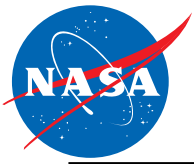


Risk Classification and Risk-based Safety and Mission Assurance

Dr. Jesse Leitner

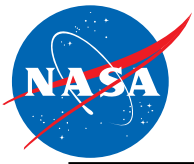
Chief Safety & Mission Assurance Engineer
NASA GSFC

December 15, 2014



Agenda

- **Risk Classification and Class D**
- **Layered risk reduction efforts to eliminate defects**
- **GPR 8705.4 introduction**
- **Low cost mission categories**
- **Center challenges**
- **Approaches for EEE parts for low cost projects**
- **What is risk-based SMA?**



Risk Classification

(NPR 7120.5 Projects)

- **Class A: Lowest risk posture by design**
 - Failure would have extreme consequences to public safety or high priority national science objectives.
 - In some cases, the extreme complexity and magnitude of development will result in a system launching with many low to medium risks based on problems and anomalies that could not be completely resolved under cost and schedule constraints.
 - Examples: HST and JWST
- **Class B: Low risk posture**
 - Represents a high priority National asset whose loss would constitute a high impact to public safety or national science objectives.
 - Examples: GOES-R, TDRS-K/L/M, MAVEN, JPSS, and OSIRIS-REX
- **Class C: Moderate risk posture**
 - Represents an instrument or spacecraft whose loss would result in a loss or delay of some key national science objectives.
 - Examples: LRO, MMS, TESS, and ICON
- **Class D: Cost/schedule are equal or greater considerations compared to mission success risks**
 - Technical risk is medium by design (may be dominated by yellow risks).
 - Many credible mission failure mechanisms may exist. A failure to meet Level 1 requirements prior to minimum lifetime would be treated as a mishap.
 - Examples: LADEE, IRIS, NICER, and DSCOVR

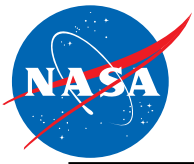


Risk Classification

(Non-NPR 7120.5 Projects)

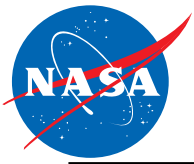
- **NPR 7120.8 “class” – Technical risk is high**
 - Some level of failure at the project level is expected; but at a higher level (e.g., program level), there would normally be an acceptable failure rate of individual projects, such as 15%.
 - Life expectancy is generally very short, although instances of opportunities in space with longer desired lifetimes are appearing.
 - Failure of an individual project prior to mission lifetime is considered as an accepted risk and would not constitute a mishap. (Example: ISS-CREAM)
- **“Do No Harm” Projects** – If not governed by NPR 7120.5 or 7120.8, we classify these as “Do No Harm”, unless another requirements document is specified
 - Allowable technical risk is very high.
 - There are no requirements to last any amount of time, only a requirement not to harm the host platform (ISS, host spacecraft, etc.).
 - No mishap would be declared if the payload doesn’t function. (Note: Some payloads that may be self-described as Class D actually belong in this category.) (Example: CATS, RRM)

7120.8 and “Do No Harm” Projects are not Class D



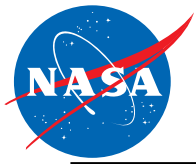
Risk Classification Trends

- **Stepping from A, B, ... “Do No Harm” results in:**
 - More control of development activities at lower levels; people actually doing the work
 - Less control by people who are removed from the development process
 - Less burden by requirements that may not affect the actual risks for the project
 - More engineering judgment required
 - Less formal documentation (does not relax need to capture risks nor does it indicate that processes should be blindly discarded)
 - Greater understanding required for reliability and risk areas to ensure that requirements are properly focused, risk is balanced to enable effective use of limited resources, and that good engineering decisions are made in response to events that occur in development
 - Emphasis on Testing/Test results to get desired operational confidence
 - Greater sensitivity to decisions made on the floor



