Radiation Hardness Assurance (RHA) Overview for Mission Success

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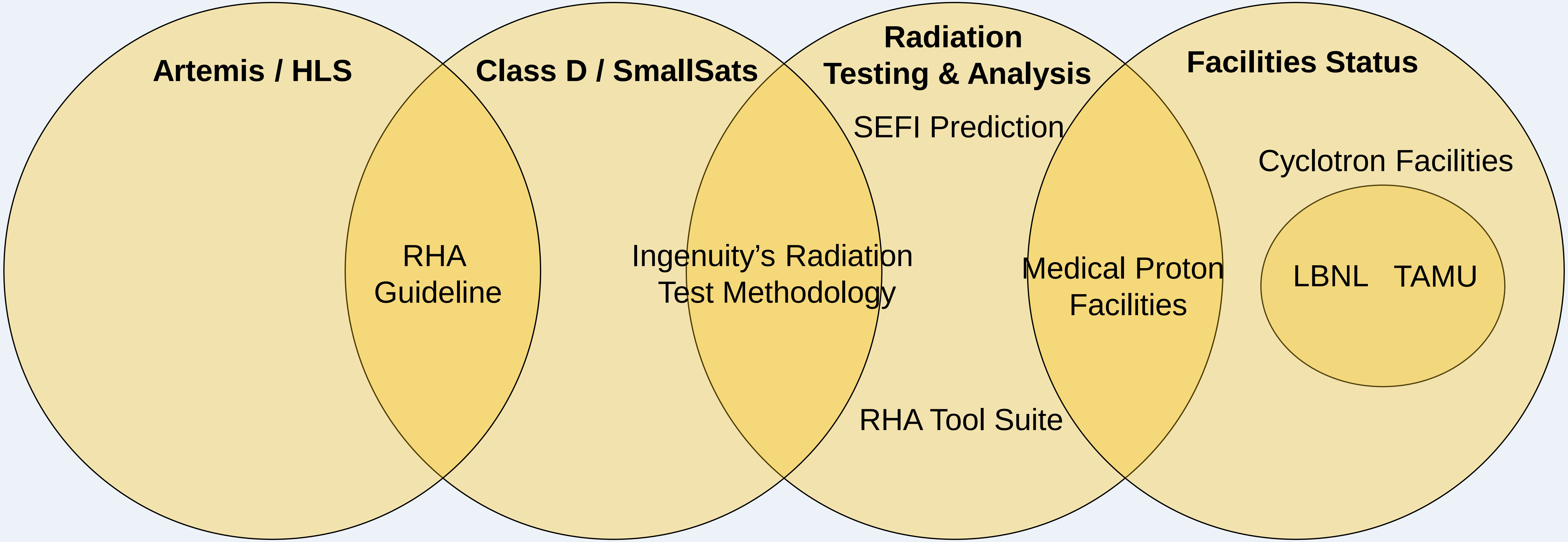
Acronyms

CME	Coronal Mass Ejection
COTS	Commercial Off The Shelf
DDD	Displacement Damage Dose
EEE	Electrical, Electronic, and Electromechanical
ELDRS	Enhanced Low Dose Rate Sensitivity
EP	Enhanced Performance
ESA	European Space Agency
GCR	Galactic Cosmic Ray
GOMAC	Government Microcircuits Applications and Critical Technologies Conference
GSFC	Goddard Space Flight Center
GSN	Goal Structuring Notation
HEART	Hardened Electronics and Radiation Technology
LEO	low earth orbit
LET	Linear Energy Transfer
MBMA	model based mission assurance
MRQW	Microelectronics Reliability and Qualification Workshop
NAND	Negated AND or NOT AND
NASA	National Aeronautics and Space Administration
NEPP	NASA Electronic Parts and Packaging
NEPP ETW	NASA Electronic Parts and Packaging (NEPP) Program Electronics Technology Workshop
NSREC	Nuclear and Space Radiation Effects Conference

