National Aeronautics and Space Administration

SMD Class D standard MAR

Jesse Leitner,

Chief SMA Engineer, GSFC

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Outline

- Class D principles
- Significant departures from common practices
- Parts and radiation
- What risks are acceptable for Class D?
- Summary

Class D Principles: 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 *indirect* requirements
  - Put more decisions into the hands of the engineers on the floor.
  - Have significant margin on mass, volume, power (not always possible, but strongly desirable)*
  - Have significant flexibility on performance (level 1/level 2) 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

While the impression may be that a Class D is higher risk from the outside, if implemented correctly (and consistent with the intention), in reality the extra engineering thought about risk may actually reduce the practical risk of implementation.

*outside scope of MAR

Significant departures from common practices (1/3)

- Inherited items process
  - Allows a holistic, risk-based process based on
    - Prior history
    - Changes from previous (in H/W, S/W, operation, environment)
    - Past anomalies
  - Allows prior processes to be used without waivers
  - Decisions to use or impose additional tests, etc., based on risk
- GMIPs (consistent with NPR 8735.2B)
  - No predefined set of GMIPs
  - Based on upfront negotiation considering
    - assessment of developer's own inspection points
    - developer identified risks
    - project identified risks; and furthermore in response to events, such as failures, anomalies, and process shortfalls that prompt a need for further inspection.
  - Will be coordinated with the project to maximize efficiency and minimize schedule impact

Inherited items process principles

(apply to products used within their bounds and qualification ranges)

- Changing processes for a proven product is unlikely to improve, but more likely to degrade the product
- Changing processes for a proven product is most often not possible to do and doing so or attempting to do so will not only increase risk, but will substantially increase cost and development time
- GMIPs inserted into a standard build only cause a distraction from the standard build process and should only be attempted if there is a history of quality escapes that have entailed mission risk that GMIPs have caught for the product. Review of records for common standard components has not revealed any such escapes.
- Changing parts or part screening practices for a proven design or system will add both risk and cost to the system and likely will not be feasible
- Reliability analyses are needed only if a design is unproven
- The MAR requirements can be categorized as safety, quality, or reliability, but the purpose of quality requirements is to achieve reliability
  - Established standard products are already proven reliable and thus should not be assessed from a piece-part, one-of-a-kind design perspective

Significant departures from common practices (2/3)

- Workmanship
  - Workmanship standards (industry and NASA) provided as guidance, developer standard practices allowed
- EEE parts
  - Follows NASA-STD-8739.10 for Class D: Level 4 = COTS parts with no additional screening
  - Guidance provided to consider:
    - Prior usage of the part and qualification for the specific application
    - Manufacturing variability within lots and from lot to lot for parts
    - Traceability and pedigree of parts
    - Reliability basis for parts.
    - Parts stress/application conditions

Significant departures from common practices (3/3)

- Radiation
  - Emphasis on radiation-tolerant design
  - Part-by-part analysis and testing (for susceptible* parts) otherwise
- Printed Wiring Boards
  - Use own preferred standard
  - Project retains coupons or spare boards until mission disposal

*susceptible parts are generally microcircuits and active semiconductors

Intelligent use of COTS parts

- Always use parts within the limits of their datasheets
  - Respect the datasheet!
- AEC-qualified parts (not just "for automotive use") from leading manufacturers, produced under IATF 16949 will maximize reliability
- Use familiar parts when possible
- Avoid an approach that prompts you to use more parts as often happens with capacitors
- Conservative derating is good practice, but excessive and forced derating may result in need for many extra parts, a mass or space problem, or a weaker design with less margins.
- Use parts that the manufacturer declares to be for reliable use
- Use parts that have been established for over a year and in high volume production
- Buy parts from authorized distributors
  - There is no purpose in MIL-SPEC distributor restrictions when buying COTS parts
- There are many great options for "enhanced space" COTS parts for microcircuits and discretes
- Avoid requiring the tightest performance and tolerances from passive parts
- Strive for flexible resistance values (ranges) in current sensing applications
- Be sure that parts only offered with pure tin have matte tin finish, when available.
  - Give preference to manufacturers that use JEDEC tin whisker acceptance testing or similar approach
- Often increased performance and modern design and manufacturing drive increased reliability
- In some cases, you can only use what's available against the guidance – accordingly assess and acknowledge the risk and explore reasonable mitigations

Common approaches for addressing radiation

- Avoidance: dormancy of sensitive electronic elements in high stress regions such as SAA or Van Allen Belts
- RHBD: Proven rad-hard by design approach, applied to circuits and/or parts
- Traditional parts-centric: Use of RHA* parts with radiation-tolerant design to accommodate high stress region operation
- Modern parts-centric: Use of familiar sensitive** parts along with proven circuit designs in comparable environment, normally combined with select strategic parts testing outside of specific projects to characterize variability or parts changes in general
- Radiation-tolerant design: Use radiation-tolerant circuit design techniques including features such as MOSFET protection and overcurrent detection with reset capability, resettable processors, EDAC, derating beyond EEE-INST-002 recommendations, etc.
- Risk-based approach combining past on-orbit experiences in similar stressing environments.
- System fault-tolerance (including redundancy): This may include new, unproven approaches, with backup proven systems.

