Radiation Hardness Assurance (RHA) for Small Missions

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Acronyms

CREME	Cosmic Ray Effects on Micro-Electronics
DD	Displacement Damage
EEE	Electrical, Electronic andd Electromechanical
ELDRS	Enhanced Low Dose Rate Sensitive
ESA	European Space Agency
ETW	Electronics and Technology Workshop
FET	Field Effect Transistor
GSFC	Goddard Space Flight Center
JEDEC	Joint Electron Device Engineering Council
JPL	Jet Propulsion Laboratory
LET	Linear Energy Transfer
MOSFETs	Metal Oxide Semiconductor Field Effect Transistor
NASA	National Aeronautics and Space Administration
NEPP	NASA Electronics Parts and Packaging
NOVICE	Numerical Optimizations, Visualizations, and Integrations on CAD/CSG Edifices
PDR	Preliminary Design Review
REAG	Radiation Effects and Analysis Group
RHA	Radiation Hardness Assurance
RLAT	Radiation Lot Acceptance Testing
SEB	Single Event Burnout
SEE	Single Event Effects
SEFI	Single Event Functional Interrupt
SEGR	Single Event Gate Rupture
SEL	Single Event Latchup
SER	Single Event Rate
SET	Single Event Transient
SEU	Single Event Upset
TID	Total Ionizing Dose

Introduction

- What are small missions? What goes into them?
- Implementing RHA gives unique challenges in small missions
  - No longer able to employ risk avoidance
  - Design trades impact radiation risks, cost, and schedule
  - Difficult accounting for all risks to the system
- Useful risk practices
  - Risk identification and comparison
  - Categorizing risk based on manifestation at the system level
- Leveraging some RHA improvements

Definitions

- Small Spacecraft
  - Mass < 180kg (Small Spacecraft Technology Program)
  - Can be any class mission!
  - Independent of cost, not talking about small budgets necessarily
  - Mission goals for small spacecraft are growing as is the need for reliability
- Radiation Hardness Assurance

