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NASA Procedural Requirements

NPR 8715.3D

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COMPLIANCE IS MANDATORY FOR NASA EMPLOYEES

NASA General Safety Program Requirements

Responsible Office: Office of Safety and Mission Assurance

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NPI 8715.93, NASA Policy Instructions: Impacts of NSPM-20 on NASA Nuclear Flight Safety Requirements and Practices.

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Change Log

Ch#	Office	Date	Description
1	Chief, Safety and Mission Assurance	10/29/2018	Updated with 1400 compliance in the Authority and Reference documents section and corrected spelling.
2	Chief, Safety and Mission Assurance	02/01/2021	Chapters 3-5 and 7-8 Cancelled by NPR 8715.1B
3	Chief, Safety and Mission Assurance	04/13/2021	<p>The following administrative changes were made:</p> <ol style="list-style-type: none"> 1. Updated to ensure consistency with NPR 8715.1B. Removed the institutional safety roles, responsibilities, and requirements (parts of Chapter 1, and all of chapters 3, 4, 5, 7, and 8, and appendices C, E, and F) that are now addressed in NPR 8715.1. Cleaned up the P.1 Purpose and P.2 Applicability to reflect changes. Removed outdated and unused references, definitions, and acronyms primarily related to institutional safety. 2. Removed other unnecessary and outdated content such as Section 1.6, Risk Assessment and Risk Acceptance (addressed in NPR 8000.4), and Section 2.3, System Safety Framework (addressed in system safety handbooks).
4	Chief, Safety and Mission Assurance	12/16/2021	Added in Section 13.11, which used to be NPR 8715.3, Chapter 7. Safety Training and Personnel Certification, to ensure safety training requirements for employees are properly documented and to document who is responsible to ensure the employees are properly trained.

Preface

P.1 Purpose

The purpose of this directive is to assure mission success. This directive defines NASA roles and responsibilities for assuring safety and mission success of NASA missions, and describes processes and evidence necessary to provide that assurance. NASA roles, responsibilities, and processes for protecting the public, workforce, and non-mission assets from NASA activities are defined in NPR 8715.1, NASA Safety and Health Programs.

P.2 Applicability

- a. This directive is applicable to NASA Headquarters and NASA Centers, including Component Facilities and Technical and Service Support Centers. This language applies to the Jet Propulsion Laboratory (a Federally-Funded Research and Development Center), other contractors, recipients of grants, cooperative agreements, or other agreements only to the extent specified or referenced in the applicable contracts, grants, or agreements.
- b. This directive is applicable to NASA missions and NASA controlled activities in support of NASA missions.
- c. In this directive, all mandatory actions (i.e., requirements) are denoted by statements containing the term "shall." The term "may" denotes a discretionary privilege or permission, "can" denotes statements of possibility or capability, "should" denotes a good practice and is recommended, but not required, "will" denotes expected outcome, and "are/is" denotes descriptive material.
- d. In this directive, the word "project" refers to a unit of work performed in programs, projects, and activities. Management of a work unit is referred to as "project management," which includes managing programs, projects, and activities.
- e. In this directive, all document citations are assumed to be the latest version unless otherwise noted. Use of more recent versions of cited documents may be authorized by the responsible Safety and Mission Assurance Technical Authority.

P.3 Authority

- a. The National Aeronautics and Space Act, 51 U.S.C. ch. 201.
- b. Procedures for Implementing the National Environmental Policy Act (NEPA), 14 CFR § 1216.3.
- c. Presidential Directive/National Security Council Memorandum Number 25 (PD/NSC-25), Scientific or Technological Experiments with Possible Large-Scale Adverse Environmental Effects and Aerospace Use of Major Radioactive Sources.
- d. NPD 1000.0, NASA Governance and Strategic Management Handbook.
- e. NPD 1000.3, The NASA Organization.

f. NPD 8700.1, NASA Policy for Safety and Mission Success.

P.4 Applicable Documents and Forms

- a. NPR 1441.1, NASA Records Management Program Requirements.
- b. NPR 7120.5, NASA Space Flight Program and Project Management Requirements.
- c. NPR 8715.1, NASA Safety and Health Programs.
- d. NASA-STD-8739.8, Software Assurance and Software Safety Standard.
- e. IAEA Safety Series Number 6, International Atomic Energy Agency (IAEA), Safety Series Number 6, Regulations for the Safe Transport of Radioactive Material.

P.5 Measurement/Verification

Compliance with the requirements contained in this directive is continuously monitored by the Center Institutional Safety Discipline Leads, by the project Safety and Mission Assurance Technical Authority, and by the NASA Office of Safety and Mission Assurance. Compliance may also be verified as part of selected life cycle reviews and by assessments, reviews, and audits of the requirements and processes defined within this directive.

P.6 CANCELLATION

NPR 8715.3C, NASA General Safety Program Requirements, dated March 12, 2008.

Chapter 1. Programmatic Safety Requirements

1.1 Overview of the NASA Safety Program

1.1.1 This document provides the procedural requirements that define the NASA Safety Program. Safety program responsibility starts at the top with senior management's role of developing policies and providing strategies and resources necessary to implement and manage a comprehensive safety program. The NASA Safety Program is executed by the responsible Mission Directorate Associate Administrators, Center Directors, Office of Safety and Mission Assurance (OSMA), component facility managers, safety managers, project managers, systems engineers, supervisors, line organizations, employees, and NASA contractors.

Note: The basic principles for governing, managing, implementing, monitoring, and controlling work at NASA are addressed in NPD 1000.0, which provides direction for Mission Directorates and Centers to execute programs and projects.

1.1.2 As stated in NPD 8700.1, the objectives of the NASA Safety Program are to protect the public from harm, ensure the safety of employees, and affect positively the overall success rate of missions and operations through preventing damage to high-value equipment and property.

1.1.3 In general, the success or failure of an organization's safety efforts can be predicted by a combination of leading indicators (e.g., the number of open vs. closed inspection findings, awareness campaigns, training metrics, progress towards safety goals/objectives, the amount of hazard and safety analyses completed, and close calls) and its achievement measured by lagging indicators (e.g., the number of incidents involving injury or death to personnel, lost productivity [lost or restricted workdays], environmental damage, or loss of, or damage to, property). Like many successful corporations, NASA has learned that aggressively preventing mishaps is good management and a sound business practice.

1.1.4 NASA undertakes many activities involving high risk. Management of this risk is one of NASA's most challenging activities and is an integral part of NASA's safety efforts.

1.1.5 Policies, requirements, and procedures for mishap investigations are provided in NPR 8621.1.

1.1.6 NASA identifies issues of concern through a strong network of oversight councils and internal auditors including the Aerospace Safety Advisory Panel (ASAP).

1.1.7 NASA's goal is to maintain a world-class safety program based on management and employee commitment and involvement; system and worksite safety and risk assessment; hazard and risk prevention, mitigation, and control; and safety and health training.

1.2 NASA General Safety Program Roles and Responsibilities

Per NPD 1000.3, Mission Directorate Associate Administrators, through their project managers, and Center Directors, through their line managers, are responsible for the safety of the public and of their

assigned personnel, facilities, and mission systems from hazards created or controlled by the Mission Directorate or Center. Toward that end, they shall establish a safety and health program in accordance with NPR 8715.1, NASA Safety and Health Programs and meet the requirements of this NPR.

1.3 Public Safety

Mission Directorate Associate Administrators and Center Directors shall ensure operational safety in accordance with NPR 8715.1.

1.4 Institutional Roles and Responsibilities in the NASA Safety Program - *RESERVED*

1.5 Program Management Roles and Responsibilities in the NASA Safety Program

1.5.1 Mission Directorate Associate Administrators shall ensure that program and project Safety and Mission Assurance (SMA) Plans:

- a. Addresses life cycle safety-relevant functions and activities.
- b. Reflects a life cycle SMA process perspective, addressing areas including: procurement, management, design and engineering, design verification and test, software design, software verification and test, manufacturing, manufacturing verification and test, operations, and preflight verification and test.
- c. Contains data and information to support each section of the SMA Plan for each major milestone review to include the Safety and Mission Success Review.
- d. Contains trending and metrics utilized to display progress and to predict growth towards SMA goals and requirements.
- e. As a minimum, addresses the following topics and associated requirements:
 - (1) Safety and mission success per this NPR.
 - (2) Risk classification of NASA payloads per NPR 8705.4.
 - (3) Reliability and maintainability per NPD 8720.1.
 - (4) Risk assessment per NPR 8705.5.
 - (5) Quality assurance per NPR 8735.2.
 - (6) Software safety and assurance per and NASA-STD-8739.8.
 - (7) Public and workforce safety and health per host Center requirements and consistent with NPR 8715.1.
 - (8) Range safety per per host Center requirements and consistent with NPR 8715.5.

- (9) Payload safety per host Center requirements and consistent with NPR 8715.7.
- (10) Orbital debris mitigation requirements per NPR 8715.6.
- (11) Planetary protection requirements per NPR 8020.12, NID 8715.128, and NID 8715.129.
- (12) Nuclear flight safety per chapter 6 of this NPR.
- (13) Human-rating per NPR 8705.2.
- (14) Mishap reporting per NPR 8621.1.
- (15) Compliance verification, SMA audits, reviews, and assessments per NPR 8705.6.

1.5.2 Project managers shall ensure that contractor operations and designs are evaluated for consistency and compliance with the safety and health provisions provided in their contractual agreements.

1.6 Risk Assessment and Risk Acceptance

Requirements for risk assessment and acceptance are addressed as part of risk management in NPR 8000.4, Agency Risk Management Procedural Requirements.

1.7 Technical Safety Requirements for NASA-Unique Designs and Operations

1.7.1 Risk Reduction Protocol

1.7.1.1 Project managers shall ensure that hazards and dominant contributors to risk are controlled according to the following:

- a. Eliminate accident scenarios (e.g., eliminate hazards or initiating events by design).
- b. Reduce the likelihood of accident scenarios through design and operational changes (hazard control).
- c. Reduce the severity of accident consequences (hazard mitigation).
- d. Improve the state-of-knowledge regarding key uncertainties that drive the risk associated with a hazard (uncertainty reduction to support implementation of the above strategies).

Note: Designs for hazard control and accident prevention and mitigation should include considerations for the possibility of human errors. The level of hazard control should be based on the level of risk associated with that hazard. Examples of risk reduction strategies include: control of system and operational characteristics, incorporation of safety devices, use of caution and warning devices, and the use of operational and management procedures and training. Some hazards may require a combination of several of these approaches for prevention, mitigation, and/or control. Providing protective clothing and equipment is considered an operational procedure.

1.7.2 Reliability and Failure Tolerance

1.7.2.1 Safety critical operations must have high reliability. High reliability is verified by reliability analysis using accepted modeling techniques and data in which uncertainties are incorporated. Where this cannot be accomplished with a specified confidence level, the design of safety critical operations shall have failure tolerance and safety margins in which critical operability and functionality are ensured. Failure tolerance is the ability of a system to perform its function(s) or maintain control of a hazard in the presence of failures of its subsystems. Failure tolerance may be accomplished through like or unlike redundancy. Safety margins are the difference between as-built factor of safety and the ratio of actual operating conditions to the maximum operating conditions specified during design.

Note: For human space systems, failure tolerance requirements are provided in NPR 8705.2. Applicable failure tolerance requirements in this NPR pertain to all other systems.

1.7.2.2 To assure operability and functionality and to achieve failure tolerance, project managers shall use these design considerations.