RADECS	Radiation Effects on Components and Systems
RHA	Radiation Hardeness Assurance
SAA	South Atlantic Anomaly
SEE	Single Event Effects
SEE/MAPLD	SEE-MAPLD Single Event Effects (SEE) Symposium/
	Military and Aerospace Programmable Logic Devices (MAPLD) Workshop
SEGR	Single Event Gate Rupture
SEL	Single Event Latchup
SEP	Single Event Effects Phenomena (includes SEU, SEL, SEGR and SET)
SERESSA	School on the Effects of Radiation on Embedded Systems for Space Applications
SET	Single Event Transient
SEU	Single Event Upset
SLU	Saint Louis University
SwaP	Size, weight, and power
TID	Total Ionizing Dose
TID	Total Ionizing Dose
TMR	triple-modular redundancy
TNID	Total Non-Ionizing Dose
UV	Ultra-Violet

This Morning's Talks

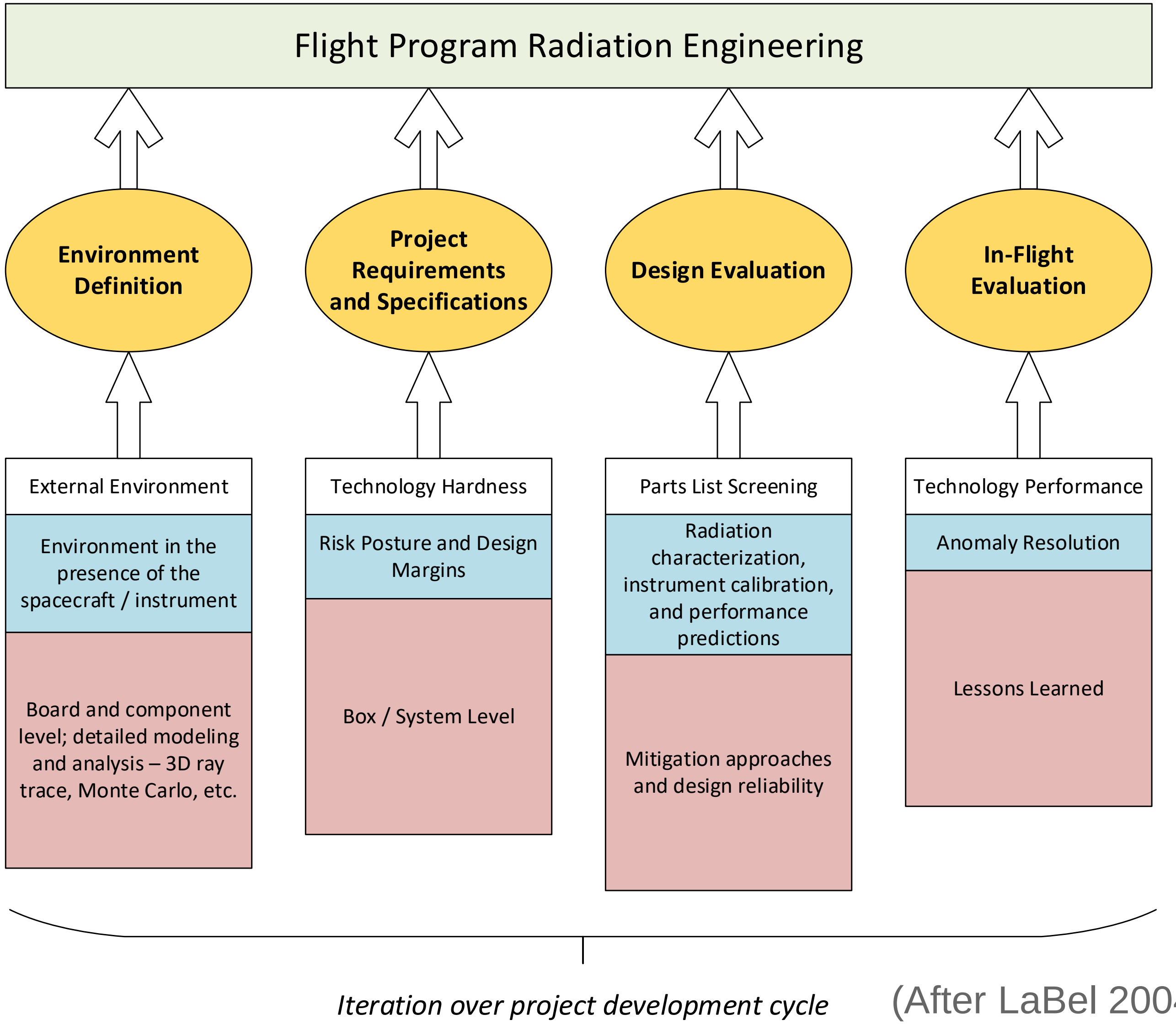
People: OSD Workforce



Radiation Hardness Assurance (RHA) Overview

RHA consists of all activities undertaken to ensure that the electronics and materials of a space system perform to their *design* specifications throughout exposure to the mission space environment