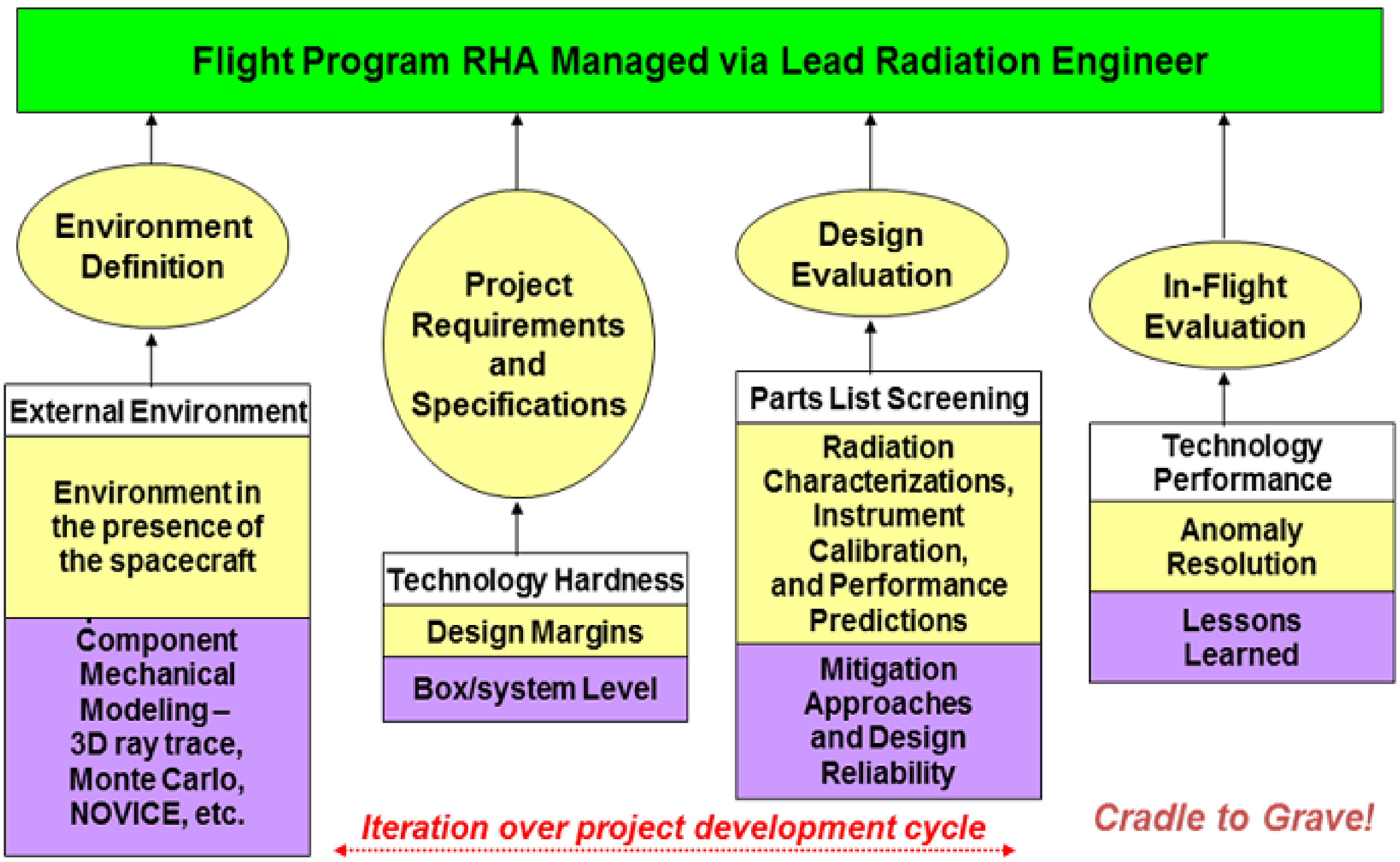
  RHA consists of all activities undertaken to ensure that the electronics and materials of a space system perform to their *design* specifications throughout exposure to the mission space environment

  (After Poivey)

Small Spacecraft “Market Research”

- CubeSat/SmallSat Subsystem Vendors (cubesat.org)
    - Not going to help radiation concerns when trying to drive costs down, do not know your mission objectives
    - Using COTS components in many sub-systems
- Small Spacecraft Partnerships
    - Universities
    - Government Institutions
    - Small Business Collaborations

RHA Overview



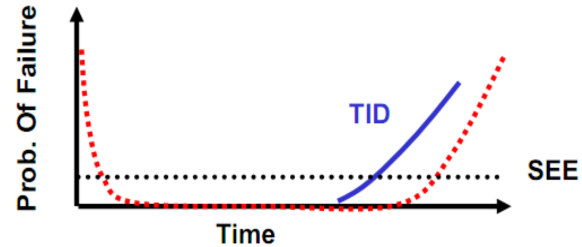
(After LaBel)

Rational Approach

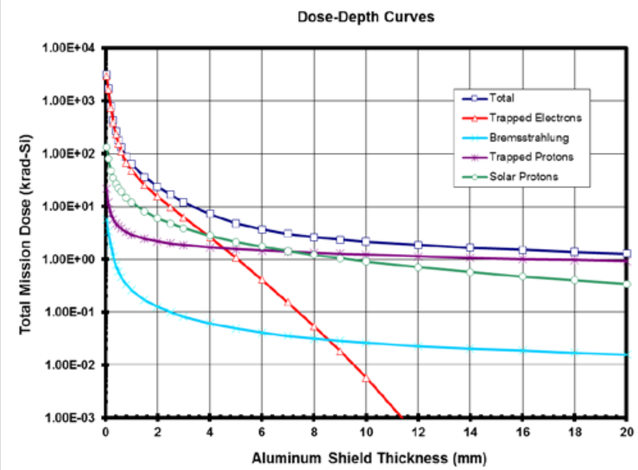
1. Hazard Analysis – Define and Evaluate
2. Smart Requirements
3. Evaluate Design/Components
4. Engineering Decisions/Trades
5. Iterate Process

