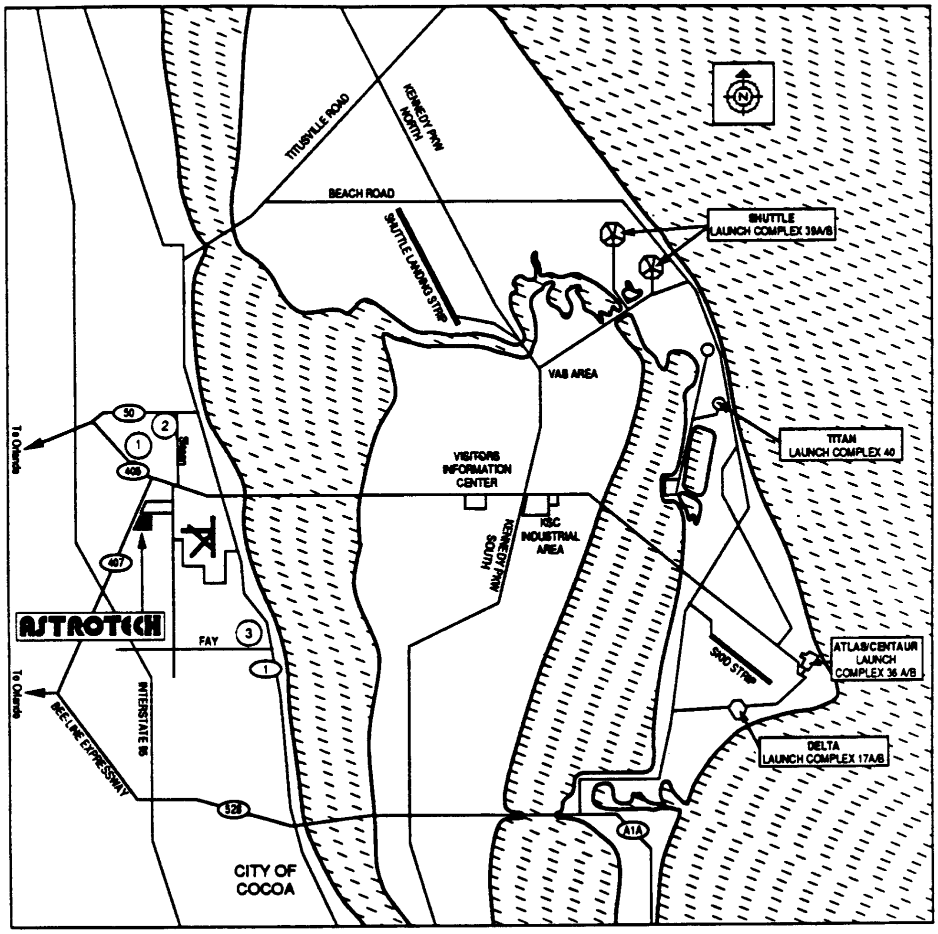


EXHIBIT 7-15 CONCENTRATIONS OF TOXIC VAPORS VERSUS DISTANCE



① Emergency Responder - 1-1/4 mi. from facility

② Emergency Responder - 2-1/4 mi. from facility

③ Emergency Responder - 6 mi. from facility

1 inch = approximately 3½ - 5 miles

EXHIBIT 7-16 IDLH CONCENTRATIONS

Toxic Material	IDLH [a] ppm
Hydrazine - N_2H_4	80
Nitrogen Dioxide - NO_2 and N_2O_4	50[b]
Nitric Acid - HNO_3	100
Hydrogen Chloride - HCl	100

[a] Immediately dangerous to life and health
[b] There is a single value because N_2O_4 dissociates into NO_2

and 28 ppm for hydrochloric acid. Injuries are not likely for the less than one minute exposures that would occur at these levels.

The concentration contours for the 50% and 10% of the IDLH for HCl are shown in Exhibit 7-17. These concentrations were derived from the initial conditions using the following equation.

$$C = 2\frac{Q_t}{\pi^{(3/2)}\sigma_y}\exp[-0.5(\frac{y}{\sigma_y})^2]$$

Where:

C = concentration per unit volume
Q_T= total quantity released
Y = crosswind distance
σ_Y= crosswind distance standard deviation

Note that the crosswind distance (width) on the contour is less than 300 feet. The exact location of the concentration contour for any toxic vapor is dependant on wind direction at the time of the release. In order to identify a zone in which there is a potential for exposure, the safety evaluation team used the maximum distance at which the 10% IDLH concentration occurs as the radius to determine a concentration zone for each of the vapors released as shown in Exhibit 7-18. Although this zone is shown as a circle, for any particular release only a small portion of the area of the circle would actually be exposed.

EXHIBIT 7-17 CONCENTRATION CONTOURS FOR HYDROCHLORIC ACID

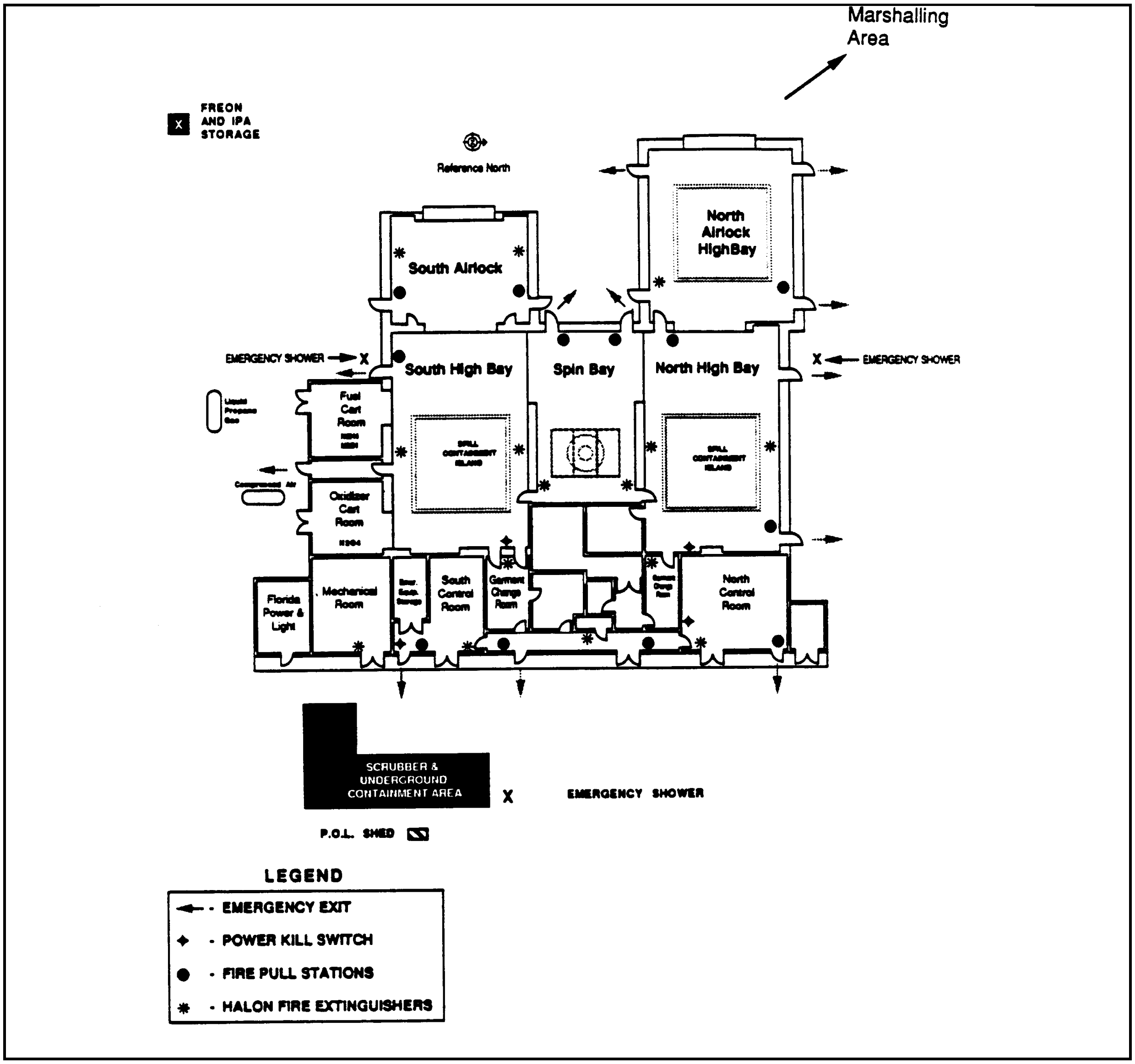
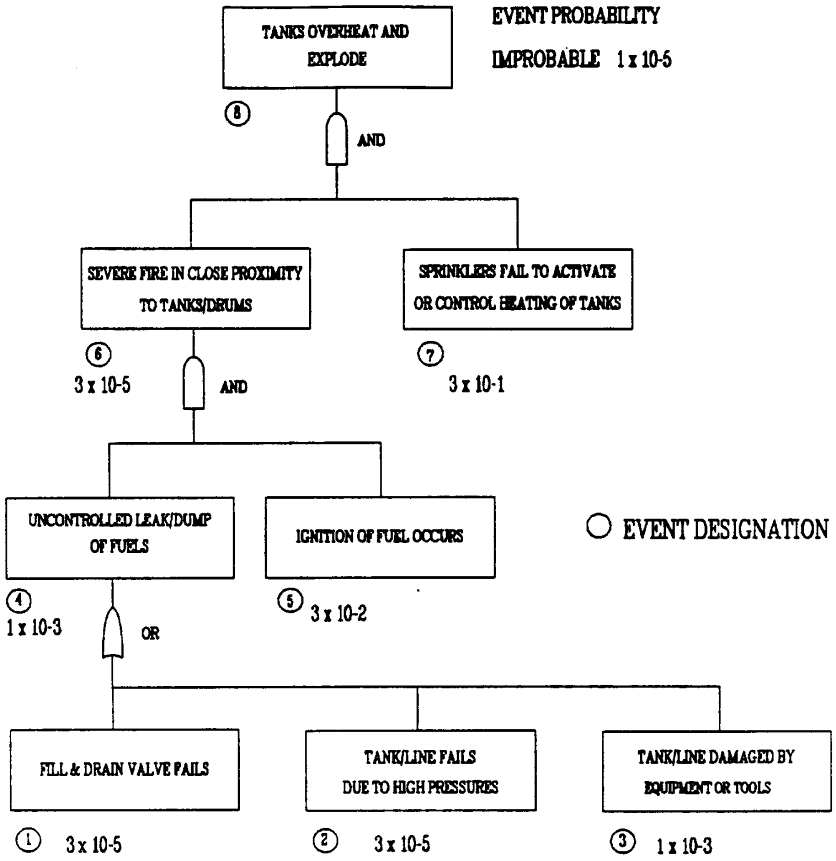


EXHIBIT 7-18 CONCENTRATION ZONES OF TOXIC VAPORS AT 10% IDLH



$$P_{\textcircled{8}} = P_{\textcircled{6}} * P_{\textcircled{7}} \quad \text{AND} \quad P_{\textcircled{6}} = (P_{\textcircled{1}} + P_{\textcircled{2}} + P_{\textcircled{3}}) * P_{\textcircled{5}}$$

$$P_{\textcircled{8}} = (P_{\textcircled{1}} + P_{\textcircled{2}} + P_{\textcircled{3}}) * P_{\textcircled{5}} * P_{\textcircled{7}}$$

7.5.6 Analysis of Vapor Concentrations in the Cloud

By the time the cloud disperses and reaches ground level, even with a series of conservative assumptions, the predicted concentrations of nitric acid and hydrochloric acid are 1 ppm and 2 ppm, respectively. These concentrations are below 10% of the IDLH, and represent no risk to public health. Details of the calculations follow.

Once the cloud reaches its stabilization altitude, it will drift with the prevailing wind growing both laterally and in the downwind direction, increasing in volume, and diffusing the toxic gases. The variability in wind direction is responsible for the lateral growth of the cloud. Growth in the downwind dimension is the result of gustiness effects and is generally less than the lateral growth.[29] Since cloud volume is a cubic function of cloud diameter (volume of a sphere = $0.167 \times \pi \times \text{diameter}^3$), growth of the cloud results in rapid decreases in the average concentration of toxic gases.

If the center of the cloud remains at the stabilization height of 1,900 feet, by the time the cloud has grown sufficiently to contact the ground (diameter 3,800 feet), the concentration will have decreased by a factor of approximately 2,500. The resulting average concentrations would thus range from approximately 1 ppm to 2 ppm by volume for the acids and gases trapped in the cloud. Since the axial and vertical concentrations should exhibit a Gaussian distribution, the actual concentration at or near ground level should be negligible. Note that the composition of the gases will have changed somewhat by this time as discussed in the previous section, further reducing the concentrations.

7.5.7 Analysis of Glass Breakage

In general, most of the injuries to the public from explosions are caused by glass breakage and impacts by flying fragments. Window breakage can cause injury beginning at overpressures of about 0.5 psi. At overpressures above 1.5 psi windows are shattered. For the maximum quantities of anhydrous hydrazine and nitrogen tetroxide permitted, 2,500 pounds and 5,000 pounds, respectively, the net equivalent explosive weight of TNT is 387.5 pounds, which exhibits an overpressure impact of 0.5 psi at a distance of 546 feet.[30] Therefore, no glass breakage hazard exists for any nearby dwellings from the potential overpressures predicted for such an accident.

