RANGE SAFETY GROUP

STANDARD 321-10

COMMON RISK CRITERIA STANDARDS FOR NATIONAL TEST RANGES

WHITE SANDS MISSILE RANGE
REAGAN TEST SITE
YUMA PROVING GROUND
DUGWAY PROVING GROUND
ABERDEEN TEST CENTER
ELECTRONIC PROVING GROUND
HIGH ENERGY LASER SYSTEMS TEST FACILITY

NAVAL AIR WARFARE CENTER WEAPONS DIVISION, PT. MUGU
NAVAL AIR WARFARE CENTER WEAPONS DIVISION, CHINA LAKE
NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION, PATUXENT RIVER
NAVAL UNDERSEA WARFARE CENTER DIVISION, NEWPORT
PACIFIC MISSILE RANGE FACILITY
NAVAL UNDERSEA WARFARE CENTER DIVISION, KEYPORT

30TH SPACE WING
45TH SPACE WING
AIR FORCE FLIGHT TEST CENTER
AIR ARMAMENT CENTER
ARNOLD ENGINEERING DEVELOPMENT CENTER
BARRY M. GOLDWATER RANGE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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15. SUBJECT TERMS
Range Safety Group; debris injury thresholds; debris hazard thresholds; acceptable risk criteria

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STANDARD 321-10

COMMON RISK CRITERIA STANDARDS FOR NATIONAL TEST RANGES

DECEMBER 2010

Prepared by

RANGE SAFETY GROUP
RISK COMMITTEE

Published by

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CHANGES TO THIS EDITION

This Standard replaces RCC Standard 321-07, Common Risk Criteria for National Test Ranges. The changes listed below apply to both this basic Standard and its RCC 321-10 Supplement.

The changes include:

a. Expanding the range safety criteria, policies, and processes to address the management of conditional risks, protection of critical assets, and treatment of risk model uncertainty.

b. Adding aircraft vulnerability criteria for business class jets.

c. Modifying the aircraft vulnerability criteria for large commercial transport aircraft.

d. Clarifying that the acceptable risk criteria are to be applied separately to launch and re-entry missions. Paragraph 4.2.2 in the Supplement was rewritten to clearly define the applicable types of launch and re-entry missions and their beginning and ending points.

e. Modifying the definition for mission essential personnel to include persons in training to perform specific tasks that are part of the current operation.

f. Updating the tables in Chapter 5 of the Supplement to list the criteria used by the national test ranges as of May 2010.

g. Moving the description of risk prediction uncertainty in Chapter 7 of the Supplement to a new paragraph in Chapter 4 of the Supplement since modeling uncertainty applies to all hazards, not just debris.

h. Modifying the description of catastrophic risk in Chapter 4 and Chapter 7 of the Supplement and combining them into a single paragraph in Chapter 4 of the Supplement.

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FOREWORD

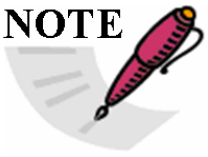
The Risk and Lethality Commonality Team (RALCT) was formed in 1996 for the purpose of reaching a consensus on reasonable common standards for debris protection criteria and analytical methods. The initial version, RCC 321-97, was very useful but was limited in scope due to the complexity of the subject and time constraints. The Standard was updated in 1999 and again in 2002 to provide additional detailed information. In August 2004, the Range Commanders Council (RCC), Range Safety Group (RSG) determined that RCC Standard 321-02, *Common Risk Criteria for National Test Ranges, Subtitle: Inert Debris*, should be updated and expanded to address other flight safety hazards (in addition to inert debris) and potential adverse consequences generated by range operations.

The RALCT became a standing committee under the RSG in 2004, and in February 2005, the RALCT was renamed the Risk Committee. The Committee subsequently developed RCC Standard 321-07 and its 321-07 Supplement. In 2010, the Committee replaced RCC Standard 321-07 and its 321-07 Supplement with Standard 321-10 and its 321-10 Supplement. Changes were made in response to RCC Tasks RS-48, RS-49, RS-50, and RS-51. The changes include:

a. Guidelines for assessing the acceptability of conditional risks associated with launch control measures.
b. Approach and sample criteria for evaluating the range safety hazards to critical assets.
c. Guidelines for accounting for and reporting the uncertainty in risk model predictions.

The RCC Standard 321-10 defines consensus standards for the range risk management process and risk criteria. The Supplement to RCC Standard 321-10 provides additional detailed information to assist in implementation of this basic Standard. The criteria in the basic Standard and its Supplement should not be considered absolute; rather, both are intended to provide guidance on defining acceptable risks for hazardous range operations and to assist the user in developing more consistent risk assessments.

This Standard represents the collective efforts of both government and contractor personnel and is the result of an extensive cooperative effort.

NOTE 	a. The RCC Standard 321-10 is referred to as the "Standard," the "RCC 321-10," or "321-10 Standard." b. The Supplement to RCC Standard 321-10 is referred to by using the word Supplement, such as "the Supplement," "Supplement," or the "321-10 Supplement."

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PREFACE

This Standard presents the results of work performed by the Risk Committee, Range Safety Group (RSG) in the Range Commanders Council (RCC). Planned and unplanned hazardous events generated by flight operations present a safety concern for all test ranges. Each range has established its own set of criteria and analytical methods for protecting personnel, facilities, aircraft, and other assets from hazardous operations. Although these separate efforts have been very successful, the logical relationships of criteria used at the test ranges, and across different operational hazards, are often difficult to comprehend. Therefore, the consensus standards presented in the 321-10 Standard and its Supplement are intended to:

a. Promote a uniform process among the ranges.
b. Promote valid, repeatable risk assessments.
c. Foster innovation to support challenging missions.
d. Nurture openness and trustworthiness among the ranges, range users, and the public.
e. Simplify the scheduling process.
f. Present common risk criteria that can reduce cost for users of multiple test ranges.

For development of this Standard, the RCC acknowledges the excellent work by the many participating members of the Risk Committee, as shown on the next page. The RCC gives special recognition to:

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NASA Dryden Flight Research Center (NASA/DFRC)
NASA Kennedy Space Center (NASA/KSC)
NASA Wallops Flight Facility (NASA Wallops)
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ACTA, Inc.
Aerospace Corporation
Air Force Space Command (AFSPC)
Analysis, Planning, Test Research, Inc. (APT Research)
ManTech

ACRONYMS

30 SW	30th Space Wing
45 SW	45th Space Wing
AAC	Air Armament Center
ABS	American Bureau of Shipping
ACGIH	American Conference of Government Industrial Hygienists
ADS	Automatic Destruct System
AEGL	Acute Emergency Guidance Level
AF	Air Force
AFB	Air Force Base
AFETAC	Air Force Environmental Technical Applications Center
AFFTC	Air Force Flight Test Center
AFI	Air Force Instruction
AFP	Air Force Pamphlet
AFPAM	Air Force Pamphlet
AFPD	Air Force Policy Directive
AFSPC	Air Force Space Command
AIAA	American Institute of Aeronautics and Astronautics
AIS	Abbreviated Injury Scale
ALARP	as low as reasonably practicable
ALCM	Air Launched Cruise Missile
ANSI	American National Standards Institute
APA	Administrative Procedures Act
AST	Associate Administrator for Space Transportation
BMD	Ballistic Missile Defense
BRL	Ballistics Research Lab
CA	Conjunction Assessment
CCAS	Cape Canaveral Air Station
CDC	Centers for Disease Control
CFR	Code of Federal Regulations
CMMI	Capability Maturity Model Integration
COLA	Collision Avoidance
CSC	Conical Shaped Charge
CSLA	Commercial Launch Space Act
DA	Department of the Army
DDESB	Department of Defense Explosives Safety Board
DFRC	Dryden Flight Research Center
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DOL	Department of Labor
DON	Department of the Navy
DOT	Department of Transportation
E/A	energy to area (ratio)
EPA	Environmental Protection Agency

ER	Eastern Range
FAA	Federal Aviation Administration
FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
FMEA	Failure Modes Effects Analysis
FMECA	Failure Modes Effects and Criticality Analysis
FOD	Foreign Object Damage
FRP	Fiber Reinforced Plastic
FSS	Flight Safety System
FTCA	Federal Tort Claims Act
FTS	Flight Termination System
GEMS	Generalized Energy Management System
GGUAS	Global Gridded Upper Atmosphere Statistics
GNC	Guidance, Navigation, and Control
GPa	Refers to: Annual General Public Risk
GPS	Global Positioning System
GRAM	Global Reference Atmospheric Model
HACK	Hazard Area Computation Kernel
HEBF	High Energy Blast Facility
HQ	Headquarters
HSC	High-speed Craft
ICAO	International Civil Aviation Organization
ICV	Intercept Control Volume
IDLH	Immediately Dangerous to Life or Health
IIP	Instantaneous Impact Point
ILL	Impact Limit Line
IMO	International Maritime Organization (United Nations)
ISDS	Inadvertent Separation Destruct System
ISS	International Space Station
JSpOC	Joint Space Operations Squadron
KE	Kinetic Energy
KIDD	Kinetic Impact Debris Distribution
KSC	Kennedy Space Center
LAP	Launch Assist Platform
LNG	Liquid Natural Gas
LOC	Level of Concern
MDA	Missile Defense Agency
MDA/QS	MDA Safety, Quality and Mission Assurance Directorate
MEa	Refers to: Annual Mission Essential Risk
MFCO	Missile Flight Control Officer
MPL	Maximum Probable Loss
MRTFB	Major Range and Test Facility Base
MSL	Mean Sea Level
NASA	National Aeronautics and Space Administration