(After Poivey 2007)



(After LaBel 2004)

The Job: Watch For the 'ilities

Survivability
- Must survive until needed
- Entire mission?
- Screening for early failures in components

Availability
- Must perform when necessary
- Subset of time on orbit
- Operational modes
- Environmental response

Criticality
- Impact to the system
- Part or subsystem function
- Mission objectives

Reliability
- Resultant of all
- Many aspects and disciplines
- Known unknowns

The People: Radiation Effects Engineers

Materials
- Material Property degradations with radiation
- Energy loss in materials

Device Physics
- Charge transport
- Device Process Dependencies
- Charge dependency of device operation

Electrical Engineering
- Part to part interconnections
- Understanding circuit response
- Device functions and taxonomy

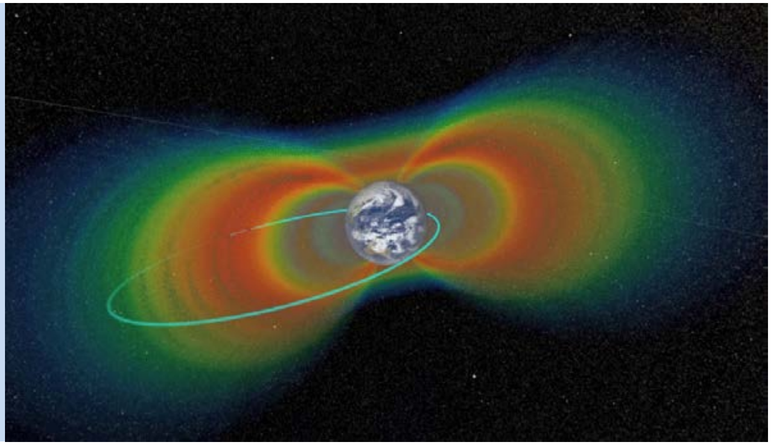
Systems Engineering
- Requirements
- System Level Impacts
- Understanding interconnections
- Understanding functionality

Space Physics
- Space weather
- Environment models/modeling
- Radiation Sources and variability

New Space – Same Old Radiation

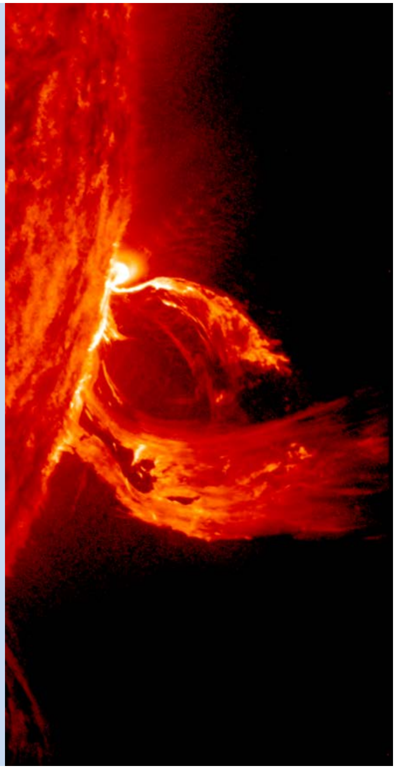
- **New mission concepts and SmallSat paradigm**
  - Radiation challenges identified in the past are here to stay; adoption of new technologies are often the risk driver
  - Commercial Space, Constellations, Small missions, etc. will benefit from detailed hazard definition and mission specific requirements
- **The need for Radiation Hardness Assurance (RHA)**
  - Radiation effects are a mix of disciplines, evolve with technologies and techniques
  - Misinterpretation of failure modes / misuse of available data can lead to over/under design
  - RHA flow doesn't change, risk acceptance needs to be tailored
- **Some Top Level Resources**
  - NPR-7120.5 – NASA Agency Program Management
  - NPR-8705.4 – *NASA Goddard Risk Classification Guidelines (updated – class D)*
  - NASA-STD-8739.10 – NASA Parts Assurance Standard