7.6 Summary of Risks to the Public from Worst Case Releases

The overall probability of having an accident involving fire and explosion with a release of toxic vapors is summarized in Exhibit 7-19. This exhibit indicates that there is a remote chance of two accidents occurring per

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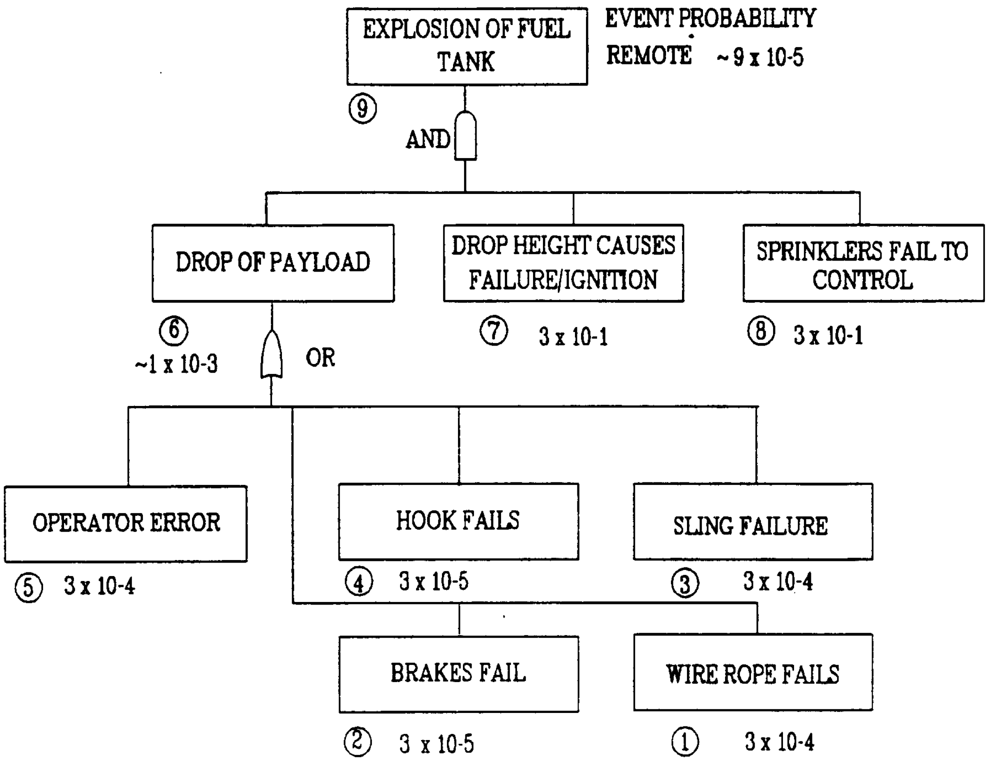
[29] Hazard and Quantity Distance Siting Analysis of Astrotech Hazardous Staging Airlock Addition to Bldg # 2, ECI Report NO. 1-88, Explosive Consultants Inc., February 1988.

[30] ATF: Explosives Law and Regulations, ATF P 5400.7, Bureau of Alcohol, Tobacco, and Firearms, Department of the Treasury, §55.218 Table of Distances for Storage of Explosive Materials, November 1982.

EXHIBIT 7-19 FAULT TREE FOR WORST CASE ACCIDENT PROBABILITY



$P_{\textcircled{9}} = P_{\textcircled{6}} * P_{\textcircled{7}} * P_{\textcircled{8}}$ AND $P_{\textcircled{6}} = P_{\textcircled{1}} + P_{\textcircled{2}} + P_{\textcircled{3}} + P_{\textcircled{4}} + P_{\textcircled{5}}$

$P_{\textcircled{9}} = (P_{\textcircled{1}} + P_{\textcircled{2}} + P_{\textcircled{3}} + P_{\textcircled{4}} + P_{\textcircled{5}}) * P_{\textcircled{7}} * P_{\textcircled{8}}$

10,000 payload operations. With a maximum processing rate of approximately 10 payloads per year, approximately two such accidents could occur per 1,000 years of payload processing operations. This analysis is in line with industry experience because there has never been an accident of this severity in more than 35 years of payload processing operations throughout the United States. However, because this analysis was based on professional judgment and best estimates of failure rates, due to the lack of industry-specific accident data, the safety evaluation team has conservatively estimated that the accident probability is somewhere between one accident per 100 years and one accident per 500 years.

The overall consequences of a worst case release would be minimal. It is unlikely that the vapor concentration estimated in this analysis could ever be achieved, since the many conservative assumptions listed below were made in the analysis. The maximum possible exposure concentrations for HNO_3 and HCl are well below one-half of their IDLH threshold levels outside the facility boundaries. Exposures just beyond the nearest facility boundary will be less than 8 ppm (10% of the IDLH) for hydrazine and 30 ppm for both nitric acid and hydrochloric acid. The duration of this exposure is estimated to be less than a minute (at low wind speed conditions). Reactions of the released vapors in the atmosphere with oxygen, carbon dioxide, water vapor and other reactive molecules will also further reduce the concentrations by changing them into other chemicals like nitrogen, hydrogen, and water.

The vapor concentrations were estimated using the following conservative assumptions:

- The maximum quantities of liquid and solid propellant permitted at the facility were used in the analysis. Payloads that contain these quantities of propellant would be extremely rare.

- The cloud stabilization height used was the lowest reported for large releases. Daytime stabilization heights are likely to be much higher at the Astrotech location, hence, concentrations in the stem would be reduced proportionally.

- An average wind azimuthal standard deviation of 10 degrees was used rather than the average daytime deviation of 14 degrees. A smaller azimuthal deviation will increase the concentrations predicted.

- The vertical distribution of gases in the stem was assumed to be uniform. Both data and models reviewed indicate that these gases tend to be distributed in a Gaussian manner with the concentrations decreasing from the stabilization height to a very low level near the surface. If a Gaussian distribution had been used in the vertical stem, concentrations near the ground would have been at least an order of magnitude (factor of 10) less.

- Although the toxic gases are known to react in the atmosphere and form non-toxic products, the analysis assumed no dissociation.

- An individual in a building will likely not be exposed to the calculated ambient concentration because the concentration inside the building will not reach the calculated level in the less than one minute exposure time.

On this basis, it is concluded that the concentrations estimated above typify worst case release conditions that are not likely to occur in an actual accident. The actual concentrations that could result from an accident would likely be much less.

7.7 Comparison With Other Public Risks

This section will qualitatively compare the probability and severity of an accident at Astrotech with hazards representative of those that may exist in communities surrounding the facility to provide a comparison of the risks posed by the Astrotech facility with commonly encountered risks. For example, many communities have highways running near or through them that are used for commercial transport of goods, including hazardous materials. Also, in many communities hazardous industrial chemicals are used at fixed facilities, such as water treatment plants, public swimming pools, and power generating facilities. As a result, there are many hazards in any given community that present risks of similar, if not greater, severity than the risk posed by the Astrotech facility.

To assist emergency planners, EPA, DOT, and the Federal Emergency Management Agency (FEMA) have co-authored two manuals on hazards analysis. These are endorsed not only by EPA, DOT, and FEMA but also by numerous other federal agencies and are routinely used by LEPCs in their emergency planning efforts. The methods presented in the manuals provide tools for identifying and examining potential hazards as well as methods for prioritizing emergency planning efforts.

Emergency planners locate and identify sources of hazardous chemicals within the local area, and qualitatively assess the frequency of release and the severity of consequences for such a release. For each facility, a value ranging from common to very unlikely is assigned for the frequency of occurrence (see Exhibit 7-20) and a value ranging from minor to catastrophic is assigned for the severity of the consequences (see Exhibit 7-21).

Local, state, and federal emergency planners evaluate the probability and severity of a possible event to focus and prioritize their emergency planning efforts. The accident/severity screening matrix (see Exhibit 7-22) is provided to emergency planners as a tool for determining the level of

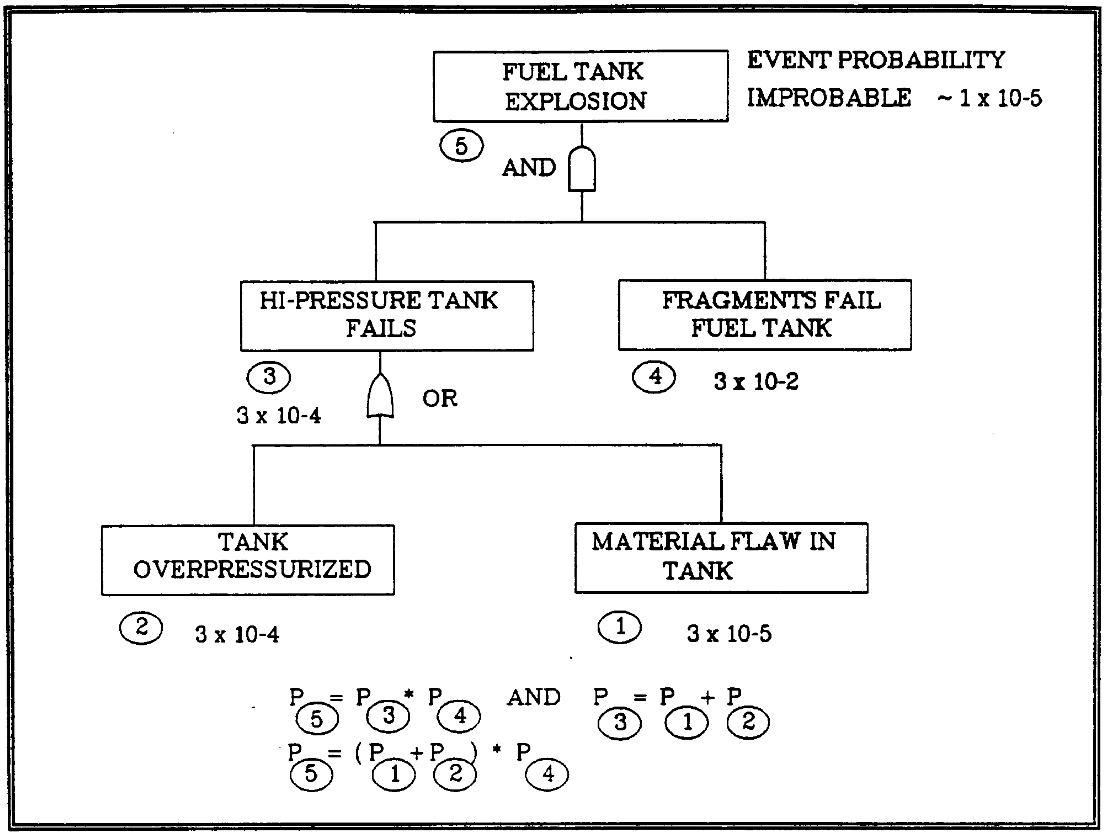
EXHIBIT 7-20 DEFINITIONS OF FREQUENCY CATEGORIES

Category	Frequency of Accident
Common	Event expected to occur one or more times per year.
Likely	Event expected to occur once every ten years
Reasonably Likely	Event expected to occur every 100 years
Unlikely	Event expected to occur every 100 to 1000 years
Very Unlikely	Event expected to occur less than once in 1000 years

EXHIBIT 7-21 DEFINITIONS OF SEVERITY CATEGORIES

Severity Category	Injuries	Fatalities	Evacuation
	Number of Individuals Effected		
Minor accident	low	none	none
Moderate	up to 100	up to 10	up to 2,000 people
Major accident	up to several hundred	up to 100	up to 20,000
Catastrophic accident	more than 300	more than 100	more than 20,000

EXHIBIT 7-22 ACCIDENT FREQUENCY/SEVERITY SCREENING MATRIX



emergency planning necessary for each postulated event. An unlikely frequency/minor severity event, such as the worst case release described above for Astrotech, according to the matrix would not require comprehensive emergency planning, unless local officials deem it necessary; however, a likely frequency/minor severity event would require comprehensive emergency planning. Emergency planners are advised to focus their planning efforts on the mandatory events first, and later move on to the events of lesser risk.

As mentioned earlier, most communities have highways and state roads running through and around them that are used for commercial transport. Materials hauled often include dangerous chemicals or consumer products containing dangerous chemicals. One such substance is ammonia. Ammonia is poisonous and may be fatal if inhaled in sufficient quantities. Contact with the liquid may cause frostbite and will chemically burn eyes and skin. Although it is not flammable, it will burn within certain vapor concentration limits and will increase the fire hazard if present with combustible materials.

Ammonia has a variety of uses in many different industries including as a coolant in refrigeration systems, a component in cleaning solutions, and a common ingredient in many products. Ammonia is often shipped in refrigerated tank trucks on interstate highways. On these highways, car and truck accidents are common and subsequently, depending on the annual number of shipments and the length of the route, a frequency of "reasonably likely" (event occurs once every 100 years) might be expected for such an accident in a specific community. If a tanker truck hauling 3,000 pounds of ammonia became involved in a collision severe enough to rupture the tank and spill the entire contents, and if that spill occurred in a densely populated area, the consequences could be major. Not only could individuals on the roadway be affected, but also individuals in adjacent neighborhoods and business localities might need medical treatment. Sensitive populations such as hospitals and schools were included in the area affected by an ammonia release would be an additional complication for emergency responders.

Overall, this transportation-related release of ammonia might be evaluated as a reasonably likely/major severity event. As shown in Exhibit 7-22, this event would require comprehensive emergency planning and preparedness by emergency planners.

Because water provided by the local municipality to the community must meet stringent Federal drinking water standards, a common fixed facility in many communities is a water treatment plant. Many water treatment plants have chlorine on-site that is used to treat the water to these standards. Chlorine is a poisonous gas, that can be fatal if inhaled. It is corrosive, and may cause burns to skin and eyes. A typical water treatment plant has 800 pounds of chlorine on-site, and if one assumes a series of equipment failures, a spill of the entire 800 pounds could occur from the plant storage tank. Because many such tanks have leak detection systems and inventory controls, this event is unlikely.

Again, site specific considerations would be used to evaluate the severity of this hazard accurately. If one assumes the water treatment plant is located near a densely populated residential community, the potential severity is major. The released chlorine would likely not be contained by a building, and because chlorine is not flammable, none would be consumed in a fire or explosion. This means that the quantity entering the environment would equal approximately the entire quantity released.

Overall, a release of chlorine from a water treatment plant might be evaluated as an unlikely frequency/major severity event. According to Exhibit 7-22, this event would not necessarily require comprehensive emergency planning and preparedness by the emergency planners.

Many communities also have recreational facilities, such as swimming pools, located in the community. An average swimming pool may have as much as 750 pounds of chlorine on-site. Chlorine used by pools is often stored in 150 pound cylinders, which are used one at a time. Therefore, it is unlikely that more than one cylinder would be ruptured in a single accident. Since the cylinders are handled regularly by pool personnel, the probability of an accident is reasonably likely (event occurs once every 100 years). Assuming an operator error leads to breakage of a cylinder seal, all 150 pounds of chlorine would be immediately released.

Depending on the density of population in the immediate area, this event could be considered of moderate or possibly major in severity by emergency planners. Thus, it would not necessarily require major emergency planning efforts.

As detailed in the preceding sections, the Astrotech facility has been designed anticipating possible accidents so that it would contain any releases of liquid or vapor, except in the event of an explosion or a transport accident. As a result of the design considerations, the extensive training of facility personnel, and the particular operating procedures, the frequency or probability of a hazardous event is unlikely. Similarly, if the worst case release were to occur, the design features of the facility, the relatively limited initial quantity of materials, and the likelihood of a fire and explosion consuming a significant portion of materials present, would prevent any significant hazards from reaching the community.

Therefore, according to Exhibit 7-22, for the Astrotech facility, which has an unlikely frequency/minor severity evaluation, comprehensive emergency planning for this facility may not need to be a community priority. The Astrotech facility presents a less likely and less severe hazard to the surrounding community than other hazards that may be present. However, in the context of Brevard County planning, the LEPC has identified the Astrotech facility as one to be considered in the local emergency planning process and the Astrotech facility has consistently been cooperative in providing both information and assistance towards this planning effort, thereby ensuring the availability of trained and informed emergency responders in the unlikely event of an accident leading to a release.