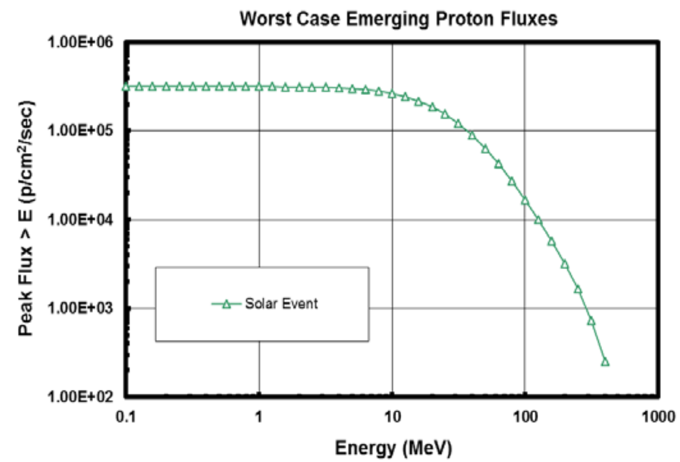
(After LaBel)

Hazard Analysis

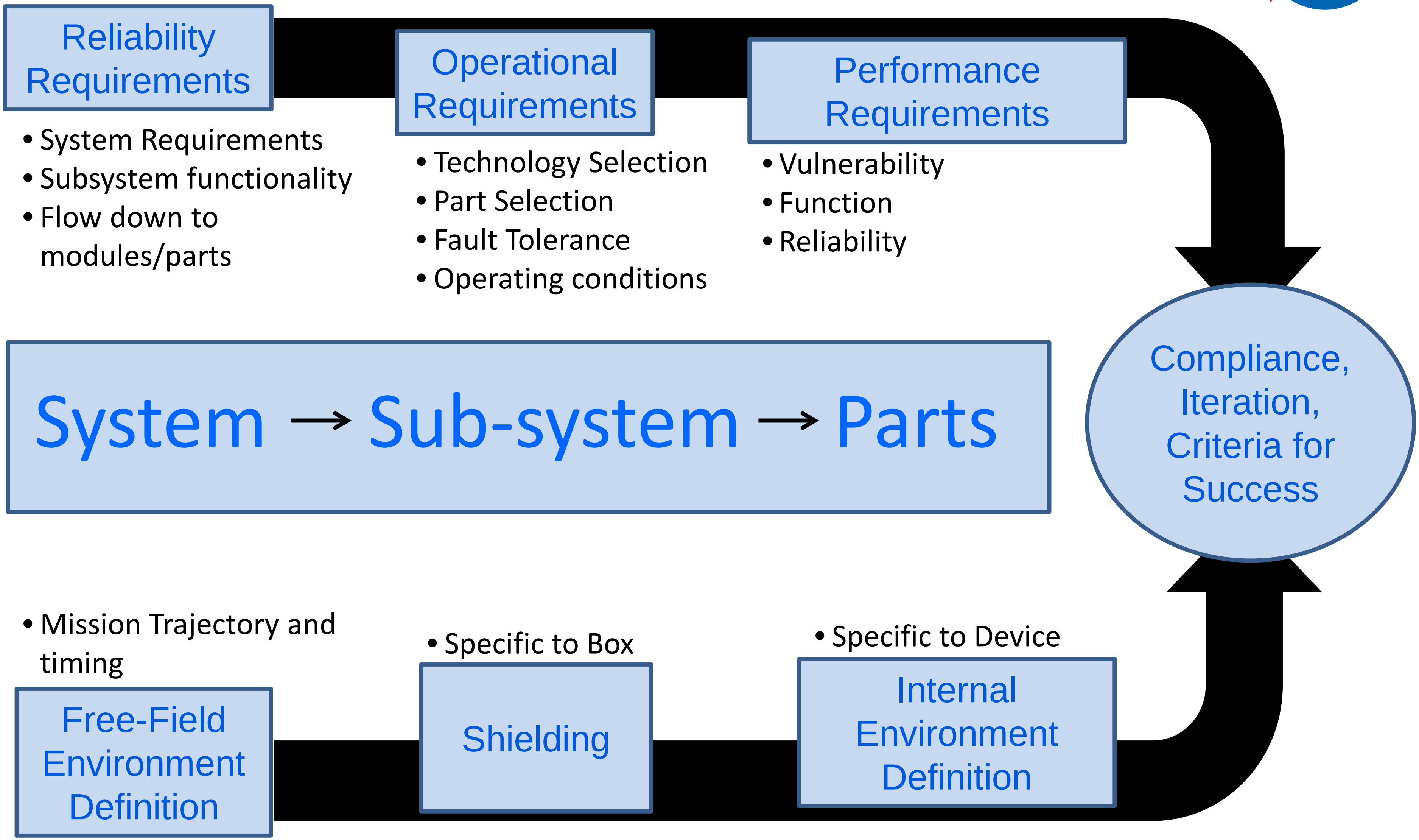


- Define the Hazard
  - Same process for big or small missions, no short cuts
  - Know the contributions
    - » Trapped particles (p^+,e^-)
    - » Solar protons, cycle, events
    - » Galactic Cosmic Rays
  - Calculate a dose-depth curve
  - Transport flux and fluence of particles
- Evaluate the Hazard
  - A continuous process throughout the mission design life





Smart Requirements



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Evaluate Design/Components

- Look at each part's response, compare with part criticality
- Determine if error will manifest at a higher level
- Utilize applicable data and the physics of failure