NAVAIR PR	NAVAIR Patuxent River
NAVAIR	Naval Air Systems Command
NAWC	Naval Air Warfare Center
NAWCWD	Naval Air Warfare Center Weapons Division
NDI	Non-destructive Inspection
NDT	Non-destructive Test
NIOSH	National Institute of Occupational Safety and Health
NOHD	Nominal Ocular Hazard Distance
NPR	NASA Procedural Requirements
NPRM	Notice of Proposed Rulemaking
NRC	Nuclear Regulatory Commission
NTSB	National Transportation Safety Board
OPNAVINST	Chief of Naval Operations Instruction
OSHA	Occupational Safety and Health Administration
OV	Orbital Vehicle
PDF	Probability Density Function
PIRAT	Propellant Impact Risk Assessment Team
PMRF	Pacific Missile Range Facility
PSS	Premature Separation System
RALCT	Risk and Lethality Commonality Team
RANS	Range Squadron
RCC	Range Commanders Council
RSG	Range Safety Group
RSO	Range Safety Officer
RSS	Range Safety System
RTS	Reagan Test Site
SEI	Software Engineering Institute
SELR	Safety Launch Risk Analysis
SLASO	Space Licensing and Safety Office (Australia)
SNL	Sandia National Laboratories
SOH	Safety and Occupational Health
SPCS	Space Control Squadron
SRI	Stanford Research Institute
STIL	Short Term Interval Launch
STS	Space Transportation System
TCCR	Transparency, Clarity, Consistency, and Reasonableness
TPS	Thermal Protection System
TT	Thrust Termination
TVC	Thrust Vector Controller
U.S.	United States
USAF	United States Air Force
USAKA	United States Army Kwajalein Atoll
USC	United States Code
USCG	United States Coast Guard
UAV	Unmanned Air Vehicle
UN	United Nations

V&V	Verification and Validation
VAFB	Vandenberg Air Force Base
WFF	Wallops Flight Facility
WR	Western Range
WSMR	White Sands Missile Range
YPG	Yuma Proving Ground

CHAPTER 1

INTRODUCTION

1.1 Purpose

This Standard provides a common set of range safety policies, risk criteria, and guidelines for managing risk to people and assets during manned and unmanned flight operations, excluding aviation operations. This Standard establishes:

a. Acceptable risk criteria for both the general public (involuntary acceptance) and mission essential personnel (voluntary acceptance) excluding people in the launch or reentry vehicle.
b. Debris injury thresholds for unprotected people.
c. Debris hazard thresholds for aircraft and ships.
c. Vulnerability models for large commercial transport aircraft and business class jets.
d. An approach for evaluating flight hazards to critical assets.

1.2 Scope

The policies and criteria in this Standard are intended for use by members of the Department of Defense (DoD) national ranges and Major Range and Test Facility Base (MRTFB). These policies and criteria apply to launch and reentry hazards generated by endoatmospheric and exoatmospheric range activities including both guided and unguided missiles and missile intercepts, space launches, and reentry vehicles. Discussions on aviation operations and unmanned aerial vehicle (UAV) operations are excluded from this 321-10 Standard and the 321-10 Supplement. The Range Commanders Council (RCC) criteria for UAVs are contained in RCC Document 323-99, *Range Safety Criteria for Unmanned Air Vehicles*.

1.3 Implementation

This Standard is an advisory Standard. The content is based on the consensus positions held by the Risk Committee within the Range Safety Group (RSG), which is made up of a broad cross section of the United States (U.S.) range safety community. Therefore, the content of this Standard represents consensus standards. Consensus standards with the highest levels of priorities are generally provided in the main body of the basic standard, while the Supplement contains lower levels of priority requirements, guidelines, and example methods. However, precise language is used in both this Standard and the Supplement in an attempt to capture the intent of the Risk Committee. Example usages for selected words are:

a. Must, shall, and will. Indicate a requirement that is strongly recommended. Legitimate alternatives may exist, but an equivalent level of safety shall be demonstrated before employing an alternative; otherwise, a waiver must be granted.
b. Should. Indicates an advisory requirement or a highly desirable procedure. When this standard uses "should," the Risk Committee intends that a range will achieve

compliance to the maximum extent practical, but no waiver or equivalent level of safety will be required.

c. Can and may. Permit a choice and express a guideline.

To effectively implement guidance in this Standard, the range should review and evaluate the contents and incorporate appropriate guidance into local range regulations and requirements.

1.4 Range Responsibilities

Department of Defense Instruction (DoDI) 3200.18, Management and Operation of the Major Range and Test Facility Base (MRTFB), assigns responsibility to each Range Commander for ensuring that all missions are conducted safely and are consistent with operational requirements. Range flight operations typically involve some level of risk. Therefore, an important aspect of the range safety responsibility is to ensure that the risk is managed properly within prescribed limits. To accomplish this, each Range Commander (or designee) must:

a. Establish risk management procedures (including hazard containment) to implement the risk management process described herein.
b. Establish acceptable risk criteria appropriate to each type of mission flown in consideration of the guidance provided herein.
c. Accept any risks, including those that exceed the established risk criteria when warranted for a mission in consideration of the operational requirements and national need.
d. Make such decisions based on a thorough understanding of any additional risk that exceeds the risk criteria and the benefits to be derived from taking the additional risk.
e. Ensure such decisions are documented in a formal waiver process (or equivalent), preferably in advance of the mission.
f. Maintain related range policy and requirements documents.
g. Maintain records of risk assessments and waivers to established risk criteria.
h. For a mission involving more than one range, coordinate with the other range(s) to clearly document safety responsibility for each phase of the mission develop and implement joint plans for controlling the mission risk due to all planned and unplanned events.

CHAPTER 2

POLICIES AND PROCEDURES

2.1 General Policy and Goals

In planning any operation, risk must be reduced to the extent that is practical in keeping with operational objectives. Safety should be balanced with operational objectives by cooperative interaction between the range and the range user. To maximize achievement of mission objectives within safety constraints, the range user should consider overall risk along with other factors that affect mission acceptability. These factors include criticality of mission objectives, protection of life and property, the potential for high consequence mishaps, local political factors, and governing range or programmatic environmental requirements.

All ranges should strive to achieve complete containment of hazards resulting from both normal and malfunctioning flights. If a planned mission cannot be accomplished using a containment approach, a risk management approach may be authorized by the range Commander or the designated representative. The risk management approach should conform to the guidelines presented in this Standard or otherwise demonstrate compliance with the objectives presented.

Range Commanders should never regard events (such as injuries) as being routine or permissible. No adverse consequences are routinely acceptable; however, the probability is finite that range mishaps producing adverse consequences may occur. The term "acceptable risks" used herein can be properly interpreted as "tolerable risks." These are risks the range Commander may tolerate to secure certain benefits from a range activity with the confidence that the risk is properly managed within prescribed limits.

Compliance with this Standard leads to defensible launch support and launch commit decisions. Employing a sound basis for accuracy and repeatability in risk assessments leads to consistent risk acceptance decisions, thereby fostering public confidence that the ranges are operated with appropriate regard for safety. Thus, individuals living or working at or near a range may go about their daily lives without concern for their proximity to range activities. Moreover, compliance with these guidelines provides assurance that flights near or over communities by space boosters or weapon systems does not significantly increase the risk to these communities. These goals have led to the policy objectives provided here.

In defining objectives for risk assessment and risk management, the RCC goals are to:

a. Create a uniform process among the ranges that will achieve the stated risk management goals.
b. Promote accurate, repeatable risk assessments by minimizing errors in estimating and ensuring their scientific validity.
c. Create a process that fosters innovation to support challenging missions.
d. Nurture openness and trustworthiness among the ranges, range users, and the public.

2.2 Policy Objectives

2.2.1 General Public. The general public includes all people located on and off base that are not essential to a specific mission or nearby critical operation. This definition applies to all people regardless of whether they are in some mode of transportation (such as airplanes, ships, and busses), are within a structure, or are unsheltered. The general public should not be exposed, individually or collectively, to a risk level greater than the background risk in comparable involuntary activities, and the risk of a catastrophic mishap should be mitigated.

In the above context, the RCC considers "comparable involuntary activities" as those where the risk arises from manmade activities that:

a. Are subject to government regulations or are otherwise controlled by a government agency, and
b. Are of vital interest to the U.S., and
c. Impose involuntary risk of serious injury or worse on the public.

2.2.2 Mission Essential Personnel. A certain degree of risk is inherent in hazardous operations. The mission essential individuals may include persons in training to perform specific tasks that are part of the current operation. The range commander or mission director (or their designees) should identify the mission essential personnel in training and justify their designation as mission essential. Those so designated should not be exposed, individually or collectively, to a risk level greater than that found in comparable high-risk occupations, and the risk of a catastrophic mishap should be mitigated.

2.2.3 Critical Operations Personnel. These individuals include persons not essential to the specific operation or launch currently being conducted, but who are required to perform safety, security, or other critical tasks at the range. The critical operations range user (or manager) provides the number and justification of personnel required to conduct the critical operations. The range safety personnel will approve or determine the number and location of critical operations personnel individuals with the concurrence of the appropriate decision authority. The critical operations individuals should be included in the same risk category as mission essential personnel.

2.2.4 Catastrophe Potential and Transportation Systems. People on aircraft, ships, and other modes of transportation and people on oil rigs and offshore platforms should be protected to a level commensurate with the background risk associated with those activities. The risk assessment should account for potential catastrophic consequences to all exposed people, and mitigations should be implemented to ensure that the risk from catastrophic events is consistent with the allowable risk given in paragraph 3.6.3 and paragraph 3.6.4.

Scenario-specific information should be considered in providing protection against catastrophic consequences. Combinations of factors that should be considered include the number of people who may be simultaneously injured, the risk of damage to high value assets, the risk of a casualty, factors that may significantly impair the range's ability to perform its mission, and factors that may have national or international consequences.

Transportation systems include all modes of transportation such as airplanes, ships, trains, busses, and automobiles. People in transportation systems must be categorized following the same rules that apply to unsheltered people and people in fixed shelters (i.e., mission essential personnel, critical operations personnel, or general public. Each individual in a transportation system must be protected to the level for his population category (i.e., one of the three categories in the preceding sentence. Collective risk must be assessed to include people in transportation systems. The collective risk to people in transportation systems must be added to the collective risk for unsheltered people and the collective risk for sheltered people. The numerical value defining the acceptability of the total collective risk must be based on the population category. Additional protection, such as defined in paragraph 3.6, must be applied to people in transportation systems in order to minimize the potential for catastrophic risk.