- a. Design safety critical systems such that the critical operation or its necessary functions can be assured. To provide assurance, design the component, subsystem, or system so it is capable of being tested, inspected, and maintained.
- b. Where high reliability cannot be verified by reliability analysis using accepted data in which uncertainties are incorporated, design safety critical systems so that no combination of two failures and/or operator errors (fail-safe, fail-safe as a minimum) will result in loss of life.

Note: Safety-critical operational controls are applied to conditions, events, signals, processes, or items for which proper recognition, control, performance, or tolerance are essential to safe system operation, use, or function.

- c. Where high reliability cannot be verified by reliability analysis using accepted data in which uncertainties are incorporated, design safety critical operations so that no single failure or operator error (fail-safe) will result in system loss/damage or personal injury.
- d. Where high reliability cannot be verified by reliability analysis using accepted data in which uncertainties are incorporated, provide functional redundancy where there is insufficient time for recovery or system restoration. Where there is sufficient time between a failure and the manifestation of its effect, design for restoration of safe operation using spares, procedures, or maintenance provides an alternative means of achieving failure tolerance.
- e. Design safety critical systems and operations to have a safety margin.
- f. When using redundancy, verify that common cause failures (e.g., contamination, close proximity) do not invalidate the assumption of failure independence.
- g. When using redundancy in operations that could cause or lead to severe injury, major damage, or mission failure (safety critical operations), verify operability under conditions that singularly or separately added together represent the operating intended condition.
- h.. When using reliability analyses, assess the probability of failure and associated uncertainties to

provide the function and the time to restore the function, where loss of life, serious injury, or catastrophic system loss can occur. The time to restore the function shall include the active time to repair and the time associated with the logistics or administrative downtime that affects the ease or rapidity of achieving full restoration of the failed function.

1.7.2.3 To assure functional protection, project managers shall ensure that:

- a. Loss of functional protection for safety-critical operations requires termination of the operation at the first stable configuration.
- b. At least one single level of functional protection is used to protect high-value facilities and flight systems.

1.7.3 Inhibits

1.7.3.1 Where high reliability is not verified by reliability analysis using accepted data with uncertainties incorporated, the project manager shall ensure that:

- a. Operations that require the control of a condition, event, signal, process, or item for which proper recognition, performance, or tolerance is essential to safe system operation, use, or function are designed such that an inadvertent or unauthorized event cannot occur (inhibit).
- b. Operations have three inhibits where loss of life can occur.
- c. Operations have two inhibits where personal injury, illness, mission loss, or system loss or damage can occur.
- d. The capability of inhibits or control procedures when required in operations by this paragraph are verified under operational conditions including the verification of independence among multiple inhibits.

Note: Inhibits (designs that specifically prevent an inadvertent or unauthorized event from occurring) are not to be confused with the lockout/tagout program, which is a program to isolate or control facility system hazards; e.g., electrical, mechanical, hydraulic, pneumatic, chemical, thermal, or other energy.

1.8 SMA Program Reviews

Requirements for conducting and supporting independent SMA audits, reviews, and assessments are provided in NPR 8705.6.

1.9 Advisory Panels, Committees, and Boards

The Aerospace Safety Advisory Panel and the Independent Verification and Validation Board of Advisors are addressed in NPD 1000.3.

1.10 Coordination with Organizations External to NASA - *RESERVED*

1.11 Safety Motivation and Awards Program - *RESERVED*

1.12 Safety Management Information - *RESERVED*

1.13 Tailoring Agency Mission SMA Requirements

1.13.1 This section is applicable to programs and projects governed by NPR 7120.5 and NPR 7120.8. Processes for tailoring Agency SMA requirements will follow the requirement tailoring principles defined in NPRs 7120.5 and 7120.8.

1.13.2 NPR 8715.1, NASA Safety and Health Programs, describes the process for tailoring institutional safety and health requirements.

1.13.3 The Chief, SMA delegates the authority to approve tailoring of Agency mission SMA requirements imposed on programs and projects, including the acceptance of alternate technical standards, to the Center-level SMA TA except for the following areas for which the Chief, SMA retains this authority:

a. Orbital debris mitigation, including requirements in NPR 8715.6, NASA Procedural Requirements for Limiting Orbital Debris and Evaluating the Meteoroid and Orbital Debris Environments, and standards incorporated by reference therein.

b. Planetary protection, including requirements in NPR 8715.24, Planetary Protection Provisions for Robotic Extraterrestrial Missions, NID 8715.129, Biological Planetary Protection for Human Missions to Mars, and agreed to standards used to implement those requirements.

c. Nuclear flight safety, including requirements in Chapter 6, Nuclear Safety for Launching of Radioactive Materials, and agreed to standards used to implement those requirements.

Note: This reference to Chapter 6 will be replaced with NPR 8715.yy, Nuclear Flight Safety, once the new NPR is published.

d. Human-rating spaceflight systems, including requirements in NPR 8705.2, Human-Rating Requirements for Space Systems, excluding standards incorporated by reference therein.

e. Mission risk classification, including requirements in NPR 8705.4, Risk Classification for NASA Payloads, excluding standards incorporated by reference therein.

f. Mishap investigations, including requirements in NPR 8621.1, NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping.

g. NASA interim directives that replace or augment the documents cited above.

1.13.4 The Chief, SMA will consult on the tailoring of requirements in those areas with the Associate Administrator, Administrator, or other authorities as appropriate.

1.13.5 When tailoring requirements, the Mission Directorate Associate Administrator, or designee, shall include the following information in the request:

a. Identify the requirement(s) being tailored.

- b. Describe the tailoring of the requirement (i.e., the nature of the proposed departure from the requirement).
 - c. Justify the reasons for the tailoring, why it is not possible, or desirable, to comply with the requirement .
 - d. Describe the resulting change in risk to the public, workforce, high-value property, and orbital and planetary environments.
 - e. Describe the resulting change in risk to crew safety and mission success.
 - f. Confirm the tailoring does not conflict with applicable Federal statutes or regulations, or with Agency policy or higher-level requirement.
 - g. Indicate when and whether compliance will be achieved.
 - h. Describe alternate actions to be taken for managing the risk.
 - i. Describe findings and recommendations from the project-level SMA TA regarding the technical merits of the case.
 - j. For matters involving human safety risk, obtain formal agreement to assume the risk from the actual risk taker(s) (or official spokesperson[s] and applicable supervisory chain).
- 1.13.6 NPR 8000.4 contains requirements for decisions to accept risk to safety and mission success.

1.14 Hazardous Work Activities That Are Outside NASA Operational Control

Note: Non-spaceflight activities are now addressed in NPR 8715.1, in particular section 4.3.10, Multiemployer Worksites - Worksites not under NASA control, and section 13.8, Test / Operations Safety, for requirements on NASA civil servant participation in hazardous work activities outside NASA operational control.

1.14 Hazardous Work Activities That Are Outside NASA Operational Control

1.14.1 It is NASA policy to formally review and approve NASA participation in hazardous work activities that are outside NASA operational control as needed to ensure that NASA safety and health responsibilities are satisfied. This policy applies unconditionally to NASA participation in commercial human spaceflight where current federal regulations do not necessarily provide for the safety of spaceflight vehicle occupants. This policy is non-retroactive and applies to hazardous ground or flight activities that involve research, development, test and evaluation, operations, or training, where all five of the following conditions exist:

- a. NASA civil service personnel, Government detailees, specified contractors, or specified grantees are performing work for NASA.

Note 1: Paragraph 1.14 of this NPR applies to contractors and grantees only as specified by the responsible NASA manager in consultation with the cognizant NASA Center SMA organization based on an assessment of NASA safety responsibilities and/or obligations with regard to the activity.

Note 2: This policy only applies to personnel participating in activities within their official NASA duties.

- b. The activity is outside NASA's direct operational control/oversight.
- c. An assessment by the responsible NASA manager indicates there are insufficient safeguards and/or oversight in place.

Note: This policy does not apply to activities where safety oversight and/or safety regulations of other entities provide for safety of the participants (e.g., FAA, DoD, OSHA, ESA, JAXA) and foreign government-associated safety regulatory regimes.

- d. The activity is not covered by a basic contract, grant, or agreement where Federal, State, and/or local requirements address personnel safety.
- e. The nature of the activity is such that, if NASA were controlling it, a formal safety and/or health review would be required as part of the NASA approval process.

Note: Paragraph 1.14 of this NPR applies to activities conducted in unusual or unforgiving environments (such as underwater or extreme temperature/altitude), as well as activities conducted in remote areas where there is little or no access to medical care or other assistance in an emergency.

1.14.2 For NASA work activities that satisfy the conditions listed in paragraph 1.14.1 of this NPR, it is NASA policy to document and verify that risks are adequately controlled and any residual risk is acceptable following the steps below or through implementation of the System Safety process in Chapter 2 of this NPR:

- a. As early as practical, conduct a comprehensive, documented review of the planned activity (the review may address a series of related activities). (See paragraph 1.14.3.h of this NPR for requirements that apply to the review.)
- b. Document Agency approval by cognizant NASA officials, including formal acceptance of all associated risks.
- c. Ensure activity participants are fully briefed on the safety and health aspects of the activity and the associated risks and that they formally consent to take the risk.
- d. Ensure activity participants have all necessary training, equipment, and support.

1.14.3 Roles and Responsibilities. The following roles and responsibilities apply with regard to implementing the policy stated in paragraph 1.14.2 of this NPR.

- a. The Chief, Safety and Mission Assurance shall oversee and resolve any questions regarding the implementation and applicability of this policy and related requirements to a proposed work activity.
- b. Each Center Safety and Mission Assurance Director shall:
 - (1) Establish and implement processes and requirements needed to ensure compliance with this policy for applicable work activities within the scope of their authority.
 - (2) Provide safety expertise as needed to assist programs and projects to successfully complete the required NASA review and approval of applicable work activities.

- (3) Formally concur in the scope of hazard assessments executed per paragraph 1.14.3.h.(2) for activities under their cognizance.
- (4) Maintain records of all approvals granted under this policy and track the status of each activity.
- c. The NASA official, at the appropriate level of authority in the supervisory chain over the participating personnel and any applicable non-NASA supervisor (identified by the Review Team per paragraph 1.14.3.h.(5) of this NPR), shall sign the approval documentation indicating consent for their assigned personnel to take the risk and participate in the activity.
- d. Where deemed applicable by the review, the following NASA officials shall sign the approval documentation indicating that the risks are properly characterized for their area of responsibility and that they concur with acceptance of the risks to personnel under NASA safety responsibility, risk to NASA property, and any public risk due to NASA's part in the activity:
- (1) The Center SMA official with cognizance over the activity (mandatory for any activity that involves safety risk to participants, the public, or to NASA property).
- (2) The Center Health and Medical official with cognizance over the activity (mandatory for any activity that involves health risk to participants or the public or involves medical equipment or operations as part of the safety risk mitigation strategy).
- (3) The NASA General Counsel or Center Chief Counsel (mandatory for any activity that involves U.S. or international law).
- (4) The designated Technical Authority(ies) with cognizance over the associated project/program (mandatory for any activity that involves system design changes or invocation of NASA technical requirements as part of the risk mitigation strategy).
- e. The personnel participating in the hazardous activity shall sign the approval documentation indicating that they are fully briefed on all safety and health risks inherent in the activity and are willing and able to participate.
- f. After signature by the officials/personnel identified in paragraphs 1.14.3.c, 1.14.3.d, and 1.14.3.e of this NPR, the NASA official, at the appropriate level, as identified by the review per paragraph 1.14.3.h.(6) of this NPR, shall sign the approval documentation indicating formal acceptance of the associated risks to personnel under NASA safety responsibility, risk to NASA property, and any public risk due to NASA's part in the activity.
- g. NASA managers (program/project/grant/institutional/other) shall ensure that all aspects of the policy in paragraph 1.14.2 of this NPR are satisfied for applicable work activities under their authority. In accomplishing this, NASA managers shall:
- (1) Identify work activities that fall under the applicability of this policy in consultation with the cognizant Center SMA organization.

