# 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

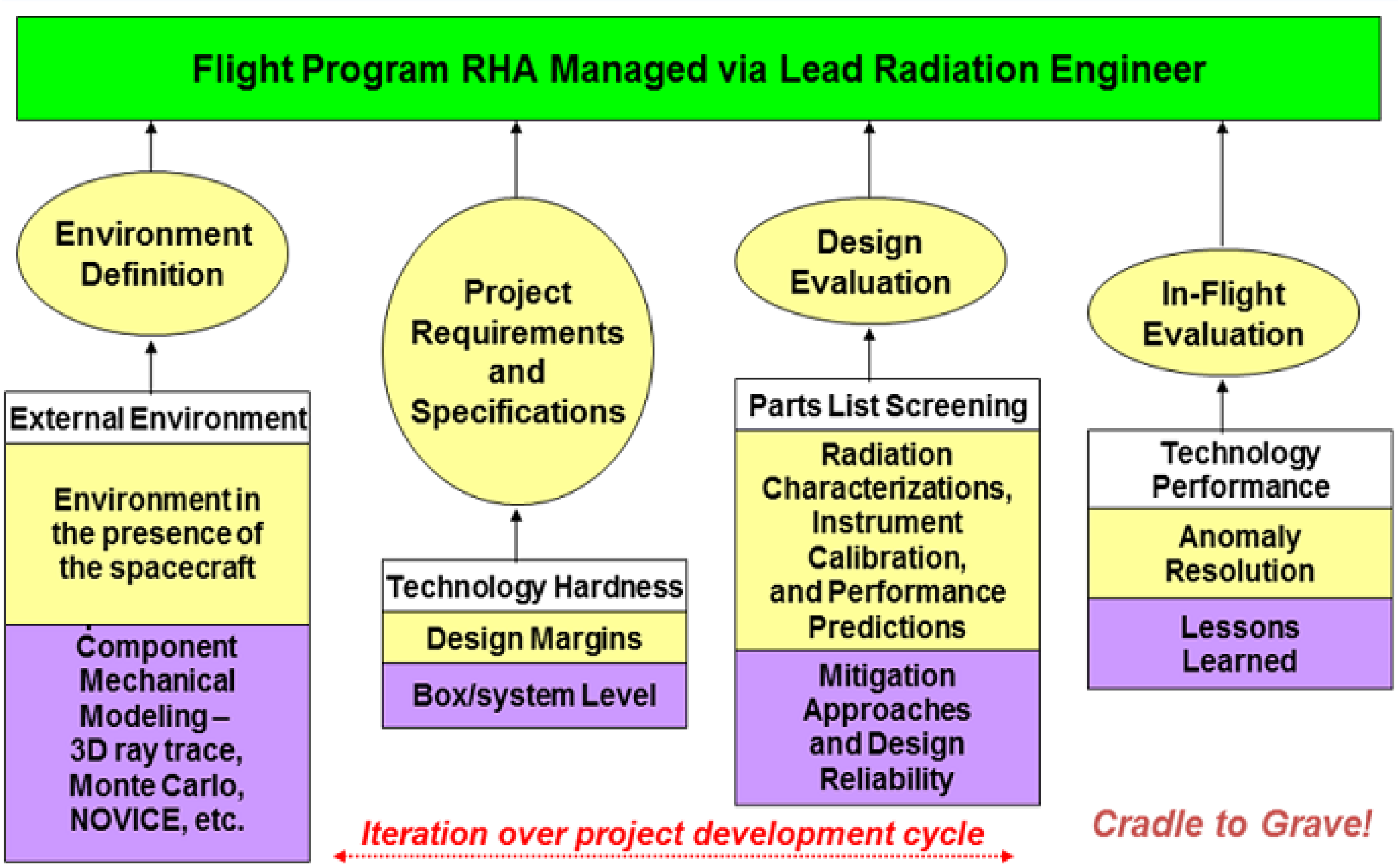
  RHA consists of all activities undertaken to ensure that the electronics and materials of a space system perform to their *design* specifications throughout exposure to the mission space environment

  (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)

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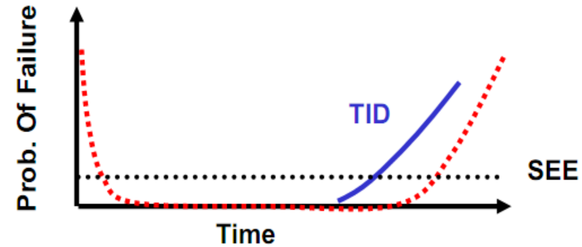
# Rational Approach