Trapped Radiation



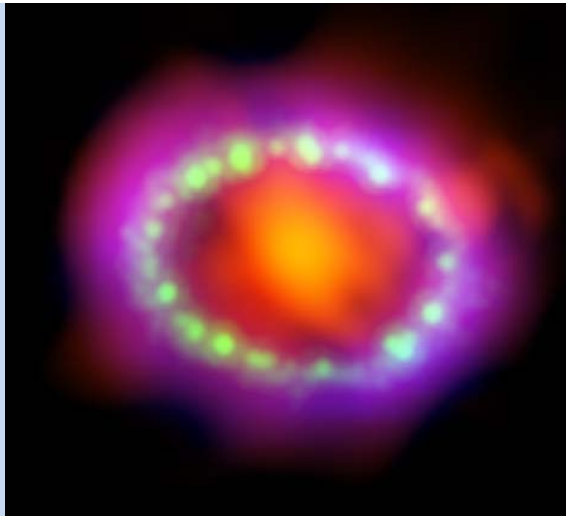
https://www.nasa.gov/van-allen-probes

Solar Events & Activity



https://sdo.gsfc.nasa.gov

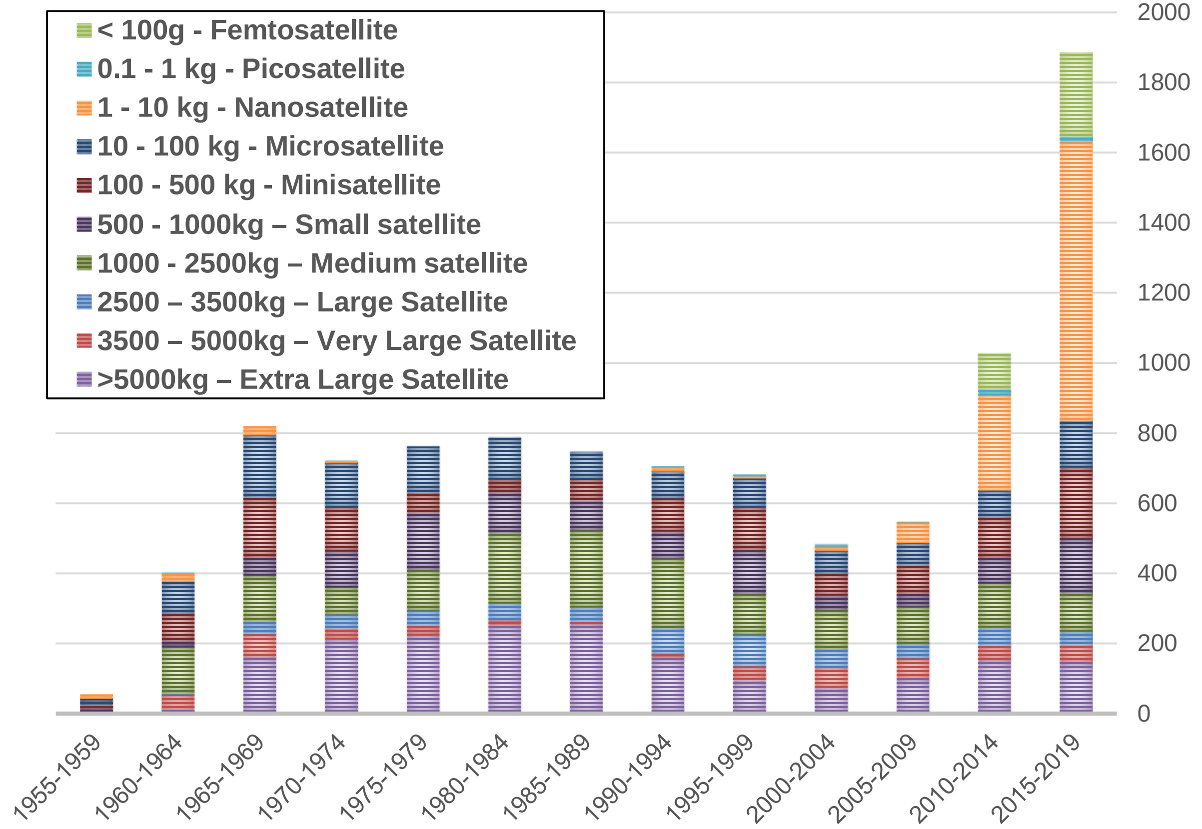
Supernovae



NASA, ESA, and L. Hustak (STScI)

