Procedures and Guidelines

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COMPLIANCE IS MANDATORY

Responsible Office: 500/AETD Safety

Title: Applied Engineering and Technology Directorate Safety Manual

PREFACE

P.1 PURPOSE

The Applied Engineering and Technology Directorate (AETD) Safety Manual is intended to establish the safety requirements of the AETD safety program, and to provide GSFC personnel contacts on specific subjects. It summarizes the required safety information needed to conduct activities in AETD facilities. This Manual lists the pertinent NASA, GSFC, and Occupational Safety and Health Act (OSHA) requirements documents. It is not intended to replace any of the above documents. For more detailed information, the reference documents listed in each section must be consulted. For specific requirements for operations within each Division, refer to the specific Division Manual.

P.2 APPLICABILITY

This Manual applies to all GSFC organizational elements, contractors, commercial projects, and personnel from other Government agencies while in AETD facilities and all AETD personnel when located in non-AETD work areas, unless the local requirements are stricter. The Manual sets the minimum requirements needed to conduct safe operations.

P.3 AUTHORITY

NPR 8715.3, NASA Safety Manual
OSHA 29 CFR 1910, Occupational Safety and Health Standards

P.4 REFERENCES

Each section lists the unique reference documents applicable for that section.

P.5 CANCELLATION

None

P.6 SAFETY

This Manual sets forth the requirements for conducting safe operations within the Applied Engineering and Technology Directorate, Goddard Space Flight Center (GSFC), Greenbelt, Maryland and Wallops Flight Facility (WFF), Wallops Island, Virginia. It defines the requirements, responsibilities, and authorities for all activities conducted within the AETD facilities, and it delineates policies, processes, and approvals for those activities.

Although this AETD Manual does not specifically list the NPR 8715.3, *NASA Safety Manual* in each section of the Manual, it is understood that NPR 8715.3 sets the requirements for the overall safety program, which will always be followed. Cross-referenced section numbers, which point to more detailed information on a subject within the document, are enclosed in parentheses. The reader should check the table of contents.

This Manual is arranged to benefit both local facility users and personnel coming into AETD from outside the organization. It is divided into sections to help the reader. These sections contain the following information:

- Section 1.0 is an overview of responsibilities and generic information that applies throughout the Manual.
- Section 2.0 provides safety information strongly associated with test articles being brought into facilities
- Section 3.0 describes other AETD general operating/safety requirements over and above those specific topics addressed in section 2.0.

P.7 TRAINING

Any required training is listed in the applicable section.

P.8 RECORDS

Record Title	Record Custodian
Non-ionizing Radiation Systems, forms GSFC 23-6RF, 23-28RF, 23-35RF, 23-6L, 23-28L, 23-67B, and 23-35LU	GSFC Radiation Protection Office
Ionizing Radiation Systems, forms GSFC 23-6I, 23-28I, 23-35IP, 23-6ID and 23-28ID	GSFC Radiation Protection Office
Flight Weight Pressure Systems Formal Certification Report	Appropriate Branch Head
Medium Weight Pressure Systems Formal Certification Report	Appropriate Branch Head
Hot Work Permit forms GSFC 23-4 and 23-4A and Utility Outage Request Form	Issuing Organization
Confined Space Entry Permit form GSFC 23-52	Issuing Organization
Hazardous Waste Disposal form GSFC 23-54	Hazardous Waste Environmental Office
Material Safety Data Sheets (MSDS)	Appropriate Branch Head or Safety Representative
Incident or Mishap NASA Form 1627A and NASA Form 1627 or on the Incident Reporting Information System (IRIS) at web site https://nasa.ex3host.com/Iris/newmenu/login.asp	Issuing Organization

P.9 METRICS

None

P.10 DEFINITIONS

Ω	ohm
µ	micro
ac or AC	alternating-current
ACGIH	American Conference of Governmental Industrial Hygienists
AETD	Applied Engineering and Technology Directorate
AGMA	American Gear Manufacturer's Association
amu	atomic mass units
ANSI	American National Standards Institute
APT	automatically programmed tool
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing Materials
AWS	American Welding Society
°C	degrees Celsius
CFM	cubic feet per minute
CG or cg	center of gravity
c	centi
CMAA	Crane Manufacturer's Association of America, Inc.
CPR	cardiopulmonary resuscitation
CTD	cumulative trauma disorder
CTS	carpal tunnel syndrome
dB	decibel
dc or DC	direct-current
DOT	Department of Transportation
EDM	electrical discharge machine
EED	electro-explosive device
EMC	electromagnetic compatibility
EMI	electromagnetic interference
ESD	electrostatic discharge
ETU	engineering test unit
°F	degrees Fahrenheit
FMD	Facilities Management Division
FMEA	failure modes and effects analysis
FOM	Facility Operations Manager
ft	feet
g	gram
g	unit of acceleration (9.81 m/sec^2)
GFCI	ground fault circuit interrupter
GHB	Goddard Handbook
GHz	gigahertz
GMI	Goddard Management Instruction
GN_2	gaseous nitrogen
GND	ground
GSE	ground support equipment
GSFC	Goddard Space Flight Center
HCC	High Capacity Centrifuge
HOPs	Hazardous Operating Procedures
HVAC	heating, ventilation, and air conditioning
Hz	Hertz (cycles per second)
IDLH	Immediately Dangerous to Life or Health
IEEE	Institute of Electrical and Electronic Engineers
IR	infrared radiation
IRIS	Incident Reporting Information System
ISI	inservice inspection
k	kilo
K	degrees Kelvin
kpa	kilopascal
lb	pound
lb/ft^2	pound/square foot
LDE	lifting devices and equipment
LEV	local exhaust ventilation
LFL	lower flammable limit
LN_2	liquid nitrogen
m	milli or meter
M	mega
MAWP	maximum allowable working pressure
MDP	maximum design pressure
MGSE	mechanical ground support equipment
MIL STD	Military Standard
MOI	moment of inertia
MSDS	Material Safety Data Sheet

n	nano
NC	numerically controlled
NDT	Nondestructive testing
NEC	National Electrical Code
NFPA	National Fire Protection Association
Ni-Cd	nickel-cadmium
NIOSH	National Institute for Occupational Safety and Health
NHB	NASA Handbook
NSS	NASA Safety Standard
OEM	original equipment manufacturer
OHA	operating hazard analysis
OSHA	Occupational Safety and Health Act
pa	Pascal
PEL	permissible exposure limit
PETS	payload environmental transport system
PIT	Powered Industrial Truck
psi	pounds per square inch
psig	pounds per square inch gauge
PPE	personal protective equipment
PSTL	Project Support Team Lead
PV/S	pressure vessels and systems
RBO	regulator burnout
RECERT	Recertification Program
RF	radio frequency
RFI	radio frequency interference
RMSS	Remote Manipulator System Simulator
RPO	Radiation Protection Officer
RWA	reaction wheel assembly
S&ED	Safety and Environmental Division
SCA	Spacecraft Checkout Area
SED	stored energy device
SES	Space Environment Simulation
SLM	sound level meter
SMTF	Spacecraft Magnetic Test Facility
SO_2	sulfur dioxide
SPL	sound pressure level
SSDIF	Spacecraft Systems Development and Integration Facility
T	temperature
T/H	temperature humidity
T/V	thermal vacuum
TCU	thermal conditioning unit
TIG	tungsten inert gas
TLV	threshold limit value
TLV-C	threshold limit value—ceiling
TLV-STEL	threshold limit value—short-term exposure limit
TLV-TWA	threshold limit value—time-weighted average
UL	Underwriter's Laboratories
UV	ultraviolet
VDT	video display terminal
w	watt
WFF	Wallops Flight Facility

PROCEDURES

In this document, a requirement is identified by "shall" or "must," a good practice by "should," permission by "may" or "can," expectation by "will," and descriptive material by "is."

Table of Contents

List of Figures and Tables

1.0 Introduction

Safety, in the context of this document, represents the efforts to identify and minimize the hazards associated with operations in AETD. This document provides all personnel operating in AETD facilities the requirements established for their safety. It is our goal to meet these safety requirements with minimum impact to operations.

1.1 Policies

It is the policy of the AETD to provide a safe work place for all personnel and operations. AETD strives to eliminate or reduce all potential hazards, thereby avoiding undue risk and accidents that can result in loss of life, injury to personnel, damage to property, or loss of operating time and effectiveness. Safety shall always take precedence over operations or schedule. Where hazards cannot be eliminated, engineering controls, personal protective equipment (PPE), and controlled areas shall be used to protect personnel, equipment, and facilities.

1.2 Responsibility

Safety is everyone's responsibility. 500-PG-8715.1.1, *AETD Safety Plan*, list the responsibilities of the Directorate Office, Division Offices, Branch Heads, Safety Representatives, and employees.

Each building or complex has an appointed Facility Operations Manager (FOM). The FOM's responsibilities as delineated in the Facilities Operations Manager Handbook are to do the following:

- Identify hazards not adequately controlled by the line supervisor. The FOM has the authority to stop work where risk to personnel, facility, or equipment is unacceptable.
- Initiate action to correct or control hazards.
- Ensure that Facilities Management Division (FMD) safety plans for work within their jurisdiction are adequate and comply with this Manual. Questions the FOMs have as to safety requirements shall be directed to the Safety and Environmental Division (S&ED).
- Approve and issue emergency evacuation plans for the facility, and monitor the designation and indoctrination of building evacuation wardens.

Each individual—including GSFC government personnel, personnel from other government agencies, and contractors—is responsible for complying with this Manual and identifying and correcting hazardous situations when noted. They shall correct unsafe conditions if it is within their ability to do so. If they cannot correct the situation, they shall ensure that the area is secure, to prevent harming others or damaging equipment, and notify their supervisor.

Flight project management or Product Design Leads (PDL) are responsible for assuring their team safety when working within AETD facilities. They shall assess the hazards inherent in their operations and hardware, mitigating all hazards to the lowest level. They are responsible for informing all other groups working on or within close proximity of their operations or hardware of any known hazards.

1.3 Personnel Certification/Qualification Definitions

Personnel must be trained in the special skills, technical knowledge, and safety requirements necessary to perform their jobs and operate facilities, systems, and machines within AETD. Unless specifically noted otherwise, the following personnel certification and qualification definitions apply throughout this Manual:

- Authorized or Designated—An individual who has been selected or assigned by the Branch or organization management as being qualified to perform specific duties.
- Certified—An individual who has completed required training and whose specific knowledge or proficiency in a skill has been demonstrated and documented by the Authority Having Jurisdiction.
- Competent—An individual who is capable of identifying existing and predictable hazards in the working environment, or working conditions which are dangerous to personnel, and who has authorization to take prompt corrective measures to eliminate them.
- Critical—An individual who has the duties and responsibility to make decisions that could affect the safety of personnel, hardware, or facilities; or one who is working critical operations, such as assembling high dollar value equipment. Examples of critical persons are task leaders and critical crane operators.
- Qualified—An individual who, by possession of a recognized degree, certificate, or professional standing, or knowledge, training, and experience, has successfully demonstrated the ability to solve or resolve problems related to the subject matter, the work, or the project, or to satisfactorily operate a facility, system, or machine. The Branch or organization management determines necessary qualifications according to the assigned task.
- Training—An organized and documented program of activities designed to impart the knowledge and skills required to be qualified to perform specific duties.

1.4 Waivers

Compliance with the requirements of this Manual is mandatory unless an approved waiver has been obtained from Director of. Waiver requests for other GSFC Safety Program requirements and/or policies must be prepared and submitted to the authority having jurisdiction for process and approval.

1.5 Mishaps/Incidents

All significant mishaps and incidents (requiring more than first aid) and close calls (could have caused death or serious injury) shall be reported to the Branch Head, Division Chief, Deputy Director for Planning and Development and S&ED. Significant mishaps or incidents shall be reported using the NASA mishap reporting system (NASA form 1627). Definitions of mishaps, investigation requirements, and instructions for completing the required forms may be found in Appendix B. Mishaps and close calls shall be assessed to determine where improvements in the safety program are required. Section 1.14 describes the continuous improvement process.

1.6 Emergency Evacuation

1.6.1 General

Any time evacuation alarms sound in the facilities, personnel are to evacuate. Emergency Action Plans for GSFC are found on web site http://safety1st.gsfc.nasa.gov/emp.html. To have personnel remain on station during critical testing (one in which sudden shut down could damage critical hardware), a separate evacuation plan must be submitted and approved by S&ED. The plan must reduce personnel on station and when eminent danger exists totally shut down and evacuate. All guest groups to AETD facilities shall have an evacuation plan for their employees that notify the Branch Head and S&ED of anyone needing assistance during emergency situations. Never use the elevators during an emergency. Any planned deviations to this procedure must be arranged beforehand, in writing, with the Branch Head and S&ED. Appendix A discusses mishaps and reporting requirements.

1.6.2 Non-Life-Threatening Emergency

In the event of a non-life-threatening emergency situation:

- Secure the area around the emergency, clearing all personnel except those seriously injured in cases where movement would make the injury worse and the injured is in no immediate danger.
- If the emergency situation can be brought under control without placing personnel in danger, do so.
- Call the Emergency Console (911). Specify the emergency condition, location (building and room), and your name and phone number.
- Designate a specific person to meet the Goddard emergency personnel to inform them of the problem and the status of the situation, and to direct them to the emergency.
- Clean up the area when authorized to do so.

1.6.3 Life-Threatening Emergency

In the event of a life-threatening emergency situation:

- Sound the nearest fire alarm. All personnel shall immediately secure their equipment and evacuate to the designated evacuation area. Stay at least 100 feet from the building, out of the road.
- Go to the nearest safe telephone and call the Emergency Console (911). Specify the emergency condition, location (building and room), and your name and phone number.
- If conditions permit, divert personnel from the hazardous area until trained personnel arrive.
- Designate a specific person to meet the emergency response personnel to inform them of the problem and status of the situation, and direct them to the emergency.

- Buildings 7 and 10 high bays have emergency exhaust fans, which may be activated.
- Re-enter only when told to do so by the emergency response personnel or Fire Department.
- Evacuation is required any time alarms sound longer than 30 seconds. (When the alarm is heard, start securing equipment in case this is not an alarm test.)

1.7 Construction

Most construction work performed under the control of FMD. When construction work is performed under the direction of any division within Code 500, this document and 29 CFR 1926, *Safety and Health Regulations for Construction*, shall apply.

1.8 Housekeeping

Although not specifically mentioned in each section, housekeeping is important to the safety of the overall operation. Each person is responsible for cleaning up the work area. Areas not adequately maintained in a clean state not only add to an unsafe condition, but normally affect the quality of the work product. As part of maintaining the work area, outside doors should be kept closed as much as possible.

1.9 Buddy System

The buddy system (two or more persons working together), established for work in hazardous situations, is designed to summon immediate help and provide assistance in case of an emergency. The most important guideline of the buddy system is that the buddy must summon help before providing assistance. When the buddy system is used, at any given time there should always be one individual not exposed to the hazard. The buddy system shall be used on all jobs that involve unprotected height, high voltage, confined spaces, hazardous materials used near or above Immediately Dangerous to Life and Health levels, or any other task that places personnel at extreme risk. When using the buddy system, personnel shall stay within sight of each other or be able to communicate.

1.10 Powered Vehicles

Containers of gasoline or gasoline-powered vehicles/equipment shall not be brought inside buildings. The appropriate Branch Head must approve the use of diesel-powered or propane-powered equipment inside the building on a case-by-case basis. If the Branch permits storage of equipment with diesel fuel within the building, a procedure must be written/approved and followed that verifies the system is not leaking, specifies steps to take if a leak occurs and notifies the S&ED of the location of the fuel.

1.11 Joint Occupied Areas

Work areas that are jointly occupied by Code 500 personnel and other groups shall be the safety responsibility of the facility owner unless a Memorandum of Understand (MOU) is developed to identify the responsible party. Appendix C provides an example of MOU that may be used to establish responsibility. Code 500 expects all groups working in Code 500 areas, as a minimum, to comply with this Manual. Failure to do so may result of a shut down of operations. Code 500 personnel and facilities shall not be placed at risk without the approval of Code 500 Management.

1.12 Procedural Requirements

Hazardous operations are those tasks that potentially have an immediate danger to the individual (death or injury) if not performed correctly, could create a danger to other individuals in the immediate area, or are a danger to the environment. These types of operations shall have written procedures and/or hazard analysis. The procedures must be written in detailed steps to provide maximum protection to personnel, prevent procedural error, and minimize misinterpretation. They must include appropriate warnings and cautions where malfunctions or errors may cause injury or damage. Prior to the start of any hazardous portion of a procedure, a pre-task briefing shall be held by the task leader with all personnel involved with the task to discuss the hazards, precautions, and required personal protective equipment. The completion of this shall be documented in the procedure. Hazardous procedures must be approved by the appropriate Line Manager or designee and by the appropriate safety engineer/representative. If a hazard analysis is used instead of a written procedure, it shall identify all hazards that shall be encountered during the performance of the operation.

1.13 Extended Work Hours

It is AETD policy to establish a limit on the maximum number of consecutive work hours per person to minimize the probability of mishaps due to personnel fatigue. Exceptions must be approved by the appropriate branch head. Personnel shall work:

- No more than 72 total work hours in a single work week (consecutive 7 day period)
- No more than 60 total work hours per work week when the overtime requirement extends into 2 work weeks or longer
- No more than 12 consecutive hours without an off duty break

Note: A minimum of 8 hours of off-duty between work periods is required.

1.14 Continuous Improvement

Safety programs are living programs that must change, constantly improving. In order to do this, AETD has implemented area inspections, safety discussions, review of mishaps/close calls, and surveys. Each branch shall generate reports when inspections are conducted and open items tracked until closed. Inspection shall be done at least quarterly. When employees are observed violating safety, not only is that employee's behavior corrected, but the overall program is assessed to determine where improvements are needed. Mishap

investigations and incident reports are used as a tool to correct problem areas within the program. Lessons learned from investigations shall be shared with all Divisions. Monthly discussions are held on safety topics, including close call/mishap reports, survey results, and inspection results. All inspection, audit, surveys, and mishap action items are posted in the AETD database (http://aetdsrrt.gsfc.nasa.gov/index.cfm).

1.15 Roll-Up Door Safety

Roll-up doors shall only be operated by authorized personnel. The authorizing official is posted at each door. Roll-up doors can unexpectedly fall when partially open if the drive mechanism fails. Doors must be parked in the full open or full closed positions, never partly open. Operators must be instructed in the following:

- Before operating the door inspect both sides to ensure there is clearance. Equipment can, and has been caught by a moving door and tipped over.
- Never travel or pass equipment under a moving door.
- Do not allow others to travel or pass equipment under a moving door. As the operator you are responsible for their safety.
- Do not travel or pass equipment under a partially open door. The door must be fully opened prior to equipment or personnel passing through. When partially open the door mechanism is loaded by the weight of the door.
- Never work under an open door.
- Close outside door as quickly as possible to keep birds and weather out.

2.0 Specific Safety Requirements

This section of the Manual is designed to summarize requirements and to specify the requirements to be used when working in AETD facilities. This is not meant to replace existing documents, but to help the reader locate the knowledge needed to work safely.

2.1 Mechanical Handling

2.1.1 Lifting Devices and Equipment (LDE)

2.1.1.1 Scope

This section covers lifting devices, such as overhead cranes, mobile cranes, and hoists.

2.1.1.2 Acronyms/Definitions

1. AGMA—American Gear Manufacturer's Association.
2. ANSI—American National Standards Institute.
3. CMAA—Crane Manufacturer's Association of America, Inc.
4. Critical Lift Coordinator (CLC)—A CLC is responsible for directing and giving commands to the rigger/crane operator, instead of the rigger/crane operator, during a lifting operation if designated in a critical lift procedure. If the CLC is in charge of the lifting operation, he/she shall instruct all personnel involved in the proper preparation, rigging, lifting, and final positioning to be achieved in the pre-lift briefing. Any transfer of responsibility for directing the lifting operation (e.g., from the CLC to the rigger/crane operator and vice versa) shall be identified in the critical lift procedure and emphasized in the pre-lift briefing.
5. Critical Lifts—Lifting operations with special, high-dollar items such as spacecraft, one-of-a-kind articles, or major facility components, whose loss would have serious programmatic or institutional impact. Critical lifts also include operations with special personnel and equipment safety concerns beyond normal lifting hazards.
6. LDE—Lifting Device and Equipment.
7. LDE Certification/Recertification—A process performed by the RECERT Manager, which leads to the initial certification, or continuation of certification, that an LDE is safe for use up to its rated load. The process includes, but is not limited to, LDE compliance and documentation reviews, tests, inspections, nondestructive testing, and analyses.
8. LDE Operator Certification—The documented status of LDE operators validating that they have been trained and are qualified and medically fit to perform lifting and rigging operations in accordance with NASA-STD-8719.9 and have been certified by the RECERT Manager.
9. NFPA—National Fire Protection Association.
10. Noncritical Lifts—Lifting operations that are of a routine, minimal-hazard nature and are governed by standard industry rules and practices.
11. OSHA—Occupational Safety and Health Administration.

2.1.1.3 General

The *Standard for Lifting Devices and Equipment*, NASA-STD-8719.9, establishes minimum safety requirements for LDE used for material handling. Compliance with NASA-STD-8719.9 is mandatory for all NASA-owned, NASA contractor, and visitor-supplied equipment to be used in support of NASA operations.

GPR 8719.1 and GPR 8834.1 defines the applicability, policy, and requirements to implement NASA-STD-8719.9 at NASA/GSFC in terms of LDE and LDE operator certification, and lifting operational requirements, respectively. The following section summarizes the salient requirements of the aforementioned documents.

2.1.1.4 Design/Operational Requirements

1. General Safety Rules for Lifting Operations:
   - Lifting devices shall not be loaded beyond their rated capacity.
   - Prior to an operation, the operator shall review the lifting device Logbook to determine possible impact on planned activity.
   - The operator shall ensure that the LDE certification is current prior to operation.
   - The operator shall establish safety zones before initiating operations. Safety zones should have appropriate barriers (rope, cones, etc.) established prior to lift.
   - The lifting hook shall be connected to facility ground before connecting to explosives or EEDs. (See Section 2.2.4)
   - Keys for access to some cranes may be controlled by the Branch Head.
   - Before starting lifting operation, the operator shall perform the required daily crane inspection, fill in the inspection sheet in the crane's log book, print name, sign and date it. The operator shall ensure that the hook is centered over the center of gravity in such a manner as to prevent swinging or side pulls.
   - When raising loads that approach the rated capacity of the crane, the operator shall test the brakes by raising the load minimally above the surface and holding the load long enough to allow any dynamics to dampen out, then check for load movement/drift.
   - If radio communications are to be used, crane operators shall test the communication system prior to the operation. Operation shall stop immediately upon communication loss, and shall not continue until communication is restored.
   - If hand signals are required, only standard signals shall be used, unless preplanned and agreed upon.
   - Loads shall be secured, balanced, and stabilized with proper slings. The use of tag lines may be required to keep the load controlled. Tag line personnel shall use caution not to impart undesirable motion to the load.
   - Person(s) shall not ride the hook or load at any time.
   - Suspended load operations, as defined in NASA-STD-8719.9 (Appendix A, NASA Alternate Standard for Suspended Load Operations), are discouraged at GSFC. However, if a suspended load operation must be conducted, the operation shall be in compliance with NASA-STD-8719.9. Prior to any suspended load operation, the operation shall be documented and coordinated through the RECERT Manager, and the RECERT Manager shall, in turn, consult with NASA HQ Office of Safety and Mission Assurance for guidance and concurrence.

- Personnel, or any limbs, shall not be located under suspended or moving loads. Waiver for any suspended load operations must be in accordance with the OSHA-approved *NASA Alternate Standard for Suspended Load Operations* and must be processed through the RECERT Manager.
- A Critical Lift Coordinator may be in charge of the operation and in his/her pre-lift briefing shall instruct all personnel involved about the positioning and moving to be done. There is no mandatory requirement for a CLC. Procedures shall specify the requirement, if a CLC is needed. The Critical Lift Coordinator is separate from the Crane Operator/Rigger.
- An operator shall be at the crane controls at all times while a load is suspended (OSHA requirement). Due to the length of some NASA operations, an operator change may be required while a load is suspended. This shall be accomplished via a procedure.
- Outdoor hoisting operations should not start if winds are above 20 knots (23 mph) steady state or if gusts exceed 35 knots (40 mph).
- Flight hardware should not be hoisted during a storm warning condition Code 3 (power outage could occur), unless the stoppage of cranes and other handling equipment due to a power failure cannot result in a condition unacceptable to the Project or AETD Managers. A waiver approved by the applicable Branch Head is required to hoist critical hardware during a Code 3 storm warning. The requesting organization shall make provisions to guard the suspended load until power is restored.
- If a crane fails to respond, lock the crane to prevent use, record the problem in the log book and notify the RECERT Group.

2. Equipment Certification:
   - GPR 8719.1 establishes the policy and requirements that lifting devices and equipment to be used for material handling service at GSFC are required to be certified/recertified by the RECERT Manager.
3. Critical lift requirements include the following:
   - LDE shall be certified for critical lifts.
   - Operators must be certified for critical lifts.
   - Safety Engineer or designee must be present.
   - Stress analysis must be performed.
   - Lift stability analysis must be performed.
   - Safety analysis must be performed.
   - Special lift procedures (technical operating procedures) must be followed.
4. Noncritical Lift:
   - LDE shall be certified per NASA-STD-8719.9 for noncritical lifts.
   - Operators, as a minimum, must be certified for noncritical lifts.

5. Personnel Training/Certification:
   - Only operators certified (licensed) by the RECERT Manager shall operate GSFC cranes. Personnel certification process includes formal training, written test, medical examination, and practical demonstration.
   - Operators shall have licenses in their possession when performing lift operations.
6. Safety Variances:

In the event that a mandatory NASA LDE requirement cannot be met, the Flight Project/Division Office shall prepare a safety variance request package in accordance with GPR 8719.1. Safety variances to mandatory NASA LDE requirements shall be approved by the Center Director in accordance with NPR 8715.3, *NASA Safety Manual*.

2.1.1.5 GSFC Contacts

RECERT Manager: (301) 286-4209
RECERT Support Function, Manager: (301) 286-5183
AETD Safety Manager: (301) 286-1035

2.1.1.6 Reference Documents Unique to this Section

American Welding Society (AWS) D1.1, *Structural Welding*

ASME B30.2, *Overhead and Gantry Cranes (Multiple Girder)*

ASME B30.9, *Slings*

NASA-STD-8719.9, *Standard for Lifting Devices and Equipment*

CMAA Specification No. 70, *Specifications for Electric Overhead Traveling Cranes*

CMAA Specification No. 74, *Specifications for Top Running and Under Running Single Girder Electric Overhead Traveling Cranes*

GPR 8719.1, *Certification and Recertification of Lifting Devices and Equipment*

GPR 8834.1, *Lifting Operation Requirements*

NFPA No. 70, *National Electric Code*

OSHA 29 CFR 1910.179, *Overhead and Gantry Cranes*

OSHA 29 CFR 1910.184, *Slings*

OSHA 29 CFR 1910.67, *Vehicle-Mounted Elevating and Rotating Work Platforms*

2.1.2 Lifting Assemblies/Components and Load Cells

2.1.2.1 Scope

This section covers the safety requirements to be met when using lifting assemblies and load cells. Lifting assemblies include lift slings and spreader bars, as well as individual lifting components such as shackles, eyebolts, hoist rings, and turnbuckles.

2.1.2.2 Acronyms/Definitions

1. Critical weld—A weld that if removed from the structural sling or component would cause structural failure.
2. Hyrda-set—A manually operated hydraulic lifting device designed to incrementally lift and lower critical loads such as space flight hardware.
3. Lift equipment (components)—Components such as wire rope cables, nylon straps, shackles, and hoist rings intended to be used in lifting operations.
4. Lift sling—A lifting device used for hoisting that has one or more legs to attach the load to the lift point.
5. Load cell—A device used to monitor applied load during lifting operations.
6. Nondestructive Testing (NDT)—Methods to examine materials or components in ways that do not impair future usefulness and serviceability of the material or component.
7. Spreader bar—a lifting device used for hoisting that employs a beam or beams to span the attached load and may include the use of a lift sling(s) in the assembly.

2.1.2.3 General

Operations employing lifting assemblies, load cells, and lifting components shall be considered hazardous, and proper safety precautions must be adhered to at all times. The employee must be certified to use the equipment, and the equipment must be thoroughly inspected prior to each use and possess a clearly visible, current certification tag. Employees must understand the most common hazards of their operation, such as:

- Injuries from falling items due to equipment or hardware failure.
- Injuries from swinging items due to inattention or poor equipment operation.
- Shock, fire, and electrocution from electrical problems.

2.1.2.4 Design/Operational Requirements

Employees who work with lifting assemblies, load cells, and lifting components shall inspect them before each use to verify that they are in proper working condition and that they have visible and current certifications. Guidelines for the use of this equipment are as follows:

1. Lifting operations require the use of hard hats except in the specific circumstances described in Section 3.6.4. Safety glasses or goggles must be worn in the presence of flight hardware containing high-pressure fluids with low safety factors (less than 4 to 1).

2. Lifting assemblies, individual lifting components, and load cells shall be certified and affixed with a tag in accordance with GPR 8719.1. All out-of-date equipment shall be segregated and positively controlled to preclude inadvertent use by placing in a designated area and labeling as out of service until recertified. The certification tag shall include the following:
   - Assembly or component identification number.
   - LDE category.
   - Rated load.
   - Date due.
   - Inspector's identification.
3. A lift stability analysis and stress analysis shall be required for all critical lifts. Stress analysis shall verify factors of safety for structural slings to a minimum of either three times yield or five times ultimate. (See NASA-STD-8719.9 for detailed requirements.)

   In general, slings and components must be tested to a factor of 2.0:1 if they are new, repaired, or modified. If a recertification test is performed, it must be to a factor of 1:1. When the item is used to lift critical hardware, testing must be performed annually; otherwise, the testing period is every four years. (See NASA-STD-8719.9 for exact testing and NDT requirements.) If replacement of a damaged lifting assembly component is required, the replacement must be identical and individually proof tested. The RECERT Manager shall approve all proof test procedures performed on GSFC. Incoming hardware shall be inspected in accordance with RECERT requirements. Documentation, including procedures, NDT reports, and/or certification of compliance, for hardware that is proof tested and inspected out-of-house must be submitted to the RECERT Manager for review and hardware certification prior to use.

   - If a lift assembly is presented to RECERT for (re)certification with the individual items color-coded, tethered, or otherwise configuration controlled, and there are no plans to disassemble the assembly or rearrange the configuration, then the assembly shall be load tested as a unit with each item NDT's and one RECERT tag applied.
   - If a lift assembly is presented to RECERT for (re)certification, and the assembly will be disassembled and the individual items are not color-coded, tethered, or otherwise configuration controlled, the assembly may be load tested as a unit or each component load tested individually with each item NDT'd. Load test RECERT tags are applied to each component.
   - If a lift assembly is presented to RECERT for (re)certification, and the configuration will be rearranged, then the assembly is load tested in all applicable configurations with each item NDT'd and one load test RECERT tag per configuration is applied. Note: There may be variations in the number of tags depending upon the similarities among the different configurations.
   - If loose, individual components are presented to RECERT for (re)certification, each component is load test RECERT tagged.

Regardless of the load testing, NDT tags shall be applied to each individual item that is NDT'd. NDT is required each time a sling assembly or component is load tested. The minimum NDT required shall be as delineated in GPR 8719.1. NDT, including visual inspection, shall be performed by personnel certified in accordance with the requirements of ASNT SNT-TC-1A.

Equipment or hardware that is not affixed with a proper certification and NDT tag, or has a certification date that has expired, is considered uncertified and shall not be used. This equipment shall be submitted to the RECERT Manager for segregation or certification.

Load cells shall be calibrated and tested annually to 100% of safe working load. Eyebolts shall be safety-wired to the load cell to preclude inadvertent disengagement from the cell during use.

4. Basic safety guidelines: Personnel can prevent injuries and payload damage involving the use of lifting assemblies, load cells, and individual lifting components by obeying the following guidelines:
   - Thoroughly inspect each piece of equipment and hardware prior to its use, and report any problems immediately.
   - If you are not certified to use the equipment or hardware, do not use it.
   - If the equipment or hardware has expired certification, or if the certification tag is missing, do not use it.
   - Make sure the equipment or hardware is rated to handle the desired load. If there are any doubts about the rating or the load to be applied, see your supervisor.
   - Wear the proper PPE. Training for PPE must be per Section 3.6.

2.1.2.5 GSFC Contacts

See Section 2.1.1.5.

2.1.2.6 Reference Documents Unique to this Section

See Section 2.1.1.6.

2.1.3 Powered Industrial Trucks

2.1.3.1 Scope

This section covers powered industrial trucks (PITs) used for material handling. PITs include forklifts and tugs used for moving equipment and flight hardware.