2.2.5 Spacecraft. Orbiting manned spacecraft will be protected to a level equivalent to that provided to mission essential aircraft. When the planned missions involve vehicles or propagated hazards with altitude capability greater than 150 km, ranges should coordinate with the Joint Space Operations Squadron (JSpOC) for Conjunction Assessment if needed. In addition, ranges should establish Collision Avoidance periods in the launch window if there are any manned spacecraft within 50 km of, or lower than, the 3-sigma altitude capability of the launch vehicle, payloads, jettisoned objects or debris cloud boundary.

The Risk Committee recognizes that protection for critical unmanned space systems should also be provided; however, it is currently considered outside the scope of this safety standard. While DoDD 3100.10 states that DoD activities are to be conducted "…in a safe and responsible manner that protects space systems…," it does not specify which DoD activity, the launching agency (range user) or the range, has the responsibility for assuring this protection.[1] Until responsibility is resolved by appropriate authorities, the Risk Committee recommends that the launching agencies and the ranges continue their current practices.[2]

2.2.6 Critical Assets. Damage to range resources can have public safety, as well as mission assurance implications. As a minimum, the decision authority should protect resources that could increase the risk to surrounding population centers if they were damaged or not available in the event of an emergency. Additionally, since national security is dependent on range resources, the decision authority should consider the protection of selected facilities and equipment necessary to conduct the range's mission

In this Standard, critical assets include property that is essential to protect the public health and safety, maintain the minimum operations of the range, or protect the national security or foreign policy interests of the U.S. Critical assets include property/infrastructure that must remain operational following a mishap such as range facilities and equipment, as well as hospitals, fire stations, and power plants/substations.

[1] Historically, protection of unmanned systems has been addressed as part of mission assurance by the launching agency but only for DoD missions or highly valued NASA missions. In the commercial space industry, the launching agency retains liability insurance to cover such potential mishaps and has historically not utilized conjunction assessments for mission assurance or asset protection purposes.

[2] In the case of the Air Force, the roles and responsibilities for collision avoidance are documented in AFI 91-217.

The criteria for protecting critical assets depend on the consequences of an impact. Criteria can be influenced by the importance of the critical asset in terms of emergency response or continued range operations, the down time and cost of repairing the critical asset, as well as other considerations. Therefore, the individual ranges need to establish the protection criteria to meet the policy objective for their particular situation. For illustration purposes, sample criteria are included in Chapter 4 of the Supplement. The ranges will need to modify the criteria to fit the conditions at their particular range.

2.2.7 Environment. As part of environmental documentation preparation in compliance with federal and local regulations, the launch and flight test hazards should be taken into account and mitigated as necessary. While safety is a factor in environmental compliance, environmental protection and regulation is beyond the scope of this standard.

2.3 Risk Management Process

Risk management is a systematic and logical process to identify hazards and control the risk they pose. This process should include the phases shown in Figure 2-1.

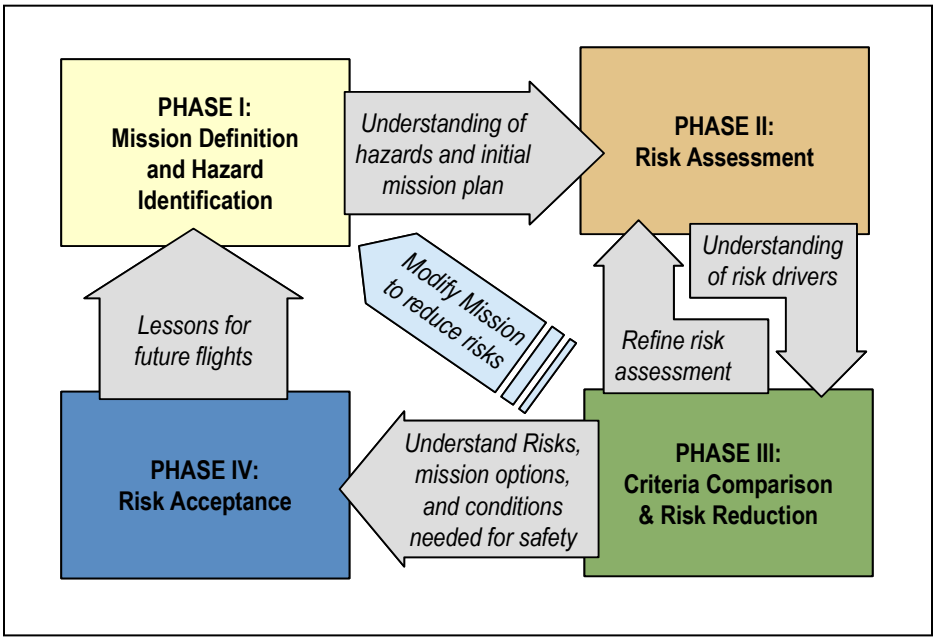

Figure 2-1. Risk management process.

The risk management phases are:

a. Phase I Mission Definition and Hazard Identification (paragraph 2.3.1)
b. Phase II Risk Assessment (paragraph 2.3.2)
c. Phase III Criteria Comparison and Risk Reduction (paragraph 2.3.3)
d. Phase IV Risk Acceptance (paragraph 2.3.4)

The initial goal of the risk management approach is to contain the hazards and isolate them from populated areas wherever practical. An alternative to hazard isolation is to define

hazard containment areas so as to minimize the population exposed or be able to evacuate persons not associated with the hazard-generating event. This is in accordance with the primary policy that no hazardous condition is acceptable if mission objectives can be attained from a safer approach, methodology, or position (i.e., minimizing the hazards and conducting the mission as safely as reasonably possible). When hazards cannot be contained or minimized to an insignificant level, more detailed assessments are performed to determine if the remaining risk is acceptable. An additional benefit of hazard containment is that this process is typically less costly than risk assessments and can be evaluated relatively quickly with straightforward assumptions and with less required data.

2.3.1 Phase I: Mission Definition and Hazard Identification. Phase I is the "problem definition" step of the process. Information is assembled to identify mission characteristics, objectives, and constraints. Potential hazard sources must be identified by evaluating the system to be flown and the range safety constraints. Information sources typically include:

a. Range safety data packages.
b. System description documents.
c. Mission essential and critical operations personnel locations.
d. Surrounding population data to include public and commercial facilities and public and commercial transportation assets (including aircraft corridors and shipping lanes).
e. Seasonal meteorological data.
f. The range safety system used.
g. Lessons learned on similar missions.

Further details of information sources are in Chapter 2 and Chapter 7 of the Supplement to this Standard. The output of this step provides a basis for hazard analysis and risk assessment and for use in evaluating options for mitigating risks in ways that will minimize adverse mission impact.

2.3.2 Phase II: Risk Assessment. This step provides information needed to determine whether further risk reduction measures are necessary. Risk levels for identified hazards are expressed using qualitative and quantitative methods. This step produces basic measures of the risks posed by hazards. These hazards include inert, explosive, and flammable debris dispersions, explosive overpressure fields, exposure to toxic substances, and exposure to ionizing and non-ionizing radiation. In some cases, this step will provide sufficient information to support the decision-making without further analysis.

A valid risk assessment must account for all potential hazards posed by the range activity to personnel, facilities, and other assets. The assessment must be based on accurate data, scientific principles, and an application of appropriate mathematics. The assessment must be consistent with the range safety control that is planned for the mission. Valid calculations to assess risk can be made using the methods presented in the Supplement. These typically produce conservative estimates (i.e., they produce a scientifically plausible result that characteristically overestimates risk given existing uncertainties). In all cases, the analyst is responsible for ensuring that the application of the methods in the Supplement produces reasonable results. This

assessment leads to mitigation measures needed to protect individuals and groups of people. This topic is discussed more fully in Chapter 3.

In general, risk is expressed as the product of the probability of occurrence of an event and the consequences of that event. Total risk is the combination of the products, over all possible events, of the probability of each event and its associated consequence. The probability of an event is always between zero and one; however, the consequences of that event can be any value. Risk can be relatively high if the probability is high, or the consequence is great, or a combination of the two.

Simple risk models are often employed to make an initial determination of risk. They are also used when the identified hazards are known to result in low risks and the analyst is assured that the estimated risk is conservative. For example, simple models can be used when only inert debris occurs and the debris is fairly limited in size and weight with relatively low values of kinetic energy or ballistic coefficients and shelters would provide protection from debris. These models are generally less costly, minimize schedule impacts, and have the following characteristics:

a. Simplified application of input parameters and assumptions.
b. Simplified measures of population estimation utilized.
c. A basic injury model and associated casualty areas.
d. Conservative assumptions of debris fragmentation and survivability.

If the resulting risk estimate is conservative and well within acceptable limits, then models that are more costly and time consuming, more complex, or of higher fidelity, will not be necessary.

When the identified hazards are significant or the initial risk estimate shows that acceptance criteria are, or may be, exceeded, then more complex risk models are typically used. Use of these models may be more costly, be time consuming to execute, and require a higher fidelity and more sophisticated application of input data and assumptions. The assessment may require detailed population and sheltering models, more complex human vulnerability models, and more realistic debris fragmentation and survivability models. This may require input parameters and assumptions to be supported by empirical evidence or expert elicitation and quantification of the impact of uncertainty in the risk model and model parameters. Complex risk assessment models are typically used when significant size debris or explosive debris impacts are present that could compromise shelters and the associated population.

2.3.3 Phase III: Criteria Comparison and Risk Reduction. Risk measures are compared with criteria to determine the need or desirability for risk reduction. If the risk is initially unacceptable, measures should be considered to eliminate or mitigate it. Elimination is achieved by design or system changes that remove the hazard source, such as replacing a hazardous material with a non-hazardous one or moving a trajectory to achieve containment. Mitigation is achieved by reducing the consequences of an event or the probability of an event happening. For example, increasing system reliability of a launch vehicle or test article will increase the probability of success, thereby lowering risk. Alternatively, designing a mission to avoid flight

over densely populated areas will decrease consequences of casualties and thereby reduce the risk. Mitigation measures may include elements in the operation plan that reduce risk and are consistent with operational objectives, flight termination systems, containment policies, evacuation, sheltering, and other measures to protect assets from the hazards. Flight termination criteria and mission rules should be reviewed to assure that the risks induced, should they be exercised, are tolerable. To evaluate the effectiveness of mitigation measures, risk must be reassessed assuming they have been implemented. These risk reduction procedures should be followed until risk levels are as low as reasonably practical.