* RHA = radiation-hardness assured, with lot-specific testing and accompanying paperwork

**Sensitive parts include actives such as memory, processors, CMOS devices, MOSFETs, etc.

Will use of COTS cause a radiation nightmare?

- It certainly can if you're in a radiation environment and you pretend it's not there, but that has **nothing** to do with COTS.
- Typically, about 90% of the part count even for large missions are not radiation-hardness-assured (because they don't need to be).
  - The majority of places where COTS are really needed are for non-susceptible parts
- The problem is no different from that of using a 5962-XXX microcircuit or a JANS2NXXXX BJT (neither of which is radiation hardness assured)
- For reference, an IRHM58160 is a COTS part (and it is radiation hardness assured).

- No matter whether you use COTS, MIL-SPEC or "special drawing" parts, radiation should be addressed in the same way
- As we transition to newer technologies and higher performance, we will have to think about radiation mitigation in different ways because parts with RHA will almost always be multiple generations behind
  - However, some of the new technology parts will be less susceptible to radiation by the nature of their designs (thinner gate oxides, etc)

Radiation and on-orbit non-RHA performance data sources

- Test data:
  - Traditional: radhome.gsfc.nasa.gov, transitioned to https://nepp.nasa.gov/pages/pubs.cfm
  - New: esarad.esa.int
  - New: pmpedia.space
- On-orbit experiences ("fact of" - some info available)
  - Spacecube data (LEO on-orbit – extensive non-RHA and COTS – 10+ yr)
  - Aerocube data (LEO on-orbit – 100% non-RHA COTS – 10+ yr) (Aerospace Corporation)
  - Swift data (585km x 604km, 20.6 deg - extensive COTS ~ 19 yrs)
  - Ascent (GEO cubesat – launched 12/2021) (AFRL)
  - Biosentinel (deep space cubesat – launched with Artemis)
  - Newspace – extensive, limited data availability

What kinds of risks are acceptable?

- Those tied to compressed schedules and tight development constraints as long as there is a solid plan and acknowledgement of the challenging elements
- The use of new, modern, innovative approaches at development
- The use of yet-to-be-established standard or COTS components that are the only solution
  - Use of standard and COTS components outside of their qualified environment, or that are as of yet unproven when they constitute the only viable solution
    - Risk should be acknowledged with a plan for addressing or accepting
  - Note: Use of standard and COTS components that have been proven in the same environment for same time frame is lower risk than any piece-part assured approach
- The use of new select new technologies when necessary to advance science, with a viable plan for maturation and incorporation

Summary

- A Standard Mission Assurance Requirements document has been produced to represent the general set of requirements to impose on SMD Class D missions
- This is the first such document that truly addresses significant costs and programmatic risks that were not really addressed in the past.
- The document is baselined as a formal SMD document

Minor departures from common practices

- ARB/MRB/FRB
  - Government notified and invited to participate in type I (form, fit, function)
  - Type II – Government given access to, but timely notification not required
- Reliability
  - Project completes reliability analysis (e.g., FTA, FMEA) for faults that may lead to injury to personnel or the public, or produce orbital debris, or that may affect host platforms
  - Parts stress and derating analysis per EEE-INST-002 or comparable
- Software assurance
  - NASA-STD-8739.8 required
- Software safety
  - Safety critical elements determined from the hazard analysis and range requirements
- GIDEP: project shall take action to mitigate the effects of alerts on the project

Agency Team

- GSFC: Jesse Leitner (lead), Ron Perison
- LaRC: Joey Patterson, Don Porter
- JPL: Tom Ramsey, Sammy Kayali, Naomi Palmer
- Glenn: Cynthia Calhoun
- MSFC: Rodney Key, Kelly Bellamy, Michael Giuntini, James Kissell, Keith Dill
- ARC: Steve Jara, Don Mendoza
- APL: Steve Pereira, Rick Pfisterer
- SWRI: Joerg Gerhardus, John Stone

Background

- Numerous activities have taken place over the past several years to address the fact that Class D practices across the agency have differed little from those for Class A, B, or C missions
- Most of these activities have not resulted in substantial efforts to tangibly change how we perform Class D developments
- The result is that we have been limited in our ability to push the boundaries for moderate-risk/high-payoff missions
- This development effort has taken a very detailed view of the practices that are in place to ensure safety and mission success, and tunes them into risk-driven activities that accept developers' approaches in contrast to the current "do it the way we always have" approaches that have been difficult to depart from.
- This approach emphasizes the processes that provide the most risk reduction payoff and avoids the "feel-good" types of requirements that are abundant for Class A and Class B missions, where there is significant tolerance for overrun.
- This approach further emphasizes developer standard practices as opposed to prescriptive "do it our way" practices.
- At this point, there will be no choice, no matter what the risk posture, but to implement a "true Class D" for the new wave of highly resource-constrained missions that are abundantly emerging

Other elements

- Lifting
  - Vendor practices if command media exist
  - NASA-STD-8719.9 for all others
- ESD: ANSI/ESD S20.20-2007
- Lead-free and whisker controls required
- Assurance Plan for new digital electronic designs (FPGAs, ASICs, etc)
- Planetary Protection for outside of earth orbit
- Cybersecurity and Command Link Protection
  - FIPS 140 compliance (being superseded by NIST 800-53)
  - NASA-STD-1006A