NASA Radiation Hardness Assurance (RHA) Standard: Status for 2023 NEPP ETW

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Introduction

- In 2021, the NESC recommended the development of a NASA Agency-level RHA Standard
  - TI-19-01489, https://ntrs.nasa.gov/citations/20210018053
- The RHA Standard initial formulation task is funded by NEPP
  - The effort started in 2022 and continued during FY 2023
  - ECD is Sep 30, 2023
- Review and release process planned for FY 2024

RHA Standard Development Requirements & Challenges

- The RHA Standard must:
  - Envelop the entire portfolio of NASA programs & projects
    - These are very different in terms of MEAL factors
      - Mission (class, criticality), Environments, Application, and Lifetime
  - Address modern technology needs of NASA Programs
    - Use of non-RHA parts, balancing system- and part-level RHA
    - Flexibility: Allow for non-traditional RHA approaches while providing radiation assurance commensurate with the mission-applicable success- and safety requirements
  - Augment but not override existing Center, Program, or IP RHA Standards
  - Include technical rationale “the why”
    - Technology maturation leads to new threats
    - Not intended as a comprehensive RHA textbook
  - Avoid ambiguities in the RHA vernacular
    - “Radiation hard” “Radiation tolerant” “COTS” “EEEE Parts Grade”
  - Be consistent with existing NASA processes

MEAL tailoring is key to accomplishing mission objectives within the program constraints and risk tolerance posture

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Standard-at-a-glance

- Levies requirements for:
  - RHA schedule
  - RHA deliverables
- Requires programs & projects to accept a risk if the schedule / deliverables are not met

- Establishes a process for programs & projects to baseline their RHA approach consistent with the mission-applicable MEAL factors making use of:
  - A defined RHA process taxonomy &
  - A standard correlation with mission class / criticality levels
- In some cases, the process requires programs & projects to accept a risk

- Leverages NASA Risk Management Process[1]
  - Mitigation plan, risk tracking to closure

[1]Risks are not intended as a negative for projects and programs. Instead, the NASA Risk process ensures that projects benefit from program visibility and system-level resources towards meeting mission goals

RHA Process Requirements

	Project Formulation				Project Implementation						Program
	Pre- Phase A	Phase A		Phase B	Phase C		Phase D		Phase E	Phase F	
	KDP A	KDP B		KDP C	KDP D		KDP E		KDP F		
Milestone	MCR	SRR[1]	SDR	PDR	CDR	SIR	ORR	FRR	DR	DRR	FRR
Assign RHA Lead	RAD3										
RHA Feasibility	RAD4	Update as necessary									
RHA Baseline		RAD5									
ERD/EDD	Preliminary estimates	Initial (RAD6)		Update	Final						
RHARD		Initial (RAD7, RAD8)		Update	Final						
Rad Analysis Reports				Initial (RAD9)	Mature (RAD10)	Update as necessary					Final (RAD11)
Parts List Rad Review		Critical Technologies		Initial	Update	Update as necessary					
Test Schedule Plan incl RLAT[2]				Initial	Update	Update as necessary					
Subsystem Rad Req Allocations[3]		Initial		Update	Final						
Radiation Risk	RAD2, then track to closure										
System-level Rad Analysis & Report[4]					Inputs (RAD10)	Update as necessary					Final (RAD11)

RAD 1 The schedule of RHA Activities shall comply with Table 1.

RAD2 If at any time during the program or project life cycle the schedule of RHA activities deviates from Table 1 or the deliverables are insufficient, programs and projects shall accept a radiation risk and formulate a mitigation plan.