2.3.4 Phase IV: Risk Acceptance. Presentations to the decision authority must be sufficient to support an informed decision. The presentations should include all range-mandated risk control measures, residual risks, measures of catastrophic loss potential (such as collective risk given a flight termination action, collective risk given failure of a flight termination system, and risk profiles), key analysis assumptions, the size and impact of uncertainties in the analysis and the protective measures that have been considered and implemented and their effectiveness. The decision authority must approve proposed mission rules and should compare the operational risk to the criteria defined in this Standard and to other applicable mission requirements. When local agreements are in place and the range has adequately communicated the content and rationale of RCC Standard 321 to the representatives of local government, local agreements should govern. This shall not be interpreted as overriding any Federal or state laws or regulations. The three-tiered hierarchy of requirements is federal and state laws and regulations, local agreements, and RCC Standard 321.

In general, higher-risk operations require a higher level of approval. The Range Commander may tolerate risk levels within criteria given herein to secure certain benefits from a range activity with the confidence that the risk is properly managed and consistent with "best practices." The outcome of these presentations to the decision authority is the acceptance of operational risks by a properly informed decision authority. This acceptance includes a determination that the residual operational risk is within tolerable limits. By doing so, it avers/ justifies that the proposed conditions for allowing the operation to be initiated and the rules to allow the mission to continue to completion comply with "best practices" for ensuring that the risk is less than accepted/tolerable levels.

The terms of this acceptance and required implementation conditions must be documented. The responsible safety office should document a risk assessment to demonstrate compliance with the risk management policy applied.

2.3.5 Conditional Risk Management. Flight termination action is a good example of a risk mitigating safety intervention that induces a conditional risk that should be managed. A conditional risk management process should be implemented to assure that mission rules and flight termination criteria do not induce unacceptable levels of risk when they are implemented. This review process is outlined in the Supplement in paragraph 2.5 and paragraph 2.8. The relationship between the risk management process just outlined and the conditional risk management process is shown in Figure 2-2.

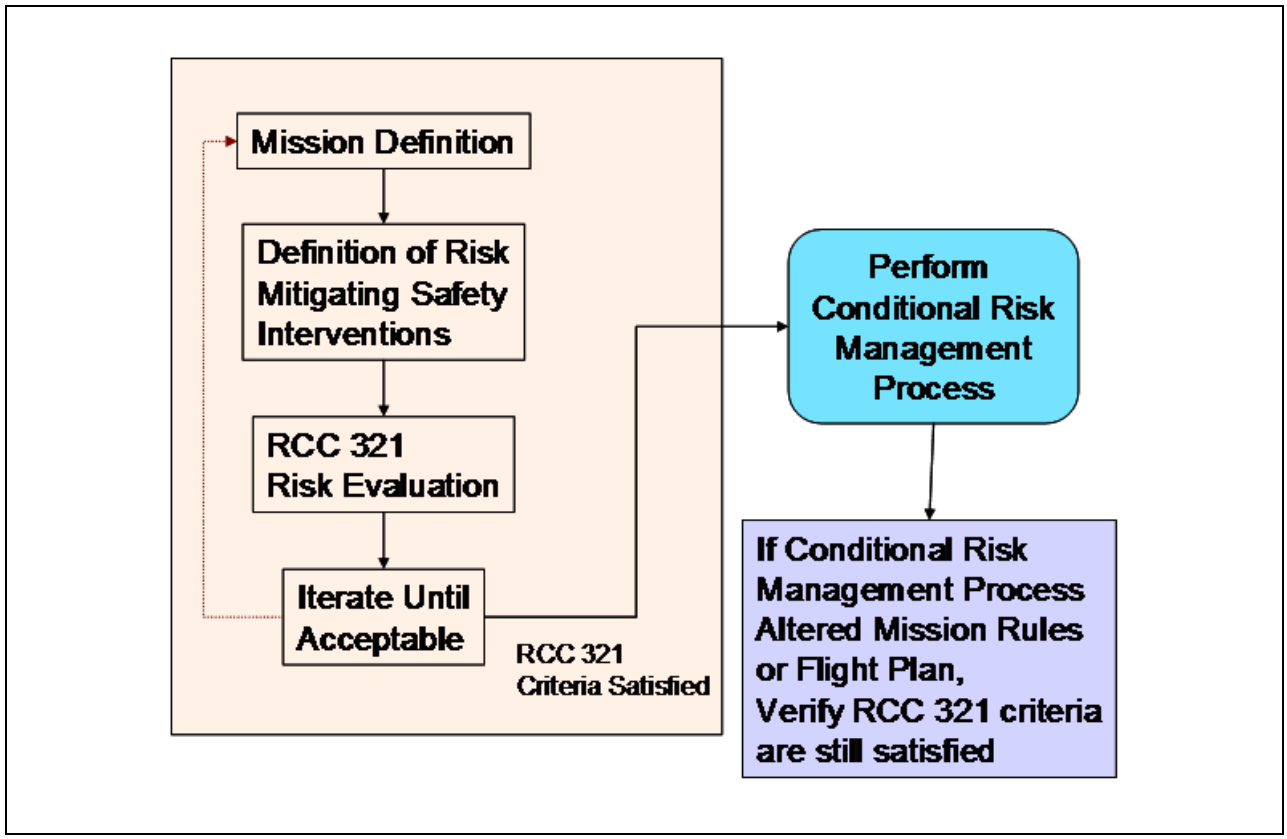

Figure 2-2. Relationship between conditional risk management and basic risk management.

2.4 Uncertainty in the Computed Risk

The Risk Committee recognizes that there is significant uncertainty in the computed risks of rocket launches. Ninety 90 percent confidence bounds describing the uncertainty in the computed risk can have a range of several orders of magnitude. For this reason, uncertainty cannot be ignored. However, it is not necessary to deal with uncertainty if the estimate of the E_C or E_F is so small that even with a large uncertainty the true risk is unlikely to challenge the acceptability criterion. The Risk Committee has introduced a process whereby the uncertainty does not have to be considered if the computed risk is less than one-third of the primary aggregated collective risk criterion.[3] On the other hand, if the risk level does not pass this test, the range should compute the uncertainty to assure that a launch is not allowed that would violate the criterion based on best estimates that account for uncertainty. The decision process regarding risk acceptability under uncertainty is shown in Figure 2-3.

[3] The choice of 1/3 is consistent with the recommendation in Air Force Space Command (AFSPC) Manual 91-710VI, 1 July 2004, which uses 30×10^{-6} as the acceptability criterion for casualty expectation. In the range between 10 and 30×10^{-6} (equivalent to one third of the risk criterion), AFSPCMAN 91-710V1, Attachment 4, page 11 states: "A4.4.2.2. Hazard Risks >10 through 30 in 1,000,000 ($E_C > 10\times10^{-6}$ through 30×10^{-6}). This level of risk may require the Range User to take additional measures to protect personnel and resources. Examples include fix/correct/improve existing noncompliances, improve risk analyses to reduce the level of uncertainty, require day-of-launch risk analyze, establish disaster aversion criteria. Range safety is the approval authority for risks >10 through 30 in 1,000,000 ($E_C > 10\times10^{-6}$ through 30×10^{-6}). "

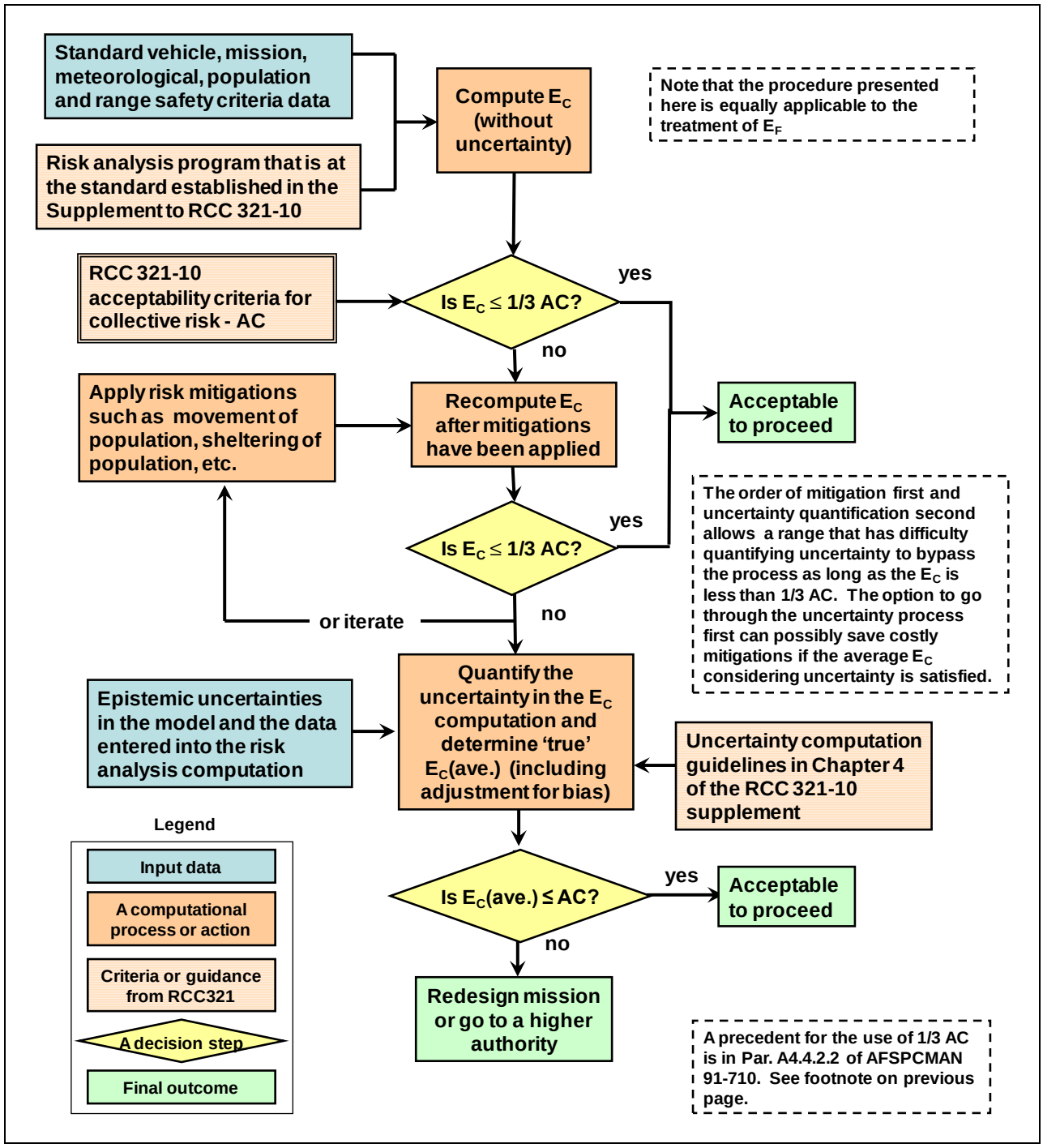

Figure 2-3. Flow diagram for the launch risk acceptability process considering uncertainty.

