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Goddard Space Flight Center (GSFC)

Wallops Flight Facility Range Safety Manual (RSM)

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Concurred By:

Original Signed By:
Range Safety Chief Engineer
Wallops Flight Facility

Original Signed By:
Chief of Safety Office
Wallops Flight Facility

Approved By:

Original Signed By:
Steve Scott
Chief Engineer
Goddard Space Flight Center

Original Signed By Juan Roman For:
Felicia Jones
Director of Applied Engineering and Technology
Goddard Space Flight Center

Original Signed By:
Dave Mitchell
Director of Flight Projects
Goddard Space Flight Center

Original Signed By:
Dave Pierce
Director of Wallops Flight Facility
Goddard Space Flight Center

Original Signed By:
Eric Isaac
Director of Safety and Mission Assurance
Goddard Space Flight Center

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FOREWORD

This standard is published by the Goddard Space Flight Center (GSFC) Wallops Flight Facility (WFF) to serve as the Range Safety Manual (RSM) for GSFC WFF range flight operations. It provides uniform engineering and technical requirements for ground and flight hardware processes, procedures, practices, and methods that have been endorsed as standard for NASA range flight operations, including requirements for selection, application, and design criteria of an item.

This standard establishes the Range Safety Program for protecting the public, workforce, and property for GSFC WFF. It implements NASA Procedural Requirements (NPR) 8715.5, *Range Flight Safety Program*, NASA-STD-8719.25, *Range Flight Safety Requirements*, and sections of NPR 8715.3, *NASA General Safety Program Requirements* that address range safety concerns. It also contains safety policy and requirements that are specific to GSFC's WFF and is designed to address unique safety concerns associated with WFF range operations and programs/operations conducted under the cognizance of WFF at other launch/landing sites.

This standard serves as a companion to 800-PG-8715.5.1, *Range Safety Process for Programs and Projects* which identifies roles and activities that are key to safe and successful range operations.

Requests for information, corrections, or additions to this standard should be submitted via "Contact Us" on the GSFC Technical Standards website at **http://standards.gsfc.nasa.gov**.

Josef A. Wonsever
Technical Standard Coordinator
Goddard Space Flight Center

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1. SCOPE

1.1 Purpose

The purpose of this standard is to identify WFF range requirements to implement safety policies and criteria defined in NPR 8715.5, *Range Flight Safety Program*, NASA-STD-8719.25 *Range Flight Safety Requirements*, and sections of NPR 8715.3, *NASA General Safety Program Requirements* applicable to range safety. The standard defines the technical design requirements, restrictions, operations procedures, and other support requirements. It identifies data requirements and general schedule requirements for WFF to perform appropriate safety analysis per 800-PG-8715.5.1, *Range Safety Process for Programs and Projects*.

Safety participation early in the planning stages of a program will reduce the possibility of costly engineering changes.

1.2 Applicability

This standard is applicable to all programmatic operations and specific aircraft operations conducted at or managed by WFF. It applies to all NASA personnel, NASA contractors, tenants, experimenters, and range users. NASA WFF Partner Organizations (e.g., commercial partners, other Federal agencies, international parties, and tenants) performing Non-NASA range operations at WFF may invoke Goddard Procedural Requirements (GPR) 8700.11 *Safety Program for Non-NASA Operations on Wallops Flight Facility (WFF)*. In this case, the range user will work with the WFF Safety Office to determine applicable RSM requirements.

Section 4.0 contains range safety requirements that apply to hazardous systems (i.e. vehicles, payloads, instruments, experiments and associated ground support equipment (GSE)) incorporated within or attached to manned aircraft platforms, Unmanned Aircraft System (UAS) operations conducted on NASA property or in support of NASA missions, and any specific aspect of an aircraft operation that exposes the public, workforce, or property to risk greater than that incurred by normal piloted aircraft operations. Aircraft operations also must comply with requirements in NPR 7900.3, *Aircraft Operations Management* and the associated projects must work with the NASA WFF Aircraft Office (Code 830) to ensure compliance.

For WFF managed operations conducted at other ranges, the requirements established by this document apply as a minimum unless requirements of the host range are more stringent, in which case the more stringent requirements apply. Should the host range waive or accept a variance to a shared requirement, NASA is responsible for ensuring the NASA requirements are still upheld or follow the process defined in 800-PG-8715.5.1, *Range Safety Process for Programs and Projects* for waivers.

More stringent safety requirements will be considered by WFF if requested by the range users, principle investigators (PIs), or tenants.

NASA payloads involved in uninhabited orbital and uninhabited deep space missions that fly onboard Expendable Launch Vehicles (ELVs) (including aircraft assisted ELVs) under the cognizance of the WFF are subject to NPR 8715.7, *ELV Payload Safety Program*, NASA-STD-

8719.24, *NASA ELV Payload Safety Requirements*, and the applicable requirements of this document.

2. APPLICABLE DOCUMENTS

The documents listed in this section contain provisions that constitute requirements of this standard as cited in the text of Section 4. The latest issuances of the cited documents shall be used unless otherwise approved by the Range Safety Chief Engineer, who is vested with Range Safety Technical Authority (TA).

2.1 Government Documents

a. 14 CFR 173.185, Lithium Cells and Batteries
b. 14 CFR Part 101, Moored Balloons, Kites, Unmanned Rockets and Unmanned Free Balloons
c. 14 CFR Part 417, Launch Safety
d. 29 CFR 1910.134, Respiratory Protection
e. 29 CFR 1910.1200, Hazard Communication Standard (HCS)
f. NPD 8710.5, Policy for Pressure Vessels and Pressurized Systems
g. NPR 1800.1, NASA Occupational Health Program Procedures
h. NPR 7150.2, NASA Software Engineering Requirements
i. NPR 7900.3, Aircraft Operations Management
j. NPR8621.1, NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping
k. NPR 8715.3, NASA General Safety Program Requirements
l. NPR 8715.5, Range Flight Safety Program
m. NPR 8715.7, Expendable Launch Vehicle (ELV) Payload Safety Program
n. NASA-SPEC-5022, NASA Manufacturing and Test Requirements for Normally Closed Pyrovalves for Hazardous Flight Systems Applications.
o. NASA-STD-5005, Standard for the Design and Fabrication of Ground Support Equipment
p. NASA STD-8709.22,
q. NASA-STD-8719.9, Lifting Standard
r. NASA-STD-8719.12, Safety Standard for Explosives, Propellants, and Pyrotechnics
s. NASA-STD-8719.13, NASA Software Safety Standard
t. NASA-STD-8719.17, NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems PVS)
u. NASA-STD-8719.24, NASA ELV Payload Safety Requirements
v. NASA-STD-8719.25, Range Flight Safety Requirements
w. NASA-STD-8739.8, NASA Software Assurance Standard
x. NASA-STD-8739.12, Metrology & Calibration
y. NASA-STD-4010, NASA Standard for Lightning Launch Commit Criteria for Space Flight
z. GPR 1700.8, GSFC Hazard Communication Program
aa. GPR 1860.1, Ionizing Radiation Protection
bb. GPR 1860.2, Laser Radiation Protection
cc. GPR 1860.3, Radio Frequency Radiation Protection
dd. GPR 1860.4, Ultraviolet (UV) and High Intensity Light (HIL) Radiation Protection
ee. GPR 8621.4, GSFC Mishap Preparedness and Contingency Plan
ff. GPR 8700.11, Safety Program for Non-NASA Operations on Wallops Flight Facility (WFF)

gg. GPR 8710.3, Certification and Re-certification of Ground Based Pressure Vessels and Pressurized Systems (PVS)
hh. gg. GPR 8710.7, Cryogenic Safety
ii. hh. GPR8719.1, Lifting Devices and Equipment (LDE) Certifications and Operations.
jj. ii. GPR8730.1, Metrology: Control of Measurement and Test Equipment
kk. jj. GSFC-STD-8715.1, Goddard Space and Flight Center (GSFC) Explosive Safety Program
ll. GSFC 23-6R, GSFC Request for Radiation Safety Committee Action Non-Ionizing Radiation Form
mm. GSFC 23-35RF, RF/EMF Source Personnel Approval Form
nn. GSFC23-28UV-HIL, GSFC Request for Non-Ionizing Radiation Safety Committee Action
oo. UV/HIL Radiation Source Questionnaire
pp. GSFC23-6UV-HIL, GSFC Request for Non-Ionizing Radiation Safety Committee Action Ultraviolet/High Intensity Light Radiation Source Approval
qq. GSFC23-28L, Laser Radiation Source Questionnaire
rr. GSFC23-6L, Laser Radiation Source Use Approval
ss. GSFC23-35LU, Laser Radiation Source Personnel Approval Form
tt. 360-PG-8710.0.2, High Pressure Systems Operator Certification
uu. 800-PG-1700.1.1, Wallops Flight Facility Personal Protective Equipment Program
vv. 800-PG-7150.4.1, Software Safety and Mission Assurance Process Interface
ww. 800-PG-8710.3.1, Wallops Flight Facility Flex Hose Handling and Installation
xx. 800-PG-8715.0.4, Certification Procedures for Operations Safety Specialists at Wallops Flight Facility
yy. 800-PG-8715.1.1, Unmanned Roadblocks for Hazardous Operations
zz. 800-PG-8715.5.1, Range Safety Process for Programs and Projects
aaa. 803-PG-8715.1.16, Autonomous Flight Termination System (AFTS) Certification
bbb. 800-WI-8715.2.1, Severe Weather Notification
ccc. 803-WI-7150.4.1, Software Safety and Mission Assurance Process
ddd. 830-AOM-0001 Aircraft Operations Manual
eee. AFSPCMAN 91-710, Air Force Space Command Manual, Range Safety User Requirements Manual

2.2 Non-Government Documents

a. RCC 319, Range Commanders Council Flight Termination Systems Commonality Standard
b. RCC 321, Common Risk Criteria Standards for National Test Ranges
c. RCC 323, Range Safety Criteria for Unmanned Aerial Vehicles
d. RCC 324 Range Safety Performance Standards
e. FDSS-21-0182, Launch COLA Operations
f. EWR 127-1, Range Safety Requirements
g. NFPA 497, Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installation in Chemical Process Areas
h. NFPA 2112, Standard on Flame Resistant Garments for Protection of Industrial Personnel Against Flash Fire
i. ANSI Z136.1, Safe Use of Lasers
j. ANSI Z136.6, Safety Use of Lasers Outdoors

k. ANSI Z540.1, Calibration Laboratories and Measuring and Test Equipment – General Requirements
l. ANSI Z540.3, Requirements for the Calibration of Measuring and Test Equipment
m. ANSI/ISEA 107-199, American National Standard for High-Visibility Apparel
n. ANSI/AIAA S-080, Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components
o. ANSI/AIAA S-081, Space Systems – Composite Overwrapped Pressure Vessels (COPVs)
p. IEEE C95.1, Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields
q. 28 February 2012 AIR FORCE MEMORANUM FOR JFCC Space/J/9, entitled Satellite Protection Guidance for the Laser Clearinghouse (Appendix G)
r. National Fire Protection Association (NFPA) National Electric Code, Article 500 – Hazardous Locations

2.3 Order of Precedence

When this standard is applied as a requirement or imposed by contract on a program or project, the technical requirements of this standard take precedence, in the case of conflict, over the technical requirements cited in the above applicable documents or referenced guidance documents.

3. ACRONYMS AND DEFINITIONS

3.1 Acronyms and Abbreviations

AFSRB	Airworthiness Flight Safety Review Board
AFTS	Autonomous Flight Termination System
AGC	Automatic Gain Control
AIAA	American Institute of Aeronautics and Astronautics
AIS	Automatic Identification System
ANSI	American National Standards Institute
AOM	Aircraft Operations Manual
ASAP	As Soon As Possible
ASME	American Society of Mechanical Engineers
ASO	Aviation Safety Officer
ATC	Aircraft Traffic Control
AWG	American Wire Gauge
BPO	Balloon Program Office
CDI	Capacitive Discharge Ignition
CM	Campaign Manager
CMS	Contingency Management System
COLA	Collision Avoidance
COPV	Composite Overwrapped Pressure Vessel
COTS	Commercial Off the Shelf
CSpOC	Consolidated Space Operations Center
DFO	Distance Focus Overpressure
DoD	Department of Defense
DoP	Dilution of Precision
DoT	Department of Transportation

EBW	Exploding Bridgewire
E_c	Expectation of Casualty
EED	Electro-Explosive Device
EGSE	Electrical Ground Support Equipment
ELS	Equivalent Level of Safety
ELV	Expendable Launch Vehicle
ESD	Electrostatic Discharge
ESO	Explosive Safety Officer
FAA	Federal Aviation Administration
FMEA	Failure Mode and Effects Analysis
FSDP	Flight Safety Data Package
FSP	Flight Safety Plan
FSS	Flight Safety System
FTS	Flight Termination System
FUR	Frequency Utilization Request
GOTS	Government Off the Shelf
GPS	Global Positioning System
GSDP	Ground Safety Data Package
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GSO	Ground Safety Officer
GSP	Ground Safety Plan
HERF	Hazards of Electromagnetic Radiation to Fuel
HERO	Hazards of Electromagnetic Radiation to Ordnance
HIF	High Intensity Light
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
IRT	Interim Response Team
LDE	Lifting Devices and Equipment
LOS	Loss of Signal
LPM	Launch Pad Manager
LPS	Lightning Protection System
LSRB	Laser Safety Review Board
MARS	Mid-Atlantic Regional Spaceport
MAWP	Maximum Allowable Working Pressure
MEOP	Maximum Expected Operating Pressure
MOC	Mission Operations Center
MOD	Mission Operations Document
MOTS	Modified Off the Shelf
MPCP	Mishap Preparedness and Contingency Plan
MRSO	Mission Range Safety Officer
MSDS	Material Safety Data Sheet
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NCSL	National Conference of Standards Laboratories
NFPA	National Fire Protection Association
NOTAMS	Notice to Airmen
NOTMARS	Notice to Mariners
NPR	NASA Procedural Requirements
NPT	National Pipe Thread
NRC	Nuclear Regulatory Commission

NSA	National Security Agency
OSHA	Occupational Safety & Health Administration
OSS	Operations Safety Specialist
P_C	Probability of Casualty
P_i	Probability of Impact
PIC	Pilot in Command
PPE	Personal Protective Equipment
PVS	Pressure Vessel System
RCC	Range Commanders Council
RF	Radio Frequency
RPO	Radiation Protection Office
RSCE	Range Safety Chief Engineer
RSG	Range Safety Group
RSM	Range Safety Manual
RSP	Range Safety Plan
S/A	Safe Arm
SCAPE	Self-Contained Atmospheric Protective Ensemble
SDS	Safety Data Sheet (also known as MSDS)
SMA	Safety & Mission Assurance
TA	Technical Authority
TD	Test Director
TM	Telemetry
TNT	Trinitro-toluene
UAS	Unmanned Aircraft Systems
UAV	Unmanned Aerial Vehicle
UV	Ultraviolet
VACAPES	Virginia Capes
VDC	Voltage Display Current
WFF	Wallops Flight Facility

3.2 Definitions

a. A-State – The state of a hazardous system that is defined by the high potential for inadvertent actuation or high likelihood of hazard exposure if a hazardous system is inadvertently actuated. Generally, personnel restrictions are implemented as a result of the Ground Safety Analysis Process and in effect when hazardous systems are in an A-State.

b. B-State – The state of a hazardous system that is defined by the a low or decreased potential for inadvertent actuation or has a low likelihood of hazard exposure if inadvertently actuated. Personnel restrictions are generally more relaxed and access within the system's danger area is permitted as long as it is consistent with the operation taking place.

c. Burst Pressure -The pressure at which pressure system components undergoing pressurize-to-burst testing rupture or exhibit an unstable fracture.

d. Burst Factor - This quantity is equal to the Design Burst Pressure divided by the Maximum Allowable Working Pressure (MAWP).

e. Catastrophic Hazard - A hazard, condition or event that could result in a mishap causing fatal injury to personnel and/or loss of vehicle, payload, or ground facility.

f. Category 1 Hazardous System – A hazardous system whose consequence of inadvertent initiation cannot be physically contained. Reducing the likelihood of inadvertent initiation of a Category 1 system does not change the consequence of the associated hazard.

g. Category 2 Hazardous System – A hazardous system whose consequence of inadvertent initiation is physically contained when personnel would be exposed to the hazard. Containment of the hazard mitigates the safety consequence of the hazard effects to a negligible level.

h. Collective Risk - The total combined risk to all individuals exposed to one or more particular hazards during a specified period of time or event (a specific phase of flight). Unless otherwise noted, collective risk for a range flight operation is the mean number of casualties expected (Ec) during an established period or event (e.g., a launch) due to the combination of all hazards associated with the operation.

i. Containment – A range safety technique that precludes hazards from reaching the public, the workforce, or property that requires protection.

j. Contingency Management System - A system designed to manage the vehicle throughout the atmospheric flight envelope that provides a controlled response under the full set of circumstances defined by the risk assessment. The system may be comprised of a set of elements within the vehicle, including but not limited to manual control, autonomous control, and recovery capability. It may be used as a risk mitigation factor in the risk assessment when applicable.

k. Critical Hazard – A hazard, condition or event that may cause severe injury or occupational illness, or major property damage.

l. Critical Operations Personnel - Includes persons not essential to the specific operation (launch, entry, flight) currently being conducted, but who are required to perform safety, security, or other critical tasks at the launch, landing, or flight facility. Critical Operations Personnel are notified of the hazardous operation and either trained in mitigation techniques or accompanied by a properly trained escort. Critical Operations Personnel do not include individuals in training for any job or individuals performing routine activities such as administrative, maintenance, or janitorial. Critical Operations Personnel may occupy safety clearance zones and hazardous areas and need not be evacuated with the public. Critical Operations Personnel are included in the same risk category as Mission Essential Personnel.

m. Danger Area - An area defined by ground and/or flight safety analysis (including impact areas, abort areas, storage areas, or hazard areas) where normal operations or a system malfunction will create impacting objects, debris, blast, toxic release, or other hazards and where access must be restricted or otherwise controlled in order to satisfy established risk criteria.

n. Design Burst Pressure - The pressure is a calculated test pressure that pressurized components shall withstand without rupture to demonstrate its design adequacy in a qualification test. It is equal to the product of the MAWP and a Burst Factor.

o. Electro-Explosive Device - An electric initiator or other component in which electrical energy is used to cause initiation of explosives contained therein.

p. Equivalent Level of Safety (ELS) (determination) - The approval of an alternative approach to satisfying a range safety requirement where the alternative provides an approximately equal level of safety as determined by qualitative or quantitative means

q. Expectation of Casualty (Ec) - The average number of casualties expected per event, such as vehicle flight, if a large number of events could be carried out under identical circumstances. This is also referred to as collective risk.

r. Flight Hardware - Any hardware that is flown on or is a part of an aircraft, experimental flight vehicle, satellite, lighter than air vehicle, unmanned aerial vehicle, or space transportation system.

s. Flight Safety - A philosophy and methodology whereby rocket, balloon, drone, Unmanned Aircraft Systems (UAS) and aircraft flight operations can be performed in a reasonable and prudent manner without undue risk to people or property or embarrassment to NASA or the United States Government.

t. Flight Safety System (FSS) - A system (including any subsystem) whose performance is factored into the Range Safety Analysis and relied upon during flight to mitigate hazards. These systems include range safety displays, range clearance capability, radar, optic tracking systems, telemetry, tracking display systems (including instantaneous impact predictors), contingency management systems, flight termination systems, and command and control capability for flight termination systems.

u. Ground Safety - Those safety considerations, procedures, and resultant restrictions associated with hazardous systems during storage, handling, prelaunch, launch, and recovery/abort operations, where by operations can be performed in a reasonable and prudent manner without undue risk to people or property or the environment.

v. Hazard - A state or condition that could lead to an undesirable consequence (i.e. casualty or property damage).

w. Impact Area - The operational area within which one or more objects are predicted to impact in the vicinity of each other.

x. Individual Risk - The probability of an individual from a certain group (or subgroup) at a specific location suffering a casualty from exposure to hazards from a given event during a specific period (e.g., a launch). Individual risk is typically stated as a Probability of Casualty (P_c).

y. Inhibit – an independent and verifiable mechanical or electrical device that prevents a hazardous event from occurring: device has direct control and is not the monitor of such a device. An inhibit is a physical interruption or barrier between an energy source and the action or function that would take place if the energy source is released. Examples would be a relay or transistor between a battery and a pyrotechnic initiator, or a latch valve between a pressurized propellant tank and a thruster. Note: An inhibit control is a device or function that operates an inhibit. Controls do not satisfy the inhibit or failure tolerance requirements for hazardous functions.

z. Instantaneous Impact Point - The point at which an object would impact if thrusting were stopped at a given time.

aa. Launch Vehicle - Any rocket, rocket system, or balloon that is used to launch a suborbital or orbital payload, probe, satellite, or other experiment.

bb. Marginal Hazard - A hazard, condition or event that may cause minor injury or minor occupational illness to personnel.

cc. Maximum Allowable Working Pressure (MAWP) - The maximum pressure at which a component or system can continuously operate based on allowable stress values and functional capabilities. This maximum pressure value is most often cited in requirements and standards that address ground based pressure systems, such as the ASME Boiler and Pressure Vessel Code and the NASA Standard on Ground Based Pressure Vessels.

dd. Maximum Expected Operating Pressure (MEOP) – This term is used in requirements and standards that address aerospace pressure vessels, such as AIAA/ANSI S-080, AIAA/ANSI S-081, or Mil-Std-1522. It is the highest pressure that a pressure vessel, pressurized structure, or pressure component is expected to experience during its service life and retain its functionality, in association with its applicable operating environments; synonymous with maximum operating pressure. or maximum design pressure includes the effect of temperature, pressure transients and oscillations, vehicle quai-steady, and dynamic accelerations and relief valve operating variability. .

ee. Mission Essential Personnel - Those individuals whose activities contribute directly to the performance of a potentially hazardous operation which is actually under way, and whose presence is mandatory for completion of the operation.

ff. Notice to Airmen (NOTAMS) - An advisory issued to airmen listing restricted or hazardous airspace during certain times.

gg. Notice to Mariners (NOTMARS) - An advisory issued to mariners listing restricted or hazardous areas during certain times.

hh. Operating Pressure - The pressure a system shall be subjected to during static and dynamic conditions (maximum temperature, maximum relief pressures, maximum regulator pressure, and, where applicable, transient pressure excursions).

ii. ii. Power Switching - The changing of the power state of any power system manually, remotely or automatically. Examples include On/Off, Off/On, External/Internal, Internal/External, Battery Charging, etc.

jj. Proof Pressure - The test pressure applied to pressure systems or individual components without failure, leakage, or permanent deformation. This pressure is obtained by multiplying MEOP or MAWP by a factor (usually 1.5 based on ASME standards, but can be as low as 1.25 based on AFSPMAN 91-710).

kk. Public - For the purposes of range safety risk management, all people who are not Mission Essential Personnel or Critical Operations Personnel. Public includes visitors and personnel inside and outside NASA-controlled property who are not Critical Operations Personnel and who may be on land, on waterborne vessels, or in aircraft.

ll. Radio Frequency (RF) avoidance - No radiation from any transmitters capable of producing a potential hazard to any ordnance operation that involves exposing the ordnance side of the initiating circuit within ±20 degrees (azimuth and elevation) of the ordnance site.

mm. Range Safety - Application of safety policies, principles, and techniques to protect the public, workforce, and property from hazards associated with range operations.

nn. Range Safety System - A system used to mitigate risk to the public

oo. Self-Contained Atmospheric Protective Ensemble (SCAPE) - This is a category of full body and respiratory protection suits with supplied air that is used primarily on hypergolic fuels and oxidizers, such as hydrazine and nitrogen tetroxide.

pp. System Initiator - Any device that initiates the action of a system. This includes but is not limited to Electro-Explosive Devices (EEDs), non-explosive initiators, and exploding bridge wire initiators.

qq. Tailoring - The process where the authorities responsible for range safety requirements and a range user review each requirement and jointly document whether the requirement is applicable to the range user's planned operations and, if it is applicable, document whether the range user will meet the requirement as written or achieve an equivalent level of safety through an acceptable alternative. Tailoring includes equivalent level of safety (ELS) determinations. Tailoring does not include the approval of Range Safety Waivers, which are addressed by a separate process.

rr. Trinitro-toluene (TNT) Equivalency - The explosive energy per unit mass of the energetic material in question (propellants in our case) divided by the energy per unit mass of Trinitro-toluene (TNT); this number can be expressed as a percentage or a fraction.

ss. Unmanned Aircraft Systems (UAS) - A UAS includes an Unmanned Aerial Vehicle (UAV) or similar vehicle and all the associated support equipment, control station, data links, telemetry, communications and navigation equipment necessary to operate the vehicle.

tt. Unmanned Aerial Vehicle (UAV) - A vehicle that is controlled remotely or autonomously and operates at speeds ranging from subsonic to hypersonic in a manner consistent with a 'conventional' aircraft. A UAV may be launched from the ground or dropped from other aerial vehicles, subscale flight test vehicles, or lifting bodies. A UAV may also be referred to using a different name such as Unmanned Air Vehicles, Uninhabited Aerial Vehicles, Remotely Piloted Vehicles, drones and cruise missiles.

uu. Waiver – A variance that authorizes departure from a specific safety requirement where a certain level of risk has been documented and accepted.