Note: Per paragraph 1.14.3a of this NPR, the Chief, Safety and Mission Assurance is responsible for resolving any questions regarding the applicability of this policy to a work activity.

- (2) Satisfy local SMA processes and requirements designed to implement this policy.

- (3) Establish a Review Team (see paragraph 1.14.3.h of this NPR for Review Team responsibilities) in consultation with the cognizant SMA, Health and Medical, Engineering, and Legal organizations; and ensure that the Review Team incorporates all necessary expertise as required.
- (4) Ensure that funding and other resources needed to satisfy this policy are budgeted and allocated.

Note: This includes any funding needed to staff the Review Team, obtain data, and develop the various review products required by the Review Team, such as the hazards analyses and risk assessments.

- (5) Ensure all conditions for NASA approval are met, including implementation of all actions identified by the Review Team.
- (6) Ensure the preparation and finalization of the approval documentation.

h. The Review Team established per paragraph 1.14.3.g.(3) of this NPR and program/project/grant/institutional/other personnel as needed shall coordinate to:

- (1) Identify and evaluate the safety, health and medical, and any safety-legal aspects of the activity.
- (2) Identify and evaluate all associated hazards (design and/or operational), including evaluation of existing hazard/risk mitigations and safety requirements being implemented.

Note: The extent of this hazard evaluation is determined by the Review Team with the concurrence of the cognizant Center SMA Director and may vary depending on the specific safety concerns associated with the work activity.

- (3) Assess and characterize any residual safety risks to personnel, public, and property.

Note: Characterization of the safety risks may be quantitative or qualitative as determined by the Review Team and as needed to ensure that NASA officials understand any risks they are asked to accept. The basis for the risk assessment includes the current NASA policies, requirements, and standards that would apply if NASA were controlling the activity.

- (4) If the initial risks are unacceptable, identify actions that must be implemented to mitigate the risks as conditions for NASA approval to participate.

Note: This may include implementation of NASA technical standards and/or processes (or portions thereof).

- (5) Identify the NASA official(s), at the appropriate level of authority in the supervisory chain over the participating personnel and any non-NASA supervisor(s) (in the event that non-NASA personnel are involved), who must consent for the personnel to take the risk and participate in the activity.

Note: In accomplishing this, the Review Team identifies the appropriate level of NASA management in the supervisory chain with authority to represent the participating personnel based on the risk level and the applicable NASA risk management policy.

- (6) Identify the NASA official who must formally accept the risks associated with and grant final approval of the activity.

Note: In accomplishing this, the Review Team identifies the appropriate level of NASA program/project management with authority for final approval based on the risk level and the applicable NASA risk management policy.

(7) For a series of related activities (that may involve the same or different participants over a period of time), identify a NASA readiness process to be implemented for each activity.

i. If the Review Team determines that a series of activities is a repetition of, or essentially the same as, a previously reviewed and approved activity, the Review Team may recommend that the NASA approving official (identified per paragraph 1.14.3.h.(6) of this NPR) grant a standing approval that will remain in effect until there are substantive changes in the activity, personnel, or a specified period of time has elapsed, not to exceed 5 years.

j. The Assistant Administrator for Procurement, NASA Grant and Contracting Officers, and Cooperative Agreement, and other agreement officers shall ensure that grants, contracts, and agreements governing activities performed in support of NASA allow for implementation of this policy where specified by the cognizant NASA manager in consultation with the cognizant NASA Center SMA organization (per paragraph 1.14.3.g(1) of this NPR).

Chapter 2. System Safety

2.1 Introduction

2.1.1 This chapter establishes requirements for the implementation of system safety processes to support decision making aimed at ensuring human safety, asset integrity, and mission success in programs/projects.

2.1.2 System safety assessment is a disciplined, systematic approach to the analysis of risks resulting from hazards that can affect humans, the environment, and mission assets. It is a critical first step in the development of risk management strategies. System safety covers the total spectrum of technical risk and management activities including safety and risk assessments and safety performance monitoring.

2.1.3 The format of this chapter is different than that of the rest of this NPR because of the need to discuss advanced concepts in system safety by the references.

2.2 Institutional Roles and Responsibilities

2.2.1 Mission Directorate Associate Administrators, Center Directors, program and project managers, and line managers shall ensure that system safety activities are conducted for all programs and projects including system acquisitions, in-house developments (research and technology), design, construction, fabrication and manufacture, experimentation and test, packaging and transportation, storage, checkout, launch, flight, reentry, retrieval and disassembly, maintenance and refurbishment, modification, and disposal.

2.2.2 Center Directors, through their Center SMA Directors, shall ensure that knowledgeable system safety and technical risk analysts are made available to program/project managers and Center engineering directors to define and conduct system safety activities, including assurance of prime contractor system safety activities.

2.3 System Safety Framework

NASA's framework for system safety is described in NASA/SP-2010-580, NASA System Safety Handbook, Volume 1: System Safety Framework and Concepts for Implementation, and NASA/SP-2014-612, NASA System Safety Handbook Volume 2: System Safety Concepts, Guidelines, and Implementation Examples.

2.4 Scope of System Safety Modeling

2.4.1 Decision makers throughout the entire life cycle of the project, beginning with concept design and concluding with decommissioning, must consider safety. However, the level of formality and rigor that is involved in implementing the system safety processes should match project potential consequences, life cycle phase, life cycle cost, and strategic importance. To assist in determining the scope of activities for safety evaluations as a function of project characteristics, two tables are

provided. The categorization scheme identified in Table 2.1 is used to determine a project priority. This table is similar to Table 1 from NPR 8705.5, Probabilistic Risk Assessment (PRA) Procedures for NASA Programs and Projects.

Table 2.1, Criteria for Determining the Project Priority

CONSEQUENCE CATEGORY	CRITERIA / SPECIFICS		Project Priority Ranking
Human Safety and Health	Public Safety and Health	Planetary Protection Program Requirement	I
		White House Approval (PD/NSC-25)	
		Space Missions with Flight Termination Systems	
	Human Space Flight		
Mission Success (for non-human rated missions)	High Strategic Importance Projects		I
	Limited Window		
	High Cost (See NPR 7120.5)		
	Medium Cost (See NPR 7120.5)		II
	Low Cost (See NPR 7120.5)		III

2.4.2 Once the project priority is determined, the scope of system safety modeling is determined using Table 2.2.

2.4.3 Projects identified as "Priority I" ranking from Tables 2.1 are generally the most visible and complex of NASA's product lines. Because of this, the system safety technical processes for Priority I projects must include probabilistic risk assessment as specified in NPR 8705.5, Probabilistic Risk Assessment (PRA) Procedures for NASA Programs and Projects. For Priority II or III projects, Table 2.2 provides latitude to adjust the scope of system safety modeling. This graded approach to the application of system safety modeling also operates on another dimension. That is, the level of rigor and detail associated with system safety modeling activities must be commensurate with the availability of design and operational information. The two-dimensional nature of the graded approach is intended to ensure that allocation of resources to system safety technical activities considers the visibility and complexity of the project and to ensure that the level of rigor associated with system safety models follows the level of maturity of the system design.

Note: For example, during the formulation phase, an order-of-magnitude or bounding assessment may be performed. In this type of assessment, the probability and/or the magnitude of consequence is approximated or bounded instead of deriving a best-estimate. These assessments are useful for screening purposes and initial risk tradeoff studies.

Table 2.2, Graded Approach to System Safety Modeling

Priority Ranking	Scope (The level of rigor and details are commensurate with the level of design maturity)
I	Probabilistic risk assessment (per NPR 8705.5) supported by qualitative system safety analysis
II	Qualitative system safety analysis supplemented by probabilistic risk assessment where appropriate
III	Qualitative system safety analysis

2.5 Core Requirements for System Safety Processes

2.5.1 The system safety modeling approaches previously described should be implemented as part of technical processes that represent system safety activities. Conceptually, system safety activities consist of three major technical processes as shown in the circular flow diagram in Figure 2.6. These processes are designed to systematically and objectively analyze hazards and identify the mechanism for their elimination or control. These processes begin in the conceptual phase and extend throughout the life cycle of a system including disposal. In general, requirements for safety system technical processes must provide a risk-informed perspective to decision makers participating in the project life cycle. The three critical technical processes to a successful system safety program are (1) system safety modeling, (2) life cycle applications of models for risk-informed decisions and, (3) monitoring safety performance. The circular flow indicates that these technical processes are linked and are performed throughout the project life cycle. A System Safety Technical Plan is used to guide the technical processes and establish roles and responsibilities. This plan is established early in the formulation phase of each project and updated throughout the project life cycle.

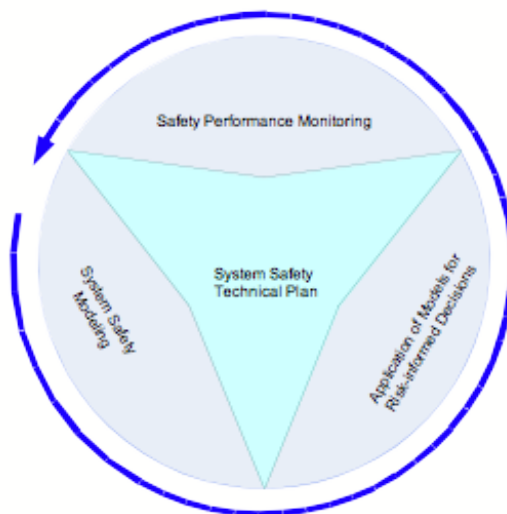


Figure 2.1, The System Safety Technical Processes

2.5.2 System Safety Technical Plan (SSTP)

2.5.2.1 The SSTP is designed to be a technical planning guide for the technical performance and management of the system safety activities. The SSTP can be a stand-alone document, or part of the SMA plan or the Systems Engineering Management Plan (SEMP). It provides the specifics of the system safety modeling activities and describes what and how safety adverse consequences will be modeled, how system safety models (qualitative and probabilistic risk assessments) will be integrated and applied for risk-informed decision making and safety monitoring, how the technical team(s) responsible for generating and maintaining system safety models will interact with the system engineering organizations, the reporting protocol, and the cost and schedule associated with accomplishing system safety modeling activities in relation to the critical or key events during all phases of the life cycle.

2.5.2.2 Project managers shall:

- a. Ensure, for Category I project/programs, that the SSTP is approved by the governing Program Management Council (PMC) and has concurrence by the cognizant SMA managers and the project's senior engineer.
- b. Ensure that the System Safety Manager and the prime contractor (for out-of-house projects) have the resources to implement the SSTP.
- c. Ensure, for Category I project/programs, that changes to the SSTP are approved by the governing PMC and have concurrence by the Chief, Safety and Mission Assurance.
- d. When the SSTP is not an integral part of the SEM, ensure the SSTP is coordinated with the SEM for the integration of system safety activities with other system engineering technical processes.

2.5.2.3 The Center SMA Director shall:

- a. In coordination with the program/project manager, assign a System Safety Manager to have specific responsibility for the development and implementation of the SSTP.
- b. Ensure that the assigned System Safety Manager has demonstrated expertise in safety analysis including, in the case of Category I and II projects, the application of probabilistic risk assessment techniques.
- c. Ensure that all personnel with project safety oversight responsibilities are funded by other than direct project funding sources.