- The "we can't test everything" notion
    - Requirements and risk impacts to the system should determine the order of operations when limited

Engineering Decisions/Trades

- Be conscious of design trades
  - Mission parameter changes impact the radiation hazard
  - Weigh the hazard and risk
  - SWaP trades need to be carefully considered
  - Parts replacement/mitigation is not necessarily the best
- Test where it solves problems and reduces system risk (risk buy down)
- Only when failure modes are understood can we take liberties to predict and extrapolate results

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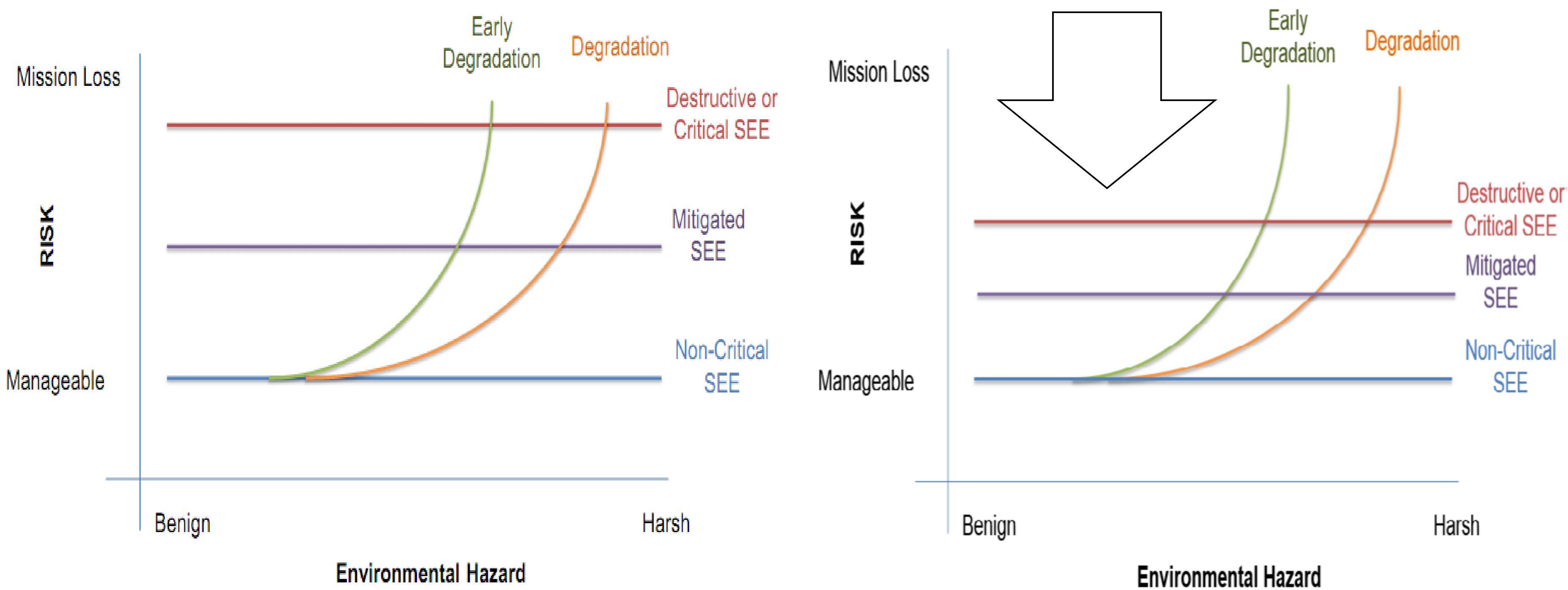
Single Strain vs. Allowable Losses