4. REQUIREMENTS

Requirements are defined by shall statements and indicate the responsible organization. In most cases, the range user or vehicle program are responsible for meeting the requirement. The term 'range user' is typically associated with the flight vehicle provider conducting an operation at a launch range where the WFF Safety Office holds operational responsibility. The term 'program' refers to NASA programs and projects conducted under the cognizance of WFF at locations and at other launch ranges (i.e. Balloon Program Office (BPO)). These terms can be used interchangeably in most cases, but should be tailored specifically to the range user or program via the Range Safety Tailoring process.

Some requirements are accompanied by a text box. The information in the text box identifies alternatives in meeting the intent of the requirement and may be used by the range user or vehicle in the Range Safety tailoring. The text box may also provide additional clarifying information, requirement rationale, or recommended practices. For recommended practices, the range user should work with the WFF Safety Office to determine its applicability and enforcement.

4.1 Responsibilities and Range Safety Requirements Tailoring

4.1.1 Range User and Tenant Requirements

4.1.1.1 The range user or program shall obtain WFF Safety Office approval prior to conducting any hazardous operation. See Section 4.2.2, Operations Control and Procedures, for specific requirements.

4.1.1.2 The range user or program shall provide the necessary data to complete the required safety documentation identified in 800-PG-8715.5.1, *Range Safety Process for Programs and Projects*. See Section 4.5, Safety Data Requirements, for specific data requirements.

4.1.1.3 The range user or program shall define any other safety requirements imposed upon that operation and/or program and provide them to the WFF Safety Office. In most cases, the more stringent requirements will apply.

4.1.1.4 The range user or program shall inform the WFF Safety Office of all meetings and/or reviews pertaining to Range Safety or Safety related issues. The range user or program is encouraged to inform the WFF Safety Office of all mission related meetings/reviews to help gain additional familiarization.

4.1.1.5 The range user or program shall participate in real-time data evaluation for mission control and/or flight termination as identified and required by the WFF Safety Office.

4.1.1.6 The range user or program shall participate in failure and anomaly investigations and provide post flight data as required.

4.1.2 Range Safety Requirements Tailoring

The Range Safety requirements specified in this document have been written to cover all types of range operations. WFF recognizes that not all requirements are applicable to each and every operation, and therefore recommends range users participate in the range safety tailoring process. The overall intent is to ensure proper interpretation and implementation of the requirements while providing WFF and range users with the authority and flexibility needed to accomplish mission objectives.

NASA-STD-8719.25, *Range Flight Safety Requirements,* defines tailoring as the process where the authorities responsible for range safety requirements and a range user review each requirement and jointly document whether the requirement is applicable to the range user's planned operation, and if it is applicable, document whether the range user will meet the requirement as written or achieve an equivalent level of safety (ELS) through an acceptable alternative. Examples of tailoring of range safety requirements include deletion of a requirement, change to a requirement, or documenting an approach that differs from the stated requirement. Tailoring includes ELS determinations. If an ELS determination results in no increased risk, the approval of the tailored requirement shall suffice as the necessary ELS documentation (i.e. no additional ELS form is required). Tailoring does not include the approval of Range Safety Waivers. The process for ELS determinations as well as Range Safety Waivers is documented in 800-PG-8715.5.1 *Range Safety Process for Programs and Projects*.

4.1.2.1 The range user or vehicle program shall work with the WFF Safety Office to identify and assess compliance with the requirements in this RSM and any other applicable range safety requirements.

An example of other applicable range safety requirements is the Range Commander's Council (RCC) 319, *Flight Termination Systems Commonality Standard.*

4.1.2.2 If the range user/program has government approved tailoring of range safety requirements from another range or range safety standard, the range user shall perform a gap analysis and document any differences between those and this RSM. That gap analysis shall serve as the set of formal WFF tailored requirements for that specific program or range operation.

WFF is an active participant in the RCC's Range Safety Group (RSG), a national range safety community, in order to ensure commonality in conducting range operations. It is necessary for the tailoring process to be consistent with the approach used at other the national ranges. WFF will participate in joint tailoring with other ranges and the Federal Aviation Administration (FAA) where applicable to help facilitate vehicle programs that operate at multiple ranges. WFF will ensure tailoring is consistent throughout NASA, FAA, and the Department of Defense (DoD).

4.1.2.3 The range user shall compile all requirements, including any tailored requirements (working directly with the WFF Safety Office) into a program or operation specific document.

Range Users/Programs should not attempt to self-tailor or interpret range safety requirements without direct assistance from the WFF Safety Office. Attempting to self-tailor may result in misinterpretation of the applicability of requirements and may lead to unnecessary schedule and cost impacts associated with late corrections.

4.1.2.4 The range user shall ensure that the document containing the tailored range safety requirements identifies any change to a requirement (including any addition or deletion) and includes sufficient rationale for the tailored change.

4.1.2.5 The signatories of each tailored requirements document shall include, but are not limited to, the range user/vehicle program manager (or designee) and the WFF Range Safety Chief Engineer (RSCE) (or designee).

The RSCE approves range safety tailoring and serves as the Range Safety Technical Authority (TA) and GSFCs Range Safety Manager. For additional description of the role of the RSCE, see 800-PG-8715.5.1, *Range Safety Process for Programs and Projects*.

4.1.2.6 The range user shall submit proposed changes to approved tailored requirements as a change request to the WFF Safety Office. The WFF Safety Office will determine if the change requires an ELS or Waiver, and in that case will implement the Relief of Range Safety Requirements Process as defined in 800-PG-8715.5.1, *Range Safety Process for Programs and Projects* and document the change accordingly. Changes that do not require an ELS or Waiver shall be documented as a change page or equivalent document and approved by the original tailored requirements signatories.

4.1.2.7 If the WFF Safety Office or other range safety authority determines that proposed tailoring of a requirement results in increased safety risk, the vehicle program shall prepare and submit a waiver request following the process defined in 800-PG-8715.5.1, *Range Safety Process for Programs and Projects*. (The waiver request format and instructions are maintained by the WFF Safety Office and are available on the WFF Safety Office web site and upon request.)

4.1.2.8 In the event that an authority does not concur on any tailored requirement and the issue cannot be resolved with the RSCE (or designee) or any other cognizant Safety and Mission Assurance (SMA) Technical Authority (TA) for Range Safety, the range user/program shall brief their position to the next higher level SMA TA and so on until resolved.

4.2. Ground Safety Requirements

The overall goal of the ground safety technical requirements is to ensure personnel and property involved in conducting range operations for or at GSFC's WFF are protected by mitigating hazards and managing associated residual risk. It is a goal that all systems be designed such that it will take a minimum of two independent unlikely failures to occur in order for personnel to be exposed to a hazard.

This RSM addresses those hazards that represent heighted concern that are often not routine throughout industry but are common at a launch range. Unique hazards not addressed by this document are addressed on a case-by-case basis and related mitigations and controls are documented by WFF Safety in a Ground Safety Plan(s) (GSP), Data Package (GSDP) or Range Safety Plan (RSP). The process for developing these documents is in 800-PG-8715.5.1 *Range Safety Process for Programs and Projects.*

4.2.1 Hazardous System Requirements

4.2.1.1 Hazardous System Categorization

Hazard categories, as defined in this RSM, establish a level of risk associated with the effects of inadvertent initiation/actuation of a hazardous system or other potential hazard scenario. It is then used to determine the applicable requirements for system design and personnel exposure limits. The following terms are used in the determination of a system's category:

a. Hazard - A state or condition that could lead to an undesirable consequence (i.e. casualty or property damage). [NASA-STD-8709.22, Safety and Mission Assurance Acronyms, Abbreviations, and Definitions]

- Catastrophic hazard - a hazard, condition or event that could result in a mishap causing fatal injury to personnel and/or loss of vehicle, payload, or ground facility.

- Critical hazard - a hazard, condition or event that may cause severe injury or occupational illness, or major property damage.

- Marginal hazard - a hazard, condition or event that may cause minor injury or minor occupational illness to personnel.

b. Hazardous system - A system that, by the expenditure of its own energy or because it initiates a chain of events, may result in a catastrophic, critical, or marginal hazard.

c. Hazardous System Categories
Hazardous system categories are used to determine the system's design requirements for personnel safety. Once a system's category is determined, it does not change throughout the various stages of processing. For example, removing inhibits or safeties in the initiating circuit of the hazardous system does not change the consequence (severity) of hazard exposure.

- Category 1 – A hazardous system whose consequence of inadvertent initiation cannot be physically contained, regardless of hazardous system state. Reducing the likelihood of inadvertent initiation of a Category 1 system (i.e. inhibits) does not change the consequence of the associated hazard.

- Category 2 – A hazardous system whose consequence of inadvertent initiation is physically contained when personnel would be exposed to the hazard. Containment of the hazard mitigates the safety consequence of the hazard effects to a negligible level.

d. Hazardous System States
The system's hazardous state defines the likelihood of hazard exposure, and is used to determine personnel restrictions while working on or within the system's hazard area.

- A-State – The hazardous system has increased potential for inadvertent actuation or has a high likelihood of hazard exposure if inadvertently actuated. Generally, personnel restrictions (i.e. clearance) are implemented as a result of the Ground Safety Analysis Process and in effect when hazardous systems are in an A-State.

- B-State – The hazardous system has decreased potential for inadvertent actuation or has a low likelihood of hazard exposure if inadvertently actuated. Personnel restrictions are generally more relaxed and access within the system's danger area is permitted as long as it is consistent with the operation taking place.

The removal of inhibits, restraints or other safeties during processing may change the hazardous system from B-State to A-State, and increases the likelihood of inadvertent initiation.

The hazardous system category is paired with the system state and thereby referred to as Category 1A, 1B, 2A, or 2B. The following chart summarizes hazardous system Categories and provides a list of examples.

Table 1: Categorization of Hazardous Systems and Associated States

	Category 1 Systems (ALWAYS Cat 1)	Category 2 System (ALWAYS Cat 2)
Definition	Sufficient energy exists to result in injury, death, or destruction of property and cannot be physically contained. Ex: Rocket Motor, FTS Ordnance, hazardous chemical release systems, etc.	• Sufficient energy exists to result in injury, death, or destruction of property AND can be physically contained when personnel are within the hazard area. Ex: Guillotine pyros for De-spin or Boom Release System, Stage Separation System with a mechanical restraint (i.e.V-Band Safety)
Design Requirements	Rigorous design that mitigates the risk of inadvertent actuation. See 4.2.1.3, Category 1 Hazardous Circuit Design Requirements. Ex: Capacitive Discharge Ignition (CDI) System, electromechanical Safe/ARM devices, two fault tolerate designs, etc.	• Simpler design with min of 2 independent inhibits • Conversion from B-State to A-State must happen as late as possible • Containment devices and/or mechanical restraints approved by WFF Safety Office • See 4.2.1.4, Category 2 Hazardous Circuit Design Requirements. Ex: Payload Pyro Circuit
A-State	Category 1A – Elevated risk of hazard exposure Ex: Arm plugs installed, Safe/Arm in ARM position	Category 2A – Elevated Risk of hazard exposure when not contained Ex: Stage Separation System w/o V-Band Safety Installed
B- State	Category 1B – Low risk of hazard exposure Ex: safe plugs installed, Safe/Arm in SAFE position, or initiators are not electrically connected	Category 2B –Negligible risk of hazard exposure Ex Stage Separation System w/ V-Band Safety Installed. *Note, if the system cannot cause injury or death, it's always 2B. Ex. Guillotine pyros in De-Spin or Boom Release systems.

4.2.1.1.1 All hazardous systems, including electrical, chemical, pressure, etc. shall be categorized as Category 1 or Category 2 based on the definitions in this RSM.

4.2.1.1.2 The range user shall work with the WFF Safety Office to categorize all hazardous systems. The WFF Safety Office has final determination on a system's category.

4.2.1.1.3 The containment device or mechanism design used in Category 2 systems shall be approved by the WFF Safety Office. At a minimum, the containment device or mechanism **shall meet all of the following:**

(A) Be successfully demonstrated to contain the hazard effects or shown through analysis if demonstration is not feasible/practical.

(B) Reduce the hazard effects to negligible.

An example of a containment device or mechanism in a Category 2 system is the mechanical restraint that is placed over a Category 2 V-Band system to contain the effects of the V-Band energy after inadvertent initiation. In this case, the V-Band system would be Category 2B with the mechanical restraint installed, and 2A when it is not installed.

4.2.1.1.4 For a hazardous system with the capability to change states, the system design and operational procedures shall ensure the change from B-State to A-State occurs as late as possible in the processing sequence and minimizes personnel exposure to the hazard of inadvertent initiation.

4.2.1.1.5 A hazardous system is in A-state (Category 1A or 2A) until conditions have been met that permit a change to B-state. The following identifies such conditions:

4.2.1.1.5.1 A hazardous system that is installed/integrated in a vehicle is in B-State if it is not connected to its initiating circuit or other source of initiating energy and it is not subject to potential external sources of initiating energy (e.g. an ordnance system, see Paragraph 4.2.1.1.5.2 regarding ordnance systems).

4.2.1.1.5.2 An installed/integrated hazardous ordnance system is in a B-State if it is not connected to its initiating circuit and its Electro-Explosive Devices (EEDs) are shorted, shielded, and grounded. An exception is made for shorting, provided the EED and shielding cap **satisfy all of the following:**

(A) The EED satisfies the 1 amp, 1 watt no-fire safety standard.

(B) Shielding caps are placed on each EED during shipment, storage, handling, and installation up to the point of electrical connection.

(C) The shielding cap has an outer shell made of conductive material that provides an RF shield and makes electrical contact with the EED case.

(D) No RF gaps exist around the full 360-degree mating surface between the shielding cap and the EED case. This shall be verified by inspection.

(E) The installation of the shielding cap is performed by certified ordnance handlers following written procedures approved by the WFF Safety Office.

(F) The written procedures identify any special tools, specifications (e.g. torque setting) and check points designed to ensure the shielding cap is properly installed and will serve its safety function.

4.2.1.1.5.3 EEDs that are not installed is in a B-State when they are shorted, shielded and grounded, or just shielded and grounded if the EEDs and shielding caps meet the caveats listed in Section 4.2.1.1.5.2 above.

EEDs with exposed leads that are not shielded are considered to be in an A-State.

4.2.1.1.5.4 An installed/integrated hazardous ordnance system that is connected to its initiating circuit and employs an approved mechanical or electromechanical SAFE/ARM (S/A) device and the S/A is in the SAFE position is in B-state.

Approved mechanical or electromechanical S/A devices provide physical separation of the ordnance and the initiating power source. Other approaches to placing a hazardous ordnance system into B-State will be considered by the Safety Office during the requirements tailoring process. For example, the use of safeing plugs in the initiating circuit provide a physical separation and meet the intent.

4.2.1.1.5.5 An installed/integrated hazardous ordnance system is in a B-State when connected to its initiating circuit if the circuit utilizes a SAFE/ARM continuity jack or plug, and the SAFE plug is installed. The SAFE/ARM continuity jack or plug **shall meet all of the following:**

(A) Electrically adjacent to the ordnance device.
(B) The wire between the initiator and the SAFE/ARM continuity jack or plug shall be contained inside the vehicle or payload.
(C) The continuity jack or plug shall contain only wires from the ordnance device and the ordnance firing lines.
(D) When the SAFE plug is installed, the ordnance device is electrically isolated from the firing circuit in both the positive and the return lines, each bridge wire is shorted, and the bridge wire is isolated from ground by a static bleed resistor of 10kohms or more.

4.2.1.1.5.6 A hazardous system that has a Two-Fault Tolerant circuit design is in B-State if the requirements identified in Section 4.2.1.3.5 are satisfied and the associated inhibits/safeties are in place.

4.2.1.1.5.7 A Category 2 system is in B state if the approved containment mechanism(s) are installed thus reducing the effects of inadvertent actuation to negligible.

4.2.1.1.5.8 A hazardous chemical system is in B-State when **all of the following conditions are satisfied:**

(A) The system is closed,
(B) The system contains two independent verifiable safeties in the flow path,
(C) The leak integrity is verified.

4.2.1.1.5.9 A hazardous pressure system is in B-State when the pressure is at steady state and less than or equal to the Maximum Allowable Working Pressure (MAWP) or the Maximum Expected Operating Pressure (MEOP), whichever is lower.

4.2.1.2 Operational Design Requirements

When designing hazardous systems, it is important to consider the pre-launch/flight concept of operations to ensure risk to personnel is minimized during ground processing. This section outlines design requirements for hazardous systems, which if implemented, allow range users to comply with the Personnel Restrictions listed in Section 4.2.2, Operations Controls and Procedures, when working around these systems.

Requirements in this section make reference to a hazardous system's danger area. The results from the ground safety analysis (process defined in 800-PG-8715.5.1, *Range Safety Process for Programs and Projects*) provide calculations that define the danger area(s) based on the state of the hazardous system and its hazardous effects. The requirements in this section identify design characteristics that, in conjunction with the danger area, protect personnel from the hazard effects of inadvertent initiation.

> Per 800-PG-8715.5.1, the WFF Safety Office is typically responsible for calculating and determining hazardous system danger areas. Each range user is responsible for providing the necessary data for the determination of these areas.

4.2.1.2.1 The design and operation of a hazardous system shall ensure the danger area is clear of personnel during the 'first power on' regardless of the hazardous state (i.e. Category 1A, 1B, 2A,. 2B). This is applicable to both the system actuating the hazard as well as other systems connected to the vehicle or payload.

> The 'first power on' is defined as the first time power is supplied after installing and connecting a hazardous device (ordnance, chemical, pressure, etc.) to its initiating circuit. This also applies to any sub-system either mechanically or electrically connected to the hazardous system or after the system is electrically or mechanically connected to any other hazardous system. For example, switching on a telemetry transmitter for the first time after integrating with a rocket motor requires the vehicle's danger area to be clear. This generally requires the ability to remotely power on hazardous systems and/or other systems connected to hazardous systems.

4.2.1.2.2 The design and operation of a hazardous system shall ensure the danger area is clear of personnel during any power switching, vehicle or payload RF transmissions, or when the system is reduced to 1 inhibit. This applies only when the system is in an A-State (Category 1A or 2A) and is applicable to both the system actuating the hazard as well as other systems connected to the vehicle or payload.

> Personnel may be permitted within the danger area if the system is in B-State. Personnel may be permitted inside the danger area to perform work external to a vehicle or other hazardous system that is in an A-State provided the requirements of Paragraph 4.2.2.2.6 are satisfied.

4.2.1.2.3 The design and implementation of Ground Support Equipment (GSE) connected to the launch vehicle, payload, or other hazardous system shall ensure the applicable danger area is clear of personnel prior to switching the GSE ON and/or using the GSE to power other hazardous systems for the first time regardless of system status.

The term 'applicable' danger area refers to the GSE or other connected hazardous system with the greatest hazard distance when it is in an A-State.

4.2.1.2.4 The design of an ordnance system shall allow for voltage checks prior to connecting the system's initiator to its electrical circuit to ensure no voltage is present that could initiate ordnance. In addition, **all of the following must be met:**

(A) The voltage checks shall include checking between each leg of the circuit and from each leg to ground.

(B) If voltage is present, the voltage shall be loaded to ensure the amount of induced current (amps) is less than 10% of the initiator's NO FIRE current prior to mating the initiator.

This check is also known as the 'no voltage' check. The goal is to ensure no voltage is present which mitigates risk of inadvertent initiation, however ensuring less than 10% of the initiator's NO FIRE current is acceptable to meet the intent.

4.2.1.2.5 The design and implementation of a hazardous system **shall allow for the all of the following conditions during arming operations:**

(A) The vehicle and payload are powered off.

(B) GSE is powered off with no automated power switching, unless the GSE can be shown through design and testing to be electrically isolated from the systems being armed.

(C) RF avoidance, which is obtained from specific range transmitters based on Hazards of Electromagnetic Radiation to Ordnance (HERO) and/or Hazards of Electromagnetic Radiation to Fuel (HERF) calculations. Exceptions may be granted for RF avoidance if the system's initiating circuit provides shielding with at least 94% optical coverage.

Arming operations involve changing the state of a hazardous system (i.e. Category 1B to 1A, or Category 2B to 2A) and may require personnel to be located within a system's danger area. Arming operations for EEDs typically involve exposing the bridge wires for the initiating circuit, thus increasing the risk for inadvertent initiation. The requirements in Section 4.2.1.2.5 reduce the likelihood of inadvertent initiation from stray voltage.

4.2.1.2.6 For planned recovery and/or land impact of any vehicle or payload (to include rockets, balloons, and UAS), the design and implementation of associated recovered hazardous systems shall ensure the requirements of Section 4.2.2.9, Nominal Recovery or Planned Land Impacts Procedures are satisfied.

4.2.1.3 Category 1 Hazardous Circuit Design Requirements

Requirements in this section apply to all Category 1 hazardous systems, regardless of the hazardous system state. Since hazards resulting from inadvertent initiation of Category 1 hazardous systems cannot be contained, there is potential personnel exposure during ground processing. In general, safety is achieved for Category 1 systems through the implementation of rigorous design requirements that mitigate the risk of inadvertent initiation.

4.2.1.3.1 Initiating circuits for Category 1 hazardous systems shall be approved by the WFF Safety Office prior to granting approval for use on WFF programs and projects. In general **one of the following shall be met:**

(A) If inadvertent initiation of a Category 1 system may lead to a catastrophic hazard, the system shall be two-fault tolerant. See 4.2.1.3.6.

(B) If inadvertent initiation of a Category 1 system may lead to a critical hazard, the system shall be single fault tolerant.