2.5.2.4 The assigned System Safety Manager shall:

- a. Develop a SSTP during the project formulation phase and update the plan throughout the system life cycle.
- b. Ensure that the scope of system safety technical processes in the SSTP follows the graded approach specified in Tables 2.1 and 2.2.
- c. Ensure that the SSTP provides the specifics of the system safety modeling activities and their application to risk-informed decision making and safety monitoring throughout the project life cycle.

- d. In consultation with the project managers, establish and document in the SSTP the objectives and scope of the system safety tasks and define applicable safety deliverables and performance measures.
- e. Provide technical direction and manage implementation of system safety activities as specified in the SSTP.
- f. Ensure that system safety engineering activities are integrated into system engineering technical processes.
- g. Determine the acceptability of residual risk stemming from safety assessments.
- h. Ensure that specific safety requirements are integrated into overall programmatic requirements and are reflected in applicable program and planning documents including the statement of work for contractor designs.
- i. Maintain appropriate safety participation in the program design, tests, operations, failures and mishaps, and contractor system safety activities at a level consistent with mishap potential for the life of the program.
- j. Establish an independent safety reporting channel to keep the Center SMA Director apprised of the system safety status (including tests and operations), particularly regarding problem areas that may require assistance from the Center, the NASA Engineering and Safety Center, or Headquarters.
- k. Support OSMA requirements for audits, assessments, and reviews.

2.5.3 System Safety Modeling

2.5.3.1 Developing and maintaining technically sound and tractable safety models are essential activities for ensuring safety. In these activities, analysts use all the relevant and available information including design documents, operational procedures, test results, operational history, and human and software performance to develop comprehensive system safety models. Developing these models is multidisciplinary and may involve diverse and geographically dispersed groups. Thus, it is important for the safety modeling activities to be coordinated in order to ensure consistency and technical quality.

2.5.3.2 Safety models need to be synchronized with the system design and operational state-of-knowledge to ensure the models match the collected engineering information during operation with model predictions.

2.5.3.3 System Safety Managers shall ensure that the system safety modeling activities are fully integrated into system engineering and are supported by domain, systems, and specialty engineers.

2.5.3.4 System engineers shall:

- a. Ensure that system safety models use systematic, replicable, and scenario-based techniques to identify hazards, to characterize the risk of accidents, to identify risk control measures, and to identify key uncertainties.
- b. Initially conduct system safety analyses during project formulation and design concept

phases (prior to the Preliminary Design Review) and maintain and update these analyses continuously throughout the project life cycle.

- c. Ensure, for Category I and II program/projects, probabilistic risk assessment techniques are used for system safety analysis.
- d. Ensure that the system safety models are developed in an iterative process to allow model expansion, model updating, and model integration as the design evolves and operational experience is acquired.

Note 1: Relevant leading-indicator (or precursor) events should be documented and evaluated for their impact on the system safety analyses assumptions. Trending of these precursor events should be conducted and contrasted to applicable performance measures.

Note 2: A precursor is an occurrence of one or more events that have significant failure or risk implications.

- e. Use system specific and all relevant data including failure histories, mishap investigation findings, and the NASA Lessons Learned Information System in system safety analysis.
- f. Maintain an up-to-date database of identified hazards, accident scenarios, probabilities and consequences, and key uncertainties throughout the life of the program.
- g. Document the bases for the system safety analyses including key assumptions, accident scenarios, probabilities, consequence severities, and uncertainties such that they are traceable.

2.5.4 Application of System Safety Models for Risk-informed Decisions

2.5.4.1 Safety and technical risk considerations are critical in the decision-making process. When faced with a decision, several conflicting alternatives may be available to the decision maker. In a risk-informed decision-making framework, the decision maker considers safety and other technical attributes as well as programmatic attributes, such as cost and schedule, to select the best decision alternative.

2.5.4.2 Program/project managers shall:

- a. Ensure that a framework is constructed for systematically incorporating system safety analysis results into the evaluation of decision alternatives.
- b. Establish and document a formal and transparent decision-making process for hazard closure and formally accepting residual risk that has been determined to be acceptable by the cognizant technical authority.

Note: Closure of a hazard condition or other safety issue is the demonstration that all safety requirements expressly formulated to address the condition or issue have been satisfied.

c. Ensure acceptable residual risks are accepted in writing. (See paragraph 1.6 of this NPR.)

Note: Residual risk is the level of risk that remains present after applicable safety-related requirements have been satisfied. In a risk-informed context, such requirements may include measures and provisions intended to reduce risk from above to below a defined acceptable level.

d. Ensure that decisions to accept risk are coordinated with the governing SMA organization and communicated to the next higher level of management for review. (See paragraph 1.6.2 of this NPR.)

e. Where residual risks have been determined by either the cognizant technical authority or the cognizant SMA authority as "unacceptable," initiate risk mitigation/control activities, as appropriate, to reduce the risk to an acceptable level.

f. Ensure that the requirements of this Chapter are specified in related contracts, memoranda of understanding, and other agreement documents. (See Chapter 9 of this NPR.)

2.5.4.3 The System Safety Manager shall:

a. Ensure that system safety models are constructed to support the implementation of the risk-informed decision framework.

b. Ensure that the system safety models incorporate all the safety attributes important to risk-informed decision making by working with the project manager and other decision makers as deemed appropriate.

c. Establish the methods and tools that are used in the risk-informed framework.

d. Check and validate the methods and tools before implementation and obtain concurrence from the project manager.

e. Document the bases for the methods and tools used and analytical results.

2.5.5 Performance Monitoring

2.5.5.1 Safety, like other performance attributes, is monitored during the entire life cycle to ensure that an acceptable level of safety is maintained.

2.5.5.2 Project managers shall ensure that the performance attributes and precursors that are identified as being important indicators of system safety are monitored.

2.5.5.3 The System Safety Manager shall:

a. Establish the methods and tools that are used in the performance monitoring and precursor assessments.

b. Check and validate the methods and tools used for performance monitoring and precursor assessments before implementation.

c. Maintain an up-to-date database of the performance monitoring results and precursor

results.

- d. Ensure that the performance monitoring and precursor data are fed back into system safety analyses and the results updated.
- e. Document the bases for the methods and tools that are used in the performance monitoring and precursor assessments.

2.6 System Safety Reviews

2.6.1 System Safety and Mission Success Program Reviews are conducted in conjunction with other program milestones. The purpose of these reviews is to evaluate the status of system safety and risk analyses, risk management, verification techniques, technical safety requirements, and program implementation throughout all the phases of the system life cycle.

2.6.2 The program/project manager shall:

- a. Conduct periodic system safety and mission success reviews of their program/project depending on the complexity of the system.

Note: The greater the risks, complexity of the system, or visibility of the programs, the greater the independence and formality of the reviews.

- b. Document the periodicity of the System Safety and Mission Success Program Reviews in the SSTP.
- c. Ensure that the System Safety and Mission Success Program Reviews focus on the evaluation of management and technical documentation, hazard closure, and the safety residual risks remaining in the program at that stage of development.
- d. Establish and maintain dedicated independent assessment activities for Priority I programs and projects, such as the Constellation Program.

2.6.3 The System Safety Manager shall:

- a. Conduct periodic independent reviews of the system safety tasks keyed to project milestones.
- b. Assist and support independent review groups established to provide independent assessments of the program.
- c. Support the OSMA independent safety assessment process to determine readiness to conduct tests and operations having significant levels of safety risks.

2.7 Change Review

2.7.1 Systems are changed during their life cycle to enhance capabilities, improve safety, provide more efficient operation, and incorporate new technology. With each change, the original safety aspects of the system can be impacted, either increasing or

reducing the risk. Any aspect of controlling hazards can be weakened, risks can be increased, or conversely, risks can be decreased. Even a change that appears inconsequential could have significant impact on the baseline risk of the system. Accordingly, proposed system changes should be subjected to a safety review or analysis, as appropriate, to assess the safety and risk impacts, including implications on controls and mitigations for significant hazards and failure modes.

2.7.2 The project manager and the System Safety Manager shall:

- a. Update the system safety analyses to identify any change in risk.
- b. Ensure that safety personnel assess the potential safety impact of the proposed change and any changes to the baseline risk and previously closed hazards.
- c. Ensure that proposed changes to correct a safety problem are analyzed to determine the amount of safety improvement (or detriment) that would result from incorporation of the change.
- d. Ensure that the safety impact for every change that is proposed to a program baseline (even if the statement is "No Impact") is documented.

2.8 Documentation

2.8.1 The maintenance of the SSTP is required to provide ready traceability from the baseline safety requirements, criteria, and efforts planned in the conceptual phases through the life cycle of the program.

2.8.2 The project manager (or designated agent) and the System Safety Manager shall:

- a. Ensure that all pertinent details of the system safety analysis and review are traceable from the initial identification of the risks through their resolution and any updates in the SSTP.
- b. Ensure that records are maintained per NPR1441.1, NASA Records Retention Schedules.

2.8.3 The System Safety Manager shall:

- a. Submit a system safety analysis report to the program/project manager at each milestone (formulation, evaluation, implementation, or other equivalent milestones [e.g., Safety Requirements Review, Preliminary Design Review, Critical Design Review, and Flight Readiness Review]) detailing the results of the system safety analyses completed to date to document the status of system safety tasks.

Note: Safety requirements include both deterministic and risk-informed requirements. A deterministic safety requirement is the qualitative or quantitative definition of a threshold of action or performance that must be met by a mission-related design item, system, or activity in order for that item, system, or activity to be acceptably safe. A risk-informed requirement is a safety requirement that has been established, at least in part, on the basis of the consideration of a safety-related risk metric and its associated

uncertainty.

- b. Ensure that each submitted revision to the system safety analysis report lists the risks that have been addressed, the risks that have yet to be addressed, and expected residual risks that will remain following the implementation of risk reduction strategies.
- c. Ensure that the system safety analysis report documents management and technical changes that affect the established safety baseline (by changes in the planned approach, design, requirements, and implementation) and is revised when required.
- d. Ensure that a final approved system safety analysis report is produced that contains a verification of the resolution of the risks and a written acceptance of the residual risks from the program/project manager to complete the audit trail.

Chapter 3. Operational Safety

This chapter on Operational Safety was cancelled by [NPR 8715.1B](#). NPR 8715.1 provides the requirements for ensuring operational safety.

Chapter 4. Aviation Safety

This chapter on Aviation Safety was cancelled by [NPR 8715.1B](#). NPR 8715.1 and NPR 7900.3, Aircraft Operations Management, provide the requirements for ensuring aviation safety.

Chapter 5. Fire Safety

This chapter on Fire Safety was cancelled by [NPR 8715.1B](#). NPR 8715.1 provides the requirements for ensuring fire and life safety.

Chapter 6. Nuclear Safety for Launching of Radioactive Materials

This chapter on Nuclear Safety for Launching of Radioactive Materials was cancelled by NPR 8715.26. NPR 8715.26 provides the requirements for ensuring NASA's nuclear flight safety activities.

Chapter 7. Safety Training and Personnel Certification

This chapter on Safety Training and Personnel Certification was cancelled by [NPR 8715.1B](#). NPR 8715.1 provides the requirements for ensuring safety training and personnel certification.

Chapter 8. Safety for Facility Acquisition, Construction, Activation, and Disposal

This chapter on Safety for Facility Acquisition, Construction, Activation, and Disposal was cancelled by [NPR 8715.1B](#). NPR 8715.1 provides the requirements for ensuring safety during facility acquisition, construction, activation, and disposal.