2.1.3.2 Acronyms/Definitions

1. Equipment Certification—A process performed by the RECERT Support Function, which leads to the initial certification, or continuation of certification, that a PIT is safe to operate up to its rated load.

2.1.3.3 General

For PITs covered by NASA-STD-8719.9, it is NASA's and GSFC's policy to follow standard industry/manufacturer recommended practices and applicable Federal, State, and local government regulations. PITs shall be inspected and certified by the RECERT Manager.

2.1.3.4 Design/Operational Requirements

1. Equipment Certification:
   - Only PITs designed and constructed in accordance with ASME- B56.1, B56.9, and B 56.10 shall be used on AETD properties.
   - Fork extensions, if required, must be obtained from the Original Equipment Manufacturer (OEM). No modification to equipment is allowed without written OEM approval and documentation. If the OEM is no longer available, an engineering analysis may be submitted for review.
   - The owner organization shall perform a recognized safety hazards analysis such as a fault tree analysis, FMEA, O&SHA on all PITs used for lifts where failure or loss of control could result in loss of or damage to flight hardware.
   - The owner organization shall perform maintenance and repairs per OEM recommendations.
   - All PITs shall be certified, recertified, and tagged by the RECERT Manager.
2. Operator Training and Medicals:
   - Only operators trained and qualified by their employer and certified (licensed) by the RECERT Manager shall be authorized to operate PITs. Training, refresher, and qualification shall be documented by the operator's supervisor. Formal license renewal and medical examination shall be performed every three years. Annually, the employee's supervisor shall certify the employee has had an informal refresher. Annually, the employee's supervisor shall certify the employee has received an informal refresher by supplying RECERT with a certification letter.

3. General Requirements:
   - Approved forklifts shall bear a label/identifying mark indicating approval by the testing laboratory.
   - Capacity, operation, and maintenance instruction plates, tags or decals shall be changed according to documented OEM-approved modifications/additions.
   - PITs shall be marked to identify front-end attachments, other than factory installed units, to indicate the revised rated capacity of the lift/attachment combination at maximum elevation with the load laterally centered.
   - Name plates and markings shall be maintained in place and in a legible condition.
4. General Safety Rules:
   - The operator shall perform a daily inspection prior to the first use each day and recorded in the logbook. Defects when found shall be reported immediately to the RECERT Support Function and corrected.
   - Verify that the transported load, including the transporter, does not exceed the allowable floor or hatch loading. Check with the area supervisor to determine the weight restrictions on floors and hatches.
   - Diesel-powered or propane-powered vehicles are not allowed inside the building beyond the truck locks without FOM approval. The use of gasoline-powered vehicles inside the truck locks or buildings shall be approved by the FOM on a case-by-case basis.

2.1.3.5 GSFC Contacts

See Section 2.1.1.5.

2.1.3.6 Reference Documents Unique to this Section

OSHA 29 CFR 1910.178, *Powered Industrial Trucks*

ASME B56.1, Part II, *Safety Standard for Low Lift and High Lift Trucks*

ASME B 56.9, *Safety Standard for Operator Controlled Industrial Tow Tractors*

ASME B 56.10, *Safety Standard for Manually Propelled High Lift Industrial Trucks*

Original Equipment Manufacturer's Maintenance Manuals and Recommendations

See also Section 2.1.1.6.

2.1.4 Mechanical Ground Support Equipment (MGSE)

2.1.4.1 Scope

This section covers MGSE such as dollies, tables, jacks, stands, and other hardware used to transport, orient or support payloads, fixtures, or any other item employed in the integration and test complex.

2.1.4.2 Acronyms/Definitions

None specific for this section.

2.1.4.3 General

Certain MGSE may use mechanical, electrical and/or hydraulic power to orient a payload or fixture that is mounted to it. The MGSE must be thoroughly inspected prior to use and the user must be fully cognizant of its proper operation. Employees must also understand the most common hazards of their operation, such as:

- Injuries from contact with unguarded areas of operation, such as rotating shafts and crush points.
- Shock, fire, and electrocution from electrical problems.
- Injury from high-pressure fluids.
- Injury caused by defective equipment, structural failure, or improper use of the equipment.

MGSE is also intended to be moved throughout the facilities on casters or air-bearing support assemblies and to be raised or lowered with jacks. The employee must understand the most common hazards of these operations, which are:

- Collision of moving MGSE with the employee and the resultant injury.
- Collision of moving MGSE with hardware or equipment located in the facility and the resultant personal injury due to indirect causes.
- Injury from high pressure gases or fluids.
- Crushing injury caused by defective jacks or stands.

2.1.4.4 Design/Operational Requirements

Employees who work with MGSE shall inspect the equipment before use to verify it is in proper working condition, and shall be familiar with the equipment's proper operation. Guidelines for the use of MGSE are as follows:

1. Always wear PPE (Section 3.6) appropriate for the task at hand. Safety glasses or goggles must be worn in the presence of high-pressure fluids and gases unless the system/equipment has been proven stable. Garments that protect the body but are not prone to snagging in moving mechanisms are appropriate.
2. Equipment certification: All MGSE shall be properly certified by the Project Manager. Certification must include a stress analysis. All movable structures shall have stability analysis. After a proof test

has been completed a tag or other readily visible identification attesting to this shall be affixed to the structure by the Project. Tagging requirements are the same as stated in Section 2.1.2.4 for lifting assemblies. Testing must be performed to applicable NASA and OSHA standards. Stands, dollies and non-commercial tables used for critical hardware require a one-time proof test of at least 1.25 times the rated load, followed by a surface examination of critical welds. (Requirements for jacks are discussed below.) Any repair or modification to the load-bearing elements of the MGSE requires that testing and certification be repeated. Certification tags shall contain as a minimum the following information:

- MGSE identification.
- Certification document number.
- Test load.
- Rated load.
- Test date.
- Inspections identification.
- Recertification due date, if applicable.

Personnel shall not use MGSE if any of the following applies:

- The equipment does not have a clearly visible and properly prepared certification tag
- It is not being used for its intended function
- It is handling loads greater than it has been certified for
- It has been damaged or altered and has not been repaired and recertified.

2. MGSE with pressurized and electrical equipment shall follow the safety requirements as stated in the applicable sections of this Manual.
3. Jacks must comply with the regulations contained in OSHA 1910.244, NASA-STD-8719.9 and ASME/ANSI B30.1. Observe the following when working with jacks:
   - Jacks used to lift or support flight hardware or where loss of control could damage flight hardware shall be analyzed, tested, inspected, and certified per NASA-STD-8719.9.
   - The jack shall be legibly and permanently marked in a prominent location with its rated load capacity.
   - The manufacturer shall test all new jacks to rated load. All altered, modified, or repaired jacks shall be tested to rated load by the Structural Test Group before use.
   - The operator shall inspect the jack before use, and ensure that the capacity is sufficient to raise and sustain the load.
   - The operator shall watch the stop indicator, which shall be kept clean, in order to determine the limit of travel. The indicated limit shall not be overrun.
   - Once the load is raised, personnel shall crib, block, or otherwise secure the load. Follow the load with cribbing where practical. Take measures to prevent personnel from working or passing under the load until it is secured.

- Ensure that there is sufficient swing area for the operating lever(s).
- Remove operating levers when not in use to avoid accidental dislocation of the jack and to reduce the tripping hazard.
- Ensure that operators are instructed as to signals and other procedures for multiple jacks or other special lifts.
- Off-center loading of jacks should be avoided.
- Extenders shall not be used unless authorized by a qualified person.

4. All critical fixtures used for environmental testing shall have stress and stability analysis and be approved by the appropriate Branch engineering to verify adequacy for the proposed purpose and proper mating with facility systems. Critical fixtures are those that support or are mounted over critical hardware as defined in NASA-STD-8719.9. In the Environmental Test Engineering & Integration Branch, all fixtures brought in from outside sources shall have an independent review by Code 549 engineering.

2.1.4.5 GSFC Contacts

AETD Safety Manager: (301) 286-1035
RECERT Manager: (301) 286-4209
RECERT Support Function, Manager: (301) 286-5183

2.1.4.6 Reference Documents Unique to this Section

OSHA 1910.244, *Other Portable Tools and Equipment*

ASME/ANSI B30.1, *Jacks*

NASA-STD-8719.9, *Standard for Lifting Devices and Equipment*

2.1.5 Hydra-sets

2.1.5.1 Scope

This section covers Hydra-sets.

2.1.5.2 Acronyms/Definitions

1. Hydra-set—A manually operated hydraulic lifting device designed to incrementally lift and lower critical loads such as spaceflight hardware.
2. Hydra-set certification/recertification—A process performed by the RECERT Group which leads to the initial certification, or continuation of certification, validating that maintenance, test, or other operational checks have been performed and are current.
3. Hydra-set operator certification—The documented status of Hydra-set operators validating that they have been trained, and are qualified and medically fit to perform lifting and rigging operations in accordance with NASA-STD-8719.9 and certified by the RECERT Manager.

2.1.5.3 General

Hydra-sets shall be used when there is a requirement for precise adjustment when lifting critical hardware and the crane is not capable of providing the precision required.

2.1.5.4 Design/Operational Requirements

1. Hydra-sets used for critical lifts shall have a 5:1 factor of safety, based on the ultimate strength for load-bearing elements.
2. The rated load shall be plainly marked on each Hydra-set.
3. Hydra-sets that have the necessary design features, maintenance/inspection, and test intervals to lift critical loads shall be conspicuously marked so that the operator and assurance personnel can distinguish that the Hydra-set is qualified for critical lift.
4. For best performance, select a Hydra-set so that the intended load is between 20% and 80% of the Hydra-set's capacity.
5. Exercise Hydra-Sets prior to critical lifts with a dummy load that is at least equivalent to the weight of the item to be lifted.
6. RECERT tags are issued and attached to certified/recertified equipment.
7. Only certified (licensed) operators are authorized to operate GSFC Hydra-sets. Training shall include the properties of Hydra-sets, operating procedures, hands-on training, and an operational demonstration.
8. RECERT Hydra-set checkout/return standing procedures must be followed, including completion of the Logbook.
9. Check all components for certifications: hoses, Hydra-set, and lifting hardware.

2.1.5.5 GSFC Contacts

See Section 2.1.1.5.

2.1.5.6 Reference Documents Unique to this Section

DEL PUB 81-1, *Model A Hydra-Set*

DEL PUB 81-2, *Model B Hydra-Set*

DEL PUB 81-3, *Model C Hydra-Set*

DEL PUB 81-4, *Model D Hydra-Set*

DEL PUB 81-5, *Model E Hydra-Set*

DEL PUB 81-6, *Model ES Hydra-Set*

NASA-STD-8719.9, *Standard for Lifting Devices and Equipment*

GPR 8719.9, *Certification and Recertification of Lifting Devices and Equipment*

See also Section 2.1.1.6.

2.2 Ordnance

2.2.1 Scope

This section describes the requirements for ordnance brought into or used within AETD facilities.

2.2.2 Acronyms/Definitions

1. Class 1.4—Consists of explosives that present a minor explosion hazard (moderate fire, no blast). The explosive effects are largely confined to the package and no projection of fragments is expected. An external fire must not cause instantaneous explosion of almost the entire contents of the package.
2. Electro-Explosive Device (EED)—A device containing some reaction mixture (explosive or pyrotechnic) that is electrically initiated. The output of the initiation is heat, shock, or mechanical action.
3. Electrostatic Discharge (ESD)—An arcing of electric charge across a gap between two points not in contact, or through a nonconductor when the voltage exceeds the dielectric breakdown voltage of the nonconductor.
4. Explosives—Term "explosive(s)" includes any chemical compound or mechanical mixture that, when subjected to heat, impact, friction, detonation, or other suitable initiation, undergoes a very rapid chemical change with the evolution of large volumes of highly heated gases that exert pressures in the surrounding medium. The term applies to materials that either detonate or deflagrate.
5. Fragmentation—Breaking up of the confining material of a chemical or mechanical mixture when an explosion takes place. Fragments may be complete items, subassemblies, pieces thereof, or pieces of equipment or buildings containing the items.
6. Grounding—The practice of providing an electrical path from an object to ground or the process of connecting one or more conductive objects to the ground.
7. Ordnance—See explosive.
8. Pyroshock test—A test in which the actuation device is a type of electro-explosive device, which imparts a shock to the item under test.

2.2.3 General

The most generally recognized hazard in handling and use of ordnance/explosives is unplanned initiation. The most probable causes of unplanned initiation are as follows:

- Electrostatic hazard—Discharge of static electricity due to possible buildup of a static charge caused by two insulating materials rubbing each other or through moving air or other gasses.
- Lightning hazard—During thunderstorms, statically charged fields can cause static discharge between grounded and ungrounded items.
- Electromagnetic radiation hazard—Situations in which sources are intense and close enough to electro-explosive devices such that current is induced that may cause initiation.

- Mechanical shock hazard—Ordnance becomes pinched or crushed, a hot spot can form which can initiate the explosive, or a severe mechanical shock can fracture the bridge wires, causing the device to fail by not firing.
- Thermal hazard—Exposure to heat may cause detonation rather than deflagration, causing much higher stresses on the device housing.

2.2.4 Design/Operational Requirements

1. The only ordnance or explosives allowed in AETD Facilities are Class 1.4 or less, unless a waiver is approved by S&ED and the applicable Branch Head.
2. All explosives brought into the facility shall be coordinated with S&ED.
3. Explosives shall not be stored in AETD Facilities unless approved by S&ED, including ordnance installed in flight hardware. All spare ordnance should be stored in Building 27A, Explosive Storage Building until needed for specific tests.
4. The fire symbol for fire division 4 (hazard Class 1.4) shall be displayed at the entrance to the work area containing explosives.
5. Explosive operations (working on or with explosives) shall be discontinued as electrical storms approach, and personnel evacuated from the immediate area/room.
6. Containers/hardware containing explosives shall be grounded at all times.
7. Portable ground cables shall be visually inspected prior to each use. Prior to use, it shall be verified that an electrical continuity test has been conducted on the ground cable within the last seven months.
8. Personnel performing installation/hookup operations shall wear static dissipating devices and anti-static clothing/coveralls. Unless conductive flooring is provided, wristats shall be worn. Static dissipating devices shall be checked each time the device is donned to verify the resistance is 1 megohm to 10 megohms.
9. Static generating materials (wools, nylon, silk, plastics, etc.) should be removed from the area containing ordnance.
10. Areas in which ordnance installation operations are conducted shall have at least two separate accessible exits.
11. The buddy system shall be used during ordnance operations.
12. Only personnel necessary to perform ordnance operations shall be present.
13. All personnel involved in ordnance operations shall wear safety glasses or goggles.
14. Autoclaves and other pressure equipment containing explosives or other hazardous chemicals shall be placed in separate cubicles/bays that are designed to confine and direct the force of possible explosions away from personnel and facilities.
15. Operations involving explosives must be separated from those not involving explosives by an approved operational shield or barrier (example: Acoustics Lab reverberant chamber).
16. Operations involving the installation or initiation of ordnance shall be by approved detailed procedure. Procedures shall require that the ordnance be initiated remotely. Procedures must

include a list of approved test equipment by part number and serial number. The appropriate Branch Head or designee shall review and approve the procedure prior to the start of the operation. Testing that includes explosives requires the S&ED approval. The written request shall be submitted at least one week prior to testing and shall include:

- The test procedure.
- Type and number of devices involved (spec sheet preferred).
- Test objective.
- Date of test.
- List of essential personnel.
- List of approved test equipment.
- Test location.

17. Procedures shall incorporate an emergency section that deals with a misfire or hangfire. This section shall require that the test area be secured immediately for a minimum of one hour, and that S&ED be notified.
18. For lifting and handling operations involving explosives, the adequacy of grounding of the crane hook, forklift, container, flight hardware, personnel, and facility shall be determined by a qualified electrical engineer.
19. The relative humidity should be maintained at 30% or higher when working with ordnance.
20. No personnel shall be allowed within the hazard area during a pyroshock test.
21. Electrical equipment used for testing EEDs shall be approved by S&ED and the applicable Branch Head. Ohmmeters for measuring resistance of EEDs shall be specially designed for testing pyrotechnic devices. Approved ohmmeters are commonly referred to as "squib checkers," and are designed to limit the current applied to the EEDs. Standard multimeters shall not be used to measure EEDs. Note: If Alinco meters are used, the maximum current output must be checked prior to each use (should be <10ma).
22. Stray voltage tests shall be run on the circuit prior to installation or any electrical hookup of EEDs.
23. Radios or transmitting devices shall not be used near ordnance connection operations, unless reviewed and pre-approved by the applicable safety representative.

2.2.5 GSFC Contacts

S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035

2.2.6 Reference Documents Unique to this Section

29 CFR 1910.109, *Explosives and Blasting Agents*

NASA-STD-8719.12, *NASA Safety Standard for Explosives, Propellants, and Pyrotechnics*

2.3 Pressure & Vacuum Systems

2.3.1 Ground-Based Pressure Vessels and Pressurized Systems (PV/S)

2.3.1.1 Scope

This section covers ground-based PV/S, including vacuum systems, in permanent or temporary configuration. Appendix B of this Safety Manual contains detailed requirements for PV/S design, modifications, repairs, procurement, etc.

2.3.1.2 Acronyms/Definitions

1. ASME—The American Society of Mechanical Engineers.
2. ANSI—The American National Standards Institute.
3. Ground-Based PV/S—Systems used for ground operations, including pressure vessels, piping, flexible hoses, components for cryogenic service, pressurized research and development stepups, compressed gases, hydraulic service, vacuum service, purge carts, Engineering Test Units (ETU's), Payload Environmental Transport System (PETS) and other flight project specific PV/S used for ground activities.
4. Inservice Inspection (ISI)—On-going RECERT inspections or tests performed on PV/S and components after a system has been certified and put into service.
5. Maximum Allowable Working Pressure (MAWP)—The maximum pressure permissible at the top of a vessel in its normal operating position at the coincident operating temperature.
6. Maximum Design Pressure (MDP)—The maximum pressure permissible for each component in a piping system at the most severe condition of coincident internal or external pressure and temperature (minimum or maximum) expected during service.
7. PV/S Certification/Recertification—A process performed by the RECERT Manager, which leads to the initial certification, or continuation of certification, that a PV/S is safe to operate within specific certification parameters. The process includes PV/S compliance and documentation reviews, tests, inspections, nondestructive testing, and analyses.
8. RECERT—The NASA Recertification Program for periodic certification and/or recertification of ground-based PV/S outlined in NPD 8710.5, NPR 8715.4, and GPR 8710.3.
9. Recertification Program (RECERT) Manager—The RECERT Manager has overall implementation, managerial, certification, and recertification responsibility for the Center's RECERT Program for PV/S and Lifting Devices and Equipment.

2.3.1.3 General

All pressure vessels, pressurized components, and pressurized systems (including vacuum systems) in permanent or temporary configuration shall be designed, fabricated, installed, operated, periodically inspected, maintained, repaired, and certified/recertified in accordance with GPR 8710.3.

2.3.1.4 Design/Operational Requirements

1. Certification Policy and Requirements (GPR 8710.3):
   - All PV/S shall be formally certified by the RECERT Manager as safe to operate before initial use and shall be recertified periodically after initial certification.
   - PV/S brought onto GSFC property for temporary use in support of mission or facility operations shall comply with the requirements of GPR 8710.3.
   - The documentation delineated in NPR 8715.4 shall be provided to the RECERT Manager as part of the certification requirements.
   - The owner organization shall perform preventive and corrective maintenance on PV/S per OEM recommendations. If OEM recommendations are not available, recommended industry practices shall be followed.
2. All ground-based PV/S shall comply with RECERT ISI requirements.
3. PV/S Safety Requirements:
   - There shall be no welding or brazing on installed PV/S, unless approved by the RECERT Manager.
   - The Branch Office shall notify the RECERT Manager immediately of all deficiencies, incidents, and mishaps involving PV/S.
   - All flex hoses, including LN2 hoses, shall be recertified periodically on a schedule established by the RECERT Manager.
   - All flex hoses operating at a pressure greater than 150 psig (1,034 kpa) shall be mechanically restrained at each end and every five feet (1.5 m) to prevent whipping in the event of separation. In addition, intermediate restraint shall be provided at any location where two hoses are joined together. Refer to T.O. 00-25-223 for approved restraint details.
   - All U.S. Department of Transportation (DOT) certified compressed gas cylinders and mobile liquid cryogenic dewars shall be within their current U.S. DOT certification.
   - All compressed gas cylinders shall have protective caps installed or be connected to manifolds/regulators and be positively restrained to prevent falling.
   - Pressure gages shall have a one piece shatter-proof window and a blow out back, or equivalent.
   - Pressure gages should be selected such that the maximum operating pressure (MOP) of the system falls within the middle third of the range of the gage. In no event shall a gage be used on a system whose MOP is less than 25% of the gage range, nor greater than 75% of the gage range.

- In no event shall any pressure system segment or component be disconnected while the system is under pressure. (Note: Quick-disconnects built to be disconnected under pressure, with an internal check valve, may be disconnected under pressure.) It must be verified that all residual energy has been dissipated prior to disconnection. (Reference Section 3.8, Lockout/Tagout)
- In no event shall tube fittings be tightened while the system is under pressure.
- Overpressure Protection Requirements:
  a. All pressure vessels shall be equipped with approved overpressure protection devices.
  b. All piping/tubing systems shall be equipped with approved overpressure protection devices unless specifically exempted by the applicable ASME B31 pressure piping code.
  c. All overpressure protection devices shall be set to function at or below the MAWP of the vessel or MDP of the piping/tubing system. In order to avoid simmering and to allow an actuated pressure relief valve to reseat completely, pressure relief valve set points should be specified to take into account the blowdown characteristics established by the manufacturer. In no case, however, shall the relief valve set point exceed the MAWP of the vessel or MDP of the piping/tubing system.
  d. Reactions on piping systems due to actuation of overpressure protection devices shall be considered in the piping design, and adequate strength shall be provided to withstand these reactions.
  e. All overpressure protection devices shall be installed so they are readily accessible for inspection and cannot be rendered inoperative.
  f. All new relief valves shall have their set points certified by the RECERT Manager prior to being placed in service.
  g. Relief valves of adequate capacity shall be installed in all cryogenic piping/tubing segments located between isolation or control valves.
  h. The discharge of overpressure protection devices located on indoor cryogenic systems shall be controlled or diverted to avoid contact of the discharge plume with personnel and equipment, and any back-pressure or flow effects of such diversion shall be taken into account in the design of the overpressure protection device.
  i. Adjustable type relief valves shall not be used on any piping/tubing system without the prior written approval of the RECERT Manager.
  j. No repairs to PV/S overpressure protection devices shall be made.
  k. Any repaired PV/S pressure-indicating gage shall be recertified prior to reinstallation.

4. PV/S Modifications and Repairs

- System Modifications—All modifications to PV/S shall void the system's certification. Appendix B contains the requirements that must be met in order for the modified system to be recertified and placed into/returned to service by the system owner.
- System Repairs – Appendix B contains repaired-system recertification requirements.

5. Safety Variances—When the technical requirements of applicable Codes/regulations (with the exception of Federal Regulations) cannot be met, a safety variance request package shall be prepared by the initiating Flight Project/Division Office. Preparation shall be in accordance with NPR 8715.3 and RECERT requirements.
6. Personnel operating high-pressure systems (>150 psi [1,034 kpa]) must be trained and certified by the system owner.

2.3.1.5 GSFC Contacts

RECERT Manager: (301) 286-4209
RECERT Support Function, Manager: (301) 286-5183
AETD Safety Manager: (301) 286-1035

2.3.1.6 Reference Documents Unique to this Section

ANSI/ASME Code for Pressure Piping, B31

ANSI/ASME Boiler & Pressure Vessel Code

GPR 8710.3, *Certification and Recertification of Ground-Based Pressure Vessels and Pressurized Systems*

NPD 8710.5, *NASA Safety Policy for Pressure Vessels and Pressurized Systems*

NPR 8715.4, *In-service Inspection of Ground-Based Pressure Vessels and Pressurized Systems* (with current changes)

2.3.2 Flight Pressure Vessels, Pressurized Systems, and Ground Support Equipment

2.3.2.1 Scope

This section covers flight PV/S which are brought into AETD facilities for testing and/or integration, and which are not included within the RECERT Program. Note that flight project ground support equipment (GSE), such as purge carts, engineering test units (ETUs), and payload environmental transport systems (PETS), are considered to be ground-based PV/S and are subject to the requirements of section 2.3.1.

Design, fabrication, test, and certification requirements of these PV/S are covered by the GSFC Quality Management System (QMS).

2.3.2.2 Acronyms/Definitions

Flight PV/S —An assembly of components under pressure, including vessels, piping, valves, relief devices, pumps, expansion joints, gages, etc. that are fabricated in accordance with program requirements including ANSI/AISS S-080, Space Systems-Metallic Pressure Vessels, Pressurized Structures, Pressure Components, or ANSI/AIAA S-081, Space Systems- Composite Overwrapped Pressure Vessels (COPV).

2.3.2.3 General

Although flight pressure systems may have been designed to meet launch site criteria, they may not meet all the requirements for testing and/or integration in AETD facilities.

2.3.2.4 Design/Operational Requirements

1. Certification:

   Prior to arrival at an AETD facility, the Project Manager shall formally certify to AETD or the appropriate Branch Head that flight PV/S comply with the requirements of AIAA S-080 or AIAA S-081, as applicable.
2. Documentation:
   - Flight PV/S—Prior to arrival at an AETD facility, project personnel shall certify that the following items are complete. Copies of applicable documents shall be made available to the applicable Branch Head upon request.
     a. Structural and Stress Analysis.
     b. Fatigue Life Analysis.
     c. Fracture Mechanics Analysis.
     d. Reflown Hardware Analysis (if applicable).
     e. Pre-Proof Pressure Test Inspection.
     f. Proof Pressure Test.
     g. Post-Proof Pressure Test Inspection.
     h. Calibration of gages, regulators, and relief valves.

- Prior to arrival, Project personnel shall provide copies of the following documents to the applicable Branch Head upon request:
  a. Operating procedures.
  b. Inspection methods and intervals.
  c. Probable location of defects.
  d. Pressure/temperature history.

3. Recertification—Flight PV/S shall be recertified at intervals established by the Project in accordance with requirements contained within the applicable code.
4. General Requirements—PV/S safety requirements delineated in Section 2.3.1.4.3 are applicable hereto, with the following additions:

   - Hazardous Operating Procedures (HOPs) shall be prepared prior to performing operations involving PV/S. HOPs shall be approved by the appropriate Branch Head prior to use.
   - In the event that a project wishes to perform PV/S proof testing using AETD facilities, the project shall perform an operating hazard analysis (OHA) of the proposed test. OHAs shall be approved by the appropriate Branch Head prior to use.

2.3.2.5 GSFC Contacts

AETD Safety Manager: (301) 286-1035
Systems Safety Contact: (301) 286-7852

2.3.2.6 Reference Documents Unique to this Section

ANSI/AIAA S-080, *Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components*

ANSI/AIAA S-081, *Space Systems – Composite Overwrapped Pressure Vessels (COPV)*

U.S. Air Force Technical Manual, T.O.00-25-223, *Integrated Pressure Systems and Components (Portable and Installed)*

2.4 Stored Energy Devices

2.4.1 Batteries

2.4.1.1 Scope

This section covers the various types of batteries that are used to power equipment, experiments, and systems brought into AETD facilities.

2.4.1.2 Acronyms/Definitions

1. Battery or battery pack—A device composed of individual cells connected in series and/or parallel arrangements, and used for the storage and controlled use of electrical energy.
2. Cell—The smallest component of a battery pack, containing a subset of the total power required to run a device.
3. Short circuit—Direct connection of the positive and negative terminals together with no load in the current path.

2.4.1.3 General

The types of batteries used in the AETD can be alkaline, lead-acid, nickel-cadmium, nickel-hydrogen, lithium-ion, or lithium-sulfur. Some are rechargeable and some are non-rechargeable types. The non-rechargeable alkaline and nickel-cadmium button batteries used in watches and calculators are considered safe and will not be discussed here.

2.4.1.4 Design/Operational Requirements

1. Projects shall notify the appropriate Branch Head if non-commercial batteries are present in equipment, experiments, and systems brought into AETD facilities. At a minimum, the Project's test plan shall address the following items when it is expected that battery charging shall take place:
   - Describe the types and number of batteries. Include information concerning all manufacturer safety warnings and precautions for handling, using, and disposing of the batteries.
   - Perform a hazard analysis and describe all steps necessary to mitigate the hazards. If battery hazards are present, describe what warning signs and personnel access controls will be needed in the affected area. If the batteries do not present potential hazards, the test plan shall state this fact.
   - Based on the Project test plan, the Project shall develop step-by-step integration and testing procedures that ensure that all affected personnel know their responsibilities and duties when working on or around systems containing batteries. Personnel shall be informed of all potential dangers and emergency actions.
2. Procurement and Handling—All battery procurements shall be accompanied by a Material Safety Data Sheet (MSDS) and the manufacturer's certification and traceability information. Follow the manufacturer's technical recommendations for packaging, labeling, and shipping batteries.

3. Lead-Acid Batteries—These are the standard batteries that power the forklifts, personnel lifts, tugs, etc. They contain a liquid electrolyte of sulfuric acid and water and have lead plates inside. Operational requirements for lead-acid batteries are as follows:
   - Charge and maintain batteries near an emergency eyewash station and personnel shower. Battery charging stations for powered equipment are located in approved locations where eye wash stations and showers are present.
   - When handling batteries, appropriate PPE shall be used to protect the body from contacting the sulfuric acid electrolyte. Use rubber gloves, goggles or full face shields, and safety shoes if lifting heavy batteries. Long sleeved shirts, lab coats, or coveralls provide additional skin protection and can be removed in the event of a spill before acid contacts the skin. If any liquid contacts the body, immediately flood the area with massive amounts of clean water (15 minutes or longer). Do not allow lead or lead deposits to contact the skin. Seek medical attention as required.
4. Nickel-Cadmium Batteries—These batteries are typically used in powered electronic equipment such as portable oscilloscopes, photographic equipment, laptop computers, etc. The electrolyte is a mixture of potassium hydroxide and water. Operational requirements for nickel-cadmium batteries are as follows:
   - When servicing the batteries, appropriate PPE shall be used to protect against exposure to the electrolyte, which can cause severe eye irritation and chemical burns to the skin.
   - During short circuit conditions, very high currents may flow, causing damage to the battery and creating heat, which may cause fire. Use class D fire extinguishers on the batteries to extinguish the fire. Use other fire extinguisher types only on surroundings, not on the batteries. Use caution when extinguishing a Ni-Cd battery fire because the smoke is toxic.
   - Battery packs of multiple cell design should be built by the manufacturer and not assembled in the field. The user should not attempt to connect cells in parallel to create a larger capacity battery, because mismatches in current and voltage might create unwanted current flow between the individual battery packs or cells.
   - Ni-Cd batteries can explode if over-charged. If non-commercial charging equipment is used, it should be analyzed to verify inhibits are in place to prevent over-charging. Additionally, these may be pressure vessels and should meet the requirements of Section 2.3.2 if designed and built for use as flight hardware.
5. Nickel-Hydrogen Batteries—Typically these batteries will be used to power spacecraft, experiments, and flight projects. The electrolyte is a diluted alkaline solution. Self-sealing venting is provided to prevent pressure build-up during recharging. These may pose the same hazard as Ni-Cd batteries if over-charged.
6. Lithium-Ion Batteries—This is a battery technology used to power everything from calculators, computers, and camcorders to the cordless HST pistol grip tools, spacecraft, and satellites. The potential hazards resulting from shorting, over-charging, or over-discharging this type battery include high heat and fires that may release toxic gases.

7. Lithium-Sulfur Batteries—Typically these batteries will be used in spacecraft and flight projects. Before using them, consult and follow the operating precautions contained in the NASA Reference Publication 1099, *Lithium-Sulfur Dioxide Cell and Battery Safety* (latest revision.) The potential hazards resulting from shorting, over-charging, or over-discharging this type battery, include high heat and fires that may release noxious sulfur dioxide gas and/or electrolyte. Also, small quantities of cyanide and methane could be released in a sulfur dioxide-limited (excess lithium) cell.
8. Storing Batteries—Batteries may be stored safely for years if these basic guidelines are observed:
   - Batteries shall be stored in an area that is well ventilated, dry, and cool (under 50 $^{\circ}$C). Temperatures must be maintained above those, which would freeze the electrolyte (specified by the manufacturer), to prevent damaging the battery and spilling electrolyte.
   - Batteries should be stored in the original shipping container if possible.
   - Batteries not in the original container should be stored in containers of wood, fiberboard, or plastic designed to prevent contact between batteries.
   - Smoking and creation of sparks around stored batteries shall be strictly prohibited.
   - Fire extinguishers should be class D type for extinguishing fires. If only the water type is available, try to keep the surroundings cool and prevent the spread of flames, but don't aim the water at the batteries because the water could trigger an explosion.
9. Charging Batteries—General guidelines for battery charging operations are as follows:
   - Never smoke or create sparks around charging batteries. It is possible to ignite the hydrogen gas produced during the charging process.
   - When mixing electrolyte for batteries, always pour acid slowly into water. Never pour water into acid because the chemical reaction may run away and cause an explosion.
   - Charge batteries only in well ventilated areas designated for charging, where emergency eyewash stations and personnel showers are located.
   - Ensure that the area is well posted with warning and "No Smoking" signs. Rope off the area as required for safety.
   - Never eat food in the charging area, because of the danger of contamination.
   - Wash thoroughly after handling and charging batteries to remove skin irritating contaminants.