> Initiating circuits for Category 1 ordnance systems (i.e. rocket motors) may satisfy the two-fault tolerance requirement by implementing a mechanical Safe/ARM device in addition to the two independent electrical inhibits which satisfy Section 4.2.1.3.2. The intent can also be met by implementing a Capacitive Discharge Ignition (CDI) system (See Section 4.2.1.3.5).
>
> When performing work on a Category 1 system, these independent inhibits shall be in place to mitigate hazard exposure to an acceptable level.

4.2.1.3.2 All circuits initiating Category 1 hazardous systems **shall satisfy all of the following circuit design criteria:**

(A) All Category 1 EEDs in the hazardous system shall meet the 1 amp/1 watt NO FIRE requirement and be 100% qualified with a 500 Voltage Display Current (VDC) megohmmeters test for 5 seconds from bridge wire to case confirming a minimum resistance of 2 megohmmeters.

(B) Firing Lines and power sources shall be completely independent and isolated from all other systems; they shall not share common cables, terminals, tie points, or connectors with any other system.

(C) All circuit wiring shall be twisted, shielded and independent of all other systems. When not physically possible to maintain the shielding throughout the entire electrical circuit, at a minimum the wiring shall be twisted and shielded from the system initiator to the point of the first short circuit condition. This requirement is applicable both before and after installation of S/A type connectors. The use of single wire firing lines, with the shield as the return, is prohibited.

(D) Shielding shall provide a minimum of 20 dB safety margin below the minimum rated function current of the system initiator (max NO FIRE current for EEDs) and provide a minimum of 85% optical coverage.

> A solid shield rather than a mesh provides 100% optical coverage. Shielding is typically verified through inspection. A manufacturer's data sheet for the cable may be used to verify the safety margin and coverage requirements.

(E) Shielding shall be continuous and terminated to the shell of connectors and/or components. The shield shall be electrically joined to the shell of the connector/component around the full 360 degrees of the shield. The shell of the connectors/components shall provide attenuation at least equal to that of the shield.

(F) The electrical circuit to which the system EED is connected shall be isolated from vehicle ground by no less than 10K ohms.

(G) The electrical circuit to which the system EED is connected shall provide an electrical short on the bridgewire(s).

> EEDs designed with shielding caps that meet 4.2.1.1.5.2 A-F may not require an electrical short as long as the EED can be shielded and grounded. When the shielding caps are removed, the system is in an A-State, and personnel restrictions may apply.

(H) Any electrical relay or switch, which is electrically adjacent to the system initiator (either in the power or return leg of the electrical circuit), shall not have voltage applied to the switching coil (or the enable/disable circuit for solid state relays/switches) until the programmed initiation event.

4.2.1.3.3 Batteries installed in Category 1 hazardous systems shall remain un-charged until the latest feasible point in the countdown or processing sequence. The design of the electrical system connecting to the battery must allow for remote battery charging. Charged batteries (also known as “hot batteries”) may be installed into a Category 1 hazardous system only **if at least one of the following design approaches is utilized:**

(A) The hazardous system is designed with a remotely controlled mechanical or electromechanical S/A device, the S/A is in the SAFE position, and the device is capable of containing the output of the system or its initiator without propagation of the hazard.

(B) The system design meets all the Capacitive Discharge Ignition (CDI) circuit requirements under Section 4.2.1.3.5.

(C) The system design meets all Two-Fault Tolerant circuit design requirements under Section 4.2.1.3.6.

(D) The system design meets all Exploding Bridge wire (EBW) circuit requirements under Section 4.2.1.3.7.

4.2.1.3.4 Hazardous circuits for Category 1 hazardous systems shall be designed such **that all of the following operations can be accomplished:**

(A) Mechanical installation and electrical connection of the system initiators are performed as late as possible in the assembly process, consistent with other assembly operations.

(B) Prior to connecting an EED to its electrical circuit, it shall be shorted, shielded, and physically grounded. If the shielding caps meet all the caveats listed in Section 4.2.1.1.5.2, only shielding and grounding is required and shorting is optional.

> When physical grounding of the EED is not possible, grounding may be accomplished by connecting the EED to chassis ground and the chassis to a single-point earth ground. Grounding can also be accomplished by ensuring the EED and its electrical circuit are at the same potential.

4.2.1.3.5 A Capacitive Discharge Ignition (CDI) system used in a Category 1 hazardous system **shall satisfy all of the following:**

(A) The charging battery shall be current limited such that it shall not exceed the maximum NO-FIRE current of the system initiator (this is 10% of the minimum rated function current of the EED).

(B) The firing capacitor shall be provided with a low impedance path for discharge (when the circuit is in the SAFE condition) and a means of remotely monitoring capacitor voltage. Whenever personnel are exposed to the system, the firing capacitor shall be discharged through a low impedance path resistor.

(C) There shall be a minimum of two independent open switches between the power source and the system initiator.

> The circuit is in a SAFE condition when the battery is not connected to the capacitor. Low impedance is considered less than or equal to 100 Ohms. For CDI type systems, the power source is the firing capacitor, not the battery that charges the firing capacitor.

4.2.1.3.6 A Two-Fault Tolerant circuit design used in a Category 1 hazardous system **shall satisfy all of the following:**

(A) The system initiator shall be isolated from the power source by a minimum of three independent inhibits. This requirement is applicable both before and after installation of S/A plug type connectors.

(B) The system initiator shall be electrically isolated by switches in both the power and return legs.

(C) The wiring shall be in a separate cable, which is twisted, shielded, double insulated, and independent of all other systems.

(D) Protection by use of physical barriers or by physical location of components shall be employed such that short circuits to other power systems are impossible, even assuming loose or broken wires.

(E) A Failure Mode and Effects Analysis (FMEA) or equivalent shall be performed to ensure a minimum of three independent failures are required for inadvertent initiation to occur. The level of detail in the analysis shall be established by the WFF Safety Office and shall be based on factors such as the type of system, system design, and the level of hazard.

(F) The range user shall implement an independent Quality Assurance Program that will verify compliance with all requirements and certify the 'as built' configuration.

A Two-Fault Tolerant circuit design is typically employed when a Category 1 hazardous system that has the potential to result in a catastrophic hazard (e.g., rocket motor) must be connected to its power supply and operations require personnel to be within the associate danger area. In such cases, the safety of personnel is almost solely dependent on the circuit design and the associated electrical inhibits. For example, the Two-Fault Tolerant requirements applies to the initiation circuits of an ordnance system in an operational scenario that requires personnel to install charged/hot batteries into the system. The Quality Assurance program may be within the range user's organization, as long as there is enough formal independence from the engineering/operational teams.

4.2.1.3.7 An Exploding Bridge Wire (EBW) Circuit design used in a Category 1 hazardous system **shall satisfy all of the following:**

(A) A means of continuously monitoring the firing capacitor voltage shall be provided.
(B) Two separate electrical paths to discharge the firing capacitor shall be provided. This can be provided either through the EBW circuit or through the GSE.
(C) A means of interrupting the capacitor charging circuit must be provided.
(D) A means of interrupting the EBW triggering circuit shall be provided.
(E) A time delay of several seconds between the application of the arming signal and the application of the trigger signal for the EBW to fire shall be provided.

An EBW used as part of a Flight Termination System is subject to the requirements of RCC 319, *Flight Termination Systems Commonality Standard.* The applicable requirements of RCC 319 may be used as guidance for other EBW applications.

4.2.1.4 Category 2 Hazardous Circuit Design Requirements

Hazardous circuit design requirements for Category 2 systems are less rigorous than for Category 1 systems because the primary hazard will be contained during the various stages of processing.

4.2.1.4.1 Initiating circuits and hazard containment mechanisms for Category 2 hazardous systems shall be approved by the WFF Safety Office prior to use on WFF programs and projects.

4.2.1.4.2 All Category 2 hazardous systems shall contain a minimum of two independent verifiable inhibits which prevent inadvertent initiation.

Two independent inhibits do not make a system Category 2. Containment of the hazard resulting from inadvertent initiation must exist through approved mechanisms in order to categorize the system as Category 2.

4.2.1.4.3 The design and implementation of a Category 2 hazardous system shall ensure that personnel within the vicinity of the system are notified prior to making any electrical or other energetic change to the system regardless of whether the hazard containment mechanism is in place.

The intent of notifying personnel of an impending change in the system's status is to protect against personnel being startled by loud noises or otherwise effected in a way that could lead to a mishap even though the primary hazard is contained.

4.2.1.5 Ground Support Equipment (GSE) Requirements

Ground Support Equipment (GSE) is defined as any system used to make measurements on or provide control of hazardous devices, systems, or circuits. These requirements apply to GSE for any vehicle, payload, or other hazardous system and the associated ground operations.

4.2.1.5.1 The design of GSE shall be approved by the WFF Safety Office.

4.2.1.5.2 The range user shall apply a NASA or industry standard for GSE to ensure adequate safeties are in place.

The requirements tailoring process will identify which standard and version apply to a particular program or range operation. The Wallops Safety Office uses NASA-STD-5005, *Standard for the Design and Fabrication of Ground Support Equipment* as a baseline.

4.2.1.5.3 The design and implementation of launch vehicle firing circuits for use at WFF shall ensure a launch can be interrupted/held/aborted from the WFF Range Control Center.

The WFF Range Control Center maintains launch hold/abort buttons which have the capability to interrupt the launch firing circuit via the WFF Range timing system. The Mission Operations Center (MOC) also maintains this capability, but should not be considered in lieu of the Range Control Center's ability to inhibit launch.

4.2.1.5.4 All electrical meters or test equipment used to make electrical measurements of hazardous ordnance systems shall be current limited to the manufacturer's recommendation for that device. This value shall not exceed 50 mA.

Section 4.2.1.5.4 primarily applies to hazardous systems involving ordnance. The requirements tailoring process will determine the applicability of this requirement to other hazardous systems.

4.2.1.5.5 GSE owned by NASA used in, or to obtain measurements of, hazardous systems (electrical meters, pressure gauges, load cells, scales, etc.) shall comply with NASA-STD-8739.12, *Metrology and Calibration*, and GPR 8730.1, *Metrology: Control of Measurement and Test Equipment*. GSE not owned by NASA used in, or to obtain measurements of, hazardous systems shall comply with a standard equivalent to those specified in Section 4.2.1.5.5.2.

4.2.1.5.5.1 Any GSE used beyond its certification period shall be specifically approved by the WFF Safety Office.

4.2.1.5.5.2 Calibrations and/or certifications shall be performed by a calibration laboratory compliant with American National Standards Institute (ANSI)/National Conference of Standards Laboratories (NCSL) Z540.1, ANSI/NCSL Z540.3, or ISO/IEC 17025, or equivalent. The calibration certificate shall be reviewed by the GSFC WFF Metrology Laboratory.

4.2.1.5.6 Each meter or instrument used to measure the resistance of EEDs or other ordnance devices **shall satisfy all of the following:**

(A) Have a record of certification (ex. Sticker) indicating compliance with Sections 4.2.1.5.4 and 4.2.1.5.5.

(B) Undergo an ammeter output check to ensure proper operation immediately prior to connecting to ordnance. Powering off a meter, any alteration to the meter (including replacement of batteries), any change to the meter's configuration, or leaving the meter unattended shall invalidate any prior meter check and the meter's output shall be rechecked prior to connecting to ordnance.

Numerous ordnance devices may be tested one after the other without rechecking the meter's output provided the above requirement is satisfied.

4.2.1.5.7 All lifting devices, fixtures, and equipment and all lifting operations shall conform to the standards and regulations of NASA-STD-8719.9, *Standard for Lifting Devices and Equipment* and GPR-8719.1, *Lifting Devices and Equipment (LDE) Certifications and Operations.*

4.2.1.5.8 The design and implementation of all electrically operated GSE used in connection with a Category 1 hazardous system shall ensure the GSE can be remotely switched ON and OFF from outside the applicable danger area.

Examples include vacuum systems, heaters, and pumps, etc. Vehicle, payload, and GSE design should consider the impact of the above restrictions on operations. Flyaway connectors should be used to permit system operation late in the countdown or launch sequence. For vacuum systems, a remotely operated valve is recommended to maintain vacuum integrity when power is switched OFF.

4.2.1.5.9 GSE shall be switched OFF prior to and shall remain OFF during system arming operations that require personnel within the system's danger area **unless one of the following exceptions applies:**

(A) GSE may remain ON during arming operations for a Category 2B system as long as there is no change from B-State to A-State.

(B) GSE may remain ON during arming of a hazardous vehicle system if the GSE is external to the vehicle, electrically isolated from the hazardous system being armed, and the operation specifically approved by the WFF Safety Office.

> System arming operations typically involve the removal of inhibits and/or safeties that mitigate the risk of inadvertent actuation. The provisions of Section 4.2.1.5.9 are designed to preclude GSE induced electrical power switching or power related anomalies. Removing inhibits of a Category 2 system that do not change the state from B-State to A-State does not have the potential to cause injury since the hazard is always contained. Therefore GSE may remain on during arming of those systems and does not require electrical/mechanical isolation. For other hazardous systems, physical and electrical isolation of the GSE may provide equivalent safety as determined by the WFF Safety Office on a case-by-case basis.

4.2.1.5.10 GSE that automatically switches ON and OFF shall be turned OFF and remain OFF during system arming operations that require personnel within the system's danger area. The exceptions listed under Section 4.2.1.5.9 also apply to this type of GSE.

> An example of this is an air conditioner that cycles power after the system is initially powered up. These systems typically remain off (no automatic switching of power) when power is not supplied to the controlling GSE.

4.2.1.6 Radiation Systems

Radiation control ensures the protection of personnel, facilities, and equipment. For the purposes of this safety manual, a radiation device is defined as a machine that produces radiation electronically. Radiation devices can typically be turned off. Examples of radiation devices include radio-frequency (RF) or microwave emitters, lasers, X-Ray devices, and optical emitters (i.e. ultraviolet, infrared, and high-intensity light). Radiation devices can be ionizing or non-ionizing. A radiation source is defined as a radioactive matter that constantly emits radiation and cannot be turned off. An example of a radioactive source would be a discrete mass of a radioisotope.

This section identifies the requirements for obtaining GSFC and WFF Safety Office approval for each radiation device or source including specific design requirements for safety. Restrictions for use when conducting operations at or under the cognizance of WFF are detailed in Section 4.2.2, Operations Controls and Procedures. This section and Section 4.2.2 are applicable to all ground based and/or airborne emitters.

The WFF Safety Office implements GSFC's Radiation Protection Program. A series of GSFC procedural requirements documents contain the specific requirements that apply to radiation devices or sources used at WFF as well as any program or project operating under the cognizance of WFF. These documents are GPR 1860.1, *Ionizing Radiation Protection*, GPR 1860.2, *Laser Radiation Protection*, GPR 1860.3, *Radio Frequency Radiation Protection*, and GPR 1860.4, *Ultraviolet and High Intensity Light Radiation Protection*. The WFF Safety Office provides coordination with the GSFC Radiation Protection Office (RPO) on behalf of each range user or program.

WFF has also established the Wallops Frequency Utilization Management Working Group. This working group ensures radiation devices used specifically at the WFF Range are reviewed not just for safety, but also to ensure the emitters comply with applicable federal and state regulations and other NASA requirements. Further, this group provides coordination with other sources of RF within the area around WFF.

4.2.1.6.1 The range user in coordination with WFF Safety Office and the WFF Spectrum Manager shall ensure that radiation from any source is controlled in compliance with applicable federal, state, and NASA regulations. The WFF Spectrum Manager is responsible for ensuring compliance with federal, state, and NASA regulations outside the scope of the WFF Safety Office.

4.2.1.6.2 The range user and the WFF Safety Office shall ensure ionizing and non-ionizing radiation devices and/or sources are coordinated with the GSFC Radiation Protection Office (RPO). The WFF Safety Office facilitates this coordination on behalf of the range user.

4.2.1.6.3 All operations involving the use of non-ionizing RF/microwave radiation devices shall comply with the standards and regulations specified in Institute of Electrical and Electronics Engineers (IEEE) C95.1 *Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields* and GPR 1860.3, *Radio Frequency Radiation Protection.*

4.2.1.6.3.1 All operations involving the use of non-ionizing RF/microwave radiation devices shall be approved by the WFF Safety Office through coordination with the RPO. RF/microwave devices used specifically at WFF shall also be approved by the Wallops Frequency Utilization Management Working Group. Approval is granted based on the **submission of the following required documents**:

(A) RF/Microwave Source Questionnaire, GSFC 23-28RF, to the WFF Safety Office. This initiates a hazard evaluation by the WFF Safety Office and the GSFC RPO.

(B) Based on the hazard evaluation, GSFC 23-6RF, GSFC Request for Radiation Safety Committee Action Non-Ionizing Radiation, as well as RF/EMF Source Personnel Approval form GSFC 23-35RF to the WFF Safety Office. Devices which require these additional forms must be approved by the GSFC Non-Ionizing Radiation Safety Committee.

(C) Also based on the hazard evaluation, an RF Safety Plan may be required per GPR 1860.3. The WFF Safety Office will work with the range user to provide the requirements associated with this document, should it apply.

(D) Frequency Utilization Request (FUR) to the WFF Spectrum Manager for devices used specifically at WFF.

Per GPR 1860.3, GSFC forms must be submitted at least two weeks prior to the need date to guarantee processing. Complicated projects, extremely hazardous operations, off-site activities, and other flight activities should be coordinated early in the planning stages to ensure there is no impact to schedule. Approvals are valid for a maximum of 3 years.

4.2.1.6.4 All operations involving the use of Ultraviolet (UV) and High Intensity Light (HIL) radiation devices shall comply with the requirements specified in GPR 1860.4, *Ultraviolet (UV) and High Intensity Light (HIL) Radiation Protection.*

4.2.1.6.4.1 UV and HIL radiation devices shall be approved by the WFF Safety Office through coordination with the GSFC RPO. Approval is granted based on the **submission of the following required documents:**

(A) GSFC23-28UV-HIL, GSFC Request for Non-Ionizing Radiation Safety Committee Action UV/HIL Radiation Source Questionnaire, to the WFF Safety Office. This initiates a hazard evaluation by the WFF Safety Office and the GSFC RPO.

(B) GSFC23-6UV-HIL, GSFC Request for Non-Ionizing Radiation Safety Committee Action Ultraviolet/High Intensity Light Radiation Source Approval to the WFF Safety Office. Devices which require these additional forms must be approved by the GSFC Non-Ionizing Radiation Safety Committee.

Per GPR 1860.4, GSFC forms must be submitted at least two weeks prior to the need date to guarantee processing. Complicated projects, extremely hazardous operations, off-site activities, and other flight activities should be coordinated early in the planning stages to ensure there is no impact to schedule. Approvals are valid for a maximum of 3 years.

4.2.1.6.5 All operations involving the use of lasers shall comply with the standard and regulations of NPR 1800.1, *NASA Occupational Health Program Procedures*, ANSI Z136.1, *Safe Use of Lasers*, ANSI Z136.6, *Safety Use of Lasers Outdoors*, and GPR 1860.2 *Laser Radiation Protection.*

4.2.1.6.5.1 All operations involving the use of lasers shall be approved by the WFF Safety Office through coordination with the GSFC RPO. The Wallops Safety Office facilitates these approvals. Approval is granted based on the **submission of the following required documents:**

(A) GSFC23-28L, Laser Radiation Source Questionnaire, to the WFF Safety Office. This initiates a hazard evaluation.

(B) Submit GSFC23-6L, Laser Radiation Source Use Approval, as well as, GSFC23-35LU, Laser Radiation Source Personnel Approval Form to the WFF Safety Office. Lasers which require these additional forms must be approved by the GSFC Non-Ionizing Radiation Safety Committee.

Per GPR 1860.3, GSFC forms must be submitted at least two weeks prior to the need date to guarantee processing. Complicated projects, extremely hazardous operations, off-site activities, and other flight activities should be coordinated early in the planning stages to ensure there is no impact to schedule. Approvals are valid for a maximum of 3 years. NASA Centers responsible for developing a laser safety plan for use during operations conducted under the cognizance of WFF are responsible for facilitating concurrence from the NASA HQ Laser Safety Review Board.

4.2.1.6.6 All range users with operations that involve lasers with the potential to emit hazardous laser radiation over the horizon, without a backstop, and could interfere with air traffic or orbiting assets and/or pose a hazard to NASA or contractor personnel or the public shall obtain a Letter of Concurrence from NASA HQ's Laser Safety Review Board (LSRB). The WFF Safety Office will facilitate this submission with the GSFC RPO on behalf of the range user.

4.2.1.6.7 All range users with operations that involve use of a laser within the National Airspace System (NAS) shall have a letter of non-objection from the FAA.

NASA GSFC Programs will submit the necessary form and or supporting documentation to the WFF Safety Office, who facilitates this through GSFC and the FAA.

4.2.1.6.8 Range users with operations involving lasers that are fully or partially funded by the DoD where the laser has the potential to strike orbiting satellites shall obtain and implement a 'site window' from the Air Force Space Command's Laser Clearing House in accordance with 28 February 2012 AIR FORCE MEMORANUM FOR JFCC Space/J/9, entitled Satellite Protection Guidance for the Laser Clearinghouse (Appendix G).

The Laser Clearing House is located at Vandenberg Air Force Base and tracks the orbits of satellites. They calculate what is known as a 'site window' or 'shutter time', which are periods where lasers must be switched off to avoid passing satellites.

4.2.1.6.9 Range users shall restrict personnel access to laser illumination to ensure no personnel are present within the ocular and skin hazard areas of a laser unless suitable protection is provided.

4.2.1.6.10 All operations involving the use of Ionizing radiation devices and/or sources shall comply with the requirements specified in GPR 1860.1, *Ionizing Radiation Protection.*

4.2.1.6.10.1 Prior to shipment to WFF, all Ionizing radiation devices and/or sources shall be approved by the WFF Safety Office through coordination with the GSFC RPO and the GSFC Ionizing Radiation Safety Committee. This includes calibration sources, x-ray producing devices as well as test sources. Approval is granted based on the **submission of the following required documents:**

(A) GSFC23-28I, Ionizing Radiation Source Questionnaire, to the WFF Safety Office. This initiates a hazard evaluation by the WFF Safety Office and GSFC RPO.

(B) Submit GSFC23-6I, Ionizing Radiation Source Use Approval, form as well as GSFC23-35I, Ionizing Radiation Source Personnel Approval, form to the WFF Safety Office. Devices which require these additional forms must be approved by the GSFC Ionizing Radiation Safety Committee.

Per GPR 1860.1, GSFC forms must be submitted at least two weeks prior to the operation to guarantee processing. Approvals are valid for a maximum of 3 years.

4.2.1.6.11 The range user shall ensure that all ionizing radiation devices and/or sources are inspected by the WFF Safety Office. This typically occurs upon arrival and prior to shipment to another location unless otherwise agreed to by the WFF Safety Office. The devices and/or source shall also be monitored, depending on the circumstances. The GSFC Ionizing Radiation Safety Committee will determine the monitoring requirements per GPR 1860.1.

4.2.1.6.12 The range user shall remove all ionizing radiation devices and/or sources from the WFF at the end of the operation or program.

4.2.1.6.13 The range user shall provide WFF with detailed operating procedures for the use, handling, and storage of each ionizing radiation device and/or source as required by GPR 1860.1 to minimize exposure to personnel.

4.2.1.6.14 All operations involving the use of radioactive sources shall comply with the standards and regulations of the U.S. Nuclear Regulatory Commission (NRC) and regulations of the host range.

4.2.1.6.15 The range user shall obtain all licenses for radioactive sources and provide these to the WFF Safety Office and the host range. This includes a copy of the users NRC license or state equivalent license.