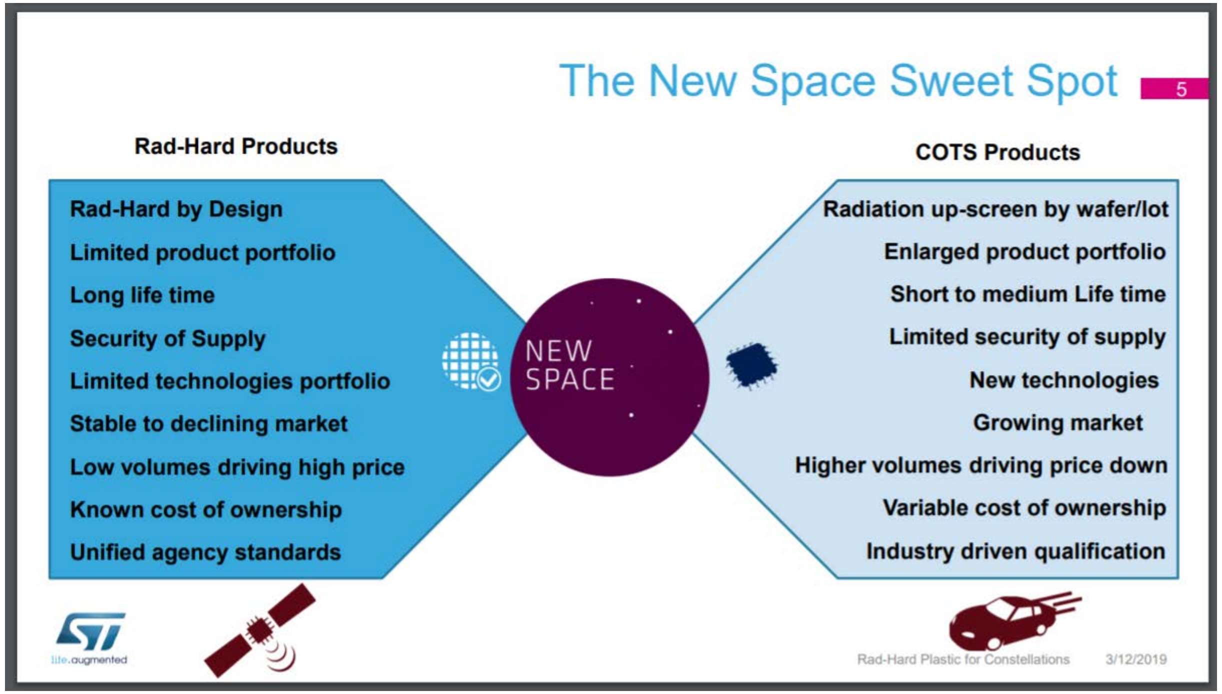
New Space – New Point of View

SmallSats Come in Many Sizes



Seradata SpaceTrak Data

Component Grades are Merging



ESSCON : Eccofet

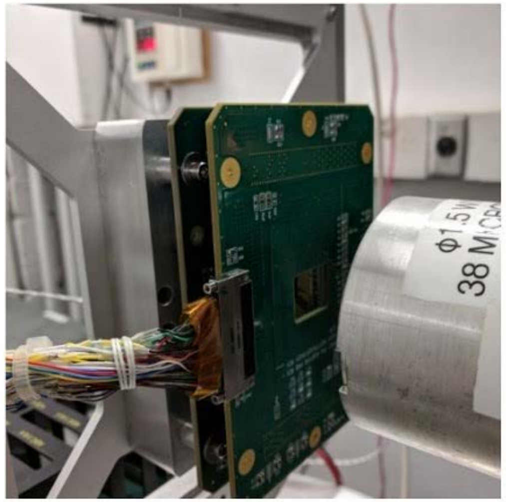
Risk acceptance is being used as a means to enable innovation