10. Using and Discharging Batteries—General guidelines for using and discharging batteries are as follows:
    - Be sure the battery is proper for the application. For example, lead-acid batteries that will fly aboard airplanes must be designed not to leak electrolyte regardless of their position.
    - Never mix battery types such as Ni-Cd and lead-acid in one application. This can lead to rapid discharge of one battery pack by another, which can lead to fire or explosion.
    - Avoid testing batteries in a vacuum, unless designed to do so.
    - Always read and follow the manufacturer's recommendations on how to use and recharge a particular type of battery. Ensure that the recharging method and charging rate are correct for the type of battery. For example, charging equipment for lead-acid batteries might cause explosions in nickel-cadmium batteries.
11. Disposing of Batteries—All batteries shall be considered controlled/hazardous waste for disposal purposes. General guidelines are as follows:
    - Never dispose damaged, corroded, or worn-out batteries in dumpsters or trash cans. Contact the Hazardous Waste Environmental Specialist (x6-9233) for assistance.
    - Do not mutilate or crush batteries. Corrosive electrolytes and acids will be released.
    - Do not incinerate batteries. They will release toxic vapors or explode.
    - Do not create a short circuit to discharge failing batteries before disposal. This can cause arcing or enough heat to start a fire. Discharge slowly through a predetermined load at or below the maximum discharge rate.
    - Do not dispose of batteries in a charged state.

2.4.1.5 GSFC Contacts

GSFC Hazardous Waste Disposal: (301) 286-9233
S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035
Systems Safety Contact: (301) 286-7852

2.4.1.6 Reference Documents Unique to this Section

OSHA 29 CFR 1910.178 Section 2g, 1926.441, 1926.400

NASA Reference Publication 1099 (Lithium-Sulfur Dioxide Cell and Battery Safety)

NASA Goddard Space Flight Center Electrical Safety Policy Manual

National Electrical Code, Article 480 Storage Batteries

2.4.2 Mechanical

2.4.2.1 Scope

This section covers mechanical stored energy devices (mechanical SEDs) such as springs, booms, gyros, solar array deployments, reaction wheels, and other types of kinetic or rotational systems.

2.4.2.2 Acronyms/Definitions

1. Reaction wheel—Reaction wheels are large spinning masses that operate at variable rotational speeds.
2. Deployment—In this Manual, a deployment is defined as any system that is stored in one configuration and then opened to another by some forcing mechanism. Examples include solar array and boom deployments and yo-yo de-spins.

2.4.2.3 General

Projects shall inform the appropriate Branch Head of the presence of SEDs that could pose a hazard to personnel or facilities, defining what the potential hazards are, and specifying how the hazards will be mitigated while the payload is in AETD. A major concern is the unplanned initiation of the stored energy system, particularly if it is actuated by an electro-explosive device. Special procedures, and in many cases isolated facilities, are required to integrate and test systems that contain mechanical SEDs.

2.4.2.4 Design/Operational Requirements

1. Personal protective equipment (PPE)—The Project test plan and procedures shall specify what PPE should be worn by personnel who work with mechanical SEDs.
2. Electro-explosive devices (EED)—(See Section 2.2 for specific information on working with payloads that contain EEDs and other ordnance systems.) EEDs are highly controlled and monitored items while they are within AETD.
3. Hazards analysis—The Project shall perform a hazard analysis of all mechanical SEDs and explain how the hazards will be eliminated or mitigated while they are within AETD. The Project test plan shall be approved by the applicable Branch Head before the item is delivered to GSFC.
4. General safety rules—The following requirements apply to mechanical SEDs:
    - Post signs in the area, warning of the presence and status of mechanical SEDs. Signs shall list the appropriate personnel and phone numbers to call in emergency situations.
    - Keep unauthorized personnel away from the area by using barrier tapes or shields as required. If necessary, a designated monitor shall guard the area and restrict access to authorized personnel only.

- There shall be locking mechanisms or other structural means to secure deployable parts of a payload to prevent their unplanned activation. For example, spring-actuated devices shall have marmon clamps or other mechanisms that are fastened with structural hardware rated to a minimum factor of safety of three on yield. Test plans and procedures shall state clearly at what point in the operations it is safe to remove locking mechanisms and arm firing circuits. As a general rule, this should be as close in time to the actual firing as is practical.
- It may be necessary to perform boom deployments or spacecraft separation testing in a controlled area where the walls and structure of the facility provide physical protection. It is possible for pieces of the payload to be ejected at high speed and with great force. Verify that no facility appurtenances such as lighting, piping, wiring, alarm systems, etc., are in the path of ejected pieces. Where analysis requires it, protect all such appurtenances with covers and shields.
- Verify that no flicker detectors, smoke alarms, etc. shall be activated inadvertently by the operations. It is possible for rotating or oscillating systems to reflect light intermittently which could send false signals to a flicker detector.
- Personnel must exercise extreme caution when working around or handling payloads that are in the deployed state, since they may be extremely fragile.
- Check overall clearances throughout the facility to verify that all items can deploy without interference. Pay particular attention to wiring and cable harnesses that might have to deploy along with the hardware. Verify that adequate grounding systems are installed and will be effective in the stored and deployed configurations.
- Where possible, proof test deploying and arresting systems with dummy payloads before conducting actual tests. Dummy payloads should simulate actual conditions as nearly as possible, particularly with respect to actual masses and their centers of gravity. Sometimes deployed systems tend to bounce, rotate, or swing in unexpected ways that are more damaging than the shock of deployment.
- To the extent possible, closed circuit television cameras and video recorders (or film cameras) should be used to monitor the status and actuation of mechanical SEDs. Personnel shall be excluded from the immediate area (or from inside the chamber) during actuation of mechanical SEDs, unless the hazards analysis and test plan have documented clearly that there is no potential chance of injury.

5. Reaction wheel assemblies (RWA) and gyros—Some of these devices have large masses that spin at potentially dangerous rotational speeds. Depending on project requirements, the masses may or may not be spinning during a particular test and evaluation phase. The test plan and procedures shall state clearly the anticipated operational status and the precautions required for a given phase. Some general guidelines for reaction wheels and gyros follow:
   - The test plan shall provide a hazards analysis of the device and the precautions that must be taken to eliminate or mitigate the hazards.

- Each device shall be analyzed for its structural, electrical, thermal, and materials properties. The device housing should be adequate to contain the mass and prevent any parts from being ejected in the event of wheel failure, or the device should be placed in a secure facility during testing. Mounting bolts and structural hardware shall be analyzed and designed with a minimum safety factor of three on yield.
- The first preference is for the wheels not to be spinning in RWAs and gyros during payload integration and testing, so there is no potential danger to personnel. The second preference is for all personnel to be excluded from being allowed inside the test cell or near the payload if the wheels are to be spinning. The third preference is that if personnel must be near a spinning wheel, the hazard analysis and test plan shall state clearly under what circumstances and with what protective measures this would be allowed. The third option shall be approved by the appropriate Branch Head before the operation is allowed.

2.4.2.5 GSFC Contacts

S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035
Systems Safety Contact: (301) 286-7852

2.4.2.6 Reference Documents Unique to this Section

N/A

2.5 Hazardous Materials and Hazardous Waste

2.5.1 Hazard Communication Program

I. Purpose and Scope

This section of the Safety Manual establishes general policy and procedures for the Hazard Communication Program to inform employees in AETD of chemical hazards they may be exposed to in the workplace under normal conditions, or in a foreseeable emergency. Compliance with this Program ensures the safe use and handling of chemicals. It describes the requirements for the use of hazardous materials and the disposal of hazardous waste used in AETD facilities. For convenience, this section is organized in a stand-alone format that can be excerpted as needed by the user.

II. Applicability

The Hazard Communication Program is applicable to all civil servants and contractors working in AETD facilities. Employees engaged in the laboratory use of hazardous chemicals shall comply with the latest revision of *GSFC's Chemical Hygiene Program* (GPR 1700.2), which outlines the requirements of the *Occupational Safety and Health Administration's Laboratory Standard*, 29 CFR 1910.1450.

III. Policy

The AETD policy is to establish and implement a comprehensive Hazard Communication Program, which fully meets the requirements of the *Hazard Communication Standard* (29 CFR 1910.1200) promulgated by the Occupational Safety and Health Administration (OSHA.)

IV. Responsibilities

Specific responsibility and authority for administering and implementing the AETD Safety Program, including the Hazard Communication Program, are defined in 500-PG-8715.1.1, *AETD Safety Plan*. Additional responsibilities specific to the Hazard Communication Program are defined below:

A. Director of has overall responsibility for ensuring that the Hazard Communication Program is implemented in this organization, including the following:

1. Ensure that resources needed to comply with the Hazard Communication Program are available.
2. Ensure Division Chiefs implement and maintain an effective hazard communication program.

B. Division Chiefs shall:

1. Ensure Branch Heads/supervisors comply with Hazard Communication Program requirements.
2. Ensure that all line managers/supervisors and their employees attend required training.

C. Branch Heads shall identify and acquire all resources needed to implement the Hazard Communication Program for their areas of responsibility, including the following:

1. Ensure that new employees are appropriately trained in the Hazard Communication Program and location of a copy of this Program.

2. Ensure that Material Safety Data Sheets (MSDSs) for every hazardous chemical in their area are maintained and are readily available to employees in the GSFC Database.

3. Maintain an accurate and current inventory of the hazardous chemicals in their area. The inventory should be updated at least quarterly, shall be updated at the beginning of each fiscal year.
4. Ensure all personnel working with or near hazardous materials are trained in the elements of the program and the hazards of the material they are working with.

D. Line Supervisors are responsible for direct action and enforcement to ensure compliance with the Hazard Communication Program, including the following:

1. Maintain readily accessible copies of MSDSs for each hazardous chemical in the GSFC Database.
2. Maintain an accurate inventory of the hazardous chemicals used in the workplace.
3. Ensure that containers of hazardous chemicals are appropriately labeled.
4. Ensure that all employees under their supervision attend all required Hazard Communication training, understanding how to access the Database.
5. Develop operating procedures for all tasks involving hazardous chemicals, and ensure that all personnel use required personal protective equipment (PPE) and safe working methods.
6. Annually review this written program, MSDS's, inventory list, and training records to verify compliance. When changes are needed to the written program, notify the AETD Safety Office.
7. Ensure all employees exposed to chemicals which results in an illness or injury receive medical treatment. Provide medical personnel with copies of the MSDS and any additional information on how it was used.

E. All Employees shall:

1. Read the MSDSs and labels to become familiar with the safety precautions, chemical and physical properties, and potential health hazards of the chemicals prior to handling them. MSDSs may be found on the GSFC web site.
2. Wear prescribed personal protective equipment (PPE), follow applicable operating procedures, and exercise all necessary precautions in the safe use of hazardous chemicals.
3. Participate in scheduled hazard communication training sessions.
4. Notify the supervisor of any apparent deficiencies involving hazard communication operating practices, and report all working conditions that may cause substantial personal exposure to hazardous chemicals.

F. AETD Safety Office shall:

1. Assist in determining the level and content of training required to adequately inform employees of the hazards of workplace chemicals to fully comply with the Hazard Communication Program.
2. Audit the program to ensure that employees are trained in accordance with the Hazard Communication Program and that chemicals are being properly stored, labeled and MSDS maintained.

3. Review and update this Program as needed.

G. Safety and Environmental Division or its designated representative has overall responsibility for monitoring this program. Specific responsibilities include the following:

a. Providing revisions of the GSFC Hazard Communication Program on an as-needed basis.

b. Providing technical support including industrial hygiene surveys and monitoring; and observations and reviews of work practices, procedures, personal protective equipment (PPE), and procurements.

H. Contracting Officer's Technical Representatives shall ensure that Contractors administer a Hazard Communication Program that complies with 29 CFR 1910.1200, the *Hazard Communication Standard* promulgated by the Occupational Safety and Health Administration.

V. Labeling and Other Forms of Warning

Every container of hazardous materials shall be properly labeled or tagged with the identity of the hazardous material, appropriate hazard warning (Flammable, Toxic, etc.) including target organ effects, and name and address of the chemical manufacturer, importer, or other responsible party. Labels or tags shall be legible, written in English, and prominently displayed on the container. Return products to the manufacturers that do not have proper labels. Secondary containers must also have the same information unless contents will be used within one shift and not left unattended. Pipes, ducts, and valves carrying hazardous materials shall be clearly identified with the contents and hazard warnings.

VI. Hazardous Materials Inventory

A hazardous materials inventory for each chemical storage cabinet/work area is required and shall be posted on the cabinet or in the area and maintained on the GSFC database. The inventory shall list the material present, container size, quantity of containers, and location. The supervisor shall maintain this list and review it quarterly, at a minimum. Along with the inventory, the point of contact and phone number of the person responsible for the storage cabinet/work area shall be posted on the cabinet.

VII. Material Safety Data Sheet (MSDS)

1. The MSDS is a document that describes the physical and chemical properties of products, their physical and health hazards, and precautions for safe handling, storage, and use. An MSDS is required for each hazardous chemical used in the facility. Employees are not required to work with hazardous chemicals until an MSDS is made available for their review.
2. Supervisors shall ensure that an MSDS accompany each shipment of hazardous materials. When shipping materials to another location shall ensure an MSDS accompanies the material.
3. The MSDSs shall be kept in the GSFC database located at http://safety1st.gsfc.nasa.gov/chem.html
4. The supervisor may maintain the MSDS's in a notebook in an organized manner for quick review by the employee when required. The most current version of the MSDS shall be maintained (updated at least once every two years) in the GSFC database.

VIII. Employee Training

1. All employees who work with or are potentially exposed to hazardous chemicals during the normal course of work or in a foreseeable emergency shall receive information and training on chemicals. This shall occur at the time of the employee's initial assignment, a change in assignment, or whenever a new hazard is introduced into the workplace or upon assignment to non-routine tasks. Records of the training shall be kept in the appropriate supervisor.
2. Training shall include:
   - The requirements of the OSHA Hazard Communication Standard and employee rights and responsibilities.
   - Operations in the employee's work areas involving the use of hazardous chemicals
   - The location and availability of the Hazard Communication Program, the hazardous chemical inventories, and the MSDSs of the hazardous chemicals in the work areas.
   - The contents of this Hazard Communication Program, including an explanation of the labeling system and MSDSs.
   - Methods and observations that may be used to detect the presence or release of a hazardous chemical in the work area.
   - The physical and health hazards of the chemicals in the work area.
   - The measures employees can take to protect themselves from these hazards, such as safe procedures, emergency actions, and appropriate personal protective equipment (PPE).
3. Employees who use hazardous chemicals shall annually attend GSFC Hazardous Waste Generator Training.

2.5.2 Acronyms/Definitions

1. Asphyxiant—A substance, which can displace the oxygen in an area.
2. Bonding—Eliminating a difference in static electric charge potential between two or more objects.
3. Chemical—Any element, compound, or mixture of elements and/or compounds. Includes treated woods, metals, etc.
4. Class I—A liquid having a flash point below 100 °F (37.8 °C) and having a vapor pressure less than or equal to 40 psia (276 kpa).
5. Class II—A liquid having a flash point at or above 100 °F (37.8 °C) and below 140 °F (60 °C).
6. Class III—A liquid having a flash point at or above 140 °F (60 °C).
7. Combustible liquid—Any liquid having a flash point at or above 100 °F (37.8 °C) (Class II and III), but below 200 °F (93 °C).
8. Cryogenic liquid—A liquid with a normal boiling point below -238 °F (-150 °C).

9. Flammable aerosol—An aerosol that when tested yields a flame projection exceeding 18 inches (46 cm) at full valve opening, or a flashback at any degree of valve opening.
10. Flammable gas—A gas that, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13% or less by volume, or forms a range of flammable mixtures with air greater than 12% by volume, regardless of the lower limit.
11. Flammable liquid—Any liquid having a flash point below 100 °F (37.8 °C) (Class I), except any mixture having components with flash points of 100 °F (37.8 °C) or higher, the total of which make up 99 % or more of the total volume of the mixture.
12. Flammable solid—A solid other than a blasting agent or explosive that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious hazard.
13. Flash point—The minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite.
14. Grounding—Eliminate a potential difference between an object and the ground (earth).
15. Groups—This term shall include government divisions, other centers, contractors, and subcontractors.
16. Hazardous material/chemical—A chemical, which is a physical or health hazard.
17. Health hazard—Based on statistical evidence that acute (normally short term exposure and duration) or chronic (long term exposure and long duration) health effects may occur in exposed employees. This includes chemicals which are carcinogens, toxins, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents that act on the hematopoietic system, and agents which damage the lungs, skin, eyes, or mucous membranes.
18. Immediate use—The hazardous chemical will be under the control of and used only by the person who transfers if from a labeled container and only within the work shift in which it is transferred.
19. National Electrical Code (NEC)—The most widely adopted set of electrical safety requirements, used for regulatory purposes in the interest of life and property protection.
20. Permissible Exposure Limit (PEL)—The OSHA term for the time weighted average concentration, which must not be exceeded for a normal 8-hour workday and a 40-hour workweek.
21. Physical hazard—Evidence that a chemical is a combustible liquid, compressed gas, explosive, flammable, organic peroxide, pyrophoric, reactive, or water-reactive.
22. Pyrophoric—A chemical that will ignite spontaneously in air at a temperature of 130 °F (54.5 °C) or below.
23. Reactive—A chemical which will vigorously polymerize, decompose, condense, or will be come self-reactive under conditions of shock, pressure or temperature.

24. Satellite Accumulation Point—A site in the immediate area of waste generation, which is under the control of the employees in the area. No discrete site can accumulate more than 55 gallons (208 liters) of hazardous waste or one quart (0.95 liter) of acute hazardous waste.
25. Threshold Limit Value (TLV) or Threshold Limit Value-Time-Weighted Average (TLV-TWA)—The time weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect. These are recommended levels established by the American Conference of Governmental Industrial Hygienists (ACGIH).
26. Threshold Limit Value-Ceiling (TLV-C)—The concentration that should not be exceeded during any part of the working exposure.
27. Threshold Limit Value – Short-Term Exposure Limit (TLV-STEL)—The concentration to which workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage, or 3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, and provided that the daily TLV-TWA is not exceeded.
28. Toxins—Poisons.
29. Water-reactive—A chemical that reacts with water to release a gas that is either flammable or presents a health hazard.

2.5.3 General

Exposure to hazardous materials must be eliminated or reduced to the greatest extent possible. The purpose of this section is to ensure all employees are informed as to the chemical hazard they may be exposed to in the workplace under normal conditions or in a foreseeable emergency. To ensure that employees are not exposed to hazardous materials/chemicals, employees must be aware of and use the MSDSs to determine both health and physical hazards associated with the materials. Part of employee awareness is training in chemical detection and procedures to follow to prevent exposure.

2.5.4 Design/Operational Requirements

1. The S&ED shall approve all new hazardous materials/chemicals brought onto GSFC prior to their arrival. This applies to government, contractor, and subcontractor work. When a new hazardous material purchase is being made, the material's MSDS shall be routed to the S&ED for approval of the purchase.
2. MSDSs must be entered into the GSFC Database for all hazardous chemicals brought into AETD facilities. All MSDSs shall be maintained on the GSFC Database, even those used temporarily.

3. All outside organizations using hazardous chemicals in AETD shall develop their own written hazard communication program. This shall be supplied to the Branch Office. AETD shall use this section of the Manual as their program. OSHA 1910.1200 requires each supplier, manufacturer, or user of hazardous materials to have a hazard communication program. This program consists of evaluating the hazards of the material used in the work place, having a written program, having MSDSs available for all hazardous materials, training employees in their rights to know what they are being exposed to, and labeling containers.
4. Hazardous materials shall always be properly stored at the end of each shift. Flammables must be stored in Flammable Storage cabinets and acids in Acid Storage cabinets. Never mix incompatible materials, like flammables and acids. Do not store acids near bases, since the heat of reaction between the two can be intense enough to ignite flammable and combustible materials. Always have leaky or damaged containers removed and disposed of immediately.
5. Whenever chemicals can be splashed on the skin or in the eyes, PPE shall be worn and an emergency shower and/or eyewash stations shall be available. Showers and eyewash stations shall be tested at least weekly.
6. Flammable and combustible liquid requirements are:
    - Keep all heat sources away from flammable and combustible materials.
    - Control of vapors is the primary means of controlling the fire risk. Ventilation is considered adequate if it is sufficient to prevent accumulation of significant quantities of vapor-air mixture in concentrations over 10% of the Lower Flammable Limit (LFL).
    - If being used in locations where the concentrations of flammable vapors may be greater than 10% of the LFL, equipment must be rated for use in hazardous locations, meeting NEC, Article 500. Class I locations are those in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures. Class II locations are those that are hazardous because of the presence of combustible dust. Each Class has associated Divisions, which further define types of concentrations.
    - Do not use or store flammable and combustible liquids near strong sources of radio frequency (RF) radiation.
    - Do not use more than one gallon of flammable liquids on the job at a time.
    - When transferring flammable liquids, especially Class I liquids, from one metallic container to another, provide a means of bonding between the two conductive containers prior to pouring. Additionally, these containers must be grounded. Static charges can build up due to pouring, pumping, mixing, filtering, or agitating flammable liquids. Bonding and grounding systems should be inspected prior to each use for broken wires, corrosion or other damage, and should be inspected annually for electrical continuity.

7. Oxidizers, peroxides, and organic peroxides:
   - Most peroxides are sensitive to heat and/or shock.
   - Keep oxidizers, peroxides, and organic peroxides away from other chemicals.
   - Do not allow peroxides to freeze. This increases their sensitivity to shock.
   - Avoid contact with metals. Metals react, helping the release of oxygen.
8. Pyrophoric materials must be handled with extreme care. Refer to the appropriate MSDS for detailed handling requirements. Operations involving pyrophorics must be designated as hazardous and must have detailed procedures approved by S&ED.
9. The use of toxic materials or materials which present health hazards should be limited. When they are used, adequate ventilation must be provided and the exposure limits described in the *ACGIH Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*, and 1910.1000, *Air Contaminants* must be followed. If in doubt as to how much exposure employees may be subjected to, area or personal monitoring is required.
10. Fume hoods should be considered as a backup safety device to contain and exhaust toxic, offensive, or flammable materials. Hoods shall be evaluated prior to use and annually thereafter by Industrial Hygiene to verify adequate airflow. When used, front closures must be closed as much as possible to improve performance.
11. Extremely hazardous materials, or containers, which have contained extremely hazardous material, such as hydrazine, should not be brought into the AETD facilities. Check with the building FOM or appropriate branch head prior to bringing the material on Center.
12. Carbon tetrachloride is not authorized for use, except in minute quantities as approved by the Branch Head and S&ED.
13. Asphyxiants (nitrogen, helium, etc.) shall not be used/transferred in enclosed areas/labs or confined spaces unless a calibrated oxygen meter is used to verify that the oxygen levels in the ambient air are a minimum of 19.5% when personnel are present.
14. Hazards and requirements for cryogenic agents are as follows. (Appendix D has additional details on cryogens.)
    - Personnel involved in cryogenic operations must have specific training in the hazards and requirements for working with this material.
    - Operations involving non-DOT rated dewars shall be reviewed and approved by the Peer Review Team. Information on the requirements may be found at http://aetdsrrt.gsfc.nasa.gov/docDir/index.cfm in the folder labeled “Dewar Policy.”
    - Extreme cold is one of the most obvious hazards when dealing with cryogenics. Their cold “boil-off” vapor can rapidly freeze human tissue, and can cause many common materials such as carbon steel, plastics, and rubber to become brittle or even fracture under stress. Cryogenic liquids in containers and piping having temperatures at or below

the boiling point of liquefied air (-318 °F, -195 °C) can actually condense the surrounding air to a liquid. Liquid oxygen is an oxidizing agent.

- Cryogenic liquids spilled on exposed skin or eye tissue can cause frostbite. Always rope off and stand clear of boiling or splashing liquid and its vapors unless properly attired. Appendix D discusses PPE requirements.
- Cryogenic containers must be protected with pressure relief devices (see Section 2.3.1).
- Most cryogenic materials are odorless, colorless, and tasteless when vaporized to the gaseous state.
- When a warm container is filled or when warm objects are inserted into a cryogenic liquid, boiling and splashing always occur. Perform these operations slowly to minimize boiling and splashing.
- Never allow any unprotected part of the body to contact uninsulated pipes or vessels containing cryogenic fluids. Extremely cold material may stick quickly and tear the flesh when you attempt to withdraw it.
- Use tongs to withdraw objects immersed in a cryogenic liquid.
- Components used in cryogenic systems must be designed and approved for such use. For example: valves that have longer stems to allow for application of insulation and seals are compatible with extreme cold. Carbon steel becomes brittle at low temperatures and may easily fracture when stressed.
- Dispose of cryogenic liquids (nitrogen or helium) only in well-ventilated areas.

15. Corrosives are capable of destroying living tissue and have a destructive effect on other substances, particularly on combustible materials; this effect can result in a fire or explosion. Adequate ventilation must be provided, as well as goggles and face shield, gloves, and an apron. Corrosive solids are activated by water. Small amounts of water will create a highly concentrated liquid corrosive.
16. Ammonia handling:
    - Physical Properties:
        a) At ambient conditions, ammonia is a colorless gas with a sharp, pungent odor. It is soluble in water, alcohol, and many other solvents.
        b) Anhydrous (having no water) ammonia is shipped as a liquefied gas under its own vapor pressure.
        c) Although ammonia is lighter than air, the vapors from a leak initially hug the ground until it thermally stabilizes. At that point, it rises and mixes slowly.
        d) Ammonia has a flammability limit between 16 (160,000 ppm) and 26.8% by volume with air. An ammonia fire is difficult to extinguish because of the large amount of water required to control it. A water spray/fog is effective in reducing the concentration of ammonia due to its high solubility. The auto ignition temperature is 651°C. The probability of an ammonia fire is infinitesimal. In order to ignite, the

ammonia would have to leak to the atmosphere, which would expose it to oxygen. Then the gas would have to be exposed to an ignition source while in a critical concentration. This concentration can only occur in a small area near the leak.

e) In the anhydrous form, ammonia is highly reactive. Ammonia corrodes copper, tin, zinc, and alloys containing these metals. It is compatible with aluminum and stainless steel. Ethylene propylene (EP) is recommended for O-rings when required.

- Physiological Effects:

  Liquid ammonia produces severe burns on contact due to its caustic nature and from freezing during evaporation. Gaseous ammonia is a strong irritant and can cause damage to the eyes and respiratory tract.

  a) Exposure limit is 35 ppm for 5 minutes without protection. Safety requires that levels be kept below 25 ppm for workers exposed for a normal workday of 8 hours.

  b) Most people can begin detecting ammonia at 5 ppm. 20 ppm is easily noticeable and 100 ppm is strong.

  c) At 400–700 ppm, symptoms include nose, throat, and eye irritation. The (immediately Dangerous to Life and Health (IDLH) level is 500 ppm.

  d) At 2,000–3,000 ppm, symptoms include convulsive coughing and serious eye irritation. May be fatal after short exposures.

  e) Above 5,000 ppm, symptoms include respiratory spasm and rapid asphyxia, and these are fatal.

  f) Ammonia is classified as a toxic gas; however, the odor is perceptible at very low levels, and the acute discomfort that it causes will warn personnel of its presence. This will allow personnel to escape from small leaks or spills.

- Handling Procedure:

  During handling operations of test items containing ammonia, the following rules shall be adhered to:

  a) All personnel involved with the operation shall be familiar with this document.

  b) The buddy system shall be implemented at all times.

  c) Personnel working in confining areas, such as vacuum chambers, shall wear chemical goggles.

  d) Eyewash stations shall be readily accessible and tested/verified operational.

  e) Personnel shall be briefed as to the location and operation of building exhaust fans.

- Ammonia Leak Emergency Procedures:

  Always remain calm in an emergency. The following must be adhered to:

  a) Activate the building fire alarm and evacuate all personnel from the building.

  b) Activate the building emergency exhaust fans by pressing the start button at any location.

c) Go to the designated evacuation location (parking lots at the front and rear of the buildings) and meet with the GSFC Incident Commander. Do not re-enter until told to do so by the Incident Commander.

- First Aid:

  If unsure of first aid measures to take, immediately contact the Emergency Console at 911.

  a) Eye or Skin Exposure—Flush ammonia-exposed areas with large quantities of water for a minimum of 15 minutes. Affected clothing must be removed immediately. Wash exposed skin areas thoroughly with soap and water.

  b) Inhalation—Victim must be taken to an uncontaminated area. Emergency personnel should avoid self exposure to ammonia. Call the Emergency Console, 911, if breathing is difficult, so that oxygen can be administered. If the victim has stopped breathing, administer rescue breathing. If no pulse is detected, administer CPR.

17. Large quantities of flammable chemicals, such as drum-sized containers shall be stored in the buildings/areas provided for storage of such quantities. The building FOM must approve the location used for drum storage.

18. Hazardous waste shall never be poured down the drain or disposed of in trashcans. Chemicals scheduled for disposal shall be placed in properly marked containers, separated by class of waste (health hazard, corrosive, flammable). Never accumulate more than 45 gallons (170.3 liters) of waste at any Satellite Accumulation Point. Only one/half quart (0.475 liter) of acute hazardous waste (e.g., cyanides) shall be assimilated at a Satellite Accumulation Point. For removal contact the GSFC Hazardous Waste Environmental Specialist (6-9233). Prepare a Hazardous Waste Disposal Inventory Form, GSFC 23-54, and submit it to the waste disposal personnel. Copies of the MSDSs shall be readily available.

21. Spill control – In the event of a spill, always review the MSDS prior to attempting any cleanup. Personnel shall never attempt to cleanup a spill of a material they have not worked extensively with. If the material is unknown or not familiar to the employee, evacuate the area. Secure the area well enough to keep unauthorized personnel away from the spill. Only attempt cleanup of any spill if specifically trained to do so, training is current and protective equipment is available. Contact the Emergency Console at 911. A contractor specifically trained to handle spills shall respond.

2.5.5 GSFC Contacts

S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035

2.5.6 Reference Documents Unique to this Section

29 CFR 1910.1200, *Hazard Communication Standard*

29 CFR 1910.1450, *OSHA Laboratory Standard*

29 CFR OSHA, *Subpart Z: Toxic and Hazardous Substances*

NHS/IH-1845.3, *NASA Health Standard on Hazard Communication*

United States Department of Agriculture, Hazard Communication: A Program Guide for Federal Agencies. August 1987

Fed-Std-313, *Material Safety Data, Transportation Data and Disposal Data for Hazardous Materials Furnished to Government Activities*

GPR 1700.2, *GSFC Chemical Hygiene Program*

NFPA 70, *The National Electrical Code*

2.6 Non-Ionizing Radiation Systems

2.6.1 Scope

This section describes the requirements for the safe use of non-ionizing radiation systems brought into or used within AETD facilities.

2.6.2 Acronyms/Definitions

1. Carcinogenic—Capable of causing cancer in a biological system.
2. Electromagnetic Radiation—The flow of energy consisting of orthogonally vibrating electric and magnetic fields lying transverse to the direction of propagation. X-rays, ultraviolet, visible, infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in their frequency and wavelength.
3. Infrared Radiation (IR)—Invisible electromagnetic radiation with wave-lengths which lie within the range of 0.70 to 1,000 μm. These wave-lengths are often broken up into regions: IR-A(0.7-1.4 μm), IR-B (1.4-3.0 μm), and IR-C (3.0-1,000 μm).
4. Laser—An acronym for Light Amplification by Stimulated Emission of Radiation. A laser is a cavity with mirrors at the ends filled with material such as crystal, glass, liquid, gas, or dye. It is a device which produces an intense beam of light with the unique properties of coherency, collimation, and monochromaticity.
5. Point Source—A source of radiation whose dimensions are small enough compared with the distance between source and receptor for them to be neglected in calculations.
6. Pulsed Laser—A laser which delivers its energy in the form of a single pulse or a train of pulses. In this Safety Manual, the duration of a pulse is less than or equal to 0.25 seconds.
7. Radio-Frequency (RF) Radiation—Invisible radiation most commonly produced by radio or television transmitters and radar equipment. When arcing or "sparking" occurs, it is projected by a variety of other electrical equipment in a random form perceptible through ordinary radio or television receivers as "static." It is also deliberately produced for therapeutic effects in limited areas by the diathermy devices used in doctors' offices.
8. Ultraviolet (UV) Radiation—Electromagnetic radiation with wavelengths between soft x-rays and visible violet light, often broken down into UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (100-280 nm).
9. Visible Radiation (Light)—Electromagnetic radiation, which can be detected by the human eye. It is commonly used to describe wavelengths, which are in the range of 0.4 to 0.7 μm.

