# SmallSat Best Practices Implementation Example

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Sept 2017

# *Agenda*

- Overview, what is this example trying to do?
- Top level requirements
  - *Example 1, LEO large constellation, earth observation operational mission*
  - *Example 2, GEO operational mission*
  - *Example 3, LEO short life tech demonstration mission*
- Relevant MAIW recommendations and discussion for each example
- Wrap up

## *Overview*

- We are in a learning mode and hope to engage with industry and other Gov't areas to assemble a useful best practices implementation guide that could be used as a starting point to improve overall small sat reliability
- The best practices basis is the Mission Assurance Improvement Workshop (MAIW) TOR "Improving Mission Success of CubeSats", TOR-2017-01689
- This presentation will walk though a some examples of how top level requirements could drive design choices, trades, and acquisition strategy
- We are looking inputs based on actual programs and on thought processes behind part/component procurement and test decisions

## *Mission Types*

- Mission types can fall into several broad classes:
  - *Large constellations*
  - *One or few spacecraft, longer (>5 yrs) life times, can be GEO or interplanetary*
  - *One or few spacecraft, short life times, Science or tech demo type missions*
- Even within these broad classifications there is considerable variability
- Having clear definitions of scope, goals, & success criteria, or top level requirements are very important and is the 1st "best practice" from the MAIW document (TOR-2017-01689)

# *Focus of this presentation*

| Risk Tolerance → Activity or Process ↓ | Lower Risk Tolerance | ← → | Higher Risk Tolerance |
|---|---|---|---|
| **Reviews** | Formal SRR, PDR and CDR with external review board | ← → | Internal informal reviews with key stakeholders |
| **Drawings** | Configuration managed drawings / CAD models with critical review and signoff | ← → | Capture as-built configuration and key dimensions. Rudimentary CAD model recommended. |
| **EEE Parts** | Rad-hard or rad-tolerant parts in critical areas | ← → | COTS parts |
| **Thermal Cycling** | Cycling at board, box, and full vehicle level | ← → | At least four cycles at full vehicle level recommended |
| **Environmental Test** | Qual unit to validate design and Acceptance testing to validate workmanship | ← → | As required by launch provider |

- While there are decisions to be made for a number of programmatic items listed above, this presentation focusses on EEE parts/components to illustrate possible implementation strategies for different mission types
- Similar discussions would be expected for other items such as reviews, drawings, testing etc.

# *Most Relevant MAIW recommendations*

- Define your scope, goals, and success criteria at program start
  - *Justify your ability to complete it within the available time, using the available budget and resources*
  - *During the project lifecycle, aggressively defend it against growth, but have a plan to de-scope, if necessary*
- Maintain a healthy skepticism on vendor subsystem datasheets
  - *Hold margin on all performance numbers during design, and verify after receipt*
- Design for simplicity and robustness
  - *Assume designs will fail and then prove they will work*
  - *Design the satellite for easy assembly and disassembly*
  - *Have respectable margins, robust safe modes, few deployables, graceful performance degradation, and frequent preventative satellite resets*
- Stock spare components
  - *Extra boards support parallel software development and are flight spares*
  - *Extra hardware protects schedule during mechanical testing*

# *Definitions*

- A part is defined as a single item such as an ASIC, resistor, transistor, IR sensor, capacitor, etc. In short, items that are assembled onto circuit boards or other higher level assemblies
- A component is effectively the next higher level of assembly, such as a software defined radio board, or a power board with or without integrated batteries, a guidance and navigation board, or a reaction wheel. This is generally the highest level of assembly for CubeSat elements prior to being integrated into the CubeSat as a complete vehicle
- A Unit is a fully assembled subsystem such as a high power amplifier, a receiver, on board computer, or an electronic power conditioner, all of which would be assembled in their own chassis with connectors at the interfaces. In general a unit such as those found on the larger satellites are too complex or use too much power for a CubeSat, but may be found on some SmallSats, particularly in the 100kg class

# *Example 1, large constellation*

# *Example 1, large constellation*

- This example is like Planet, earth observation, but could apply to any large constellation
- Goal, 99.7% data availability for users in a given month for any location between the arctic and ant-arctic circles
  - *No plan to state pixel resolution for now as this is not as important for this example*
- This would be an operational mission