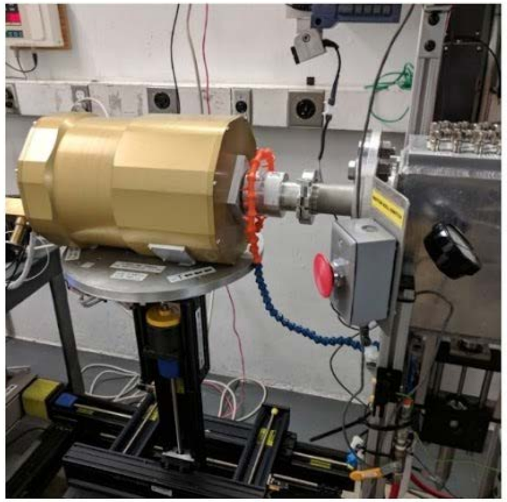
Ecosystem is Changing, Now What?

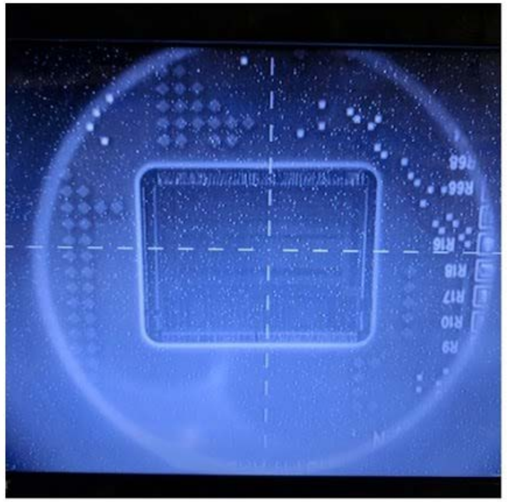
- **We know we have RHA challenges, but:**
  - New architectures and technologies enable progress
  - Quantifying the risk helps communicate across disciplines
- **Focus on risk acceptance**
  - Failure awareness as well as countermeasures and mitigation
    - At what level (part, card, box, mission)?
  - Know when to test vs. when to model
  - Tools
    - Single Event Effect Criticality Analysis (SEECA)
    - Radiation Guidelines for Notional Threat Identification and Classification (R-Gentic)
    - Model-Based Mission Assurance (MBMA)

When Do You Test? When Do You Model?

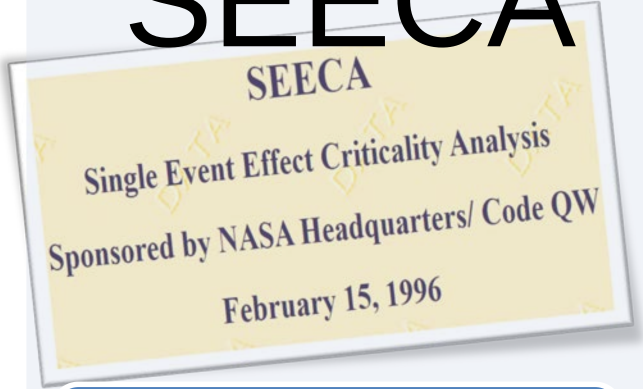
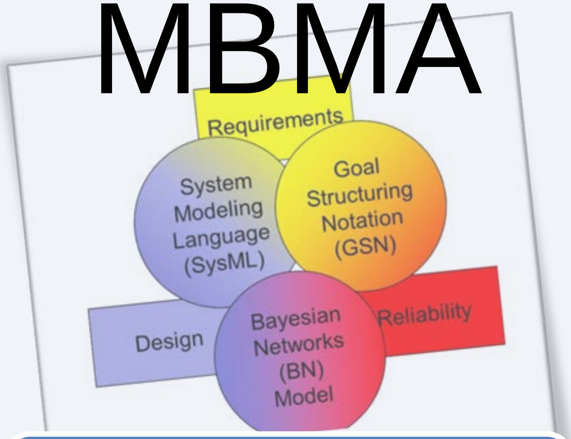
- **Know your risk threshold**
  - Reliability/Availability
  - Criticality of functions
- **Unknown failure modes**
  - New technologies should be identified early on
  - Known unknowns can be carried as a risk
- **Fault propagation may be the problem**
  - This can include cumulative effects!
  - Fault injection may not be able to cover the state space (see past talks from <u>Melanie Berg</u>)
- **Destructive single event effects**
- **Can you tolerate a part replacement in your design cycle?**
  - Lead times, board re-spins, etc.