Chapter 9. Safety and Risk Management for NASA Contracts

9.1 Purpose

This chapter provides the procedural requirements for assuring that NASA contractors have effective safety and risk management programs. This chapter provides requirements for NASA officials with responsibility for assuring safety under NASA contracts.

9.2 Applicability and Scope

9.2.1 When NASA activities include contractor involvement, Center Directors and project managers shall include contractors in the NASA Safety Program.

9.2.2 Center SMA Directors, project managers, Contracting Officers (CO), and Contracting Officers Technical Representatives (COTR) shall ensure that NASA contracts are written to hold contractors accountable for the safety of their employees, their services, their products, and for complying with NASA and Center safety requirements.

9.3 Authority and Responsibility

9.3.1 Project managers shall:

- a. Work with cognizant safety officials to develop and approve safety requirements and objectives for efforts to be contracted, and advise COs and COTRS of specific safety concerns or issues related to contract performance.
- b. Ensure that the application of the requirements in Chapter 2 of this NPR are specified in related contracts memoranda of understanding, and other documents for joint ventures between NASA and other parties including commercial services, interagency efforts, and international partnerships.
- c. Ensure that NASA responsibilities are specified in contracts, memoranda of understanding, and other documents for joint ventures between NASA and other parties including commercial services, interagency efforts, and international partnerships.
- d. Ensure that contracts contain safety, mission success, and risk management requirements for design, development, fabrication, test, and the operations of systems, equipment, and facilities in consultation with Center SMA Directors.
- e. Use the software safety requirements in NASA-STD-8739.8, as the basis for contracts, memoranda of understanding, and other documents related to software.
- f. Provide specific safety tasks to the CO for incorporation into contracts.
- g. Define the surveillance of contractor safety matters with respect to the nature of the procurement.
- h. Ensure that performance-based contracts have a surveillance plan.

9.3.2 Project Managers, COs, and COTRs shall:

- a. Develop system safety requirements and objectives that are clearly delineated in contract specifications in conjunction with project officials.
- b. Establish system safety performance as an element to be evaluated in contracts with fee plans.
- c. Participate in onsite visits and pre-bid conferences to ensure potential bidders understand safety provisions.
- d. Review, comment, and approve (or disapprove) the contractors' system safety risk assessment, submitted in response to paragraph 9.3.3, before the start of any hazardous deliverable work or support operations.
- e. Coordinate any matter regarding proposed requests for relief to safety requirements of 48 CFR pt. 1823.70, with the OSMA or designated representative.
- f. Implement NPR 5100.4.
- g. Implement 48 CFR pts. 1807; 1823; 1842, and 1846.

9.3.3 COs or the COTR shall ensure the contractors' safety risk assessments are developed and provided to NASA for approval before the start of any hazardous deliverable work or support operations.

9.3.4 Project Managers shall:

- a. Assist the CO and COTR in evaluating the prospective contractor's system safety program.
- b. Assist the CO and COTR in applying any special system safety provisions to grants or cooperative agreements (see paragraph 2.7).
- c. During the pre-award phase of acquisition, develop, document and provide to the CO criteria for the system safety performance elements to be evaluated in contracts with fee plans in a timely manner to ensure inclusion in the solicitation.

9.4 Requirements

9.4.1 Project managers, COs and COTRs shall ensure that system safety and risk management evaluation criteria and solicitation instructions are developed in conjunction with responsible project personnel and Center SMA organization representatives.

9.4.2 Center Directors, SMA Directors, COs, and COTRs shall ensure that contracts contain appropriate institutional safety and health requirements as required by NPR 8715.1, NASA Safety and Health Programs.

APPENDIX A. Definitions

Accident. A severe perturbation to a mission or program, usually occurring in the form of a sequence of events, that can cause safety adverse consequences, in the form of death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment.

Assessment. Review or audit process, using predetermined methods, that evaluates hardware, software, procedures, technical and programmatic documents, and the adequacy of their implementation.

Assurance. Providing a measure of increased confidence that applicable requirements, processes, and standards are being fulfilled.

Audit. Formal review to assess compliance with hardware or software requirements, specifications, baselines, safety standards, procedures, instructions, codes, and contractual and licensing requirements.

Catastrophic. (1) A hazard that could result in a mishap causing fatal injury to personnel, and/or loss of one or more major elements of the flight vehicle or ground facility. (2) A condition that may cause death or permanently disabling injury, major system or facility destruction on the ground, or loss of crew, major systems, or vehicle during the mission.

Center SMA Director. As used in this directive, this term includes all Center management personnel designated by the Center Director to implement SMA audits, reviews, and assessments requirements.

Critical. A condition that may cause severe injury or occupational illness, or major property damage to facilities, systems, or flight hardware.

Emergency. Unintended circumstance bearing clear and present danger to personnel or property which requires an immediate response.

Exposure. (1) Vulnerability of a population, property, or other value system to a given activity or hazard; or (2) other measure of the opportunity for failure or mishap events to occur.

Factor of Safety (Safety Factor). Ratio of the design condition to the maximum operating conditions specified during design (see also Safety Margin and Margin of Safety).

Fail-Safe. Ability to sustain a failure and retain the capability to safely terminate or control the operation.

Failure. Inability of a system, subsystem, component, or part to perform its required function within specified limits.

Failure Tolerance. Built-in capability of a system to perform as intended in the presence of specified hardware or software failures.

Functional Redundancy. A situation where a dissimilar device provides safety backup rather than

relying on multiple identical devices.

Hazard. A state or a set of conditions, internal or external to a system that has the potential to cause harm.

Hazard Control. Means of reducing the risk of exposure to a hazard.

Independent Verification and Validation. Test and evaluation process by an independent third party.

Inhibit. Design feature that prevents operation of a function.

Mission Assurance. Providing increased confidence that applicable requirements, processes, and standards for the mission are being fulfilled.

Mission Success. Meeting all mission objectives and requirements for performance and safety.

Nuclear Flight Safety Assurance Manager (NFSAM). The person in the Office of Safety and Mission Assurance responsible for assisting the project offices in meeting the required nuclear launch safety analysis/evaluation.

Operability. As applied to a system, subsystem, component, or device is the capability of performing its specified function(s) including the capability of performing its related support function(s).

Operational Safety. That portion of the total NASA safety program dealing with safety of personnel and equipment during launch vehicle ground processing, normal industrial and laboratory operations, use of facilities, special high hazard tests and operations, aviation operations, use and handling of hazardous materials and chemicals from a safety viewpoint.

Oversight. The transition in NASA from a strict compliance-oriented style of management to one which empowers line managers, supervisors, and employees to develop better solutions and processes.

Precursor. An occurrence of one or more events that have significant failure or risk implications.

Programs. For the purposes of this NPR the term "programs" is interpreted to include programs, projects, and acquisitions.

Quality. The composite of material attributes including performance features and characteristics of a product or service to satisfy a given need.

Radiological Control Center (RADCC). A temporary information clearinghouse established on an as-needed basis to coordinate actions that could be required for mitigation, response, and recovery of an incident involving the launching of nuclear material.

Range Safety. Application of safety policies, principles, and techniques to ensure the control and containment of flight vehicles to preclude an impact of the vehicle or its pieces outside of

predetermined boundaries from an abort which could endanger life or cause property damage. Where the launch range has jurisdiction, prelaunch preparation is included as a safety responsibility.

Redundancy. Use of more than one independent means to accomplish a given function.

Reliability. The probability that a system of hardware, software, and human elements will function as intended over a specified period of time under specified environmental conditions.

Reliability Analysis. An evaluation of reliability of a system or portion thereof. Such analysis usually employs mathematical modeling, directly applicable results of tests on system hardware, estimated reliability figures, and non-statistical engineering estimates to ensure that all known potential sources of unreliability have been evaluated.

Residual Risk. The level of risk that remains after applicable safety-related requirements have been satisfied. In a risk-informed context, such requirements may include measures and provisions intended to reduce risk from above to below an acceptable level.

Risk. The combination of (1) the probability (qualitative or quantitative) of experiencing an undesired event, (2) the consequences, impact, or severity that would occur if the undesired event were to occur and (3) the uncertainties associated with the probability and consequences.

Risk Management. An organized, systematic decision-making process that efficiently identifies, analyzes, plans, tracks, controls, communicates, and documents risk to increase the likelihood of achieving project goals.

Risk (Safety) Assessment. Process of qualitative risk categorization or quantitative risk (safety) estimation, followed by the evaluation of risk significance.

Safety. Freedom from those conditions that can cause death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment. In a risk-informed context, safety is an overall mission and program condition that provides sufficient assurance that accidents will not result from the mission execution or program implementation, or, if they occur, their consequences will be mitigated. This assurance is established by means of the satisfaction of a combination of deterministic criteria and risk criteria.

Safety Analysis. Generic term for a family of analyses, which includes but is not limited to, preliminary hazard analysis, system (subsystem) hazard analysis, operating hazard analysis, software hazard analysis, sneak circuit, and others.

Safety Analysis Report (SAR). A safety report of considerable detail prepared by or for the program detailing the safety features of a particular system or source.

Safety Analysis Summary (SAS). A brief summary of safety considerations for minor sources; a safety report of less detail than the SAR.

Safety Critical. Term describing any condition, event, operation, process, equipment, or system that could cause or lead to severe injury, major damage, or mission failure if performed or built improperly, or allowed to remain uncorrected.

Safety Device. A device that is part of a system, subsystem, or equipment that will reduce or make controllable hazards which cannot be otherwise eliminated through design selection.

Safety Evaluation Report (SER). A safety report prepared by the INSRP detailing the INSRP's assessment of the nuclear safety of a particular source or system based upon INSRP's evaluation of the program-supplied SAR and other pertinent data.

Safety Margin. Difference between as-built factor of safety and the ratio of actual operating conditions to the maximum operating conditions specified during design.

Safety Oversight. Maintaining functional awareness of program activities on a real-time basis to ensure risk acceptability.

Safety Program. The implementation of a formal comprehensive set of safety procedures, tasks, and activities to meet safety requirements, goals, and objectives.

Serious. When used with "hazard," "violation," or "condition," denotes there is a substantial probability that death or serious physical harm could result.

System Safety. Application of engineering and management principles, criteria, and techniques to optimize safety and reduce risks within the constraints of operational effectiveness, time, and cost throughout all phases of the system life cycle.

System Safety Manager. A designated management person who, qualified by training and/or experience, is responsible to ensure accomplishment of system safety tasks.

Validation. (1) An evaluation technique to support or corroborate safety requirements to ensure necessary functions are complete and traceable; or (2) the process of evaluating software at the end of the software development process to ensure compliance with software requirements.

Verification (Software). (1) The process of determining whether the products of a given phase of the software development cycle fulfill the requirements established during the previous phase (see also validation); or (2) formal proof of program correctness; or (3) the act of reviewing, inspecting, testing, checking, auditing, or otherwise establishing and documenting whether items, processes, services, or documents conform to specified requirements.

APPENDIX B: Acronyms

CO	Contracting Officer
COTR	Contracting Officers Technical Representative
DOE	Department of Energy
IAEA	International Atomic Energy Agency
INSRP	Interagency Nuclear Safety Review Panel
NEPA	National Environmental Policy Act
NFSAM	Nuclear Flight Safety Assurance Manager
OCHMO	Office of the Chief Health and Medical Officer
OPR	Office of Primary Responsibility
OSMA	Office of Safety and Mission Assurance
OSTP	Office of Science and Technology Policy
PD/NSC	Presidential Directive/National Security Council
PMC	Program Management Council
RADCC	Radiological Control Center
SAS	Safety Analysis Summary
SEMP	Systems Engineering Management Plan
SER	Safety Evaluation Report
SMA	Safety and Mission Assurance
SSTP	System Safety Technical Plan

APPENDIX C. Safety Motivation and Awards Program - *RESERVED*

Appendix D. Activity and Radioactive Material Limits - Basic A₁/A₂ Values

D.1 Determination of A₂ Mission Multiple.