> The GSFC Radiation Protection Office is responsible for maintaining a broad scope NRC license for operations using radioactive sources that take place on GSFC property or temporary worksites, which includes WFF. NASA GSFC Programs will submit all supporting information regarding radioactive materials to the WFF Safety Office, who coordinates the NRC license with the GSFC Radiation Protection Office.

4.2.1.6.16 Radioactive sources used in a payload shall be approved by NASA Headquarters (HQ) prior to launch. Congressional approval may also be required depending on the quantity and activity level of the material. The WFF Safety Office facilitates this approval with the GSFC RPO on behalf of the range user.

> These approvals require additional processing time and should be a factor when planning the delivery of data associated with radioactive materials to the WFF Safety Office.

4.2.1.7 Chemical Systems

Any chemical (solid, liquid or gas) that presents a physical hazard or a health hazard is considered a hazardous chemical. The term physical hazard refers to chemicals for which scientific evidence exists demonstrating the material is a combustible liquid, compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive), or water-reactive materials. The term health hazard refers to chemicals for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur after exposure. The term health hazard includes chemicals that are carcinogens, toxic, or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents that act on the hematopoietic system, and agents that damage the lungs, skin, eyes, or mucous membranes. Appendices A and B of the 29 Code of Federal Regulations (CFR) 1910.1200

Hazard Communication Standard (HCS) provide further guidance in defining the scope of health hazards and determining whether or not a chemical is to be considered hazardous for GSFC/WFF purposes.

This section identifies the design requirements for hazardous chemical systems and associated hardware as well as requirements associated with the handling, storage, transportation, and spill/clean up response. Operations involving hazardous chemicals are considered hazardous operations and should follow the requirements specified in Section 4.2.2. These requirements apply to the range user, range, or any other entity performing operations dealing with hazardous chemicals on WFF property or in support of programs managed under the cognizance of WFF.

For cryogenic systems the requirements of this section and Section 4.2.1.9 Cryogenic Systems apply.

4.2.1.7.1 The range user or program shall develop procedures addressing use, transportation, storage, cleanup, and spill response of hazardous chemicals. These procedures shall be reviewed and approved by the WFF Safety Office and the WFF Environmental Office.

4.2.1.7.2 The range user or program shall notify the WFF Environmental Office of hazardous chemicals requiring disposal and properly remove hazardous materials from the facility or host site at the end of their operation.

4.2.1.7.3 The range user or program **shall comply with all of the following**:
(A) Maintain a hazardous chemicals/materials inventory.
(B) Provide a copy of the Safety Data Sheets (SDS, previously known as MSDS) to the WFF Safety Office and WFF Fire Department (or local Fire Department for off-site operations) along with the requested storage location.
(C) Ensure a copy of the SDS is available during all operations involving hazardous materials.

4.2.1.7.4 Hazardous chemicals/materials handlers, cognizant WFF Safety Office personnel, the WFF Environmental Office, and Emergency Responders shall be trained in hazardous chemical material capabilities, physical and health hazards, and first aid techniques relevant to the hazardous chemical materials in use.

4.2.1.7.5 To ensure personnel are informed of chemical hazards they may be exposed to at the workplace, the range user or program shall comply with requirements specified in GPR 1700.8, GSFC Hazard Communication Program, for proper labeling on all primary and secondary containers housing hazardous chemicals.

4.2.1.7.6 If the possibility of a hazardous chemical spill exists, the range user or program shall ensure a means to minimize the surface area of the spill is readily available.

Examples of this include diking or contamination pallets.

4.2.1.7.7 All GSE electrical hardware (provided by the range or the range user/program) used in areas where flammable/combustible chemicals may be present in local vapor concentrations greater than 25% of the Lower Explosive Limit shall be rated explosion proof in accordance with the National Fire Protection Association (NFPA) National Electric Code, Article 500 – Hazardous Locations.

> The NFPA 497 Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installation in Chemical Process Areas contains guidance on determining the proper classification of the location.

4.2.1.7.8 Work areas and storage areas containing highly toxic or reactive chemicals (e.g., hydrazine and nitrogen tetroxide) or highly flammable chemicals (e.g., liquid hydrogen) shall be continuously monitored (including alarm system) to the maximum extent possible by approved equipment to detect toxic and/or flammable concentrations as determined by the WFF Safety Office. This requirement does not apply to routine industrial work areas that meet Occupational Safety and Health Administration (OSHA) requirements. In addition, **both of the following apply:**

(A) In cases where continuous monitoring is not possible or feasible in a daily work area, the work area shall be "sniff checked" using approved equipment at the beginning of the work period prior to personnel performing work and periodically (minimum every two hours) while personnel are present.

(B) In cases where continuous monitoring is not possible or feasible in a storage area where personnel are not performing daily operations, the area shall be "sniff checked" prior to entry and periodically (minimum every two hours) while personnel are present.

> After the initial sniff check is performed, dosimeter badges may be used instead of performing periodic sniff checks while personnel are present. See Section 4.2.2.5, Personal Protective Equipment (PPE), for PPE requirements when performing sniff checks in lieu of continuous monitoring.

4.2.1.7.9 Hazardous chemical system hardware shall be designed to prevent hazardous chemicals from spilling or leaking.

4.2.1.7.10 The range user or program shall design hazardous chemical systems that release caustic, toxic, or reactive chemicals resulting in a critical or marginal hazard such that the flow path contains two independent inhibits to prevent inadvertent release. If a release results in a catastrophic hazard, three independent inhibits are required.

> An inhibit that utilizes a pyrotechnic valve may meet the intent of the two independent inhibits as long as the chemical system is not hypergolic, a spill/leak does not present a catastrophic hazard, and it is reviewed and approved by the WFF Safety Office. When designing pyrotechnic valves, NASA-SPEC-5022 is recommended.

4.2.1.7.11 Components of hazardous chemical systems shall feature welded fittings or redundant mechanical seals at all fittings to prevent inadvertent flow or release of caustic, toxic, or reactive chemicals.

4.2.1.7.12 Materials selected for use in hazardous chemical systems shall be compatible with the hazardous chemical used. This includes compatibility under operating pressure, shock, vibration, reactivity, and temperature conditions.

4.2.1.7.13 Bi-propellant systems that incorporate both a fuel and an oxidizer shall be designed such that a malfunction of either the oxidizer or the fuel subsystems cannot result in mixing.

4.2.1.7.14 Monopropellant systems that feature a fuel and a catalytic bed shall incorporate at least two independent inhibits in the flow path to prevent inadvertent contact of the propellant with the catalytic bed.

4.2.1.7.15 If remote status monitoring is required, the range and/or range user shall provide monitoring of hazardous chemical systems, their components, and/or operating personnel. The WFF Safety Office will determine the required level of monitoring, if any.

4.2.1.7.16 Hazardous chemical system GSE hardware (tanks, transfer lines, etc.) shall comply with the applicable safety and design standard for GSE.

> The requirements tailoring process will specify which standard and version apply to a particular program or range operation. Department of Transportation (DoT), American Society of Mechanical Engineers (ASME), NASA-STD-5005, *Standard for the Design and Fabrication of Ground Support Equipment,* and/or NASA-STD-8719.17 *NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems (PVS)* are encouraged.

4.2.1.7.17 Hazardous chemical system flight hardware shall at a minimum comply with ANSI/AIAA S-080 *Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components* or ANSI/AIAA S-081 *Space Systems – Composite Overwrapped Pressure Vessels (COPVs)* requirements as determined by the WFF Safety Office.

> Department of Transportation (DoT), America Society of Engineers (ASME), or AFSPCMAN 91-710 *Air Force Space Command Manual* standards can be used to satisfy this requirement.

4.2.1.8 Pressure Vessels and Pressurized Systems

Any vessel used for the storage or handling of a fluid or gas under positive or negative pressure is considered a pressure vessel. A pressure system is an assembly of components under pressure (e.g. vessels, piping, valves, relief devices, pumps, expansion joints, and gages). The requirements in this section contain design criteria for both flight and ground based pressure vessels and systems. Flight pressure vessel systems are typically not designed with a high factor of safety as compared to ground based systems (e.g. 4:1) and therefore additional restrictions such as pressurizing remotely must be put in place to mitigate the risk of hazard exposure.

Since all pressure vessels and pressure systems are considered hazardous systems, the hazard categorization requirements apply, see Section 4.2.1.1.5. Cryogenic systems also present pressure related hazards, and in which case the requirements of this Section in addition to Section 4.2.1.9 Cryogenic Systems apply.

4.2.1.8.1 All flight and ground based pressure vessels and pressure systems shall meet NPD 8710.5 *Policy for Pressure Vessels and Pressurized Systems.*

4.2.1.8.2 Flight pressure vessels and pressure systems shall be designed in accordance with ANSI/AIAA S-080 *Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components* or ANSI/AIAA S-081 *Space Systems – Composite Overwrapped Pressure Vessels (COPVs)* to the extent specified in NPD 8710.5, or another applicable standard as determined by the WFF Safety Office.

DoT, ASME, or AFSPCMAN 91-710 *Air Force Space Command Manual* standards can be used to satisfy this requirement.

4.2.1.8.3 Flight pressure vessels and pressurized systems shall be pressurized and depressurized remotely during initial pressurization following system assembly or refurbishment, during pressurization above 25% Design Burst Pressure, after the system has been exposed to excessive vibration and/or shock, and after transportation in an unknown environment. **This does not apply if the system meets one of the two caveats:**

(A) The system is designed in accordance with a recognized Department of Transportation (DoT)and American Society of Mechanical Engineers (ASME) standard.

(B) The system's stored energy is less than 19,306 joules (14,240 ft. lbf), its operating pressure is less than 100 psi, and it does not contain hazardous or toxic materials.

Systems designed to meet DoT or ASME standards are rigorously tested, and their safety factors are chosen in order to allow personnel in their vicinity during pressurization. See definitions for description and examples of hazardous and toxic materials.

4.2.1.8.4 Flight pressure vessels and pressurized systems shall be designed such that, prior to recovery, the system is remotely depressurized below 100 psi and its stored energy is less than 14,240 ft. lbf.

4.2.1.8.5 Once flown and recovered, flight pressure vessels and pressure systems shall be re-evaluated by inspection, testing, and/or analysis prior to being re-flown. The method of evaluation shall be documented and approved by the WFF Safety Office for each vessel/system.

4.2.1.8.6 Ground based pressure vessels and pressure systems shall be designed and certified in accordance with NASA-STD-8719.17 *NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems (PV/S)*. Unrestricted access may be granted to ground pressure systems that operate at less than 150 psi and do not contain hazardous or toxic materials. The WFF Safety Office is responsible for certifying the system and its adherence to the standard.

4.2.1.8.7 Ground based pressure vessels and pressure systems shall be certified in accordance with GPR 8710.3, *Certification and Re-certification of Ground Based Pressure Vessels and Pressurized Systems.*

It is recommended that pressure relief devices used in ground based pressure systems be set and certified by tagging at no greater than 10% above MEOP.

4.2.1.8.8 Pressure systems utilizing flex hoses shall comply with 800-PG-8710.3.1, *Wallops Flight Facility Flex Hose Handling and Installation.*

Flex hoses present whipping and lashing hazards in the event of a rupture or fitting failure and should be properly contained. 800-PG-8710.3.1 specifically addresses containment/restraint and safety devices to mitigate this hazard.

4.2.1.9 Cryogenic Systems

A cryogenic system is defined as a hazardous system that contains at least one component that operates at a cryogenic temperature, specifically at or below -150°C. Cryogenic systems have the potential to cause chemical and temperature related hazards such as frostbite as well as over-pressurization hazards. Cryogenic systems that remain unpressurized or maintain pressure readings at low levels (less than 100 psi) may still present a pressurization hazard due to the possibility of expansion from inadvertent heating. Cryogenic systems can also present an oxygen deficiency hazard given there is enough potential to displace the percent of oxygen in a given space. In general, the requirements for chemical systems and pressure systems apply to all cryogenic systems. The Range User is encouraged to exercise the Range Safety Tailoring Process with the WFF Safety Office to identify the applicable requirements to the specific hazardous system.

Requirements for personal protective equipment (PPE) when conducting operations with cryogenic systems are provided in Section 4.2.2.5.

4.2.1.9.1 Hazardous cryogenic systems shall meet the requirements specified in GPR 8710.7, *Cryogenic Safety*.

4.2.1.9.2 All personnel performing work on cryogenic systems and/or working with cryogenic fluids shall be trained in accordance with GPR 8710.7, *Cryogenic Safety*, or equivalent.

4.2.1.9.3 All hazardous cryogenic systems shall meet the requirements of Section 4.2.1.7 Chemical Systems.

4.2.1.9.4 All hazardous cryogenic systems shall meet the requirements of Section 4.2.1.8 Pressure Vessels and Pressurized Systems.

4.2.1.10 Liquid Propulsion Systems

Liquid propulsion systems involve both chemical and pressure related hazards. Depending on the propellant used, these hazards could be catastrophic (leading to permanent injury or death), or critical (leading to a severe injury). Typically, a leak/spill will lead to personnel exposure quickly before a leak/spill response can be performed. Propulsion systems utilizing hypergolic propellants or hydrogen are examples of these types of systems. This section outlines the necessary precautions that must be implemented on both system design and the activities associated with ground processing. The WFF Safety Office determines the applicability of these requirements during the range safety requirements tailoring process.

4.2.1.10.1 A liquid propulsion system's primary flow path (i.e. from the propellant tank through the thrusters) shall contain a minimum of three independent, mechanical inhibits in series to prevent inadvertent flow or leakage. If the mechanical inhibits are electrically controlled, the electrical controls shall be independent of each other.

> A pyrotechnically actuated isolation valve (with a "parent metal" seal and three electrical inhibits) that is located immediately downstream from the liquid propellant tank may be considered equivalent to two mechanical flow control inhibits upon WFF Safety Office approval of the valve design and associated quality control and testing processes. Refer to NASA-SPEC-5022 for guidance.
>
> A parent metal seal is created by machining the valve input and output orifices from a single metal block and leaving some of the "parent metal" between the input and output. The tolerances have to be tightly controlled so the seal doesn't inadvertently crack and leak yet will reliably break open when hit by the pyro-activated ram. Such pyro-valves are typically built one at a time in a process that involves significant hand work and where quality control and testing is critical to each valve's reliability and safety.

4.2.1.10.2 Seals associated with potential leak paths (i.e. through or around wetted fittings to the ambient environment) shall be two-fault tolerant to prevent a catastrophic leak/spill past a wetted fitting. *Note: A certified weld is not considered a credible leak path.*

> To be considered two-fault tolerant, the system or component must have three independent, verifiable inhibits to ensure the system can sustain two failures and still retain capability.

4.2.1.10.3 All connections in a hypergolic flight hardware system shall be made with certified welds in accordance with applicable design codes and standards. Non welded connectors and fittings, such as National Pipe Thread (NPT) and flared tubing (i.e. type AN) are not permitted in hypergolic flight hardware.

> The requirements tailoring process will determine the appropriate design codes and standards for the certification of the welds.

4.2.1.10.4 Prior to a launch, any operation of flow control devices within a loaded liquid propulsion system shall be conducted with spill/leak response capabilities in place.

A fairing access door, when incorporated, makes for easy access to the spacecraft propulsion system fill and drain valve after the integrated launch vehicle and payload have been staged on the launch pad.

4.2.1.10.5 The range user shall incorporate design features to address contingency liquid propellant off-loading operations into the design of the launch vehicle and/or payload in all phases of ground processing.

4.2.1.10.6 Electrical circuits that operate liquid propellant flow control devices shall have three independent inhibits (two-fault tolerant) and comply with Section 4.2.1.3.6. At least two of the three electrical inhibits shall be monitored remotely when conditions preclude spill/leak response.

4.2.1.10.7 Electrical circuits that operate components whose failure may cause the liquid propellant to catastrophically overheat (thus causing either propellant decomposition or propellant tank over pressurization) shall have three independent inhibits (two-fault tolerant).

4.2.1.10.8 A liquid propulsion system shall be single-fault tolerant (either electrically, mechanically, or a combination of both) against pressurizing beyond the system's Maximum Expected Operating Pressure (MEOP).

4.2.1.10.9 For pressurizing beyond the system's design burst pressure, the liquid propulsion system shall be both mechanically and electrically two-fault tolerant (i.e. two mechanical and two electrical inhibits).

For cryogenic systems, if single fault tolerance is not achievable, the pressurizing side can be equipped with a pressure relief device set at 10% above MEOP and set pressure tolerances in accordance with applicable relief device standards.

4.2.1.10.10 The range user shall implement a quality control program to verify that all system fittings and seals are properly installed and have leak integrity. This program **shall ensure all of the following:**

(A) Welds are made by qualified welders.

(B) Lot and batch short term capability testing is performed for elastomeric seals to ensure material compatibility.

(C) The system implements positive means such as periodic leak checking, manufacturer's gauging techniques, and/or other measures to ensure that metal-to-metal seals do not lose leak integrity by improper installation or loosening ("backing-off") during transport or handling.

The optimum design for redundant mechanical seals is to seat one at the fitting face and one at the other radially to seal the fitting.

4.2.1.10.11 During ground processing or any operation that involves personnel working on or around a loaded liquid propulsion system, the system shall be continuously monitored for airborne concentrations of the hazardous chemical (see Section 4.2.1.7.8). During other activities (e.g., captive flight of an air launched vehicle), the system pressure shall be monitored at a minimum.

4.2.1.11 Battery Systems and High Voltage

There are four main hazards associated with batteries: 1) the battery acid that is corrosive and can burn the skin, 2) flammable gasses that are emitted and can easily cause fire or explosion if accumulated in a small area, 3) electrical shock, and if large enough, and 4) battery weight, which presents a lifting hazard. This section identifies the design and operational requirements associated with batteries used in hazardous systems, including any flight hardware or GSE. The requirements in this section are not applicable to batteries used in UL or MSA-approved appliances that include the battery as part of their certification (e.g., cell phone or computer batteries).

Lithium-ion (Li-Ion) batteries present their own unique hazards. See Section 4.2.1.11.4 for additional requirements specific to those systems.

4.2.1.11.1 The design and operation of batteries used in hazardous systems (including associated GSE) shall be approved by the WFF Safety Office.

4.2.1.11.2 All procedures involving the charging and discharging of batteries shall be reviewed by the WFF Safety Office. Depending on the battery, charging operations may be considered a hazardous operation.

4.2.1.11.3 Flight systems with voltage greater than 50 milliamps (AC or DC) shall be evaluated by the WFF Safety Office. If deemed hazardous, the system shall be protected by an enclosure to prevent unauthorized access with metallic enclosures being grounded.

4.2.1.11.4 Lithium Ion (Li-Ion) Battery Systems

4.2.1.11.4.1 Li-Ion battery systems shall be designed with appropriate safeties. Examples include fuses, overpressure relief devices, over temperature cut-off devices, reverse current blocking diodes, and current limiting resisters. The range user is responsible for working with the WFF Safety Office to determine acceptable safeties.

4.2.1.11.4.2 GSE used for Li-Ion battery charging and discharging **shall comply with all of the following:**

(A) Be two fault tolerant against overcharge or hazardous discharge conditions. Individual cells that have internal protections (e.g. positive temperature coefficient devices and internal fuses) may be considered to already have one inhibit as determined in coordination with the WFF Safety Office.

(B) Prevent each cell from exceeding 4.4 volts during charging.

(C) Prevent each cell from discharging to less than manufacturer's specification or other unsafe condition recognized by the WFF Safety Office.

4.2.1.11.4.3 The range user **shall implement individual cell monitoring and recording for charging and discharging through all of the following:**

(A) Cell voltages shall be recorded at least every minute. For charge rates that exceed battery capacity (i.e. if capacity is 1 Amp-Hour and charger is supplying greater than 1 Amp of current) voltages shall be recorded every 10 seconds for charge rates between 1 and 2 times battery capacity and every second for charge rates that exceed 2 times battery capacity.

(B) Charging data shall be reviewed for anomalies and verification of voltage limits.

4.2.1.11.4.4 Electrical GSE (EGSE) used for charging, monitoring, and recording of each cell shall be intrinsically safe per NFPA regulations and must prevent high heat, sparking, and high charge/discharge current rates.

4.2.1.11.4.5 Li-Ion battery discharge shall not take place below -20°C or above 60°C.

4.2.1.11.4.6 The range user shall implement high pressure protection in the design of Li-Ion battery systems. Specifically, **the design shall meet all of the following:**

(A) Battery and cell case design (non-polymer) shall have a 3:1 burst pressure based on vent device and operating pressure with individual cells capable of surviving a short circuit current with a vent opening to release products.

(B) Cell pressure relief devices shall be demonstrated by test to show that the vent operates as intended and that the vent is adequate to prevent cell fragmentation. Recommended test is NAVSEA 9310 High Temperature Test.

(C) Battery case design shall not impede cell vent operation. Battery design shall accommodate all cells within the battery venting at the same time. This shall be demonstrated by test.

The applicability of these requirements to any battery or cell case designs that are not sealed or otherwise do no present a pressure related hazard will be addressed during the requirements tailoring.

4.2.1.11.4.7 Li-Ion battery and cells shall be treated as always having a voltage potential, therefore connection or disconnection of a battery shall be considered a personnel electrical hazard and a 'spark' potential.

4.2.1.11.4.8 Li-Ion batteries/cells shall be evaluated for toxic, reactive, flammable and combustion materials. This evaluation shall include the products if the cell case vents. Fratricide of all cells in a pack will be assumed in this evaluation unless the design incorporates mechanical and thermal barriers between cells.

4.2.1.11.4.9 Support equipment (ground or airborne) used with Li-Ion battery systems shall be verified to operate correctly prior to first operational use at WFF, including fault tolerant devices or subsystems, prior to connecting to the battery. Verification shall include inducing overvoltage, under voltage, and temperature extremes to the monitoring devices as intended when in use prior to connecting of the battery. The range user is responsible for providing this verification to the WFF Safety Office.

4.2.1.11.4.10 Storage of Li-Ion batteries (when not installed in GSE or flight hardware) shall be in approved battery storage locations.

4.2.1.11.4.11 Transportation to and/or from the launch site shall meet DoT requirements. Li-Ion batteries shall not be installed in flight hardware prior to transporting, unless specifically approved by the WFF Safety Office. In addition, the battery system **shall meet all of the following requirements:**

(A) When transported on publically accessed roadways, they shall not exceed 50% of rated charge.

(B) When lithium content exceeds 8.0 grams per battery, transportation packaging of individual batteries shall have caution labels in accordance with 49 CFR 173.185 *Lithium Cells and Batteries*.

4.2.2 Operations Controls and Procedures

A hazardous operation or work activity by definition is any operation that, without implementation of proper mitigations, has a high potential to result in loss of life, serious injury to personnel or public, or damage to property due to the material or equipment involve or the nature of the operation/activity itself. The WFF Safety Office is responsible for determining whether or not an operation is hazardous through the review and approval of hazardous procedures. See 800-PG-8715.5.1, *Range Safety Process for Programs and Projects.*

Operational controls in the form of personnel restrictions and procedures help to minimize the risk associated with a hazardous operation to an acceptable level. Hazardous operations typically involve hazardous systems identified in Section 4.2.1. Controls and protocols must also be established where hazardous systems are located even when hazardous operations are not taking place (i.e. storage). The following sections establish the necessary controls and procedures to mitigate risk associated with hazardous operations, work areas, and storage locations.