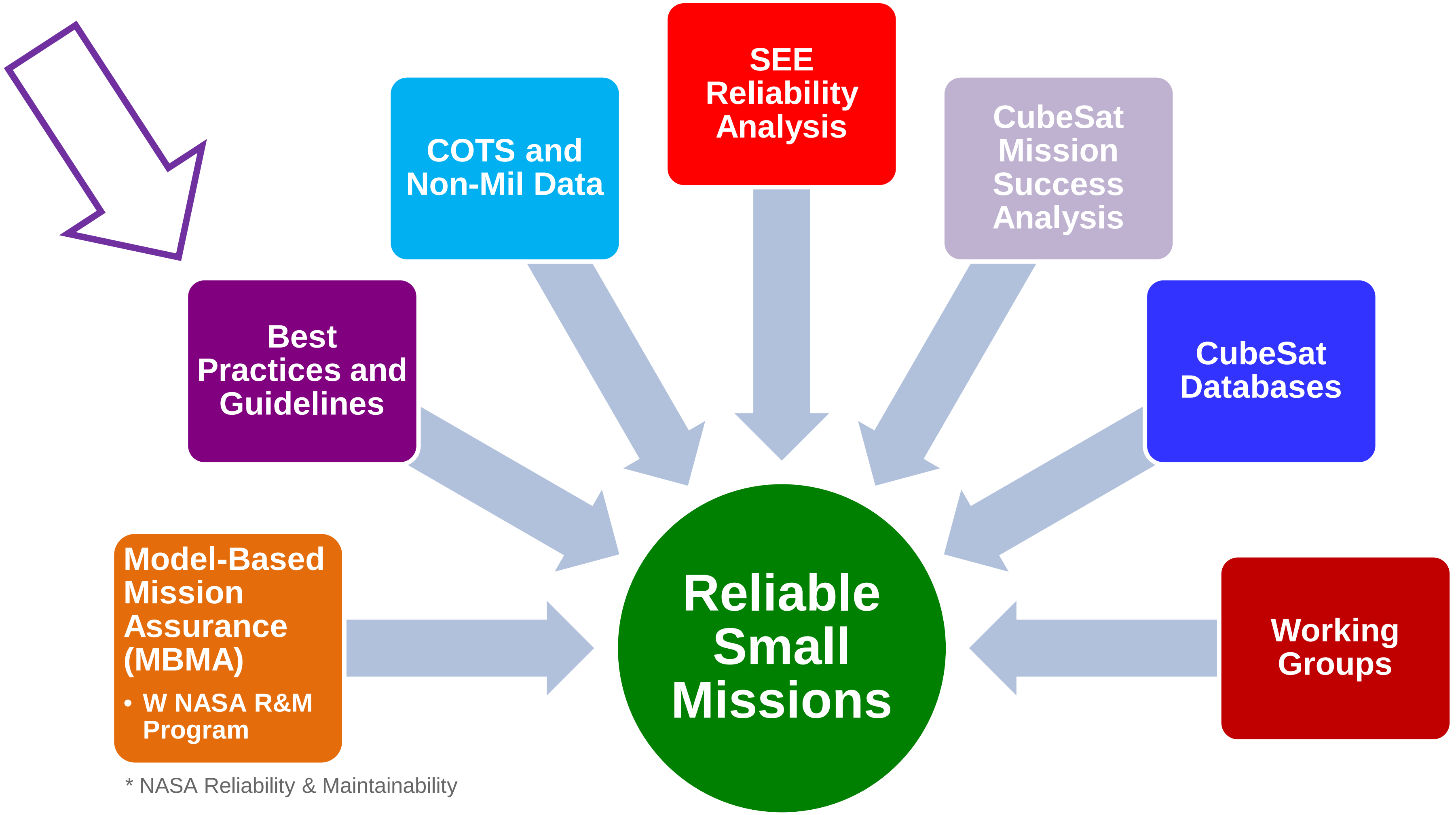




RHA Tools – Getting to Risk Acceptance

Tool	SEECA	R-Gentic	MBMA
NASA Electronic Parts and Packaging Program	 SEECA Single Event Effect Criticality Analysis Sponsored by NASA Headquarters/ Code QW February 15, 1996		
Inputs	**Functional Requirements** • Reliability • Availability	**Mission Framework** • MEAL • Part Types	**SEAM Environment** • System Architecture • MEAL & Requirements • Assumptions/Models/Data
Outputs	**Analysis** • Error Critical • Error Vulnerable • Error Functional	**Guidelines** • Environment Comparisons • Technology Threats • Class Guidance	**Assurance Case Study** • Requirements Verification • Visual Arguments • Coalesces Impacts

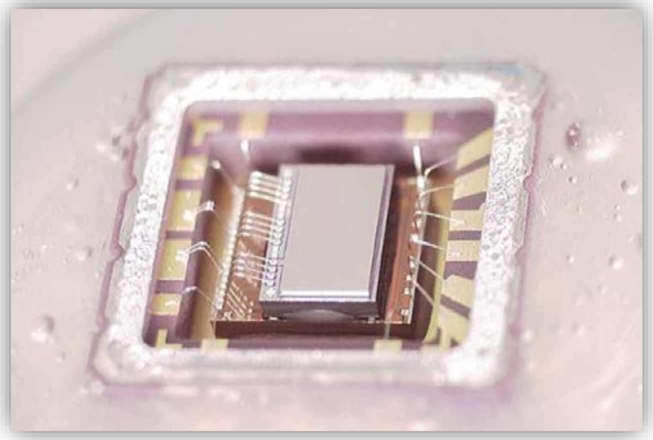