2.6.3 General

Forms of non-ionizing radiation include light—both visible and invisible—infrared (radiant heat) and ultraviolet rays, as well as the whole spectrum of radio waves. At their ordinary levels, these forms of radiation are not usually harmful and are often beneficial. In sufficient quantities, however, they can produce harmful effects, ranging from sunburn and skin cancer to blindness or other injury.

2.6.4 Operational Requirements

1. Use of any non-ionizing radiation source requires completion of the following forms:
   - GSFC Form 23-6RF, GSFC Request for Radiation Safety Committee Action RF/Microwave Source Questionnaire
   - GSFC Form 23-28RF, Request for Radiation Safety Committee Action RF/Microwave Source Questionnaire
   - GSFC Form 23-35RF, GSFC Request for Radiation Safety Committee Action: RF/EMF Source Personnel
   - GSFC Form 23-35UL, Contractor Laser User Eye Exam Verification
   - GSFC Form 23-28L, Request for Radiation Safety Committee Action – Laser Radiation Source Questionnaire
   - GSFC Form 23-6L GSFC Request for Radiation Safety Committee Action Laser Radiation Source Personnel Approval.
   - GSFC Form 23-67B, Laser Configuration for Outdoor Operations

   The forms must be submitted to the GSFC Radiation Protection Officer (RPO) for approval at least two weeks before the source is to be brought onto the Center. In the case of ultraviolet and high intensity lights (such as those used for NDT work), no form is required; however, the user shall verbally notify the RPO that such lights are being used. Wear the eye protection and/or protective clothing prescribed for any equipment you are operating.
2. Proper warning signs shall be posted in any areas in which dangerous radiation exists, and if necessary, erect barriers and exercise traffic control to prevent injury to other persons who enter the area.
   a. Consult individual device manuals for hazard prevention.
   b. Although infrared radiation is not actually heat, it produces heat in objects that it strikes. In sufficient intensity, it may ignite flammable materials or severely burn living tissue. Serious eye damage may result from looking directly at a source of infrared light before any symptoms become apparent. Two basic rules shall be observed:
      - Do not expose flammables or explosives to concentrated infrared rays.
      - Do not look directly at a source of concentrated infrared light without adequate eye protection.

   NOTE: Glasses that protect against ultraviolet radiation do not always protect against infrared. Eye protection must be rated for the level of infrared protection you may be exposed to.
3. Radio-Frequency (RF) radiation's most common biological effect is a rise in body temperature, usually noticeable before serious damage occurs. However, it can cause severe burns in the case of any bodily contact with metal objects such as rings, belt buckles, etc. In sufficient concentrations (usually only in close proximity to a powerful transmitter), it may cause serious permanent damage to the eyes. In such concentrations, it may also cause temporary damage to the male reproductive organs, resulting in temporary sterility (but not impotence) that later disappears.

- Random RF radiation from devices such as arc welders is not directed in a concentrated beam and is rapidly dissipated.
- Besides its biological effect, RF radiation creates another hazard: it may ignite or detonate explosive devices at a considerable distance from its source. This hazard is discussed in Section 2.2.

4. Lasers:
   - Avoid looking directly into any laser beam or its reflections.
   - Remove all unnecessary specular (shiny) reflecting surfaces from the area. Avoid looking at reflections in the laser mirrors, shiny spherical objects such as doorknobs, screw heads, window panes, watch crystals, rings, tools, jewelry, or the mirrors and shiny surfaces of laboratory equipment.
   - When the laser system is not in use, ensure that it is inaccessible to unauthorized personnel.
   - Immediately report any accident to the medical facility, especially if an eye is involved.
   - Before high-power, advanced-type (Class 3b and 4) laser systems are used, the user shall complete training, develop a safety plan, and obtain prior approval of the GSFC Radiation Safety Committee. Safety precautions should include at least the following:
     a) Never look directly into the laser beam or pump source during firing or at the laser's specular reflection.
     b) Lasers shall be used only in controlled areas. Post the area with appropriate signs to alert persons passing by the area that a potential hazard exists.
     c) Never permit any part of the body to intercept the laser beam or its reflection.
     d) When possible, physically isolate the laser firing area from the control panel. Post the control and firing area with adequate signs warning of the hazard, carefully control personnel access, and recommend visible and/or audible signals for the area.
     e) Illuminate all areas used for laser firing with high-level lighting that will constrict the pupil of the eye to reduce the probability of retinal damage.
     f) Aim the beam indirectly and never look into the primary beam. Adopt a count-down system with eyes completely closed for use when high-power pulsed lasers are energized.
     g) Use a nonreflective, fire-resistant surface as a target background. Paint or coat the surrounding area to absorb any scattered or reflected radiation. Ensure that the laser beam is directed so it cannot strike vessels that contain combustible materials.
     h) Clear the area along all parts of the anticipated path of the laser beams of personnel, reflective objects, and flammable materials.
     i) Remember that materials that are bombarded and vaporized by the incident beam can result in atmospheric contamination. Toxic materials from such vapors or fumes include lead, ozone, carbon monoxide, cadmium, and mercury.

j) Take positive action to prevent accidental energizing of pulsed lasers. Turn the power off and discharge the capacitors before making any repairs or adjustments that may expose the operator or others to the incident beam or to electrical shock.

k) Do not rely on safety glass to view the direct laser beam. If safety goggles are to be furnished, ensure that they protect against the specific energy and wavelength of the beam under consideration.

5. Ultraviolet Radiation:

- Ultraviolet radiation is an invisible form of light, present in ordinary sunlight. In greater concentrations, it can burn the eyes and skin. All solar simulators, blacklights, and some optical testing facilities produce such concentrations. In particular, it can cause severe skin burns and eye damage up to and including total and permanent blindness.
- Ultraviolet radiation is not apparent to the ordinary human senses except through symptoms that appear only after the damage has been done. Fortunately, ordinary clothing and glass quartz used in solar simulators or even window glass eliminate the worst effects of normal concentrations.
- When any black light is brought into AETD facilities a letter must be provided to S&ED at least 30 days prior to bring onto GSFC indicating: 1) manufacturers specifications and warnings; 2) where the light will be used; 3) the designated light custodian (name and project); and 4) how it will be used.
- The basic safety precautions to be observed in the presence of ultraviolet radiation are as follows:

  a) Do not operate, or remain in the vicinity of, devices that produce ultraviolet radiation without wearing prescribed eye and skin protection.

  b) Do not expose unclothed portions of your body to ultraviolet radiation devices.

  c) Post appropriate warning signs in any area in which ultraviolet radiation is present; and, if necessary, exercise traffic control to ensure that other personnel who enter the area will not be exposed to dangerous radiation.

  d) If you are not involved in operations involving ultraviolet radiation but must enter such an area, obey all warning signs and instructions of operating personnel.

  e) Do not use glass as transmitting windows for solar simulators where energy collection can cause glass failure.

6. Solar Simulation:

- A series of powerful lamps, designed to duplicate the spectrum of the sun as closely as possible, produce simulated solar radiation in intensity far greater than that of ordinary sunlight which reaches Earth after filtration through the atmosphere. This light consists of infrared, ultraviolet, and visible light. Direct exposure of unprotected personnel to simulated solar radiation can cause severe burns and eye damage. Ozone is a byproduct. Any person who must occasionally be exposed to such radiation must wear prescribed eye protection or masks with suitable radiation-filtering lenses, as well as hoods and other

protective clothing to preclude burns. This equipment may also produce some ionizing radiation.

- Solar simulation lamps have an explosion hazard.
  a) Wear specially designed heavy insulated gloves, protective clothing, safety glasses and face shields when changing simulation lamps.
  b) Because of their high internal pressure, place simulation lamps in protective housings immediately during changing and storage.
  c) Permit only authorized and qualified personnel to operate and maintain solar-simulation equipment. Post the area with warning signs and clear non-essential personnel from the area when performing lamp changeout.
  d) Ensure all viewing ports on solar simulators are quartz and are protected with a polycarbonate (Lexan) to protect against an implosion hazard.
  e) Do not use glass as transmission ports for solar simulators where energy collection can cause glass failure.

7. Light:

- Light can cause not only severe skin burns but also serious and permanent damage to the eyes. Even "natural sunlight," reinforced by reflections from wide expanses of snow, can cause the "snow blindness" familiar in high altitudes; and all of us are familiar with the "blinding" effects that result from looking at the sun or from the sudden appearance of headlights on a dark highway. Although the light of various devices, including ultraviolet and welding devices, is sufficiently perceptible to cause personnel to avoid serious danger, it can cause damage and should not be underrated. Any source of light that is more intense than those encountered in everyday life should be treated with respect. The general precautions specified previously for infrared and ultraviolet light are usually more than adequate to avoid danger from visible light.

2.6.5 GSFC Contacts

S&ED: (301) 286-2281
Radiation Protection Officer (RPO): (301) 286-8482
AETD Safety Manager: (301) 286-1035

2.6.6 Reference Documents Unique to this Section

GPR 1860.2, *Radiation Safety Handbook—Radio Frequency*

GPR 1860.3, *Radiation Safety—Laser*

GPR 1860.4, *Radiation Safety—Ultraviolet and High Intensity Light Radiation*

ANSI C95.1, *American National Standard Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields*

ANSI Z136.1, *American Standard for Safe Use of Lasers*

ASNT 018-82, *Radiation Protection Section 18, The Non-Destructive Testing Handbook on Radiography and Radiation Heating*

EIA LEB1-70, *Safety Classification of Laser Equipment and Installations*

OSHA 29CFR 1910.96, *Radiation Safety*

OSHA 29CFR 1910.97, *Non-Ionizing Radiation*

OSHA Instruction PUB 8-1.7, *Guidelines for Laser Safety and Hazard Assessment*

2.7 Ionizing Radiation Systems

2.7.1 Scope

This section describes the requirements for the safe use of ionizing radiation sources brought into or used within AETD facilities.

2.7.2 Acronyms/Definitions

1. Background radiation—Ambient ionizing radiation to which individuals are always exposed.
2. Contamination (radiation)—A condition in which radioactive material has spread to places where it may harm persons, spoil experiments, or make products or equipment unsafe or unsuitable for some specific use.
3. Dosimeter—Any instrument which integrates the dose rate with time.
4. Film badge—A dosimeter consisting of an appropriately packaged nuclear emulsion film for detecting the amount of radiation personnel have received. Film badges are usually dental-size x-ray film worn on the person.
5. Monitoring—Periodic or continuous check on the amount of ionizing radiation contamination present in the environment. This check is a measure for health protection.
6. Radiation, ionizing—Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter or air.
7. Radiation, nuclear—Radiation emitted by the nucleus, which includes gamma rays, beta and alpha particles and sometimes neutrons and protons. It does not include x-rays.
8. Radiation-producing equipment—Any device, machine, or equipment capable of producing radiation (e.g., x-ray tubes, accelerators, cathode-ray tubes, klystrons, thyratrons, magnetrons, resonance transformers, and electrostatic precipitators.)
9. Radiation source—Any radioactive material or radiation-producing equipment.

2.7.3 General

- Ionizing radiation is produced by certain naturally occurring and man-made elements (e.g., uranium, plutonium, einsteinium, lawrencium and radium, etc.); in lower intensities by some isotopes of a great variety of more common elements; and by a number of man-made devices, including x-ray apparatus and particle accelerators.
- In sufficient concentrations, ionizing radiation can cause serious damage to living tissue. Such damage may be genetic (affecting future generations), as well as somatic (up to and including death). The action of ionizing radiation is particularly insidious because it is not perceptible by the ordinary human senses except through symptoms that appear after the damage has been done.

2.7.4 Operational Requirements

1. The RPO must approve all uses of ionizing radiation. For radiation sources the following forms shall be submitted at least two weeks prior to the arrival of the source.
   - GSFC Form 23-6I, GSFC Request for Radiation Safety Committee Action Ionizing Radiation Source Use Approval
   - GSFC Form 23-28I, GSFC Request for Radiation Safety Committee Action Ionizing Radiation Source Questionnaire
   - GSFC Form 23-35IP, GSFC Request for Radiation Safety Committee Action Ionizing Radiation Source Personnel Approval
   - GSFC Form 23-6ID, GSFC Request for Radiation Safety Committee Action Ionizing Radiation Producing Device Approval
   - GSFC Form 23-28ID, GSFC Request for Radiation Safety Committee Action Ionizing Radiation Producing Device Approval
2. Personnel using ionizing radiation shall take a basic course and a refresher course on this topic every two years. The training is provided by the RPO. Reference GPR 1860.1 contains detailed safety rules and procedures for operations in this field. All personnel whose duties involve exposure to ionizing radiation shall become familiar with its provisions. They will not be repeated here except for the following, which deserve special emphasis:
   - The location of ionizing radiation sources shall never be changed/moved without notifying the RPO.
   - Responsibility for the use, storage, and handling of any source of ionizing radiation shall be assigned to an RPO-approved custodian, as specified in GPG 1860.1.
   - All wipe tests (arrival, periodic, and after environmental/vacuum tests) shall be scheduled with the S&ED as far in advance as practical. Sources shall not be unpacked without S&ED presence. The procedure shall be as follows:
     a) Call the S&ED to establish tentative schedules for wipe tests. Reschedule when major changes occur.
     b) When the wipe test is ready to be performed, make arrangements with the S&ED one day before the wipe test.
   - All ionizing radiation areas must be posted with warning signs as provided in GPR 1860.1. When appropriate, traffic control should be exercised to prevent accidental exposure of personnel not involved in the operation in progress.
   - All personnel occupationally exposed to ionizing radiation shall be provided with film badges, dosimeters, or other personnel monitoring equipment, as prescribed by GPR 1860.1.

3. Procedures shall be prepared for each device that produces ionization. Procedures shall be approved by the RPO and posted in the vicinity of the device in question. Personnel involved in the operation of each device shall be required to read the instructions and indicate by initial that they have done so.

2.7.5 GSFC Contacts

S&ED: (301) 286-2281
RPO: (301) 286-8482
AETD Safety Manager: (301) 286-1035

2.7.6 Reference Documents Unique to this Section

GPR 1860.1, *Ionizing Radiation Protection*

Title 10 CFR 19, *Notices, Instructions and Reports to Workers: Inspections*

Title 10 CFR 20, *Standards for Protection Against Radiation*

2.8 Electrical Systems and Equipment

2.8.1 Electrical Safety Program

I. Purpose and Scope

This section covers safety-related work practices and various electrical systems and equipment containing inherent electrical hazards that are found throughout AETD facilities. Work practices shall be employed to prevent electric shock or other injuries resulting from either direct or indirect electrical contact, when work is performed near or on equipment or circuits which are or may be energized.

II. Applicability

The Electrical Safety Program is applicable to all civil servants and contractors working in AETD facilities. Employees engaged in electrical or electronic work shall comply with this program, which outlines the requirements of the *Occupational Safety and Health Administration's Electrical Safety Standard*, OSHA Subpart S, 29 CFR 1910.331 through 1910.335.

III. Policy

The AETD policy is to establish and implement a comprehensive Electrical Safety Program, which fully meets the requirements of the Occupational Safety and Health Administration (OSHA), Subpart S.

IV. Responsibilities

Specific responsibility and authority for administering and implementing the AETD Safety Program, including the Electrical Safety Program, are defined in 500-PG-8715.1.1, *AETD Safety Plan*. Additional responsibilities specific to the Electrical Safety Program are defined below:

A. Director of has overall responsibility for ensuring that the Electrical Safety Program is implemented in this organization, including the following:

1. Ensure that resources needed to comply with the Electrical Safety Program are available.
2. Ensure Division Chiefs implement and maintain an effective Electrical Safety program.

B. Division Chiefs shall:

1. Ensure that all line managers/supervisors and their employees attend required training.
2. Ensure that new employees are appropriately trained in the Electrical Safety Program and location of a copy of this Program.

C. Branch Heads shall identify and acquire all resources needed to implement the Electrical Safety Program for their areas of responsibility, including ensuring that proper procedures are developed and following and required PPE is readily available to employees working on electrical or electronic equipment.

D. Line Supervisors are responsible for direct action and enforcement to ensure compliance with the Electrical Safety Program, including the following:

1. Developing operating procedures for hazardous electrical work. Hazardous electrical work would include work on equipment which could cause death where an employees

training would not address all the hazards present. Work on live electrical circuits, such as trouble shooting will require a hazard review and/or procedure approved by the applicable supervisor.

2. Ensuring only qualified personnel are assigned to perform electrical work where hazards exist. Only qualified personnel may work on equipment that has not been de-energized equipment. These employees shall also be familiar with the proper use of special precautionary techniques, PPE, insulating and shielding materials, and insulated tools.
3. Ensuring damaged electrical equipment is taken out of service until replaced or repaired.

E. All Employees shall:

1. Only work on equipment that you are qualified and certified to perform work on. Qualified persons are those who have been trained in avoiding the electrical hazards of working on or near exposed energized components. They must possess the skills, techniques, and knowledge necessary to:
   - Distinguish exposed live parts from other components of electric equipment.
   - Determine the nominal voltage of exposed live components.
   - Know the proper clearance distances to be observed for the voltage involved.

   If direct contact or contact by means of tools or material is required, must be capable of working safely on energized circuits, and shall be familiar with the proper personal protective equipment (PPE), insulating and shielding materials, and insulated tools

F. AETD Safety Office shall:

1. Assist in determining the level and content of training required to adequately inform employees of the Electrical Safety Program requirements.
2. Audit the program to ensure that employees are trained in accordance with the Program.
3. Review and update this Program, as needed.

G. Safety and Environmental Division or its designated representative has overall responsibility for monitoring this program. Specific responsibilities include the following:

1. Providing revisions of the GSFC Electrical Safety Program on an as-needed basis.
2. Providing technical support including observations and reviews of work practices, procedures, personal protective equipment (PPE), and procurements.

H. Contracting Officer's Technical Representatives shall ensure that Contractors administer a Electrical Safety Program that complies with 29 CFR 1910. promulgated by the *Occupational Safety and Health Administration's Electrical Safety Standard*, OSHA Subpart S, 29 CFR 1910.331 through 1910.335.

V. Training

The training requirements contained in this section apply to employees who face a risk of shock that is not reduced to a safe level by the installation as required by the National Electrical Code and 29CFRl910 Subpart S, Electrical. Listed below are employees who may face such a risk and shall be trained.

- Electrical and electronic engineers
- Electrical and electronic technicians
- Electricians
- Mechanics and repairers
- Welders

Additionally, the follow may apply.

1 . Other employees who also may reasonably be expected to face comparable risk of injury due to electric shock or other electrical hazards must also be trained.
2. Employees who are covered by the scope this policy, but who are not qualified persons shall also be trained in and familiar with any electrically related safety practices not specifically addressed but which are necessary for their safety.
3. The training required shall be of the classroom or on-the-job type. The degree of training provided shall be determined by the risk to the employee.

2.8.2 Acronyms and Definitions

1. Ground (GND)—Stable voltage reference of 0.0V against which all other voltages are referenced. Also referred to as earth, circuit, or signal ground.
2. Ground fault circuit interrupter (GFCI)—Device that instantaneously detects when a ground fault has occurred, and automatically disables the power.
3. Hazardous Voltage—Typically defined as 50 volts and above with respect to ground. This must be treated as an approximation because voltage alone does not injure; currents as low as 0.1amp can injure. Systems carrying large current (tens or hundreds of amps) can operate at voltages lower than 50 volts.

2.8.3 General

The remainder of this section will address safety requirements that shall be adhered to by personnel involved in repairing and maintaining electrical equipment. Only qualified personnel shall work on electrical equipment.

1. Always use applicable lockout/tagout procedures (Section 3.8). Check all electrical services with a calibrated meter to verify that the electrical service is positively secured. Always check for additional or secondary circuit breakers and power sources, which need to be locked/tagged out for the specific piece of equipment.
2. Obtain all safety equipment required for the job (glasses, goggles, shoes, gloves, meters, etc.) before working on any equipment or electrical service.
3. Check calibration dates to ensure that equipment has been inspected and is in good working order before working on a job.

4. Always ensure adequate illumination when working on electrical or electronic equipment.
5. Conductive materials or equipment that are in contact with any part of an employee's body shall be handled in a manner that will prevent them from contacting exposed energized conductors or circuit parts. If the employee must handle conductive objects in areas with live parts, the hazard must be minimized by the use of insulation, guarding, or material handling techniques. (example: non-conductive fish tapes when pulling wire)
6. Verify that the outer cabinets of custom GSE are at ground potential, using calibrated meters to ensure safety.
7. When operating or repairing any electrical equipment, ensure that you are not standing on wet concrete or earth unless you have rubber soled shoes, boots, or other insulation, such as a rubber mat. Use a GFIC wherever possible.
8. Ensure that you are protected when near metal piping ducts or metal structural members. Observe minimum clearance distances around energized components (see OSHA 1910.303). Uninsulated conditions could cause a grounding situation and result in severe electrical shock.
9. Do not attempt to repair or adjust electrical equipment before disconnecting it from its power source. If power must be left on for a specified operation of this type, the area supervisor shall perform a hazard review and incorporate special safety procedures for the operation before the job is started. It must be demonstrated that de-energizing introduces additional hazards or is infeasible due to equipment design or operational limitations. Live parts that operate at less than 50 volts to ground need not be de-energized if there will not be increased exposure to electrical burns or explosion due to electrical arcs. The buddy system is mandatory for work on live equipment. Use appropriate warning signs, barriers, and traffic control measures.
10. Do not attempt to bypass safety interlocks.
11. When the manufacturer has provided a grounding connection, use it.
12. When working on overhead electrical circuits, use wooden or fiberglass ladders rather than aluminum or metal ones.
13. All multi-phase power outlets shall be wired such that there is a clockwise rotation at the outlet.
14. Ensure that proper tags and warning signs are attached to all equipment that is left unattended while in operation or undergoing repair.
15. Ensure that all other equipment that requires special warnings is appropriately tagged to warn personnel of the hazard.
16. Be familiar with first aid and CPR techniques for shock and burns.
17. Do not attempt maintenance work on any electrical equipment unless you are qualified and have obtained the permission of your immediate supervisor for the work in question.

18. If you feel yourself to be unqualified to perform work for any reason (lack of knowledge, lack of training, poor information available on the system, feeling sick, etc.) report the problem to your supervisor.

2.8.4 Portable Equipment

The following are requirements for use of cord and plug connected equipment, including extension cords.

1. Extension cords are to be used for temporary use.
2. Flex cords may not be run under floors, ceilings, through doors.
3. Check plugs and cords for wear, damage, or abrasion. Do not use a tool if it is damaged in any way. Plugs with removable dust covers shall be replaced.
4. Do not use home-made extension cords, unless they are built with materials approved for that purpose. (Example: Metal handy boxes with knockout plugs are not made for portable use.)
5. Power outlet strips are designed for equipment that requires surge protection and should not be used as an extension cord.
6. No more than one power outlet strip may be connected to a single extension cord. Power outlet strips may not be plugged into one another to make a longer cord.
7. Never use a power cord to raise, lower or carry a piece of equipment.

2.8.5 High-Voltage Equipment (600 Volts and Greater)

The guidelines provided in Section 2.8.5 apply to all high-voltage equipment. In addition, the following shall be observed when performing maintenance on specific equipment:

1. Special Precautions:
   - All work on high-voltage equipment shall be conducted using the buddy system and written procedures. The buddy shall be a qualified safety observer whose primary responsibilities are to do the following:
     a) Enforce safety procedures and summon help in the event of an emergency.
     b) Know and be capable of using emergency first aid treatment, including cardiopulmonary resuscitation (CPR).
     c) Permit no one to approach the equipment without first giving positive warning of the potential dangers.
     d) Stand where he/she can see all personnel who are working on the equipment and can easily reach the main power switch in an emergency.
     e) Immediately disconnect the power source at the first sign of an emergency or accident.
   - First aid training, including CPR, shall be provided to all safety observers.
   - Warning signs shall be installed in all areas where high voltages in excess of 600 volts are present or exposed conductor where the combination of voltage and current could cause electrocution to personnel.

- Conspicuous signs containing precautions that apply to the particular equipment shall be installed on all high-voltage equipment. When large capacitors are used, the hazard exists even when the voltage and current are turned off.

  Personnel involved in maintaining high-voltage electrical equipment shall not wear any metal objects, such as rings, metal wrist bands, watch chains, etc., when working on the equipment.

2. Buss Bars:
   - Before performing any maintenance, the power shall be off and the circuit breaker locked and tagged out.
   - The line shall be de-energized both in front of and behind the buss bar, using a calibrated meter to verify the circuit is de-energized.
   - Connect a ground strap to a ground connection and to the buss bar. This will shunt voltage and current to ground if the system is accidentally re-energized.
   - Wear insulated gloves when installing or removing buss bars to prevent injury from accidental energizing of the line.
3. Circuit Breakers:
   - Before performing any maintenance, the power shall be secured and the line side of the breaker is disconnected. The means of accomplishing the disconnection varies with the type of circuit breaker; the manufacturer's instructions describing the procedure and precautions for the disconnection should be followed.
   - The load side of the breaker should then be grounded to prevent shock from energy-storage devices in the load.
   - Shall be labeled as to existing voltage.
4. Generators and Motor-Generator Sets:
   - Before performing maintenance, the power shall be off, the circuit breaker locked and tagged out, and all electrical storage devices (isolation capacitors, saturable reactors, transformers, etc.) shall be fully discharged.
   - Always keep a grounding bar in the vicinity of the generator control panel.
5. Isolation Capacitors:
   - Before performing any maintenance, the power shall be off and the circuit breaker locked and tagged out.
   - With a voltmeter, ensure that the capacitor is fully discharged before performing a maintenance operation.
   - Attach a grounding strap to the ground connection and to the line and load sides of the capacitor.

6. Power Amplifiers:
   - Before performing any maintenance, the power supply shall be off, the circuit breaker shall be locked and tagged out, and a nylon rescue rope is available to pull the person to safety in the event of a mishap. The buddy system must be used for this operation.
   - Discharge all energy-storage devices (capacitors, autotransformers, reactors, etc.) using the grounding bar that is connected to the ground side of the amplifier. Ensure that all of the energy-storage devices are completely discharged.
7. Rheostats, Power Resistors, and Rectifiers:
   - Observe applicable capacitor precautions.
   - Allow rheostats, power resistors, or rectifiers time to cool before removing or replacing them.
8. Shock Boards, Contactors, and Relays:
   - Observe applicable capacitor precautions.
   - Observe additional manufacturer's safety precautions.
9. Transformers and Autotransformers:
   - Before performing any maintenance, the power supply shall be off and the circuit breaker locked and tagged out. When de-energizing the incoming power autotransformer, wear heavy thick-soled rubber boots, pull the circuit breaker at the side of the transformer, lock and tag the circuit breaker, and then attach a grounding strap to a ground connection and to the load side of the transformer. Verify that the oil fill is non-hazardous (no polychlorinated biphenyls, etc.). If the oil fill is in question, contact the S&ED for their recommendations.
   - Open the vent valve and note the oil level in the transformer. Before energizing the transformer, ensure that the oil level is proper and the vent valve is shut.
   - When renewing the oil in a power transformer, exercise extreme caution to prevent splashing oil on the insulators at the top of the transformer.
   - Maintain "Danger" signs in all areas in which power transformers or autotransformers are located.
10. Miscellaneous High-Voltage Equipment:
   - In general, when dealing with high-voltage equipment, remove the equipment from the line and discharge the line and load sides of the equipment.
   - Use the manufacturer's procedures for removing, maintaining, and reinstalling the equipment.

2.8.6 Alternating-Current Equipment

Alternating-current (ac) equipment usually presents a lower level of hazard than direct-current (dc) equipment, although accidents occur more frequently with ac. However, special

hazards are inherent in high-voltage ac equipment and in some ac equipment that generates energy in high-frequency forms. Special precautions given previously in the section on high voltage apply to all high-voltage ac equipment. The following additional precautions for each equipment category below shall be observed during the operation and maintenance of ac equipment:

1. Motors and Alternators:
   - Before disconnecting a motor from a power supply, connect a ground strap to the input leads to discharge any energy storage devices on the line.
   - Do not wear loose clothing when working near moving motors or generators.
   - Keep all objects away from the motor cage.
   - When examining the brushes or slip rings on a motor or alternator during operation, wear insulated shoes and gloves.
2. Transformers and Amplifiers:

   This classification includes various specialty transformers, servomechanisms, specialty amplifiers, limited-power amplifiers, and operation amplifiers. Follow the manufacturer's procedures when servicing this equipment.
3. Test Equipment:
   - Be thoroughly familiar with the use of test equipment before applying it to a live circuit.
   - When using a voltmeter with a range selector, ensure that the proper range is being used. Additionally, ensure the meter wires are rated for voltages higher than expected for the system being checked. Failure to observe this precaution may result in destruction of the meter or injury to the operator.
4. Calibration Equipment:
   - Keep ac voltage reference sources in a standby condition when left on between tests.
   - When operating with a thermal transfer voltmeter, exercise care to prevent overloading the meter.

2.8.7 Direct-Current Equipment

The most significant hazard inherent in dc equipment is that in making or breaking a contact, an arc may result that can cause damage to eyes, depending on the position of the individual with respect to the arc. Both alternating and direct current can hold an individual when contact is made. However, the person who makes contact with direct-current may be thrown rather then held, in which case the injuries sustained are less severe. In most cases, the proper safety precautions for dc equipment are the same as those for high-voltage equipment. However, the following additional precautions shall be observed while servicing dc equipment:

1. Current Shunts:
   - Do not use a current shunt for any other purpose than its design (calibration, contactor heater, etc.).

- Do not touch a current shunt during operation.
- If the rating of a shunt is not known, do not use it.
- Before connecting or disconnecting a current shunt, ensure that the power supply is off and all energy-storage devices on the line have been discharged.

2. Knife Switches and Fuses:
   - When making or breaking a contact with a knife switch or fuse, ensure that the contact is fast enough to prevent arcing.
   - Use a fuse puller when removing or installing fuses. Fuses should not be removed or inserted into live circuits. Always turn off the power first.
   - Do not look directly at the arcing of contact points.
   - Ensure that you are not grounded.
   - All fuse and switch boxes shall be marked on the outside and inside covers to show the voltage present, rated fuse capacity, and the equipment circuit controls.
3. Motors and Generators:
   - Observe applicable ac motor precautions.
   - When examining the brushes or commutator on a motor or generator, wear safety glasses or goggles and insulated gloves, and either wear insulated shoes or stand on an insulated surface such as a rubber mat.
4. Nonquenching Contactors:
   - Observe applicable circuit breaker precautions.
   - Observe applicable fuse precautions.
   - Never engage a contactor by hand.
   - When a contactor trips out because of overload, reduce the load; do not shunt the overload relay or heater.
5. Regulators and Converter:
   - Before performing any maintenance on a regulator or converter, ensure that the power supply is off and the circuit breaker is locked and tagged.
   - Attach a ground strap to the line and load sides of the regulator or converter.
6. Test Equipment:
   - Observe applicable ac test equipment precautions.
7. Calibration Equipment:
   - Observe applicable current-shunt precautions given previously.
   - Exercise extreme caution when operating dc voltage and current sources. Keep these sources on “standby” when not in use.

- When performing operations with a thermal transfer voltmeter, exercise care to prevent overloading the meter, which would result in damage to the meter and possible injury to the operator.

2.8.8 Grounding

1. Grounding of GSE and flight hardware:
   - Custom GSE shall be constructed so the hardware case is grounded to prevent electrical shock to the operators.
   - Custom GSE should have all exterior switches, pushbuttons, displays, etc. isolated from power and at ground potential along with the case.
   - Any exposed power access (such as knife switches, fuses, etc.) shall be marked with appropriate hazard tags and shielded from common access.
   - Flight hardware should be constructed so the structure is at ground potential to help shield electrostatic discharge (ESD) sensitive components.
   - Personnel operating with or near such ESD sensitive hardware should wear ground straps and connect them to grounds provided near the GSE or flight hardware.
2. Working clearance around facility high-voltage equipment:
   - Working clearance of 3 feet (0.9 m) minimum must be provided between a panel, buss bar, circuit breaker panel, etc. with exposed live parts between 0 and 150 volts and any adjacent non-insulated ground (exposed concrete wall, exposed conduit, etc., which is considered to be at ground potential).
   - Working clearance of 3.5 feet (1.1 m) minimum must be provided for panels with voltages between 151 and 600 volts and exposed grounds.