Areas where hazardous operations involving ordnance processing or storage are subject to the requirements of NASA-STD-8719.12, *Safety Standard for Explosives, Propellants, and Pyrotechnics* and GSFC-STD-8715.1, *Goddard Space and Flight Center (GSFC) Explosive Safety Program* in addition to the requirements in this section.

4.2.2.1 General Operational Controls

All programs and projects that conduct operations under the cognizance of WFF are expected to comply with the operational safety controls outlined in this section.

4.2.2.1.1 The range user and/or program shall submit all comprehensive handling, assembly, and/or checkout procedures for all hazardous systems for review and approval to the WFF Safety Office. The operation shall not be conducted without approved procedures.

The WFF Safety Office will make a determination if the procedure is hazardous or non-hazardous during the approval process.

4.2.2.1.2 Hazardous operations involving NASA personnel, contractors, or if the hazardous operation has the capability to affect NASA personnel or contractors, shall be observed by a NASA certified Operations Safety Specialist (OSS). Hazardous operations shall not be conducted until approval is granted by the observing OSS.

See 800-PG-8715.5.1 for the roles/responsibilities of the NASA OSS. Range users and programs are permitted to provide their own OSS personnel, provided they are specifically approved by the WFF Safety Office through 800-PG-8715.0.4, *Certification Procedures for Operations Safety Specialists at Wallops Flight Facility*.

4.2.2.1.3 The range user shall submit any change to approved hazardous procedures to the WFF Safety Office as a revision for review and approval. Changes to non-hazardous procedures or changes to nonhazardous sections of a hazardous procedure that change it to hazardous shall be submitted for approval by the WFF Safety Office.

The OSS assigned to a hazardous operation has the authority to approve a change to the associated hazardous procedure in the field (known as a "hand write" or "redline") provided the change does not violate the requirements of this document or any applicable safety requirement. If the change is to be permanent for use in future operations Section 4.2.2.1.3 applies.

4.2.2.1.4 For off-range operations, NASA personnel and/or NASA contractors shall abide by the requirements of this section in addition to any related requirements of the host range or other range safety authority conducting the operation(s) if that range has requirements or limits more stringent than WFF.

Should the host range or other range safety authority choose to grant relief of a common requirement through either a variance or waiver, NASA is still responsible for ensuring the requirements of this RSM are still met. This includes following the ELS and Waiver process defined in 800-PG-8715.5.1, *Range Safety Process for Programs and Projects* for relief.

4.2.2.1.5 For hazardous operations conducted on launch pads at WFF, personnel shall obtain access to the danger area from the Launch Pad Manager (or equivalent) and the Ground Safety Officer (GSO) or OSS, whichever is applicable. For hazardous operations not on launch pads, personnel shall obtain access to the danger area through the OSS.

Access to launch pads and danger areas operated under the cognizance of the Mid Atlantic Regional Spaceport (MARS) require additional approval from the appropriate MARS Launch Pad Manager.

4.2.2.1.6 For hazardous operations conducted at WFF, a warning system shall be implemented for all danger areas and/or associated facilities, which incorporates the use of lights, signs, and/or roadblocks to alert personnel of the potential hazards present and restrict access.

In general an amber light is illuminated on the exterior of the building or near the entryway to indicate potential hazards exist within the area of the building. A red light is illuminated to indicate a hazardous operations is currently taking place. The WFF Safety Office will consider other approaches on a case-by-case basis.

4.2.2.1.7 For hazardous operations conducted at WFF, personnel shall comply with the requirements of 800-PG-8715.1.1, *Unmanned Roadblocks for Hazardous Operations*.

4.2.2.1.8 For hazardous operations conducted at other locations where WFF has operational Range Safety responsibility, the range user and/or program shall work with the WFF Safety Office to identify an appropriate danger area warning system for that location and operation, to include the use of lights, signs, and/or roadblocks.

4.2.2.1.9 All vehicles, including but not limited to personally owned vehicles, government vehicles, and rentals shall be clear of all hazard areas during launch operations unless specifically approved by the WFF Safety Office.

If the physical arrangement or adverse climate conditions at the launch site prevent adequate separation of hazardous operations and vehicle location, alternate approaches to meeting the intent of this requirement can be addressed through the requirements tailoring process.

4.2.2.2 Exposure and Personnel Limits

The cardinal principle during a hazardous operation is to limit the exposure to a minimum number of personnel, to a minimum period of time, and to a minimum number of potential hazards. This goes for any location or operation involving explosives, severe fire hazards, high pressure systems, or other hazardous materials even if a hazardous operation is not being conducted. An example of this would be installing fins on a rocket motor as the motor is still considered a hazardous system. Operations should be arranged such that an incident would cause the least possible injury to personnel and damage to facilities or surrounding property. The requirements in this section identify specific controls and procedures to ensure this principle is upheld.

As a general rule, when a hazardous system is in a B-State, personnel access within the system's danger area is permitted for mission essential personnel performing tasks consistent with mission requirements. As inhibits and/or safeties are removed, the system transitions to an A-State and restrictions for personnel access within the system's danger area are implemented to mitigate the higher risk of inadvertent initiation. The requirements in this section serve as general requirements. Requirements regarding personnel access within a particular system's danger area are specified in the operation's Ground Safety Plan or Data Package.

4.2.2.2.1 Only Mission Essential Personnel shall be permitted in hazardous areas including locations where hazardous material is present (i.e. launch pads, explosive handling areas, etc.).

> This requirement is applicable to all hazardous areas containing hazardous chemicals, rocket motors, hazardous pressure systems, etc. These areas are typically identified in the mission's Ground Safety Plan or Data Package or individual hazardous procedures provided by the Range User. Mission Essential Personnel are defined as any government, contractor, or commercial personnel who are directly involved in the safety and success of a mission or operation. This requirement does not preclude tours, as long as Section 4.2.2.4 is satisfied.

4.2.2.2.1.1 The range user and/or program shall identify all mission essential personnel applicable to each hazardous operation and provide that information to the WFF Safety Office. The Mission Range Safety Officer (MRSO) (or designee) is responsible for approving all mission essential personnel for launch operations in accordance with 800-PG-8715.1.1, *Range Safety Process for Programs and Projects*. In all other cases, the OSS is responsible for approving.

4.2.2.2.2 For hazardous operations, the number of personnel performing hazardous tasks shall be kept to a minimum (no less than 2, including the OSS). The OSS shall verify only mission essential personnel applicable to a hazardous operation are present prior to the start of the operation.

4.2.2.2.3 For non-hazardous operations around hazardous materials, the minimum number of personnel shall be maintained by those individuals involved while upholding the cardinal principle.

4.2.2.2.4 Multiple unrelated operations conducted simultaneously within a single operational hazard area are permitted provided they are specifically approved by the WFF Safety Office. This involves review of planned activities, the associated hazards, and establishment of protocols between the operations teams.

4.2.2.2.5 Personnel shall remain clear of a hazardous system's danger area during power on, power switching, and/or vehicle and payload RF transmissions (including any electrically or mechanically connected system) unless the system is in a B-State (i.e. Category 1B or 2B).

> Section 4.2.1.1.5 identifies the minimum criteria for a hazardous system to be considered Category 1B or 2B. The Ground Safety Plan or Data Package further identifies the specific conditions for each hazardous system.

4.2.2.2.6 Personnel may be permitted within the system's danger area while in an A-State (i.e Category 1A or 2A) to perform work external to the vehicle when power is on, as long as **<u>all of the following conditions are satisfied:</u>**

(A) No power switching is occurring,
(B) Two independent inhibits are verified to be in place,
(C) The operation has been specifically approved by the MRSO for launch operations and the OSS for all other hazardous operations,
(D) Power has been cycled at least 3 times, and
(E) Power has remained ON after cycling in a steady state for at least 5 minutes.
(F) No vehicle or payload RF transmissions.

> This applies only for work performed while power is on and stable. Meeting the caveats listed in this requirement do not meet the intent of Section 4.2.1.2.2.

4.2.2.2.7 During a hazardous operation, the range user shall obtain permission from the GSO (or from the OSS for operations that do not require a GSO) prior to switching ON/OFF any vehicle, or payload system GSE. On a launch pad, depending on the state of the system and hazards present, if an OSS is not required, the range user shall obtain permission from the Launch Pad Manager (LPM) (or equivalent).

4.2.2.2.8 For hazardous flight pressure vessels and pressurized systems, personnel are permitted within the system's danger area when the system pressure is in a steady state and the pressure does not exceed the MEOP.

4.2.2.2.8.1 Whenever a flight system is being pressurized and/or there is potential for the system pressure to exceed MEOP, personnel shall remain outside the danger area or be separated from the system by a barrier designed to protect against blast and fragmentation.

> Flight pressure systems are considered to be in an A-State when the pressure is unstable (pressurizing, depressurizing, etc.), when the pressure exceeds MEOP, or when the potential exists for the pressure to exceed the MEOP.

4.2.2.2.9 Wireless communication devices are not permitted in any system's danger area or at locations where hazards may be present unless specifically approved by the WFF Safety Office.

4.2.2.3 Radio Frequency (RF) Controls

4.2.2.3.1 Ground-based RF emitters used at WFF or by WFF at other locations shall be periodically analyzed by the WFF Safety Office (or equivalent) to determine whether or not they pose a potential hazard to personnel or ordnance. When a potential hazard exists, the responsible organization shall establish operational restrictions and/or controls to protect personnel and/or ordnance systems.

> Common devices includes cell phones, smart phones, etc., many of which contain lithium ion batteries that present a fire hazard and in addition have the potential for distraction during hazardous operations. The WFF Safety Office has specifically approved certain models of hand held radios, which are exempt from this requirement.

4.2.2.3.2 In areas where RF hazards to personnel exist, the responsible organization shall ensure signs and or barricades are erected to prevent personnel from entering the potentially hazardous area.

4.2.2.3.3 High power RF emitters, such as radar systems, shall incorporate red and blue warning lights to warn personnel of the potential RF hazard. A red flashing light indicates that power is applied to the system. A blue flashing light indicates the emitter is radiating.

4.2.2.3.4 The range user or other responsible organization shall coordinate with the WFF Explosive Safety Officer (ESO) to ensure that RF radiation into areas where ordnance operations are conducted is controlled.

> This requirement generally applies to ordnance operations where the ordnance side of the initiating circuit is exposed. RF can be a potential source of stray voltage that, upon exposure of the ordnance side of the circuit, has the potential to cause inadvertent initiation or failure to initiate. Examples of control include RF silence and RF avoidance. The WFF ESO is responsible for ensuring all Hazards from Electromagnetic Radiation to Ordnance (HERO) is mitigated
>
> For Category 1 hazardous systems, control mechanisms for RF may be reduced and/or eliminated at the ESO's discretion if the hazardous system's initiating circuit provides shielding with 94% optical coverage in addition to meeting 4.2.1.3.2 (D).

4.2.2.3.5 The use of RF sources during hazardous operations at WFF is managed by the Test Director's (TD) Office and by equivalent authorities at other locations. Range users shall obtain permission from the responsible authority through the OSS before any RF transmitter is switched on.

4.2.2.3.6 Open air transmission of ARM and DESTRUCT tones at WFF shall be scheduled with the TD's Office to ensure proper notification to the range and all range users and to de-conflict operations as necessary. The range or range user shall request and obtain permission from the WFF TD for each open air transmission.

> Transmitters or receivers utilizing Flight Termination System (FTS) command frequencies fall under the category of Non-Ionizing radiation. Range users implementing a ground based FTS are required to submit a Frequency Utilization Request (FUR) to the WFF Spectrum Manager per Section 4.2.1.6.3.

4.2.2.4 Restrictions for Tour Groups and Official Visitors

This section identifies the requirements regarding tour groups, official visitors or guests, etc. within established hazardous areas.

4.2.2.4.1 The tour/group responsible party shall properly notify the program/project and WFF Safety Office in advance of an impending tour/visit. It is encouraged to provide at least 24-hours-notice so the program/project team can plan accordingly.

4.2.2.4.2 Prior to a tour/visit inside a defined hazard area, the range user/responsible organization shall bring all hazardous operations to a safe stopping place and cease work on all hazardous systems while the tour is in progress.

> All systems should be in a B-State prior to the tour entering the hazardous area. If this is not possible, and the tour/visit is absolutely necessary, the OSS, MRSO, and, if applicable, the LPM will collectively determine the conditions and associated system state(s) for which the tour may be conducted.

4.2.2.4.3 For operations at other locations, the WFF lead manager (Campaign Manager, Project Manager, or Mission Manager) shall work with the local safety official(s), if applicable, and the NASA OSS to plan tours/visits to areas where NASA is conducting hazardous operations.

4.2.2.4.4 For tours/visits conducted at tenant locations (e.g. the Mid-Atlantic Regional Spaceport), the activity shall be coordinated with the responsible organization and their associated safety requirements shall apply.

4.2.2.4.5 The LPM, OSS, MRSO, or other individual specifically approved by the WFF Safety Office shall provide all tour groups with a safety briefing prior to entering the hazardous area.

4.2.2.4.6 All tour groups shall be escorted by the LPM, OSS, MRSO, or other individual specifically approved by the WFF Safety Office. If the group size is too large to be reasonably managed by the escort, the group shall split into two or more groups.

> The LPM, OSS, MRSO, etc. reserve the right to limit the tour group size depending on the hazards present and the ability to ensure everyone's safety.

4.2.2.4.7 The approved escort shall ensure all members of the tour group maintain a safe distance of no less than 3 feet from any ordnance or other hazardous hardware.

4.2.2.4.8 The approved escort shall ensure members of a tour group do not bring any RF emitting device into the hazardous area during the tour/visit. This includes cell phones, pagers, handheld two-way radios, etc.

4.2.2.4.9 The approved escort shall ensure members of a tour group complying with the specific PPE requirements associated with the operation they will be observing (i.e. safety glasses, hard hats, etc).

4.2.2.5 Personal Protective Equipment (PPE)

PPE is required by all WFF personnel, including contractors and tenants, in addition to all range users and programs when exposed to certain hazardous operations. The use of PPE helps to reduce the risk of injury and help protect the health and safety of personnel. Common PPE includes static dissipative outer garments, safety shoes, safety glasses, hard hats, arctic clothing, etc.

The WFF PPE program is established through 800-PG-1700.1.1, *Wallops Flight Facility Personal Protective Equipment Program.* This document establishes a standard practice for the general use of PPE in a variety of disciplines, identifies the training requirements and roles/ responsibilities for PPE, and serves as the basis for the requirements in this section that apply to hazardous operations in support of range safety programs and projects.

4.2.2.5.1 For operations involving ordnance and other hazardous systems susceptible to electrostatic discharge (ESD), all personnel shall wear static-dissipating outer garments (i.e. lab coats or coveralls). Personnel shall not wear articles of clothing, such as reflective safety vests, over static dissipating clothing. This requirement does not apply to hazardous operations conducted in outdoor environments where the humidity is measured and is expected to remain above 60% for the duration of the operation.

> For operations involving hazard class 1.1, 1.2, or 1.3 systems, personnel are strongly encouraged to wear outer garments that are both static-dissipative and flame-resistant per NFPA 2112. An example would be an operation to install flight termination system ordnance on a non-explosive vehicle body.

4.2.2.5.2 For operations involving an EED or exposed grain, all personnel shall wear approved, grounded wrist-straps. Approved leg-straps may be used in place of wrist straps for operations specifically approved by the WFF Safety Office. All straps shall be tested prior to each use.

4.2.2.5.3 For operations where personnel work on multiple levels or where overhead objects may impact the employee (i.e. crane and lifting operations), all personnel shall comply with the requirements identified for head protection in 800-PG-1700.1.1.

4.2.2.5.4 For operations involving chemicals that pose a health hazard, personnel shall comply with the requirements identified for chemical protection clothing in 800-PG-1700.1.1. Personnel shall work with the WFF Safety Office to identify PPE that provides full body and/or respiratory protection during operations that **involve any of the following, but are not limited to:**

(A) Connecting or disconnecting wet lines or contaminated (neither purged or flushed) dry lines.
(B) Chemical sampling operations.
(C) Chemical flow/transfer operations.
(D) Chemical system pressurization (until system integrity has been verified, i.e. no leaks)
(E) Chemical operations where there is only one safety device or inhibit preventing a chemical spill.
(F) Connections or disconnections of ground support equipment (tanker, storage, cart, etc.)
(G) Removal and/or replacement of chemical components in a liquid line, or on purged, isolated liquid, drained, and vent lines.
(H) Opening any chemical system that has not been drained, purged, and flushed with referee fluid where applicable.
(I) Chemical and/or pressure system leak checks.
(J) Chemical spill cleanup operations.
(K) Operations where the condition of the chemical system is unknown.
(L) Sniff checks in areas where hazardous chemicals are transferred and/or stored that do not contain continuous monitoring devices.

4.2.2.5.5 For operations listed in Section 4.2.2.5.4 that involve hypergolic propellants, personnel shall wear Self Contained Atmospheric Protective Ensemble (SCAPE) or Level A protection. The PPE shall provide appropriate skin and respiratory protection per 29 CFR 1910.134, *Respiratory Protection*. Once system integrity has been verified, personnel can request concurrence to downgrade to full protective gear.

PPE may be downgraded to provide splash protection based on the quantity and concentration of hypergolic propellant and the operation involves initial connection to storage containers where the lines have been previously purged and are clean/clear of any residue.

4.2.2.5.6 For the operations listed in Section 4.2.2.5.4 involving non-liquid chemicals, personnel shall wear Level B protection unless specifically approved by the WFF Safety Office.

4.2.2.5.7 For operations where personnel are required to wear SCAPE, Level A, or Level B protection, an acceptable method of communication shall be established and approved by the WFF Safety Office.

4.2.2.5.8 For operations involving cryogens (flammable and non-flammable), personnel shall wear the appropriate PPE for eye protection, hand protection, clothing, and footwear identified in GPR 8710.7, *Cryogenic Safety*.

4.2.2.5.9 For operations involving flammable/reactive cryogens (i.e. liquid oxygen, liquid hydrogen, etc.) personnel shall wear non-static, flame resistant, and liquid resistant coveralls in addition to the PPE identified in Section 4.2.2.5.8.

4.2.2.5.10 For operations where ocular hazards may exist, all personnel shall comply with the requirements identified for eye and face protection in 800-PG-1700.1.1.

4.2.2.5.11 For operations on or adjacent to roads, construction sites, or WFF operationally controlled areas personnel shall wear reflective vests meeting the requirements of ANSI/ISEA 107-199 *American National Standard for High-Visibility Apparel*, Section 1A.11), and be labeled as meeting ANSI/ISEA 107-199 standard for performance for Class 2 risk exposure.

> Aircraft operational parking areas and runways, rocket and balloon launch pads, test areas, or operations performed under a written Hazardous Procedure are WFF operationally controlled areas if those operations performed in support of WFF Programs or Projects, regardless of geographic location. Range user and/or program specific tailoring may address deviations to this requirement.

4.2.2.6 Electrostatic Discharge Protocols

Certain precautions should be taken to limit and/or mitigate the potential hazard associated with electrostatic discharge (ESD) during hazardous operations. ESD has been identified to have the potential to inadvertently initiate certain hazardous systems, primarily EEDs. A primary method in reducing or eliminating static electricity is to provide an electrically continuous path to ground. Operations where ESD may be a concern are areas where the relative humidity is less than 60%. The use of ESD field meters to detect the presence of an electrostatic field and/or anti-static sprays applied prior to the ESD sensitive hazardous operations to help mitigate the risk associated with ESD should be considered for any operation on a system when it is in an A-State. Air ionizers can also be used to neutralize the air around the operation, provided the operation has been coordinated with the safety office and the equipment has been properly maintained and tested prior to use.

The following requirements apply to ESD sensitive hazardous operations:

4.2.2.6.1 All conductive objects (including the personnel in contact with the hazardous system) shall be electrically connected to a common ground.

4.2.2.6.2 Grounding straps shall be used to bridge locations where electrical continuity may be broken by grease, paint, or rust and connected to a certified ordnance ground. Equipment in contact with conductive floors or tabletops are not considered adequately grounded. The grounding straps shall be checked prior to first use for valid resistance value less than 5 ohms and visually inspected for defects.

> It is recommended that wire used in grounding straps be no less than American Wire Gauge (AWG) No. 8 or a braided cable of equal conductivity. However, measuring the grounding strap resistance meets this intent.

4.2.2.6.3 Wire used as a static ground conductor in grounding straps to bridge locations shall be robust enough to withstand mechanical damage.

4.2.2.6.4 Connection of a static ground connector shall be made to certified grounding points.

> In areas where it is not possible to connect to a certified grounding point, the first-touch rule should be implemented. This involves the person touching a non-hazardous, grounded conductive surface such as metal so the ESD that is built up on the person is transferred.

4.2.2.6.5 Grounding point certification shall be performed annually and shall be verified as having had its annual certification before the start of a hazardous procedure requiring grounding.

> A range user or program may rely on a formal grounding point certification process conducted by the local authority responsible for the facility.

4.2.2.6.6 When performing potentially hazardous operations on electrostatic sensitive systems, **personnel shall ensure all of the following:**

(A) Wear the appropriate PPE identified in Section 4.2.2.5 that is applicable to that type of hazardous operation.

(B) Touch the ground system upon entering an ordnance work area. This applies even when wearing PPE.

4.2.2.7 Electrical Storm Protocols

4.2.2.7.1 Hazardous operations conducted at WFF shall follow 800-WI-8715.2.1, *Severe Weather Notification*, which defines the criteria and protocols for electrical storm advisories and warnings. Per NASA-STD-8719.12, Safety Standard for Explosives, Propellants, and Pyrotechnics, minimum clearance distances apply during electrical storm warnings for hazardous operations involving ordnance. This also applies to Section 4.2.2.7.2 below.

> 800-WI-8715.2.1, *Severe Weather Notification* defines conditions where evacuation of work areas is required unless the hazardous operation is conducted at a facility with an annually certified Lightning Protection System (LPS). In this case, operations are to be brought to an appropriate stopping point, personnel need not evacuate.

4.2.2.7.2 Hazardous operations conducted at other locations shall implement the protocols identified for lightning advisories and lightning warnings in 800-WI-8715.2.1 *Severe Weather Notification*, at a minimum. If hazardous operations are conducted at locations where meteorological support is unavailable to issue these notifications, personal shall clear the hazardous work area upon hearing thunder or observing weather conditions that have the potential to produce electrical storms.

4.2.2.8 Hazardous Operations Training and Certification Requirements

Personnel performing hazardous operations should be trained and experienced in the operation they are conducting. This ensures the safety of participants and reduces the likelihood of a hazard. The following requirements identify the training and/or certification requirements for personnel directly performing the operation. These do not apply to all personnel involved in the hazardous operation, only those physically performing the operation unless otherwise stated. WFF allows for certification by equivalency, provided the range user supplies the necessary supporting documentation for the training, experience or certification that is consistent with the requirements specified below.

4.2.2.8.1 Personnel performing hazardous operations involving explosives, propellants, and pyrotechnics, including ordnance handlers, shall be trained and certified in accordance with NASA-STD-8719.12, *Safety Standard for Explosives, Propellants, and Pyrotechnics*, or equivalent. Personnel shall coordinate this through the NASA WFF Explosive Safety Officer (ESO).

4.2.2.8.2 Personnel performing hazardous operations involving chemical systems shall work with the WFF Safety Office to identify the required training and experience specific to those operations.