# *Notional Mission characteristics for a large constellation*

| Risk Tolerance → <br> Mission Characteristics ↓ | Very Low | Low | Moderate | High | Very High |
|---|---|---|---|---|---|
| **Mission Criticality** | National Security; Operational | Operational; Primary Science | Gap Filler | Experimental; Technology Demo | Technology Demo; Teaching System |
| **LEO Mission Life** | 5+ years | 3-5 years | ~1 year | Months | Days to weeks |
| **GEO/Deep Space Mission Life** | 10+ years | 5+ years | 1-3 years | Months | Days |
| **<10 Satellites** | Operational Mission | Data gathering | Gap Filler | Experiment | Technology Demonstration |
| **Constellation (>10) Satellites** | Common mode failures ruled out | High unit cost; limited "spare" vehicles | | Multiple spare vehicles | Re-launch readily available |
| **Flight Development Time** | >5 years | 2 to 5 years | ~ 2 years | 1 to 2 years | <12 months |

# *Large Constellation Questions*

- Despite being operational, can the risk tolerance for any single space vehicle (SV) be high?
  - *Large constellation means slow graceful degradation if an individual node (or SV) is lost*
- Is single string (no internal redundancy) is OK?
- What kind of testing should take place for the $1^{st}$ few SV’s vs. SV’s later in the production line?
- Are part choices based on design application and not specific part grade?
- How is variability between lots and even within lots for COTs parts accounted for?

# *Notional Part choices for a large constellation*

| Piece Parts | higher confidence | Mid level confidence | Lower confidence |
|---|---|---|---|
| Part type | JAN-S level parts | Industrial/Automotive | COTS |
| Radiation tolerance | Radiation hardened | Radiation tolerant/possible upscreening | Minimal/unknown |
| Testing | full qualification | thermal | None, possibly some incoming inspection |
| Documentation | QPL/QML list parts with full pedigree and traceability | some traceability | Minimal |

**Nominal part choice decisions based on LEO/large constellation configuration**

| Components | higher confidence | Mid level confidence | Lower confidence |
|---|---|---|---|
| Component type | Highly customized boards or subsystems | Some customization such as rad tolerant parts | COTS boards/subsystems |
| Radiation tolerance | Radiation hardened | Radiation tolerant | Minimal/unknown |
| Vendor oversight | Full oversight and part traceability | Review vendor design practices | None, mitigate risk with timers, derating etc. |
| Testing | full qualification | thermal | None or simple functional tests |
| Documentation | Complete BOMs and test documentation | some traceability<br>Some test documentation | Minimal |

# *Notional Piece Part choices, Testing*

| Requirement | Low Risk/high confidence | med-low Risk/Med-high confidence | med-high Risk/Med-low confidence | High risk/low confidence |
|---|---|---|---|---|
| Lot acceptance | Per QPL/QML req'ts when possible. Upscreen part when no QPL/QML equivalent available | Optional Per QPL/QML req'ts | Not required | Not required |
| Temperature cycling | Per QPL/QML req'ts when possible. Upscreen part when no QPL/QML equivalent available | Optional Per QPL/QML req'ts | Not required | Not required |
| Serialization | Not required. Any serializing of key components done by supplier's judgement. | Not required | Not required | Not required |
| Burn-in | Per QPL/QML req'ts when possible. Upscreen part when no QPL/QML equivalent available | Optional Per QPL/QML req'ts | Not required | Not required |
| Radiation | Mission TID analysis required. Optional TID testing. Optional SEL part screening to 37 MeV. Optional customer review and approval of EEE parts. | Expected mission TID must be below 20k RAD after shielding. Optional customer review and approval of EEE parts. | Optional customer review and approval of EEE parts. No testing required. | Not required |
| Derating Analysis | Analysis required, customer furnished requirements | Analysis, supplier determined requirements | Analysis, supplier determined requirements | Not required, derating may not be required |

***This table and next table courtesy of Chris Day of VACCO (with edits by the author), numbers in table are notional***

# Notional Component Choices, Testing

| Requirement | Low Risk/high confidence | med-low Risk/Med-high confidence | med-high Risk/Med-low confidence | High risk/low confidence |
|---|---|---|---|---|
| Thermal cycling | Optional cycles | Optional cycles | Not required | Not required |
| Serialization | Board and subsystem level | Board and subsystem level | Subsystem level | Optional subsystem level |
| Burn-in | 72 hours at room temperature plus thermal testing | 72 hours at room temperature plus thermal testing | 72 hours at room temperature plus thermal testing | Implied by operational testing |
| Thermal testing | +10C above max, -10C below min expected operating temp, 24 hours each | +5C above max, -5C below min expected operating temp, 24 hours each | expected operating temp, 24 hours each | Must operate over expected operating temp |
| Vacuum operation testing | Components screened to not outgas | Components screened to not outgas | Not required | Not required |
| Soldering | J-STD-001 certified soldering. | Must pass intent of J-STD-001 | Must pass intent of J-STD-001 | Not required |
| Vibe/shock testing | Optional | Optional | Vibe only | Not required |
| Acceptance test plan | Extensive, operating parameters recorded | Comprehensive, time and cost efficient, operating parameters recorded | Operating parameters recorded | Must operate in relevant thermal environment |