8.0 FINDINGS, RECOMMENDATIONS, AND GUIDANCE

This section presents the findings of the safety evaluation team; comparisons between the Astrotech facility and government facilities with a similar function; recommendations of the site evaluation team; and some general guidance for ensuring safe operations at similar industrial facilities. The determinations presented here are based on a physical inspection of the Astrotech facility and viewing some of the hazardous operations, knowledge of existing facilities performing similar operations owned by NASA and the Air Force, interviews with Astrotech staff, questions asked of payload owners that use the facility, and discussions with state regulatory personnel and local and county emergency preparedness and planning agencies.

Overall, Astrotech appears to have taken every reasonable precaution in designing and constructing a facility which is safe for its employees and those living nearby, and in implementing the policies and operating procedures that have been successfully used by DoD and NASA for many years. Astrotech has commissioned safety studies both to initially site the buildings on the property and to analyze the design and construction changes for expansion. Astrotech has also attempted to identify and incorporate as many safety, monitoring, and detection features into the facility as was feasible.

Part of Astrotech's incentive for building and maintaining a safe facility is to convince spacecraft manufacturers that it is prudent and desirable to use the facility. The extremely high value of the payloads processed at the Astrotech facility causes both Astrotech and the spacecraft manufacturers to have a vested interest in ensuring that the Astrotech facility is operated and maintained as safely as possible.

8.1 Findings of the Safety Evaluation Team

The Astrotech facility is a state-of-the-art design for payload processing operations. It was apparent that Astrotech has not only complied with all applicable DoD and NASA requirements, but also sought out additional recommendations from spacecraft manufacturers and owners as well as government agencies during the construction stage and during continuing operations, to ensure maximum safety during efficient operation.

8.1.1 Facility and Procedures

The facility design and operating procedures employed at the Astrotech facility have been successful in ensuring safe operations at the facility in large part due to the personal experience of the General Manager, Safety Officer and others at Astrotech who have had long careers operating and working at payload processing facilities belonging to NASA and the Air Force. It is the direct result of this experience, and the lessons learned during the time spent at these Government facilities, as well as industry-wide input solicited prior to design and construction of the facility, that has enabled Astrotech to build and operate a state-of-the-art commercial facility. This knowledge, experience base, and interest in operating a facility which meets or exceeds the standards set by NASA and the Air Force was apparent to the evaluation team during the on-site inspection and interviews.

Specifically, with regard to the facility and operating procedures, the evaluation team found that:

- The buildings where hazardous materials are handled are separated from the public and from the non-hazardous work areas by distances determined using DoD and ATF explosives siting criteria. Therefore, if an accident involving an explosion were to occur, the public would not be exposed to any primary explosion effects (i.e., overpressure from the blast, flying fragments, or fire).

- The facility and equipment are state-of-the-art design and quality. Specific example of Astrotech's commitment to continuing improvements are their recent acquisition of portable MDA toxic vapor detectors to supplement the traditional Draeger tube vapor analyzers in monitoring liquid propellant handling and loading operations, and their planned acquisition of a closed-loop distillation system for recovery of freon contaminated during equipment cleaning operations.

- Building 2, is designed to minimize the risk to the public of any potential releases of propellant liquid or vapor that could result from a small spill inside the building. The containment and scrubber systems provide protection to the public from any incidental exposures during normal operations.

- The physical facilities compare favorably to Government facilities that serve similar functions. See Section 8.2 for a more extensive discussion.

- Prior to and during operations, policies and procedures are in place to ensure safety. These include attention to all aspects of operations including such things as customer safety plans and documentation for hazardous operations, careful weather and lightning storm monitoring, proper use of personal protective equipment, inspection and maintenance of facility equipment, and emergency planning.

- The formal, documented procedures for processing payloads meet accepted standards as applied by industry and Government agencies, specifically DoD and NASA.

- No accidents or incidents have occurred at the Astrotech facility since it began operations in 1984 that have required reporting the National Response Center. In fact, in the course of operations only one small spill of anhydrous hydrazine, amounting to less than a teaspoonful, has ever occurred. This spill was completely neutralized by the tank and scrubber systems.

To summarize, the facility and procedures appear more than adequate to safely support the operations that take place at the Astrotech site.

8.1.2 Emergency Response and Preparedness

The evaluation team found in interviews with local and county emergency response and preparedness officials that Astrotech management has been extremely open and cooperative with local public safety officials in the construction and operation of their Titusville, Florida facility. Through detailed planning, training and equipping, the public safety officials assisted by Astrotech management have been provided means for responding to an accident should one occur. Although there is interest at Astrotech and in the public sector for a joint exercise with county emergency personnel based on a simulated chemical release at Astrotech, no exercise has yet been conducted.

Astrotech's current written emergency response plan has been furnished to local emergency planning and response officials. Identification and management of emergency situations on site would be handled by Astrotech's small and closely-coordinated staff, under the direction of the facility Safety Officer. Procedures are in place and communications equipment is available to protect and evacuate workers in hazardous situations, to summon a facility emergency response team, and to call for off site assistance should it be required.

8.2 Comparison of Astrotech Facility to Comparable Government Facilities

NASA at KSC and the Air Force at CCAFS have a number of payload processing facilities where they have performed operations similar to those that take place at Astrotech. The Government processing facilities, most of which were built 20 to 25 years ago, handle the identical payload systems, ground support equipment, and hazardous materials as Astrotech. These facilities include:

- Delta Payload Spin Test Facility
- Navstar Processing Facility
- Solid Motor Assembly Building
- Shuttle Payload Integration Facility
- Vertical Processing Facility
- Horizontal Processing Facility
- Orbiter Processing Facility
- Vertical Assembly Building

In addition, other hazardous materials operations are conducted at the Propellant Servicing Facility, and the Propellant Conditioning Facility as well as, of course, at the launch pads and related service structures.

The Astrotech facility was designed and constructed by utilizing the safety and operating experience gained by NASA and the Air Force over the past three decades. The safety features and related policies and procedures at the Astrotech facility are a direct benefit from the lessons learned at KSC and CCAFS. Since the processing facility at Astrotech is one of the newest of its kind and the only commercial operation to-date, the facility has consequently taken advantage of and uses state-of-the-art equipment and procedures. Many users of the facility (Astrotech customers) believe it to be superior to the existing facilities located on government property nearby. (See customer letters in Appendix F.)

Because the only other comparable facilities and operations are operated by the Air Force and NASA; because of the close proximity of the Government facilities to Astrotech; and because the Astrotech facility has specifically drawn upon the lessons learned from operations at the Government-operated processing facilities, some discussion of the special features at the Astrotech facility that make it more advanced technologically and safe enough to operate in an industrial park, is warranted here. The specific features which were incorporated by Astrotech and which are believed to be an improvement over the existing DoD and NASA processing facilities are described below.

Vapor Containment

Vapor containment inside Astrotech's Building 2 is a characteristic not found in many older payload processing facilities. The structure was designed and built from the very beginning to be a containment facility in case a small propellant release or spill should occur inside the structure during normal operations. The containment technology has advanced considerably over the last 30 years since the Government-owned facilities were originally designed. This same technology is now, according to Astrotech personnel, being incorporated into the Government-owned hazardous processing facilities which currently vent any stray vapor emissions to the atmosphere.

Electrostatic Dissipation

The floor covering in the high bays is electrostatically dissipating tile. This technology was originally developed for use in hospital operating rooms where static electricity created potentially hazardous situations in handling sensitive equipment. The tiles are vinyl, impregnated with graphite, and are fixed to the floor with a conductive mastic that dissipates static electricity to the building ground system. This reduces considerably the potential for spontaneous electrostatic discharge in an environment where highly flammable liquids and vapors and solid rocket motors could be present. In the older facilities large metal sheets are laid over the floor in the working bay to provide a ground link for dissipation of possible electrical charge buildup, making operations more cumbersome.

Spill Collection and Containment

In the north and south high bays and the north airlock, fueling operations are performed on "fueling islands." These islands are surrounded by a stainless steel propellant collection trench. The fueling island floor does not slope toward the trench, it is extremely flat to ensure payload stability during loading, however, the rest of the floor is very slightly sloped toward the trench. The trench itself is graded and drains toward the underground propellant containment tanks located outside the building. This trench drainage system reduces the "wetted area" of a propellant spill and accommodates containment and cleanup in case of a release. In the event of a fuel spill involving a fire, this system would also serve to confine the fire to the fueling island and help prevent its spread to other areas. The Government facilities have no internal spill containment system.

Remote Visual Access to Hazardous Operations

Explosion-proof observation windows have been installed between the control rooms and the high bays in Building 2. This allows Astrotech and customer payload safety and quality control personnel to observe hazardous operations directly without necessitating their physical presence in the high bay during hazardous operations. Astrotech also has the traditional CCTV monitoring capacity found in the NASA and DoD payload processing facilities. In addition, Astrotech videotapes all fueling operations and makes these tapes available to customers.

Fuel/Oxidizer Containment and Neutralization

A containment system, consisting of oxidizer and fuel holding tanks - with the appropriate valving and manually-switched piping system to separate the tanks - and a scrubber system, has been installed. The scrubber is operated under permit by the Florida DER. Astrotech maintains a check-off procedure and visual verification to ensure proper switching of valves and tanks between hazardous operations. No such containment and neutralization system exists at the government facilities.

Vapor Detectors

At all times that liquid propellants are on site, Astrotech monitors atmospheric conditions in Building 2. They use state-of-the-art toxic vapor detectors to supplement the more conventional Draeger tube vapor analyzers. These new monitors are sensitive and are microprocessor-controlled for speed, accuracy, and specificity. The detectors are enclosed in special clear plastic cases designed for use in potentially flammable or explosive conditions.

Pre-Action Fire Suppression

A pre-action fire suppression system is in place that has compressed air in the lines, maintaining a "dry pipe" condition. The system is activated by two independent but necessary actions: first, a smoke/heat detection alarm signal from any of the mounted detectors or from a manual pull station; and second, an intense heat source sufficient to melt the fusible link in the sprinkler head. The IR smoke/heat detection alarm system (or the manual pull system) opens a valve which then charges the system with water. A high intensity heat source must then be present to melt the fusible plug at the sprinkler head, allowing the sprinkler to wet the area. This system provides some protection for sensitive payloads and other equipment in case there is a false alarm or other problem. Government facilities currently use only wet pipe sprinkler systems.

Computer Monitoring of Alarms

Alarms are automatically sent to the guard house at the front gate by means of a computer link for various parameters and systems including:

- temperature and humidity (HVAC system)
- loss of air pressure in the fire suppression system
- toxic vapor detector alarm
- toxic vapor detector status alarm (low battery or tape break)
- generator failure
- fire alarm

The alarm panel indications displayed to the guard allow prompt identification of potential problems and notification of proper personnel and authorities.

8.3 Specific Recommendations

8.3.1 Equipment, Operations and Procedures

Evaluate the Operations Sequence

Although the probability of a major accident at the Astrotech facility is small, it could possibly be further reduced by modifying the sequence of processing operations. The presently used sequence was established when payloads were loaded and pressurized on the launch pad. However, in recent years the final payload propellant loading, pressurization, and integration with large apogee kick motors has shifted location and now occurs within a payload processing facility. Also, the amounts of liquid propellants and the size of SRMs have increased considerably.

Given these changes in payload processing, the safety evaluation team recommends that Astrotech undertake a study to determine the technical and economic feasibility of altering the operations sequence to further minimize risk. Even though no such study has been completed, it is possible to suggest a modified operations sequence. For example, the modified sequence below minimizes the risks from the greater volume of propellants and takes advantage of the sequencing flexibility available within the payload processing facility.

Present Sequence	Modified Sequence
Oxidizer load	Tank pressurization
Fuel load	Fuel Load
Mate payload and SRMs	Oxidizer load
Tank pressurization	Mate payload and SRMs
Encapsulate and transport	Encapsulate and transport

The general rationale for these changes is to sequence activities to minimize risk by minimizing the opportunities for release of propellants and for interactions between fuel, oxidizer and SRMs. In the modified sequence, the first step is to pressurize the payload high pressure tanks because failure of a tank is most likely to occur during pressurization. In the modified sequence, pressurization is completed prior to the loading of liquid propellants, so that a tank failure could not involve liquid propellants. This would be feasible if the payload design includes valves that isolate the high pressure tanks from the propellant tanks.

The sequences above assume a bipropellant spacecraft, where both fuel and oxidizer are loaded. Because spills or leaks of fuel (i.e., anhydrous hydrazine or MMH) are more likely to result in fires or explosions than spills or leaks of oxidizer alone (i.e., nitrogen tetroxide), in the modified sequence the fuel sampling and loading operations are scheduled before the oxidizer sampling and loading operations. In the present sequence, it is more likely that a fire or explosion resulting from a fuel leak would spread and involve the previously loaded oxidizer.

Because the technical and economic feasibility study necessary to support a recommendation to resequence operations is beyond the scope of this study, and because the safety evaluation team has not examined in detail all possible risks or technical constraints that might arise from the modified sequence, the above discussion should be considered by Astrotech as a beginning point for further evaluation, and not an strictly recommended sequence.

Install Additional Communications Capability in Cart Storage Rooms

Currently, the only communication link from the fuel and oxidizer cart storage rooms is to the control room through an intercom mounted in each cart storage room. The evaluation team recommends that Astrotech consider installing an additional communication link out of the cart storage rooms (e.g., a telephone with an outside line, or an internal connection to the guard house) so that if an individual needed to make outside contact, and no one was present in the control rooms, there would be a communication link.

8.3.2 Safety Policies and Requirements

Define Propellant Loading Sequencing in Safety SOP

In considering the possibility of resequencing the sequence of operations, the safety evaluation team examined the Astrotech Safety Standard Operating Procedures (SOP) to see if any limitations are placed on operations sequencing. As none were found in the SOP, the evaluation team assumed the proposed resequencing may be viable. However, the scrubber procedures checklist[1] does state that fuel must be processed before oxidizer. If the scrubber system operations checklist indicates that there are operational sequencing limitations, these limitations should also be detailed in the SOP, so that payload owner/operators can properly plan their operations.

Specify Training Requirement Criteria

Astrotech requires that payload owner/operator personnel be "properly" trained and that the payload owner/operator "certify" that this training has taken place. However, Astrotech Safety policies do not detail the requirements that, if met, ensure proper training. Although this could be interpreted as a lack of specificity on Astrotech's part, the evaluation team is aware that training requirements are not specified elsewhere in the space launch industry. Because the commercial space industry has a relatively limited number of facilities and personnel, training to date has largely been accomplished through on-the-job apprenticeship, supplemented by applicable courses (e.g., OSHA requirements and the KSC propellant handlers video) in hazardous materials handling. As the industry expands, it will be important to detail the training required before personnel can be given responsibility for certain operations. Of the payload owner/operators that currently use the Astrotech facility, most have teams for specific hazardous payload processing operations (i.e., propulsion teams) that have worked together for long periods of time and have successfully completed many propellant fueling operations. The evaluation team recommends that Astrotech review its criteria for proper training, and also recommends that the industry as a whole evaluate training program availability and content and begin to institutionalize training and certification requirements to ensure competency and an adequately trained work force for the future.