D.1.1 The A₂ multiplier for each radioactive source is based upon the International Atomic Energy Agency (IAEA), Safety Series Number 6, Regulations for the Safe Transport of Radioactive Material, 1985 Edition as amended in 1990, Section III, paragraphs 301 through 306, and summed to determine the A₂ mission multiple.

D.1.2 Table I of this Appendix contains the referenced IAEA document section which tabulates the A₂ values for specific isotopes and forms of radioactive material. Except as noted, for radioisotopes whose A₂ limit in Table I is "Unlimited" or is unlisted, the value of 3.7×10^{-2} teraBecquerals (TBq) (1.0 Curies (Ci)) shall be used as the A₂ value.

D.1.3 Exceptions are Sm-147, use 9×10^{-4} TBq (0.024 Ci) and Th-232, use 9×10^{-5} TBq (0.0024 Ci) as their respective A₂ values.

D.1.4 The A₂ mission multiple shall be determined as follows where n represents each source or line on the report in paragraph 5.4.1.2 for each radioactive material on the launch vehicle and spacecraft:

$$A_2 \text{ Mission Multiple} = \sum_n (\text{Radioactive Source}_n \text{ Activity}) / \text{Source}_n \text{ Isotopic } A_2 \text{ Value}$$

D.1.5 Values of A₁ and A₂ for individual radionuclides, which are the basis for many activity limits elsewhere in this NPR, are given in Table I.

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D.2 Determination of A₁ and A₂

D.2.1 For individual radionuclides whose identities are known, but which are not listed in Table I, the determination of the values of A₁ and A₂ shall require competent authority approval or, for international transport, multilateral approval. Alternatively, the values of A₁ and A₂ in Table II may be used without obtaining competent authority approval.

D.2.2 In the calculations of A₁ and A₂ for a radionuclide not in Table I, a single radioactive decay chain in which the radionuclides are present in their naturally occurring proportions and in which no daughter nuclide has a half-life either longer than 10 days or longer than that of the parent nuclide shall be considered as a single radionuclide, and the activity to be taken into account and the A₁ or A₂ value to be applied shall be those corresponding to the parent nuclide of that chain. In the case of radioactive decay chains in which any daughter nuclide has a half-life either longer than 10 days or greater than that of the parent nuclide, the parent and such daughter nuclides shall be considered as mixtures of different nuclides.

D.2.3 For mixtures of radionuclides whose identities and respective activities are known, the following conditions shall apply where B(i) is the activity of radionuclide i and A₁(i) and A₂(i) are the A₁ and A₂ values for radionuclide i, respectively:

(a) For special form radioactive material:

$$\sum_i B(i) / A_1(i) \text{ less than or equal to } 1$$

(b) For other forms of radioactive material:

$$\sum_i B(i) / A_2(i) \text{ less than or equal to } 1$$

Table D-1. A₁ And A₂ Values for Radionuclides

Symbol of radionuclide	Element and atomic number	A ₁ (TBq)	A ₁ (Ci)	A ₂ (TBq) (approx. *)	A ₂ (Ci) (approx. *)
²²³ Ac (b)*	Actinium (89)	0.6	10	1 x 10 ⁻²² x 10 ⁻¹	10
²²⁷ Ac		40	1000	2 x 10 ⁻²⁵ x 10 ⁻⁴	
²²⁸ Ac		0.6	10	0.4	
¹⁰³ Ag	Silver (47)	2	50	2	50
¹⁰⁸ Ag ^{db}		0.6	10	0.6	10
¹¹⁰ Ag ^{db}		0.4	10	0.4	10
¹¹¹ Ag		0.6	10	0.6	10
²⁶ Al	Aluminum (13)	0.4	10	0.4	10
²⁴¹ Am	Americium (95)	2	50	2 x 10 ⁻⁴⁵ x 10 ⁻³	
²⁴² Am ^{db}		2	50	2 x 10 ⁻⁴⁵ x 10 ⁻³	
²⁴³ Am		2	50	2 x 10 ⁻⁴⁵ x 10 ⁻³	
³⁷ Ar	Argon (18)	40	1000	40	1000
³⁹ Ar		20	500	20	500
⁴¹ Ar		0.6	10	0.6	10
⁴² Ar (b)		0.2	5	0.2	5
⁷² As	Arsenic(33)	0.2	5	0.2	5
⁷³ As		40	1000	40	1000
⁷⁴ As		1	20	0.5	10
⁷⁶ As		0.2	5	0.2	5
⁷⁷ As		20	500	0.5	10
²¹¹ At	Astatine (85)	30	800	2	50

* Note: (b) indicates a footnote at the end of Table I: this form is used to avoid confusion with the superscript m.

Symbol of radionuclide	Element and atomic number	A ₁ (TBq)	A ₁ (Ci)	A ₂ (TBq) (approx. *)	A ₂ (Ci) (approx. *)
¹⁹² Au	Gold (79)	6	100	6	100
¹⁹⁴ Au		1	20	1	20
¹⁹⁵ Au		10	200	10	200
¹⁹⁶ Au		2	50	2	50
¹⁹⁸ Au		3	80	0.5	10
¹⁹⁹ Au		10	200	0.9	20
¹³¹ Ba	Barium (56)	2	50	2	50
¹³² Ba ^{db}		10	200	0.9	20
¹³³ Ba		3	80	3	80
¹⁴⁰ Ba (b)		0.4	10	0.4	10
⁷ Be	Beryllium (4)	20	500	20	500
¹⁰ Be		20	500	0.5	10
²⁰³ Bi	Bismuth (83)	0.6	10	0.6	10
²⁰⁶ Bi		0.3	8	0.3	8
²⁰⁷ Bi		0.7	10	0.7	10
²¹⁰ Bi ^{db} (b)		0.3	8	3 x 10 ⁻²⁸ x 10 ⁻¹	
²¹⁰ Bi		0.6	10	0.5	10
²¹² Bi (b)		0.3	8	0.3	8
²⁴⁷ Bk	Berkelium (97)	2	50	2 x 10 ⁻⁴⁵ x 10 ⁻³	
²⁴⁹ Bk		40	1000	8 x 10 ⁻²²	
⁷⁶ Br	Bromine (35)	0.3	8	0.3	8
⁷⁷ Br		3	80	3	80
⁸² Br		0.4	10	0.4	10

¹² C	Carbon (6)	1	20	0.5	10
¹⁴ C		40	1000	2	50
⁴¹ Ca	Calcium (20)	40	1000	40	1000
⁴³ Ca		40	1000	0.9	20
⁴⁷ Ca		0.9	20	0.5	10
¹⁰⁹ Cd	Cadmium (48)	40	1000	1	20
¹¹² Cd ^{ab}		20	500	9 x 10 ⁻²	
¹¹³ Cd ^{ab}		0.3	8	0.3	8
¹¹⁴ Cd		4	100	0.5	10
¹³⁹ Ce	Cerium (58)	6	100	6	100
¹⁴¹ Ce		10	200	0.5	10
¹⁴³ Ce		0.6	10	0.5	10
¹⁴⁴ Ce (b)		0.2	5	0.2	5
²⁴⁸ Cf	Californium (98)	30	800	3 x 10 ⁻³⁸ x 10 ⁻²	
²⁴⁹ Cf		2	50	2 x 10 ⁻⁴⁵ x 10 ⁻²	
²⁵⁰ Cf		5	100	5 x 10 ⁻⁴¹ x 10 ⁻²	
²⁵¹ Cf		2	50	2 x 10 ⁻⁴⁵ x 10 ⁻²	
²⁵² Cf		0.1	2	1 x 10 ⁻³² x 10 ⁻²	
²⁵³ Cf		40	1000	6 x 10 ⁻²	
²⁵⁴ Cf		3 x 10 ⁻³⁸ x 10 ⁻²	6 x 10 ⁻⁴¹ x 10 ⁻²		

Symbol of radionuclide	Element and atomic number	A ₁ (TBq)	A ₁ (Ci)	A ₂ (TBq) (approx. *)	A ₂ (Ci) (approx. *)
³⁶ Cl	Chlorine (17)	20	500	0.5	10
³⁸ Cl		0.2	5	0.2	5
²⁴⁰ Cm	Curium (96)	40	1000	2 x 10 ⁻²⁵ x 10 ⁻¹	20
²⁴¹ Cm		2	50	0.9	
²⁴² Cm		40	1000	1 x 10 ⁻²² x 10 ⁻¹	
²⁴³ Cm		3	80	3 x 10 ⁻⁴⁸ x 10 ⁻²	
²⁴⁴ Cm		4	100	4 x 10 ⁻⁴¹ x 10 ⁻²	
²⁴⁵ Cm		2	50	2 x 10 ⁻⁴⁵ x 10 ⁻²	
²⁴⁶ Cm		2	50	2 x 10 ⁻⁴⁵ x 10 ⁻²	
²⁴⁷ Cm		2	50	2 x 10 ⁻⁴⁵ x 10 ⁻²	
²⁴⁸ Cm				1 x 10 ⁻³	
		4 x 10 ⁻²	5 x 10 ⁻³		
⁵⁵ Co	Cobalt (27)	0.5	10	0.5	10
⁵⁶ Co		0.3	8	0.3	8
⁵⁷ Co		8	200	8	200
⁵⁸ Co ^{ab}		40	1000	40	1000
⁵⁹ Co		1	20	1	20
⁶⁰ Co		0.4	10	0.4	10
⁵¹ Cr	Chromium (24)	30	800	30	800
¹³⁹ Cs	Cesium (55)	4	100	4	100
¹³¹ Cs		40	1000	40	1000
¹³² Cs		1	20	1	20
¹³⁴ Cs ^{ab}		40	1000	9	200
¹³⁴ Cs		0.6	10	0.5	10
¹³⁵ Cs		40	1000	0.9	20
¹³⁶ Cs		0.5	10	0.5	10
¹³⁷ Cs (b)		2	50	0.5	10
⁶⁴ Cu	Copper (29)	5	100	0.9	20
⁶⁷ Cu		9	200	0.9	20
¹⁵⁹ Dy	Dysprosium (66)	20	500	20	500
¹⁶³ Dy		0.6	10	0.5	10
¹⁶⁶ Dy (b)		0.3	8	0.3	8
¹⁶⁹ Er	Erbium (68)	40	1000	0.9	20
¹⁷¹ Er		0.6	10	0.5	10
¹⁴⁷ Eu	Europium (63)	2	50	2	50
¹⁴⁸ Eu		0.5	10	0.5	10
¹⁴⁹ Eu		20	500	20	500
¹⁵⁰ Eu		0.7	10	0.7	10
¹⁵³ Eu ^{ab}		0.6	10	0.6	10
¹⁵² Eu		0.9	20	0.9	20
¹⁵⁴ Eu		0.8	20	0.8	10