# *Other supplier comments/questions*

- Cultivating relationships with suppliers will also pay off with better reliability as OEMs as inexpensive parts can change without notice
  - *For these COTS type choices it is more important than ever to test piece parts and components upon receipt?*
  - *There will be no pedigree and little actual test data available for this type of component. This is a case where the integrator assumes more of the risk of ensuring the overall SV will function as needed*
- Appendix A provides a list of questions to ask part and component suppliers. Note that most suppliers will not have satisfying answers to many of them. Also note that most of the statements above would also apply to those building a single purpose SV on a shoe string such as universities

# *Example 2, GEO orbit mission with a few small spacecraft*

# *Example 2, Few SVs, GEO mission*

- GEO orbit operational mission with a few small spacecraft
- Success for this mission is defined as delivering precise orbital tracking data for GEO satellites which will also be used for satellite collision avoidance as the Geostationary Belt gets more crowded over coming years

# *Notional Mission characteristics for a Small GEO mission*

| **Risk Tolerance →<br>Mission Characteristics ↓** | **Very Low** | **Low** | **Moderate** | **High** | **Very High** |
|---|---|---|---|---|---|
| **Mission Criticality** | National Security; Operational | Operational; Primary Science | Gap Filler | Experimental; Technology Demo | Technology Demo; Teaching System |
| **LEO Mission Life** | 5+ years | 3-5 years | ~1 year | Months | Days to weeks |
| **GEO/Deep Space Mission Life** | 10+ years | 5+ years | 1-3 years | Months | Days |
| **<10 Satellites** | Operational Mission | Data gathering | Gap Filler | Experiment | Technology Demonstration |
| **Constellation (>10) Satellites** | Common mode failures ruled out | High unit cost; limited "spare" vehicles | | Multiple spare vehicles | Re-launch readily available |
| **Flight Development Time** | >5 years | 2 to 5 years | ~ 2 years | 1 to 2 years | <12 months |

# *Small GEO Mission Questions*

- In this example, would the parts/component selections and overall testing would tend to be more like current practices the larger programs use?
  - *If so, clearly cost will increase, mainly due to a far less benign space environment and other concerns such as outgassing and bulk/surface charge management must also be considered.*
- How is onboard redundancy designed in?
  - *In the case of CubeSats, targeted use of redundancy to improved confidence may be utilized, but is usually constrained by volume and power. In SmallSats, use of redundancy may be more feasible. Note that including redundancy itself increases complexity of the system, so use of redundancy must be carefully considered to determine its ultimate value to the program*
- If advanced electronics/sensors are used that are not space rated then are they up-screened? Is shielding considered?
  - *If Shielding is not possible then risk mitigations such as planned resets, derating etc. should be used*

# *Notional Part choices for a GEO small constellation*

| Piece Parts | higher confidence | Mid level confidence | Lower confidence |
|---|---|---|---|
| Part type | JAN-S level parts | Industrial/Automotive | COTS |
| Radiation tolerance | Radiation hardened | Radiation tolerant/possible upscreening | Minimal/unknown |
| Testing | full qualification | thermal | None, possibly some incoming inspection |
| Documentation | QPL/QML list parts with full pedigree and traceability | some traceability | Minimal |

**Nominal part choice decisions based on GEO and small constellation configuration**

| Components | higher confidence | Mid level confidence | Lower confidence |
|---|---|---|---|
| Component type | Highly customized boards or subsystems | Some customization such as rad tolerant parts | COTS boards/subsystems |
| Radiation tolerance | Radiation hardened | Radiation tolerant | Minimal/unknown |
| Vendor oversight | Full oversight and part traceability | Review vendor design practices | None, mitigate risk with timers, derating etc. |
| Testing | full qualification | thermal | None or simple functional tests |
| Documentation | Complete BOMs and test documentation | some traceability<br>Some test documentation | Minimal |

# Notional Piece Part choices, Testing

| Requirement | Low Risk/high confidence | med-low Risk/Med-high confidence | med-high Risk/Med-low confidence | High risk/low confidence |
|---|---|---|---|---|
| Lot acceptance | Per QPL/QML req'ts when possible. Upscreen part when no QPL/QML equivalent available | Optional Per QPL/QML req'ts | Not required | Not required |
| Temperature cycling | Per QPL/QML req'ts when possible. Upscreen part when no QPL/QML equivalent available | Optional Per QPL/QML req'ts | Not required | Not required |
| Serialization | Not required. Any serializing of key components done by supplier's judgement. | Not required | Not required | Not required |
| Burn-in | Per QPL/QML req'ts when possible. Upscreen part when no QPL/QML equivalent available | Optional Per QPL/QML req'ts | Not required | Not required |
| Radiation | Mission TID analysis required. Optional TID testing. Optional SEL part screening to 37 MeV. Optional customer review and approval of EEE parts. | Expected mission TID must be below 20k RAD after shielding. Optional customer review and approval of EEE parts. | Optional customer review and approval of EEE parts. No testing required. | Not required |
| Derating Analysis | Analysis required, customer furnished requirements | Analysis, supplier determined requirements | Analysis, supplier determined requirements | Not required, derating may not be required |