Class D at GSFC

- **What is Class D?** = Highest risk posture for missions governed by NPR 7120.5
- **What is Class D not?** – A catch-all for projects that are not NPR 7120.5 Classes A-C
- ***Is there a problem unique to Class D at GSFC?***
 - **No**
 - There is an unbalanced approach to risk that affects Class D more than others
 - There is a lack of definition of how key processes for mitigating risk vary across all risk classifications
 - These problems even affect Class A
- GSFC Class D Constitution addresses some of the programmatic processes such as management structure, waivers, etc
- GPR 8705.4 effort and new organizational structure addresses the technical processes
- Organizational changes in 300 will provide the infrastructure for implementation
 - Implementation has already begun



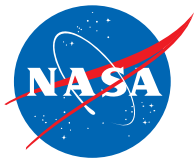
Class D (and below) Dos & Don'ts

- **Do:**

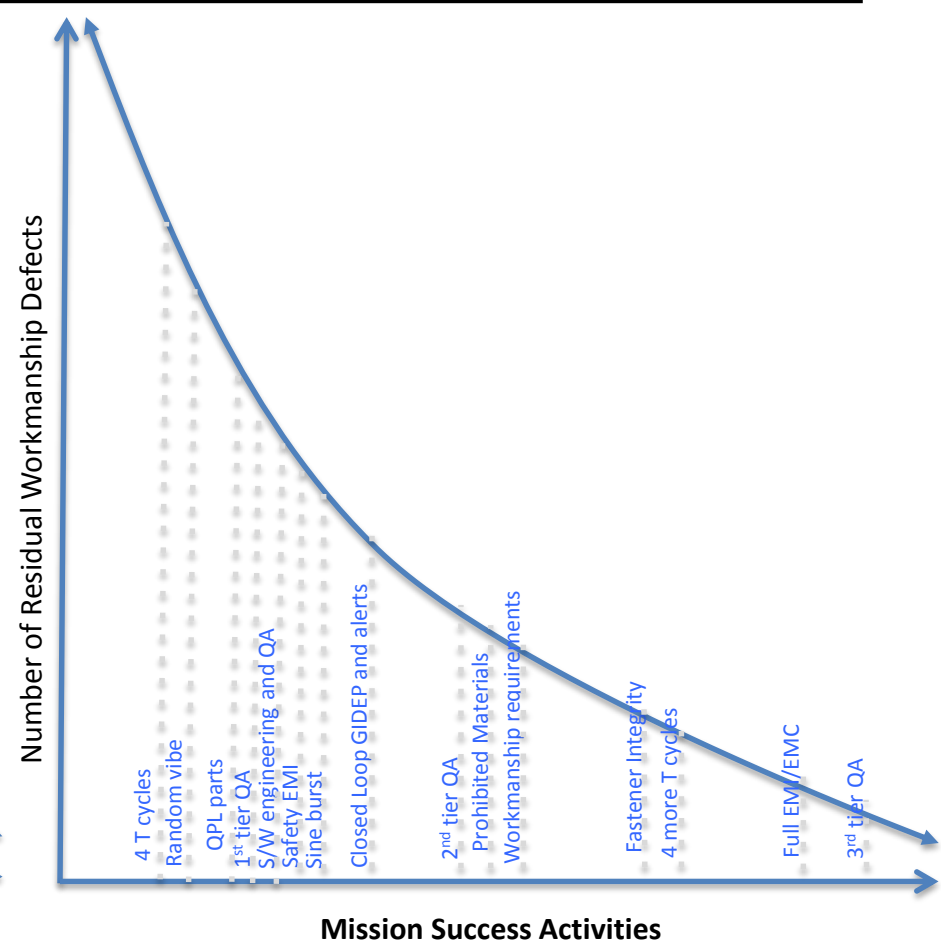
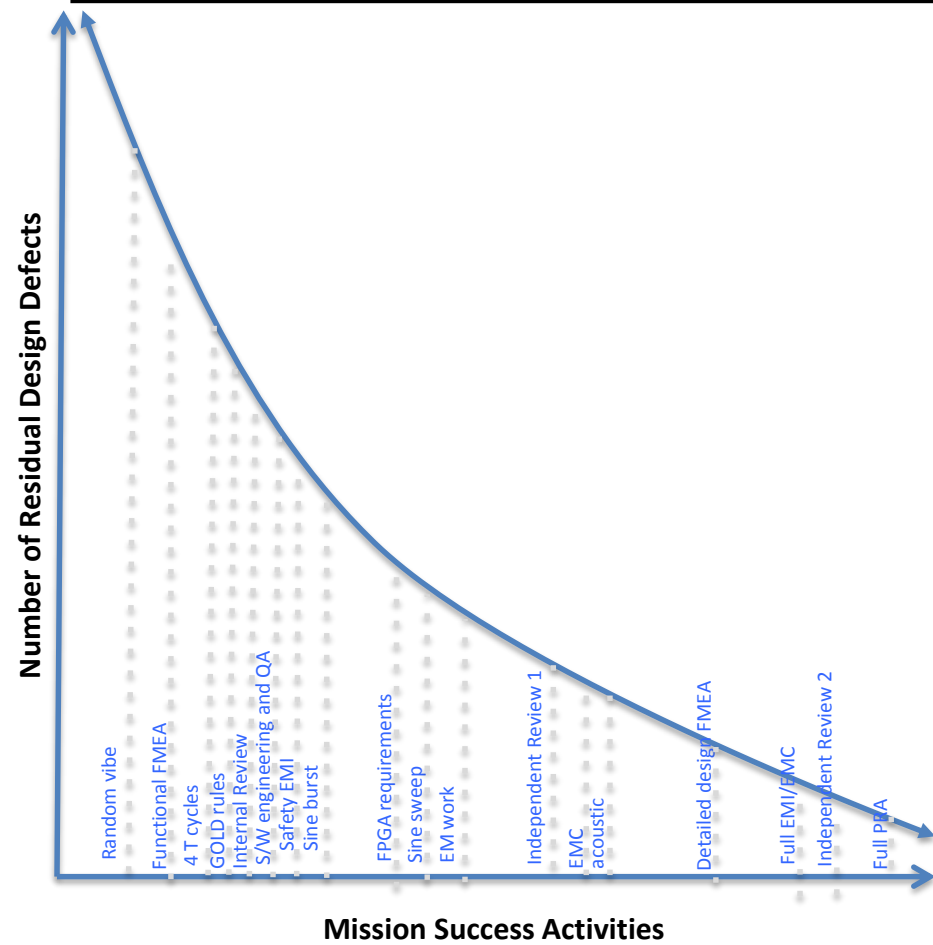
- Streamline processes (less formal documentation, e.g., spreadsheet vs. formal software system for waivers, etc.)
- Focus on tall poles and critical items from a focused reliability analysis
- Tolerate more risk than A, B, or C (particularly schedule risk)
- Capture and communicate risks diligently
- Rely more on knowledge than requirements
- Put more authority in the hands of PMs and PIs.
- Have significant margin on mass, volume, power (not always possible, but strongly desirable)
- Have significant flexibility on performance requirements (not always possible, but strongly desirable)