¹⁵³ Eu		20	500	2	50
¹⁵⁶ Eu		0.6	10	0.5	10
Symbol of radionuclide	Element and atomic number	A₁ (TBq)	A₁ (Ci)	A₂ (TBq) (approx. *)	A₂ (Ci) (approx. *)
¹⁸ F	Fluorine (9)	1	20	0.5	10
⁵⁷ Fe (b)	Iron (26)	0.2	5	0.2	5
⁵⁹ Fe		40	1000	40	1000
⁵⁵ Fe		0.8	20	0.8	20
⁶⁰ Fe		40	1000	0.2	5
⁶⁷ Ga	Gallium (31)	6	100	6	100
⁶⁸ Ga		0.3	8	0.3	8
⁷² Ga		0.4	10	0.4	10
¹⁴⁶ Gd (b)	Gadolinium (64)	0.4	10	0.4	10
¹⁴⁸ Gd		3	80	3 x 10 ⁻⁴ x 10 ⁻³	
¹⁵³ Gd		10	200	5	100
¹⁵⁷ Gd		4	100	0.5	10
⁶⁸ Ge (b)	Germanium (32)	0.3	8	0.3	8
⁷¹ Ge		40	1000	40	1000
⁷⁷ Ge		0.3	8	0.3	8
¹⁷² Hf (b)	Hafnium (72)	0.5	10	0.3	8
¹⁷³ Hf		3	80	3	80
¹⁸⁰ Hf		2	50	0.9	20
¹⁸² Hf		4	100	3 x 10 ⁻⁷ x 10 ⁻¹	
¹⁹⁸ Hg (b)	Mercury (80)	1	20	1	20
¹⁹⁹ Hg ^{eb}		5	100	5	100
¹⁹⁷ Hg ^{eb}		10	200	0.9	20
¹⁹⁹ Hg		10	200	10	200
²⁰⁰ Hg		4	100	0.9	20
¹⁶² Ho	Holmium (67)	40	1000	40	1000
¹⁶⁶ Ho ^{eb}		0.6	10	0.3	8
¹⁶⁶ Ho		0.3	8	0.3	8
¹²³ I	Iodine (53)	6	100	6	100
¹²⁴ I		0.9	20	0.9	20
¹²⁵ I		20	500	2	50
¹²⁶ I		2	50	0.9	20
¹²⁹ I					
¹³¹ I		Unlimited	80	Unlimited	10
¹³² I		3	10	0.5	10
¹³³ I		0.4	10	0.4	10
¹³⁴ I		0.6	8	0.5	8
¹³⁵ I		0.3	10	0.3	10
¹³⁵ I		0.6		0.5	
¹¹¹ In		Indium (49)	2	50	2
¹¹² In ^{eb}	4		100	4	100
¹¹⁴ In ^{eb} (b)	0.3		8	0.3	8
¹¹⁵ In ^{eb}	6		100	0.9	20
Symbol of radionuclide	Element and atomic number	A₁ (TBq)	A₁ (Ci)	A₂ (TBq) (approx. *)	A₂ (Ci) (approx. *)
¹⁸⁷ Ir	Iridium (77)	10	200	10	200
¹⁹⁰ Ir		0.7	10	0.7	10
¹⁹² Ir		1	20	0.5	10
¹⁹² Ir ^{eb}		10	200	10	200
¹⁹⁴ Ir		0.2	5	0.2	5
⁴⁰ K	Potassium (19)	0.6	10	0.6	10
⁴² K		0.2	5	0.2	5
⁴³ K		1	20	0.5	10
⁸¹ Kr	Krypton (36)	40	1000	40	1000
⁸³ Kr ^{eb}		6	100	6	100
⁸⁵ Kr		20	500	10	200
⁸⁷ Kr		0.2	5	0.2	5
¹³⁷ La	Lanthanum (57)	40	1000	2	50

¹⁴⁰ La		0.4	10	0.4	10
LSA	Low specific	activity material	(see paragraph.	131 of Parent	Document)
¹⁷² Lu	Lutetium (71)	0.5	10	0.5	10
¹⁷³ Lu		8	200	8	200
¹⁷⁴ Lu ^{eb}		20	500	8	200
¹⁷⁴ Lu		8	200	4	100
¹⁷⁷ Lu		30	800	0.9	20
MFP	For mixed fission	products, use	formula for	mixtures or	Table II
²⁸ Mg (b)	Magnesium (12)	0.2	5	0.2	5
⁵² Mn	Manganese (25)	0.3	8	0.3	8
⁵³ Mn		Unlimited		Unlimited	
⁵⁴ Mn		1	20	1	20
⁵⁶ Mn		0.2	5	0.2	5
⁹² Mo	Molybdenum (42)	40	1000	7	100
⁹⁹ Mo		0.6	10	0.5	10
¹³ N	Nitrogen (7)	0.6	10	0.5	10
²² Na	Sodium (11)	0.5	10	0.5	10
²⁴ Na		0.2	5	0.2	5
⁹² Nb ^{eb}	Niobium (41)	0.7	10	0.7	10
⁹³ Nb ^{eb}		40	1000	6	10
⁹⁴ Nb		0.6	10	0.6	10
⁹⁵ Nb		1	20	1	20
⁹⁷ Nb		0.6	10	0.5	10
¹⁴⁷ Nd	Neodymium (60)	4	100	0.5	10
¹⁴⁹ Nd		0.36	10	0.5	10
⁵⁹ Ni	Nickel (28)	40	1000	40	1000
⁶⁰ Ni		40	1000	30	800
⁶³ Ni		0.3	8	0.3	8

Symbol of radionuclide	Element and atomic number	A ₁ (TBq)	A ₁ (Ci)	A ₂ (TBq) (approx. *)	A ₂ (Ci) (approx. *)
²³² Np	Neptunium (93)	40	1000	40	1000
²³⁶ Np		7	100	1 x 10 ⁻²² x 10 ⁻²	
²³⁷ Np		2	50	2 x 10 ⁻⁴⁵ x 10 ⁻³	10
²³⁹ Np		6	100	0.5	
¹⁸⁴ Os	Osmium (76)	1	20	1	20
¹⁹¹ Os ^{eb}		40	1000	40	1000
¹⁹¹ Os		10	200	0.9	20
¹⁹² Os		0.6	10	0.5	10
¹⁹⁴ Os (b)		0.2	5	0.2	5
³² P	Phosphorus (15)	0.3	8	0.3	8
³³ P		40	1000	0.9	20
²³⁰ Pa	Protactinium (91)	2	50	0.1	2
²³¹ Pa		0.6	10	6 x 10 ⁻³¹ x 10 ⁻³	20
²³³ Pa		5	100	0.9	
²⁰¹ Pb	Lead (82)	1	20	1	20
²⁰² Pb		40	1000	2	50
²⁰³ Pb		3	80	3	80
²⁰³ Pb		Unlimited		Unlimited	
²¹⁰ Pb (b)		0.6	10	9 x 10 ⁻²² x 10 ⁻¹ ,	8
²¹² Pb (b)		0.3	8	, .3 , , ,	
¹⁰² Pd	Palladium (46)	40	1000	40	1000
¹⁰⁷ Pd		Unlimited		Unlimited	10
¹⁰⁹ Pd		0.6	10	0.5	
¹⁴³ Pm	Promethium (61)	3	80	3	80
¹⁴⁴ Pm		0.6	10	0.6	10
¹⁴⁵ Pm		30	800	7	100
¹⁴⁷ Pm		40	1000	0.9	20
¹⁴⁸ Pm ^{eb}		0.5	10	0.5	10
¹⁴⁹ Pm		0.6	10	0.5	10
¹⁵¹ Pm		3	80	0.5	10

²⁰⁸ Po	Polonium (84)	40	1000	2 x 10 ⁻²⁵ x 10 ⁻¹	
²⁰⁹ Po		40	1000	2 x 10 ⁻²⁵ x 10 ⁻¹	
²¹⁰ Po		40	1000	2 x 10 ⁻²⁵ x 10 ⁻¹	
¹⁴² Pr	Praseodymium (59)	0.2	5	0.2	5
¹⁴³ Pr		4	100	0.5	10
¹⁹⁵ Pt (b)	Platinum (78)	0.6	10	0.6	10
¹⁹¹ Pt		3	80	3	80
¹⁹² Pt ^{en}		40	1000	9	200 1000
¹⁹³ Pt		40	1000	40	50
¹⁹⁴ Pt ^{en}		10	200	2	20
¹⁹⁷ Pt ^{en}		10	200	0.9	10
¹⁹⁷ Pt		20	500	0.5	
Symbol of radionuclide	Element and atomic number	A ₁ (TBq)	A ₁ (Ci)	A ₂ (TBq) (approx. ^a)	A ₂ (Ci) (approx. ^a)
²³⁶ Pu	Plutonium (94)	7	100	7 x 10 ⁻⁴	1 x 10 ⁻²
²³⁷ Pu		20	500	20	500
²³⁸ Pu		2	50	2 x 10 ⁻⁴⁵ x 10 ⁻³	
²³⁹ Pu		2	50	2 x 10 ⁻⁴ 5 x 10 ⁻³	5 x 10 ⁻³
²⁴⁰ Pu		2	50	2 x 10 ⁻⁴	
²⁴¹ Pu		40	1000	1 x 10 ⁻² x 10 ⁻¹	
²⁴² Pu		2	50	2 x 10 ⁻⁴⁵ x 10 ⁻³	
²⁴⁴ Pu (b)		0.3	8	2 x 10 ⁻⁴⁵ x 10 ⁻³	
²²³ Ra (b)	Radium (88)	0.6	10	3 x 10 ⁻²⁸ x 10 ⁻¹	
²²⁴ Ra (b)		0.3	8	6 x 10 ⁻² 1	
²²⁶ Ra (b)		0.6	10	2 x 10 ⁻²⁵ x 10 ⁻¹	
²²⁸ Ra (b)		0.3	8	2 x 10 ⁻²⁵ x 10 ⁻¹	
²²⁸ Ra (b)		0.6	10	4 x 10 ⁻² 1	
⁸¹ Rb	Rubidium (37)	2	50	0.9	20
⁸³ Rb		2	50	2	50
⁸⁴ Rb		1	20	0.9	20
⁸⁶ Rb		0.3	8	0.3	8
⁸⁷ Rb		Unlimited		Unlimited	
Rb (natural)		Unlimited		Unlimited	
¹⁸³ Re	Rhenium (75)	5	100	5	100
¹⁸⁴ Re ^{en}		3	80	3	80
¹⁸⁴ Re		1	20	1	20
¹⁸⁶ Re		4	100	0.5	10
¹⁸⁷ Re		Unlimited		Unlimited	
¹⁸⁸ Re		0.2	5	0.2	5
¹⁸⁹ Re		4	100	0.5	10
Re (natural)	Unlimited		Unlimited		
⁹⁹ Rh	Rhodium (45)	2	50	2	50
¹⁰¹ Rh		4	100	4	100
¹⁰² Rh ^{en}		2	50	0.9	20
¹⁰² Rh		0.5	10	0.5	10
¹⁰³ Rh ^{en}		40	1000	40	1000
¹⁰³ Rh		10	200	0.9	20
²²² Rn (b)	Radon (86)	0.2	5	4 x 10 ⁻²¹ x 10 ⁻¹	
⁹⁷ Ru	Ruthenium (44)	4	100	4	100
¹⁰⁰ Ru		2	50	0.9	20
¹⁰¹ Ru		0.6	10	0.5	10
¹⁰⁶ Ru (b)		0.2	5	0.2	5
³² S	Sulfur (16)	40	1000	2	50
¹²³ Sb	Antimony (51)	0.3	8	0.3	8
¹²⁴ Sb		0.6	10	0.5	10
¹²⁵ Sb		2	50	0.9	20
¹²⁶ Sb		0.4	10	0.4	10
Symbol of radionuclide	Element and atomic number	A ₁ (TBq)	A ₁ (Ci)	A ₂ (TBq) (approx. ^a)	A ₂ (Ci) (approx. ^a)
⁴⁴ Sc	Scandium (21)		0.5	10	0.5
⁴⁶ Sc			0.5	10	0.5