Define Accident Events and Develop Specific Response Procedures

When on the site visit, the evaluation team inquired of Astrotech what their procedures would be in the event of an uncontrollable spill. Although Astrotech clearly stated the necessary activities (e.g., attempt to control spill by turning off valves, evacuate personnel, turn off power and thereby seal the building), the exact sequencing and timing of these activities is not documented in plans and procedures. Although the sequence would vary

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[1] Scrubber System Check Lists at Astrotech Space Operations, Inc., Titusville, Florida, Don J. Wade, Manager, Spacecraft Operations, July 18, 1984.

depending on the specific spill event, more thought should be given and a written procedure developed for general types of events. The procedure should include a definition of the accident that initiates the stated response (e.g, a spill of a stated volume of fuel or oxidizer, a vapor monitor reading at a specific level), the actions taken to mitigate and evacuate, and the steps for re-entry at specified vapor concentrations. Specific consideration should be given to determining the capabilities and limitations of the scrubber and tank containment systems for a variety of accident scenarios.

8.3.3 Emergency Planning and Preparedness

Although the current emergency planning and preparedness status of the Astrotech facility appeared to be adequate, the evaluation team has several recommendations for improvements that would facilitate communications and rapid response.

Clarify Astrotech Personnel Assignments

Astrotech places heavy reliance on the knowledge and presence of their Safety Officer in dealing with emergencies. Although all personnel appear to be familiar with the safety procedures, it is important that Astrotech formalize the Safety Officer back-up by assigning a specific person to develop the same detailed familiarity with Astrotech's plans and procedures. By formalizing a Safety Officer back-up, either one person or several individuals who would rotate depending on the shift, two goals would be accomplished: the selected individuals would make an additional effort to learn how to direct implementation of the safety procedures, and in the event of an emergency occurring in the absence of the Safety Officer or one that injured him, all personnel present would know immediately who would assume leadership responsibility, alleviating possible confusion.

An additional personnel consideration is a local media spokesperson. Astrotech's corporate media contact is normally stationed away from the plant. It would be helpful for the facility to have a local spokesperson available to furnish information in coordination with local emergency management officials should an emergency occur. Although the team has assumed that the Safety Officer would take on that role, in the event of an emergency, the Safety Officer's other duties would likely be so time consuming that a different person would be preferable for the media contact.

Expand Emergency Contact Lists

Astrotech's procedures depend solely on the emergency telephone number 911 as an entry point into the outside emergency system. Their notification list needs to be expanded to include telephone numbers of other critical contacts in the local emergency management system (i.e., county emergency management director) for reinforcement.

Astrotech's plan should also include a list of contact persons and telephone numbers for its nearest industrial neighbors, since a situation could arise that would require Astrotech to notify them. The local emergency management agency should be able to assist in compiling such a list.

Circulate SARA Title III Reporting Requirements

Three chemicals which are on-site periodically at Astrotech depending on the specific spacecraft being processed, have been designated as hazardous substances under CERCLA. Two of these chemicals are listed as Extremely Hazardous Substances (EHSs) under SARA Title III. SARA has specific reporting requirements for facilities to follow when designated amounts of these substances are accidentally released into the environment. Information required in these reports is itemized in Section 304 of Title III. Astrotech needs to identify these items specifically in its plans and procedures and indicate that they are to be furnished when reporting a release.

In the event of a reportable release of a CERCLA chemical, Astrotech should furnish the same information as that required for the EHSs. In order to ensure proper implementation of the reporting requirements, Astrotech should include the reportable quantity for each chemical that it handles on the notification list.

Exercise Emergency Plan with Local Authorities

Astrotech should schedule, if possible, a full scale exercise of its emergency plan with local authorities. If scheduling of the full scale exercise continues to present difficulties, at least a tabletop exercise should be scheduled.

8.4 General Guidance for Ensuring Safe Operations

The safety evaluation team brought to the Astrotech Safety Evaluation a wide range and depth of expertise in issues necessary to ensure safe operations at a payload processing facility. Knowledge of payload processing procedures, hazardous characteristics of specific materials, emergency planning requirements, and other applicable regulations was necessary to evaluate the facility completely. In the event that communities are working with other existing facilities to evaluate risk, or industrial facilities are seeking to initiate or expand operations, the safety evaluation team has prepared general guidance for ensuring safe operations. These general observations are not aimed at the Astrotech facility, in fact in many cases, Astrotech has followed or exceeded the guidelines that the team has identified and could be used as an example for effectively implementing them.

Many industries handle and use hazardous chemicals in a variety of operations and processes under varying handling conditions (e.g., high or low temperatures, high pressures) at locations throughout the United States. The occurrence of accidents at major industrial facilities in the chemical and petrochemical processing industries that have caused injury or death has focused both public and government attention on safety, training, emergency preparedness and planning, and accident prevention. When an industry is considering siting a facility or expanding its operations in an area, the first step is to consider prior assessments of safety or hazards analyses for similar facilities in terms of such things as siting criteria and safety designs. Astrotech accomplished this step by surveying operators of Government facilities and potential customers for design suggestions, and by commissioning a safety expert to evaluate compliance with siting criteria.

It is critical to coordinate early with the local planning officials and begin by laying out the overall plans for siting, design, and construction regarding safety and accident prevention especially if chemicals will be handled on site that should be included in the community emergency preparedness and planning efforts. At this point it may be advisable to bring in safety experts to help make decisions about where to expend time and resources to maximize safety by including special designs or safety systems or by adapting operations sequences.

In general the components of an adequate safety program at a facility include not only the design, but also operating and maintenance controls, training, documentation and record keeping, and internal audits and inspections. The overall safety program at a facility is a key factor in protecting the public and the environment. Proactive programs designed to prevent chemical releases are the most effective way to protect community health and safety and the environment. To prevent accidents, a facility must anticipate the circumstances that could result in releases and include precautionary and preemptive actions appropriate to the nature of the hazardous chemical(s) handled as well as the operations at the site.

Existing safety, health, and environmental audit programs established at a facility are important in improving emergency response and risk reduction. It is critical to identify facility hazards, carefully evaluate the associated risks presented by the hazards and if possible, reduce those risks to prevent and mitigate the effects of releases. This can be effectively achieved through communication and cooperation between industry and government to prevent or minimize accidents.

An additional assurance of safe operations can be implemented by establishing a regular monitoring program for industries in a local area. Although many federal, state and local authorities monitor industrial facilities for compliance with specific regulations (e.g., at Astrotech the City of Titusville tests neutralized liquid before accepting it into the sewer), generally there is no established authority that ensures a facility is complying with its own internal safety requirements. Although the broad general scope of this Astrotech Safety Evaluation is not likely to be frequently repeated, it would be reasonable and useful for an expert to annually monitor and observe that established safety procedures are implemented at industrial facilities.

Some of the equipment or procedures that may be considered in addressing safety and accident prevention include:

1. All equipment used in handling hazardous chemicals

2. Safety procedures addressing:

    -storage tanks
    -piping
    -pressure relief, venting, scrubbing systems
    -secondary containment systems
    -detection, warning or alarm systems
    -emergency shut-down and fail safe systems
    -critical controls and interlocks
    -safety training
    -checklists for critical safety activities
    -inspection, maintenance, repair or replacement of critical safety systems
    -loss of power or utilities
    -emergency procedures for employee evacuation and notification of emergency responders and nearby neighbors

Additional information of interest may include the accident history of facility or of the industry in general, local weather patterns, proximity to water sources, any nearby businesses or residences, and any special facilities (e.g., hospitals or schools) or environmentally sensitive areas in the vicinity.

Many groups in the U.S. and in the international community have been developing methods to provide technical guidance to assist in the evaluation of industrial safety. The Environmental Protection Agency, the Federal Emergency Management Agency, and the U.S. Department of Transportation have all coordinated to publish documents that are also important to these issues. Private groups and industrial trade associations have also addressed these issues. One particularly helpful industrial association, the American Institute of Chemical Engineers (AIChE) has established the Center for Chemical Process Safety (CCPS). This group is a leader in producing guidelines for hazard investigations and evaluations, establishing industrial safety guidelines, and developing and improving industrial safety procedures. Many of the new publications by CCPS may be of use in looking at safety, risk management, and accident prevention programs. These references and others are listed in Appendix G, which provides an overview of references that deal with safety, hazards evaluation, risk management and release prevention programs.

GLOSSARY OF TERMS

AIRLOCK - An intermediate chamber or room, usually located between the outer air and an inner working chamber in which air pressure and/or temperature can be regulated.

APOGEE KICK MOTOR (AKM) - A solid rocket motor that provides energy and velocity needed, once a satellite has reached apogee, to circularize the orbit.

BIPROPELLANT - Rocket propellant mixtures of fuel and oxidizer not stable at ordinary atmospheric conditions. Fuel and oxidizer are stored separately with contact taking place only in a rocket combustion chamber.

CLEAN ROOM - An environmentally controlled area (i.e., humidity and temperature) in which the airborne concentration of particles is limited by extensive filtering of all incoming air.

CREDIBLE ACCIDENT SCENARIO - A probable, possible, and/or plausible accident scenario, or sequence of failure events which can lead to the occurrence of accidents.

COMBUSTION PRODUCT - Material produced or generated during the burning or oxidation of a material.

DEFLAGRATION - Rapid burning of material below the speed of sound in the unreacted material.

DETONATION - A heat-producing reaction that propagates through the unreacted material at speeds exceeding the speed of sound.

DIFFUSION - The spontaneous movement and scattering of particles (atoms and molecules) of liquids, gases, and solids.

DOD CLASS 1.3 EXPLOSIVE - Explosives in this class are defined as fire hazards that burn vigorously with little or no possibility of extinguishment in storage situations. Explosions normally will be confined to pressure rupture of containers and will not produce propagating shock waves or damaging overpressure beyond a specified distance.

EMERGENCY - A situation created by an accidental release or spill of hazardous chemicals which poses a threat to the safety of workers, residents, the environment, or property.

EVACUATION - Removal of residents and other persons from an area of danger.

ELECTROEXPLOSIVE DEVICE (EED) - Any detonator or initiator activated by an electric current.

EXERCISE - A simulated accident or release set up to test emergency response methods and for use as a training tool.

EXPLOSION - The sudden production of a large quantity of gas or vapor, usually hot, from a much smaller amount of gas, vapor, liquid or solid. An explosion may also be viewed as a rapid equilibration of a high pressure gas with the environment; the equilibration must be so fast that the energy contained in the high pressure gas is dissipated as a shock wave.

FAULT TREE ANALYSIS - A deductive analysis procedure which represents all possible sequences of failures and chains of events which can result in the final event at the top of the tree.

FLAMMABLE LIMITS - The upper and lower vapor concentrations of fuel to air which will ignite and burn in the presence of external ignition sources; often called the explosive limits although these are not identical.

FUEL - A material which may be burned by itself or used with an oxidizer to liberate energy for use in vehicle propulsion systems.

GAUSSIAN DISTRIBUTION - A statistical distribution named for mathematician Karl F. Gauss. It is also known as the normal distribution or bell curve, and the distribution is symmetrical around a point referred to as the mean. The spread of points is determined by the standard deviation.

GRAIN - A single mass of solid propellant of the final geometric configuration as used in a rocket motor.

GROUND SUPPORT EQUIPMENT (GSE) - Non-flight equipment, implements and devices required for the handling, servicing, inspection, testing, maintenance, alignment, adjustment, checking, repairing and overhauling of a payload system or sub-system. This may include equipment required to support another item of GSE as defined here.

HAZARD - Any situation that has the potential for causing damage to life, property, and/or the environment.

HYPERGOLIC - Term applied to the ignition upon contact of a fuel and an oxidizer without a spark or other external aid.

IMMEDIATELY DANGEROUS TO LIFE AND HEALTH (IDLH) - The maximum level to which a healthy worker can be exposed for 30 minutes and escape without suffering irreversible health effects or escape-impairing symptoms.

LEGSTAT - A device connecting a person's leg to the bottom of his shoe so that when that person is standing on a conductive floor, an electrostatic grounding path is provided.

MAGNAFLUXING - Using magnetic particles and applying a field to test load bearing hooks, shackles, eyebolts and critical welds (single point of failure) for cracks.

MONOPROPELLANT - Liquid mixtures of fuel and oxidizer or liquid molecules containing both fuel and oxidizer constituents that are stable at ordinary atmospheric conditions but react when heated, pressurized or catalyzed.

NFPA 56A - A code of the National Fire Protection Association that contains specifications for fire protection equipment.

ORDNANCE - All electroexplosive devices (EEDs), detonators, squibs, primer, pyrotechnic devices, initiators, igniters, solid propellants, explosives, warheads, ammunition, fuses and energy transfer systems (as defined in ESMCR 127-1). In a spacecraft, ordnance serve as separation devices and as igniters for motors.

OVERPRESSURE - Blast wave parameter indicating pressure significantly above what is usual or normal. Overpressure is used to quantify the strength of an explosion, and the expected damage from an explosion is determined by its overpressure. Overpressure is strongest at the point of the explosion and reduces with distance, so damage also decreases with distance.

OXIDIZER - A substance that yields oxygen readily to support the combustion of organic matter, powered metals, and other flammable material.

PAYLOAD - The total complement of specific instruments, space equipment, support hardware, and consumables carried into space to accomplish a discrete activity.

PAYLOAD FAIRING - Outer shroud or casing used to protect a payload during launch and through the escape of the dense atmosphere of the earth.

PERIGEE KICK MOTOR (PKM) - A solid rocket motor that provides the substantial energy needed to boost a satellite to a higher apogee from a lower orbit, typically to the 22,000 mile geosynchronous orbit altitude. This motor section of the spacecraft is designed to separate from the payload after its energy is expended.

PERSONAL PROTECTIVE EQUIPMENT (PPE) - Equipment designed and used to protect a worker from the hazards present during a given operation. The PPE level (ranging from most protective level A to less protective level C) required depends on the operation. For example, PPE level A includes a chemical resistant suit, gloves, and boots, and a self-contained breathing apparatus, and is suitable for protection in atmospheres where hazardous vapors may be present.

PRIMER - A relatively small and sensitive initial explosive train component, which when actuated, initiates the function of the explosive train, and with an adequate booster, will reliably initiate high explosives.

PROPELLANTS - Balanced mixtures of fuel and oxidizer designed to produce large volumes of hot gases at controlled, predetermined rates, once the burning reaction is initiated.