RAD6 If at any time the RHA approach does not meet or exceed the default for mission class/criticality, programs and projects shall accept a radiation risk and formulate a mitigation plan

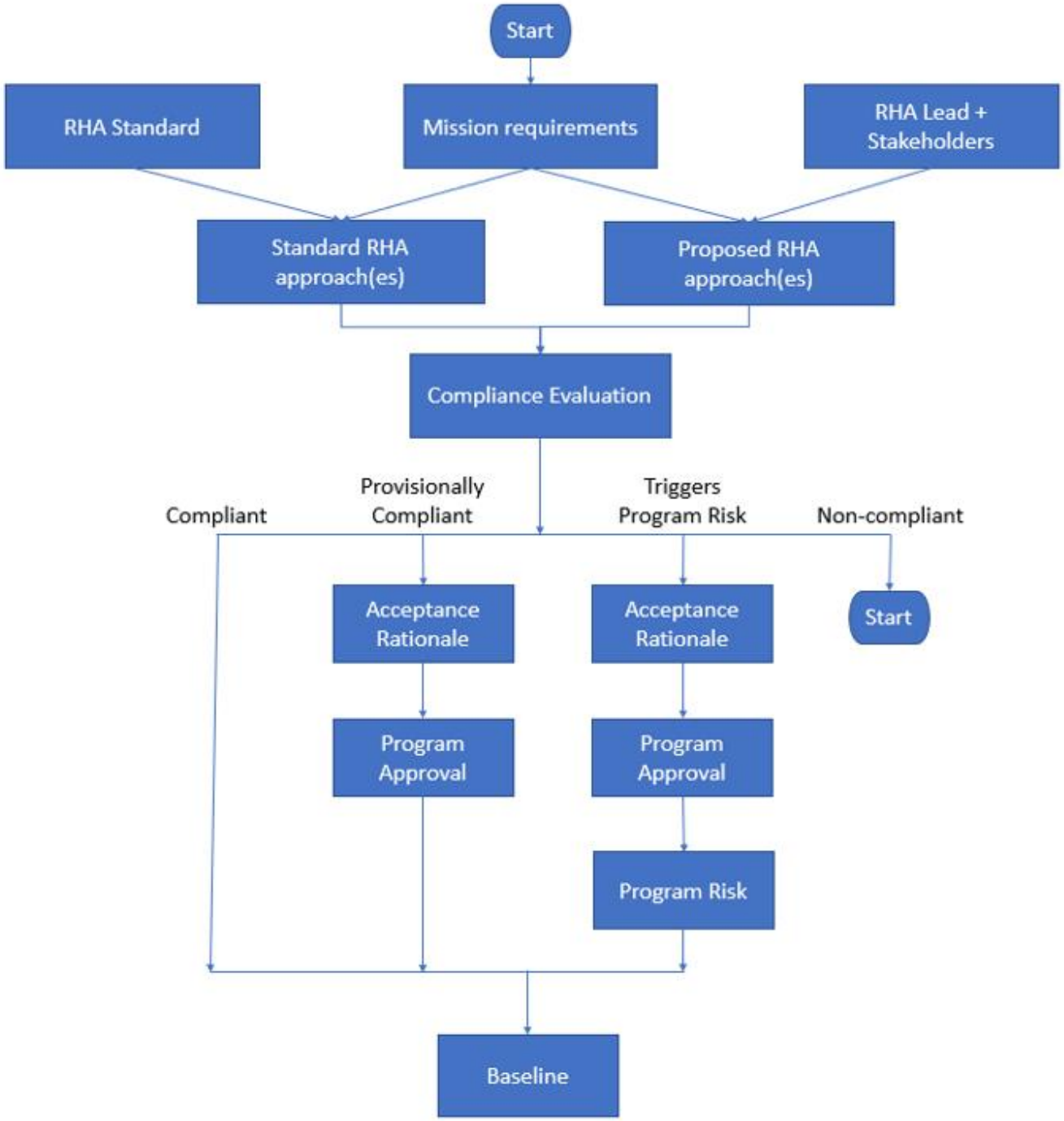
The program and project life cycles are consistent with the NASA Project Life Cycle described in NPR 7120.5F