> Operations that involve the use of chemicals as propellants for spacecraft and/or launch vehicles fall under the NASA-STD-8719.12, *Safety Standard for Explosives, Propellants, and Pyrotechnics*, and training shall be coordinated through the ESO. Personnel performing operations that involve the use of hypergolic propellants or working within the vicinity of a hypergolic system shall meet Section 4.2.2.8.1 in addition to Hypergolic Hazard Awareness Training provided by the WFF Safety Office.

4.2.2.8.3 Personnel performing hazardous operations involving pressure vessels and pressurized systems shall be trained and certified in accordance with 360-PG-8710.0.2, *High Pressure Systems Operator Certification*, or equivalent.

4.2.2.8.4 Personnel performing work on cryogenic systems and/or working with cryogenic fluids shall be trained in accordance with GRP 8710.7, *Cryogenic Safety*, or equivalent.

4.2.2.8.5 Personnel performing lifting operations or operating lifting devices and/or equipment shall be trained and certified in accordance with NASA-STD-8719.9, *Lifting Standard,* and GPR-8719.1, *Lifting Devices and Equipment (LDE) Certifications and Operations*.

4.2.2.9 Nominal Recovery or Planned Land Impacts Procedures

During a planned recovery of any vehicle or payload (to include rockets, balloons, and UAS), the risk of potential hazard exposure should be kept to a minimum. This is achieved by reducing the energy of the hazardous system to their lowest energy states and consuming all hazardous materials. Mitigation of onboard hazards should be factored into the design and operation planning.

4.2.2.9.1 Prior to performing recovery operations, all possible hazards shall be eliminated or reduced to acceptable levels as determined by the WFF Safety Office prior to personnel performing recovery operations.

4.2.2.9.2 The range user shall submit recovery plans, procedures, and associated hazard mitigations to the WFF Safety Office for review and approval during the mission design phase.

4.2.2.9.3 The range user shall ensure all personnel involved in recovery operations are briefed on the potential hazards and required mitigations associated with the operation.

4.2.2.9.4 The status of on-board hazards shall be verified safe prior to allowing personnel to approach the vehicle or payload. Each range user or program is responsible for establishing mitigations for all hazards on a mission by mission basis. At a minimum, **all of the following requirements apply for common hazardous systems:**

(A) Ordnance shall be expended prior to mission completion or if unexpended the ordnance shall be returned to a shorted state as soon as possible following impact of the vehicle or payload. This can be accomplished by the onboard ignition circuits which provide shorts across ordnance except during firing. If the payload or vehicle cannot incorporate an inherent shorting device, shorts may be manually installed by a trained and certified ordnance handler (see Section 4.2.2.8) using an approved hazardous procedure during or post recovery.

(B) Hazardous systems involving chemicals, including cryogens, shall have a means of removing, containing, or releasing all chemical material prior to recovery. In some situations, a wait time may be required in order to recover the vehicle or payload, which will be determined by the WFF Safety Office. If full release cannot be achieved, a means of detecting chemical leaks using approved hazardous procedures and/or other techniques shall be implemented and coordinated with the WFF Safety Office.

(C) Hazardous systems involving pressure vessels and/or pressurized systems that do not involve hazardous chemicals shall have residual pressure less than 100 psi and less than 14,240 ft lbs. stored energy prior to recovery. Depressurization to these levels is strongly recommended to be performed in flight. Otherwise, depressurization early during the recovery operation is required.

(D) Hazardous systems involving mechanical or stored energy hazards shall have a means of restraining the energy prior to recovery. Methods of reducing this hazard include applying approved containment, restraint, and/or safety devices while limiting access to recovery hazard areas.

4.2.2.9.5 For unplanned events (vehicle or payload failures), contingency plans shall be developed and implemented to protect recovery personnel from potential hazards.

4.2.2.9.6 For missions where no recovery is planned, but vehicle and/or payload hardware is potentially accessible to the public, vehicle and/or payload designs and operational plans shall ensure public safety. Mission designs shall ensure all energy sources, hazardous chemicals/cryogens, and other hazards are expended, released, or otherwise mitigated.

4.2.2.10 Emergency Procedures

Emergency procedures for range operations occurring on and off-site are documented in the program/project specific Mishap Preparedness and Contingency Plan (MPCP) generated for each program and/or project. NASA WFF is responsible for the preparation of these documents, with participation from the Range User. They provide the necessary guidance for the implementation of NPR8621.1, *NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping* and GPR 8621.3 *GSFC Mishap Preparedness and Contingency Plan*. The MPCP also provides guidance related to the response, especially in cases where responders may be exposed to hazards in addition to the reporting protocols for mishaps and close-calls. The MPCP's are developed by the cognizant WFF Program or Project Management Office, and submitted to the WFF Safety Office.

4.2.2.10.1 The cognizant WFF Program/Project Management Office shall develop mission/campaign specific MPCP in accordance with GPR 8621.4, *GSFC Mishap Preparedness and Contingency Plan* and submit to the WFF Safety Office for review and concurrence.

4.2.2.10.2 The range user is responsible for working with the cognizant WFF Program/Project Management Office and the WFF Safety Office to provide the necessary data, information, etc. to support the development of the MPCP.

4.2.2.10.3 The cognizant WFF Program/Project Management Office as part of the MPCP development shall identify an Interim Response Team (IRT). To support this effort, the range user is required to appoint personnel to serve on the IRT as subject matter experts.

> The purpose of the IRT is to collect data, impound evidence, and take witness statements to support the mishap investigation phase.

4.3 Flight Safety Requirements

The overall goal of flight safety is to protect the public, the workforce (including participants), and property during hazardous range flight operations conducted under the cognizance of WFF. Flight safety risks generally cannot be completely mitigated. Missions are planned and executed such that the flight safety risks are controlled to acceptable levels while enabling the missions to obtain their objectives.

It is NASA WFF policy to, as the first order of precedence, apply flight safety techniques to contain vehicle related hazards from reaching the public, the workforce, or property requiring protection. This generally involves developing approved operating and/or impact areas and associated mission rules. For range operations where the hazards cannot be fully contained, NASA WFF implements a risk management approach to characterize and mitigate range safety risks and ensure any residual risk satisfies NASA safety risk criteria. In these cases, the WFF Safety Office performs and/or reviews and approves a flight safety risk analysis that accounts for the entire set of mission specific variables (vehicle aerodynamic/ballistic capabilities; azimuth and elevation angles; wind effects, air and sea traffic, and proposed impact areas). Vehicle design, reliability, performance, debris model, hazards, and model uncertainties for each flight and phase of flight are needed in order for the WFF Safety Office to characterize the associated risk, and when applicable, apply risk mitigation measures. Section 4.5 provides the data requirements for this process.

The period for which flight safety requirements apply are from launch through impact, landing, or orbital insertion for each flight vehicle component.

4.3.1 Risk Criteria, Application, and Assessment Process

All mission activities are planned such that the assessed risk satisfies the risk criteria listed in this section. In order to proceed with a mission where the risk cannot be mitigated sufficiently to satisfy the risk criteria, the range user may request a waiver in accordance with 800-PG-8715.5.1, *Range Safety Process for Programs and Projects,* Relief from Range Safety Requirements.

NASA WFF conducts range flight operations at other locations where both WFF and local safety requirements and safety risk criteria apply. In the event of conflicting requirements or criteria, the more stringent applies unless the WFF Safety Office and the local safety authority agree to an alternate approach.

WFF implements procedures and methodologies for assessing flight safety risk that are consistent with those employed by other national ranges, such as the Air Force Eastern and Western Ranges, and as defined in the Range Commanders Council (RCC) Standard 321 *Common Risk Criteria Standards for National Test Ranges*. Risk assessment provides the basis for identifying risk controls needed to protect people and property. WFF assesses and manages Expectation of Casualty (E_c), Probability of Casualty (P_c), and Impact Probability (P_i) in accordance with criteria that are defined in NASA-STD-8719.25 *Range Flight Safety Requirements* and is consistent with RCC 321 the exception of catastrophic risk. Catastrophic risk analysis is not required by the NASA Agency Range Safety Program per NASA-STD-8719.25.

WFF implements local probability of impact criteria for protecting ships and aircraft, which for ships, ensures that any risk to people onboard is sufficiently low such that it does not contribute to the overall E_c. In some instances, impact probabilities may not ensure the P_c criteria are satisfied, and in that case additional analysis may be required (See Paragraphs 4.3.1.1.6-9). The probability of impact criteria for protecting aircraft is based on guidance from the FAA, which stems from a standard level of protection for commercial aviation.

Unless otherwise stated for a specific criterion, these criteria apply to the aggregate risk resulting from the combination of all planned and potential unplanned hazards associated with a range operation. E_c, also known as collective risk, is an aggregate determination of risk resulting from debris, distant focused overpressure, and toxic material release. Debris hazards are understood to include all near field hazards such as overpressure and thermal as well as kinetic energy hazards associated with debris. P_c, also known as individual risk, is determined separately for debris, blast overpressure, to include distant focused overpressure, and toxic material release.

Different safety risk criteria apply to Mission Essential or Critical Operations Personnel vs. the general public. The range user is responsible for identifying Mission Essential and/or Critical

Operations Personnel associated with each range flight operation for WFF Safety Office approval.

4.3.1.1 Public and Mission Essential Risk Criteria

4.3.1.1.1 The range user or program shall coordinate with the WFF Safety Office and the authority for the range, launch site or landing site if applicable to make operational decisions to ensure the following risk criteria are satisfied for each flight or phase of flight (see Section 4.3.1.2 with regard to applying risk criteria to phases of flight).

4.3.1.1.2 The Probability of Casualty (P_c) for public personnel shall be less than or equal to (≤) $1x10^{-6}$ for each individual.

4.3.1.1.3 The Probability of Casualty, (P_c) for mission essential or critical operations personnel shall be less than or equal to (≤) $10x10^{-6}$ for each individual.

4.3.1.1.4 The Expectation of Casualty (E_c) for public personnel shall be less than or equal to (≤) $100x10^{-6}$ except as provided in Paragraph 4.3.1.1.5 for FAA licensed operations.

4.3.1.1.5 For FAA licensed launches, the Expectation of Casualty (E_c) for public personnel shall be less than or equal to (≤) $1x10^{-4}$ in accordance with the interpretation and implementation defined in the 14 CFR Part 417.

> 14 CFR Part 417 identifies the commercial launch regulations for FAA licensed launches. It states the public E_c criterion as not to exceed $1x10^{-4}$ while reducing the number of significant digits used to present the results to one significant digit. While the NASA criterion of $100x10^{-6}$ is numerically equal to $1x10^{-4}$, the FAA's implementation of one significant digit permits the acceptance of a relatively small increase in assessed risk depending on the fidelity of the calculations. For example, if the assessed risk for a given launch falls between $100x10^{-6}$ and $149x10^{-6}$ (i.e., between $1.00x10^{-4}$ and $1.49x10^{-4}$) according to the FAA implementation it would be rounded down to $1x10^{-4}$ and thereby satisfy the FAA criterion. The FAA regulation defines the level of acceptable public risk to be applied evenly across the commercial launch industry. WFF accepts and implements the FAA public E_c criterion for FAA licensed launches conducted under the cognizance of WFF in place of the NASA criterion.

4.3.1.1.6 The Expectation of Casualty (E_c) for mission essential or critical operations personnel shall be less than or equal to (≤) $300x10^{-6}$.

> For each range flight operation, the E_c and P_c criteria apply to people on land. The criteria also apply to people on waterborne vessels and in aircraft unless the P_i criteria stated in Sections 4.3.1.1.7, 4.3.1.1.8, 4.3.1.1.9, and 4.3.1.1.10 are implemented for the operation.

4.3.1.1.7 The Probability of Impact (P_i) for hitting a ship shall be less than or equal to (≤) $1x10^{-5}$ for each distinct impact area. This applies to all ships not identified as mission essential or critical operations (i.e., public ships).

> Additional analysis may be required for planned events to ensure the P_c criterion is met. A ship size threshold may be implemented to ensure P_i can be used as a measure to satisfy the P_c criterion. This also applies to 4.3.1.1.8. When applicable, guidance for addressing this will be provided in the operation's Flight Safety Plan.

4.3.1.1.8 The Probability of Impact (P_i) for hitting a mission essential or critical operations ship shall be less than or equal to (≤) $10x10^{-5}$ for each distinct impact area.

> The intent of Paragraphs 4.3.1.1.7-8 may be met by factoring the risk to people onboard ships into the risk assessment for E_c and P_c as long as the corresponding risk criteria for the ship and type of person (public or mission essential) are met. The range is responsible for providing a list of all mission essential or critical operations ships involved in the range operation for review and approval.

4.3.1.1.9 The Probability of Impact (P_i) for hitting an aircraft shall be less than or equal to (≤) $1x10^{-6}$ for each distinct impact area. The minimum distance for the aircraft clearance area shall be 2-sigma dispersion for planned events. This applies to all aircraft not identified as mission essential or critical operations aircraft.

4.3.1.1.10 The Probability of Impact (P_i) for hitting a mission essential or critical operations aircraft shall be less than or equal to (≤) $10x10^{-6}$ for each distinct impact area.

4.3.1.1.11 The Probability of Impact (P_i) for any property that could result in the damage of concern identified by the local range authority shall be less than or equal to (≤) 1×10^{-3}, applied for each flight.

> The local range authority and range user are responsible for determining property that requires protection and the level of damage that would be unacceptable (for example, potential impact by light debris that could cause only minor damage might be acceptable for some property, but not others). Local authorities for off-site operations may have risk management requirements that apply to high value equipment, assets, or other property. There may be specific property for which the program requires risk management due to its proximity to the flight and the consequences associated with potential hazards.

4.3.1.2 Application of Risk Criteria

4.3.1.2.1 The risk criteria identified in Section 4.3.1.1 shall be applied per flight vehicle per range operation unless Section 4.3.1.2.2 applies. A range operation consists of all phases, from launch through impact or orbital insertion of all vehicle and payload components.

4.3.1.2.2 For operations involving an orbital Reusable Launch Vehicle, or any vehicle that operates continuously for extended periods, the public and mission essential risk criteria may be applied independently for each phase of flight (e.g. launch, entry, ascent, cruise, or descent) **if all three of the following are satisfied:**

(A) Operational decision points and commit criteria are developed based on a risk assessment that is conducted or validated just prior to each phase of flight.
(B) The assessment or validation accounts for updated vehicle status and updated predictions of flight conditions.
(C) The vehicle has sufficient controllability to allow for risk management (e.g., flight termination) as a pre-requisite to beginning each phase of flight.

4.3.1.2.3 For operations involving more than one vehicle operating simultaneously, the public and mission essential risk criteria may be applied independently for each vehicle if the vehicle has sufficient independent controllability to allow for individual vehicle risk management (e.g., flight termination).

> The risk criteria should applied collectively to a range operation involving a salvo of launches without FTS if there is no time or ability to individually inhibit each launch.

4.3.1.3 Risk Assessment Process

The flight safety risk assessment is a formally documented analysis that identifies and characterizes the risk as input to the risk management process. The risk analysis employs quantitative means unless the WFF Safety Office determines the quantitative risk assessment is not necessary or not feasible; in which case qualitative measures are applied. Key elements of the risk assessment include analyzing, characterizing, and documenting safety risks resulting from planned and potential unplanned flight hazards including debris, distant focusing overpressure, and toxic material release.

Traditionally, the WFF Safety Office performs this assessment using input data provided by the range user or Program (See Section 4.5 Safety Data Requirements). The range user may provide their own assessment for review and approval by the Safety Office as long as it meets the technical requirements identified in this section, and the WFF Safety Office concurs with this approach during the Range Safety Tailoring Process. If the range user elects to perform the risk analysis for their operation, the WFF Safety Office will assign a primary point of contact to provide guidance. Periodic progress reviews with the WFF Safety Office are highly recommended to ensure a timely and successful risk assessment process.

4.3.1.3.1 The flight safety risk assessment shall satisfy the requirements defined in NASA-STD-8719.25, *Range Flight Safety Requirements,* or tailored version.

> The requirements in NASA-STD-8719.25, Section Range Safety Analysis address the hazards associated with a typical range flight operation and may be tailored for each program/project. Guidance for proper interpretation of the risk criteria and methodologies for performing various aspects of the risk assessment are provided in RCC 321, *Common Risk Criteria Standards for National Test Ranges* and the RCC 321 Supplement.

4.3.1.4 Collision Avoidance (COLA)

4.3.1.4.1 Prior to launch and entry operations, the vehicle, including any jettisoned component, or payload **shall meet one of the following criteria with regard to all orbital manned spacecraft**:

Option 1 - The probability of impact, P_i, shall be less than or equal to ($\leq$) 1×10^{-6}

Option 2 - The ellipsoidal miss distance shall be greater than or equal to ($\geq$) 200 kilometers in track and 50 kilometers cross track or radially

Option 3 - The spherical miss distance shall be greater than or equal to ($\geq$) 200 kilometers.

> A spacecraft is designated as "manned" if it is actively maintained and is currently inhabited or is intended to be inhabited. WFF works with the CSpOC to implement the most current approach regarding collision avoidance. The above criteria for manned spacecraft are listed in order of preference. Option 1 is the most sophisticated approach and directly incorporates vehicle trajectory covariance estimates, which serves to improve accuracy and launch availability. Options 2 and 3 use only the nominal trajectory. Option 2 is preferred over Option 3 because the largest uncertainty is in the in-track dimension and therefore the ellipsoidal approach reduces some conservatism associated with the spherical approach.

4.3.1.4.2 Prior to entry operations, an analysis shall be performed that indicates that the vehicle, including any jettisoned component, or payload would have a probability of impact, P_i, less than or equal to ($\leq$) 1×10^{-4} with respect to all unmanned (active or inactive) space objects.

> NASA does not require active launch collision avoidance screening against unmanned (active or inactive) on-orbit objects. FDSS-21-0182, "Launch COLA Operations: an Examination of Data Products, Procedures, and Thresholds" Revision A, demonstrates that the probability of impact threshold of 1×10^{-4} is currently satisfied without operational launch collision avoidance screening due to the large uncertainties inherent in launch vehicle flight. This position will be periodically evaluated based on the evolution of launch vehicle guidance, navigation, and control systems as well as growth in the on-orbit population. If requested by a range user, WFF will work with the CSpOC to obtain launch collision avoidance screening against unmanned on-orbit objects on a case-by-case basis.

4.3.1.4.3 The range (or range user where applicable) shall obtain a collision avoidance (COLA) analysis from the CSpOC or obtain another analysis that **satisfies all of the following criteria**:

(A) Establishes each wait in a planned launch/entry window during which the range user will not initiate or commit to launch/entry in order to satisfy the criteria of Section 4.3.1.4.1 and any range or program specific criteria.

(B) Accounts for the vehicle, any jettisoned component, or payload achieving altitudes greater than 150 kilometers.

(C) Accounts for uncertainties associated with vehicle performance and timing and ensures that any calculated launch/entry waits to incorporate all additional time periods associated with such uncertainties.

(D) For an orbital launch, accounts for the period starting from ascent through at least 3 hours after liftoff. This time period should account for all nominal object's orbit type, altitude in relation to each other as needed, and provide sufficient time for each new orbital object to be catalogued by CSpOC.

> The COLA analysis need not account for a manned orbital object if the three-sigma maximum altitude capability of the launch vehicle, any jettisoned component, or payload is 50 kilometers or more below the orbital perigee of the manned object.

(E) For a suborbital launch, accounts for the entire flight to landing or final impact.
(F) For an entry operation, accounts for the entry trajectory from the point that the deorbit is committed through landing or final impact.

4.3.1.4.4 The range (or range user where applicable) shall provide the CSpOC with proper notification of planned launch or entry operations regardless of whether the CSpOC provides the COLA analysis. This shall be performed according to CSpOCs latest process and requirements.

> It is standard practice for the WFF range to coordinate with the CSpOC to obtain the COLA analysis and the required notification occurs as part of that process. However, in the event that the range or range user does not utilize the CSpOC to obtain the analysis, notification is still required. A 15 day notice is recommended.

4.3.1.4.5 The range (or range user where applicable) shall notify the CSpOC immediately of any change in the planned launch or entry operations that occurs after the initial notification.

4.3.1.5.6 The range (or range user where applicable) shall ensure any launch/entry waits and any other constraints needed to satisfy the COLA requirements are implemented as launch/flight commit criteria.

4.3.2 Flight Safety Systems

A Flight Safety System (FSS) plays an integral role in the success of the Range Safety Risk Management Process. An FSS and its associated reliability factor into the risk assessment and is relied on during flight to make safety related decisions to mitigate hazards. The FSS includes, but is not limited to, range safety displays, range surveillance capability, radar, optical tracking systems, telemetry, tracking display systems (including instantaneous impact predictors), contingency management systems, flight termination systems, and command and control capability for flight termination systems.

The range user is typically responsible for providing a portion of the FSS for their specific vehicle (flight termination system, recovery, or contingency management system). The range and/or vehicle program, where applicable, is responsible for providing the infrastructure needed to support the range safety decision process, which typically includes the ground based instrumentation and support systems.

4.3.2.1 The range user **<u>shall provide a FSS</u> for each range operation, unless the Safety Office determines the operation is inherently safe** per one of the following criteria:

(A) The vehicle does not have sufficient energy to exceed a containment area established for the operation and the assessed risks are acceptable per Section 4.3.1.1.

(B) The vehicle does not contain an active guidance or control system, the predicted flight is solely based on launch and dispersion parameters and known system errors, the vehicle can be accurately wind weighted to provide for an acceptable impact location, and the assessed risks are acceptable per Section 4.3.1.1.

> The WFF Safety Office generally conducts an FSS needs analysis, which reviews the vehicle's capabilities and planned operational factors against the elements of the above criteria. The needs analysis may be performed by the range user and presented to the WFF Safety Office for review and approval during the requirements tailoring process.

4.3.2.2 The range user shall coordinate with the WFF Safety Office to determine the appropriate type of FSS for their vehicle or program and implement it, whether it be a traditional commanded flight termination system (FTS), an autonomous flight termination system (AFTS), or a contingency management system (CMS).

4.3.2.3 The range and/or range user shall ensure prelaunch checkouts and testing are performed on all elements of the FSS prior to launch or entry.

> Depending on the FSS configuration and range systems utilized (commanded or autonomous) there is shared responsibility between the range and the rang user to ensure the entire FSS is properly checked out and tested prior to launch or entry.

4.3.2.4 Flight Termination System Requirements

4.3.2.4.1 A vehicle, stage, or payload with propulsive capability that poses elevated public risk that requires mitigation as determined by flight safety analysis shall have a FTS.

> The appropriate type of FSS for a vehicle program is documented in the tailored requirements specific to that vehicle and/or program.

4.3.2.4.2 A FTS shall satisfy the requirements of AFSPCMAN 91-710, *Range Safety User Requirements Manual*, RCC-319, *Range Commanders Council Flight Termination Systems Commonality Standard*, or a tailored set of equivalent requirements.

> Under the grandfathering provisions of AFSPCMAN 91-710, some existing vehicle programs are governed by Eastern Western Range (EWR) 127-1, which is the predecessor to AFSPCMAN 91-710. NASA WFF accepts grandfathering where applicable.

4.3.2.4.3 For a NASA or NASA-sponsored vehicle, the range user shall evaluate the need to use a secure FTS in coordination with the WFF Safety Office. This evaluation shall occur during the range safety tailoring process and be documented in the range user's mission or vehicle specific requirements.

> A secure FTS provides a robust ability to terminate the mission free from potential interference, and may be warranted based on the assessment of risk and vehicle capabilities. Range users are also encouraged to consider the mission assurance aspects of using a secure FTS (i.e., ensuring robust ability to prevent unintended termination).