REPORTABLE QUANTITY (RQ) - The quantity of a hazardous substance that triggers reporting under CERCLA; if a substance is released in a quantity that exceeds the RQ, the release must be reported to the National Response Center (NRC), as well as to the State emergency response commission (SERC), and the community emergency coordinator for areas likely to be affected by the release.

RISK - A measure of probability or likelihood that damage to life, property, and/or the environment will occur if a hazard manifests itself; this measure includes the severity of anticipated consequences to people.

SAFETY DISTANCES - Safety distances are empirical distances in relation to quantities of explosives and are the minimum permitted for separation of facilities within a hazard area of possible explosions and for separation of the explosive hazard from inhabited buildings, passenger railroads and public highways in order to control the magnitude of damage, loss of life, and serious injuries. Separation distances are not absolute safe distances but are relative.

SCRUBBER - An air pollution control device for removing impurities from a gas stream. Toxic constituents in the vapor phase are absorbed into and react with the "scrubber liquor" on the packed bed material in the scrubber tower. Vertical flow units like the one at Astrotech commonly use countercurrent flow of gas and liquid for maximum mixing and contact.

SOLID PROPELLANTS - These propellants act as monopropellants. Homogeneous propellants are ones in which each molecule contains both fuel and oxygen (e.g., nitrocellulose-containing compounds). Composite propellants are physical mixtures of a finely ground oxidizer in a matrix of plastic, resinous or elastomeric fuel (e.g., ammonium perchlorate in a resin binder).

SOLID ROCKET MOTOR - Motor which operates using homogeneous solid propellants. Following ignition, the propellant charge burns, and it is not possible to interrupt or control the combustion process. The advantages of SRMs are the short time needed for the activation, a long storage life, and a simple design.

SPACECRAFT - Another term for payload.

SPECIAL POPULATIONS - Groups of people that may be more susceptible than the general population due to preexisting health conditions (e.g., asthmatics) or age (e.g., infants and the elderly) to the toxic effects of an accidental release.

SPIN BALANCING - An operation performed during payload processing, to ensure that all weight is evenly distributed around the spin axis of a spacecraft.

SQUIB - Generally, any various small size pyrotechnic explosive device. Specifically, a small explosive device, loaded with low explosive such that its output is primarily heat as opposed to an explosion. The device is usually electrically activated and used to initiate the action of pyrotechnic devices and rocket propellants.

STABILITY CLASSES, ATMOSPHERIC - Pasquill stability classes (ranging from "A" TO "F") are meteorological categories of atmospheric conditions. Pasquill stability class A represents unstable conditions under which there are strong sunlight, clear skies, and high levels of turbulence in the atmosphere, conditions that promote rapid mixing and dispersal of airborne contaminants. At the other extreme, class F represents light, steady winds, fairly clear nighttime skies, and low levels of turbulence. Airborne contaminants mix and disperse far more slowly with air under conditions, and may travel further downwind at hazardous concentrations than in other cases. Stability class D, midway between A and F, is used for neutral conditions, applicable to heavy, overcast, daytime or nighttime.

SWALE - A low tract of land or slight depression, especially moist or marshy ground.

TOXICITY - The ability of a substance to cause damage to living tissue, impairment of the central nervous system, severe illness, or death when ingested, inhaled, or absorbed by the skin.

ULLAGE - The amount a container lacks of being full, the empty space being filled with gas or vapor.

UPPER STAGE - An expendable launch vehicle such as the Titan, Delta and Atlas/Centaur have several "stages." As each stage completes its burn during launch it is discarded. The first stage is usually called the "booster stage," the second stage the "sustainer stage'" and subsequent stages "upper stages." The upper stages of most ELVs are capable of placing payloads into elliptical transfer orbits.

VAPOR DISPERSION - The movement of clouds or plumes in air due to wind, gravity spreading, and mixing.

VOLATILE - A substance that has a high vapor pressure (i.e., it will readily vaporize) at a low temperature.

WRISTSTAT - A device that connects a person's wrist to a cable that leads to a grounding path to the building grounding grid. A wriststat is used when work is not being performed on a conductive floor and a grounding path cannot be established through a legstat.

APPENDIX A

Brevard County Hazards Analysis

Appendix A contains the Brevard County Hazards Analysis for the Astrotech facility. Astrotech's Safety Officer has worked closely with local emergency planners and emergency response officials in performing this hazards analysis (as defined in EPA's Technical Guidance for Hazards Analysis). The vulnerable zones predicted using the EPA model, are based on assumptions that are admitted by EPA are extremely conservative and therefore lead to unrealistically large zones; the function of the identified vulnerable zone is for screening purposes. This assists local emergency planners in identifying the potential hazards at industrial facilities and in setting preparedness and planning priorities for those facilities within their planning area.

Brevard County, using a computer program developed for the State of Florida by its emergency planning agency, has projected vulnerable zones around Astrotech based on a sudden release of six barrels or 3,000 pounds of either anhydrous hydrazine or monomethyl hydrazine, even though the maximum amount of either chemical allowed by the permit at the facility at any time is 2,500 pounds. The Technical Guidance recommends assuming that a spill occurs outside of the containment building. However, because the maximum quantity of fuel that is at any time transported to Astrotech is two drums (approximately 925 pounds of anhydrous hydrazine or 800 pounds of monomethyl hydrazine) a release of the maximum permitted quantity is a large overestimation of any possible release.

The widest zone of exposure to a concentration of vapor that is 10% of the IDLH, based on the EPA model, would come from a sudden release of the estimated amount of monomethyl hydrazine into a 3.4 miles per hour wind. Under these conservation wind conditions, the vulnerable zone would extend approximately one-half mile from the facility. A map of this vulnerable zone, which would include parts of Highways 405 and 407, a residential neighborhood of approximately twelve families across Highway 407 from the facility and an area of the industrial park past Grissom Parkway, is shown in the attached report.

Although Brevard County emergency management officials believe that an accidental release of the magnitudes on which the vulnerable zones were estimated would be highly unlikely, their site emergency plan for Astrotech and the evacuation plan for the area surrounding the facility are based on this "worst case scenario" that assumes the total quantity of propellant allowed on-site is released outside of the facility. County emergency officials view a more realistic, but still unlikely, incident as one in which a release would be initiated within the building and exposure would be confined to the facility and the immediate vicinity of the facility.

Hazards Analysis

Facility ID: 00-00000-01
Page: 1

Facility Name: Astrotech Space Operations, LP
Last Date of Update: 04/03/90
Address: 1515 Chaffee Dr. (Grissom
Industrial Pk) Titusville
Zip: 32780-
Coordinator: Bruce Campbell
Position: Safety Engineer
Phone: (407)268-3830
Business Type: Satellite fueling
Parent Company: Westinghouse Electric Corp.
Address: P.O Box 746
Baltimore, MD
Zip: 21203-

Location(Rural/Urban): urban

Transportation Routes:
Interstate Highway I-95
State Road 407
State Road 405
US Highway 1

Evacuation Routes
WIND FROM (Take route indicated until VZ is exited)
NE to SE SR 407

SE to SW SR 405

SW to NW SR 405

NW to NE SR 407

CAS Numbers for all Extremely Hazardous Substances on site:
00302-01-2,00060-34-4,

INFORMATION
(For Field Use Only)

Facility ID: 00-00000-01
Page: 2

Facility Name: Astro Technologies Inc

Physical Location: Inside satellite processing facility

Alarm System?(Y/N): Y

Back Up?(Y/N): Y

To Whom: Safety Systems

Materials Properly Separated: Y

(P)ump or (G)ravity feed system: G

Frequency of Inspection or Test: Daily

Safety Equipment: SCBA, Level A suits, diking,Oxygen cannisters, showers

Mutual Aid Agreements: Kennedy Space Center, McDonell Douglas

Site Emergency Plan?(Y/N): Y

Hours of Operation: As necessary

PCT. of Trained Personnel: 100

Training Program?(Y/N): Y

Security: Guards

Waste Disposal System?(Y/N): Y

1st Resp. Pub. Safety Agency: Titusville Fire Department

Historical Accident Record: Three drops of hyrdrazine spilled on disconnect of fueling line in

Probability of any release: Less than 1%

Comments:
Astrotech is a highly technical, sophisticated fueling facility of satellites (commercial and government) being launced from Kennedy Space Center or Cape Canaveral Air Force Station complexes.
Critical Facilities: None within vunerable zone.

```
Chemical Name                  HAZARDS IDENTIFICATION
Hydrazine

                          F. DOT      Max Quantity          Weight Largest Vessel or
      CAS NO.             ID. NO.       On Site               Interconnected Vessels
       302-01-2           2029            3000(lbs)                 3000(lbs)
+-----------------------------------------------------------------------------+
|                                 Physical State                              |
+-----------------------------------------------------------------------------+
|  Liquid |  Gas  |                               Solid                       |
+---------+-------+-----------------------------------------------------------+
|         |       |             Powder         |      Solution      |  Molten |
+         +       +----------------------------+--------------------+---------+
|   100 % |   0 % |               0  %         |          0 %       |    0 %  |
+---------+-------+----------------------------+--------------------+---------+

Temperature           Temperature          Frequency of          Form Of
  Stored                Handled              Shipments           Shipments
 AMBIENT                AMBIENT            6 year                55 gal dr

Quantity of         Mode of                Fire Data
 Shipment         Transportation           Combustible, hypergolic
  6                 flat bed

Area of Dike:     500(sqft)                Explosive Data
                                            Highly explosive. May be ignited by
Storage Above Ground?(Y/N):Y                high heat, spark or flame.
                                           Reactive Data
 ocation(Urban/Rural): urban                Highly reactive with nitrogen/nitrate
                                            based chemicals.
```

RISK ANALYSIS

CAS #: 302-01-2
CHEMICAL NAME
Hydrazine

Probability of Release:
Probability of a release of Hydrazine from this facility is very slight. This facility employs state of the art containment, scrubber, and neutralization technology. This facility has an excellent training and safety program as well as a comprehensive emergency response program.

Consequence if people are exposed:
Dizziness, nausea, corrosive to eyes/skin/mucous membranes. May cause temporary blindness, damage to major organs and fetal malformations. Suspect human carcinogen.

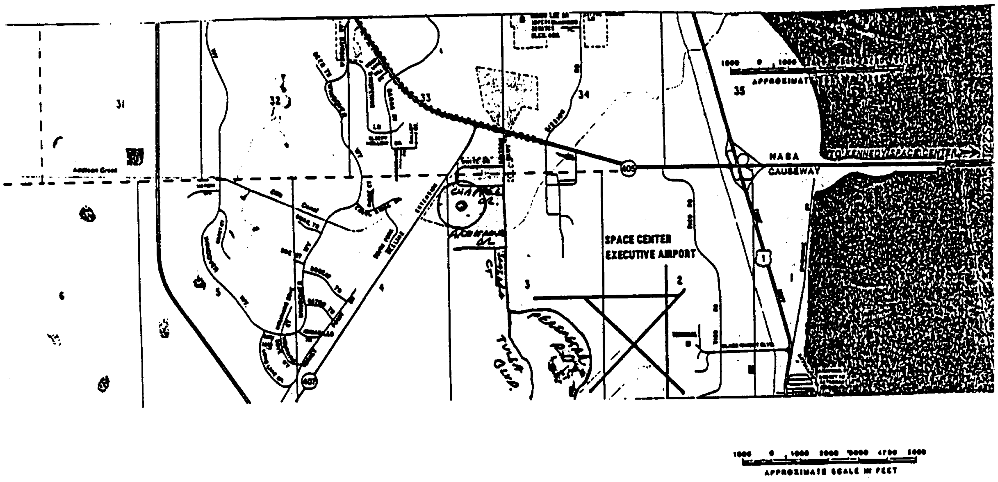
Consequences for Property:
Property damage limited to site.

Consequence of Environmental Exposure:
Uncontrolled spill could cause pollution.

Historical Accident Record:
Three drops of product were spilled in 1986 due to a faulty disconnect procedure.

GENERAL INFORMATION

General Information to assist first responders :
Evacuate away from product. Flood with water to fight fire, to prevent reignition. Isolate area of spill by diking. Stop source of leak. Dilute to 5% or less. Add 5% concentration of a hypochlorite solution.



```
EHS: Hydrazine

  CAS #        :   302-01-2
  Facility Name: Astro Technologies Inc
        Address: 1515 Chaffee Dr.  (Grissom
                 Industrial Pk) Titusville
                                     32796-
    Coordinator: Bruce Campbell          Phone: (407)268-3830
Location     : urban
  Vulnerable Zone(3.4 mph Windspeed)          Vulnerable Zone(11.9 mph Windspeed)
               Radius:    0.1 (mi.)                        Radius:    0.0 (mi.)
              VZ Area:    0.0 (sq.mi.)                    VZ Area: SITE ON(¥q.mi.)

Critical Nearby Facilities: There are no critical facilities within the vulnerable zone.
```

Chemical Name
Methyl Hydrazine

CAS NO.	F. DOT ID. NO.	Max Quantity On Site	Weight Largest Vessel or Interconnected Vessels
60-34-4	1244	3000(lbs)	3000(lbs)

```
+--------------------------------------------------------------------------+
|                            Physical State                                |
+--------------------------------------------------------------------------+
| Liquid |  Gas  |                          Solid                          |
+--------+-------+---------------------------------------------------------+
|        |       |          Powder         |     Solution     |   Molten   |
+        +       +-------------------------+------------------+------------+
|  100 % |  0 %  |            0  %         |        0 %       |     0 %    |
+--------+-------+-------------------------+------------------+------------+
```

Temperature Stored	Temperature Handled	Frequency of Shipments	Form Of Shipments
AMBIENT	AMBIENT	6 year	55 gal drm

Quantity of Shipment
6

Mode of Transportation
flat bed

rea of Dike: 500(sqft)

Storage Above Ground?(Y/N):Y

Location(Urban/Rural): urban

Fire Data
Combustible, hypergolic

Explosive Data
Highly explosive. May be ignited by heat, spark, or flames.

Reactive Data
Highly reactive with Nitrogen based chemicals & oxidizing agents.

RISK ANALYSIS

CAS #: 60-34-4
CHEMICAL NAME
Methyl Hydrazine

Probability of Release:
Possibility of release of Monomethyl Hydrazine from this facility is very slight. This facility employs state of the art containment, scrubber, and neutralization technology. The facility has an excellent training and safety program as well as a comprehensive emergency response program.