RHA Process Requirements

	Project Formulation				Project Implementation						Program
	Pre- Phase A	Phase A		Phase B	Phase C		Phase D		Phase E	Phase F	
	KDP A	KDP B		KDP C	KDP D		KDP E		KDP F		
Milestone	MCR	SRR[1]	SDR	PDR	CDR	SIR	ORR	FRR	DR	DRR	FRR
Assign RHA Lead	RAD3										
RHA Feasibility	RAD4	Update as necessary									
RHA Baseline		RAD5									
ERD/EDD	Preliminary estimates	Initial (RAD6)		Update	Final						
RHARD		Initial (RAD7, RAD8)		Update	Final						
Rad Analysis Reports				Initial (RAD9)	Mature (RAD10)	Update as necessary					Final (RAD11)
Parts List Rad Review		Critical Technologies		Initial	Update	Update as necessary					
Test Schedule Plan incl RLAT[2]				Initial	Update	Update as necessary					
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Radiation Risk	RAD2, then track to closure										
System-level Rad Analysis & Report[4]					Inputs (RAD10)	Update as necessary					Final (RAD11)

RAD5 At SRR, programs and projects shall baseline their RHA approaches for SEE and TID/TNID, obtain program approval, and carry program risk as required, per the process described in section 4.2 “RHA Baseline Process”.

The program and project life cycles are consistent with the NASA Project Life Cycle described in NPR 7120.5F



RHA Baseline Process

Step 1: Evaluate mission

Step 2: Define the proposed RHA approach

Step 3: Determine the programmatic activities required to baseline the proposed RHA approach

- Categorization per taxonomy
- Compliance evaluation

Step 4: Execute the required programmatic activities to baseline the proposed RHA approach at SRR

- This is where program visibility is pursued up to and including program risk

RHA Taxonomy and Compliance Matrices

- The taxonomy defines categories of RHA approaches
  - The categorization is based on several criteria grouped self-consistently
    - Example criteria (for SEE): Predominant EEEE parts usage (RHA vs. non-RHA), anticipated scope of SEE testing, typical SEE data level of abstraction, DSEE and NDSEE acceptance criteria (LET levels), SEE circuit and criticality analysis (SEECA) scope, etc.
  - Table defining RHA categories separately for SEE and TID/TNID
- Compliance matrices for RHA categories vs. mission class or criticality

4.2.1 RHA SEE Taxonomy

RHA Type	S1	S2	S3	S4	S5 (do nothing)
SEE part selection criteria[12]	**Enforced**	**Enforced**	**Enforced**	**Enforced**	**Not enforced**
Typical SEE data level of abstraction	Piece-part characterization	Piece-part characterization	CCA- and/or piece-part	CCA-level test	None
					None
Acceptable SEE data sources[11A]	MIL-STD or Vendor guarantees[10A], or acceptable Project-specific-, equipment supplier heritage-, or third party data[10C].	MIL-STD or Vendor guarantees[10A], or acceptable Project-specific-, equipment supplier heritage-, or third party data[10C].	Project-specific-, equipment supplier heritage-, or third party data[10C] at a minimum.	Project-specific-, equipment supplier heritage-, or third party data[10C] at a minimum.	None
SEGR/SEB/SEDR acceptance criteria	Risk avoidance (37 MeV-cm^2/mg)	Risk avoidance (37 MeV-cm^2/mg)	Test-constrained (e.g., 20 MeV-cm^2/mg)	High energy protons for DSEE[5]	None
SEL/other DSEE acceptance criteria	Risk avoidance (37-75[6] MeV-cm^2/mg) or quantification	Risk avoidance (37-75[6] MeV-cm^2/mg) or quantification	Test-constrained (e.g., 20 MeV-cm^2/mg)	High energy protons for DSEE[5]	None
NDSEE acceptance criteria	Risk avoidance: threshold or max piece-part rate requirement Risk quantification: full characterization requirement	Risk avoidance or quantification limited to application relevant NDSEE type(s) (e.g., SEU, SEFI)	Risk avoidance or quantification limited to application relevant NDSEE type(s) (e.g., SEU, SEFI)	None	None
Survivability assurance result	Verified risk avoidance or quantification	Verified risk avoidance or quantification	Limited risk analysis	Limited risk analysis[7]	None
A priori confidence reliability will be met	Risk avoidance: Superior Risk quantification: Up to high[8]	Risk avoidance: Superior Risk quantification: Up to high[8]	Limited	None	None
Availability assurance product	Full analysis characterizes and quantifies probability of all unmitigated SEE at interfaces	Availability analysis limited to the application-relevant subset of SEE parameters	Limited risk analysis[9]	Limited risk analysis[9]	None
A priori confidence availability will be met	Risk avoidance: Superior[10] Risk quantification: Up to high[8]	Limited	None	None	None