     The following chart of minimum working clearances is applicable for higher voltages under varying conditions as described below:

Table 1 Minimum Working Clearances for High Voltage

Voltage to Ground	Minimum Working Clearances		
	Condition A	Condition B	Condition C
601–2,500	3 ft (0.91m)	4 ft (1.22 m)	5 ft (1.52 m)
2,501–9,000	4 ft (1.22m)	5 ft (1.52 m)	6 ft (1.83 m)
9,001–25,000	5 ft (1.52m)	6 ft (1.83 m)	9 ft (2.74 m)
25,001–75kvolt	6 ft (1.83m)	8 ft (2.44 m)	10 ft (3.05 m)
Above 75kvolt	8 ft (2.44m)	10 ft (3.05 m)	12 ft (3.66 m)

Definition of conditions A, B, and C listed above:

a) Exposed live parts on one side of the individual and no live or grounded parts on the other side of the working space; or exposed live parts on both sides effectively

guarded by suitable wood or other insulating materials. (Insulated wire or insulated buss bars operating at not over 300 volts are not considered live parts.)

b) Exposed live parts on one side and grounded parts on the other side. (Concrete, brick, or fire walls will be considered grounded surfaces.)

c) Exposed live parts on both sides of the workspace not guarded as provided in (a) with the operator between.

- Overhead clearances for 601–7,500 volts must be 8.5 feet (2.59 m) minimum and 9 feet (2.74 m) for voltage ranges of 7,501–35kv.
- Overhead clearance for voltages greater than 35kv are 9 feet plus 0.37 inches (2.74 m plus 0.94 cm) per kv above 35kv.

3. Ground Fault Circuit Interrupters (GFCI):
    - Incorporate GFCI circuits in extension cords that will be used to operate powered hand tools, especially when working in a damp or enclosed area, where the operator may also contact grounded surfaces.
    - Incorporate GFCI circuits into custom GSE for each unit and especially if the unit will be used to transmit or provide power to additional pieces of equipment.

2.8.9 Custom GSE Considerations

1. All custom GSE should have common safety features in their design, including the following:
    - All equipment shall have switches to turn off power prior to installation, use, or repair. The main power switch shall be clearly marked and should operate a power indicator light as well as energizing the rest of the equipment. Subsequent switches operating power to subcircuits should also be labeled, have indicator lights, and not bypass the main power switch.
    - Fuses, circuit breakers, and other protective devices are required for GSE primary circuits. Connect protective devices to the load side of the main power switch unless neutral power sensing is required for protection of equipment.
    - If three-phase power is being used, all three lines should be fused and tripped in common so that a fault in any phase will trip all three.
    - Redundant circuits should operate on fuses and switches separate from the primary circuits.
    - Interlocks are required on all GSE units provided with doors, covers, or plates, unless:
        a) Operating voltage is less than 30 volts rms or dc; or
        b) Barriers or guards are provided to allow operator adjustments without the risk of personnel contact with 30 volts or greater. These barriers should identify the voltage hazard.
    - Non-bypassable interlocks are required on the enclosure of subassemblies within major GSE units if voltage exceeds 500 volts rms or dc.

- "Caution" signs shall be clearly visible when the enclosed voltage range is between 30 and 500 volts.
- "Danger" signs shall be clearly visible when the enclosed voltage range is 500 volts or greater.
- For monitoring high-voltage circuits, try to incorporate proportional step-down monitoring circuits, which can be measured with little hazard.
- Connectors with different alignment pins or keyway arrangements should be used to make it impossible to incorrectly mate any external circuitry or create a hazardous condition by reversing polarity.
- If redundant external circuits are employed, they should be accessed through separate connectors.
- For transmission of power, male plugs shall not be the source of power, which would expose any handler to electric shock.
- All cases, switch knobs, controls, etc. shall be at ground potential to prevent shock to the operators.
- When equipment is to be used in a hazardous atmosphere, NEC 500 precautions and/or NASA guidelines regarding explosion-proof design shall be followed.
- When equipment is to be used in a controlled atmosphere (purged or cleanroom), observe the NEC and/or NASA guidelines regarding requirements for venting and air circulation in those atmospheres.

2.8.10 GSFC Contacts

S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035

2.8.11 Reference Documents Unique to this Section

29 CFR 1910, *Subpart S, Electrical*

Institute of Electrical and Electronic Engineers (IEEE) 510-83

National Electrical Code, 2005 Edition—Articles 430, 445, 450, 455, 460, 470

2.9 Noise

2.9.1 Scope

This section covers noise and its hazards.

2.9.2 Acronyms/Definitions

1. Action Level—An exposure to an 8-hour time-weighted average of 80 decibels, measured with a sound level meter on the A-scale, slow response. The action level is the criterion for instituting noise surveys and for employee participation in a medical monitoring program for hearing conservation.
2. Administrative Control—Any procedure that limits noise exposure by control of work schedules.
3. Audiogram—A chart or table resulting from an audiometric test. An audiogram shows an individual's hearing threshold level as a function of frequency. A baseline audiogram is one against which future audiograms are compared.
4. Decibel (dB)—A unit of measurement of sound pressure level. The decibel level of a sound is related to the logarithm of the ratio of sound pressure to a reference pressure (internationally accepted for acoustics as 20 micropascals). Decibel, A-weighted (dBA) is a sound level reading made on the A-weighted network of a standard sound level meter at slow response.
5. Engineering Control—Any mechanical device, physical barrier, enclosure, or other design procedure that reduces the sound level. This does not include PPE such as ear defenders or plugs.
6. Noise—Any unwanted sound. Hazardous noise exists wherever an operation or process generates noise of sufficient duration and intensity to be capable of producing a permanent loss of hearing in an unprotected person. A noise hazard area is any work area with a noise level of 85 dBA or greater.
7. Sound Pressure Level—A sound measurement expressed in decibels obtained with a sound level meter (SLM) that has a flat frequency response.
8. Time-Weighted Average (TWA)—The time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be exposed repeatedly, day after day, without adverse effect.

2.9.3 General

Occupational exposure to noise has been shown to be a contributing factor in the development of noise-induced hearing loss. Loss of hearing can result from exposure to impact noise and/or steady-state, continuous/intermittent noise. The hearing loss may be temporary or may become permanent through repeated exposure of unprotected personnel to hazardous noise. Initial deterioration of hearing may not be apparent to the individual until the impairment becomes substantial and irreversible.

It is NASA policy to control noise generated in their facilities and to prevent occupational noise-related hearing loss. Maximum permissible exposure limits have been established as listed in Table 2 and Table 3, below. Priority will be given to ensuring that engineering controls are used to the greatest extent practical to eliminate, control, or isolate sources of hazardous noise.

2.9.4 Design/Operational Requirements

1. Employees routinely exposed to noise (30 or more days per year) at or above the action level (80 dBA) or exposed to 85 dbA during an 8 hour TWA shall be placed in a hearing conservation program. Employees shall never be exposed to noise above the permissible limits specified in Tables 1 and 2. The hearing program shall consist of:
   - Baseline medical monitoring and annual re-examination, and record keeping of results.
   - Annual training on types of hearing protection available, use of hearing protection (including limitations), other means of reducing noise exposure, noise monitoring, effects of noise on hearing, purpose of medical monitoring, and care of hearing protectors.
   - Use of hearing protection by employees exposed to continuous noise in excess of 85 dBA TWA.
   - Area noise surveys.
2. Noise control and reduction considerations shall be integral to the site selection and design of new or modified facilities. Where feasible, newly designed or purchased equipment shall be of the type that minimizes any noise exposure hazard to personnel. Engineering controls shall be designed into new or upgraded facilities. If possible, noisy equipment shall be installed in buildings or building areas apart from personnel activities. Acoustic tile and other noise attenuating materials should be installed where practical.
3. Managers and supervisors shall conduct noise surveys of their facilities and equipment, and notify S&ED where exposure levels are expected to exceed the limits specified in Table 2 and Table 3, below. S&ED shall conduct baseline noise surveys and recommend appropriate means of controlling noise exposure.
4. Personnel who work in facilities or perform operations known to have hazardous noise levels shall be placed in a hearing conservation program and undergo periodic audiograms.
5. Personnel who work in and around noisy environments shall wear the appropriate PPE (Section 3.6). Hearing protection devices shall be made available to personnel who work in or around noise producing areas. These include earplugs, ear canal caps, ear muffs, and ear defenders. For all types of earplugs and caps, it is important to keep them clean and wash your hands before inserting them. Disposable earplugs are available. For reusable type ear defenders, keep them clean, free from cracks, and ensure that any protective cushions/pads are properly adjusted for a snug fit.
6. If there is doubt as to an individual's noise exposure, arrange to have dosimeter checks performed by S&ED. A noise dosimeter is a special sound-level meter that can be attached directly to the individual. It measures the amount of noise exposure over a given period of

time, such as an average workday. Administrative controls should be considered as a way of reducing exposure time if necessary.

7. Noise hazard warning signs, which clearly indicate the hazard of high noise levels and state the requirements to wear hearing protection, shall be posted at or near noise hazard areas.
8. Operating and maintenance procedures shall include appropriate measures for controlling or restricting personnel access in and around high-noise-level environments.
9. Fail-safe engineering controls shall be used to restrict personnel from entering areas where the noise level would be immediately dangerous to life or health. For example, the acoustic reverberation chamber shall be locked during all acoustic testing, and the key shall be kept in the possession of the acoustic control system operator until after the test run is completed.

Table 2 Permissible Exposure Limits for Continuous Noise

Duration (Hours)	dBA
16.0	80
8.0	85
4.0	90
2.0	95
1.0	100
0.5	105
0.25	110
0.125 or less	115

Table 3 Permissible Exposure Limits for Impact or Impulsive Noise

Sound Level (dB peak)	Permitted Number of Impacts or Impulses Per Day
140	100
130	1,000
120	10,000

2.9.5 GSFC Contacts

S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035

2.9.6 Reference Documents Unique to this Section

29 CFR 1910.95, *Occupational Noise Exposure*

29 CFR 1910, *Subpart I, Personal Protective Equipment*

NPR 1820.1, *Hearing Conservation*

2.10 Unique/Experimental Systems

2.10.1 Scope

This section covers unique and/or experimental systems that do not fit into any of the categories defined up to this point in the Safety Manual.

2.10.2 Acronyms/Definitions

N/A

2.10.3 General

Unique and/or experimental test articles may contain potentially hazardous systems that have not been defined and addressed in this Manual. For example, flight spacecraft may contain exotic fuels or gases in their propulsion and attitude control systems that have never been previously experienced on Center. Listed below are the steps necessary to obtain approval for bringing these payloads into AETD facilities.

2.10.4 Design/Operational Requirements

1. The Project shall determine whether their test article has potentially hazardous systems that are not addressed earlier in this Manual. The systems shall be documented in a written hazard analysis and included in the test plan.
2. The Project Manager shall call one or more of the GSFC contacts listed below and inform them of their requirements.
3. A Project Support Team Lead (PSTL) engineer will be assigned to coordinate the support. The engineer shall review the Project's hazards analysis and test plan, recommend what facilities and work-arounds are suitable for the job, and arrange scheduling.
4. It may be necessary to obtain approval from the S&ED before allowing a test article on site if it contains chemicals, gases, or other materials that are harmful to personnel or equipment. The PSTL engineer can assist in this determination and recommend the appropriate S&ED contact personnel.
5. Wherever possible, potential hazards shall be eliminated completely before arrival. For example, pressurized vessels that normally contain hazardous fuels shall be emptied and purged. Sometimes, water or other benign materials can be substituted for the fuel in the vessels if it is necessary to simulate launch conditions.
6. If potential hazards cannot be eliminated completely, engineering controls and other steps shall be taken to mitigate the hazards. In all cases, step-by-step procedures shall be prepared for approval prior to conducting the activity. Some examples of work-arounds include the following:
    - Dummy parts or systems can be fabricated and substituted for their hazardous counterparts during testing.

- The job can be performed in facilities that provide isolation. In unique circumstances, facility control systems might be modified or the facility physical characteristics modified to meet an unusual job requirement.
- Extra cleanroom facilities, purging systems, and ventilating systems might be set up near the job site.
- Specialized monitoring equipment and sensors can be set up with automatic alarm and shut down systems. Limiters can be installed to prevent overtest conditions. Redundant signal conditioning, acquisition, and analysis systems can be installed to ensure fail-safe conditions.
- Specialized emergency equipment and materials may be obtained and installed at the job site. For example, this might include extra fire protection or spill recovery systems.
- Hazardous activities can be scheduled to occur after normal working shifts to reduce personnel exposure.
- Handling and operations personnel might receive specialized training necessary to perform a unique activity.
- Specialized PPE such as full dress hazard garments might be obtained and used for a unique activity. Custom-designed protective barriers could be obtained.

7. It may be necessary to preclude a test article from entering AETD facilities if the potential hazards cannot be eliminated altogether or mitigated safely through the use of engineering controls and work-arounds. The PSTL engineer will notify the Project if no practical solutions can be devised for a unique requirement.

2.10.5 GSFC Contacts

AETD Chief Engineer: (301) 286-2413
S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035

2.10.6 Reference Documents Unique to this Section

N/A

2.11 Confined Spaces

2.11.1 Scope

This section covers the minimum requirements for constructing and working in a confined space. It will not define hazardous materials, which is covered in Section 2.5. Lockout/tagout requirements are discussed in Section 3.8.

2.11.2 Acronyms/Definitions

1. Attendant—An individual stationed outside one or more permit spaces who monitors the authorized entrants as well as activities inside and outside the space.
2. Authorized Entrant—An employee who has received the training and possesses the skills necessary to safely enter and work in a confined space and who has authorization to do so from his/her employer.
3. Confined Space—A space that:
   - Is large enough and so configured that an employee can enter bodily and perform assigned work;
   - Has limited or restricted means for entry or exit; and
   - Is not designed for continuous employee occupancy.
4. Confined Space Monitor—A person empowered by management to perform permitting duties and responsibilities for confined space operations. This person must have had additional training in confined space entry and must be approved by the S&ED.
5. Engulfment—The surrounding and effective capture of a person by a liquid or finely divided (flowable) solid substance that can be inhaled to cause death by filling or plugging the respiratory system or that can exert enough force on the body to cause death by strangulation, constriction, or crushing.
6. Entry—The act by which a person passes through an opening into a confined space. This occurs as soon as any part of the body breaks the plane of an opening into the space.
7. Hazardous Atmosphere—An atmosphere that may expose employee to the risk of death, incapacitation, impairment of ability to self-rescue, injury, or acute illness, from one or more of the following causes:
   - Flammable gas, vapor, or mist in excess of 10% of its lower flammable limit (LFL).
   - Airborne combustible dust at a concentration that meets or exceeds its LFL.
   - Atmospheric oxygen concentrations below 19.5% or above 23.5%.
   - Atmospheric concentration of any substance for which a dose or a permissible exposure limit is published in the Occupational Safety and Health Administration (OSHA) regulations or the American Conference of Governmental Industrial Hygienists (ACGIH) and which could result in employee exposure in excess of the dose or permissible exposure limit.

- Any other atmospheric condition that is Immediately Dangerous to Life or Health (IDLH).

8. Immediately Dangerous to Life or Health (IDLH)—Any condition that poses an immediate or delayed threat to life or that would cause irreversible adverse health effects or that would interfere with an individual's ability to escape unaided from a confined space.
9. Low-Hazard Permit Space—A permit-required confined space where there is an extremely low likelihood that an IDLH or engulfment hazard could be present, and where all other serious hazards have been controlled.
10. Oxygen Deficient Atmosphere—An atmosphere containing less than 19.5% oxygen by volume.
11. Oxygen Enriched Atmosphere—An atmosphere containing more than 23.5% oxygen by volume.
12. Permit-required Confined Space—A confined space that has one or more of the following characteristics:
    - Contains or has a potential to contain a hazardous atmosphere.
    - Contains a material that has the potential for engulfing an entrant.
    - Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section.
    - Contains any other recognized serious safety or health hazard (temperature extremes, radiation, biological, noise, vibration, etc.).

2.11.3 General

Confined spaces can pose extreme hazards when proper safe guards are not in place. Changes in atmosphere due to articles being brought into confined spaces and create hazards that must be addressed.

2.11.4 Operational Requirements

1. In general, personnel should not be exposed to the hazards of a confined space when engineering controls can be established.
2. Personnel entering the confined space and attendants shall be trained in entry procedures and hazards.
3. Training shall include: duties and responsibilities of attendants and entrants, hazard recognition, communication, proper use of protective equipment, permit requirements, and non-entry rescue requirements.
4. The area shall be posted with a "Danger" sign indicating the hazard.
5. GSFC Confined Space Entry Permit, form GSFC 3-17 shall be completed and posted at the confined space.

6. Area monitoring and/or ventilation shall be performed if the atmosphere presents or can present a hazard.
7. Additional lighting is required if provided lighting is not adequate for the task.
8. All hazardous energy sources (power, pneumatic, etc.) shall be secured by lockout/tagout procedure/permits.
9. Only explosion-proof electrical equipment meeting Article 500 of the *National Electric Code* and non-sparking tools shall be used in spaces that may contain flammable atmosphere.
10. Permit-required spaces require written procedures approved by the applicable safety organization in order to perform work.
11. Hot work (welding, cutting, brazing, sparks/flames, etc.) requires additional permitting.
12. Only those personnel specifically trained in rescue operations and properly equipped shall enter a confined space to rescue personnel.

2.11.5 GSFC Contacts

S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035

2.11.6 Reference Documents Unique to this Section

ANSI Z117.1-1989, *Safety Requirements for Confined Spaces*

Code of Maryland Regulations for Confined Spaces

GPR 1700.6, *Confined Space Program at GSFC*

NHS/IH-1845.2, *Entry into and Work in Confined Spaces*

OSHA 29 CFR 1910.146, *Permit-Required Confined Spaces*

3.0 General Safety Requirements

3.1 Working at Heights

3.1.1 Unprotected Heights/Fall Protection

3.1.1.1 Scope

This section describes the requirements for working at unprotected heights with fall protection.

3.1.1.2 Acronyms/Definitions

1. Fall arresters, shock absorbers, or deceleration device—A device that slows a worker's fall or breaks the fall to prevent injury, usually by rip stitches, specially woven lanyard, tearing or deforming lanyard, rope grab, or automatic self-retracting lifeline. Such a device dissipates a substantial amount of energy during a fall.
2. Free fall—The act of falling before the personal fall arrest system begins to apply force to arrest the fall.
3. Lifeline—A component consisting of a flexible line for connection to an anchorage at one end to hang vertically (vertical lifeline), or for connection to anchor at both ends to stretch horizontally (horizontal lifeline), and which serves as a means for connecting other components of a personal fall arrest system to the anchorage.
4. Restraint device—A device where the lanyard is sized such that the worker can just reach the farthest point on a platform without actually reaching the edge.
5. Safety belt or body belt—A strap worn snugly around the waist.
6. Safety harness—Straps worn around parts other than the soft tissue areas of the body.
7. Standard handrails—A rail system constructed such that the smooth top rail is 42 inches (107 cm) high nominal, the intermediate rail is halfway between the top rail and the platform, and the system has a nominal four-inch (10 cm) toeboard. The top rail must withstand a minimum of 200 pounds (91 kg) load applied in any direction.
8. Unprotected heights—Any work platform over four feet above the floor or adjacent work platform or ground which does not have standard handrails, except where there are stairs or a fixed ladder.

3.1.1.3 General

Working at unprotected heights is prohibited. Whenever platforms do not have standard handrails installed, fall protection shall be provided. Areas below personnel working at heights shall be roped off and signs posted to keep personnel out of the hazard area. Tools and all loose items shall be tethered to prevent them from falling on personnel and equipment below.

3.1.1.4 Design/Operational Requirements

1. Floor openings and hatchways shall be guarded by a standard handrail on all exposed sides or be protected by a suitable cover.
2. Personnel who are uncomfortable working at heights shall not be assigned to perform such work.
3. Anchorage points for lanyards shall be able to withstand a 5,000-lb (2,268 kg) static load per person.
4. Lanyards shall have a minimum breaking strength of 5,000 lb (2,268 kg).
5. Retracting lifelines that limit free fall to two feet (0.061m) or less must be able to sustain a minimum static tensile load of 3,000 lb (1,361 kg). If the free fall is greater than two feet (0.061m), the lifeline must sustain a minimum static tensile load of 5,000 lb (2,268 kg).
6. Horizontal lifelines shall be designed and installed as part of a complete personal fall arrest system, which maintains a safety factor of at least two, under the supervision of a qualified person.
7. Employees using fall protection shall be trained annually in the proper care and use of the specific equipment.
8. Safety belts shall not be used for fall protection; harnesses must be used. Belts shall be used for fall restraint only. Fall restraint allows the individual to approach a precipice or hazard area, but is short enough to prevent the possibility of an actual fall.
9. Each time fall protection is used, it shall be inspected by the user for wear, mildew, damage or other deterioration, and defective components. Fall protection devices shall be inspected annually by a competent person to verify that they are not damaged.
10. Fall protection devices should be stored in dry locations, free from dirt, chemical exposure, or exposure to sunlight.
11. Lanyards shall be attached above head height and at the center D-ring of the back of the harness. Free falls should be kept to the shortest distance possible, no greater than six feet (1.83 m), nor should they contact any lower level.
12. Retracting lifeline devices shall be inspected prior to use by the employee using the device and annually by a competent person.
13. Fall arresters and shock absorbers are preferred over lanyards without the devices.
14. If any part of a fall arrest system is involved in a fall, it shall immediately be removed from service and replaced.
15. Lanyard and lifelines shall never be knotted, tied around sharp edges, or attached back on themselves, or over or around rough surfaces. Tie-off using a knot in a rope lanyard or lifeline can reduce the strength by 50% or more. Tie-off around an H-beam or I-beam or similar support can reduce the device's strength as much as 70% due to the cutting action of the beam edges.

16. The following conditions require locking snap-hooks on lanyards due to possible roll-out from non-locking hooks:
    - Direct connection to a horizontal lifeline;
    - Two snap-hooks connected to one D-ring;
    - Two snap-hooks connected to each other;
    - A snap-hook connected back on its integral lanyard;
    - A snap-hook connected to a webbing loop or webbing lanyard; or
    - The dimensions of the D-ring, rebar, or other connection point would allow the keeper to be depressed (i.e., opened) by a turning motion of the snap-hook.
17. Side, front, and chest D-rings should be used for positioning only. Shoulder D-rings should be used for retrieval only.
18. Safety nets may be used when work places are more than 25 feet (7.6 m) above the ground or other surface and other means of fall protection are impractical. If used, nets shall be installed as close to the work level as possible and tested before beginning operations, in accordance with ANSI A10.11 and OSHA.
19. Fall protection shall be used on crane platforms when handrails are not present or the bridge cannot be located close to (within 12 inches [30.5 cm] of) the access platform.
20. If someone falls and is suspended by their fall protection, immediately summon trained rescue personnel by calling the Emergency Console (911).

3.1.1.5 GSFC Contacts

S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035

3.1.1.6 Reference Documents Unique to this Section

29 CFR 1910, *Subpart D—Walking-Working Surfaces*

29 CFR 1910, *Subpart F—Powered Platform, Manlifts, and Vehicle-Mounted Work Platforms*

19 CFR 1926.105, *Safety Nets*

ANSI A10.8, *Safety Requirements for Scaffolding*

ANSI A10.11-1989, *Safety Nets Used During Construction, Repair, and Demolition Operations*

ANSI A14.1, *Safety Requirements for Portable Wood Ladders*

ANSI A14.2, *Safety Requirements for Portable Metal Ladders*

ANSI A14.3, *Safety Requirements for Fixed Ladders*

ANSI A14.4, *Safety Requirements for Job-Made Ladders*

ANSI A14.5, *Safety Requirements for Portable Reinforced Plastic Ladders*

ANSI A92.3, *Manually Propelled Elevating Aerial Platforms*

ANSI A92.5, *Boom-Supported Elevating Work Platforms*

ANSI A92.6, *Self-Propelled Elevating Work Platforms*

3.1.2 Ladders

3.1.2.1 Scope

This section describes the requirements for working with ladders.

3.1.2.2 Acronyms/Definitions

See Section 3.1.1.2.

3.1.2.3 General

No matter how familiar personnel are with ladders and how harmless they seem, ladders account for a considerable percentage of accidents. Working from ladders can be extremely hazardous if the ladders are not in good condition or if they are not used properly.

3.1.2.4 Design/Operational Requirements

1. Ladders shall be manufactured per the requirements of OSHA and ANSI. Manufacturer's labels usually state the standards they meet.
2. A competent person shall inspect all ladders for damage annually, and shall tag each ladder with the inspection date, inspector's initials, and due date. A record of the inspection shall be kept on file.
3. Each time a ladder is used, the person using it shall inspect it.
4. Defective ladders shall be taken out of service immediately, and tagged or marked as "Dangerous, Do Not Use" until repaired or discarded.
5. Never paint a ladder.
6. Never stand on the top two rungs of portable ladders.
7. Never use conductive or metal ladders for electrical work.
8. When using a ladder to access a high place (traversing to a platform or leaning over to the point that the center of gravity is not centered with the ladder), lash it or have another person keep it from slipping or moving.
9. Never stand or work with one foot on the ladder and one foot on a raised platform.
10. Ladders shall extend at least three feet (0.91 m) above upper surfaces being accessed.
11. Do not overload ladders. Manufacturer's labels state the maximum weight allowed.
12. Store ladders where they shall not be exposed to the weather and where there is good ventilation. Do not store ladders where they would present a tripping hazard.
13. Place extension and straight ladders so the horizontal distance from the base to the vertical plane of the support is approximately one-fourth the ladder's height between supports.
14. Secure both the bottom and top of a ladder to prevent displacement when using the ladder to access a scaffold.
15. Always hold on with both hands and face the ladder when ascending or descending. If you need to use both hands to work while on a stepladder, use a safety belt or hook one leg around a rung.

16. Stepladders shall be fully open and the spreader locked before using.
17. Stepladders shall not be longer than 20 feet (6.1 m).
18. Do not use ladders in front of doors unless the door is blocked, locked, or guarded.
19. Type III light duty ladders shall not be used. Type I industrial ladders are preferred for all applications. However, Type II commercial ladders for medium duty may be used in offices.

3.1.2.5 GSFC Contacts

See Section 3.1.1.5.

3.1.2.6 Reference Documents Unique to this Section

See Section 3.1.1.6.

3.1.3 Scaffolds

3.1.3.1 Scope

This section describes the requirements for working with scaffolds.

3.1.3.2 Acronyms/Definitions

See Section 3.1.1.2.

3.1.3.3 General

Scaffolds have many applications. Typically, tube and coupling and tubular welded frame scaffolds are used. Personnel shall be able to distinguish scaffolding types and ensure compatibility of parts when erecting scaffolds. For example, scaffolding tubing might be either steel or aluminum, and may have different diameters and wall thicknesses, which must be mated to appropriately-sized couplers. When scaffolding is leased or purchased, safety instructions for erection and use shall accompany the equipment.

3.1.3.4 Design/Operational Requirements

1. Scaffolds and their components shall be capable of supporting without failure at least four times the maximum intended load. Load rating shall be marked on scaffolds.
2. Only heavy-duty (designed to hold a load of 75 lb/ft^2 [366 kg/m^2]) or medium duty (designed to hold a load of 50 lb/ft^2 [244 kg/m^2]) scaffolding shall be used.
3. Scaffolds shall be erected and used only by trained, certified personnel per OSHA 1926.454.
4. Damaged or weakened scaffolds or components shall be removed from service immediately.
5. Never interchange scaffold components of different manufacturers.
6. Scaffolds shall not be altered or moved horizontally while they are in use or occupied.
7. An access ladder or equivalent safe access shall be provided. Scaffolding manufactured by "UpRight" is designed to be climbed on the horizontal side rungs. Do not climb or stand on the diagonal braces.
8. Outriggers shall be used or the scaffold shall be tied-in to the building if the scaffold height exceeds four times the minimum base dimension.
9. Tools, materials, and debris shall not be allowed to accumulate on scaffolds.
10. Scaffolds shall be supplied with standard handrails on all open sides. Cross-bracing is acceptable in place of a midrail when the crossing point of two braces is between 20 inches (0.5 m) and 30 inches (0.8 m) above the work platform, or as a toprail when the crossing point of two braces is between 38 inches (0.97 m) and 48 inches (1.3 m) above the work platform.
11. Scaffold casters shall be locked when personnel are on the unit.
12. Suspended scaffolds shall be erected and used per OSHA and ANSI requirements.
13. Scaffolding shall be inspected by a qualified person before each work shift and after any change in its configuration.

3.1.3.5 GSFC Contacts

See Section 3.1.1.5.

3.1.3.6 Reference Documents Unique to this Section

OSHA 29 CFR, 1926, *Subpart L—Scaffolds*
See also Section 3.1.1.6.

3.1.4 Mobile Aerial Platforms

3.1.4.1 Scope

This section covers Mobile Aerial Platforms (MAPs) used to position personnel and necessary tools/materials at elevated work locations.

3.1.4.2 Acronyms/Definitions

1. Mobile Aerial Platform—Any device that is primarily designed and used to position personnel.

See also Section 3.1.1.2.

3.1.4.3 General

Various types of MAPs are used for working at heights up to 49 ft (14.8 m). These include motorized, flying-carpet-type, and cherry-picker-type lifts that have hydraulic and/or pneumatic elevating mechanisms. Typically, the electrical batteries that power these lifts should be recharged overnight, or after heavy duty cycles.

3.1.4.4 Design/Operational Requirements

1. Equipment Certification:
   - MAPs used shall be designed and constructed in conformance with the applicable requirements of NASA-STD-8719.9.
   - The owner organization shall perform a recognized safety hazard analysis such as fault tree analysis, FMEA, O&SHA on all MAPs used where failure or loss of control could result in loss of or damage to flight hardware.
   - The owner organization shall perform maintenance and repairs per OEM recommendations.
   - All MAPs are formally certified/recertified by the RECERT Manager.
2. Operator Training and Medicals:
   - Only operators trained and qualified by their employer and certified (licensed) by the RECERT Manager shall be authorized to operate MAPs. Training, refresher, and qualification shall be documented by the operator's supervisor. Formal license renewal and medical examination is required every three years. Annually, the employee's supervisor shall certify the employee has received an informal refresher by supplying RECERT with a certification letter, when requested.
3. General Requirements:
   - The operator shall ensure that the MAPs are used only for applications as defined in the operating manual and that recognized safety practices are observed.
   - Altering or disabling safety devices, guards, or interlocks is prohibited.
4. A copy of the manufacturer's manual shall be maintained with each MAP.
5. MAPs shall be inspected by RECERT on a quarterly basis.

6. Prior to each day's use the operator shall inspect the MAP. Legibly sign the Logbook upon completion of inspection, noting any discrepancies.
7. Any time a discrepancy is noted during an inspection or use, the equipment shall be taken from service immediately and tagged.
8. Never overload a MAP. Weight limitations are marked on the equipment.
9. MAPs shall not be used as a materials handling device unless designed and equipped by the OEM for such purpose.
10. Battery charging shall be performed only in designated locations (see Section 2.4.1 for information on battery charging).
11. Safety belts or harnesses with a lanyard attached to the device shall be worn by personnel using a MAP that is equipped with attach points, such as a bucket type lift.
12. Personnel shall adhere to the following: never sit or climb on the edge of the platform/bucket; always stand firmly on the platform/bucket floor; never stand on boxes, planks, railing or other devices in the platform/bucket.
13. When used around critical or flight hardware, MAPs should be kept parallel to the hardware whenever possible. Do not approach hardware head-on.
14. Do not use MAPs around electric power lines unless the lines are de-energized or adequate clearance is maintained.
15. Outriggers shall always be used when the MAP is so equipped.

3.1.4.5 GSFC Contacts

See Sections 2.1.1.5 and 3.1.1.5.

3.1.4.6 Reference Documents Unique to this Section

ANSI A92.3, *Manually Propelled Elevating Aerial Platforms*

ANSI A92.5, *Boom-Supported Elevating Work Platforms*

ANSI A92.6, *Self-Propelled Elevating Work Platforms*

ANSI/SIA A92.2 and OSHA CFR 1910.67, *Vehicle-Mounted Elevating and Rotating Aerial Devices*

3.2 Hand Tools and Miscellaneous Powered Equipment

3.2.1 Scope

This section covers hand tools and other miscellaneous powered equipment such as portable drills, circular saws, grinders, impact wrenches/hammers, vacuum cleaners, buffers/polishers, heat guns, jacks, pressurized cleaners, etc.

3.2.2 Acronyms/Definitions

N/A

3.2.3 General

Hand tools and miscellaneous powered equipment are commonplace. Employees must understand the most common hazards of their operation, which are:

- Injuries from contact with unguarded points of operation, such as saw blades or drill bits.
- Shock, fire, and electrocution from electrical problems.
- Injury from flying pieces, dust, shavings, etc.
- Injury from heat, pressure, hydraulic fluids, cooling oils, etc.
- Injury caused by defective equipment or improper use of the equipment.