4.3.2.4.4 When using a secure FTS, all command uplinks shall utilize National Security Agency (NSA) approved or endorsed techniques and products.

4.3.2.5 Autonomous Flight Termination System Requirements

Autonomous in this context is defined as events or actions that occur without ground-based intervention during flight and include flight termination for range safety purposes. NASA coordinates with the Air Force, the FAA and other members of the national range community to further develop and implement AFTS for range flight operations.

4.3.2.5.1 For vehicles and missions utilizing an AFTS under the responsibility of the WFF, the range user shall comply with 803-PG-8715. 1.16, *Autonomous Flight Termination System (AFTS) Certification.*

> 803-PG-8715.1.16 references RCC-319 and other applicable standards. The range user is expected to coordinate with the Safety Office to tailor this PG and the referenced documents using the same tailoring process identified in Section 4.0 of this RSM.

4.3.2.6 Recovery and Contingency Management System (CMS) Requirements

A recovery system or CMS may use a set of elements within the vehicle including both manual and autonomous control. It may also include elements that are independent of the vehicle (i.e. command transmitters and tones). These systems may provide for deliberate termination of an errant/erratic vehicle's flight, but are not considered a FTS as it is not required to meet Section 4.3.2.4.

4.3.2.6.1 In this case, the risk associated with the system failing to terminate the errant/erratic vehicle is a factor in the mission's risk assessment and operational plans/procedures are identified to ensure there is no increased risk to the public.

4.3.2.6.2 To be considered a recovery system or CMS, its activation shall not increase the risk to the public, the workforce (including participants) or property.

> A recovery system or CMS whose activation may increase risk, the range user is responsible for tailoring the applicable section of 4.3.2.4 or 4.3.2.5.

4.3.2.6.3 If a recovery system or CMS is used to mitigate safety risk, verification of system functions shall be demonstrated prior to flight.

4.3.2.6.4 A recovery system or CMS shall be employed for balloon operations, unless the maximum weight and weight per surface area criteria of 14 CFR Part 101, *Moored Balloons, Kites, Unmanned Rockets, and Unmanned Free Balloons* is satisfied. In this case, the range user or program shall satisfy all requirements of 14 CFR Part 101.

4.3.2.7 Command and Control Systems

The requirements of this section apply to any system or subsystem used to transmit a command signal to control and/or terminate vehicle flight for the purposes of range safety. Command and control systems include flight termination activation switches and/or panels, intermediate linkage equipment, command transmitter and transmitting antennas, and all support equipment that is critical for reliable operation such as power, communications, and air conditioning systems.

4.3.2.7.1 For range operations requiring a vehicle on-board flight termination system (FTS), the range shall provide a fully redundant and independent command and control system, complete with fully redundant and independent command paths.

4.3.2.7.2 The range shall ensure the command and control system(s) used to support range operations requiring a FTS undergo validation and verification to ensure operational readiness prior to supporting every range operation.

4.3.2.7.3 The range shall ensure all components of the command and control system(s) used to support range operations with a FTS are under configuration control.

4.3.2.7.4 The range shall obtain RSCE approval for command and control system(s) used to support range operations with a FTS. This approval is contingent upon the system(s) **meeting all of the following requirements:**

(A) The command and control system shall have a predicted reliability of 0.999 at 95 percent confidence when operating, starting with the completion of the preflight testing and system verification of the vehicle FTS through initiation of flight and until the end of range safety responsibility for each flight.

(B) The command and control system shall not contain any single failure point that, upon failure, would inhibit the required functioning of the system or cause the transmission of an undesired flight termination command.

(C) The system shall include a backup power supply that provides for uninterrupted full functionality, including communications, for the length of the nominal mission plus 30 minutes in the event that the primary power supply fails.

> Back-up power capability of 45 minutes would satisfy this requirement for a typical ELV mission from WFF; i.e., a 15-minute mission with a 30-minute worst-case hang fire scenario.

(D) The command and control system design shall ensure the probability of transmitting an undesired or inadvertent command during pre-launch and flight is less than (<) $1x10^{-7}$.

(E) The command and control system shall include protection to prevent interference from inhibiting the required functioning of the system or causing the transmission of an undesired or inadvertent flight termination command.

(F) The command and control system shall include independent, redundant transmitter systems that automatically switch, or "fail-over", from a primary transmitter to a secondary transmitter when a condition exists that indicates potential failure of the primary transmitter. Conditions for a failover shall be identified and agreed upon by the RSCE and Range Chief Engineer prior to approval.

(G) The command and control system shall ensure any manual or automatic switching between transmitter systems or sites (including "fail-over") does not result in radio carrier being off air long enough for any vehicle command destruct system to be captured by an unauthorized transmitter.

(H) The command and control system shall ensure sufficient radio frequency signal and radiated power density is supplied to vehicle's command destruct system to maintain the 12-dB power density margin required per RCC 319.

(I) The command and control system antenna shall provide two or more command signals to any vehicle's command destruct system throughout nominal flight and in the event of a launch vehicle failure regardless of vehicle orientation.

14 CFR Part 417 Subpart D provides additional guidance regarding command and control system requirements and may be considered during the RSCE's review and approval of the system.

4.3.2.7.5 The range shall ensure any software components of the command and control system satisfy the requirements of Section 4.4, Safety Critical Systems.

4.3.2.7.6 A command link analysis shall be performed demonstrating the ground based command and control system(s) used to support the range operation, in conjunction with the vehicle's onboard FTS command receiving system maintains the required 12-dB power density margin for each receiver throughout nominal flight or until the end of range safety responsibility, per RCC 319. The range may perform this analysis on behalf of the range user.

4.3.2.8 Range Safety Tracking, Data Processing, and Display Systems

The requirements of this section apply to ground based instrumentation systems used to satisfy range safety criteria. Examples include radars, telemetry systems, telemetry data processing systems, data systems performing calculations such as coordinate transformations, instantaneous impact prediction, data filtering, refraction correction, etc., and data display systems used to make pre-flight and in-flight safety decisions. This section also applies to data processing systems used to evaluate wind criteria (i.e. wind weighting) and any system computing data based on wind/atmospherics to satisfy range safety commit criteria.

4.3.2.8.1 The range, or range user where applicable, shall ensure all data systems that provide information used to evaluate range safety requirements undergo validation to ensure operational readiness prior to initiating any phase of flight such as launch or entry.

> Validation may include pre-launch system checkouts, data simulations, and/or analysis. These may be conducted during the launch countdown or days/weeks prior to the launch, whichever is applicable.

4.3.2.8.2 The range safety telemetry system shall provide continuous, accurate data during preflight operations and during flight.

4.3.2.8.3 The vehicle program shall coordinate with the responsible range safety organization to identify the safety data required for each flight.

4.3.2.8.4 The range shall ensure the operational systems used to perform wind weighting produce solutions with errors no greater than those used to determine vehicle dispersion and potential hazard areas.

4.3.2.9 Range Surveillance Systems

The requirements of this section are applicable to systems used by the Range to conduct surveillance to aid in Range Safety decisions regarding area clearance. This applies to both airborne assets as well as assets used to detect shipping vessels. Systems and/or assets that are deemed safety critical are also subject to the requirements of Section 4.4 Safety Critical Systems.

4.3.2.9.1 The range, shall provide the necessary range instrumentation to perform surveillance operations for hazard areas defined in the Flight Safety Plan or Range Safety Plan (RSP) where applicable.

> The Range typically provides a Surveillance Operations Plan that details the specific instrumentation for the mission and obtains Mission RSO review and approval. Common systems include ground based and airborne radar systems, automatic identification system (AIS) tracking, etc.

4.3.2.9.2 The range shall obtain WFF Safety Office approval for each system used to conduct surveillance operations.

4.3.2.9.3 The range surveillance systems shall not provide false target position(s) such that the user would be unable to distinguish them as false.

> The system may provide indications to alert the operator of an issue related to the target position and/or track and the trustworthiness of the information as displayed.

4.3.2.9.4 The range surveillance systems shall produce target information accurate within 3 degrees in bearing and 1 nautical mile in range.

4.3.3 Operational Requirements

4.3.3.1 Hazard Areas and Range Clearance

4.3.3.1.1 The range, or range user where applicable, shall implement all hazard areas and associated clearance criteria defined in the applicable Safety Plans for each range operation (i.e. FSP, GSP, RSP, etc.).

> Hazard areas are developed using maximum range capability and/or probabilistic calculations. The maximum range may be limited by the use of a FSS (e.g., FTS or CMS), factoring in its reliability. The WFF Safety Office typically develops the Safety Plans for the mission, unless an alternative approach is agreed upon by all parties and documented in the tailoring.

4.3.3.1.2 For operations conducted at WFF, the range shall schedule VACAPES operating areas for all hazard areas established in the applicable Safety Plans for each range operation.

4.3.3.1.3 The range or range user shall coordinate with the FAA (or equivalent) to reserve airspace identified by the applicable Safety Plan. For operations conducted at WFF, this includes areas outside of restricted airspace and/or the VACAPES areas.

4.3.3.1.4 The range or range user shall coordinate with the applicable agencies to issue a Notice to Airmen (NOTAM) and Notice to Mariners (NOTMAR) as defined in the applicable Safety Plan for each range operation. For planned events, the minimum notice area shall be defined by 2 sigma nominal impact dispersion.

> The submission of these notices is requested at least 30 days prior to a range operation.

4.3.3.1.5 The range shall prepare a Surveillance Operations Plan (or equivalent) that identifies the surveillance assets to be used for each range operation and obtain concurrence from the WFF Safety Office.

4.3.3.1.6 The range shall coordinate with organizations and/or surveillance assets to survey hazard areas established within the Virginia Capes (VACAPES) warning areas for operations

> The range may utilize both airborne and ground based surveillance detection capabilities in addition to coordinating with the U.S. Coast Guard, Virginia Marine Resources Commission, and commercial entities to provide surveillance support. Ship hazard areas resulting from planned impacts within VACAPES must be surveyed for ships prior to launch and must meet the criteria specified in this RSM and the operation's specific FSP.

conducted at WFF. This includes both aircraft and ship hazard areas to the maximum extent possible.

4.3.3.1.7 For operations conducted at other launch sites, the range user shall ensure the hazard areas and associated criteria defined in that operation's FSP or Flight Safety Data Package (FSDP) are fully implemented in coordination with local authorities and with concurrence from the WFF Safety Office.

4.3.3.1.8 The range user shall coordinate with the WFF Safety Office to ensure operational personnel are informed of the hazards and safety risk associated with the conduct of any range operation.

4.3.3.1.9 The range user shall coordinate with the Safety Office to ensure on-site public/visitors are informed of the hazards and safety risk associated with viewing a range operation from NASA-controlled property.

4.3.3.2 General Flight Commit Criteria

4.3.3.2.1 The range, or range user shall ensure the flight commit criteria for a range operation are documented and approved by the WFF Safety Office.

> The Mission Operations Document (MOD) is typically used by the range to document the flight commit criteria (also known as the "GO/NO-GO" criteria) and is approved by the WFF Safety Office. Flight commit criteria may be defined in other appropriate documentation as long as the WFF Safety Office is included in the document's review and approval.

4.3.3.2.2 The range, or range user shall ensure the flight commit criteria for a range operation are satisfied prior to launch, flight, and/or phase of flight and document the conditions that verify the flight commit criteria are satisfied.

4.3.3.2.3 The flight commit criteria for a range operation shall incorporate all safety related conditions that must be met to initiate flight/launch and/or each phase of flight thereafter. These conditions are typically found in the FSP, GSP, and/or RSP for each range operation (or GSDP/FSDP where applicable).

4.3.3.2.4 The flight commit criteria shall ensure the COLA requirements of Section 4.3.1.4 are satisfied prior to any range operation.

4.3.3.2.5 The flight commit criteria shall ensure all elements of the FSS are operating with parameters specified for the range operation.

> In addition to readiness of any command control system, the flight commit criteria ensure the ground based instrumentation used in the range safety decision making process is ready and functioning properly to inform range safety decisions.

4.3.3.2.6 The flight commit criteria shall ensure at least 1 tracking source is operational and qualified to track the vehicle and all vehicle components to determine impacts. Track must be maintained through all thrusting periods of flight for each piece such that post flight analysis can be performed to determine impacts should track be lost prior to actual impact.

4.3.3.2.7 The flight commit criteria shall ensure all meteorological conditions, such as wind, lightning, and visibility, are within the limits specified for the range operation. These limits are typically found in the FSP or FSDP.

> Examples include surface and ballistic wind limits and/or launcher setting limits based on the vehicle's wind sensitivity.

4.3.3.2.8 The flight commit criteria for all unguided, rail launched vehicles shall include wind weighted launcher settings with the exception of vehicles without sufficient energy to violate an established containment area per sub-paragraph (A) under Section 4.3.2.1. For guided vehicles with unguided portions of flight, the flight commit criteria shall include wind weighting for the unguided portions of flight.

> Low performance unguided rail launched vehicles without a range safety system may be launched without being wind weighted, provided the launcher effective elevation setting is less than 90 degrees and all other safety criteria are satisfied.

4.3.3.3 Vehicles with Flight Termination Systems

This section identifies the requirements for a vehicle using a Flight Termination System (e.g. rockets, missiles, and drones). This does not apply to vehicles considered to be a UAS (See Section 4.3.3.7) or balloons (See Section 4.3.3.5).

4.3.3.3.1 The range user shall coordinate with the WFF Safety Office to establish flight safety criteria. These include:

(A) Flight limits such as impact limits, vehicle attitude, heading, time of flight, and position. These limits may be implemented as launch criteria and/or flight requirements.
(B) Surface, ballistic, and other wind limits based on vehicle wind sensitivity.
(C) Effective launch azimuth and elevation settings such that planned impact occurs within approved operating areas

4.3.3.3.2 The range user or vehicle program shall coordinate with the WFF Safety Office to establish FTS termination criteria during vehicle flight. **At a minimum, these criteria shall address the following:**

(A) Valid data show the vehicle violating a flight termination boundary, unless other documented mitigations are in effect.
(B) Vehicle performance or location is unknown, the vehicle is capable of violating a flight termination boundary, and terminating flight would mitigate the risk.
(C) Orbital launch vehicles not capable of achieving a minimally acceptable orbit (approximately 70 nm perigee).

(D) Gross trajectory deviation or obvious erratic flight rendering the vehicle uncontrollable.
(E) Other mission specific conditions as defined by the WFF Safety Office.

4.3.3.3.3 For vehicles flown with a FTS, the range (or range user) shall ensure at least two independent and adequate tracking sources are operational to track the vehicle and all vehicle components from launch through the end of range safety responsibility.

A combination of radar (both skin track and transponder), optical tracking, and Global Positioning System (GPS) can be used to satisfy this requirement. Inertial Measurement Unit (IMU) may be used to satisfy one of the two sources, as long as it has been validated with another non-IMU/INS qualified source. Re-validation is required after each staging and/or shock event such as ignition. See Section 4.3.3.3.3.3 for additional requirements for using GPS to satisfy both of these sources. Tracking systems used in conjunction with a CMS or recovery system are evaluated on a case-by-case basis and addressed in the risk assessment.

4.3.3.3.3.1 The range (or range user) shall ensure each tracking source and tracking plan is designed such that no single order vehicle failure or ground based instrumentation failure mode could cause the loss of both tracking sources to the Range Safety Display System.

4.3.3.3.3.2 If one of the tracking sources is a skin tracking radar, the range (or range user) shall ensure a ceiling limitation is imposed to ensure visibility until the skin tracking radar has adequate time to provide quality data.

4.3.3.3.3.3 If GPS is used to satisfy the two tracking source requirement, the range (or range user) **shall ensure all of the following:**

(A) Two independent paths exist from receipt of GPS satellite information to transmission of GPS position data via telemetry. This can be met through redundant and independent GPS antennas, receiving systems, and telemetry transmitting systems on the launch vehicle.
(B) Two independent paths exist from the ground receiving antenna to the Range Safety Display System. This can be met through redundant and independent receiving ground antennas, telemetry decom and processing systems, and Range Safety Display Systems.
(C) The vehicle GPS system meets the requirements specified in RCC 324 *Range Safety Performance Standards*, or tailored version that is acceptable by the WFF Safety Office.

4.3.3.3.4 The range (or range user) shall ensure all tracking sources that provide information to evaluate flight termination criteria shall be operationally verified prior to launch.

4.3.3.3.5 For expendable launch vehicles (ELVs), the range (or range user) shall comply with NASA-STD 4010, *NASA Standard for Lightning Launch Commit Criteria for Space Flight.*

4.3.3.4 Vehicles without Flight Termination Systems

This section identifies the minimum launch limitations for vehicles that do not require an FTS. Examples include unguided rail-launched propulsive vehicles and guided vehicles that satisfy Section 4.3.2.1 (A). Guided vehicles determined to require an FTS shall meet the requirements of 4.3.3.3. These may also be applicable to range tests involving projectiles, where the object may not be considered a 'vehicle' per say, but still presents similar hazards as a ballistic propulsive vehicle. The range user will work with the WFF Safety Office to determine the applicable requirements in this case, and document them in the mission's specific tailoring.

4.3.3.4.1 The range (or range user where applicable) shall ensure the effective launch elevation and azimuth settings allow planned impact to occur within approved operating areas.

4.3.3.4.2 For proven rail launched vehicles, the range or (range user where applicable) shall ensure the effective launch elevation setting is no greater than 85 degrees.

> Vehicles with at least 3 flights with no vehicle failures and/or anomalies that have impact to public safety are considered proven.

4.3.3.4.3 For proven rail launched vehicles, the range (range user where applicable) shall ensure the wind corrected launch elevation setting is no greater than 86 degrees.

4.3.3.4.4 For unproven rail launched vehicles, the range (or range user where applicable) shall ensure the effective launch elevation setting is no greater than 80 degrees.

> The Range (or range user where applicable) are encouraged to select an effective launcher azimuth setting to reduce risk and account for unknown vehicle malfunctions and/or failures.

4.3.3.4.5 For unproven rail launched vehicles, the range (or range user where applicable) shall ensure the wind corrected launch elevation setting is no greater than 83 degrees.

4.3.3.4.6 The range shall ensure all unguided rail launched vehicles are wind weighted and within the limits specified by the Flight Safety Plan.

> Low performance unguided rail launched vehicles may not require wind weighting as long as the effective elevation is 80 degrees or less and all other safety criteria identified in the Flight Safety Risk Assessment are met.

4.3.3.5 Balloon Launch Vehicles and Systems Requirements

4.3.3.5.1 The range user or vehicle program shall coordinate with the FAA (or equivalent foreign agency) to ensure NOTAMs based on the predicted flight path are issued 24 hours prior to launch.

4.3.3.5.2 The range user or vehicle program shall obtain a launch clearance window from the FAA (or equivalent foreign agency).

4.3.3.5.3 The range user or vehicle program shall calculate a predicted trajectory based on the pre-launch wind profile. The predicted trajectory and the associated impact predictions shall also be included.

4.3.3.5.4 The range user or vehicle program shall calculate a recovery point and time that satisfies the risk criteria in Section 4.3.1.1. The time and location of the recovery point shall be coordinated with, and clearance to terminate shall be obtained from the FAA (or equivalent foreign agency).

4.3.3.5.5 The range user or vehicle program shall obtain WFF Safety approval for the balloon termination/recovery system when it is relied upon as a Flight Safety System to mitigate safety risk.

4.3.3.5.6 The range user shall perform a functional test of the balloon termination/recovery system prior to launch to certify the flight safety system.

> This also includes any contingency management system such as the Balloon collar system.

4.3.3.6 Manned Aircraft Systems

The intent of range safety requirements for manned aircraft system operations is to provide a level of safety to the public and workforce not covered by aircraft traffic control (ATC). The WFF Aircraft Office oversees all manned aircraft operations conducted at WFF or in support of NASA missions operating under the cognizance of WFF. Their process defines the majority of safety requirements that stem from NPR 7900.3, *NASA Aircraft Operations Management*. The WFF Aircraft Office also staffs an Aviation Safety Officer (ASO) who ensures safety requirements are being met.

The WFF Safety Office provides Range Safety input to the process through the Airworthiness Flight Safety Review Board (AFSRB). This ensures the requirements from a range safety perspective and those identified in this safety manual are implemented.

Standard manned aircraft operations typically do not require additional requirements from Range Safety. Examples of operations where Range Safety requirements may apply are ground tests of aircraft systems such as water ingestion or activities where non-standard equipment and/or personnel are located on the airfield during a flight operation that represents an abnormal increase in risk to the aircraft, personnel on the ground, or both. In addition, testing that involves the release of a payload or test article from an aircraft are considered range operations and may require additional review by Range Safety. The Pilot in Command (PIC) has ultimate authority over the operation and safety of the aircraft and crew. The PIC and MRSO share responsibility for the safe execution of a mission.

4.3.3.6.1 Manned aircraft operations shall be conducted in accordance with NPR 7900.3, *NASA Aircraft Operations Management* and 830-AOM-0001, *Aircraft Operations Manual*.

4.3.3.6.2 Manned aircraft operations shall comply with applicable regulations and limitations imposed by the FAA.

4.3.3.6.3 Manned aircraft operations shall comply with all ATC regulations and directions.

4.3.3.6.4 Manned aircraft operations involving hazardous or potentially hazardous systems such as pressure systems, ionizing and non-ionizing radiation systems including lasers, chemical systems, or systems presenting an electrical hazards shall be reviewed and approved by the WFF Safety Office. This list is not all encompassing and other hazards may be considered.

4.3.3.7 Unmanned Aircraft Systems (UAS)

UAS operations conducted at WFF or conducted in support of a program or program managed by WFF are considered WFF Range Operations and are subject to the range safety requirements of NPR 8715.3, *NASA General Safety Program Requirements* and NPR 8715.5, *Range Flight Safety Requirements.* Operations involving UAS at WFF or conducted in support of programs under the cognizance of WFF are also subject to the requirements of NPR 7900.3, *Aircraft Operations Management*. These requirements are managed by the WFF Aircraft Office, Code 830.

Containment is the primary means of establishing safety hazard areas for UAS operations at WFF. The goal of containment for UAS is to keep the system within a geographic boundary and minimize the number of non-participants in that area. In all cases, non-participants (e.g. those who are not mission essential) should be under cover if they are inside of the hazard area. The use of containment permits a more streamlined review and approval process for flight operations by the WFF Safety Office and the WFF Aircraft Office.

Containment is based on having a set of capabilities inherent in the UAS to provide an active boundary and flight area limitation. These capabilities include lost link programming, geofencing, altitude limiting, autonomy, manual take-over, navigation loss programming, physical restraints, system redundancy, and CMS. RF limiting, if available, is also a capability taken into consideration when creating the containment area. In the event that containment of the UAS cannot be implemented or cannot adequately mitigate all hazards, a probabilistic assessment is applied. This section covers requirements for both approaches to UAS operations, with containment being the preferred approach.

WFF has the authority to impose additional restrictions to the operation of a UAS if confidence in the system cannot be met or risk management is not deemed as fully adequate. Such measures may be include:

- Re-evaluating the hazard analysis incorporating changes such as flight parameters, flight path, and new information from the user.
- Imposing restrictions to planned flight to control identified risk.
- Require additional control measures or safeguards to control identified risk.

4.3.3.7.1 UAS operations shall be conducted in accordance with NPR 7900.3, *Aircraft Operations Manual* and 830-AOM-0001, *Aircraft Operations Manual.*

4.3.3.7.2 UAS operations shall comply with applicable regulations imposed by the FAA.

4.3.3.7.3 UAS operations shall comply with all ATC regulations and directions.

4.3.3.7.4 UAS operations shall obtain a flight release from the WFF Aircraft Office for all UAS operations conducted on NASA property or in support of NASA operations managed under the cognizance of WFF. The flight release process is controlled by the WFF AFSRB.