- Redundancy alone does not remove the threat
- Adds complexity to the design
- Diverse redundancy

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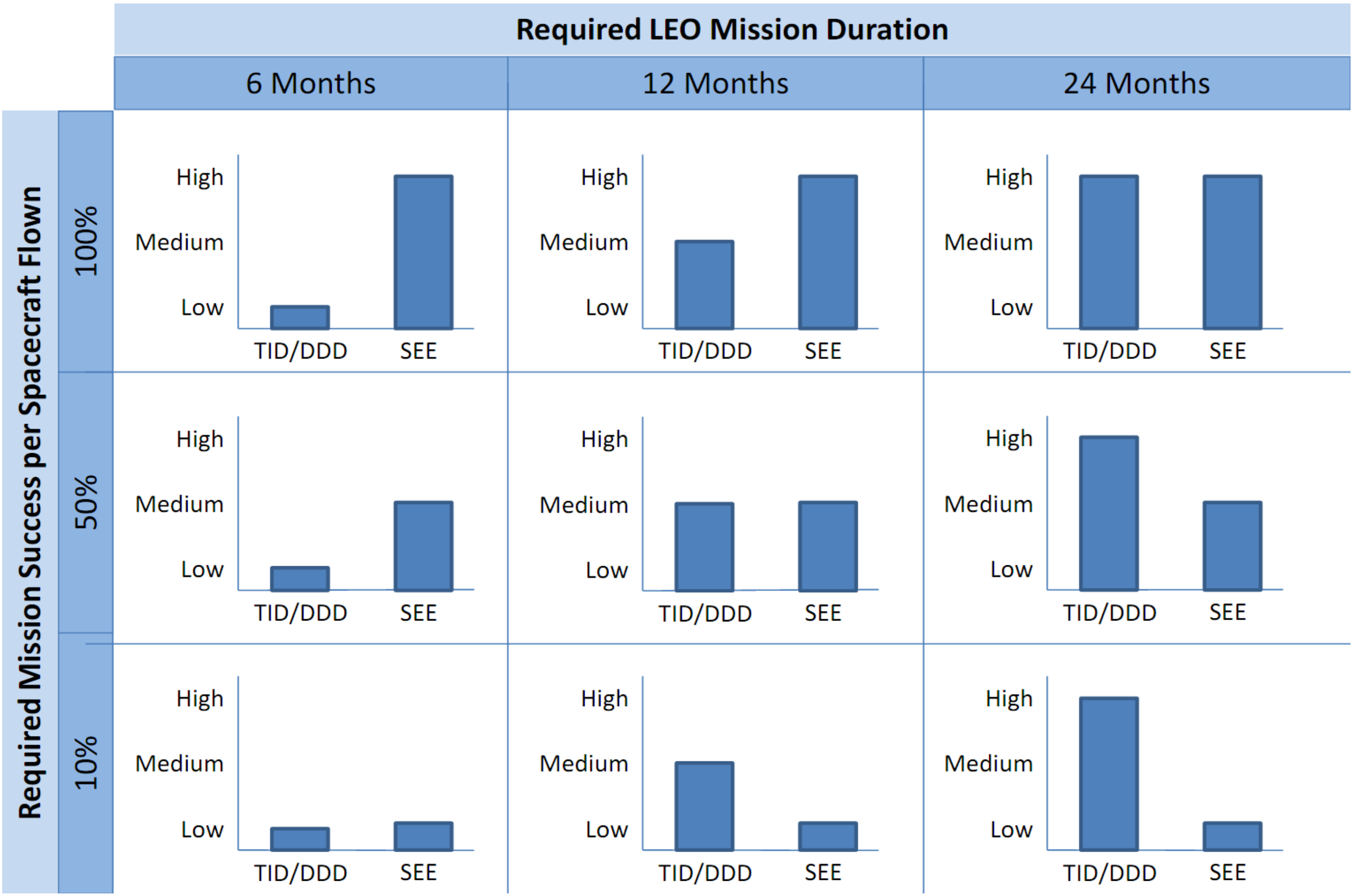
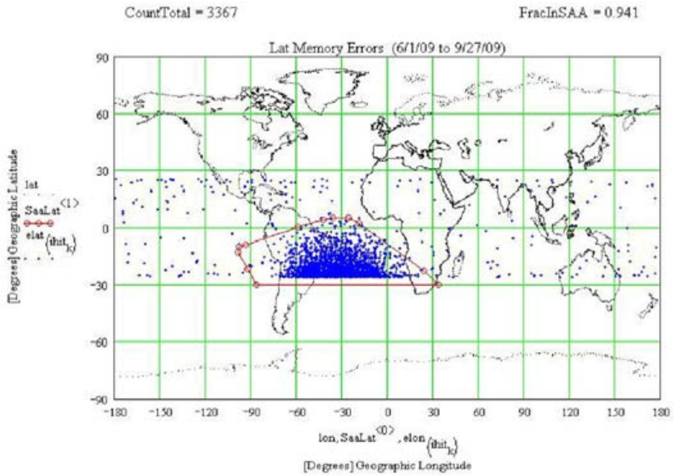
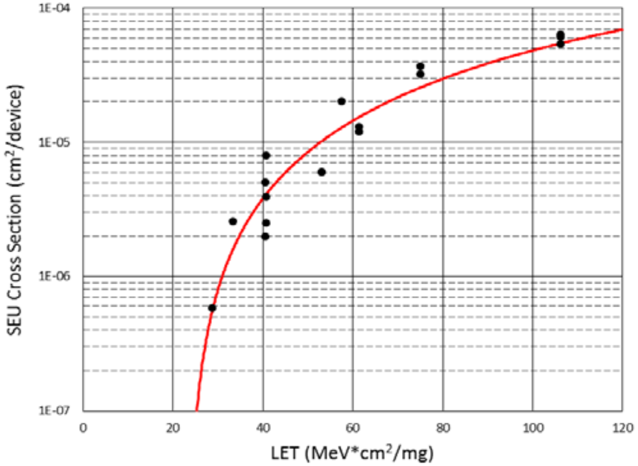
Risk Buy Down by Radiation Testing

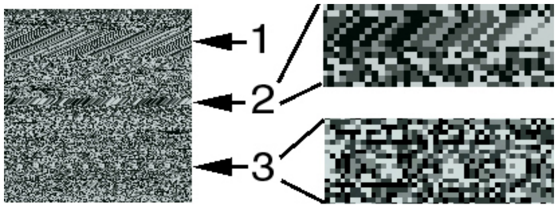


Risk Hierarchy

- Parts
  - o Radiation response
  - o Downstream/peripheral circuits
- Subsystem
  - o Criticality
  - o Complexity
  - o Interface
- System
  - o Power and mission life
  - o Availability
  - o Data retention
  - o Communication
  - o Attitude determination