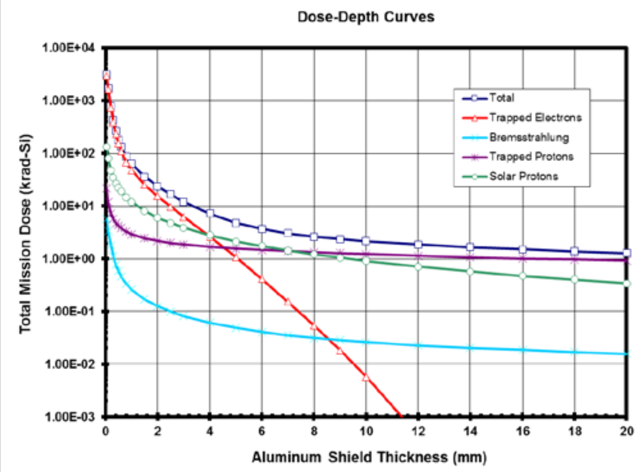
1. Hazard Analysis – Define and Evaluate
2. Smart Requirements
3. Evaluate Design/Components
4. Engineering Decisions/Trades
5. Iterate Process

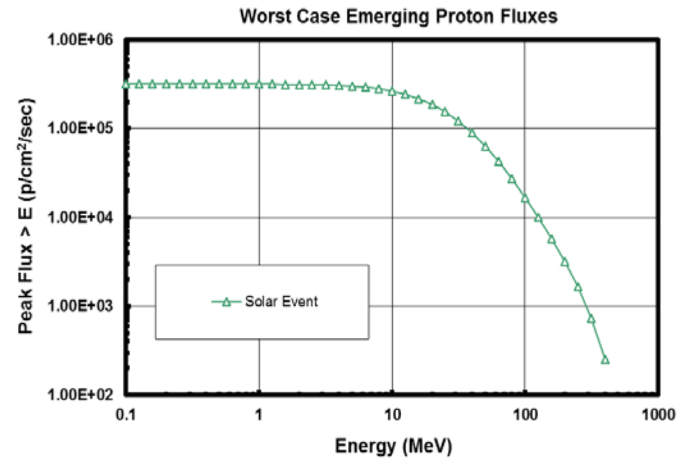
(After LaBel)