Table 6. RHA Category compliance: SEE, Crewed Space Flight

Crewed Space Flight	S1	S2	S3	S4	S5
Crit1	Compliant	Provisionally Compliant	Triggers Program Risk	Non-compliant	Non-compliant
Crit2	Compliant	Provisionally Compliant	Triggers Program Risk	Non-compliant	Non-compliant
Crit3/Non-critical	Compliant	Compliant	Provisionally Compliant	Provisionally Compliant	Non-compliant

Table 9. RHA Category compliance: TID&TNID, Robotic Space Flight

8705.4A Risk Classification	D1	D2	D3	D4	D5
A	Compliant	Provisionally Compliant	Triggers Program Risk	Non-compliant	Non-compliant
B	Compliant	Provisionally Compliant	Triggers Program Risk	Non-compliant	Non-compliant
C	Compliant	Compliant	Provisionally Compliant	Provisionally Compliant	Non-compliant
D	Compliant	Compliant	Compliant	Provisionally Compliant	Non-compliant
Less than D (e.g., 7120.8 or "do no harm")	No specific RHA standard is provided for projects operating outside of the 8705.4A risk classification system. TID and TNID are not typically a driving risk for projects organized in this manner, but consultation with radiation effects SMEs is strongly encouraged.				

Summary and Conclusions

- The Standard is non-prescriptive
  - It allows non-traditional approaches to RHA with Program buy-in, visibility, and allocated resources
- The Standard heavily leverages the existing NASA Risk process
  - Risks are not intended as a negative for projects and programs
  - Instead, the NASA Risk process ensures that projects benefit from program visibility and system-level resources towards meeting mission goals
- The formulation of the NASA Agency-level RHA Standard is on track for completion by the end of the current FY 2023
  - It is anticipated that the review and release process of the Standard will be performed in FY 2024 through the office of the NASA Chief Engineer
  - Raise community awareness through presentations at technical meetings

Thank you for your attention!

List of Acronyms

CCA: Circuit-Card Assembly

COTS: Commercial-off-the-Shelf

D&C: Design and Construction (Standards)

DDD: Displacement Damage Dose

DSEE: Destructive SEE

EDD: Environments Definition Document

FY: Fiscal Year

HEO: Human Exploration and Operations Mission Directorate

HW: Hardware

IRCP: Ionizing Radiation Control Plan

LET: Linear Energy Transfer

MEAL: Mission, Environment, Application, and Lifetime

MIL-SPEC: Military Specification

NDSEE: Non-destructive SEE

NEPP: NASA Electronic Parts and Packaging Program

NESC: NASA Engineering & Safety Center

NSPAR: Non-Standard Part Approval Request

NVROM: Non-Volatile Read-Only Memory

OSMA: (NASA) Office of Safety and Mission Assurance

RHA: Radiation Hardness Assurance

RHA Part: Radiation Hardness Assured Part

RHARD: RHA Requirements Document

SEB: Single-Event Burnout

SEGR/SEDR: Single-Event Gate/Dielectric Rupture

SEE: Single-Event Effect(s)

SEECA: SEE Criticality Analysis

SEFI: Single-Event Functional Interrupt

SEL: Single-Event Latchup

SET: Single-Event Transient

SEU: Single-Event Upset

SME: Subject Matter Experts

SMD: Science Mission Directorate

SRR: System Requirements Review

SW: Software

TID: Total Ionizing Dose

TNID: Total Non-Ionizing Dose

Backup