Risk Categorization

PIN	Generic Part No.	Part Description	Package Type	Manufacturer	FM Part No	Risk	SEL/ SEGR/ SEB	SEU	SET	SEFI	TID/ELDRS	DD
375	AT27C512R-90TI	EPROM	28 TSOP	ATMEL	AT27C512R-90TI	Medium	T	T	A	T	T	A
380	AT49BV1614T-11TI	Flash Ram	48 TSOP	ATMEL	AT49BV1614T-11TI	Medium	T	T	A	T	T	A
500	BAT54	Schottky Barrier	SOT23	ZETEX	BAT54	Low	A	A	A	N/A	A	A
510	BAT54C	Schottky Barrier	SOT23	ZETEX	BAT54C	Low	A	A	A	N/A	A	A
505	BAT54S	Schottky Barrier	SOT23	ZETEX	BAT54S	Low	A	A	A	N/A	A	A
485	BAV170 (Pb Free)	Double diode	SOT23	Philips Semiconductor	BAV170 (Pb Free)	Low	A	A	A	N/A	A	A
490	BAV23	Double diode	SOT143	Philips Semiconductor	BAV23	Low	A	A	A	N/A	A	A
495	BAV99W	High-speed double diode	SOT323	Philips Semiconductor	BAV99W	Low	A	A	A	N/A	A	A
415	BC847BS	NPN double transistor	SC-88	Philips Semiconductor	BC847BS	Medium	A	A	A	N/A	T	A
420	BCV61C (Pb Free)	NPN double transistor	SOT143B	Philips Semiconductor	BCV61C (Pb Free)	Medium	A	A	A	N/A	T	A
425	BCV62C (Pb Free)	transistor	SOT143B	Philips Semiconductor	BCV62C (Pb Free)	Medium	A	A	A	N/A	T	A
410	BFR92	Wideband	SOT23	Philips Semiconductor	BFR92	Medium	A	A	A	N/A	T	A
430	BFT92	PNP double transistor	SOT23	Philips Semiconductor	BFT92	Medium	A	A	A	N/A	T	A
385	CD74HC04M	Inverter	SO-14	Harris	CD74HC04M	Medium	A	A	A	A	T	A
395	CXA1439M	CDS	SO-8	SONY	CXA1439M	High	T	T	A	A	T	A
405	CXD1261AR	Timing Pulse Generator	QFP-64	SONY	CXD1261AR	High	T	T	A	A	T	A
400	CXD1267AN	Clock Driver	SO-20	SONY	CXD1267AN	High	T	T	A	A	T	A
315	ElanSC520-100AI	CPU	388 PBGA	AMD	ElanSC520-100AI	High	T	T	A	T	T	A
465	F-102	Current regulator diode	TBD	Sicovend	F-102	Low	A	A	A	N/A	A	A
445	FDC6506P	FET	SSOT-6	Fairchild	FDC6506P	High	T	A	A	N/A	T	A
325	HY57V651620BLTC-10S	SDRAM	TSOPII	Hyundai	HY57V651620BLTC-10S	High	T	T	A	T	T	A

RHA Improvements

- Confidence levels vs. Radiation Design Margins
  - Trapped models AE8/AP8 to AE9/AP9
  - Solar particles already handled this way
- Statistics on datasets
  - Careful analysis can bound response from different test sets and results
  - Ground based testing more sophisticated
- Requirements are getting more specific
  - By function or expected response (power, digital, analog, memory)
  - By semiconductor or fab (GaN, GaAs, SiGe, Si, 3D stacks, hybrids)

Summary

- Varied mission life and complexity is growing for small spacecraft
- Small missions benefit from detailed hazard definition and evaluation as done in the past
- Requirements need to not overburden
  - Flow from the system down to the parts level
  - Aid system level radiation tolerance
- RHA is highlighted with increasing COTS usage

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THANK YOU