Consequence if people are exposed:
Dizzyness, nausea, corrosive to eyes/skin/mucous membranes, may cause temp. blindness, damage to major organs and fetal malformations. Suspect human carcinogen

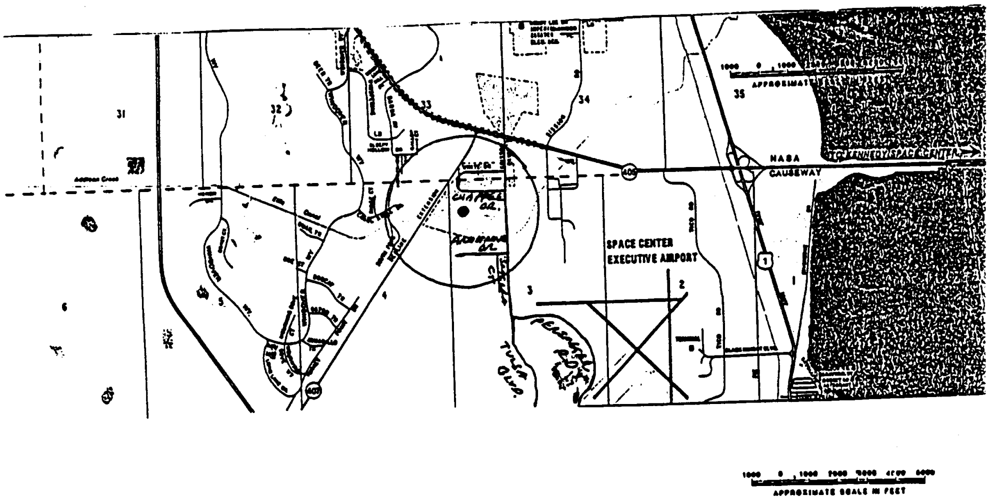
Consequences for Property:
By itself, property damage as a consequence of a release of Monomethyl Hydrazine should be limited to the site only. However, when combined with Nitrogen Tetroxide, the possibility exists that a violent reaction could result which may possibly effect off-site locations in the area of the vulnerable zone, in the form of a explosion and fire hazard.

Consequence of Environmental Exposure:
Uncontrolled spill could cause pollution.

Historical Accident Record:
As far as an overall facility record, three drops of Anhydrous Hydrazine were spilled in 1986 on disconnect of a fueling line. There has been no spill of Monomethyl Hydrazine from this facility as of this date.

GENERAL INFORMATION

General Information to assist first responders:
Evacuate away from product. Flood with water to fight fire, to prevent reignition and to keep exposed contaiers cool. Remove all sources of ignition. Isolate area of spill by diking. Stop source of leak. Dilute to 5% or less. Add 5% solution of a hypochlorite solution.



EHS: Methyl Hydrazine

CAS # : 60-34-4
Facility Name: Astro Technologies Inc
Address: 1515 Chaffee Dr. (Grissom
Industrial Pk) Titusville
32796-
Coordinator: Bruce Campbell
Phone: (407)268-3830
Location : urban

Vulnerable Zone(3.4 mph Windspeed)
Radius: 0.5 (mi.)
VZ Area: 0.8 (sq.mi.)

Vulnerable Zone(11.9 mph Windspeed)
Radius: 0.2 (mi.)
VZ Area: 0.1 (sq.mi.)

Critical Nearby Facilities: There are no critical facilities within the vunerability zone.

APPENDIX B

Releases reported to the National Response Center
1982 - 1990

Appendix B details information concerning hydrazine and NO_x releases reported to the National Response Center from 1982-1990. NO_x compounds include nitrogen tetroxide and its primary dissociation products, nitrogen dioxide and nitrogen oxide. Anhydrous hydrazine and monomethyl hydrazine, are the only compounds used by Astrotech to appear on the SARA Title III list of Extremely Hazardous Substances; releases of NO_x are also required to be reported to the National Response Center under CERCLA.

Both the hydrazines and nitrogen tetroxide have a wide variety of other uses. The largest manufacturers of anhydrous hydrazine in the U.S. are Olin Chemicals (approximately 21 million lbs/yr), Mobay (14 million lbs/yr and Fairmount Chemical (1 million lbs/yr). Total U.S. production averages around 36 million lbs/yr, of which 29 million lbs are sold commercially. Nitrogen tetroxide is manufactured by a single source in the U.S., Cedar Chemical Corporation in Vicksburg, MS. Based on data from the U.S. Air Force Directorate of Energy Management, Kelly AFB, the annual production capacity for nitrogen tetroxide is estimated to be 3 million lbs per year.

Because anhydrous hydrazine and monomethyl hydrazine can both be reported as hydrazine solutions, the graph that follows, Discharges of Hydrazine Releases, summarizes releases of all forms of hydrazine reported. The majority (35.06%) of the releases were from public utilities, with another significant portion from manufacturing/chemical industries (28.57%). NASA or space-related releases only accounted for 9.09% of the total.

A similar graph for Discharges of NO_x Releases, indicates that the majority of releases originate from manufacturing/chemical industrial users (74.24%), and that only 10.61% of the releases originate with NASA or space-related concerns.

The final figures in this appendix show the distribution of releases over a range of release rates (number of pounds per release). In the majority of hydrazine releases, less that 10 pounds was released. However, slightly more NO_x was released in each incident, with most spills falling in the 10 to 100 pound range.

HYDRAZINE AND NOX RELEASES, 1982 - 1990*

HYDRAZINE

		RELEASE DISCHARGER					
Material+	Total No Releases	Public Utilities	Manufacturing/ Chem. Industry	Transportation-Related	Aircraft-Related	NASA or Space-Related	Unknown
Hydrazine@	41	15	12	2	4	5	3
Hydrazine 35%	12	8	3	1	0	0	0
Hydrazine 54%	2	1	0	1	0	0	0
UDMH	3	0	3	0	0	0	0
Monomethylhydrazine	1	0	0	1	0	0	0
Other Hydrazine Solutions^	18	3	4	8	0	2	1
TOTALS:	77	27	22	13	4	7	4

NOX

		RELEASE DISCHARGER					
Material+	Total No Releases	Public Utilities	Manufacturing/ Chem. Industry	Transportation-Related	Aircraft-Related	NASA or Space-Related	Unknown
N2O4	31	1	19	3	1	6	1
Other NOX (NO, NO2)	35	3	30	0	1	1	0
TOTALS:	66	4	49	3	2	7	1

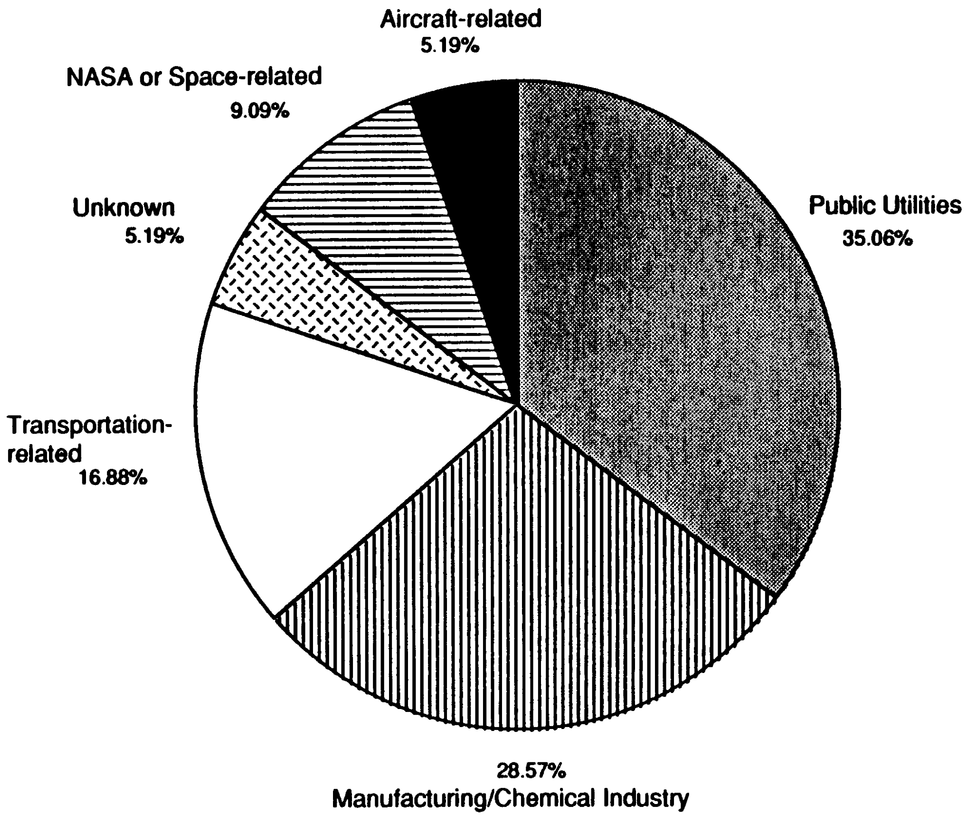
* As reported to the National Response Center (NRC).

+ Chemical characterizations as reported to the NRC. Due to inconsistencies in release reporting, reports of Hydrazine releases may include some Hydrazine solutions.

@ Includes one release of Aerozine 50 (50% UDMH, 50% Hydrazine)

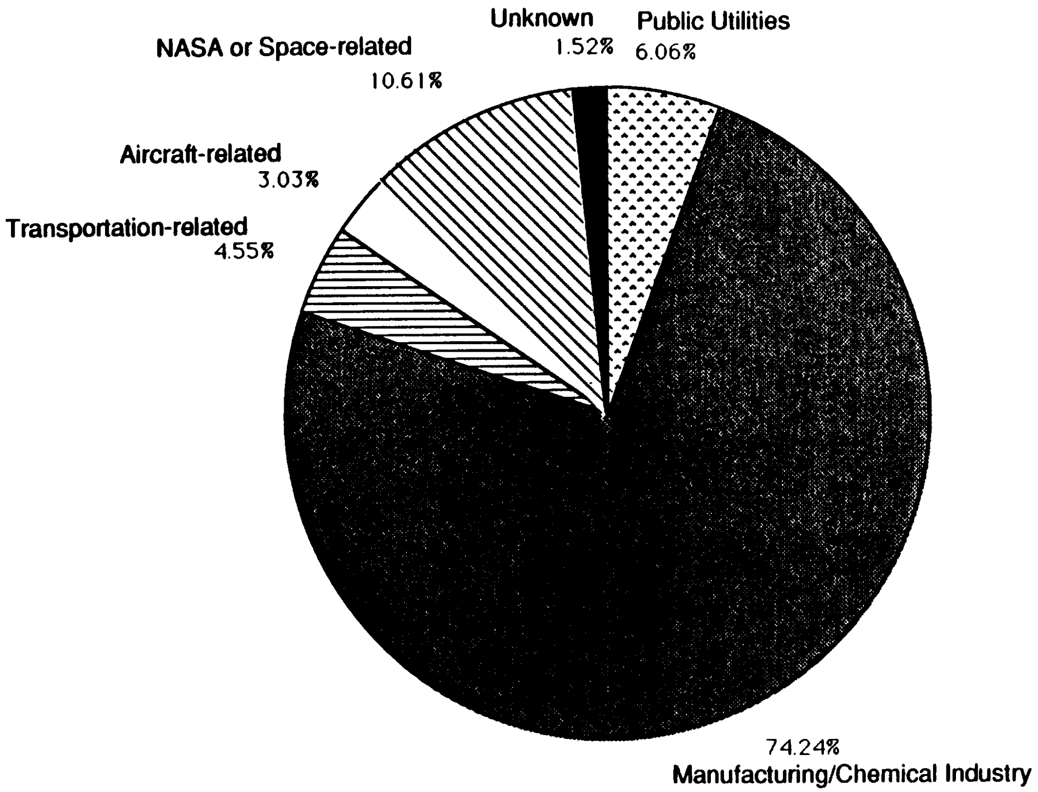
^ Solutions include: Hydrazine 22%, ORM-A.N.O.S. 30%, Hydrazine Aqueous Solution UN2030, Hydrazine 2-1/2%, and Hydrazine and NDMA (wastewater).

DISCHARGES OF HYDRAZINE, 1982 - 1990



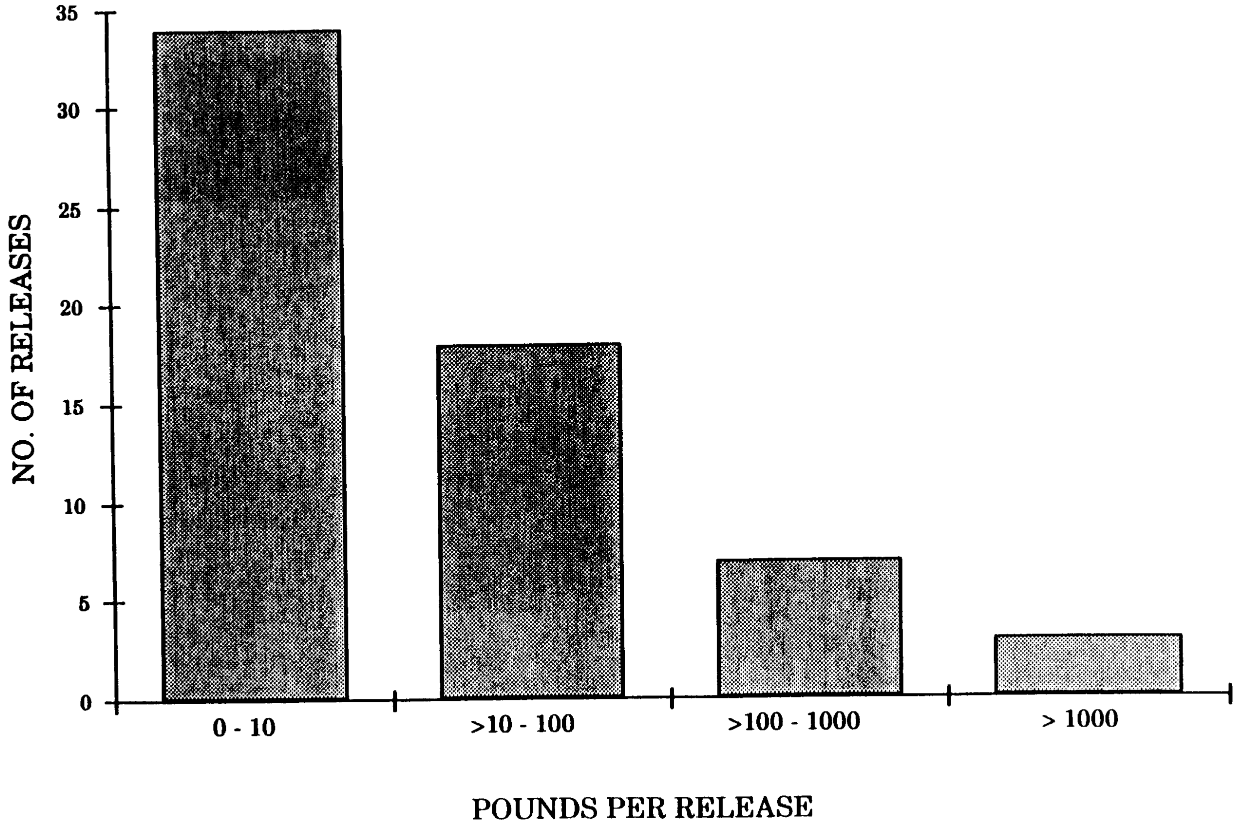
NOTE: Table shows releases as reported to the National Response Center. Due to inconsistencies in reporting, reports of hydrazine releases may include some hydrazine solutions.