3.2.4 Design/Operational Requirements

Employees who work with hand tools and powered equipment shall be responsible for inspecting them before each use to verify that they are in proper working condition, with all safety guards in place and effective. Guidelines for this equipment are as follows:

1. Always wear PPE appropriate for the job at hand (see Section 3.6). Safety goggles shall be worn to protect the eyes from flying debris, dust, and chips. Other PPE includes hard hats, safety shoes, dust filter or respirators with the appropriate filter cartridges, gloves, hearing protection, and garments which protect the body but are not prone to snagging in moving mechanisms.
2. The following unsafe acts shall be avoided:
    - Unauthorized operation or use of equipment.
    - Using defective tools or equipment, or using them improperly.
    - Operating equipment at an unsafe speed.
    - Poor housekeeping (failure to put things away when not in use or to dispose of trash properly).
    - Removing or bypassing safety devices.
    - Riding moving equipment not designed for that purpose.
    - Failure to warn or signal as required.
    - Standing in an unsafe place or taking an unsafe posture.

- Indulging in horseplay, or distracting or startling other employees.
- Failure to wear the appropriate PPE.

3. Unsafe conditions might exist which require the help of other people or organizations to correct them. For the unsafe conditions listed below, the employee can take corrective actions such as returning unsafe tools or rendering them unusable, then tagging them, and alerting maintenance sections; reporting unsafe conditions to their supervisor or safety contacts; and suggesting methods to correct unsafe conditions. The following are specific unsafe conditions:
   - Lack of adequate guards or safety devices.
   - Lack of adequate warning systems.
   - Fire and explosion hazards.
   - Improper or inadequate PPE available.
   - Poor ventilation.
   - Protruding object hazards.
   - Close clearance and congestion hazards.
   - Hazardous arrangement of workstations.
   - Inadequate illumination or hazardous noise.
   - Defective tools and equipment, or lack of the proper tools for the job.
4. OSHA requires machine guards and constant pressure switches and controls on many types of equipment. For example, grinders have face shields and grinding wheel containment housings; saws have blade shields and adjustable anti-kickback mechanisms; and many tools have safety guards at the point of operation that exposes the operator to injury. Some guards are fixed in place, while others must be adjusted by the operator for the job at hand. Employees shall never remove or bypass these devices when using the equipment. Always replace the guards after machine maintenance or repair. Never tape down or circumvent pressure switches that automatically turn off machinery when the operator releases hand or foot pressure on the controls. (See Section 4.7.4 Item 8 for further safety guard information.)
5. The following safety rules shall be followed when working with powered equipment:
   - Check that connectors and insulation on the electrical cords are in good condition.
   - Verify that tools are properly grounded (three wire cords/plugs or double insulated). Tools that are double insulated in their design to prevent electrical shock hazard may be plugged into ordinary outlets. All tools that are not double insulated should be plugged into power outlets, which are protected by ground fault interrupter (GFI) devices. Correctly match plugs to outlets, and never modify a plug to adapt to an inappropriate outlet. Plugs and outlets are designed with different physical geometry according to voltage, current, and power needs (i.e., three pronged, four pronged, small or large sized prongs, right-angled prongs, etc.).

- Where possible, avoid using electrical extension cords; however, if they are necessary for temporary, ensure that they are rated high enough for the job, and route them where they don't cause tripping or snagging problems.
- Be sure hands are dry before handling electrical tools.
- Immediately turn off and tag out of service any tool that smokes, smells, sparks, or shocks.

6. Specialized equipment may be powered by compressed air (e.g., pneumatic drills and wrenches) or hydraulic systems (e.g., hydraulic jacks). Observe these guidelines when maintaining or operating such equipment:
   - Before using the equipment, inspect air hoses, hydraulic lines, connections, and fittings; keep them clean and free of kinking, cracking, tangling, etc.
   - Air hoses and hydraulic lines shall be designed for the maximum pressure and service to which they are subjected, and shall have adequate restraining mechanisms in case of failure.
   - For pneumatic tools, a tool retainer shall be installed on each piece of equipment, which keeps the tool from being ejected under pressure.
   - Be sure the service pressure and capacity are appropriately sized for the manufacturer's operating specifications.
   - Air hoses and hydraulic lines shall be certified prior to use and periodically recertified (see Section 2.3.1.4). All hoses and lines not certified shall be removed for service and be segregated.
7. Workers can prevent injuries involving power tools by treating them with respect and following these basic safety procedures:
   - Choose the right tool for the job.
   - Inspect each tool before use to be sure it has all its parts and they are in good working order.
   - Air hoses and hydraulic lines shall be certified prior to initial use and periodically recertified (see Section 2.3.1.4).
   - Keep tools properly lubricated and free of dust, dirt, and grime.
   - Compressed air shall not be used for cleaning purposes, except where reduced to 30 psi (207 kpa), and then only with effective chip guarding and proper PPE.
   - Follow manufacturer's instructions for using the tool, including changing blades, bits, heads, etc.
   - Don't load a tool with fasteners until you are ready to use it, and don't leave a tool loaded with fasteners unattended.
   - Don't wear loose garments, jewelry, loose long hair, or other items that can catch in machinery.

- Keep the work area free of anything flammable that could catch fire from a tool spark.
- Alert personnel in the area of your actions. Cordon off the work zone or erect barriers to keep unauthorized personnel away from the work site.
- Keep tools not in use in a safe place where they cannot get turned on accidentally or fall on someone.
- When working at heights or above other workers or equipment, remove loose items from pockets and tether the tools to keep them from falling and causing injury or damage. The area beneath personnel working at heights must be roped off and signs posted to keep personnel out.
- Clamp work securely to prevent its movement while drilling, sanding, etc.
- Attach chuck key to the power cord so it must be unplugged before inserting the key in the chuck.
- Check the operation for possible pinch points. Allow adequate clearance for any potential movements of the work piece or shifting of the body.
- Always cut or move the tool away from, not toward, any parts of the body.
- Direct spray cleaning fluids away from the body and wear the appropriate PPE to prevent exposure to steam, cold water, etc.

3.2.5 GSFC Contacts

S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035

3.2.6 Reference Documents Unique to this Section

OSHA 29 CFR Part 1910.242 *Hand and Portable Powered Tools and Equipment, General*

OSHA 29 CFR Part 1910.243 *Guarding of Portable Powered Tools*

OSHA 3067 *Concepts and Techniques of Machine Safeguarding*

3.3 Machine Shops

3.3.1 Scope

This section presents the safety guidelines and procedures for common machine shops.

3.3.2 Acronyms/Definitions

None

3.3.3 General

Machine shops, scattered throughout AETD, provide a complete manufacturing facility to meet GSFC's machining requirements. They contain a wide variety of conventional machining equipment. Typical examples include mills, lathes, drill presses, borers, saws, grinders, brakes, presses, rollers, punches, shears, metal shrinking and stretching machines, bending machines, etc. The general shop guidelines discussed below apply to this wide variety of machinery types.

3.3.4 Design/Operational Requirements

Good housekeeping in the work area can help establish good work habits when operating machine tools. These two factors—good housekeeping and good habits—result in fewer accidents. Special procedures for the machine shops are as follows:

1. Personnel training: Operators shall be trained under an apprenticeship program and shall demonstrate their ability on each piece of equipment they run. Their supervisor shall approve their demonstrated performance. No one shall be allowed to operate a piece of machine shop equipment unless they have been trained under the direction of lead personnel and approved by the area supervisor.
2. PPE: When operating machinery, eye protection shall be worn. Eye protection with side shields—such as goggles or full-face shield with glasses/goggles—shall be worn if chips, dust, debris, or other materials can become airborne. Machine operators shall wear safety-toed shoes. Gloves can be used to protect the hands when handling rough or jagged materials but must be removed when operating rotating machinery where they are liable to get caught.
3. Hearing protection: Wear hearing protection such as ear plugs or ear defenders around noise-producing machinery. Refer to Section 2.9 for permissible noise exposure limits. If in doubt as to noise levels, arrange to have the S&ED conduct noise level surveys and/or noise level dosimeter checks of the affected personnel.
4. Clothing/accessories: Do not wear loose-fitting garments, loose sleeves, lab coats, rings, necklaces, or other jewelry or accessories, which could get caught in moving parts of the machinery. Keep hair secured to prevent it from being snagged.
5. Use splash guards, shields, PPE, and other means to minimize exposure of workers to cutting oils or cleaning solvents. Personnel should use barrier creams where appropriate and wash thoroughly to minimize skin irritations. Avoid breathing cutting oils and cleaning solvent vapors, as much as possible.

6. All machine shop equipment shall be installed with electrical circuits and switches that comply with the NFPA 70, *National Electrical Code* (see Section 2.8). Other metalworking standards are in NFPA 79, *Electrical Standard for Industrial Machinery*. Each machine must have a disconnect switch that can be locked in the off position to isolate the machine from the power source.
7. All machine shop equipment shall have guard mechanisms that comply with OSHA 3067, *Concepts and Techniques of Machine Safeguarding*. Guards shall be affixed to the machine where possible and secured elsewhere if for any reason attachment to the machine is not possible. The point of operation of a machine that exposes the operator to injury shall be guarded. Do not operate the equipment without the guards in place and functioning properly. Never override a safety interlock, automatic kill switch, guard mechanism, or other device, which is designed to protect the operator while the machine is running or to shut the system off in an emergency.
8. All non-portable machines shall be firmly secured to the floor, bench, or other properly designed workstand to prevent walking.
9. Only maintenance personnel who are authorized and experienced with the equipment shall perform maintenance on the machines. This includes changing cooling fluids, oils, dielectric fluids in EDM machines, etc. Lockout/Tagout/Blockout procedures shall be used when performing maintenance (see Section 3.8).
10. Some machines have automatic dust collection systems. Before starting, verify that the exhaust ducts are unobstructed and venting properly, and that the collection bins have adequate capacity for the job at hand.
11. Shop personnel shall clean debris and waste materials from surfaces on and around machinery. Use brushes, vacuum equipment, or special tools for removing chips—do not use hands. Machine operators shall direct custodial personnel to clean floor and office areas but, as a safety precaution, shall not allow them to clean near machines or facilities that present a potential hazard. Metal chips shall be placed in metal recycle bins. All metal is collected for recycle.
12. House-supplied compressed air is available in the shops. Compressed air shall not be used for cleaning purposes except where reduced to less than 30 psi (207 kpa), and then only with effective chip guarding and proper PPE. Do not use flexible compressed air hoses unless they are certified. Vacuum equipment is preferred for removing dust and debris from machinery. Air shall not be used to clean personnel.
13. Eyewash stations shall be inspected weekly and records kept for three years.
14. Personnel who operate equipment in any of the machine shops shall familiarize themselves with the locations of the nearest eyewash stations, fire extinguishers, emergency rescue equipment, and first aid kits. Personnel must be trained in the use of fire extinguishers.

15. Safety rules for operating machine tools:

- Establish and maintain safe working procedures; do not take short cuts. Devote full-time attention to the work in progress. Do not be distracted by onlookers. Do not leave machine tools running unattended unless the machine has been designed to do so.
- Operators shall have and be familiar with the operations manual and understand all the precautions before setting up or running a machine tool. Observe all precautions and warning labels affixed to the machines.
- Inspect each tool before use to be sure it has all its parts and that they are in good working order. Do not use blades, bits, heads, etc. that have visual defects such as cracks, chips, pitting, or warping. Follow the manufacturer's instructions for using the tool, including sharpening and changing blades, bits, heads, etc. Verify that all chucks, bits, workpiece securing devices, etc., are tightened to manufacturer's specifications before running the machine.
- Clamp work securely to prevent its movement while drilling, milling, etc. Verify that no part of the machine tool will hit the clamps or any part of the workpiece not intended to be machined.
- Do not operate the machine at higher speeds than specified for the blade, bit, head, etc.
- Where possible, use autofeed drive mechanisms to minimize the need for manual feeding of the workpiece. Set autofeed limits according to the manufacturer's specifications and verify them before starting the machine.
- Verify that there is adequate clearance around the machine for the workpiece to move as it is being machined. Provide supports for overhanging workpieces, and ensure that sections of the workpiece that are to be cut off do not present a hazard as they separate from the main piece.
- Keep onlookers away from the immediate area around a running machine tool. If necessary, post warning signs and use barrier tape cordons to prevent unauthorized personnel access, but do not erect physical barriers that impede aisles, emergency exit routes, or doors leading away from the machine.
- Do not talk to the operator while the machine is running. Wait until the machine is turned off before addressing the operator.
- Keep tools properly lubricated and free of dirt and grime. Keep cooling fluids and cooling systems clean and flowing properly.
- Do not manually adjust and gauge work while the machine is running.
- Understand the differences in machining ferrous and non-ferrous metals, and know the health or fire hazards of working with these metals. Consult an MSDS for accurate information about materials if in doubt as to their properties and potential hazards. Special machining procedures, over and above those required for aluminum and steel, are required when working with exotic materials such as beryllium, magnesium, and titanium used in the aerospace industry. There may be prohibitions or special regulations on

machining exotic materials at GSFC. When in doubt, check with the S&ED or area safety representatives to obtain the latest regulations on exotic materials.

- Select the proper hand tools where necessary, and use them for their intended purpose. Do not improvise an operation with an improper tool.
- Keep the body in proper balance with firm footing to avoid falling into or bumping the workpiece. Do not stretch arms or place hands in awkward positions. Use appropriate clamping jigs, push rods, etc., to avoid placing parts of the body near the machining heads.

3.3.5 GSFC Contacts

S&ED: (301) 286-2281

AETD Safety Manager: (301) 286-1035

3.3.6 Reference Documents Unique to this Section

OSHA 29 CFR Part 1910 Subpart O, *Machinery and Machinery Guarding*

OSHA 29 CFR Part 1910.242, *Hand and Portable Powered Tools and Equipment, General*

OSHA 3067, *Concepts and Techniques of Machine Safeguarding*

NFPA 70, *National Electrical Code*

NFPA 79, *Electrical Standard for Industrial Machinery*

3.4 Welding, Brazing, and Cutting

3.4.1 Scope

This section covers welding, brazing, and cutting operations.

3.4.2 Acronyms/Definitions

1. Brazing—Metal joining process using high heat and a filler metal.
2. Performance Qualification—The documented demonstration of a welding or brazing operator's ability to produce welds or brazes meeting prescribed standards.
3. Thermal Cutting—Cutting process, which melts the metal (material) to be cut.
4. Weld—A localized coalescence of metals produced either by heating the materials to suitable temperatures—with or without the application of pressure—or by the application of pressure alone, and with or without the use of filler material.
5. Welding Operator—One who operates welding equipment.

3.4.3 General

Welders shall be trained and certified, and their work product shall undergo quality assurance inspections. Personnel who operate welding machines shall also be responsible for posting warning signs and protecting bystanders and equipment/facilities.
The hazards generally associated with welding are hot sparks, radiant energies, air contamination, electrical shock, chipping slag, flammable liquids and gases, and handling of compressed gases. There is always the potential for fire or explosion in the welding area. Laser welding requires special operating and personnel access control procedures, which shall be approved by S&ED.

3.4.4 Design/Operational Requirements

1. In general, welders shall be properly instructed and qualified to maintain and operate the equipment per ANSI Z49.1 and OSHA 1910.252.
2. Welders required to work on flight hardware or other high-dollar-value hardware shall be trained and certified to the qualification requirements of MIL Std 1595 (or equivalent certification standard). Their work product shall pass an independent quality assurance inspection to MIL Std 1595 specifications on a yearly basis. Laser welding operators shall be trained and have eye examinations that comply with GPR 1860.3 and ANSI Z136.1 requirements.
3. Personnel performing welding or brazing on ground-based pressure vessels/systems shall be certified per GPR 1860.3. For welding on lifting devices personnel must be certified per NASA-STD-8719.9.

4. All persons exposed to welding/cutting/brazing hazards (workers, observers, and their immediate supervisors) shall be trained in the use of, and understand the reasons for, protective clothing and equipment. Section 3.6 details PPE training and use requirements.
   - Respiratory protection—If gases, dusts, fumes, and particulate matter cannot be kept below threshold limits, welders shall wear respiratory protection. Inert gas shielded arc welding requires additional precautions, such as positive ventilation or local exhaust removal.
   - Eye protection – Welders and their helpers shall wear goggles, helmets, and shields that give maximum protection for each welding and cutting process. These items shall conform to ANSI Z87.1. Consult the ANSI/AWS F2.2-89 Lens Shade Selector Chart for the minimum protective shade needed for a particular job. Welders in the welding shop usually wear shields with a protective shade #10.
   - Gloves—Wear flame resistant gauntlet gloves of leather or other suitable material. They may be insulated for heat.
   - Aprons—Wear flame resistant aprons of leather to withstand radiated heat and sparks.
   - Boots/leggings—For heavy work, wear fire resistant leggings, high boots, or similar protection.
   - Safety shoes—Wear safety shoes for heavy work protection. Never wear low-cut shoes with unprotected tops, because of the spark hazard.
   - Safety hats—Wear safety helmets for protection against sharp or falling objects.
   - Overhead work gear—For overhead work, wear capes or shoulder covers of leather. Skull caps of leather may be worn under helmets to prevent head burns. Protect the ears from sparks with wire screen protectors or equivalent means.
   - General garment rules—Wear dark, wool clothing instead of light, cotton clothing. Dark clothing offers more protection against ultraviolet and infrared radiation skin burns, and wool is more resistant to deterioration and is not readily ignited. Clothing should be reasonably free from oil and grease. Keep sleeves and collars buttoned. Aprons shall not have pockets to catch sparks; trousers shall not have turned up cuffs. Thermal insulated underwear is designed to be worn only under outer clothing, and should not be exposed to open flames or sparks.
5. If the nature of the work permits, the welding should be accomplished near a fume hood to remove hazardous materials. (See Section 2.5.4 for fume hood inspection requirements.)
6. If welding or cutting involves asbestos, special procedures shall be approved by the S&ED. It may be necessary to contract with a company that is certified for handling and removing asbestos.
7. Electric arcs and gas flames produce ultraviolet and infrared rays. Use welding blankets or shields to protect personnel not involved in the welding operation.
8. In welding and associated work, noise levels may exceed the permissible limits (Section 2.9). Appropriate hearing protection shall be worn in such cases.

9. Regulators can be a potential hazard if they are maintained or used improperly. Regulator burnout (RBO) is an oxygen regulator fire or explosion. The following guidelines shall be used to prevent RBO:
   - Verify that all connecting hoses are clean, unobstructed, and free of cracks, kinks and defects.
   - Always close valves and bleed down hoses when finished work for the day.
10. Hazards in the operation of resistance welding equipment include the following: lack of point-of-operation guards, flying hot metallic particles, improper handling of materials, and unauthorized adjustments and repairs. These may cause eye injuries, burns, and electrical shock.
11. Arc welding uses two electrical leads: the electrode lead and the work lead. Guidelines for arc welding are:
    - The welder shall be insulated from the work and from the metal electrode and holder. The bare metal part of the electrode shall never be permitted to touch the welder's bare skin or wet clothing. Use well insulated electrodes, holders, and cables; and keep clothing, hands, and body dry. Never change electrodes with bare hands or wet gloves, or when standing on wet floors or grounded surfaces.
    - Ground the frame of portable or stationary welding units in accordance with the NEC, NFPA 70.
12. Welders shall be specially trained to operate tungsten inert gas (TIG) arc welding equipment.
13. Only trained and certified personnel shall operate laser welding equipment such as the LASAG. The area shall be properly posted for this type of equipment. (See Section 2.6.4 Item 8 for further laser information.)
14. Permanent welding areas shall have fire protection according to ANSI Z49.1 and NFPA 51B.
15. For welding jobs outside the shop areas, the following guidelines shall apply: a hot work permit is mandatory; the welder must ensure that welding activities (i.e., light and fumes) do not inadvertently activate fire alarm systems; hot work permits shall be obtained from the S&ED (or other authority as designated by S&ED) at least 48 hours before beginning any hot work; and the Facilities Management Division (FMD) shall approve, in advance, any work that affects GSFC building operations. The following forms are necessary to request a hot work permit:
    - Form GSFC 23-4 Hot Work Approval - Approved by an authorized person/S&ED. If the work will impact building utility systems, then a Utility Outage Request Form is needed also (see below).
    - Form GSFC 23-4A Hot Work Supplement Log Sheet – Form completed each day by the employee performing the work to verify the area was properly inspected.
    - Utility Outage Request Form—Obtain this form and approvals from the FMD. The form addresses the areas and systems, which may be impacted by the work being done on the hot work permit.

16. The following welding requirements ensure protection of personnel and facilities:

- It is mandatory to provide a fire extinguisher—either multipurpose chemical or carbon dioxide—at the welding site. If welding near wood construction or combustible materials that cannot be moved, provide a fire hose, water pump tank extinguisher, or fire pails convenient to the welder. Welders or their helpers must have current fire extinguisher training.
- Prevent sparks or hot slag from reaching combustible materials. If the work cannot be moved away from such materials, then protect the materials with sheet metal covers, welding blankets, or equivalent means. Spray booths and ducts should be cleaned to remove combustible materials. Floors shall be swept clean and covered with metal or equivalent protective means.
- Hot metal or slag shall not be permitted to fall through cracks in the floors, walls, into machine tool pits, etc. Remember that hot slag can roll along the surface to out-of-the-way places.

3.4.5 GSFC Contacts

S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035

3.4.6 Reference Documents Unique to this Section

OSHA 29 CFR 1910 *Subpart Q, Welding, Cutting and Brazing*

ANSI/ASC Z49.1, *Safety in Welding, Cutting and Allied Processes*

ANSI Z87.1, *Practice for Occupational and Educational Eye and Face Protection*

ANSI/AWS F3.1-89 *Guide for Welding Fume Control*

GPR 8715.5, Fire Protection at GSFC/Greenbelt

NFPA 51B *Cutting and Welding Processes* and NFPA 70 *National Electrical Code*

MIL Standard 1595 *Qualification of Aircraft, Missiles, and Aerospace Fusion Welders*

GPR 1700.2, *Chemical Hygiene Program*

GPR 1860.3, *Radiation Safety - Laser*

3.5 Smoking

3.5.1 Scope

This section describes the GSFC smoking policy.

3.5.2 Acronyms/Definitions

Smoking—A lighted cigar, cigarette, pipe, or any lit tobacco or plant material.

3.5.3 General

This policy is to promote good health and provide an environment reasonably free from pollutants, including tobacco smoke.

3.5.4 Design/Operational Requirements

1. Smoking is prohibited in all GSFC buildings and facilities.
2. Smoking outside of buildings is prohibited in areas posted as such.
3. Smoking at building entrances is limited to those supplied with ashtrays.

3.5.5 GSFC Contacts

S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035

3.5.6 Reference Documents Unique to this Section

GMI 1772.1, *Center Smoking Policy*

3.6 Personal Protective Equipment

3.6.1 Scope

This section describes the requirements for using personal protective equipment (PPE). Additional information on hazardous materials, hearing protection, and working at heights may be found in Sections 2.5, 2.9, and 3.1, respectively.

3.6.2 Acronyms/Definitions

1. Immediately Dangerous to Life or Health (IDLH)—any condition that poses an immediate or delayed threat to life, or that would cause irreversible adverse health effects, or that would interfere with an individual's ability to escape unaided from a confined space.
2. NIOSH—National Institute for Occupational Safety and Health.
3. MSA—Mine Safety and Health Act.
4. PPE—Personal Protective Equipment.
5. Time-Weighted Average (TWA)—The time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be exposed repeatedly, day after day, without adverse effect.

3.6.3 General

Engineering controls shall always be used in lieu of PPE. PPE shall be provided, used, and maintained in a sanitary and reliable condition whenever there are hazards that may cause injury or impairment and engineering controls have not been established. Appropriate PPE shall be provided by the employee's section or company. The employee's supervisor is responsible for ensuring that the proper PPE is used. The employee is responsible for using the equipment as required.

3.6.4 Design/Operational Requirements

1. Prior to employees being issued PPE, a hazard assessment shall be conducted to verify that the appropriate PPE is used, and the individual shall be trained in its use. Training shall include all of the following:
   - When PPE is necessary.
   - What PPE is necessary.
   - How to properly don, doff, adjust, and wear PPE.
   - Limitations of the PPE.
   - Proper care, maintenance, useful life, and disposal.
   - How to obtain PPE.

   Retraining shall be required when: new equipment is introduced, there are changes in the work site, or an employee is found not using/maintaining PPE properly. A written

certification that the employee has successfully completed training shall be maintained by each section/Branch or company.

2. Eye and face protection (prescription and non-prescription) shall meet ANSI Z87.1 and be selected for the specific job. The following lists some requirements for common hazards:
   - Safety glasses used for impact hazards shall have side shields when there is a chance of particles entering from the side.
   - Face shields must be combined with basic eye protection (safety glasses or goggles) when protecting against impact hazards.
   - The only type of goggle that may be used when working with hazardous liquids is one with indirect vents.
   - OSHA 1910.133 contains guidelines for protection against radiant energy (welding/cutting).
   - ANSI Z87.1 contains guidelines for all types of eye and face protection.
3. Prior to the use of respiratory protection, an assessment shall be made as to the type of protection needed. The assessment shall take into account type of material, quantity of material, and other methods of reducing exposure or removing the materials.
   - Only those personnel who have been medically certified to wear respiratory protection and have completed specific training, including qualitative or quantitative tests, shall do so. Training and medical evaluations are required annually.
   - Respiratory protection shall be approved by the National Institute for Occupational Safety and Health (NIOSH) or Mine Safety and Health Act (MSA).
   - Air-purifying respirators shall never be used in oxygen-deficient atmospheres, when levels are above the protection factor, or when levels are at or near IDLH.
   - When performing maintenance on the respirator, only parts specified by the manufacturer shall be used.
   - Respirators shall be maintained in a clean, sanitary condition and inspected prior to each use.
4. Where there is a possibility of injury to the head from falling objects, hard hats shall be worn. Hard hats must be worn when personnel are working above one another with tools. These helmets shall meet ANSI standard Z89.1. No decals shall be affixed to hard harts, nor shall they be painted.

   Hard hats shall not be worn within six feet of flight hardware, unless protection is required from an identified head hazard, and the hazards cannot be eliminated or mitigated. Chin straps shall be used if the possibility exists that the helmet could fall and impact another individual or hardware.
5. Where a possibility exists of injury to feet, foot protection that meets ANSI standard Z41 shall be worn. When working with heavy materials, steel-toed shoes are required. If there is a chance of puncture, puncture-resistant soles are required.

6. Gloves shall be worn to protect the hands when a hazard exists from exposure to chemicals or abrasions. For chemical exposures, gloves shall be selected based upon manufacturers' permeation tests. Leather or cotton gloves shall be used when the possibility of abrasion or splinters exists.
7. Employees routinely exposed to noise (30 or more days per year) at or above 80 dBA Time Weighted Average (TWA) or exposed to 85 dBA on any given day shall be placed in a hearing conservation program. Employees shall never be exposed to impact or impulse noise in excess of 140 dB. This program shall consist of the following:
   - Baseline medical monitoring and annual re-examination.
   - Annual training on the types of hearing protection available, use of hearing protection (including limitations), other means of reducing noise exposure, noise monitoring, effects of noise on hearing, purpose of medical monitoring, and care of hearing protectors.
   - Use of hearing protection by employees exposed to continuous noise in excess of 85 dBA TWA.
   - Area noise surveys.

   For more information on hearing protection, see Section 2.9.
8. Protective clothing (coveralls, smocks, etc.) shall be used when the possibility exists that an employee's clothing could become contaminated by hazardous materials or when protection is needed against abrasions, heat, or cold.
9. Fall protection shall be used when working at unprotected heights. Employees using fall protection shall be trained annually in the proper care and use of the specific equipment. Safety belts shall not be used for fall protection; harnesses must be used. Belts may be used for fall restraint. Fall restraint is defined as a device that allows the individual to approach a precipice or hazard area, but is short enough to prevent the possibility of an actual fall.

3.6.5 GSFC Contacts

S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035

3.6.6 Reference Documents Unique to this Section

29 CFR 1910.66, *Appendix C, Personal Fall Arrest System*

29 CFR 1910.95, *Occupational Noise Exposure*

29 CFR 1910, *Subpart I, Personal Protective Equipment*

ANSI Z41-1991, *American National Standards for Personal Protection—Protective Footwear*

ANSI Z87.1-1989, *American National Standard Practice for Occupational and Educational Eye and Face Protection*

ANSI Z89.1-1986, *American National Standard for Personnel Protection-Protective Headwear for Industrial Workers—Requirements*

GPR 1700.2, *GSFC Chemical Hygiene Program*

NPR 1820.1, *Hearing Conservation*

3.7 Office Safety

3.7.1 Scope

This section describes the requirements for office safety. Although this is written for an office area, the general requirements apply to any area containing desks, file cabinets, etc.

3.7.2 Acronyms/Definitions

1. Carpal Tunnel Syndrome (CTS)—CTS is one type of CTD. There are three main kinds of cumulative trauma disorders (tendonitis, trigger finger, and rotator cuff tendonitus). They often happen near the joints, where tendons rub against ligaments and bones.
2. Cumulative Trauma Disorder (CTD)—Injuries to the musculoskeletal and nervous systems caused by excessively repetitive motion, high force, and awkward body postures.
3. Ergonomics—The study of human characteristics for the appropriate design of the living and work environment.
4. Human Factors—Understanding the user's role in the overall system performance.
5. Video Display Terminals (VDT)—VDTs are comprised of a display screen, a keyboard, and a central processing unit.

3.7.3 General

Although office work is considered non-hazardous, numerous and costly worker's compensation claims are incurred by office workers. Office safety includes not only slips, trips, and falls, but also ergonomics issues. The primary cause of injury in an office setting is complacency.

3.7.4 Design/Operational Requirements

1. Areas shall be provided with adequate illumination. General office areas usually need between 50 and 100 foot-candles. Areas where personnel are working on computers should have lighting levels somewhat lower (i.e., 28–50 foot-candles). Along with reduced levels of lighting, glare on screens should be reduced or eliminated.
2. Extension cords should be eliminated as much as possible. No cord should be run across walkways. (See Section 2.8 for additional requirements for electrical equipment.)
3. All equipment shall be inspected prior to use and used only if in good condition. This is especially true for chairs. Only five-legged, caster chairs should be used. Never tilt back on two legs of a chair. Chairs should be adjustable for proper height and back support.
4. Computer stations should be set up to accommodate the worker and eliminate strain. Health effects from using VDT include eyestrain, fatigue, and musculoskeletal problems, such as CTS. OSHA's publication 3092 recommends proper VDT configuration.
5. File cabinets shall always be loaded from the bottom up, placing heavier items in the bottom. Never open more than one drawer at a time. Never leave an open file drawer unattended. Never open a drawer if someone is underneath it or in danger from it.

6. Never stand on a chair with casters to reach high. Use a ladder.
7. Housekeeping is extremely important. Pick up debris from the floor. Even something as small as a paper clip or piece of paper can cause slipping hazards.
8. Remove or tape down torn carpets until repaired. Remove loose or curled mats. Wipe up liquid spilled on floors.
9. Do not store items on top of bookcases or cabinets above head height.
10. Do not lift items heavier than you can comfortably lift. The National Institute for Occupational Safety and Health (NIOSH) lifting guidelines state that a person could lift 37.65 lb (17.1 kg) under ideal conditions in front of the body not involving trunk twisting. Ideal conditions include: smooth lifting (no jerking), the hands spread 30 inches (76 cm) or less, lifting posture unrestricted, and object held close to the body. Additionally, there must be good couplings (handles, shoes, floor surfaces) and a favorable environment. If all of these conditions are not met, the maximum weight must be decreased.

3.7.5 GSFC Contacts

S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035

3.7.6 Reference Documents Unique to this Section

ANSI/IES, RP1-1982, *Practice for Office Lighting*

NPR 8831.2, *Facilities Maintenance Management*

NIOSH *Work Practices Guide for Manual Lifting*

Occupational Safety and Health Act of 1970

3.8 Lockout/Tagout

3.8.1 Lockout/Tagout Program

I. Purpose and Scope

This section of the Safety Manual establishes general policy and procedures for the Lockout/Tagout Program in AETD. These are the minimum requirements for lockout/tagout, and securing hazardous energy sources. Energy sources include: mechanical, electrical, hydraulic, pneumatic, chemical, thermal, cryogenic, electromagnetic, and other types of energy. For convenience, this section is organized in a stand-alone format that can be excerpted as needed by the user.

II. Applicability

The Lockout/Tagout Program is applicable to all AETD civil servants and contractors performing servicing or maintenance on equipment, where release of energy could cause injury or death, and personnel who operate the equipment being serviced or maintained.

III. Policy

The AETD policy is to establish and implement a comprehensive Lockout/Tagout Program which meets the requirements of OSHA 1910.147, The Control of Hazardous Energy (Lockout/Tagout).

IV. Responsibilities

Specific responsibilities and authority for administering and implementing the AETD Safety Program, including the Lockout/Tagout Program are defined in 500-PG-8715.1.1, *AETD Safety Plan*. Additional responsibilities are listed below:

A. Director of has overall responsibility for ensuring that the Lockout/Tagout Program is implemented in this organization, including the following:

1. Ensure that resources needed to comply with the Lockout/Tagout Program are available.
2. Ensure Division Chiefs implement and maintain an effective Lockout/Tagout program.

B. Division Chiefs shall:

1. Ensure that all line managers/supervisors and their employees attend required training.
2. Ensure Branch Heads/supervisors comply with the Lockout/Tagout Program.