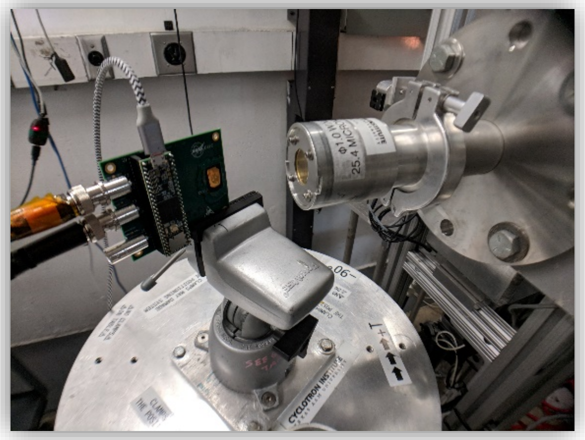
NEPP Program (OSMA)- Small Mission Efforts

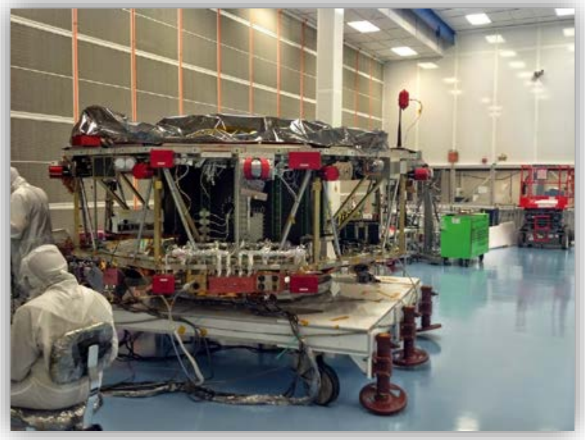


* NASA Reliability & Maintainability

Forward Work

- **RHA Tools Integration**
  - **R-Gentic updates and integration into SEAM**
    - **Radiation 101 and R-Gentic Demo this year at SmallSat Conference (free to all!)**
  - **Taxonomy agreement with PMPedia**
- **Presentations/Publications**
  - **NSREC Within RHA topic, system-Level focus/highlight**
  - **SEECA guidance for SEE/MAPLD**
- **Cooperation with SSRI**
  - **Mission confidence framework**
  - **Radiation section into CubeSat 201**
- **Small Mission RHA Guideline**



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THANK YOU