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CHAPTER 3

ACCEPTABLE RISK CRITERIA

This chapter defines acceptable risk criteria for people, aircraft, ships, and spacecraft that may be exposed to hazards associated with range flight operations. Hazard thresholds for people, aircraft, and ships are provided in Chapter 6 of the Supplement.

There are two major components of the risk acceptability criteria: a set of performance standards for establishing and implementing appropriate risk criteria at a range, followed by a set of quantitative standards. The quantitative risk criteria contained in this chapter prescribe limits on a per mission and an annual basis. The per mission requirements are intended to apply separately to launch and reentry missions as defined in the glossary. Chapter 4 of the Supplement provides guidelines for establishing a risk budget for complex missions, such as those that involve multiple launches or distinct phases of flight. Chapter 4 also provides guidelines for implementation of these criteria, including annual risk management, catastrophe aversion, as well as protection of ships, aircraft, and manned spacecraft.

3.1 Performance Standards

Each range must:

a. Assess the risk to all people from launch and reentry activities in terms of hazard severity and mishap probability. Note: Hazardous operations that can be contained within a controlled area may not require a risk assessment.
b. Estimate[4] the expected casualties associated with each activity that falls within the scope of this Standard. Additional risk measurements may be useful for range operations that are dominated by fatality to ensure fatality risks do not exceed acceptable limits.
c. Document its measure(s) of risk and risk acceptability policy in local requirements and policy documentation.
d. Maintain documentation to demonstrate that its risk measures provide a complete and accurate assessment of the risks, to include documentation needed to demonstrate that its risk measures:
   (1) Clearly convey the risk for decision makers.
   (2) Are consistent with the measures used by other scientific or regulatory communities involved in "comparable involuntary activities" (as described in paragraph 2.2.1).
e. Estimate the risk on a per mission basis, except under special conditions where risk management on an annual basis is justified as described below.
f. Periodically conduct a formal review to ensure that its activities and its mission risk acceptability policy are consistent with the annual risk acceptability criteria.

[4] The overall process is a risk assessment, but a particular value (i.e. a point estimate) is referred to as an estimate.

3.2 Personnel Protection

3.2.1 General Public.

a. Individual Risk Criteria. Individuals must not be exposed to a probability of casualty greater than 1E–6 for any single mission[5]. If fatality risks are also incorporated into the risk management process, then individuals must not be exposed to a probability of fatality greater than 0.1E–6 (1E–7) for any single mission.

b. Collective Risk Criteria. The collective risk for the general public must not exceed a casualty expectation of 100E–6 (1E–4) for any single mission[7]. If annual risk is measured, collective risk for the general public should not exceed a casualty expectation of 3000E–6 (3E–3) on an annual basis[6]. Risk management using only an annual measure of collective risk is only justified for range operations that occur frequently and pose low[7] risk on a per mission basis. If fatality risks are also incorporated into the risk management process, then the collective risk for the general public must not exceed 30E–6 (3E–5) expected fatalities for any single mission. If risk management using only annual risks is justified, and fatality risks are also incorporated into the risk management process, then the collective risk for the general public must not exceed 1000E–6 (1E–3) expected fatalities on an annual basis.

c. Catastrophic Risk Criteria. Catastrophic risk for the general public[8] should not exceed the provisional[9] criteria outlined in paragraph 3.6.3.

3.2.2 Mission Essential Personnel and Critical Operations Personnel.

a. Individual Risk Criteria. Individual mission essential and individual critical operations personnel must not be exposed to a probability of casualty greater than 10E–6 (1E–5) for any single mission. If fatality risks are also incorporated into the risk management process, then individual mission essential and critical operations personnel must not be exposed to a probability of fatality greater than 1E–6 for any single mission.

b. Collective Risk Criteria. Collective risk for mission essential and critical operations personnel must not exceed a casualty expectation of 300E–6 (3E–4) for any single mission. If annual risk is measured, collective risk for mission essential and critical operations personnel must not exceed a casualty expectation of 30000E–6 (3E–2) on an annual basis[1]. Risk management using only an annual measure of collective risk is

[5] If a flight operation creates a toxic risk, then the range must separately ensure the allowable level of risk enforced by them does not exceed other standards for toxic exposure limits for the public when appropriate mitigations are in place. Chapter 8 of the Supplement provides an approach for implementing this requirement.
[6] Chapter 4 of the Supplement provides guidelines to assist in the implementation of annual risk management.
[7] In this context, "low risk" means approximately two orders of magnitude below the per flight criteria for collective and individual risks.
[8] This includes people in any transportation system, such as ships and aircraft, as described in Chapter 4 of the Supplement.
[9] The Risk Committee intends to investigate this further and the criteria are subject to change in the future.

only justified for range operations that occur frequently and pose low[4] risk on a per mission basis. If fatality risks are also incorporated into the risk management process, then collective risk for mission essential and critical operations personnel must not exceed an expected number of fatalities of 300E–6 (3E–4) for any single mission. If risk management using only annual risks is justified, and fatality risks are also incorporated into the risk management process, then the collective risk for mission essential and critical operations personnel should not exceed 10000E–6 (1E–2) expected fatalities on an annual basis.

c. Catastrophic Risk Criteria. Catastrophic risk for mission essential and critical operations personnel should not exceed the provisional criteria outlined in paragraph 3.6.4.

3.3 Aircraft Protection[10]

3.3.1 Non-Mission Aircraft Criteria.

a. Non-Mission Aircraft Hazard Volumes. Non-mission aircraft will be restricted[11] from hazard volumes of airspace where the cumulative probability of impact of debris capable of causing a casualty on an aircraft[12] exceeds 0.1E–6 (1E–7) for all non-mission aircraft. As an alternative to protecting against a probability of impact, non-mission aircraft will be restricted from hazard volumes that exceed the individual risk criteria given in paragraph 3.2.1a and the catastrophe criterion given in paragraph 3.6.3[13]

b. Non-Mission Aircraft Risk Criteria. The individual and collective risks posed to the general public in any aircraft must comply with the criteria in paragraph 3.2.1.

3.3.2 Mission Essential Aircraft Criteria.

a. Mission Essential Aircraft Hazard Volumes. Mission essential aircraft will be restricted [11] from hazard volumes of airspace where the cumulative probability of impact of debris capable of causing a casualty on an aircraft exceeds 1E–6 for all mission essential aircraft. As an alternative to protecting against a probability of

[10] Chapter 4 of the Supplement provides important guidelines on the proper implementation of aircraft protection measures.
[11] In this context restricted from means that the range will (1) ensure that appropriate warnings/restrictions are issued through the FAA, and (2) not proceed with the hazardous activity if the range has knowledge that any aircraft hazard volume is violated.
[12] Chapter 6 of the Supplement provides threshold values to help define such debris.
[13] The Supplement explains how hazard areas can be defined using probability of impact values and demonstrate compliance with 3.3.1.2. A range may prefer to use other methods that demonstrate compliance with the individual and collective risk criteria. In any case, the individual and collective risk criteria requirements always apply to all people, regardless of transportation mode.

impact, mission essential aircraft will be restricted from hazard volumes that exceed the individual risk criteria given in paragraph 3.2.1a and the catastrophe criterion in paragraph 3.6.4.[14]

b. Mission Essential Aircraft Risk Criteria. The individual and collective risks posed to mission essential personnel in any aircraft must comply with the criteria given in paragraph 3.2.2.

3.3.3. Aircraft Hazard Volumes for Planned Debris Releases. The range must confirm that Notices to Airmen (NOTAMS) are issued that encompass the volume and duration necessary to protect from each planned debris release[15] capable of causing an aircraft accident.[16]

3.3.4. Mishap Response. The range must coordinate with the FAA to ensure timely notification[17] of any expected air traffic hazard associated with range activities. In the event of a mishap, the range must immediately inform the FAA of the volume and duration of airspace where an aircraft hazard is predicted.

3.4 Ship Protection[18]

The term "ship" includes boats and watercraft of all sizes.

3.4.1 Non-Mission Ship Criteria.

a. Non-Mission Ship Hazard Areas. Non-mission ships will be restricted[19] from hazard areas where the probability of impact of debris capable of causing a casualty [20] exceeds 10E–6 (1E–5) for non-mission ships. Non-mission ships should also be restricted from hazard areas where the cumulative probability of impact of debris capable of causing a catastrophic accident[21] exceeds 1E–6 for all non-mission ships.

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[14] The Supplement explains how hazard areas can be defined using probability of impact values and demonstrate compliance with 3.3.2.b. A range may prefer to use other methods that demonstrate compliance with the individual and collective risk criteria. In any case, the individual and collective risk criteria requirements always apply to all people, regardless of transportation mode.