- **Don't:**

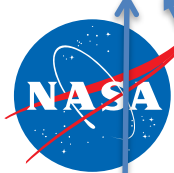
- **Ignore risks!**
- Reduce reliability efforts (but do be more focused and less formal)
- Assume nonconforming means unacceptable or risky
- Blindly eliminate processes



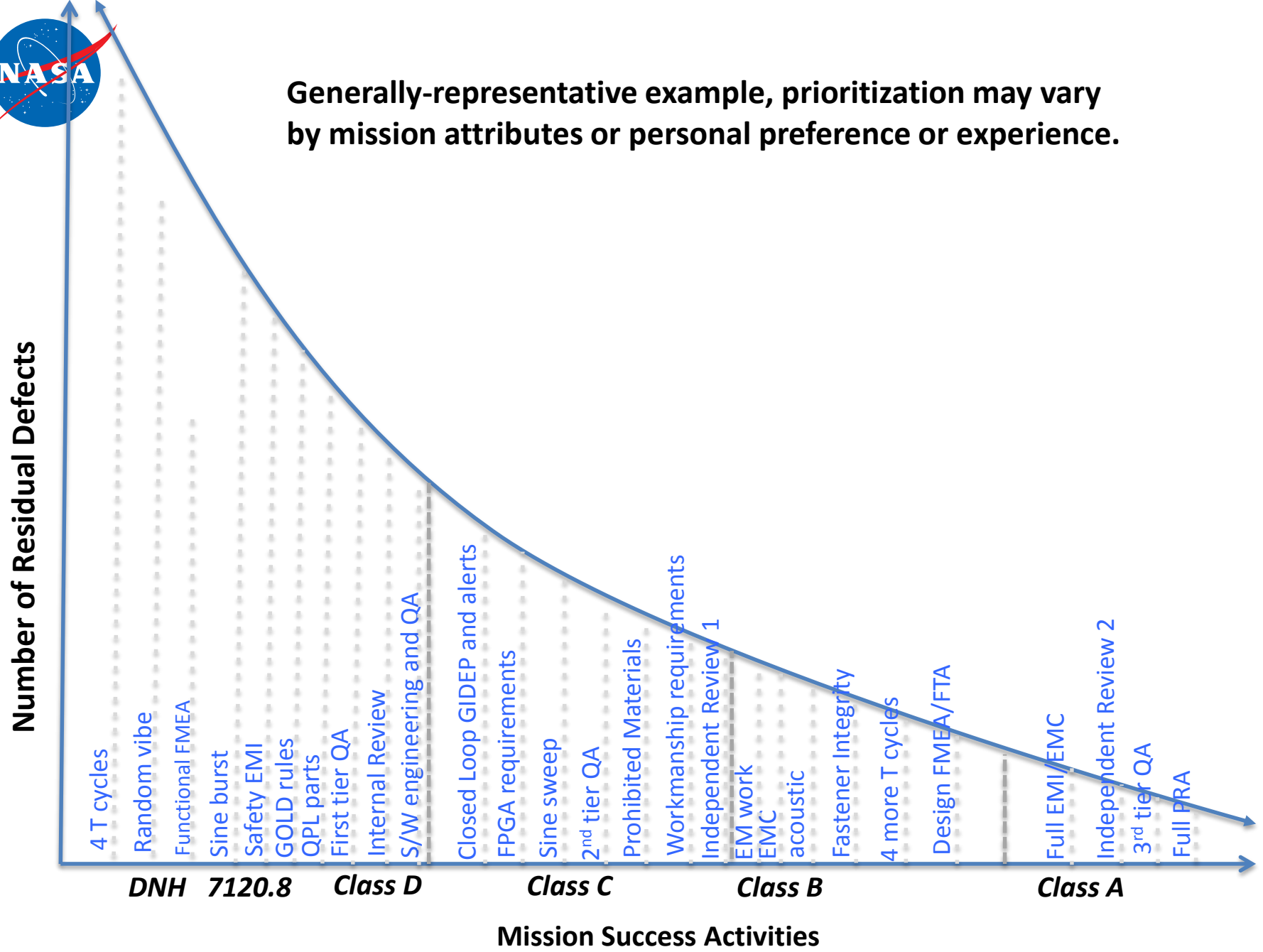
Risk can be characterized by number of defects and the impact of each.
Defects are generally of design or workmanship.

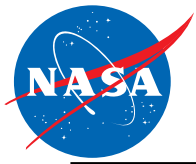


Note: A thorough environmental test program will ensure most risks are programmatic (cost/schedule) until very late, when time and money run out



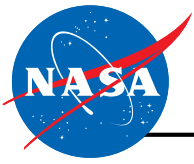
Generally-representative example, prioritization may vary by mission attributes or personal preference or experience.