C. Branch Heads shall:

1. Identify and acquire all resources needed to implement the Lockout/Tagout Program for their areas of responsibility.
2. Ensure that authorized and affected employees are appropriately trained in the Lockout/Tagout Program and know the location of a copy of this Program.

D. Line Supervisors are responsible for direct action and enforcement to ensure compliance with the Lockout/Tagout Program, including the following:

1. Ensuring authorized employees understand the program and apply it correctly and that affected employees have been briefed on the program.
2. Developing and maintaining lockout/tagout procedures that follow the program requirements.
3. Ensure all new or modified equipment/systems are capable of being locked out.
4. Ensure the annual inspection of the program is completed and documented, sending results to their Division Chief.

E. All Employees shall:

1. Read and comply with the Lockout/Tagout Program.
2. Notify their supervisor of hazards or problems encountered during lockout/tagout operations.

F. AETD Safety Office shall:

1. Assist in determining the level and content of training required to adequately inform employees of the hazards and requirements of the Lockout/Tagout Program.
2. Periodically, audit the program to ensure that employees are trained and procedures developed/maintained in accordance with the Lockout/Tagout Program.
3. Review and update this Program as needed.

G. Safety and Environmental Division or its designated representative has overall responsibility for monitoring this program. Specific responsibilities include the following:

1. Providing revisions of the GSFC Lockout/Tagout Program on an as-needed basis.
2. Providing technical support including observations and reviews of work practices, procedures, personal protective equipment (PPE), and procurements.

H. Contracting Officer's Technical Representatives shall ensure that Contractors administer a Lockout/Tagout Program that complies with 29 CFR 1910.147, the *The Control of Hazardous Energy (Lockout/Tagout) Subpart S* promulgated by the Occupational Safety and Health Administration.

V. Employee Training

A. Authorized Employees shall be trained in the following. Training shall include a test to verify understanding of the Program.

1. Recognition of applicable hazardous energy sources.
2. The type and magnitude of the energy available in the workplace.
3. The methods and means necessary for energy isolation and control.
4. Additional requirements for use of tagout only.

B. Affected employees shall be briefed or trained on the purpose and use of the energy control procedure.

C. Retraining shall be accomplished when there is a change in the employee's job assignment or machine/equipment/system that presents a new hazard or a change in the procedures.

3.8.2 Acronyms/Definitions

1. Affected employee—An employee whose job requires him/her to operate or use a machine or piece of equipment on which servicing or maintenance is being performed under lockout or tagout, or whose job requires him/her to work in an area in which such servicing or maintenance is being performed.
2. Hot tap—A procedure, used in the repair or service of equipment, which involves welding on a piece of equipment under pressure in order to install connections or appurtenances. It is commonly used to replace or add sections of pipeline without the interruption of service for air, gas, water, and steam systems.
3. Lockout device—A device that uses a positive means such as a lock (either key or combination type) to hold an energy-isolating device in the safe position and prevent the energizing of the machine or equipment. Lockout devices shall be identifiable as being used for lockout only and shall have the employee's and employer's name on the lock.
4. LOTO – Lockout/Tagout
5. Servicing and/or Maintenance—Workplace activities such as constructing, installing, setting up, adjusting, inspecting, modifying, maintaining, and/or servicing machines or equipment.
6. Tagout Device—A prominent warning device, such as a tag and a means of attachment, which can be securely fastened to an energy-isolating device to indicate that the energy-isolating device and the equipment being controlled may not be operated until the device is removed. The device must be substantial enough to prevent inadvertent or accidental removal. It must state "Danger-Do Not Operate" and the name and phone number of the worker who placed the lock or tag on the system. The attachment must be environment-tolerant and able to withstand a 50-lb (22.7 kg) force and outside conditions.

3.8.3 General

Lockout/tagout requirements are applicable to a wide range of facilities, systems, subsystems, and equipment, including project-related equipment. These requirements are applicable whenever performing servicing and/or maintenance operations where release of hazardous energy could cause injury or death. Work on energized equipment is covered under section 2.8, Electrical Systems and Equipment.

3.8.4 Design/Operational Requirements

1. All new or modified equipment/machinery shall be designed to accept a lockout device.
2. Cord-and-plug-type electrical equipment does not have to be locked out if it is unplugged from the energy source and is under the exclusive control of the employee performing the work.
3. Procedures are required for all lockout/tagout operations, except when all of the following conditions are true:
    - The equipment has no potential for stored or residual energy or re-accumulation of stored energy after shut down;

- The equipment has a single energy source which can be easily identified and isolated;
- The isolation and locking out of that energy source will completely de-energize and deactivate the equipment;
- The equipment is isolated from that energy source and locked out during servicing or maintenance;
- A single lockout device will achieve a locked-out condition;
- The lockout device is under the exclusive control of the authorized employee performing the servicing or maintenance;
- The servicing or maintenance does not create hazards for other employees; and
- There have been no accidents involving the unexpected activation or re-energization of the equipment during servicing or maintenance.

4. Procedures, approved by the applicable supervisor shall contain the following:
   - Code or company name the procedure applies to
   - Type(s) and magnitude(s) of energy and hazards
   - Name(s)or job title(s) of authorized employees
   - Name(s)or job title(s) of affected employees and how to notify them
   - Types(s) and locations of energy insolating means
   - Type(s) of stored energy- methods to dissipate or restrain
   - Method(s) selected (i.e., locks, tags, additional safety measures, etc.)
   - Specify how it is verified that the equipment is in a zero energy state
   - Name(s) or job title(s) of employees authorized for group lockout or tagout, if applicable
5. Hot taps are allowed only when approved by the Branch Head for one of the following reasons: continuity of service is essential and/or shutdown of the systems is impractical. Procedures shall be written and approved. They shall include special equipment that must be used to protect employees.
6. Keys to lockout devices shall be maintained in the control of the person applying the device and the LOTO-authorized manager or supervisor only.
7. Supervisors and Managers authorized to maintain control of lockout device keys and to remove locks and/or tags shall complete the training required for authorized employees. Prior to any equipment/system being unlocked by the supervisor or manager shall:
   - Attempt to locate the authorized employee;
   - Ensure removal does not create a hazard; and
   - Notify the authorized employee of the action taken before he/she resumes work on the equipment.

8. Tags are essentially warning devices and may be used only when some other means of securing the energy source is also used (i.e., removal of a fuse, removal of a valve handle, etc.).
9. Affected employees must be notified prior to the application of a lockout/tagout device. If the lockout/tagout removes facility equipment from service, the Branch Head must be notified. A log of all locked or tagged out equipment shall be maintained by the group placing the equipment/system out of service.
10. After application of a lockout/tagout device, the equipment shall be tested to verify that all energy sources have been removed prior to starting work. Testing shall be done by taking circuit readings, operating valves while reading gages, performing normal startup operations, etc.
11. Prior to restoring the equipment to service, procedures shall require an inspection of the area to verify that nonessential items have been removed and all system components are operationally intact.
12. When the authorized employee is unavailable for removal of his/her lock/tag, the device may be removed under the direction of the applicable Section Head or equivalent manager, provided that:
    - Specific procedures and training for the removal have been developed and approved;
    - Every effort has been made to locate the person who applied the device; and
    - The authorized employee is contacted and informed as to the removal of the device prior to removing the device, or immediately upon return to work.
13. Outside contractors performing work in AETD facilities shall have their lockout/tagout program/procedures approved by the applicable Section/Branch Head prior to starting work.
14. Where work will be continued into the following shift, the new worker shall affix his/her lock and/or tag before the previous shift's worker removes his/hers. The new worker shall then verify that all energy sources have remained secured.
15. When work is performed by more than one person or group, each person or group shall place their locks on the equipment by means of a gang lock, so that the equipment cannot be restored to service until all locks have been cleared.
16. Under no circumstances shall a piece of equipment be operated if it is locked or tagged out unless it is for checkout purposes. In those cases where testing is required, the lockout or tagout may be removed temporarily and the equipment energized when the following occur:
    - The equipment is clear of all tools and materials and the equipment components are operationally intact;
    - The area is secured from access by all non-essential employees;
    - The device is removed by the authorized employee; and
    - Immediately after testing the energy control measures are reapplied.

17. When a group lockout or tagout device is used, one employee shall be appointed as primarily responsible for the whole group. This person shall ascertain the status of all individual group members prior to removal of the device, and each authorized employee shall affix a personal lockout or tagout device to the group lockout device, group lockbox, or comparable mechanism prior to the start of work, and remove it when the work is complete. This person's lockout device should be the first one on and the last one off.

3.8.5 GSFC Contacts

S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035

3.8.6 Reference Documents Unique to this Section

ANSI Z244.1-1982, *Requirements for Lockout/Tagout of Energy Sources*

OSHA 29 CFR 1910.147, *The Control of Hazardous Energy (Lockout/Tagout) Subpart S*

GPR 1700.5, *Control of Hazardous Energy (Lockout/Tagout)*

3.9 Thermal and Other Heating Devices

3.9.1 Scope

This section covers heat-producing systems and devices.

3.9.2 Acronyms/Definitions

N/A

3.9.3 General

Many systems and devices either require or produce heat in dangerous intensities. These include thermal chambers, furnaces, ovens, hot plates, solar simulators, steam generators and lines, welding operations, and other miscellaneous heating devices.

3.9.4 Design/Operational Requirements

1. Personnel shall post warning signs wherever heated surfaces (113^{o} F (45^{o} C) or greater) are exposed or otherwise accessible to other personnel. Where necessary, erect shields or barrier tapes to keep unauthorized personnel away from potentially hazardous areas.
2. Personnel shall wear appropriate PPE (see Section 3.6) when working near heated surfaces or handling heated objects.
3. Operating procedures for walk-in thermal chambers and ovens shall include a checklist item to have the operator conduct a walk-down before operating the facility, to verify that all personnel are out of harm's way.
4. Operators of solar simulators, welding equipment (see Section 3.4), electrical heaters, etc., shall take measures to protect themselves and other personnel from inadvertent exposure to heat-producing sources.
5. Protection against heat-producing radiation is covered in Sections 2.6 and 2.7.
6. Additional ventilation may have to be provided, if an analysis of the operation indicates personnel would be exposed to harmful levels of heat, which may cause heat stroke or heat exhaustion.
7. Space heats must have devices that shut off power if a tip-over occurs. Do not leave operating when the area is unoccupied and remove all paper and wood produces near the heater.

3.9.5 GSFC Contacts

S&ED: (301) 286-2281
AETD Safety Manager: (301) 286-1035

3.9.6 Reference Documents Unique to this Section

N/A

3.10 Trailers

3.10.1 Scope

This section covers trailer fire protection and safety.

3.10.2 Acronyms/Definitions

1. Trailer—Mobile electronics, instrumentation test/evaluation trailers, containers, or vans, either self-propelled or towed, and all trailers or vans being used to satisfy a requirement for office, laboratory, technical facility, conference room, shop, storage, construction, or other space that would ordinarily be replaced by either permanent or temporary construction.
2. Mobile trailer—A trailer or container which is not located in a fixed position for greater than six months.

3.10.3 General

Trailers and mobile trailers under the authority of AETD must comply with the requirements specified in the latest revision of GPR 8715.5 *Fire Protection*. Examples are: trailers used for office space, storage space, or construction activities; trailers and instrumentation vans which are parked outside the GSFC buildings in support of flight project integration and testing programs; or the emergency generator facilities that provide backup electrical power during commercial power outages.

3.10.4 Design/Operational Requirements

Personnel must coordinate trailer operational requirements with the S&ED. The following information summarizes GPR 8715.5 regulations:

1. For trailers not associated with a major building, a Facilities Operation Manager (FOM) will be appointed to monitor and enforce GPR 8715.5 regulations.
2. As part of their annual safety inspections, safety survey teams shall inspect all trailers in their areas of responsibility. For trailers not associated with a major building, separate surveys shall be scheduled.
3. Trailer parking will be restricted to designated permanent trailer pads where trailer service is provided. All permanent trailer pads must be provided with utility services to include fire protection and security alarm connections. Trailer pads must be sized for the full dimensions of the trailer.
4. Mobile trailers are exempted from pad requirements, provided they are not located within 25 feet (7.62 m) of a building.
5. Specifications and proposed locations for trailers must be reviewed and approved by the S&ED. Trailer information must be provided to the Facilities Management Division so they can prepare site location maps and provide the necessary engineering services.
6. A reliable and unobstructed means of access to all trailers shall be maintained for vehicles and equipment responding to emergencies.

7. Stairs, landings, and handrails shall meet OSHA and NFPA 101 requirements. Stairs shall be firmly attached to the trailer but shall not be supported by the trailer. The FOMs shall inspect the stairs and appurtenances annually. Mobile trailers shall provide stairs engineered to best reflect provisions of the same codes, within their operational constraints.
8. All trailers shall be anchored unless they are actively used as mobile trailers.
9. All trailers must have suitably sized fire extinguishers, compatible with the occupancy being protected. Coordinate other fire protection requirements, such as smoke detectors, automatic alarms, fire suppression systems, etc., with S&ED. The comprehensiveness of fire protection apparatus will be determined based on variables such as life safety, dollar value, mission importance, etc.
10. Handling, use, and storage of flammable and combustible liquids shall be in accordance with NFPA 30 and approved by S&ED.
11. Trailers containing potentially hazardous liquids should have spill containment dikes around them. For example, in the event of a spill, diesel fuel in an emergency power generator should be contained by dikes.
12. The most prominent hazards of each trailer must be identified in accordance with NFPA 704.
13. Personnel contact information shall be posted near the main entrance to each trailer. Emergency procedures shall be developed for occupied trailers.
14. Requests for waivers to GPR 8715.5 requirements shall be routed through S&ED review, and approved either by S&ED or Goddard Headquarters (NPR 8715.3, Section 1.19), as applicable.

3.10.5 GSFC Contacts

S&ED: (301) 286-2281

AETD Safety Manager: (301) 286-1035

3.10.6 Reference Documents Unique to this Section

GPR 8715.5, *Fire Protection*

NASA-STD-8719.11, Fire Protection, Section 9.9

NFPA 30 and 704

3.11 Industrial Hygiene Program

3.11.1 Scope

This section covers industrial hygiene (IH) issues not previously covered. These topics include asbestos, beryllium, cadmium, formaldehyde, lead, and methylene chloride. Topics, such as exposure to noise, hazardous materials, hazardous waste, respiratory protection, and office ergonomics, are covered in other sections of this manual. Other potentially hazardous materials not mentioned here shall be reviewed on a case by case basis. All AETD employees must be aware of the potential hazards of the materials with which they work.

3.11.2 Acronyms/Definitions

1. IH – Industrial Hygiene

3.11.3 General

Exposure to chemicals and other hazardous materials can create severe health hazards. Personnel need to be aware of these hazards and ensure controls are in place to provide protection. Many times these hazards can go unrecognized, such as exposure to lead from solder or exposure to cadmium from rivets. Evaluation of exposure to these types of materials shall be coordinated with the Code 250 IH Office. Any addition of hazardous chemicals or changes in process shall be approved by Code 250 IH.

3.11.4 Design/Operational Requirements

1. Asbestos
   - Asbestos is a widely used, mineral-based material, whose fibers enter the body by inhalation of airborne particles or by ingestion. Years of exposure can lead to cancer. See GPR 1840.1, Asbestos Management Program at GSFC for more detailed requirements.
   - All work where personnel may contact asbestos-containing materials shall be assessed to determine the potential to generate airborne fibers. Work on items such as brakes that contain asbestos shall follow an approved method and be conducted by trained employees. Other areas that might include asbestos are building materials, flooring, plaster walls, pipe insulation, gasket material, electrical cords, and welding blankets.
   - Notify Code 250 IH of any suspected asbestos, especially if it appears to be crumbling or becoming airborne. IH will determine if the material contains asbestos and needs to be removed.
   - Work requiring possible contact with asbestos containing materials or supervising employees contacting asbestos containing material shall be done by employees who have completed a minimum two-hour asbestos awareness course.
   - Removal of any material containing asbestos, such as pipe insulation, flooring or mastic, must be accomplished by a State licensed contractor. The contractor must submit a plan to Code 250 IH for approval prior to the start of the operation. Following removal, a copy of the abatement report, with disposal records must be sent to Code 250 IH.

2. Beryllium
   - Beryllium is considered a likely carcinogen when airborne dust is inhaled. In AETD beryllium can be found in some test fixtures in the Vibration Lab and in flight project structural members.
   - Beryllium shall not be machined, drilled, ground, or sanded in AETD facilities without a written hazardous operating procedure and approval by the S&ED or AETD Safety. Work that may generate airborne beryllium dust or beryllium oxide shall require controls of the inhalation hazard, air monitoring, medical monitoring, respiratory protection, specially trained personnel, PPE, air filtering, and special waste handling.
3. Cadmium
   - Cadmium is used in electroplating, industrial paints, batteries, some sliver solders and metal coatings. Hazards usually exist when breathing dust or fumes containing cadmium. Exposure may result in metal fume fever or chronic exposure may result in cancer.
   - When performing work which may result in airborne cadmium, adequate ventilation shall be provided. IH shall determine if ventilation is adequate. When proper ventilation can not be provided and a written hazardous operating procedure approved by the S&ED or AETD Safety shall be followed. Procedures shall require controls of the inhalation hazard, air monitoring, medical monitoring, respiratory protection, specially trained personnel, and PPE.
4. Formaldehyde
   - Formaldehyde may cause occupational dermatitis and is linked to cancer. It is a naturally occurring substance that can be found in glue or adhesives, latex paints, and certain insulation materials. New furniture may off gas small amounts of formaldehyde. Formaldehyde may cause cancer in humans in larger amounts.
   - When performing work which may result in exposure to formaldehyde over the occupational exposure limit, adequate ventilation shall be provided. IH shall determine if ventilation is adequate. When proper ventilation can not be provided, a written hazardous operating procedure approved by the S&ED or AETD Safety shall be followed. Procedures shall require controls of the inhalation hazard, air monitoring, medical monitoring, respiratory protection, specially trained personnel, and PPE
5. Lead
   - Lead fumes and lead compounds cause poisoning after prolonged exposure through inhalation and to a lesser extent through skin absorption. Lead is commonly found in solder, rivets, power tools, older paints, and lead-containing mortar. Lead can damage the central nervous system, cardiovascular system, reproductive system, hematological system, and kidneys.
   - Work exposing personnel to lead shall be reviewed by IH to determine proper safe guards. Safe guards may include additional ventilation, respiratory protection, medical examinations, PPE, and additional training.

6. Methylene Chloride
   - Methylene chloride, also called dichloromethane, is used in various processes/materials: paint removers, metal cleaning and degreasing, polyurethane foam production, etc. It is a potential carcinogen.
   - AETD personnel should not use methylene chloride. If used, a written hazardous operating procedure approved by the S&ED or AETD Safety shall be used. The procedure shall require air sampling, medical surveillance, methods to control exposure, training, emergency response, respiratory protection, and PPE. Records shall be maintained of all objective data, exposure monitoring, and medical surveillance in accordance with 29 CFR 1910.1020.

3.11.5 GSFC Contacts

S&ED: (301) 286-2281

Code 250 IH: (301)286-6669

GSFC IH Office: (301) 286-6669

AETD Safety Manager: (301) 286-1035

3.11.6 Reference Documents Unique to this Section

NPR 1800.1, *NASA Occupational Health Program Procedures*
29 CFR 1910.1001, *Asbestos*
29 CFR 1910.1048, *Formaldehyde*
29 CFR 1910.1025, *Lead*
29 CFR 1910.1027, *Cadmium*
29 CFR 1910.1052, *Methylene Chloride*
GPR 1840.1, *Asbestos Management Program at GSFC*

Appendix A. Mishaps/Incidents

This appendix contains the information and documents needed to comply with the mishap and incident reporting requirements.

Mishaps/Incidents

A.1 Scope

The reporting procedures for mishaps and incidents are specified in NASA NPR 8715.3, NPR 8621.1, *NASA Procedural Requirements for Mishap Reporting, Investigation, and Recordkeeping,* GPR 8621.1, *Mishap and Close Calls,* GPR 8621.2, *Processing Mishap and Close Calls,* and GPR 8621.3, *Mishap and Close Call Investigation.* The requirements of these documents are summarized below.

A.2 Definitions

1. NASA Mishap—Any unplanned occurrence, event, or anomaly that meets one of the definitions below. Injury to a member of the public while on NASA facilities is also defined as a NASA mishap.
   - Type A Mishap— A mishap resulting in one or more of the following: (1) an occupational injury or illness resulting in a fatality, a permanent total disability, or the hospitalization for inpatient care of 3 or more people within 30 workdays of the mishap; (2) a total direct cost of mission failure and property damage of $1 million or more; (3) a crewed aircraft hull loss; (4) an occurrence of an unexpected aircraft departure from controlled flight (except high performance jet/test aircraft such as F-15, F-16, F/A-18, T-38, and T-34, when engaged in flight test activities).
   - Type B Mishap— A mishap that caused an occupational injury or illness that resulted in a permanent partial disability, the hospitalization for inpatient care of 1-2 people within 30 workdays of the mishap, or a total direct cost of mission failure and property damage of at least $250,000 but less than $1,000,000.
   - Type C Mishap— A mishap resulting in a nonfatal occupational injury or illness that caused any days away from work, restricted duty, or transfer to another job beyond the day or shift on which it occurred, or a total direct cost of mission failure and property damage of at least $25,000 but less than $250,000.
   - Type D Mishap – A mishap that caused any nonfatal OSHA recordable occupational injury and/or illness that does not meet the definition of a Type C mishap, or a total direct cost of mission failure and property damage of at least $1,000 but less than $25,000.
   - Close Call— An event in which there is no injury or only minor injury requiring first aid, no equipment/property damage or minor equipment/property damage (less than $1000), but which possesses a potential to cause a mishap in the same location or elsewhere..

2. NASA Contractor Mishap—Any mishaps as defined in Paragraph 1 above that involve only NASA contractor personnel, equipment, or facilities in support of NASA operations.
3. Immediately Reportable Mishaps—All mishaps that require immediate telephonic notification to local and Headquarters' safety officials. Included in this category are those mishaps defined in Paragraphs 1 and 2 above with the exception of Types C, and D injury/illness cases and incidents and Close Calls.
4. OSHA as Recordable Mishaps—An occupational death, injury, or illness that must be recorded subject to OSHA requirements in 29 CFR Part 1904.

A.3 Mishap Reporting Requirement

Any mishap or close call situation which has the potential to injure personnel, damage critical hardware, or result in AETD property damage, shall be reported by the affected area's supervisor. A report of the incident shall be reported on the IRIS system on the Safety 1st web page (http://safety1st.gsfc.nasa.gov/, select "Quick Incident"). A written report of the incident should be reported to management on the AETD Incident Report Form (Figure A-1) within 24 hours of the occurrence. Reports on IRIS are tracked through closure by S&ED. The S&ED generate SAF Alerts when needed from the mishap reports.

The Division Chief shall be informed no later than 8:30 AM on the day following a reportable mishap (Types A, B, or C and Type D or close calls with potential of affecting other Branches). If information is incomplete, an initial report should be submitted to meet the deadline, followed by the final report. It is important to complete the corrective action section and describe what positive steps will be taken to prevent future recurrence of the problem.

The AETD Directorate Office shall be informed of all Type A, B, C or Close Call that might affect other organizations as soon as possible.

A.4 Mishap Investigation and Follow-up

Affected organizations are responsible for investigating mishap causes and instituting corrective measures to prevent recurrence. In particular, investigation boards shall be appointed for mishaps categorized as Type A, Type B, and high visibility mishaps and close calls. Investigations conducted by the boards will be documented formally and the reports distributed for mishap prevention purposes. Refer to NPR 8621.1 and GPR 8621.3 for the complete requirements for mishap investigation and follow-up.

Figure A-1. AETD Incident Report Form

AETD INCIDENT REPORT				No.
(1) Title:				
(2) Incident Date:	**(3) Time**:		**(4) Location**:	
(5) Project/Activity	**(6) WOA**	**(7) Procedure**	**(8) NCR**	**(9) NASA Mishap Report**
(10) Personnel Involved:	**(11) Affiliation**	**(12) Injury**		
(13) Equipment:				
(14a) Problem Description:				
(14b) Root Cause Analysis (Required or N/A)				
(15) Immediate Corrective Action:				
(16) Task Leader Approval:				
(17) Corrective Action				
(18) Follow Up				
(19) Approval: Branch Head: **Other Approvals:**		**Eye Witness:**	**Responsible Manager/Supervisor:**	
Verified Effective:		**Originator:**		

Instructions for Completion of AETD Incident Report

Incident Reports are given unique numbers by the individual branch, which will allow the report to be tracked through closure. For any items not applicable to a specific incident, an N/A shall be placed in the block.

1. Title: This should be a short statement of incident that will give the reader a sense of content.
2. Incident Date: Include the date incident occurred.
3. Time: State the time of the incident
4. Location: State the location of occurrence (building, room, location within room, etc.)
5. Project/Activity: State the project associated with the work, if applicable, or the activity involved when the incident occurred.
6. WOA: State the Work Order Authorization, if applicable.
7. Procedure: State the procedure being performed at the time of the incident, if applicable.
8. NCR: If a non-conformance report was generated, state the number.
9. NASA Mishap Report: If a NASA Mishap report was generated, state the number or date entered in IRIS.
10. Personnel Involved: State names of all personnel involved in the incident.
11. Affiliation: State the project, company, or Code the personnel involved work for.
12. Injury: Describe any injuries involved in the incident.
13. Equipment: Describe any equipment involved in the incident.
14. a) Problem Description: Describe the incident and results
    b) Root Cause Analysis (Required or N/A): Describe what the root cause(s) of the incident was. (The root cause is the most basic cause(s) that can reasonably be identified that management has control to fix and, when fixed, will prevent (or significantly reduce the likelihood of) that problem's recurrence.)
15. Immediate Corrective Action: State the action taken to immediately safe the situation.
16. Task Leader Approval: The Task Leader shall approve the above information; verifying it is correct to his/her knowledge.
17. Corrective Action: State corrective action taken to ensure incident will not reoccur.
18. Follow-up: State any follow-up action required by outside groups.
19. Approval: The applicable branch head and/or other authority shall approve this report indicating that all corrective actions and follow-up actions have been taken.

Eye Witness: List all personnel that were not involved in the incident, but witnesses what happened.

Responsible Manager/Supervisor: The manager/supervisor for the group having the incident shall approve this report, indicating they agree with the information stated.

Verified Effective: State any audits or future actions required to be performed to ensure this does not reoccur at a future date, if applicable.

Originator: State the person completing the Incident Report.

A.5 Immediate Responsibilities Following a Mishap

1. Personnel first on the scene of a mishap:
   - Call Goddard's emergency telephone extension, 911 or for off-base or cell phones use 301-286-9111, and request assistance, if applicable. If possible, render assistance to victims and attempt to limit further injury and property/equipment damage. If the mishap is a close call or the person is ambulatory, a 911 call may not be necessary.
   - If possible, and until relieved by competent authority, secure the scene of the mishap against action that could impair investigation, and obtain the names and addresses of witnesses.
   - Report by telephone or the most expeditious means all known facts to the S&ED, (301) 286-2281.
2. Area Supervisor/Group Leader:
   - Obtain immediate medical assistance for injured personnel. Institute appropriate emergency measures to minimize further damage to personnel and property.
   - Render assistance to the emergency response personnel as requested.
   - Obtain all information necessary to fulfill the reporting requirements described in Section A.3 above. Ensure that the S&ED and the AETD Safety Office is notified.

Appendix B. Detailed Requirements for Ground-Based Pressure Vessels and Pressurized Systems (PV/S)

This appendix contains requirements for designing, operating, modifying, repairing, and certifying ground-based pressure vessels and pressurized systems (PV/S). It provides additional details not contained in Section 2.3 of this Safety Manual. Section 2.3 deals primarily with the general safety aspects and GSFC-required certifications of PV/S, whereas this appendix contains specific technical information for designing, maintaining, and operating these systems.

B.1 Scope

This Appendix covers detailed requirements for ground-based PV/S, including vacuum systems, in permanent or temporary configuration. Topics addressed herein are not all inclusive, but represent a compilation of Code requirements and good engineering practice.

B.2 Design/Operational Requirements

1. Loadings:

   All PV/S shall be designed for at least the most severe condition of coincident pressure and temperature expected in operation. In addition to pressure, the effects of the following loadings shall be considered in the design:

   a. Weight of the PV/S and its contents.

   b. Static reactions from the weight of attached equipment.

   c. Cyclic and dynamic reactions caused by pressure or thermal variations, flow-induced vibrations, or attached equipment and mechanical loadings.

   d. Wind, snow, ice, and seismic reactions.

   e. Impact reactions such as those due to fluid shock.

   f. Temperature gradients and thermal expansion.

2. Temperature:

   The temperature used in the design of a PV/S shall not be less than the mean metal temperature (through the thickness) expected under operating conditions. If necessary, the metal temperature shall be determined by computation using accepted heat transfer procedures, or by measurement of equipment in service under equivalent operating conditions.

3. Materials Selection:

   Only materials listed by appropriate codes, standards, and technical literature as compatible for each specific service shall be selected. All operating conditions such as temperature, pressure, fluid compatibility, and environmental location must be considered prior to material selection. Materials selected shall be compatible with each other as well as with the service fluid. When operating temperatures vary greatly, care shall be taken to consider the stresses caused by thermal expansion.

4. Welded Designs:

   All weldments in a PV/S, including attachments made to pressure retaining boundaries, shall be designed to the requirements of the applicable ANSI/ASME B31 *Pressure Piping Code* and/or ANSI/ASME *Boiler & Pressure Vessel Code*. Drawings and/or design specifications used for welded assemblies shall contain complete information detailing joint geometry; weld type, size, and location; material type and specification; preheat, interpass, and postweld heat treatments; and the appropriate nondestructive testing requirements. All welding symbols shall meet the requirements of ANSI/AWS A2.4, *Symbols for Welding and Nondestructive Testing*, latest edition.

5. Overpressure Protection Requirements:

   a. General Requirements:

      (1) All pressure vessels and piping/tubing systems shall be equipped with the requisite overpressure protection devices, meeting the requirements of the applicable design code, and must be selected on the basis of their intended service.

      (2) All overpressure protection devices shall be set to function at or below the MAWP of the vessel or MDP of the piping/tubing system.

      (3) The capacity of overpressure protection devices shall be sized to prevent pressure from rising more than 10% or 3 psi (20.7 kpa), whichever is greater, above the MAWP of the vessel or MDP of the piping/tubing system.

      (4) All overpressure protection devices shall be installed in such a manner that they are readily accessible for inspection and cannot be rendered inoperative.

      (5) All new relief valves shall have their set points certified by the RECERT Manager prior to being placed in service.

      (6) All overpressure protection devices shall be periodically tested and inspected in accordance with the Inservice Inspection requirements of GPR 8710.3.

   b. Specific Requirements:

      (1) In order to avoid simmering and to allow an actuated pressure relief valve to reseat completely, pressure relief valve set points should be specified to take into account the blowdown characteristics established by the manufacturer. In no case shall the relief valve set point exceed the MAWP of the vessel or MDP of the piping/tubing system.

      (2) In order to avoid premature creep-induced failure of a rupture disk, the burst point should be selected to be at least 30% above the normal operating pressure of the vessel or piping/tubing system. In no case shall the burst point of a rupture disk exceed the MAWP of the vessel or MDP of the piping/tubing system when the rupture disk is the sole source of overpressure protection.

      (3) Overpressure protection devices used in systems operating at or near temperatures and pressures where a phase change could occur (cryogenic

systems, steam systems, condensate systems, etc.) shall be selected to ensure adequate discharge capacity.

(4) Relief valves of adequate capacity shall be installed in all cryogenic piping/tubing segments located between isolation or control valves.

(5) The discharge of overpressure protection devices located on indoor cryogenic systems shall be controlled or diverted to avoid contact of the discharge plume with personnel and equipment, and any back-pressure or flow effects of such diversion shall be taken into account in the design of the overpressure protection device.

(6) Adjustable-type relief valves shall not be used on any piping/tubing system without the prior written approval of the RECERT Manager.

(7) Reactions on piping systems due to actuation of overpressure protection devices shall be considered in the piping design, and adequate strength shall be provided to withstand these reactions.

6. Piping Flexibility:

Piping systems shall be designed to have sufficient flexibility to prevent thermal, mechanical, or acoustically-induced expansion, contraction, or vibration from causing any of the following:

a. Failure of piping or supports from overstress or fatigue.

b. Leakage at joints.

c. Detrimental stress or distortion in piping or in connected equipment.

7. Piping Support Requirements:

All piping systems shall be structurally supported to prevent the development of excessive piping stresses, leakage at joints, excessive loads on connected equipment, and resonance due to flow and wind-induced vibrations. The location, spacing, and design of supporting elements in uncomplicated systems may be based upon simple calculations, applicable code requirements, and good engineering practice. Complicated piping systems will require more extensive engineering analyses to address the stresses, moments, and reactions imposed by service pressure and temperature variations, shock loads, vibration loads, and hydrostatic testing loads.