[15] Planned debris releases includes intercept debris, jettisons stages, nozzle covers, fairings, inter-stage hardware, etc.

[16] Federal law (49 CFR 830.2) defines an aircraft accident as "an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage." As described in the glossary, federal law also defines death, serious injury, and substantial damage for the purposes of accident reporting.

[17] This may be accomplished through preflight analyses and coordination as described in Chapter 4 of the Supplement.

[18] Chapter 4 of the Supplement provides important guidelines on the proper implementation of ship protection measures.

[19] In this context restricted from means that the range will (1) ensure that appropriate warnings/restrictions are issued through the U.S. Coast Guard (USCG) or other appropriate authorities, and (2) not proceed with the hazardous activity if it has knowledge that any ship hazard area is violated.

[20] This includes any debris capable of producing a casualty to an unsheltered person.

[21] In the absence of valid ship vulnerability modeling, this includes any debris capable of deck penetration as described in Chapters 4 and 6 of the Supplement to this standard.

As an alternative to protecting against a probability of impact, non-mission ships will be restricted from hazard areas that exceed the individual risk criteria given in paragraph 3.2.1a and the catastrophe criterion given in paragraph 3.6.3.

b. Non-Mission Ship Risk Criteria. The individual and collective risks posed to the general public in any ship must comply with the criteria given in paragraph 3.2.1.

3.4.2 Mission Essential Ship Criteria.

a. Mission Essential Ship Hazard Areas. Mission essential ships will be restricted[19] from hazard areas where the probability of impact of debris capable of causing a casualty exceeds 100E–6 (1E–4) for mission essential ships. Mission essential ships should also be restricted from hazard areas where the cumulative probability of impact of debris capable of causing a catastrophic accident exceeds 1E–5 for all mission ships. As an alternative to protecting against a probability of impact, mission essential ships will be restricted from hazard areas that exceed the individual risk criteria given in paragraph 3.2.1a and the catastrophe criterion in paragraph 3.6.4.

b. Mission Essential Ship Risk Criteria. The individual and collective risk posed to the mission essential personnel in any ship must comply with the criteria given in paragraph 3.2.2.

3.4.3 Ship Hazard Areas for Debris Releases. The range must confirm that Notices to Mariners (NOTMARs) are issued that encompass the area and duration necessary to protect from each planned debris impact capable of causing a ship accident.

3.4.4 Mishap Response. The range must coordinate with the USCG or other appropriate authorities to ensure timely notification of any ship traffic hazard associated with range activities. In the event of a mishap, the range must promptly inform the appropriate authority(s) of the area and duration of navigable waters where a ship hazard is predicted.

3.5 Spacecraft Protection

A spacecraft is considered manned if it is currently occupied, or expected to be occupied, and includes spacecraft en route to, and in support of, manned missions. Manned spacecraft shall be protected by:

a. Not exceeding a probability of impact greater than 1E–6 per spacecraft, or
b. Ensuring an ellipsoidal miss-distance of 200 km in-track and 50 km cross track and radially, or
c. Ensuring a spherical miss-distance of 200 km.

For objects (including launch vehicle, payload, jettisoned components, or planned debris) launched into a sustainable orbit, the duration of the conjunction assessment required for manned spacecraft protection shall be applied from launch through orbit insertion plus an analyst defined number of revolutions to account for (1) the type orbit the vehicle or component is injected into, operating in, or passing through, (2) its altitude exceeding the manned spacecraft altitude by the

appropriate miss-distance, and (3) a sufficient time for the object to be catalogued. Prior coordination with the First Space Control Squadron (1st SPCS) may allow an earlier time for the object to be catalogued and thereby result in a shorter duration for the conjunction assessment required to be performed for the launch range. Besides the launch vehicle and payload, conjunction assessments must include all components jettisoned during the launch and intentionally propagated debris.

Spacecraft vulnerability must be accounted for in the risk assessment, and the minimum debris size ascertained from the spacecraft operator whenever practicable. Otherwise, the spacecraft should be considered vulnerable to the current minimum debris size of 1 mm or greater.

3.6 Catastrophic Risk Protection

Catastrophic[22] risk criteria are designed to protect against scenarios involving numerous casualties. The following provisional catastrophic risk criteria are suggested guidelines to supplement the collective and individual risk criteria given in paragraph 3.2. Catastrophic risk assessments are especially useful for pre-flight analyses intended to evaluate and mitigate potentially catastrophic outcomes.

3.6.1 General. Missions must be permitted only when the catastrophic risks are consistent with the policy objectives given in paragraph 2.2.

3.6.2 Ship and Aircraft Hazard Areas. If ships and aircraft are excluded from the hazard areas designed to protect against excessive probability of impact limits provided in paragraph 3.3 and paragraph 3.4 in accordance with the guidelines set in Chapter 4 of the Supplement, then the catastrophic risks to ships and aircraft are consistent with the policy objectives of paragraph 2.2.

3.6.3 General Public Criterion. Catastrophic risks for the general public should not exceed the following provisional criteria:

$$P[\geq N] \leq \frac{1\times10^{-4}}{N^{1.5}} \qquad \text{(Eq. 3-1)}$$

Where

$P[\geq N]$ = cumulative probability of all events capable of causing N or more casualties.
N = number of casualties, based on the occupant load as defined in Table 3-1.
10^{-4} = maximum acceptable expected casualties as defined in paragraph 3.2.1b.

Figure 3-1 shows the relationship between P and N for the public that satisfies this criterion.

[22] The term catastrophic refers to multiple casualties with a minimum ranging from five to ten depending upon the particular regulation. The criterion presented here is "risk averse," a term that is used in the academic literature and applies to all values of N greater than one. Thus, the term catastrophe averse is a subset of the term risk averse. Another expression that could also be used is aversion to increasing numbers of casualties.

TABLE 3-1. DEFINITIONS USED TO DEFINE TOLERABLE CATASTROPHIC RISKS

Population Type	Catastrophic Outcome	Occupant Load (*N*)
Public Aircraft	An occurrence resulting in multiple fatalities,[a] usually with the loss of the airplane[b]	Maximum occupancy
Mission Essential or Critical Aircraft	An occurrence resulting in multiple fatalities, usually with the loss of the airplane	Expected occupancy
Public Ship	An occurrence resulting in multiple casualties, usually with loss of the ship	Maximum occupancy
Mission Essential or Critical Ship	An occurrence resulting in multiple casualties, usually with loss of the ship	Expected occupancy
Public Land Vehicle	An occurrence resulting in multiple casualties, usually with loss of the vehicle	Maximum occupancy
Mission Essential or Critical Land Vehicle	An occurrence resulting in multiple casualties, usually with loss of the vehicle	Expected occupancy
Public Train	An occurrence resulting in multiple casualties, usually with loss of the train	Maximum occupancy
Mission Essential or Critical Train	An occurrence resulting in multiple casualties, usually with loss of the train	Expected occupancy
Public Gatherings[c]	An occurrence resulting in multiple casualties	Maximum credible occupancy
Mission Essential or Critical Personnel Gathering	An occurrence resulting in multiple casualties	Expected occupancy

a. The Federal Aviation Administration (FAA) also has a formal definition for "severe consequence:" forced landing (which is also formally defined), loss of aircraft while occupants are on-board, serious injuries (as formally defined), or fatalities.
b. FAA Advisory Circular 39-8.
c. Public gathering places subject to catastrophic accidents include any locations where population concentrations may occur, such as schools, hospitals, stadiums, beaches, etc.

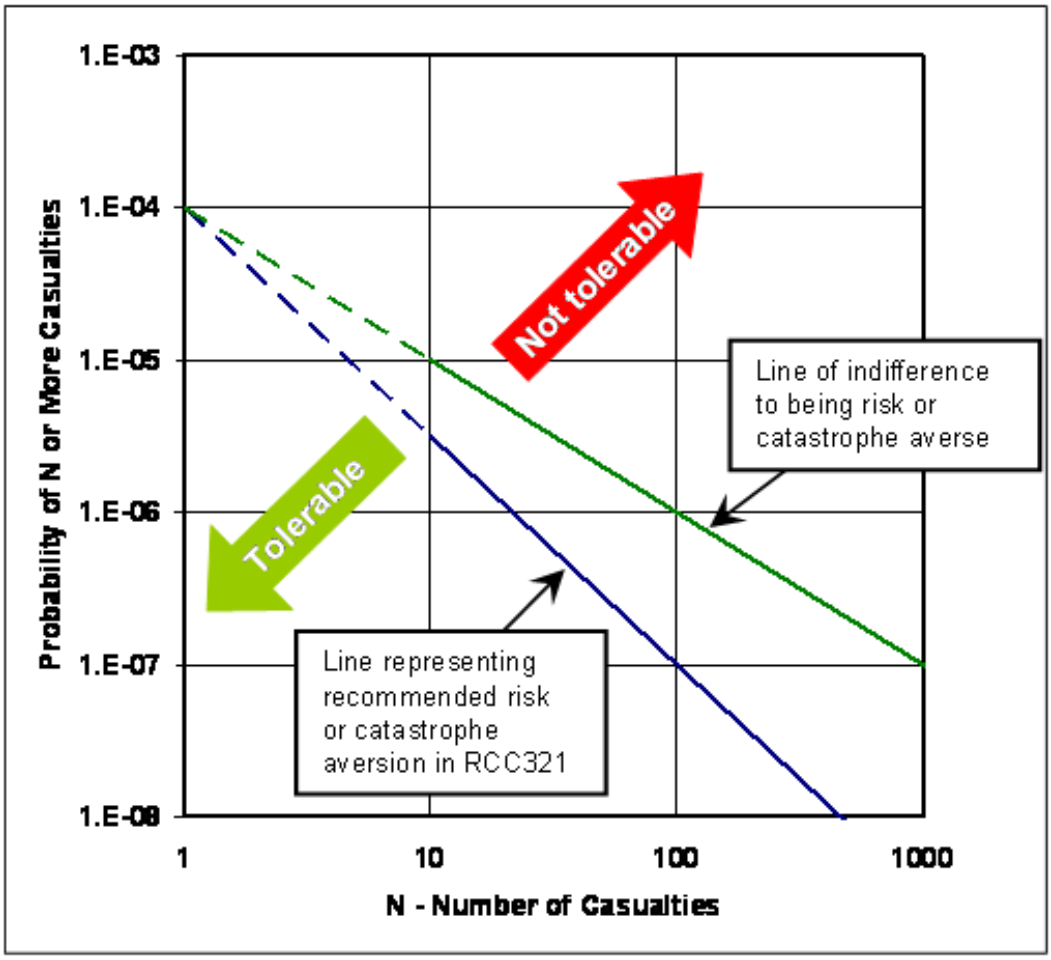

Figure 3-1. Tolerable catastrophic risks for the public.