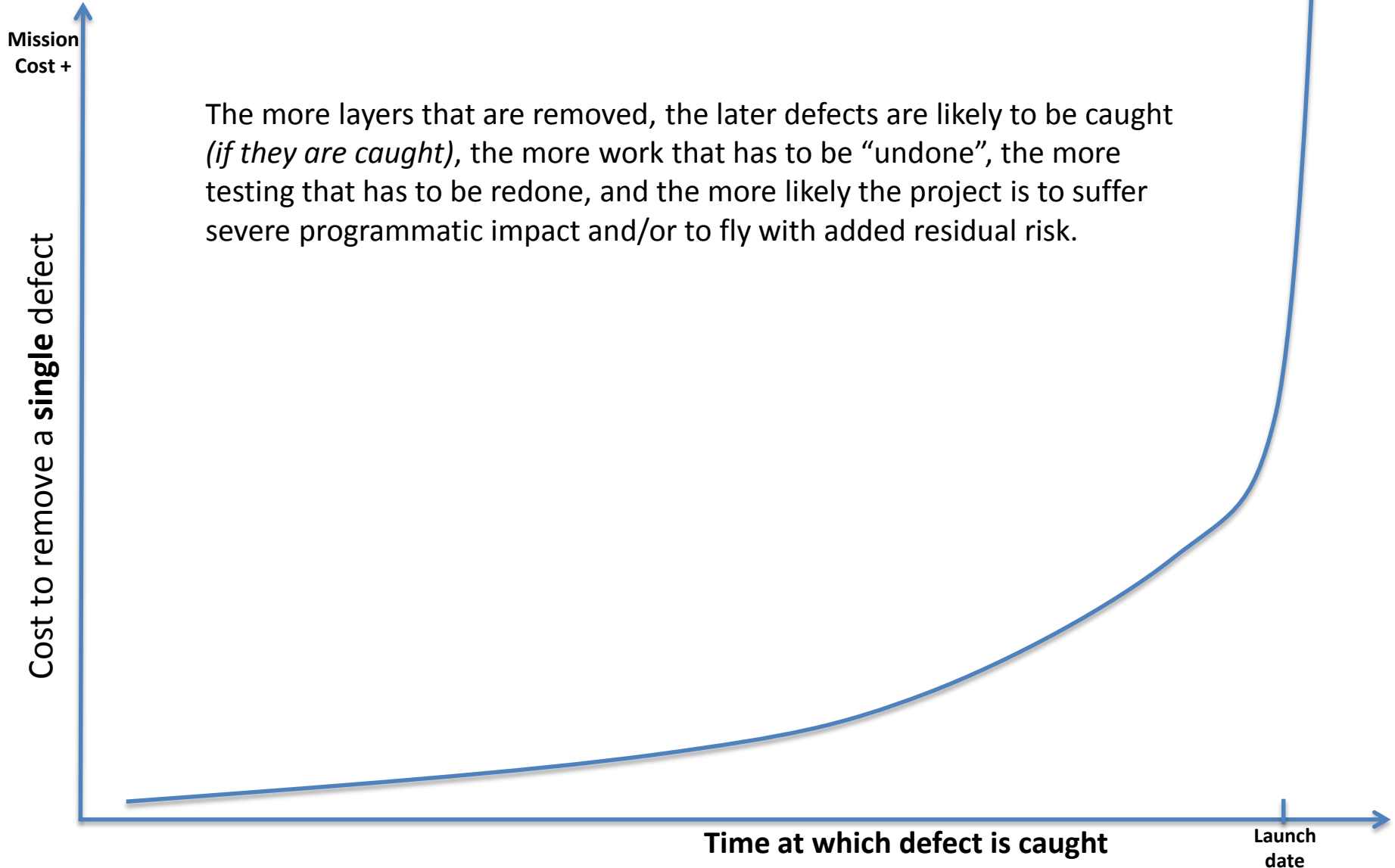
Other Activities with Cost & Risk Reduction Implications

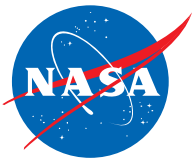
- **Nonconformance handling**
 - Is the requirement that is *not* met important for the current project in its environment?
 - Is the nonconforming item critical?
 - What is the risk for this project of the nonconformance?
 - Cost/schedule
 - Technical
- **Work orders and procedures**
- **Anomaly resolution**
 - Documentation
 - Root cause analysis
 - Lessons learned for same project or others



Removing layers results in some defects not being caught, and some being caught later

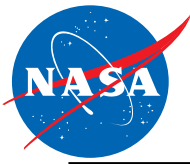
The more layers that are removed, the later defects are likely to be caught (*if they are caught*), the more work that has to be “undone”, the more testing that has to be redone, and the more likely the project is to suffer severe programmatic impact and/or to fly with added residual risk.