# Hazard Analysis

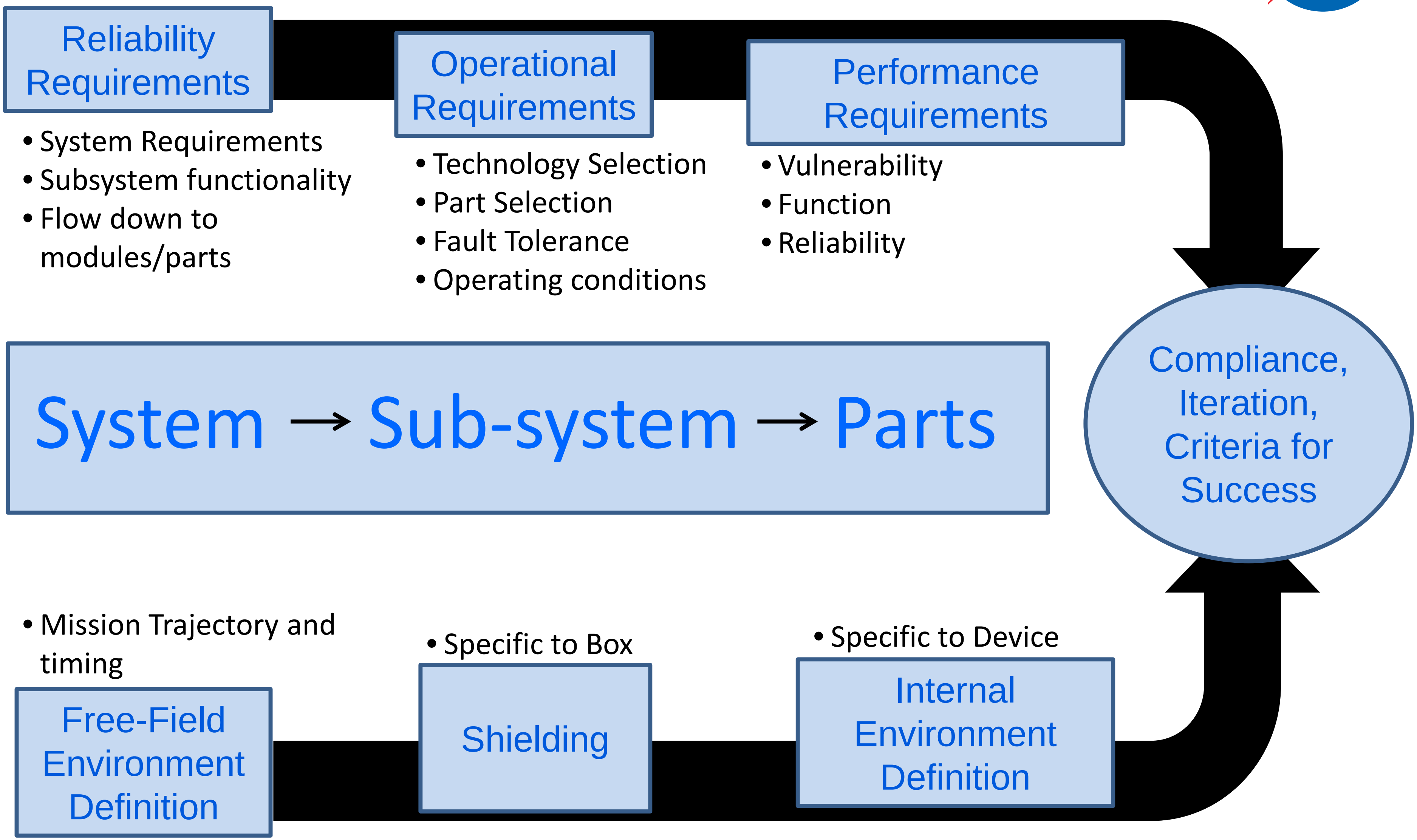



- Define the Hazard
  - Same process for big or small missions, no short cuts
  - Know the contributions
    - Trapped particles ($p^+$,$e^-$)
    - Solar protons, cycle, events
    - Galactic Cosmic Rays
  - Calculate a dose-depth curve
  - Transport flux and fluence of particles
- Evaluate the Hazard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