DISCHARGES OF NOX , 1982 - 1990



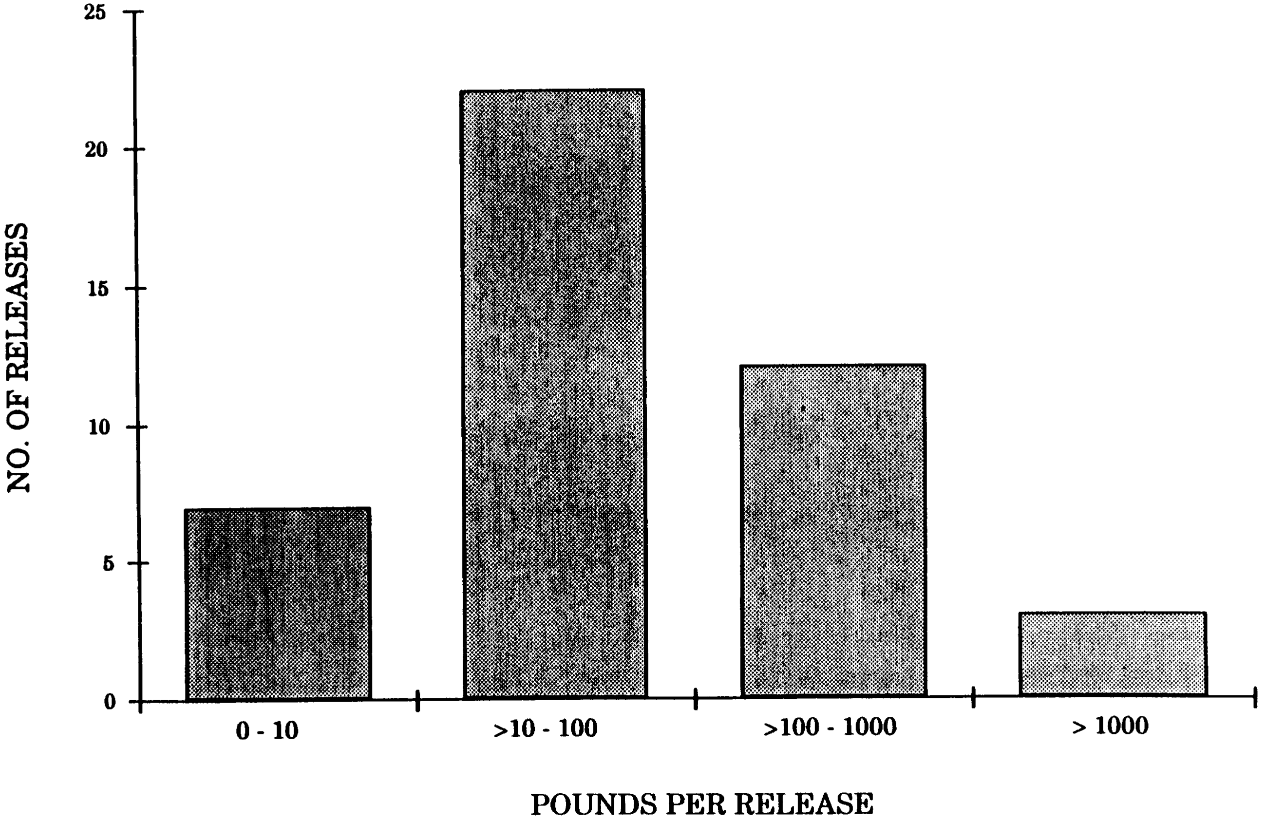
NOTE: Table shows releases as reported to the National Response Center. Releases include nitrogen tetroxide, nitrogen dioxide, and nitrogen oxide.

QUANTITIES OF HYDRAZINE RELEASED, 1982 - 1990



NOTE: Quantities shown are those reported to the National Response Center . Table includes releases of anhydrous hydrazine as well as hydrazine solutions.

QUANTITIES OF NOX RELEASED, 1982 - 1990



NOTE: Quantities shown are those reported to the National Response Center. Table includes releases of nitrogen tetroxide, nitrogen dioxide, and nitrogen oxide.

APPENDIX C

Specifications for MDA Gas Detectors

Appendix C contains general instrument specifications for MDA toxic gas detectors. In Building 2, these detectors are used to monitor the vapor concentrations of anhydrous hydrazine, monomethyl hydrazine and NO_x when liquid propellants are on site. They are a key component of Astrotech's detection and monitoring program. The detectors combine the use of a special chemical-specific detection tape with microprocessor control for speed, accuracy and specificity. MDA detectors are portable and Astrotech has encased them in special explosion-proof clear plastic cases. The concentration alarm consists of a continuous tone and a steady alarm light-emitting device. Two factory-set alarm levels are available for each chemical, as detailed in the specifications that follow. Astrotech monitors at the lower concentrations. In addition to the two alarm levels, response times and MDA chemcassette part numbers are listed in Appendix C.

TLD-1
Toxic Gas Detector

MDA The Monitoring People

Guide To Operation

TLD-1
Toxic Gas Detector

Appendix

General Instrument Specifications

Alarm Setting:	Factory set at 1 or 2 times TLV of the target gas for all gases except Diisocyanates (5 ppb or 20 ppb). Gas and alarm level indicated on faceplate of instrument.
Detection Technique:	Chemcassette Detection System
Alarm Indications:	Audio and visual alarms: SPDT relay contacts.
Voltage:	115 VAC 50/60 Hz or 230 VAC 50/60 Hz (± 10%)
Power:	20 Watts
Fuse Type:	5 × 20 mm
Fuse Rating:	F 250 mA/250 V (115 VAC systems); F 125 mA/250 V (230 VAC systems); F 630 mA/250 V (battery powered systems)
Battery Life: (where applicable)	Approximately 8 hours (with relays disabled)
Relay Rating:	48 VAC 5A: 28 VDC 5A
Analog Output:	Non-isolated 4-20 mA Max. load 1000 ohms (600 ohms for battery powered systems).
Dimensions:	6-½" × 8-⅜" × 7" (165 × 212 × 177 mm)
Weight:	7.5 pounds (3.4 kg): battery powered instrument 9.5 pounds (4.3 kg)
Operating Temperature Range:	32 to 104 deg. F: 0 to 40 deg. C

WARNING: THIS DEVICE NOT INTENDED FOR USE IN COMBUSTIBLE ATMOSPHERES; CONSULT MDA FOR APPROPRIATE ENCLOSURE SYSTEMS.

CAUTION: The TLD-1 should not be operated in direct sunlight or at elevated temperatures. This may cause damage to the instrument and/or Chemcassette.

Gas Response Specifications

Gas	Factory Set Alarm Level	Response Time (In seconds)	Chemcassette Part No.
Ammonia (NH_3)	25 ppm or 50 ppm	30	706002
Arsine (AsH_3)	50 ppb or 100 ppb	15	705502
Bromine (Br_2)	100 ppb or 200 ppb	60	711314
Chlorine (Cl_2)	1 ppm or 2 ppm	15	704006
Diborane (B_2H_6)	100 ppb or 200 ppb	30	705502
Diisocyanates			
HDI	5 ppb or 20 ppb	180	700506
TDI	5 ppb or 20 ppb	60	700506
PPDI	5 ppb or 20 ppb	60	700506
All others	5 ppb or 20 ppb	120	700506
Disilane (Si_2H_6)	5 ppm or 10 ppm	10	705502
Germane (GeH_4)	200 ppb or 400 ppb	240	705502
Hydrazines			
MMH	200 ppb or 400 ppb	120	708013
N_2H_4	100 ppb or 200 ppb	120	708013
UDMH	500 ppb or 1000 ppb	60	708013
Hydrogen Bromide (HBr)	3 ppm or 6 ppm	15	705505
Hydrogen Chloride (HCl)	5 ppm or 10 ppm	10	705505
Hydrogen Cyanide (HCN)	10 ppm or 20 ppm	10	704510

Gas	Factory Set Alarm Level	Response Time (In seconds)	Chemcassette Part No.
Hydrogen Fluoride (HF)	3 ppm or 6 ppm	30	705505
Hydrogen Selenide (H_2Se)	50 ppb or 100 ppb	60	705502
Hydrogen Sulfide (H_2S)	10 ppm or 20 ppm	10	701012
Nitric Acid (HNO_3)	2 ppm or 4 ppm	15	705505
Nitrogen Dioxide (NO_2)	3 ppm or 6 ppm	30	703012
Ozone (O_3)	100 ppb or 200 ppb	60	704514
Phosgene ($COCl_2$)	100 ppb or 200 ppb	30	702020
Phosphine (PH_3)	300 ppb or 600 ppb	15	705502
Silane (SiH_4)	5 ppm or 10 ppm	30	705502
Stibine (SbH_3)	100 ppb or 200 ppb	30	705502
Sulfur Dioxide (SO_2)	2 ppm or 4 ppm	15	705015
Sulfuric Acid (H_2SO_4)	250 ppb or 500 ppb	120	705505

APPENDIX D

Florida DER Permit

Appendix D contains a copy of the Florida DER Air Permit issued to Astrotech in 1989. In order to support the issuance of the permit, Astrotech commissioned a study by an independent consultant (see Section 7.1.2). In that study, emission rate estimates were made by reviewing processes at Astrotech and comparing them to operations at other facilities handling hydrazines (specifically the Olin anhydrous hydrazine manufacturing facility in Lake Charles, Louisiana). The scrubber efficiency (90%) as provided by the vendor (Tri-Mer Corporation) was also a component of the analysis. The resulting fugitive emissions estimates were then input to the Industrial Source Complex Short-Term dispersion model to project the maximum 8-hour ground level ambient concentrations for the materials of concern in the permit. The modeling results showed that the maximum ambient concentrations for all pollutants were below the DER's Acceptable Ambient Concentrations.

Supported by this analysis described, the Florida DER issued Astrotech a permit in November of 1989 that allows a maximum of 5,000 pounds of nitrogen tetroxide and 2,500 pounds of anhydrous hydrazine or monomethyl hydrazine. The permit also sets a monitoring schedule for yearly inspections of compliance with the permit conditions by a professional engineer, and requires that Florida DER be notified prior to these compliance inspections, so that they can also attend.

APPENDIX E

Correlation Between Sverdrup Method and MIL-STD-882B Definitions

CORRELATION BETWEEN SVERDRUP METHOD AND MIL STD 882B DEFINITIONS

Sverdrup Handbook 6000-8		MIL-STD-882B		
Threshold Level	Probability Value*	Level	Descriptive Word	Definition
8 X 10^{-2}	3 X 10^{-1}	A	Frequent	Likely to occur frequently
8 X 10^{-3} life	3 X 10^{-2}	B	Probable	Will occur several times in of item
8 X 10^{-4} life	3 X 10^{-3}	C	Occasional	Likely to occur sometime in of item
8 X 10^{-5} occur	3 X 10^{-4}	D	Remote	Unlikely but possible to in life of item
	3 X 10^{-5}	E	Improbable	So unlikely it can be assumed occurrence may not be experienced

*Arbitrarily selected, dimensionless numbers.

APPENDIX F

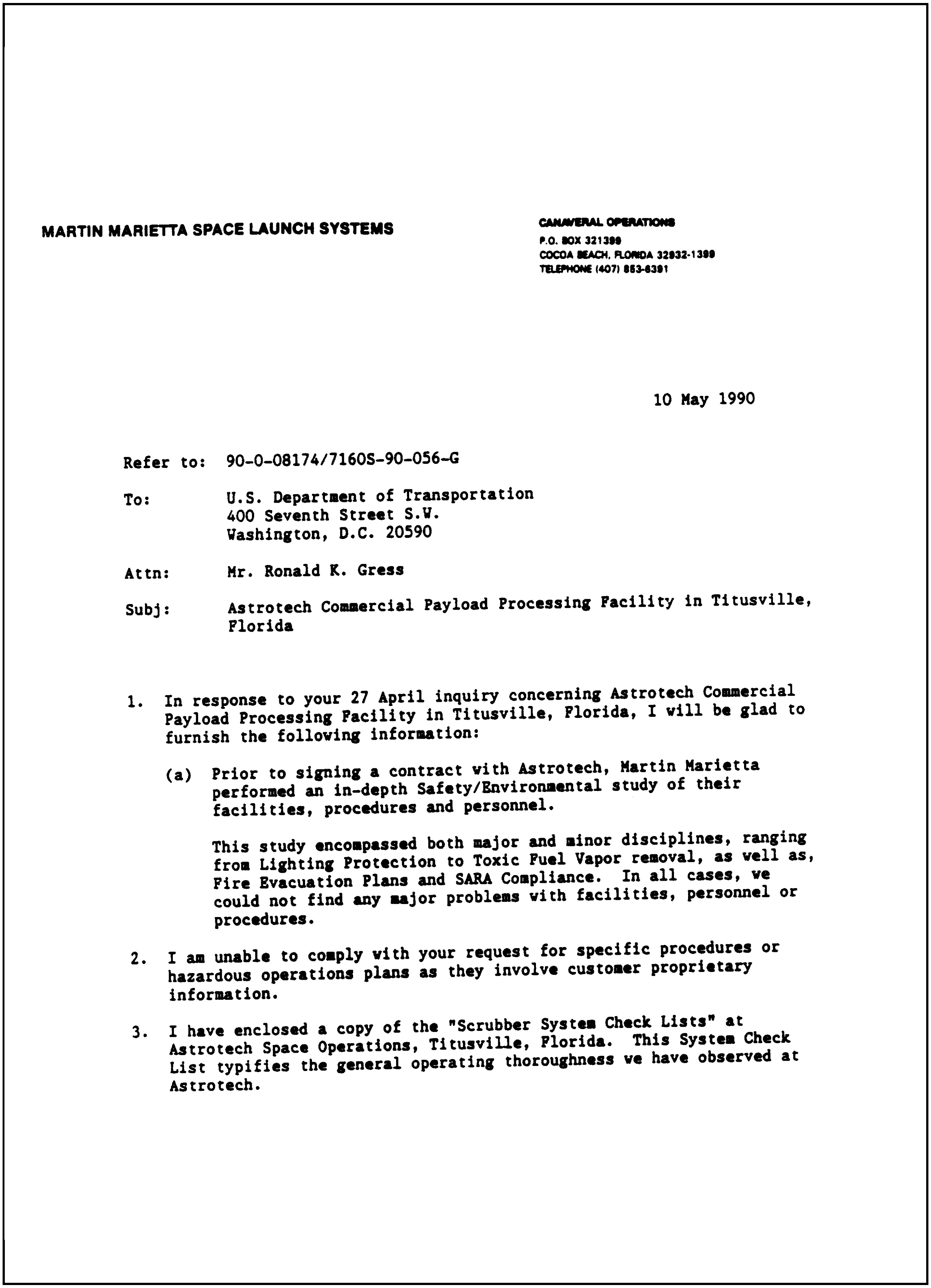
Customer Comments

Appendix F consists of comments elicited by OCST from payload customers who have used Astrotech's facility to process commercial payloads. These companies were asked to rate Astrotech's overall performance in the areas of process safety, materials storage and handling, risk management and release prevention. This overview is intended to serve as a supplement to this report, providing an additional independent view of Astrotech's performance in protecting public health and safety.