3.6.4 Mission Essential and Critical Operations Personnel Criteria. Catastrophic risks for mission essential and critical operations personnel should not exceed the following provisional criteria:

$$P[\geq N] \leq \frac{3\times10^{-4}}{N^{1.5}} \qquad \text{(Eq. 3-2)}$$

Where

$P[\geq N]$	is the cumulative probability of all events capable of causing N or more casualties.
N	is number of casualties, based on the occupant load as defined above in Table 3-1.
3×10^{-4}	is the maximum acceptable expected casualties as defined in 3.2.2b.

3.7 Criteria Summary

Table 3-2 summarizes the criteria defined by this Standard. All of the criteria are considered mandatory requirements except those identified as "Advisory requirements," which may be considered mandatory under certain circumstances as explained in Chapter 4 of the Supplement to this Standard.

TABLE 3-2. SUMMARY OF COMMONALITY CRITERIA

	General Public		Mission Essential and Critical Operations Personnel	
	Max. Acceptable	**Undesired Event**	**Max. Acceptable**	**Undesired Event**
Per Mission	1E–6[b]	Individual Probability of Casualty	10E–6	Individual Probability of Casualty
	100E–6 [b]	Expected Casualties	300E–6	Expected Casualties
	0.1E–6[a]	Individual Probability of Fatality	1E–6 [a]	Individual Probability of Fatality
	30E–6 [a]	Expected Fatalities	300E–6 [a]	Expected Fatalities
	0.1E–6	Probability of Aircraft Impact	1E–6	Probability of Aircraft Impact
	10E–6	Probability of Ship Impact	100E–6	Probability of Ship Impact
	- - -	- - -	1E–6	Manned Spacecraft
Annual	3000E–6	Expected Casualties	30000E–6	Expected Casualties
	1000E–6 [a]	Expected Fatalities	10000E–6 [a]	Expected Fatalities

[a] Advisory requirements.

[b] If a flight operation creates a toxic risk, then the range must separately ensure the allowable level of risk enforced by them does not exceed other standards for toxic exposure limits for the general public when appropriate mitigations are in place. Chapter 8 of the Supplement provides an approach for implementing this requirement.

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REFERENCES

a. United States Code (USC)

10USC	*Armed Forces*
28USC Part IV	*Judiciary and Judicial Procedures, Particular Proceedings (Federal Tort Claims Act)*
29USC	*Labor: Occupational Safety and Health Act (OSHA)*

b. Department of Defense (DoD)

DoDD 3100.10	*Space Policy*
DoDI 3100.12	*Space Support*
DoDI 3200.18	*Management and Operation of the Major Range and Test Facility Base (MRTFB)*
DoDD 4715.1	*Environmental Security*
DoDI 6055.1	*DoD Safety and Occupational Health (SOH) Program*

c. Department of the Army (DA)

AR 385-10	*The Army Safety Program*
FM 100-14	*Risk Management*

d. Department of the Air Force (AF)

AFI 90-901	*Operational Risk Management*
AFPD 91-2	*Safety Programs*
AFPD 63-12	*Assurance of Occupational Safety, Suitability, and Effectiveness*
AFPAM 90-902	*Operational Risk Management Guidelines and Tools*

e. Department of the Navy (DON)

OPNAVINST 3900.39B	*Operational Risk Management*

f. National Aeronautics and Space Administration (NASA)

NPR 8715	*NASA Procedural Requirements: Range Safety*

g. Range Commanders Council (RCC)

RCC 316-98	*Laser Range Safety*
RCC 319-99	*Flight Termination Systems Commonality Standard*
RCC 323-99	*Range Safety Criteria for Unmanned Air Vehicles*

h. Environmental Protection Agency (EPA)

EPA 100-B-00-002	*Risk Characterization Handbook*

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GLOSSARY

3-sigma: Three times the standard deviation, typically referenced to the mean value.

Abbreviated Injury Scale (AIS): An anatomically based, consensus derived, global severity scoring system that classifies each injury in every body-region according to its relative importance on a 6 point ordinal scale.

Acceptable Risk: A predetermined criterion or standard for a maximum risk ceiling which permits the evaluation of cost, national priority interests, and number of tests to be conducted.

Accumulated Risk: The combined collective risk to all individuals exposed to a particular hazard through all phases of an operation. Guidance Information is as follows:

- For the flight of an expendable orbital launch vehicle, risk should be accumulated from liftoff through orbital insertion.
- For the flight of a suborbital launch vehicle, risk should be accumulated from liftoff through the impact of all pieces of the launch vehicle, including the payload.

Aggregated Risk: The accumulated risk due to all hazards associated with a flight. Guidance Information is that, for a specified launch, aggregated risk includes, but is not limited to, the risk due to debris impact, toxic release, and distant focusing of blast overpressure.

As Low As Reasonably Practicable (ALARP): That level of risk which can be lowered further only by an increment in resource expenditure that cannot be justified by the resulting decrement in risk. Often identified or verified by formal or subjective application of cost-benefit or multi-attribute utility theory.

Background Risk: risks voluntarily accepted in the course of normal activities.

Best Practice: There are two definitions:

- A management idea which asserts that there is a technique, method, process, activity, incentive (or reward), that is more effective at delivering a particular outcome than any other solution technique, method, or process. The idea is that with proper processes, checks, and testing, a project can be rolled out and completed with fewer problems and unforeseen complications.
- An acceptable level of effort that represents the best choice available given the circumstances.

Casualty: A serious injury or worse, including death, for a human. For the purposes of this standard, serious injury is defined as Abbreviated Injury Scale (AIS) Level 3 or greater except where prior general practice at the range has been to protect to a lesser level of injury than AIS level 3, such as eardrum protection.

Casualty Expectation: See *Expected Casualties.*

Catastrophe: Any event that produces a large number (possibly five, ten, or more) of casualties or has a severe impact on continued range operations. See also definition of risk averse.

Clearance Zone: An area or volume from which objects at risk (people, ships, aircraft, etc.) are to be restricted or eliminated in order to control the risks.

Collective risk: The total risk to all individuals exposed to any hazard from an operation. Unless otherwise noted, collective risk is the mean number of casualties (E_C) predicted to result from all hazards associated with an operation. Collective risk is specified as either for a mission or per year. The collective risk should include the aggregated and accumulated risk.

Collision Avoidance (COLA): The process of determining and implementing a course of action to avoid potential on-orbit collisions with manned objects or with other specified orbiting objects. The process includes the determination of wait periods in either the launch window or spacecraft thrust firings based on validated conjunction assessments or risk analyses and accounts for uncertainties in spatial dispersions and arrival time of the orbiting objects and/or launch vehicle.

Conjunction Assessment (CA): The process of determining the point of closest approach of two orbiting objects, or between a launch vehicle and an orbiting object, in association with a specified miss-distance screening criteria or the corresponding probability of collision. Associated with the closest approach assessment is the closest approach distance, the times of launch or orbital firing that would result in the closest approach, and meeting the miss-distance or collision probability criteria.

Conservatism: As used in risk analysis conservative modeling, conservatism is a set of modeling assumptions that overstates the risk by overstating event probabilities, hazard probabilities, or consequences. Conservatism refers to the degree of overstating risk.

Containment: The launch safety strategy/process of minimizing risk to the maximum extent practical by keeping hazardous operations within defined hazard areas that are unpopulated or where the population is controlled and adequate protection can be provided to highly valued resources to stop, hold, or surround a hazard.

Critical Asset: A resource requiring protection. It normally includes property/infrastructure that is essential to protect the public health and safety, maintain the minimum operations of the range, or protect the national security or foreign policy interests of the U.S.

Critical Operations Personnel: Critical Operations Personnel include persons not essential to the specific operation or launch currently being conducted, but who are required to perform safety, security, or other critical tasks at the range. To be treated as Critical Operations Personnel they must be notified of a neighboring 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 launch areas and may not need to be evacuated with the general

public. Critical Operations Personnel should be included in the same risk category as Mission Essential Personnel.

Decision Authority: The Range Commander or senior official designated by the Range Commander to make risk decisions on his or her behalf.

Distant Focusing: An atmospheric phenomenon that can produce greatly enhanced overpressures at a distance from the acoustic (or explosive) source due to sonic velocity gradients with respect to altitude.

Endoatmospheric: Within the Earth's atmosphere, which is generally considered to be altitudes below 100 km.

Exoatmospheric: Outside the Earth's atmosphere, which is generally considered to be altitudes above 100 km.

Expected Casualties: The mean number of casualties predicted to occur as a result of an operation if the operation were to be repeated many times. This risk is expressed with the following notation: 1E–7 = 10^{-7} = 1 in ten million.

Expected Fatalities: The mean number of fatalities predicted to occur as a result of an operation if the operation were to be repeated many times. This risk is expressed with the following notation: 1E–7 = 10^{-7} = 1 in ten million.

Fatal Injury: any injury that results in death within 30 days of the accident.

Federal Tort Claims Act: A statute that limits federal sovereign immunity and allows recovery in federal court for tort damages caused by federal employees, but only if the law of the state where the injury occurred would hold a private person liable for the injury 28 USCA 2671-2680.

Fidelity: The accuracy of the representation when compared to the real world.

Flight Termination System (FTS): The airborne portion of the Flight Safety System. A flight termination system ends the flight of a vehicle and consists of the entire system on an airborne vehicle used to receive, decode, and execute the ground signals. It includes all wiring, power systems, and methods or devices (including inadvertent separation destruct systems) used to terminate flight.