# Smart Requirements



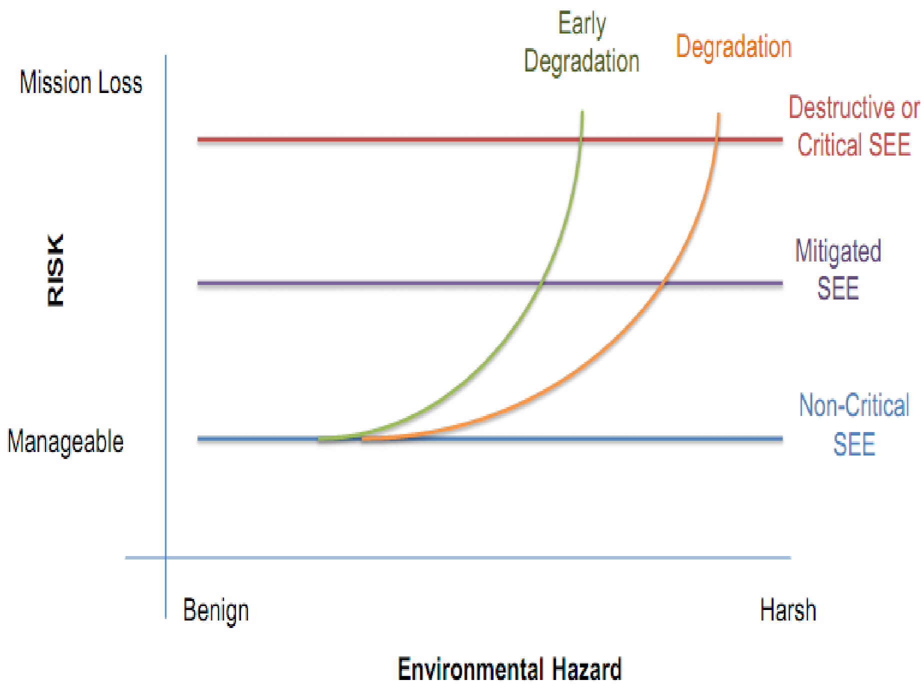
# Evaluate Design/Components

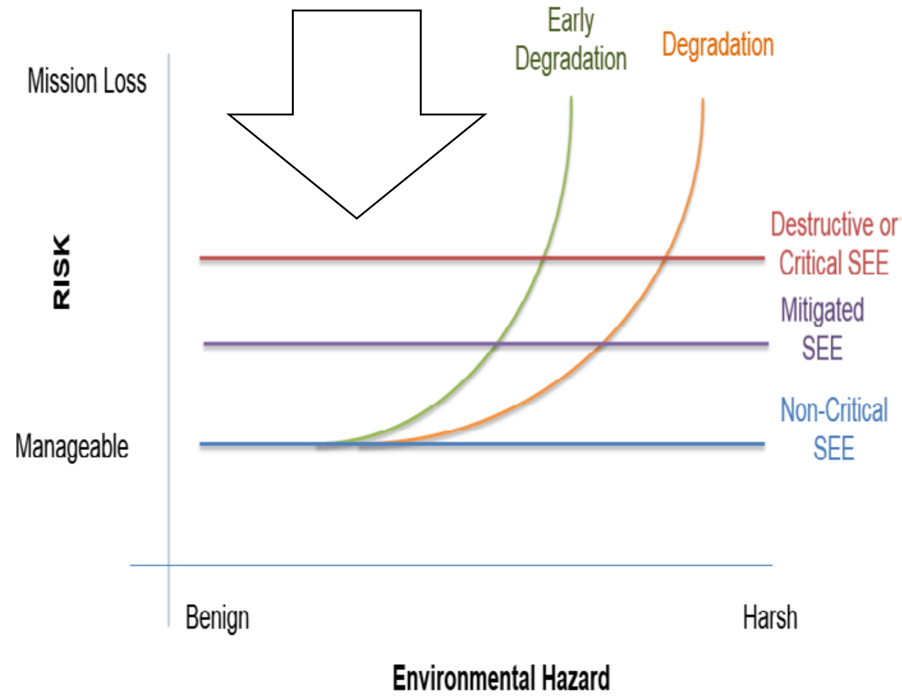
- Look at each part's response, compare with part criticality
- Determine if error will manifest at a higher level
- Utilize applicable data and the physics of failure
- The "we can't test everything" notion
    - Requirements and risk impacts to the system should determine the order of operations when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