Companies responding were:

- Martin Marietta Space Launch Systems
- Ford Aerospace
- McDonnell Douglas Space System Company
- General Electric Astro Space Division

The responses were favorable regarding Astrotech's facility and safety policy. No major criticisms were received, contractors noted that Astrotech's safety requirements were compatible with their own and those in place at Government facilities.



MARTIN MARIETTA SPACE LAUNCH SYSTEMS

CANAVERAL OPERATIONS
P.O. BOX 321399
COCOA BEACH, FLORIDA 32932-1399
TELEPHONE (407) 853-6391

10 May 1990

Refer to: 90-0-08174/7160S-90-056-G

To:
U.S. Department of Transportation
400 Seventh Street S.W.
Washington, D.C. 20590

Attn: Mr. Ronald K. Gress

Subj: Astrotech Commercial Payload Processing Facility in Titusville, Florida

1. In response to your 27 April inquiry concerning Astrotech Commercial Payload Processing Facility in Titusville, Florida, I will be glad to furnish the following information:

    (a) Prior to signing a contract with Astrotech, Martin Marietta performed an in-depth Safety/Environmental study of their facilities, procedures and personnel.

    This study encompassed both major and minor disciplines, ranging from Lighting Protection to Toxic Fuel Vapor removal, as well as, Fire Evacuation Plans and SARA Compliance. In all cases, we could not find any major problems with facilities, personnel or procedures.

2. I am unable to comply with your request for specific procedures or hazardous operations plans as they involve customer proprietary information.

3. I have enclosed a copy of the "Scrubber System Check Lists" at Astrotech Space Operations, Titusville, Florida. This System Check List typifies the general operating thoroughness we have observed at Astrotech.

4. The Commercial Titan Operations Manager, Mr. Donald W. Fleming, or a member of his staff will be available to answer any additional questions you might have to complete your review of Astrotech.

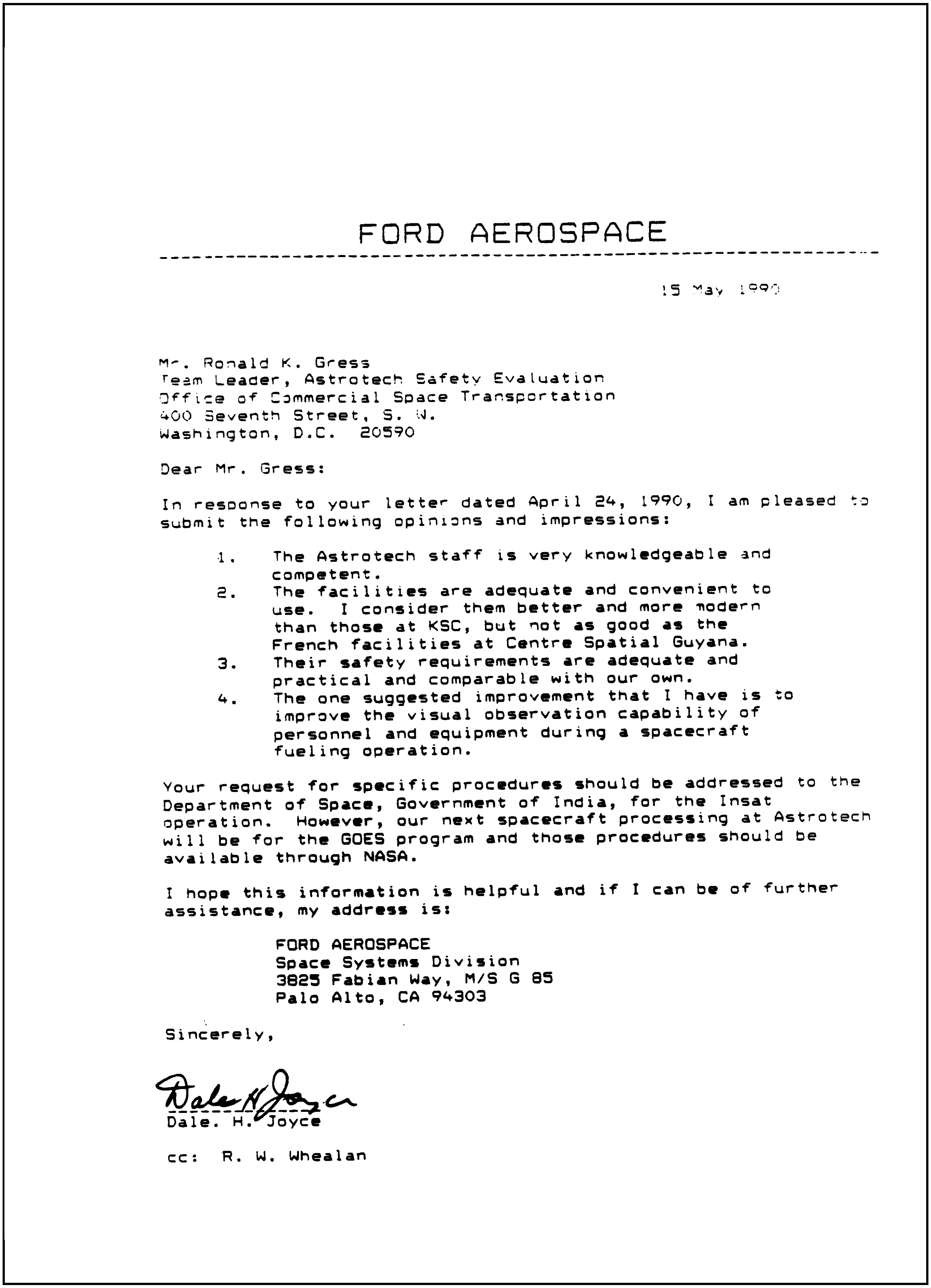
5. If you need any further assistance, please contact me at (407) 853-9191.

Very Truly Yours,

MARTIN MARIETTA CORPORATION

D.W. Fleming for
W.E. Fields,
Director
Canaveral Operations
Space Launch Systems

WEF:JCH:kd



FORD AEROSPACE

15 May 1990

Mr. Ronald K. Gress
Team Leader, Astrotech Safety Evaluation
Office of Commercial Space Transportation
400 Seventh Street, S. W.
Washington, D.C. 20590

Dear Mr. Gress:

In response to your letter dated April 24, 1990, I am pleased to submit the following opinions and impressions:

1. The Astrotech staff is very knowledgeable and competent.
2. The facilities are adequate and convenient to use. I consider them better and more modern than those at KSC, but not as good as the French facilities at Centre Spatial Guyana.
3. Their safety requirements are adequate and practical and comparable with our own.
4. The one suggested improvement that I have is to improve the visual observation capability of personnel and equipment during a spacecraft fueling operation.

Your request for specific procedures should be addressed to the Department of Space, Government of India, for the Insat operation. However, our next spacecraft processing at Astrotech will be for the GOES program and those procedures should be available through NASA.

I hope this information is helpful and if I can be of further assistance, my address is:

FORD AEROSPACE
Space Systems Division
3825 Fabian Way, M/S G 85
Palo Alto, CA 94303

Sincerely,

Dale H Joyce

Dale. H. Joyce

cc: R. W. Whealan

MCDONNELL DOUGLAS

McDonnell Douglas Space Systems Company

A41-L400-AF/DELTA-L-62
25 June 1990

Subject: SAFETY EVALUATION OF ASTROTECH SPACE OPERATIONS' TITUSVILLE FACILITY

To: Department of Transportation
Office of Commercial Space Transportation
Attention: R. K. Gress
Team Leader, Astrotech Safety Evaluation
400 Seventh Street, S.W.
Washington, D. C. 20590

Dear Mr. Gress:

McDonnell Douglas has been processing space hardware at Astrotech since late 1984. We prepared ten Payload Assist Modules in the Astrotech facility for the Shuttle Space Transportation System, and, more recently, six payloads for the Delta rocket. Our experiences with Astrotech have been satisfactory and consistent with our own safety program requirements.

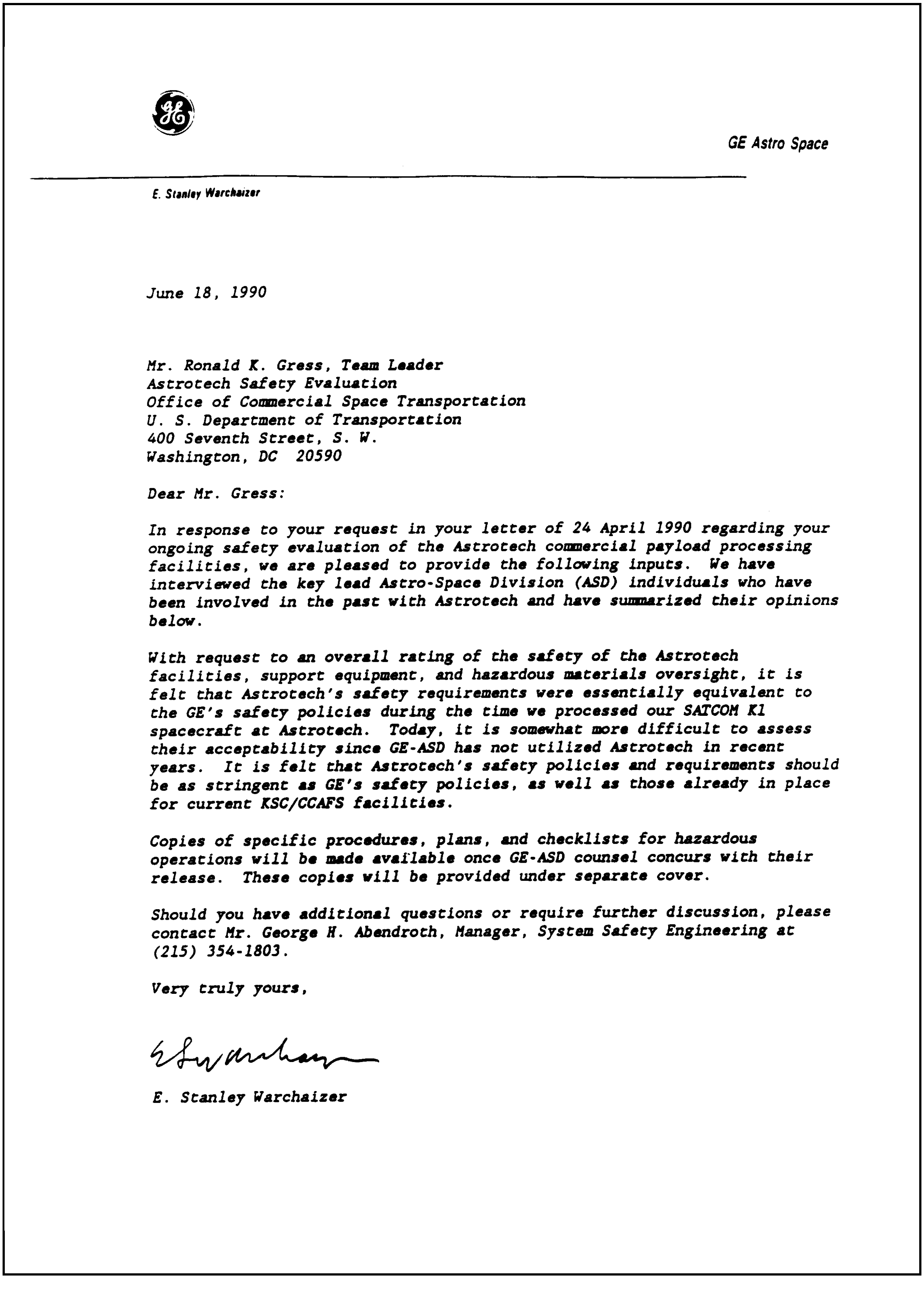
The conduct of the MDSSC operations at Astrotech are performed in the manner as when we do similar work in the USAF hazardous processing facilities on the Cape Canaveral Air Force Station. Our company's Safety Operating Procedure, SOP-F14-R2, dated September 1985, is enclosed for your review. Our requirements represent the cumulative knowledge and experience generated over the last thirty years in dealing with hazards associated with the assembly and testing of rocket systems.

If we can be of further assistance to you in evaluating Astrotech's safety programs, please feel free to call me or Don Maclean, (407) 853-5594 or 853-5196, respectively.

for L. J. Holloway
Director - Launch Sites
Delta Launch Vehicle Division
MDSSC

Enclosure: as noted

Cape Canaveral Air Force Station, P.O. Box 833, Cape Canaveral, FL 32920-0833



GE Astro Space

E. Stanley Warchaizer

June 18, 1990

Mr. Ronald K. Gress, Team Leader
Astrotech Safety Evaluation
Office of Commercial Space Transportation
U. S. Department of Transportation
400 Seventh Street, S. W.
Washington, DC 20590

Dear Mr. Gress:

In response to your request in your letter of 24 April 1990 regarding your ongoing safety evaluation of the Astrotech commercial payload processing facilities, we are pleased to provide the following inputs. We have interviewed the key lead Astro-Space Division (ASD) individuals who have been involved in the past with Astrotech and have summarized their opinions below.

With request to an overall rating of the safety of the Astrotech facilities, support equipment, and hazardous materials oversight, it is felt that Astrotech's safety requirements were essentially equivalent to the GE's safety policies during the time we processed our SATCOM K1 spacecraft at Astrotech. Today, it is somewhat more difficult to assess their acceptability since GE-ASD has not utilized Astrotech in recent years. It is felt that Astrotech's safety policies and requirements should be as stringent as GE's safety policies, as well as those already in place for current KSC/CCAFS facilities.

Copies of specific procedures, plans, and checklists for hazardous operations will be made available once GE-ASD counsel concurs with their release. These copies will be provided under separate cover.

Should you have additional questions or require further discussion, please contact Mr. George H. Abendroth, Manager, System Safety Engineering at (215) 354-1803.

Very truly yours,

E. Stanley Warchaizer

Currently Under Development