Fragmentation: The breakup of an in-flight vehicle into fragments (components of the vehicle, pieces of the structure, chunks of solid propellant, miscellaneous hardware, etc.) due to explosive loads, aerodynamic and inertial loads, activation of a flight termination system, intercept with another vehicle, or impact on a surface.

General Public: People who are not declared/identified as mission essential personnel or critical operations personnel. This includes the public plus range personnel not essential to a mission, visitors, press, and personnel/dependents living on the base/facility.

Hazard: Any real or potential condition that can cause injury, illness, or death of personnel, or damage to or loss of equipment or property.

Hazard Area: A geographical or geometrical surface area that is susceptible to a hazard from a planned event or unplanned malfunction.

Hazard Threshold: The lowest level at which adverse outcomes are expected to appear.

Hazard Volume: A geographical or geometrical volume of airspace that is susceptible to a hazard from a planned event or unplanned malfunction.

Hazardous Operation: Those activities, which, by their nature, expose personnel or property to dangers not normally, experienced in day-to-day actions.

Impact: The impingement of a fragment on a surface, a structure, a person, or a vehicle.

Inadvertent Separation Destruct System (ISDS): A specialized form of an automatic destruct system (ADS) located on vehicle components that automatically activates when inadvertent separation of the component from the main vehicle is sensed. There is often a built-in delay included, in hope that the separated component will be sufficiently displaced at charge activation to preclude damage to the main vehicle.

Individual Risk: Individual risk is the risk that a person will suffer a consequence. Unless otherwise noted, individual risk is expressed as the probability that an individual will become a casualty due to all hazards (P_C) from an operation at a specific location. Guidance Information is that:

- If each person in a group is subject to the same individual risk, then the collective risk may be computed as the individual risk multiplied by the number of people in the group.
- In the context of this Standard, individual risk refers to the probability that the exposed individual will become a casualty as a result of all hazards from a mission.

Informed Decision: The "informed decision" principle is used in tort claims against the U.S. Government. The Federal Tort Claims Act (FTCA) enjoins the U.S. court system from second-guessing decisions made by properly authorized government officials in determining the acceptability of operational risks. A key test under the FTCA requires that the decision-making official be fully advised and informed of the known risks. Failure to fully advise the decision-making authority of known risks can result in liability of the U.S. Government or its officials.

Involuntary Activity: No choice was made by the person affected which placed them in a position of increased risk; or the activity participated in or the item used was one that is generally done or used by more than 99 percent of the population. Examples include bathing, using coins, and drinking glasses.

Launch Mission: For the purposes of flight safety analyses, a launch mission begins with lift-off, ends at orbital insertion, and includes impacts from all planned debris released prior to

orbital insertion (or final impact for a suborbital mission). A launch mission includes any flight of a suborbital or orbital rocket, guided or unguided missile, and missile intercepts. See paragraph 4.2.5 of the Supplement for details on defining a launch mission for risk assessment.

Lift-off: For the purposes of flight safety analyses, lift-off occurs during a launch countdown with any motion of the launch vehicle with respect to the launch platform (which includes a carrier aircraft), including any intentional or unintentional separation from the launch platform.

Manned Spacecraft: A spacecraft that is either currently occupied or intended to be occupied. Includes spacecraft en route to, and in support of, manned missions.

Mishap: An unplanned event or series of events resulting in death, injury, occupational illness, or damage to or loss of equipment or property or damage to the environment.

Mission Essential: Those persons and assets necessary to safely and successfully complete a specific hazardous operation or launch. The ME individuals may include persons in training to perform the specific mission currently being conducted, but excludes those in training for other critical tasks. ME personnel are informed of the hazards associated with the operation and trained in mitigation techniques appropriate to the hazard level. The range commander or mission director (or their designees) should identify the ME personnel in training and justify their designation as ME.

Mission Rules: Rules that define safety constraints and conditions and establish the boundaries within which the safety team operates. The lead safety organization develops the mission rules and briefs the range user to ensure a complete understanding of the intent and application of them. Mission rules are documented and become part of the range safety plan.

Orbital Insertion: Orbital insertion occurs when the vehicle achieves a minimum 70 nm perigee based on a computation that accounts for drag.

Overpressure: The pressure caused by an explosion over and above normal atmospheric pressure. It can be significantly affected by the atmospheric conditions, particularly the temperature and wind profiles.

Probability of Casualty: The likelihood that a person will suffer a serious injury or worse, including a fatal injury, from a hazardous event. This risk is expressed with the following notation: 1E–7 = 10^{-7} = 1 in ten million.

Probability of Fatality: The likelihood that a person will die from a hazardous event. This risk is expressed with the following notation: 1E–7 = 10^{-7} = 1 in ten million.

Prudent Person: See *Reasonable Person.*

Range Safety System (RSS): The ground-based portion of the Flight Safety System. An integrated system of hardware, software, and human operators which is necessary to provide mission safety support. Includes instrumentation and communication infrastructure needed to

fulfill safety's flight control responsibility. *See also Flight Safety System* and *Flight Termination System*.

Reasonable Care: As a test of liability for negligence, the degree of care that a prudent and competent person engaged in the same line of business or endeavor would exercise under similar circumstances. Reasonable care is also referred to as due care, ordinary care, adequate care, and proper care.

Reasonable Person: A hypothetical person used as a legal standard, especially to determine if someone acted with negligence. The reasonable person acts sensibly, does things without serious delay, and takes proper but not excessive precautions. Also termed *Reasonable Man* or *Prudent Person.*

Reentry Mission: Reentry missions include both controlled and uncontrolled reentries. In this context, a controlled reentry mission begins with the final commitment to enter the atmosphere from orbit (or otherwise from outer space) and ends when all vehicle components associated with the reentry come to rest on the Earth (or are otherwise secured). For example, a controlled reentry mission could begin with the final command to commit the vehicle (or object) to a perigee below 70 nm and end when all vehicle components come to rest on the Earth. An uncontrolled reentry mission begins when the object naturally decays to a perigee below 70 nm and ends when all vehicle components associated with the reentry come to rest on the Earth. The reentry of upper-stages and payloads are separate reentry missions per the U.S. Government Orbital Debris Mitigation Standard Practices and DoDI 3100.12. In this context, reentry missions do not occur during suborbital flights because a reentry mission separate from the launch mission can occur subsequent to orbital insertion only. See Paragraph 4.2.4b of the Supplement for details on defining a reentry mission for risk assessment.

Risk: Risk is a measure that accounts for both the probability of occurrence and the consequence of a hazard to a population or installation. Unless otherwise noted, risk to people is measured in casualties and expressed as individual risk or collective risk.

Risk Analysis: A study of potential risk under a given set of conditions. Risk analysis is an activity that includes the complete array of tasks from data gathering, identification of hazards, estimation of associated risks, and verification of results.

Risk Averse: An aversion to increasing numbers of casualties that makes a single event having, for example, two casualties more than twice as undesirable as a single event having one casualty. This is exactly equivalent to the term catastrophe averse when the number of casualties is large. The term "large" could be 10 in some definitions.

Risk Management: Risk management is a systematic and logical process to identify hazards and control the risk they pose.

Risk Profile: A plot that shows the probability of N or more casualties (vertical axis) as a function of the number of casualties, N (horizontal axis). It is discrete (not fractional) and is the complementary cumulative distribution of the histogram representing the aleatory uncertainty of

number of casualties. The mean of the histogram is the Ec. In addition, the sum of the values of the P[≥N] over all N is equal to the Ec.

Safety: Relative protection from adverse consequences.

Serious Injury: Any injury that meets one or more of the following:

- Requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received.
- Results in a fracture of any bone (except simple fractures of fingers, toes, or nose).
- Causes severe hemorrhages, nerve, muscle, or tendon damage.
- Involves any internal organ.
- Involves second degree or third degree burns, or any burns affecting more than 5 percent of the body surface.

Ship Accident: A "ship accident" occurs if the vessel is involved in an accident that results in loss of life, personal injury that requires medical treatment beyond first aid, or complete loss of the vessel. This definition is consistent with the level of protection afforded people involved in a "boat accident" as defined in current regulations.

Sigma: Standard deviation.

Suborbital Mission: A suborbital launch mission is any flight of a launch vehicle, rocket, or missile that does not achieve orbital insertion. The per mission requirements for launch are intended to apply from lift-off until to landing or final impact for a suborbital mission, including all planned debris impacts.

Suborbital Rocket: A rocket-propelled vehicle intended to perform a suborbital mission whose thrust is greater than its lift for the majority of the rocket-powered portion of its flight.

Substantial Damage: Relating to aircraft vulnerability means damage or failure that adversely affects the structural strength, performance, or flight characteristics of the aircraft, and that would normally require major repair or replacement of the affected component.

Toxic Substance: A chemical or mixture that may present an unreasonable risk of injury to health or the environment.

Toxics: A Generic term for the toxic propellants and combustion by-products resulting from a nominal launch vehicle flight or catastrophic launch abort.

Uncertainty: The absence of perfectly detailed knowledge. Uncertainty includes incertitude (the exact value is unknown) and variability (the value is changing). Uncertainty may also include other forms such as vagueness, ambiguity, and fuzziness (in the sense of borderline cases).

Variability: Observed differences attributable to true heterogeneity or diversity. Variability is the result of natural random processes and is usually not reducible by further measurement or study (although it can be better characterized).

Verification: Refers to the set of activities that ensure that software correctly implements a specific function. The verification process determines whether a computer simulation code for a particular problem accurately represents the solutions of the mathematical model. Evidence is collected to ascertain whether the numerical model is being solved correctly. This process ensures that sound software-quality practices are used and the software codes themselves are free of defects and errors. The process also checks that the code is correctly solving the mathematical equations in the algorithms and verifies that the time and space steps or zones chosen for the mathematical model are sufficiently resolved.

Voluntary Activity: A choice that may place an individual in an increased position of risk compared to the rest of the population, including career and job choices. Examples are repetitive motion injuries, recreational boating, etc.

****** NOTHING FOLLOWS ******