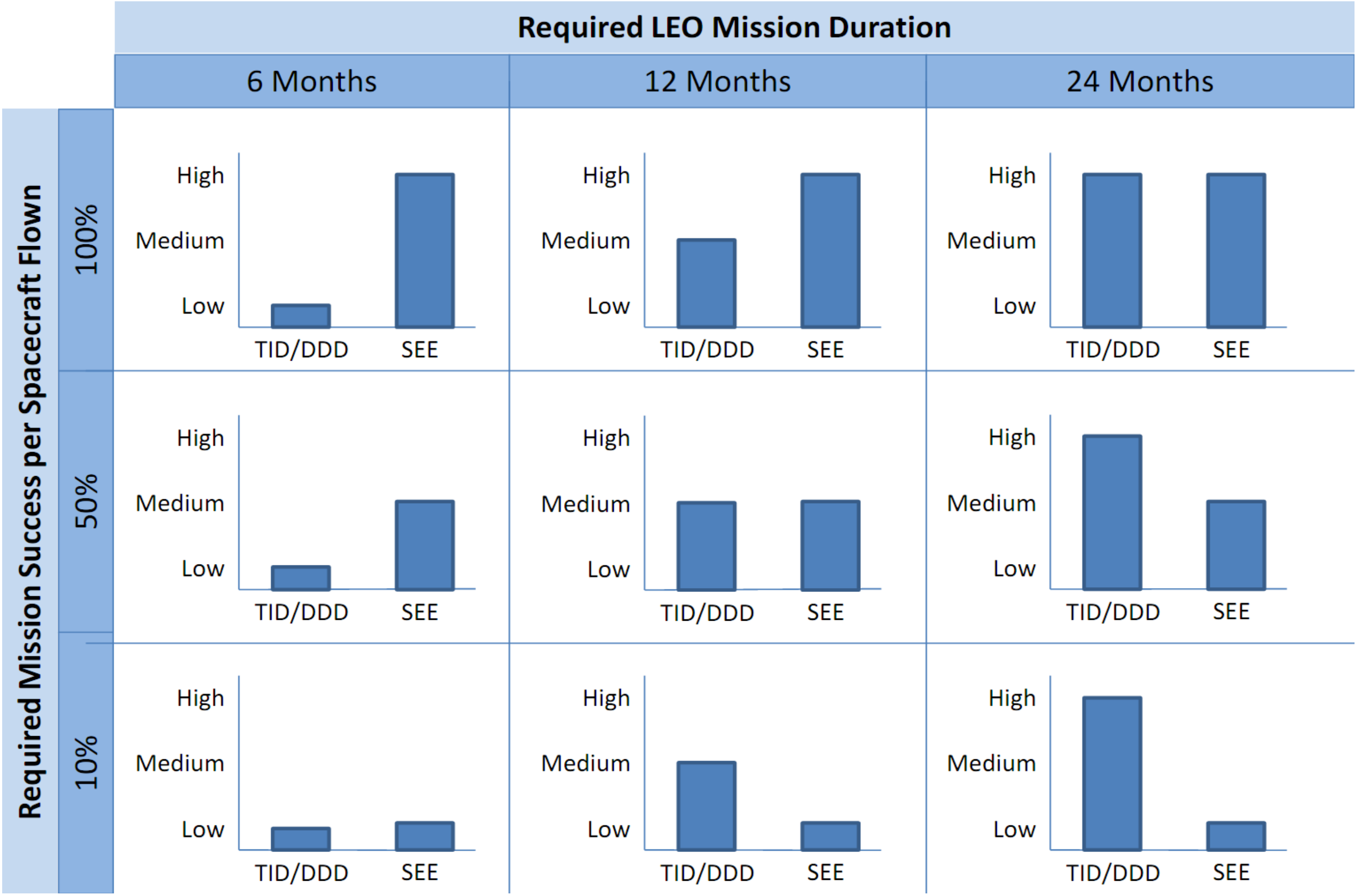
# Single Strain vs. Allowable Losses



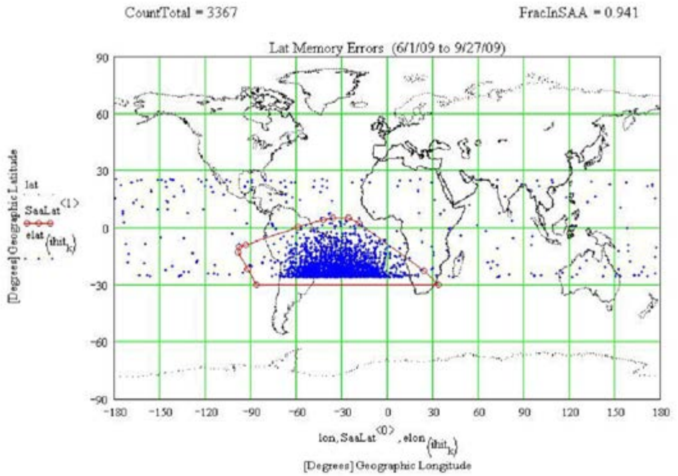

- Redundancy alone does not remove the threat
- Adds complexity to the design
- Diverse redundancy

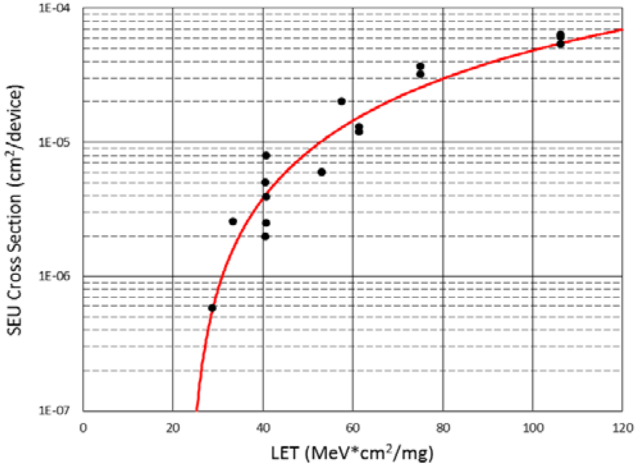
# Risk Buy Down by Radiation Testing

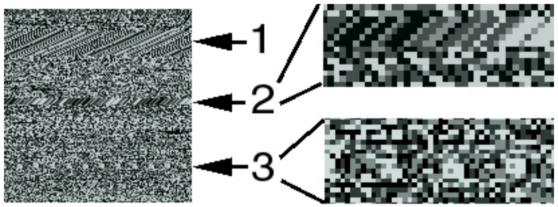


# Risk Hierarchy

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

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