GPR 8705.4

- GSFC implementation of NPR 8705.4
- Risk Classification Definitions
- Nonconformance handling
 - Do not reject without understanding the risk
 - Determine cause of NC before reproducing the item (even from different vendor)
- Guidelines for activities vs mission class
- Ultimately will be one element used to develop project Mission Assurance Requirements vs mission class
- How does a project demonstrate that they are developing a Class “X” product?
- How do we convey to a vendor what we expect for Class “X”?

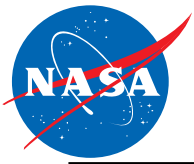


Mission Success Activities vs. Risk Posture

(example elements in draft)

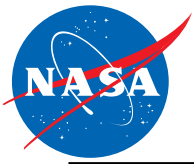
	A	B	C	D	GS	7120.8 class	DNH	Hosted payload (host requirements)
Printed Circuit Boards	IPC 6012B 3/A for rigid PCBs, independent coupon verification	IPC 6012 B 3/A or IPC 6012 C 3/A - negative etchback and 1 mil IARs allowed based on significant heritage and modern cleaning processes	IPC 6012B 3/A, with one mil ARs and negative etchback approved based on heritage, allow vendor to perform their own PCB verifications	IPC 6012B 3, 3/A, or MIL-P-55110 for rigid PCBs, vendor can perform their own PCB verifications	Commercial practice	Best effort, as tailored in project documentation	Best effort	Host practices
Materials And Processes	NASA STD 6016, 541-PG-8072.1, Lot testing of EEE parts for > 3% Pb	NASA STD 6016, 541-PG-8072.1, Lot testing of EEE parts for > 3% Pb	Tailored NASA STD 6016, supply chain and counterfeit controls from 541-PG-8072.1, > 3% Pb for EEE parts, but no lot testing required	Tailored NASA STD 6016, Supply chain and counterfeit controls from 541-PG-8072.1, whisker prevention based on mission duration	Whisker prevention (min 3% lead content or conformal coating). A parts and material review board is needed for custom designed modules	Supply chain and counterfeit controls from 541-PG-8072.1	Supply chain and counterfeit controls from 541-PG-8072.1	Host practices
EEE Parts	Level 1 parts, GSFC S-311-M-70, 500-PG-4520.2.1, EEE-INST-002.	Level 2 parts from EEE-INST-002, except Level 1 & DPA for single point failures.	Level 3 parts from EEE-INST-002, except level 2 parts for single point failures, DPA or pre-cap inspection for hybrids.	Level 3 parts, 500 PG-4520.2.1, DPA or pre-cap inspection on hybrids.	For custom designed module, quality level of parts selected needs to be consistent with the criticality of the module.	Best commercial practices, advise on part selection & derating. ISO certified facilities preferred.	Best commercial practices, ISO certified facilities preferred.	Host practices. Advise on part selection & derating.
GIDEP and other alerts	Full closed loop for all systems	Full closed loop for all elements	Full closed loop for all elements	Full closed loop for all safety critical elements	Full closed loop for safety critical elements and for	Per project documentation	Project	Full closed loop

**Excerpt from previous draft of GPR 8705.4*



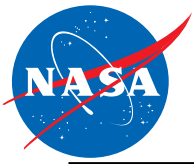
Risk Classification – All Levels

- **Class A missions can have Class D elements**
 - Non-critical
 - Highly redundant
 - Deliveries with acceptable “defects”
- **Class D mission can have Class A elements**
 - Critical elements
 - Only available
 - Spares from other projects