B.3 Special Requirements for Compressed Air Receivers

The requirements contained in this section are specific to the procurement of compressed air receivers and shall be followed by all GSFC organizational elements. Deviations will require a waiver in accordance with GPR 8710.3.

1. Purchase specifications for all new compressed air systems containing Tank Mounted Air Compressors (TMACs) must specify that the compressed air receiver meets the requirements of the ASME *Boiler & Pressure Vessel Code*, Section VIII, Paragraph UG-22 and must be so documented by the manufacturer. In accordance with the recommendations of the National Board of Boiler and Pressure Vessel Inspectors, if documentation is not provided the compressor/motor shall be removed from the vessel and mounted separately. Connections between the compressor and receiver should be 300 psi (2,069 kpa) minimum flex hose.
2. In compliance with OSHA, 29 CFR 1910.169, purchase specifications for all new compressed air receivers must state that the receiver be designed, constructed, tested, and stamped in accordance with Section VIII of the ASME *Boiler and Pressure Vessel Code*.
3. Purchase specifications for all new compressed air receivers must include the requirement that the supplier furnish to the GSFC organization purchasing the receiver a copy of the Manufacturer's Data Report, Form U-1 or Form U-1A as applicable, at the time of receiver delivery (Section VIII, Paragraph UG-120).
4. Prior to initiating procurement of a new compressed air system, the purchasing organization shall contact the RECERT Manager to obtain the applicable corrosion allowance, which must be specified per Paragraph UG-25 of Section VIII of the ASME *Boiler and Pressure Vessel Code*.

B.4 System Modifications

Any modification to a PV/S voids the system's certification. The following are requirements that must be met in order for the modified system to be recertified and placed into/returned to service by the system owner:

1. The design, installation, inspection, and testing of the modified PV/S is in accordance with the applicable consensus code and NASA documentation.
2. The proposed modification is submitted by the system owner to the RECERT Manager for approval prior to execution. The submittal shall be in sufficient detail that the RECERT Manager can perform an independent Code compliance review.
3. The documentation specified in NPR 8715.4 shall be provided by the system owner to the RECERT Manager prior to placing the modified PV/S back in service.
4. Upon completion of the modifications, the system owner must notify the RECERT Manager to arrange for system certification tests and inspections. System certification must be granted by the RECERT Manager prior to placing the modified system back in service.
5. As-built system configuration drawings showing the changes made in the system or system components shall be transmitted by the system owner to the RECERT Manager no later than two weeks after completion of the modification.

B.5 Component Repair/Replacement

1. Repairs:
   a. All repairs to a PV/S that involve welding, brazing, or soldering on a pressure retaining boundary or "plugging" of leaks using any other method shall be reviewed and approved by the RECERT Manager prior to the start of the work.
   b. Repairs of a preventive or corrective maintenance nature such as repair/replacement of packing, seals, seats, etc., on valves (other than relief valves) and pumps do not need prior RECERT Manager review and approval.
   c. No repairs to PV/S overpressure protection devices shall be made.
   d. Any repair to a PV/S pressure-indicating gage requires that the gage be recertified prior to reinstallation.
2. Replacements:

Replacement of individual components in a PV/S requires the prior review and approval of the pertinent design data by the RECERT Manager. In addition, replacement relief valves and pressure gages shall be certified by the RECERT Manager prior to installation.

B.6 Documentation Requirements Specific To GSFC PV/S

The following documentation for the applicable PV/S Class shall be provided to the RECERT Manager prior to placing the component or system in service. For all Classes of PV/S, Manufacturer's O&M manuals shall be provided where applicable. For information purposes, a summary of currently approved PV/S Classes has been provided in ***B.7***, below.

1. Class A Pressure Vessels

   Manufacturer's Data Reports (MDR) for
   a. Section VIII, Division 1 Vessels: ***MDR Form U-1 or U-1A, as applicable.***
   b. Section VIII, Division 2 Vessels: **MDR Form A-1**
   c. Section VIII, Division 3 Vessels: **MDR Form K-1**
   d. Section X, Fiber-Reinforced Plastic Pressure Vessels: **MDR Form RP-1 or RP-3, as applicable.**

2. Class A Pressure Piping
   a. Design and operating conditions
   b. Material Specification (ASTM or ASME)
   c. Pipe/tubing Size
   d. Pipe/tubing Wall thicknesses
   e. Pipe/tube fitting type and class (socket weld, butt weld, threaded, mechanical (swage), etc)
   f. Valve type, manufacturer, model number, material of construction (body, stem, seat(s)), pressure and temperature rating
   g. Overpressure protection: Manufacturer, model number, type, size, capacity, set point, seat material
   h. Pressure Regulators: Manufacturer, model number, type (single stage, dual stage), material, size, max inlet pressure, max outlet pressure
   i. Pressure gages: Manufacturer, model number, inlet size, range
   j. As-built P&ID
   k. C of C from fabricator and/or installer that the System meets the Code fabrication and installation requirements
   l. Record of Code-required NDT
   m. Record of Code-required pressure test

3. Class B Vessels and/or Piping Systems
   a. Documentation designating the Code of Record (American Petroleum Institute (API), U.S. Department of Transportation (DOT), Compressed Gas Association (CGA), American Water Works Association (AWWA), etc.) used for design; materials; fabrication and assembly; and inspection, examination, and testing, together with the design and operating conditions.
   b. Manufacturer's O&M manual, if applicable
   c. Material Specification (ASTM or ASME)

d. Pipe/tubing and/or Vessel Size
e. Pipe/tubing and/or Vessel Wall thickness
f. Pipe/tube fitting type and class (socket weld, butt weld, threaded, mechanical (swage), etc)
g. Valve type, manufacturer, model number, material of construction (body, stem, seat(s)), pressure and temperature rating
h. Overpressure protection: Manufacturer, model number, type, size, capacity, set point, seat material
i. Pressure Regulators: Manufacturer, model number, type (single stage, dual stage), material, size, max inlet pressure, max outlet pressure
j. Pressure gages: Manufacturer, model number, inlet size, range
k. As-built P&ID
l. C of C from fabricator and/or installer that the System meets the Code fabrication and installation requirements
m. Record of Code-required NDT
n. Record of Code-required pressure test

4. Class C: Code Equivalent

NASA Policy requires new PV/S installations to be either Class A or Class B.

5. Class D: Ground Support Equipment (GSE)

a. Documentation designating the Code of record used for design; materials; fabrication and assembly; and inspection, examination, and testing.
b. Design and operating conditions
c. Material Specification (ASTM or ASME)
d. Pipe/tubing and/or Vessel Size
e. Pipe/tubing and/or Vessel Wall thickness
f. Pipe/tube fitting type and class (socket weld, butt weld, threaded, mechanical (swage), etc)
g. Valve type, manufacturer, model number, material of construction (body, stem, seat(s)), pressure and temperature rating.
h. Overpressure protection: Manufacturer, model number, type, size, capacity, set point, seat material
i. Pressure Regulators: Manufacturer, model number, type (single stage, dual stage), material, size, max inlet pressure, max outlet pressure
j. Pressure gages: Manufacturer, model number, inlet size, range
k. As-built P&ID

6. Class E: Excluded PV/S

Documentation requirements shall be established on a case-by-case basis, and will generally include information necessary to validate inclusion in Class E.

8. Class R: Research and Development PV/S

   Documentation requirements shall be established on a case-by-case basis, and will generally include the same types of information required for Class D GSE.

9. Class W: Waived PV/S

   Documentation requirements shall be established on a case-by-case basis.

B.7 Summary Of PV/S Classes

The following is a summary of the RECERT Program Classification System.

CLASS A: ASME CODE COMPLIANT

Class A designation applies to those PV/S conforming to the following ANSI/ASME Codes.

- Pressure Vessels

  ASME Boiler and Pressure Vessel Code:
  a. Section VIII, Pressure Vessels, Divisions 1, 2, and 3.
  b. Section X, Fiber-Reinforced Plastic Pressure Vessels

- Pressure Piping

  ASME Code for Pressure Piping, B31:
  a. ASME B31.1, Power Piping
  b. ASME B31.3, Process Piping

CLASS B: OTHER CODE COMPLIANT

Class B designation applies to those PV/S conforming to those codes other than ANSI/ASME delineated in GPR 8710.3. Examples include American Petroleum Institute (API), U.S. Department of Transportation (DOT), Compressed Gas Association (CGA), American Water Works Association (AWWA), etc.

CLASS C: CODE EQUIVALENT

Class C designation applies to those PV/S installed prior to RECERT Program implementation in 1976 and which, due to age, pressure requirements, fabrication techniques, or material selection, did not fall within the scope of the codes and standards delineated in GPR 8710.3; yet, were designed in accordance with code formulae, documented stress values, and code-mandated joint efficiency factors. These PV/S are referred to as "Code Equivalent". Note that NASA Policy requires new PV/S installations to be either Class A or Class B.

CLASS D: GROUND SUPPORT EQUIPMENT (GSE)

This Class includes portable PV/S specifically designed and constructed to support flight payloads during test and integration activities at various locations and at the launch site. Class D ISI requirements are usually more extensive than normal ground-based PV/S and reflect requirements imposed by jurisdictions other than GSFC (KSC, USAF, e.g.). Examples include, but are not limited to, purge carts, payload environmental transport systems (PETS), and engineering test units (ETU's).

CLASS E: EXCLUDED PV/S

Certain types of PV/S are excluded from the GSFC RECERT Program due to their inherently low energy, their national record of operation without serious incident, or because they are subjected to periodic tests and inspections in accordance with requirements other than those contained in the RECERT Program. Tests and inspections may be performed at the request of the PV/S owner organization.

CLASS R: RESEARCH AND DEVELOPMENT PV/S

This classification applies to those PV/S that are assembled for a limited duration for the purpose of experimental support to a research and development project, or to support a specific flight project test.

CLASS W: WAIVED PV/S

Class W designates those flight weight or medium weight PV/S used in ground-based applications which do not meet Code or Code equivalency for ground operations, but for which an approved waiver to operate the PV/S has been obtained by the user organization in accordance with GPR 8710.3 requirements. In addition, Class W may be combined with other classes for which an approved waiver has been obtained. For example, a Class B vessel for which certain Code requirements have been waived would be designated *Class BW*.

Appendix C. Memorandum of Understanding on Workplace Safety

Document Number: _____

Memorandum of Understanding
On Workspace Safety

The following is an agreement made between Code _____(Owner of the _____Building/Room) and Code(s)/Project_____(Occupier(s) of the space) to establish responsibilities. The Occupier(s) is responsible for overseeing the safety of all operations and equipment within that space. (Note: This does not include facilities such as the Vibration Chamber, but areas and times when the occupier works independent of the owner's personnel.) The Occupier(s) shall identify operations/hazards that will be brought into the space. Any changes require immediate notification of the space Owner. A copy of this signed agreement shall be maintained in the Owner's files. This area is subject to periodic unannounced inspections by the Owner, the AETD Safety Manager, or other AETD Management representative. Failure to comply with AETD Safety requirements (found in 500-PG-8715.1.2, AETD Safety Manual) may cause a shut down of operations until a mitigation plan is in effect.

Please answer yes or no to the following statements. The status column is to be used for approval, references, or certification dates. Shaded boxes indicate areas where resolution may be necessary. An answer in the shaded boxes requires an explanation of how safety issues will be resolved. For risk mitigation explain what engineering controls, procedures, training, signage, etc. are used.

1. Mechanical Handling	Yes	No	Status
Are crane, forklift or personnel lift operations required?			

Risk mitigation: _____

_____

_____

_____

_____

2. Ordnance

	Yes	No	Status
Does the system, subsystem, or equipment have or will it have ordnance (electro-explosive devices, pyrotechnics, etc.) installed?			
a. Will ordnance be installed or fired? Indicate the DOT class of ordnance.			

Risk mitigation: _____

Note: Prior to ordnance arrival on the Center, GSFC Safety and Environmental Division must be notified as to the class and quantity of all ordnance. Ordnance must not be stored in AETD facilities without prior approval of GSFC Safety and Environmental Division.

3. Pressure & Vacuum Systems

	Yes	No	Status
Are there systems/components, which are or will be pressurized (flight/ground)?			

Risk mitigation: _____

4. Stored Energy Devices

	Yes	No	Status
a. Are there batteries?			
b. Do systems have stored energy (springs, booms, etc.)?			
c. Are there non-solid state gyros?			
d. Will there be solar array or other deployments?			
e. Will reaction wheels be operated?			
f. Are there kinetic or rotational systems?			

Risk mitigation: _____

5. Hazardous Materials & Hazardous Waste	Yes	No	Status
Are there hazardous materials (fluids or solids that may harm individuals or the environment) used on/in the system/subsystem/equipment?			
a. Are any of the following hazardous materials used? Check each applicable box:			
Flammable/Combustible			
Toxic			
Corrosive			
Reactive			
Cryogenic			
Explosive			
Oxidizer			
Health hazards			
Pyrophorics			
b. Will personnel be entering confined spaces, which contain purges or other types of hazardous materials?			
c. Are there systems that could present temperature extremes (hot or cold hazards)?			
d. Are there materials, which may pose outgassing or air contamination hazards to personnel, facilities, or other projects?			

Attach copies of Material Safety Data Sheets for all hazardous materials.
Risk mitigation: _____

_____

_____

6. Non-Ionizing Radiation Systems (Electromagnetic energy emitting systems: RF, lasers, ultraviolet radiation, microwaves, high intensity light, etc.)	Yes	No	Status
Do you have non-ionizing radiation sources?			
a. Will RF systems radiate into free space?			
b. Will non-dummy-load-terminated emitting sources in excess of 100-mw be activated outside of a shielded enclosure?			
c. Are there Class IIIB or IV lasers?			
d. Are there other sources of non-ionizing radiation?			

Copies of GSFC Form 23-6RF, Form 23-28RF and 23-35RF must be approved by GSFC Radiation Protection Office (Code 250 x8482) prior to activation. Copies of the approved forms must be attached to this Evaluation Form.
Class IIIB or IV laser operators require an eye examination, GSFC Forms 23-35LU, 23-28L and 23-6L, and an operating procedure approved by GSFC Radiation Protection Office, Code 250.
Risk mitigation: _____

7. Ionizing Radiation Sources
(NRC licensed sources, x-ray producing machines, particle accelerators, accelerator produced radioisotopes, or radium and its daughter products)

	Yes	No	Status
Are there ionizing radiation sources?			

Copies of GSFC form 23-6I, 23-28I, 23-35IP, 23-6ID, and 23-28ID must be approved by GSFC Radiation Protection Office, Code 250 prior to arrival on GSFC.
Risk mitigation: _____

8. Electrical Systems & Equipment

	Yes	No	Status
Are there electrical systems, subsystems, or equipment?			
	If no, proceed to #9.		
a. Is the equipment commercial?			
b. Is the equipment non-commercial or has the commercial equipment been modified?			
c. Is the equipment grounded?			
d. Does the equipment have exposed, live electrical components, which may be accidentally contacted by personnel?			
e. Does the equipment have adequate fuses or breakers?			
f. Are connectors keyed to prevent improper connection?			

Risk mitigation: _____

9. Noise

	Yes	No	Status
Do systems, subsystems, or equipment create noise above 80 dBA?			

Risk mitigation:_____

_____

_____

10. Other Hazards

		Yes	No	Status
a.	Are there any other systems/equipment that might pose a hazard to personnel or facilities?			
b.	Are there potentially hazardous systems that are not addressed by this questionnaire?			

Risk mitigation:_____

_____

_____

This agreement is in effect from _____to _____.

I certify the following information is correct to the best of my knowledge. Operations/equipment shall as a minimum meet the requirements of 500-PG-8715.1.2, AETD Safety Manual. I understand that failure to do so or to notify the Owner of changes in operations/equipment that could create additional risk may cause a shut down of my operations until correct and approved by the Owner and the AETD Safety Manager.

_____

Project Manager/Branch Head of the space occupant

_____

Project Manager/Branch Head of the space occupant

_____

Project Manager/Branch Head of the Space Occupant

Concurrence:

_____

Owner of the Space

_____

Lab Manager

_____

Owner's Supervisor

Appendix D Cryogens

Table of Contents

Tables

D.1 Introduction

Work with cryogens (liquids with boiling points below -150°C [-238°F]) and cryogen systems require established controls to be in place because of the hazards involved. This document describes the hazards and provides work controls, including training requirements, for operations involving the use of cryogens.

D.2 Hazards of Cryogens

All persons working with cryogens must be familiar with the properties of cryogens and must observe safe handling practices. Following are some of the hazards associated with cryogens:

- Burns to the skin can result from direct contact with a cryogen, uninsulated piping, or equipment containing a cryogen.
- Permanent damage can occur if liquid cryogen gets into the eye.
- The properties of some materials change drastically at very cold temperatures: ductile materials can become brittle, material shrinkage can exceed anticipated values, and leaks can develop that are undetectable even under pressure.
- Liquid cryogens warmed above critical temperatures will generate high pressures. This can cause a confining vessel to rupture or even explode. For example, small containers such as stoppered test tubes have overpressured and produced flying fragments. Fully containing a cryogenic fluid as a liquid at room temperature is usually not feasible-e.g., the pressure required to maintain liquid nitrogen at room temperature is 296 MPa (43,000 psi).
- Cryogens can create oxygen deficiency because they have large liquid-to-gas expansion ratios (generally >700). A small liquid spill produces a large volume of gas that can displace the air in a confined space, thus creating a serious oxygen deficiency that can suffocate occupants of the area.
- Helium and hydrogen can solidify atmospheric air. If air is not excluded from systems containing these cryogens, vents or exhaust ports to the atmosphere--relied upon for pressure relief--may become plugged by solidified air and lead to system overpressure and vessel failure. Also, if air condenses between the exterior metal surface of the system and the insulating layer, when it warms and vaporizes it can rip off the insulation with explosive force.
- Some cryogens are chemically very reactive (e.g., O_2); others are flammable (e.g., H_2 and CH_4).
- Cryogenic fluids with a boiling point below that of liquid oxygen may condense oxygen from the air if exposed to the atmosphere. Because oxygen does not evaporate as rapidly as liquid nitrogen, it will accumulate and may cause violent reactions with incompatible materials in the system.

Table D-1 provides the physical properties of some cryogens used at GSFC.

D.3 Prework Planning

The responsible user should evaluate all intended use of cryogens. Factors such as those listed below shall be considered during this evaluation.

- The quantity and intended use of a cryogen.
- The location of dewars and piping.
- Operating and nearby staff who may be affected by cryogen work.
- Potential hazards from oxygen deficiency, skin contact, pressure, and flammability.

System designers must understand the hazards of cryogenic materials and analyze the consequences of spills and system leaks. The analysis may require modification to the original work plan for reasons such as the following:

- System relocation or implementation of additional access controls due to the presence of nearby confined space.

Table D-1. Physical properties of some cryogens.

Properties	Cryogen							
	Ar	He	H_2	Ne	N_2	O_2	CH_4	CO_2
Boiling point (1 atm)								
°C	-186	-269	-253	-246	-196	-183	-161	-78
°F	-303	-452	-423	-411	-321	-297	-256	-108
Critical temperature								
°C	-122	-268		-229	-147	-118	-82	31
°F	-188	-450		-379	-232	-181	-116	88
Critical pressure								
MPa	4.89	0.23	1.30	2.65	3.39	5.08	4.64	7.37
(psig)	(710)	(34)	(188)	(385)	(492)	(736)	(673)	(1070)
Liquid density, g/l	1402	125	71	1206	808	1410	425	1560
Gas density (27°C), g/l	1.63	0.16	0.082	0.82	2.25	1.4	0.72	2.0
Liquid-to-gas expansion ratio	860	780	865	1470	710	875	650	790
Flammable	No	No	Yes	No	No	No [a]	Yes	No

[a] Although oxygen does not burn, it will support combustion. Oxygen-enriched atmospheres may lead to violent reactions, such as rapid combustion or explosions, with incompatible materials.

- Special monitoring provisions (e.g., for oxygen deficiency) may be necessary for continuous operation of a system during off hours.
- Training of workers assigned to operate the system to assure they know the emergency shut-off procedures.

D.4 Engineered Controls

Because of their inherent dangers, cryogenic-fluid systems shall be designed, installed, and used in a manner that takes into consideration each of the hazards detailed in Section D.2. Only personnel fully aware of the properties of cryogen should handle cryogenic fluids and equipment.

D.4.1 Design of Cryogenic Systems

Cold temperatures can cause the properties of some materials to change drastically. Thus, the suitability of materials must be carefully investigated before using them for cryogenic work.

Heat flux into cryogen is unavoidable. Therefore, pressure relief shall be provided to permit routing of off-gasing vapors. Such relief is best provided by spring-loaded relief devices specifically designed for venting excessive pressure or an open passage to the atmosphere. Frangible disks are recommended as additional relief devices when the capacity of the operational relief device is not adequate to take care of unusual or accidental conditions. This is especially true when insulation of the system is dependent upon maintaining a vacuum in any part of the system, including permanently sealed dewars. In any case, a relief device shall be capable of handling the maximum volume of gas that could be produced under the most adverse condition.

Each and every portion of the cryogenic system shall have uninterrupted pressure relief. Any part of the system that can be valved off from the remainder shall have a separate pressure relief device. Parts that usually require a separate pressure relief device include

- Pressurized supply dewars.
- Tubing and hoses used to transfer cryogen, unless an air gap is provided.
- Bath space surrounding experimental volume.
- Experimental volume, even if cryogen is in contact only with the exterior.
- Vacuum spaces in contact with cryogen.

Pressure relief devices shall be used in the last two cases because cracks may develop at cryogenic temperatures, thus allowing cryogen or air to leak into sealed spaces. If these cracks close on warming, the vaporizing fluid could expand and shatter the vessel.

Adequate ventilation shall be provided where toxic or flammable cryogens are used. Systems shall be designed so that the discharge from pressure relief devices and purge lines does not create a hazardous concentration. Section D.4.2 provides detailed information on preventing oxygen-deficient atmospheres.

Each part of a cryogen system must be engineered for pressure in accordance with the requirements specified in Appendix B. Pressure relief devices shall not be set higher than the maximum allowable working pressure, with the safety factor at the temperature of minimum strength.

Sufficient access shall be allowed so that work (e.g., routine filling, periodic inspection, and maintenance) can be performed safely on cryogen systems and equipment. Access to cryogen fill locations shall be free of obstacles.

D.4.2 Preventing Oxygen Deficiency

A small liquid spill produces a large volume of gas and displaces the air in a confined space, thus creating a serious oxygen deficiency that can suffocate occupants of the area. Calculations shall therefore be made to determine whether a given situation of cryogen storage or use will pose an oxygen-deficiency hazard in a worst-case credible accident. Where cryogen use requires remote piping, special care shall be taken to examine the piping to determine whether or not tunnels, pits, or trenches can develop an oxygen deficiency from a broken line, and appropriate safety procedures shall be implemented.

If the area of cryogen storage or use is small and/or poorly ventilated, it may require the installation of an oxygen sensor. Proper use of ventilation can minimize potential oxygen deficiency. If the system has routine bleed-off relief devices, they should be vented to the outdoors.

If dry ice (solidified CO_2) or a dewar containing cryogen fluids must be transported via an elevator, it shall not be accompanied by personnel. These materials shall be transported alone, and measures shall be taken to assure that passengers do not board the vehicle on intervening floors. In a typical elevator car with poor air mixing, as little as 1lb of dry ice can create a CO_2 concentration of 3% (30,000 ppm) and double the breathing rate. A concentration of 0.5% (5000 ppm) will stimulate more rapid breathing.

D.4.3 Preventing System Overpressure

Certain cryogens (e.g., helium and hydrogen) are cold enough to solidify atmospheric air. Thus, air shall be prevented from entering into cryostats.

Vents or exhaust ports to the atmosphere may become plugged by solidified air. This could lead to overpressure and vessel failure, if the ports are relied upon for pressure relief. In case of maximum possible heat flux into the system, adequate pressure-relief devices shall be provided to vent all gas produced.

Cryogen fluids that are not handled in a vacuum-jacketed vessel and piping will cause air to condense on the exterior of the system. This can result in frostbite from touching the cold surface, dripping liquid air, and exploding insulation when air condenses between the metal surface and the insulating layer. When air warms, it vaporizes and can rip off insulation with explosive force.

D.4.4 Oxygen Enrichment

Cryogenic fluids with a boiling point below that of liquid oxygen may condense oxygen from the air if exposed to the atmosphere. Because oxygen does not evaporate as rapidly as liquid nitrogen, when cryogenic fluids are replenished to make up for evaporation, oxygen will accumulate and may cause violent reactions with incompatible materials in the system.

D.4.5 Inspection and Certification of Cryogenic Storage Systems

To ensure safe operations, high reliability, and satisfaction of code requirements, RECERT will inspect and certify all bulk stationary cryogenic systems, including liquefied nitrogen, argon, and oxygen storage systems periodically on a schedule established by the RECERT Manager. Inspections will cover the liquid storage cylinder, vessels, dewars, and supporting vacuum system as well as all piping, piping support, valves, gages, relief devices, regulators, dewars, and evaporators associated with the cryogen system.

RECERT will report any deficiencies resulting from these inspections to the program or facility owner of the system, who then shall ensure that the necessary repairs or corrections are made or that the system is taken out of service.

System owners and operators shall conduct frequent work area inspections to ensure that no hazardous condition is overlooked and that a safe environment is maintained.

D.5 Administrative Controls

D.5.1 Safety Documents

If cryogenic fluids are to be used in pressurized vessels or piping systems not in compliance with the requirements of the American Society of Mechanical Engineers (ASME) or the Department of Transportation (DOT). A safety variance shall be prepared, approved, and documented in accordance with NASA Safety Manual, NPR 8715.3, Section 1.19 prior to system certification.

An Emergency Plan is recommended to guide personnel actions in the event the equipment malfunctions or a mishap occurs while working with cryogens. The plan shall include shutdown, alarms/notification, and evacuation procedures for likely incidents.

D.5.2 Labeling

Many cryogens are chemically reactive; some are flammable. Thus, storage dewars, process vessels, piping, and other associated hardware containing such materials shall be labeled with the common name of the contents and direction of flow.

D.5.3 Training

Only personnel who are fully aware of the properties of cryogenic fluids shall handle cryogens and associated equipment. A formal training program, including hands-on training with experienced workers and operators, should be considered for large cryogen systems.

D. 6 Personal Protective Equipment

The Job Hazard Analysis performed for each cryogen operation shall determine the appropriate type of personal protective equipment (PPE) necessary. Following are minimum PPE requirements for cryogen operations where personnel contact is possible:

- Eye, hand, and body protection shall be worn to prevent contact with liquid cryogens.
- At minimum, safety glasses with side shields are required any time cryogenic liquids, exposed to the atmosphere, are present. Goggles provide the best protection for the eyes.
- Full face shields shall be used in the following situations:
    - When a cryogen is poured.
    - For open transfers.
    - If fluid in an open container is likely to bubble.

Table D-2 provides guidelines for selecting additional PPE.

D.7 Emergency Procedures

D.7.1 Frostbite

The most likely cause of frostbite to the hands and body is contact with cold metal surfaces. Frostbite is almost instantaneous when the skin is moist. Call 911 for immediate treatment or report promptly to the Health Unit for medical attention.

Table D-2. Guidelines for selection of personal protective equipment.

Hands	Loose, non-asbestos insulating gloves that can be tossed off readily. Special gloves made for cryogenic work. Leather gloves without gauntlets that can be tossed off readily. Tongs or other tools to lift objects out of the liquid or liquid baths.
Feet	Closed-toe shoes that cover the top of the foot. Boots (extend trousers over the boot).
Body	Long-sleeved clothing made of nonabsorbent material. Cuffless trousers worn outside boots or over high-top shoes. Leather or other non-asbestos apron when handling large quantities of cryogens. Full protective suits where exposure to drenching is possible.
Respiratory organs	Supplied air where drenching is possible and where oxygen deficiency or asphyxiation may occur. (These types of exposures should be prevented through the implementation of engineered controls.)
Ears	Ear plugs or ear muffs where excessive noise levels may occur near filling and venting operations.

If an emergency occurs and definitive medical care is not readily available (e.g., offsite), the following emergency measures are recommended:

- Call 911 for assistance.
- Remove any clothing that may restrict circulation to the frozen area. Do not rub frozen parts, as tissue damage may result.
- As soon as practical, immerse the affected part in warm water (not less than 105^{o} F or mare than 115^{o} F, or 40 C to 46 C). Never use dry heat. The victim should be kept in a warm room, if possible.
- Frozen tissues are painless and appear waxy and yellow. They will become swollen, painful, and prone to infection when thawed. Do not rewarm rapidly. Thawing may require 15 to 60 minutes. For light skinned people, thawing should continue until the pale blue tint of the skin turns pink or red. For darker skinned people, assess frostbite by the swelling and blistering of the skin. Reduction of swelling indicates alleviation of frostbite.
- If the frozen part of the body thaws before the doctor arrives, cover the area with dry, sterile dressings and a large, bulky protective covering.
- Calm the victim and avoid aggravating the injury. People with frostbitten feet should not walk on them.

- As with any injury or illness, monitor vital signs.
- If the eyes are affected, flush them with warm water for at least 15 minutes.
- Seek medical attention in all instances.
- Alcoholic beverages and smoking decrease blood flow to the frozen tissues and should be prohibited. Warm drink and food may be administered.

D.7.2 Cryogen Spill and Oxygen Deficiency

Personnel shall immediately evacuate an area if

- An alarm signals an oxygen deficiency or other emergency condition.
- They believe a cryogen spill has caused significant oxygen depletion.
- They feel light-headed or nauseous following a cryogen spill.
- A spill of any highly toxic or flammable cryogen occurs.

Personnel re-entering the area shall wear self-contained breathing apparatus (SCBA) or air-line equipment with a self-contained escape unit until the oxygen content of the atmosphere is at least 19.5% and no toxic or flammable mixture is present.

D.8 Responsibilities

Specific responsibilities are listed below.

D.8.1 Supervisors

Supervisors are responsible for assuring that employees are trained and familiar with the properties and hazards common to all cryogens in use.

Supervisors shall ensure that personnel handling cryogens and those working nearby who may be affected by a spill or emergency are trained in safe operating techniques; emergency procedures; and the use of protective equipment, including respiratory protective devices.

Supervisors shall ensure that appropriate signage is posted to provide warning pertaining to the hazards of cryogens in use, to all potentially affected personnel.

D.8.2 Employees

- Know the properties of cryogens.
- Observe safe handling practices.
- Take appropriate training and work with an experienced person if you are not familiar with cryogen use to gain the knowledge and experience necessary.

D.8.3 Cryogenic System Owners

- Maintain systems, and make repairs when necessary. Notify RECERT for appropriate follow up actions.
- Notify RECERT when cryogen systems are installed, modified, or removed from service.

D.8.4 GSFC RECERT

RECERT will perform periodic tests and inspections of cryogenic PV/S for certification in accordance with GPR 8710.3 requirements, and report deficiencies to Owners for corrective actions.

D.9 References

8 CCR § 450- 560, *Unfired Pressure Vessel Safety Orders* (propane tanks, Air Receivers)

29 CFR 1910.101, *Compressed gases general requirements*

29 CFR 1910.103, *Hydrogen*

29 CFR 1910.110, *Storage and Handling of Liquefied Petroleum Gases*

29 CFR 1910, Subpart I, *Personal Protective Equipment*

29 CFR 1910, Subpart J, *General Environmental Controls* (1910.141 to 1910.147 App A)

29 CFR 1910, Subpart M, *Compressed Gas and Air Equipment*, (1910.166 to 1910.169)

29 CFR 1910, Subpart Q, *Welding, Cutting, and Brazing*, (1910.251 to 1910.255)

ACGIH TLVs and BEIs: *Threshold Limit Values for Chemical Substances and Physical Agents*, (excluding Biological Exposure Indices, TLVs for Physical Agents, and Biologically Derived Airborne Contaminants)

ASME Boiler and Pressure Vessel Codes, Section VIII, Div. 1 and 2, *Rules for Construction of Pressure Vessels.*

ANSI/ B 31.1, *Power Piping, ASME Code for Pressure Piping*, 1995. (B48)

Compressed Gas Association CGA P-1-1991, *Safe Handling of Compressed Gases in Containers*.

Compressed Gas Association CGA P-12-1993, *Safe Handling of Cryogenic Liquids*.

Compressed Gas Association CGA S-1.2-1995, *Pressure Relief Device Standards*, Part 2, "Cargo and Portable Tanks for Compressed Gases."

Compressed Gas Association Pamphlet S-1.3-1995, *Pressure Relief Device Standards*, Part 3, "Compressed Gas Storage Containers."

NFPA 45, *Fire Protection for Laboratories Using Chemicals.*

NFPA 51B, *Welding, Cutting, and Other Hot Work.*

UCRL-AR-128970, *LLNL Pressure Safety Standard.*

CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
Baseline	02/23/2006	Initial Release