⁴⁷ Sc		9	200	0.9	20
⁴⁸ Sc		0.3	8	0.3	8
SCO	Surface	contaminated	objects (see parag.	144 of Parent	Document)
⁷⁴ Se	Selenium (34)	3	80	3	80
⁷⁹ Se		40	1000	2	50
³¹ Si	Silicon (14)	0.6	10	0.5	10
³² Si		40	1000	0.2	5
¹⁴³ Sm	Samarium (62)	20	500	20	500
¹⁴⁷ Sm		Unlimited			Unlimited
¹⁵¹ Sm		40	1000	4	100
¹⁵³ Sm		4	100	0.5	10
¹¹³ Sn (b)	Tin (50)	4	100	4	100
¹¹⁷ Sn ^{ab}		6	100	2	50
¹¹⁹ Sn ^{ab}		40	1000	40	1000
¹²¹ Sn ^{ab}		40	1000	0.9	20
¹²³ Sn		0.6	10	0.5	10
¹²⁶ Sn (b)		0.2	5	0.2	5
		0.3	8	0.3	8
³² Sr (b)	Strontium (38)	0.2	5	0.2	5
³³ Sr ^{ab}		5	100	5	100
³⁴ Sr		2	50	2	50
³⁷ Sr ^{ab}		3	80	3	80
³⁹ Sr		0.6	10	0.5	10
⁵⁰ Sr (b)		0.2	5	0.1	2
⁹¹ Sr		0.3	8	0.3	8
⁹² Sr (b)		0.8	5	0.5	10
T (all forms)	Tritium (1)	40	1000	40	1000
¹⁷⁸ Ta	Tantalum (73)	1	20	1	20
¹⁷⁹ Ta		30	800	30	800
¹⁸² Ta		0.8	20	0.5	10
¹⁵⁷ Tb	Terbium (65)	40	1000	10	200
¹⁵⁸ Tb		1	20	0.7	10
¹⁶⁰ Tb		0.9	20	0.5	10

Symbol of radionuclide	Element and atomic number	A ₁ (TBq)	A ₁ (Ci)	A ₂ (TBq) (approx. *)	A ₂ (Ci) (approx. *)
⁹⁵ Tc ^{ab}	Technetium (43)	2	50	2	50
⁹⁶ Tc ^{ab} (b)		0.4	10	0.4	10
⁹⁶ Tc		0.4	10	0.4	10
⁹⁷ Tc ^{ab}		40	1000	40	1000
⁹⁷ Tc		Unlimited		Unlimited	
⁹⁸ Tc		0.7	10	0.7	10
⁹⁹ Tc ^{ab}		8	200	8	20
⁹⁹ Tc		40	1000	0.9	20
¹¹⁸ Te (b)	Tellurium (52)	0.2	5	0.2	5
¹²¹ Te ^{ab}		5	100	5	100
¹²¹ Te		2	50	2	50
¹²³ Te ^{ab}		7	100	7	100
¹²⁵ Te ^{ab}		30	800	9	200
¹²⁷ Te ^{ab} (b)		20	500	0.5	10
¹²⁷ Te		20	50	0.5	10
¹²⁹ Te ^{ab} (b)		0.6	10	0.5	10
¹²⁹ Te		0.6	10	0.5	10
¹³¹ Te ^{ab}		0.7	10	0.5	10
¹³² Te (b)		0.4	10	0.4	10
²²⁷ Th		Thorium (90)	9	200	1 x 10 ⁻² x 10 ⁻¹
²²⁸ Th (b)	0.3		8	4 x 10 ⁻⁴ x 10 ⁻²	
²²⁹ Th	0.3		8	3 x 10 ⁻³ x 10 ⁻⁴	
²³⁰ Th	2		50	2 x 10 ⁻⁴ x 10 ⁻³	20
²³¹ Th	40		1000	0.9	
²³² Th				Unlimited	5
²³⁴ Th (b)	Unlimited		5		

Th (natural)		0.2 Unlimited		0.2 Unlimited	
⁴⁴ Ti (b)	Titanium (22)	0.5	10	0.2	5
²⁰⁰ Tl	Thallium (81)	0.8	20	0.8	20
²⁰¹ Tl		10	200	10	200
²⁰² Tl		2	50	2	50
²⁰⁴ Tl		4	100	0.5	10
¹⁶⁷ Tm	Thulium (69)	7	100	7	100
¹⁶⁸ Tm		0.8	20	0.8	20
¹⁷⁰ Tm		4	100	0.5	10
¹⁷¹ Tm		40	1000	10	200

Symbol of radionuclide	Element and atomic number	A ₁ (TBq)	A ₁ (Ci)	A ₂ (TBq) (approx. ^a)	A ₂ (Ci) (approx. ^a)
²³⁰ U	Uranium (92)	40	1000	1 x 10 ⁻² x 10 ⁻¹	
²³² U		3	80	3 x 10 ⁻⁴ x 10 ⁻³	
²³³ U		10	200	1 x 10 ⁻² x 10 ⁻²	
²³⁴ U		10	200	1 x 10 ⁻² x 10 ⁻²	
²³⁵ U		Unlimited ^c		Unlimited ^c	
²³⁶ U		10	200	1 x 10 ⁻² x 10 ⁻²	
U (natural)		Unlimited		Unlimited	
U (enriched 5% or less)		Unlimited		Unlimited ^d	
U (enriched more than 5%)	Unlimited ^c		Unlimited ^{c,d}		
U (depleted)	10		1 x 10 ⁻² x 2 x 10 ⁻²		
		Unlimited		Unlimited ^d	
⁴⁸ V	Vanadium (23)	0.3	8	0.3	8
⁴⁹ V		40	1000	40	1000
¹⁷² W(b)	Tungsten (74)	1	20	1	20
¹⁸¹ W		30	800	30	800
¹⁸² W		40	1000	0.9	20
¹⁸³ W		2	50	0.2	10
¹⁸⁴ W (b)		0.2	5		5
¹²² Xe (b)	Xenon (54)	0.2	5	0.2	5
¹²³ Xe		0.2	5	0.2	5
¹²⁷ Xe		4	100	4	100
¹³¹ Xe ^{db}		40	1000	40	1000
¹³² Xe		20	500	20	500
¹³³ Xe		4	100	4	100
⁸⁷ Y	Yttrium (39)	2	50	2	50
⁸⁸ Y		0.4	10	0.4	10
⁹⁰ Y		0.2	5	0.2	5
⁹¹ Y ^{db}		2	50	2	50
⁹¹ Y		0.3	8	0.3	8
⁹² Y		0.2	5	0.2	5
⁹³ Y		0.2	5	0.2	5
¹⁶⁹ Yb		Ytterbium (70)	3	80	3
¹⁷³ Yb	30		800	0.9	20
⁶³ Zn	Zinc (30)	2	50	2	50
⁶⁵ Zn ^{db} (b)		2	50	0.5	10
⁶⁹ Zn		4	100	0.5	10
⁸⁸ Zr	Zirconium (40)	3	80	3	80
⁹⁰ Zr		40	1000	0.2	5
⁹³ Zr		1	20	0.9	20
⁹⁷ Zr		0.3	8	0.3	8

^a The curie values quoted are obtained by rounding down from the TBq figure after conversion to Ci. This ensures that the magnitude of A₁ or A₂ in Ci is always less than that in TBq.

^b A₁ and/or A₂ value limited by daughter product decay.

^c A₁ and A₂ are unlimited for radiation control purposes only. For nuclear criticality safety this material is subject to the control placed on fissile material.

^d These values do not apply to reprocessed uranium.

D.2.4 Alternatively, an A_2 value for mixtures may be determined as follows where $f(i)$ is the fraction of activity of nuclide i in the mixture and $A_2(i)$ is the appropriate A_2 value for nuclide i :

$$A_2 \text{ for mixture} = 1 / \sum_i f(i) / A_2(i)$$

D.2.5 When the identity of each radionuclide is known but the individual activities of some of the radionuclides are not known, the radionuclides may be grouped and the lowest A_1 or A_2 value, as appropriate, for the radionuclides in each group may be used in applying the formulas in paragraphs 3 - 5. Groups may be based on the total alpha activity and the total beta/gamma activity when these are known, using the lowest A_1 or A_2 values for the alpha emitters or beta/gamma emitters, respectively.

D.2.6. For individual radionuclides or for mixtures of radionuclides for which relevant data are not available, the values shown in Table D-2 shall be used.

TABLE D-2. GENERAL VALUES FOR A_1 AND A_2

Contents A_1 A_2

TBq (Ci)^a TBq (Ci)^a

Only beta or gamma emitting nuclides are known to be present 0.2 (5) 0.02 (0.5)

Alpha emitting nuclides are known to be present or no relevant data are available 0.1 (2) 2×10^{-5} (5×10^{-4})

Note: ^aThe curie values quoted in parentheses are approximate values and are not higher than the TBq values.

Appendix E. Sample Safety and Health Plan for Service or Operations Contracts - *RESERVED*

Appendix F. Sample System Safety Technical Plan for Systems Acquisition, Research, and Development Programs - *RESERVED*

Appendix G. References

- G.1 NPR 7120.5, NASA Space Flight Program and Project Management Requirements.
- G.2 NPR 7120.8, NASA Research and Technology Program and Project Management Requirements.
- G.3 NPR 7123.1, Systems Engineering Procedural Requirements.
- G.4 NPR 7150.2, NASA Software Engineering Requirements.
- G.5 NPR 8000.4, Agency Risk Management Procedural Requirements.
- G.6 NPR 8621.1, NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping.
- G.7 NPR 8705.2, Human-Rating Requirements for Space Systems.
- G.8 NPR 8705.4, Risk Classification for NASA Payloads.
- G.9 NPR 8705.5, Probabilistic Risk Assessment (PRA) Procedures for NASA Programs and Projects.
- G.10 NPR 8715.5, Range Flight Safety Program.
- G.11 NPR 8715.6, NASA Procedural Requirements for Limiting Orbital Debris and Evaluating the Meteoroid and Orbital Debris Environments.
- G.12 NPR 8715.7, Payload Safety Program.
- G.13 NPR 8715.24, Planetary Protection Provisions for Robotic Extraterrestrial Missions.
- G.14 NPR 8735.2, Hardware Quality Assurance Program Requirements for Programs and Projects.
- G.15 NID 8715.129, Biological Planetary Protection for Human Missions to Mars.
- G.16 NASA-STD-8729.1, NASA Reliability and Maintainability (R&M) Standard for Spaceflight and Support Systems.
- G.17 NASA-STD-8739.8, Software Assurance and Software Safety Standard.
- G.18 NASA/SP-2010-580, NASA System Safety Handbook, Volume 1: System Safety Framework and Concepts for Implementation, <https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20120003291.pdf>.<https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20120003291.pdf>
- G.19 NASA/SP-2014-612, NASA System Safety Handbook Volume 2: System Safety Concepts, Guidelines, and Implementation Examples, <https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150015500.pdf>.
- G.20 MIL-STD-882, Standard Practice for Safety Systems.
- G.21 S. Kaplan and B.J. Garrick, "On the Quantitative Definition of Risk," Risk Analysis, 1, 11-27, 1981.
- G.22 National Research Council's report "Understanding Risk: Informing Decisions in a Democratic Society," National Academy Press, Washington, DC, 1996.