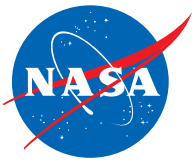
Class D (and below) Categories

Science Mission (NPR 7120.5)	Research/Technology (NPR 7120.8)	Do No Harm
<ul style="list-style-type: none">• Cost \geq mission success• Schedule flexible (low priority)• ~6 mo – 2 yr life• Project failure = mishap• Medium technical risks (may fly with many yellow risks)	<ul style="list-style-type: none">• Very low cost individual projects• Schedule flexible (low priority)• High technical risk• Very short lifetime ($< \sim 3$ months)• Success is determined over multiple projects, e.g., 85% success over one year's worth• Project failure is not a mishap	<ul style="list-style-type: none">• Only requirement – do no harm to personnel or other property (e.g. ISS)• Schedule flexible (low priority)• Very high technical risk• Lifetime is best effort• Project failure is not a mishap



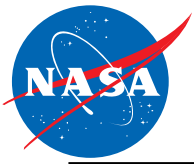
Best Applicability of a Streamlined Class D Approach

- **Simple design** (few critical elements)
- **Short mission life**
- **Clear and static science objectives and goals**
 - Sufficient, but not overreaching
- **Robust design** (tolerant to variance in workmanship)
- **Stable and repeatable manufacturing processes** (with known process variances)
- **High Margins** (to allow more design flexibility)
 - Mass
 - Power
 - Volume
 - Specifications: Dimensions, Materials
- **Prior flight experience** (with critical components in the same environment)



Center Challenges and Perceived Challenges for Low Cost Implementation In-house at GSFC

- **GSFC Directives and standards** (more detail in backup)
 - A dozen or so GPRs, centerwide PGs, and standards for workmanship, environmental test, and GOLD rules
 - Mostly handled by common practices
 - Risk classification is not handled well for those that have significant impact
 - Software requirements are the biggest burden, without particular basis in risk
- **NASA directives and standards**
 - Numerous NPRs, NPDs, and standards
 - Similar statement to above applies
- **Engineering resource budgeting** – Not closely tuned to streamlined implementation



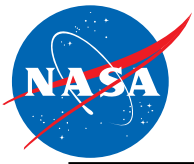
EEE Parts Approaches – Class D Science Missions

High Quality Parts (~Level 2) (parts-focused fault-tolerance)

- Very selective redundancy
- Radiation-tolerance/hardness dependent on environment, usage based on heritage
- Closed-loop GIDEP for critical applications
- Counterfeit controls

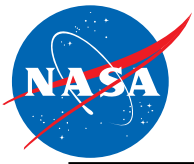
“COTS” Parts (architecture-focused fault-tolerance)

- Life testing dependent on mission life
- Use and test multiple “lots”
- Avoid SPFs at part level
- Maximize graceful degradation due to part loss
- Radiation tolerance/hardness dependent on environment, testing as required
- Factor in prior experience with specific parts
- Expect failures in test and on-orbit
- Counterfeit controls



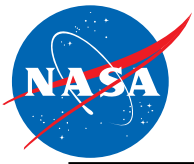
EEE Parts Approach – R&T (7120.8) Missions

- COTS parts for most from reputable manufacturers
- Level 2 for SPFs where affordable
- Very selective redundancy to avoid high likelihood SPFs
- Focused radiation analysis
- Use and test multiple “lots”
- Expect failures
- Perform “tall pole” reliability analysis
- Counterfeit controls



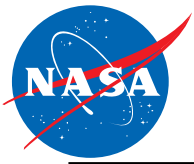
EEE Parts Approach – DNH

- COTS parts
- Use and test multiple lots
- Very selective redundancy
- Expect failures
- Counterfeit control or “sequestration”



What is Risk-Based SMA?