4.3.3.7.5 The range (or range user where applicable) shall ensure all UAS operations conducted within special use airspace is coordinated and approved by the using agency for that airspace.

Exclusive use airspace is recommended. Mitigations can be employed for co-use as long as it is approved by range safety, all participants are briefed on the operation, and it is permitted by the WFF AFSRB during the flight release process.

4.3.3.7.6 The range user shall ensure the UAS is designed with a lost link capability to operate the system upon loss of the command and control signal from the operator.

4.3.3.7.7 The range user shall ensure the lost link capability is programmed such that the lost link point, flight path, and altitude flown is clear of all obstacles such as buildings or other structures so as not to create any additional hazards.

4.3.3.7.7.1 The lost link point shall be in a position where the UAS operators have an opportunity to safely regain the link, but in the event it does not, the UAS can ditch/abort safely.

4.3.3.7.7.2 The lost link point shall be in a position that does not put the UAS in a position to interfere with other aircraft operations.

In some systems, the lost link path is an extended flight pattern and the UAS may fly a long distance back to the lost link point. This feature needs to be accounted for in the path and hazard area selection. The UAS may also have a series of lost link points depending on the mission and flight profile.

4.3.3.7.8 If the UAS design features the geofencing capability, the range user shall ensure it is utilized unless specifically approved by the WFF Safety Office.

Geofencing is a software capability inherent with some UAS that provide a geographic software boundary that the UAS may operate and is a good back-up to pilot situational awareness of UAS position. The intent is to prevent any inadvertent manual or automatic flight outside of the geographic area.

4.3.3.7.9 If the UAS design features altitude limiting, the range user shall ensure it is utilized unless specifically approved by the WFF Safety Office.

4.3.3.7.10 If the UAS design features autonomy such as the ability to pre-program a flight pattern through waypoints, altitudes, and other functions, the range user shall provide the autonomy plan to the WFF Safety Office for review and approval for each UAS flight.

Approval may be granted for multiple autonomy plans at one time. Re-approval is not required for each individual flight as long as they are utilizing an approved autonomy plan. Changes to way-points, altitudes, etc. to an approved autonomy plan may require re-approval.

4.3.3.7.11 The range user shall always maintain the ability to manually fly the aircraft, which includes the ability to manually override any autonomous operations.

4.3.3.7.12 The range user is encouraged to ensure the UAS is designed to have redundant sources of navigation. In no case will a UAS be permitted to continue the mission with a complete loss of navigation.

Should the UAS not feature redundant sources of navigation, an alternative is to ensure a response plan or automated procedure is built into the flight plan. This could involve manually flying the aircraft safely back to an approved landing site, landing immediately, or invoking a self-termination function.

4.3.3.7.13 For new or experimental UAS where the flight control system and/or navigation are untested (or minimally tested), the range user shall consider the use of physical constraints to limit operations (e.g. utilizing a tether).

4.3.3.7.14 The range user shall consider the use of redundant command and control systems to mitigate failure scenarios. These may drive how the containment area is defined and the associated constraints.

4.3.3.7.15 The range user shall ensure the UAS is equipped with a FSS such as a CMS that is approved by the WFF Safety Office.

This requirements is consistent with Section 4.3.2.2. The CMS can be used to cease operation of the vehicle and land it ASAP or it can be a parachute recovery system that deploys under certain conditions. Other systems may be considered part of the CMS depending on how they are employed in the UAS.

4.3.3.7.16 In the event containment of the UAS is not achievable or cannot adequately address all hazards, a probabilistic risk assessment shall be utilized in accordance with of RCC 323 *Range Safety Criteria for Unmanned Aerial Vehicles.*

4.4 Safety Critical Systems

4.4.1 Range systems owned by WFF or used to support NASA WFF range operations that contain safety-critical software or have the potential to contain safety-critical software shall be identified to the WFF Safety Office.

NPR 7150.2, *NASA Software Engineering Requirements* defines software as: Software - Computer programs, procedures, scripts, rules, and associated documentation and data pertaining to the development and operation of a computer system. This definition applies to software developed by NASA, software developed for NASA, commercial-off-the shelf (COTS) software, Government-off-the shelf (GOTS) software, modified –off-the-shelf (MOTS software, reused software, auto-generated code, embedded software, the software executed on processors embedded in Programmable Logic Devices, and open-source software components.

4.4.2 Software identified as safety-critical shall be developed and/or acquired in accordance with 800-PG-7150.4.1 *Software Safety and Mission Assurance Process Interface*, and 803-WI-7150.4.1 *Software Safety and Mission Assurance Process*.

These define the WFF specific implementation of NPR 7150.2 *NASA Software Engineering Requirements*, NASA-STD-8719.13 *NASA Software Safety Standard*, and NASA-STD-8739.8 *NASA Software Assurance Standard* and identify the level of WFF Safety Office involvement that can be expected for developing and maintaining safety-critical software systems. The Range user may request a tailoring of these requirements with a focus on safety.

4.5 Safety Data Requirements

This section identifies the data that a range user is generally required to submit to the WFF Safety Office for a range operation and the schedule requirements for data submittal (schedule requirements are provided in Section 4.5.5). The required data and schedule are subject to mission or program specific tailoring. The range user is responsible for coordinating data/schedule requirements with the WFF Safety Office and documenting the mission/program specific requirements in the approved tailoring.

4.5.1 Vehicle and Payload Ground Safety Data

The range user or program shall provide the following data items as input to the ground safety analysis for all vehicles and payloads.

4.5.1.1 Hazardous Electrical Circuits – a copy of schematic and wiring diagrams for all pyrotechnic and other circuits that initiate hazardous systems. The range user shall promptly notify the Safety Office of any changes to hazardous electrical circuits.

4.5.1.2 Mechanical Systems – a description, including technical details and precautions, for all hazardous mechanical systems. The submittal shall include approved engineering drawings showing the location of these and all other hazardous systems (ordnance, pressure, etc.).

4.5.1.3 Ordnance Devices

(A) Specification sheets for each EED listing the minimum all fire current, maximum no-fire current, recommended firing current, normal resistance, pin-to-case resistance, and, if available, the RF sensitivity characteristics.

(B) A technical description of all SAFE/ARM type devices employed (out-of-line S/A, S/A connectors, mechanical restraints, etc.).

(C) Manufacturers' Storage and Operating Temperatures, Humidity parameters, Net Propellant Weight, Net Explosive Weight, and Net Explosive Weight for Quantity Distance considerations.

(D) Specification sheet for ordnance devices such as; rocket motors, shape charges, detonating cord, etc., which identify the DoT explosive classification, normal output characteristics, and composition.

4.5.1.4 Chemicals and Chemical System Hardware

(A) A description and approved engineering drawing for each chemical system

(B) A description of each hardware "plumbing," component (tanks, fittings, valves), and the system safety features.

(C) A SDS for each chemical used on the project.

(D) Material compatibility documentation.

4.5.1.5 Voltage Systems – A description of all voltage systems (AC or DC) above 50 volts, including technical details and schematics.

4.5.1.6 Cryogenic Systems – A description of all cryogenic systems both flight and ground support, an SDS for each gas and/or liquid used in the system, and schematics of the design.

4.5.1.7 Battery Systems – A description of battery systems used, charging methods, and associated procedures.

4.5.1.8 Pressure Vessels and Pressurized Systems – A description and approved engineering drawing of all pressure systems used on the program and technical characteristics of each component, including design burst, proof, and MAWP pressures, internal volume, and materials of construction. Specific design requirements for pressure vessels and pressurized systems are provided in Section 4.2.1.8.

4.5.1.9 Non-Ionizing (RF) Sources - Data on all non-ionizing emitters as outlined in the applicable non-ionizing source requirements in Section 4.2.1.6.

4.5.1.10 Ionizing Sources - Data on all ionizing sources and devices as identified in Section 4.2.1.6, including NRC or State license.

4.5.1.11 Optical Sources - Data on all hazardous optical emitters (e.g., lasers) as outlined in the applicable requirements of Section 4.2.1.6 including wavelength, pulse width, pulse repetition frequency, beam diameter, divergence angle, average power output, laser classification, and verification that users are properly trained. Range users may need to coordinate outdoor laser operations with the FAA, Laser Clearinghouse (if DoD funded) or NASA HQs Laser Safety Review Board.

4.5.1.12 Ground Support Equipment (GSE) - Schematics, approved engineering drawings, operational description, technical details, and documentation of certification for all GSE used to support hazardous systems or operations. This includes but is not limited to pyrotechnic checkout meters, breakout boxes, calibration sources, pressure systems, chemical service modules, cryogenic systems, and lifting and handling devices. GSE design requirements are provided in Section 4.2.1.5.

4.5.2 Vehicle and Payload Processing Procedures

Specific requirements of this Range Safety Manual apply to those procedures deemed to be hazardous. The WFF Safety Office will use the information required by this section in conjunction with the data required by Section 4.5.1 to identify procedures as hazardous or non-hazardous. All procedures for handling, assembly, and checkout of hazardous systems must be approved by the WFF Safety Office prior to use. Revisions to procedures must also be approved by the WFF Safety Office, including revisions to non-hazardous procedures, as a revision may change the procedure to hazardous. A range user shall provide the following information regarding launch vehicle and payload processing procedures that have the potential to be hazardous for Safety Office review and approval prior to beginning the associated operation.

4.5.2.1 Hazardous Systems - Detailed procedures for handling, assembly, and checkout for all hazardous systems (ordnance, mechanical, pressure, chemical, etc.) prior to beginning operations in accordance Section 4.1.1.1.

4.5.2.2 Recovery – Procedures for recovery operations that include:
(A) A description of the items to be recovered, reasons for recovery, hazards involved, and any recovery aids and their characteristics.
(B) A description of the methods employed to verify that all hazardous systems are in a SAFE condition during recovery operations.
(C) A list of recovery aids such as chaff (frequency, quantity), locator beacons (frequency, power output, period of operation), dye marker (color persistence, time of deployment), flashing light (color, frequency, duration, candle power, directional characteristics), smoke (color, duration, time of deployment), radar reflective parachute (when deployed, size), or any other aids used.
(D) The desired period of recovery operations and the disposition of the recovered items.

4.5.2.3 Contingencies - Contingency procedures that include steps to be taken in the event of launch postponement, launch cancellation (including de-staging), hold or abort, booster ignition failure, unintentional land impact, emergency response, chemical spill cleanup, or any other contingency that may endanger personnel or property.

4.5.3 Flight Safety Data Requirements

The range user or program shall provide the following data items as input to the flight safety analysis. The range user or program is strongly encouraged to review these requirements and tailor to the specific needs of the program. These requirements assume the WFF Safety Office is performing the flight safety analysis. In cases where the range user is performing the analysis (per approval from the WFF Safety Office), the range user should discuss with the WFF Safety Office and document variances in the tailoring.

4.5.3.1 Rocket Flight Safety Data

4.5.3.1.1 Vehicle Description – Details about the vehicle and payload including a scaled drawing, operating procedures, and a description of the operation (e.g., Test Plan).

4.5.3.1.2 Launch Parameters - launcher settings, launch coordinates (WGS - 84 geodetic datum), a timeline with sequence of events (ignitions, burnouts, separations, etc.).

4.5.3.1.3 Vehicle Parameters - vehicle performance characteristics, and thrust/guidance modeling.

4.5.3.1.4 Program/Project specific information or additional information as requested by the WFF Safety Office.

4.5.3.1.5 Trajectory Model Output – Trajectory data in computer medium format for each impacting and/or orbital body for all requested trajectory profiles, launch windows, etc. to be flown. Precision shall be coordinated with the WFF Safety Office, and the FSDP shall include reference frames and units for all of the input parameters. The trajectory data shall include but is not limited to:

(A) Time
(B) Velocity
(C) Altitude
(D) Horizontal range
(E) Weight
(F) Thrust
(G) Vehicle Aerodynamic Drag Coefficient
(H) Dynamic pressure
(I) Angle of attack
(J) Velocity vector elevation and azimuth angles
(K) Body pitch, yaw, and roll angles,
(L) Present Position and Instantaneous Impact Prediction Latitude and Longitude,
(M) Earth Centered, Earth Fixed (ECEF) X, Y, Z Position and Velocity
(N) Slant Range, Azimuth, and Elevation relative to the launcher
(O) Moments of Inertia Ixx, Iyy, and Izz
(P) Distance from nozzle throat to vehicle center of gravity (Cg), when liquid fuel is pushed to rear or front of vehicle (inches).
(Q) Pitch moment of inertia, when liquid fuel is pushed to the rear or front of vehicle (slugs/ft^2).
(R) Pitch moment of inertia when liquid fuel is evenly distributed to the rear of the vehicle (slugs/ft^2).

(S) <u>Nominal vehicle speed (in units of Mach number)</u>

Including the ECEF Velocity measurements in (M) eliminates the need for (J), and also reduces the analysis effort and time by eliminating coordinate transformations.

4.5.3.1.6 Maximum Capabilities - Maximum horizontal range, maximum velocity and malfunction turn rate capability/analysis. This analysis shall include a table of turn capability at least every 4 seconds into flight lasting at least long enough for the vehicle to violate a limit or begin tumbling with the following elements:
(A) Reference malfunction turn initiation time (sec)
(B) Relative probability of turn curve data record
(C) Thrust vector deflection angle (deg.)
(D) Angle of roll plane for which data turn curves were generated (deg)
(E) Table parameters – Times into the turn at which turn angle data are input (sec), turn angle from the initial velocity vector (deg), absolute turn speed (ft/sec).

4.5.3.1.6.1 For vehicles with multiple propulsive stages or engines/motors burning simultaneously, engine out mass properties data/analysis which includes the following:
(A) Time since lift off from the pad (sec)
(B) Total vehicle thrust (lbs.)
(C) Thrust offset angle with respect to vehicle axis (deg)
(D) 1-sigma uncertainty in thrust offset angle (deg)
(E) Axial thrust component offset from vehicle centerline (inches)
(F) 1-sigma uncertainty in axial thrust offset (inches)
(G) Total vehicle weight (lbs.)
(H) Distance from nozzle throat to vehicle Cg (inches)
(I) 1-sigma uncertainty in X Cg (inches)
(J) Offset from vehicle centerline to the vehicle Cg-offset assumed to be in the tumble plane (inches)
(K) 1-sigma Uncertainty in Z Cg (inches)
(L) Pitch tumble moment of inertia (slugs/ft^2)

4.5.3.1.6.2 For vehicles with multiple propulsive stages or engines/motors burning simultaneously, engine out drag data/analysis which includes the following:
(A) Vehicle reference area (ft^2)
(B) Vehicle reference diameter (ft^2)
(C) Distance between nozzle throat and aerodynamic reference point (ft)
(D) Angle of attack (deg)
(E) Axial force drag coefficient
(F) Normal force drag coefficient
(G) Normal moment drag coefficient

4.5.3.1.7 Provide a mechanical Q-Alpha limit profile as a function of time which may be used in DFO analysis to represent the start of aerodynamic breakup of the vehicle. This is used to develop the yield histogram and trapping case analysis.

4.5.3.1.8 Provide failure trajectories for each mission/trajectory profile. This should at a minimum address the following failure modes:
(A) Minimum Perigee (for Orbital range operations)
(B) Stage ignition failures
(C) Stage separation failures
(D) Interstage separation failures (if applicable)
(E) Fairing separation failures

4.5.3.1.9 Dispersion Data - Total dispersion data as applicable, either theoretical and/or empirical, in terms of one, two, and three sigma ellipses for all impacting bodies and for all trajectory/mission profiles to be flown. A theoretical analysis shall include the following effects where applicable:
(A) Thrust offset.
(B) Thrust misalignment.
(C) Aerodynamic errors.
(D) Uncompensated wind.
(E) Launcher misalignments.
(F) Weight and impulse errors.
(G) Guidance and control system errors.
(H) Ignition delay, and any other errors unique to this vehicle.
(I) Flight history trajectory data on previous vehicle flights.
(J) When using a Monte Carlo simulation, the analysis must have a statistically significant number of runs to reliably predict vehicle dispersion.
(K) Mass variability for the launch vehicle and payload between preliminary FSDP submittal and Final FSDP submittal.
(L) Mass variability for the launch vehicle and payload between Final FSDP submittal and launch.

4.5.3.1.9.1 For Orbital range operations, provide a table and chart with perigee altitude vs time illustrating the time variability at which the perigee altitude crosses a 70 nm altitude threshold.

4.5.3.1.10 Debris Analysis - Provide a debris analysis including technique and input parameters. The WFF Safety Office may elect to perform a debris analysis. Therefore, chamber pressure and the number and type of debris fragments caused by vehicle breakup may be required. The data for each debris fragment type shall include:
(A) Ballistic coefficient and its coefficient of variance
(B) Weight, dimensions and projected area
(C) Drag coefficient and the lift over drag ratio
(D) Incremental velocity imparted by the vehicle breakup
(E) Fragment delta velocity imparted
(F) Fragment type (inert/contained propellant/partially contained propellant/uncontained propellant
(G) Number of fragments for this type
(H) Fragment material or composition
(I) Fragment heated area

(J) Fragment stagnation radius
(K) Fragment parent object
(L) Propellant weight per fragment
(M) Propellant type for each motor/stage
(N) Solid propellant for each motor density (if applicable)
(O) Solid propellant regression burn coefficient A and B (for the equation fragment depth delta_r = A * (p^B) * (delta_t) (if applicable)
(P) Cylindrical propellant inner radius values for each solid motor
(Q) cylindrical propellant outer radius values for each solid motor
(R) solid propellant yield factor estimate
(S) Propellant burn duration vs propellant burn weight
(T) Fragment mach number vs coefficient of drag for that mach number

4.5.3.1.11 Toxic Hazards Analysis – Provide Toxic hazards analysis to include types and quantities of hazardous gases and by-products of combustion of solid and liquid propellants. Provide input data for the LATRA3D pre-launch analysis tool.

4.5.3.1.12 Distant Focus Overpressure (DFO) – Provide Distant Focusing Overpressure (DFO) inputs for the Blast DFO pre-launch analysis tool.

4.5.3.1.13 Wind Effects Analysis – Provide a wind effect analysis and the method used for calculation. Coordinate with WFF Safety to provide data consistent with currently used WFF wind compensation methods. Provide parachute data, if applicable.

4.5.3.1.14 Hazards Analysis – Provide a hazard analysis on any vehicle system that poses a safety hazard beyond that of debris, toxics, or blast. The analysis must identify each hazard, measures to mitigate the hazard, and a risk assessment that characterizes the residual safety risk.

4.5.3.15 Orbital insertion data for orbital missions

4.5.3.16 For vehicles requiring COLA, provide 1 hz trajectories for all orbital objects to include the spacecraft, boosters and any deployables out to 3 hours after launch. Trajectories are for all mission profiles/trajectories planned to be flown. The trajectories must be in the required CSpOC format - 4.0 Caliper Trajectory Covariance V2.0 file (https://www.space-track.org/documentation#odr.)

4.5.3.2 Scientific Balloon Flight Safety Data

WFF oversight of scientific balloon operations is primarily focused on the NASA Balloon Program. The Balloon Program Office shall coordinate with the WFF Safety Office to develop the Program's flight safety data requirements and document them in the approved tailoring of this RSM.

4.5.3.3 Manned Aircraft Flight Safety Data

4.5.3.3.1 The range user shall provide flight profiles including aircraft velocities, altitudes, and separations (for multiple aircraft). This requirement is applicable when the operation involving manned aircraft is considered to be a range operation. See Section 4.3.3.6 for more information in this determination.

4.5.3.3.2 The range user shall provide data on platform instrumentation if it is of a hazardous nature (i.e., pressure systems, ordnance, gases, lasers, high-voltage, etc.). See payload requirements of Section 4.5.1.

4.5.3.4 Unmanned Aircraft Systems (UAS) Flight Safety Data

4.5.3.4.1 UAS Description – Details about the aerial system and payload including a scaled drawing and operating procedures. Provide a description of the operation (i.e., Test Plan). Provide a description of LOS contingencies.

4.5.3.4.2 Flight Profile - Supply nominal flight profile, including waypoints.

4.5.3.4.3 Hazard Areas – Supply a proposed keep-out area for non-participants for review and approval by the WFF Safety Office.

4.5.3.4.4 UAS Hazards Analysis – Provide a hazard analysis on any UAS system that poses a safety hazard during flight beyond that of inert debris. The analysis must identify each hazard, measures to mitigate the hazard, and a risk assessment that characterizes the residual safety risk.

4.5.4 Telemetry (TM) Data Requirements for Vehicles with Flight Termination

The specifications defined in this Section are intended as a synopsis for pre-flight and real time data requirements. Actual requirements shall be mission specific and the range user is responsible for coordinating TM data requirements with the WFF Safety Office.

4.5.4.1 Provide Command Receiver(s) signal strength Automatic Gain Control (AGC), check channel, arm and destruct indications for programs/projects utilizing a traditional FTS.

4.5.4.2 Provide Inertial Navigation System (INS) Parameters, if applicable.

4.5.4.3 Provide inertial position, velocity and acceleration, if applicable. Inertial Earth Centered Earth Fixed coordinates are preferred. All reference systems shall be defined.

4.5.4.4 Provide INS initialization parameters, if applicable.

4.5.4.5 Provide guidance commands including nozzle deflections in the pitch and yaw axes.

4.5.4.6 Provide vehicle attitude data including pitch, yaw and roll angles and rates.

4.5.4.7 Provide Motor Chamber Pressures.

4.5.4.8 Provide other FTS Parameters as required by the WFF Safety Office. This shall be documented in the program/project's tailoring.

4.5.4.9 Provide Control Circuit Status.

4.5.4.10 Provide FTS (or AFTS) External/Internal Battery Voltage.

4.5.4.11 Provide Safe/Arm Status.

4.5.4.12 Provide GPS Positional and Velocity Data.

4.5.4.13 For GPS, provide quality information such as number of satellites and dilution of precision (DOP).

4.5.5 Schedules for Providing Data

The specifications defined in this Section are intended as a synopsis for scheduling deliverables. Actual requirements shall be mission specific and the range user is responsible for coordinating schedules with the WFF Safety Office. If tailored requirements cannot be met during project execution, WFF Safety Office personnel may not be able to prepare all necessary safety plans in time to support the range operation. In every case, the mission shall not be conducted until adequate safety preparations are made.

4.5.5.1 For new launch vehicles with FTS including ELVs all preliminary data shall be submitted to the WFF Safety Office no later than T-330 days. All final data shall be supplied no later than T-100 days.

4.5.5.2 For launch vehicles previously flown from WFF with FTS including ELVs all preliminary data shall be submitted to the WFF Safety Office no later than T-200 days. All final data shall be supplied no later than T-90 days.

4.5.5.3 For rail launched unguided vehicle or payload systems not previously launched from WFF, all preliminary data shall be submitted no later than T-120 days. All final data shall be supplied no later than T-90 days.

4.5.5.4 For rail launched unguided vehicle or payload systems previously launched from WFF, all preliminary data shall be submitted no later than T-90 days. All final data should be submitted no later than T-60 days.

4.5.5.5 For balloon systems and manned and unmanned aircraft missions, all final data should be supplied no later than T-60 days. For more complex missions involving a large operating area (i.e. spanning multiple continents), additional time is required and shall be coordinated with the WFF Safety Office.