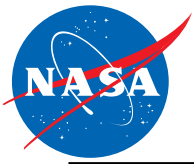
The process of applying limited resources to maximize the chance for safety & mission success by focusing on mitigating specific risks that are applicable to the project vs. simply enforcing a set of requirements because they have always worked



Attributes of Risk-Based SMA

- *Upfront assessment* of reliability and risk, e.g. tall poles, to prioritize how resources and requirements will be applied
- *Early discussions* with developer on their approach for ensuring mission success (e.g., use of high-quality parts for critical items and lower grade parts where design is fault-tolerant) and responsiveness to feedback
- *Judicious application* of requirements based on learning from previous projects and the results from the reliability/risk assessment, and the operating environment (Lessons Learned – multiple sources, Cross-cutting risk assessments etc)
- *Careful consideration* of the approach recommended by the developer
- *Characterization of risk* for nonconforming items to determine suitability for use – project makes determination whether to accept, not accept, or mitigate risks based on consideration of all risks
- *Continuous review* of requirements for suitability based on current processes, technologies, and recent experiences

Note: Always determine the cause before making repeated attempts to produce a product after failures or nonconformances



The GSFC Quality Triangle

Commodity Risk Assessment

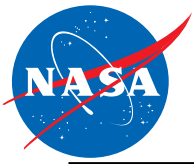
- Risk-based usage guidelines
- Risk layering requirements per risk class
- Nonconforming and out-of-family item risk assessment
- Learning through risk assessments, research, and testing

Quality Engineering

- Upfront involvement in design
- Design for manufacturability
- Assurance of Process Engineering and Qualified processes.
- SME support for Supply Chain Mgt
- Inspection
- Nonconformance and problem identification in developed hardware/software

Management Systems

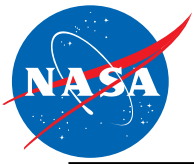
- ISO and AS9100 quality
- NCR follow-ups with vendors
- Audits and Assessments
- Supply Chain Mgt
- Lessons Learned capture



CRAE: Commodity Risk Assessment Engineer

Commodity: Tangible or intangible entity that has a major impact on risk, cost or schedule for GSFC projects

- Expert in key discipline area with background and experience with reliability and risk
- Responsible and empowered to assign risks based on warnings, alerts, environments, and “what we are stuck with”
- Establishes testing programs and protocols to keep up with current design practices and common parts and components
- Sets the policies for the risk-based decisions on use of parts, components, and processes
- Establishes layers of risk reduction based on risk classification (ownership of GPR 8705.4)
- Determines the acceptability and risk of alternate standards or requirements, or deviations and non-conformances
 - Answers, “are we ok?” “why are we ok?” “how ok are we?”
 - Provides risk assessment to the project for the project to decide how they want to disposition



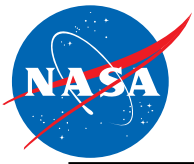
Commodity Areas

- Standard Spacecraft Components
- Printed Circuit Boards
- Digital Electronics (esp FPGAs and ASICs)
- Power Systems
- Capacitors/inductors
- Transistors
- Resistors
- Hybrid microcircuits
- Optocouplers
- On-board processors
- Workmanship/Printed Wiring Assemblies/Packaging/Components
- Software
- Materials
- Radiation
- Environmental testing
- Contamination
- Connectors
- ESD

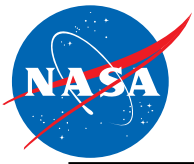


Conclusion

- There are many appropriate solutions to enable mission success for any mission classification
- It would be shortsighted to prescribe a single solution for mission success approaches for Class D, or any other classification
- The context (environment, criticality, lifetime, etc.) is essential to make intelligent decisions
- Guidelines provide a helpful starting point but they cannot replace good engineering practice



Back-Up



Most Broadly Applicable Project-specific Directives and Standards

- **NPR:** 7120.5, 7123.1, 7150.2, 8621.1B, 8715.3C, 8735.1C
- **NPD:** 8730.2C, 8730.5B
- **NASA STDs** (most broadly applicable): 8719.13, 8719.14, 8719.9, 8739.1, 8739.4, 8739.5, 8739.8
- **GPR:** 5340.3, 5340.4, 7120.4, 7120.7, 7120.9, 7123, 7150.1, 7150.2, 7150.3, 7150.4, 8070.2, 8700.4, 8700.6, 8700.7
- **PG:** 500-PG-4520.2.1, 500-PG-8700.2.7, 500-PG-8700.2.8, 541-PG-8072.1.2