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# Notional Component Choices, Testing

| Requirement | Low Risk/high confidence | med-low Risk/Med-high confidence | med-high Risk/Med-low confidence | High risk/low confidence |
|---|---|---|---|---|
| Thermal cycling | Optional cycles | Optional cycles | Not required | Not required |
| Serialization | Board and subsystem level | Board and subsystem level | Subsystem level | Optional subsystem level |
| Burn-in | 72 hours at room temperature plus thermal testing | 72 hours at room temperature plus thermal testing | 72 hours at room temperature plus thermal testing | Implied by operational testing |
| Thermal testing | +10C above max, -10C below min expected operating temp, 24 hours each | +5C above max, -5C below min expected operating temp, 24 hours each | expected operating temp, 24 hours each | Must operate over expected operating temp |
| Vacuum operation testing | Components screened to not outgas | Components screened to not outgas | Not required | Not required |
| Soldering | J-STD-001 certified soldering. | Must pass intent of J-STD-001 | Must pass intent of J-STD-001 | Not required |
| Vibe/shock testing | Optional | Optional | Vibe only | Not required |
| Acceptance test plan | Extensive, operating parameters recorded | Comprehensive, time and cost efficient, operating parameters recorded | Operating parameters recorded | Must operate in relevant thermal environment |

## *Other supplier comments*

- In contrast to the procurement of parts for a large constellation, part and component suppliers would be expected to have good answers to many of the questions in Appendix A

# *Example 3, LEO orbit single vehicle tech demo from a university*

# *Example 3, University Single SV Tech Demo*

- A university led single SV flying a tech demo payload
  - *Desired Goal: to obtain data from a new type of star tracker (for example)*
  - *Basic Goal: teaching, get this built with student labor in less than a year*

# Notional Mission characteristics for a University Single SV Tech Demo

| Risk Tolerance → Mission Characteristics ↓ | Very Low | Low | Moderate | High | Very High |
|---|---|---|---|---|---|
| Mission Criticality | National Security; Operational | Operational; Primary Science | Gap Filler | Experimental; Technology Demo | Technology Demo; Teaching System |
| LEO Mission Life | 5+ years | 3-5 years | ~1 year | Months | Days to weeks |
| GEO/Deep Space Mission Life | 10+ years | 5+ years | 1-3 years | Months | Days |
| <10 Satellites | Operational Mission | Data gathering | Gap Filler | Experiment | Technology Demonstration |
| Constellation (>10) Satellites | Common mode failures ruled out | High unit cost; limited "spare" vehicles | | Multiple spare vehicles | Re-launch readily available |
| Flight Development Time | >5 years | 2 to 5 years | ~ 2 years | 1 to 2 years | <12 months |

# Tech Demo Mission Questions

- Are COTS parts/components are the best choices?
  - *In this example parts cost and schedule for delivery are key*
- Should spare boards and components be purchased and/or made?
  - *In this case it is even more important that spare boards at least are made available to allow for swap outs in case of problems*
- If advanced electronics/sensors are used that are not space rated then are they up-screened? Is shielding considered?
  - *If Shielding is not possible then risk mitigations such as planned resets, derating etc. should be used*

# *Notional Part choices for a Tech Demo*

| Piece Parts | higher confidence | Mid level confidence | Lower confidence |
|---|---|---|---|
| Part type | JAN-S level parts | Industrial/Automotive | COTS |
| Radiation tolerance | Radiation hardened | Radiation tolerant/possible upscreening | Minimal/unknown |
| Testing | full qualification | thermal | None, possibly some incoming inspection |
| Documentation | QPL/QML list parts with full pedigree and traceability | some traceability | Minimal |

**Nominal part choice decisions based on single SV tech demo**

| Components | higher confidence | Mid level confidence | Lower confidence |
|---|---|---|---|
| Component type | Highly customized boards or subsystems | Some customization such as rad tolerant parts | COTS boards/subsystems |
| Radiation tolerance | Radiation hardened | Radiation tolerant | Minimal/unknown |
| Vendor oversight | Full oversight and part traceability | Review vendor design practices | None, mitigate risk with timers, derating etc. |
| Testing | full qualification | thermal | None or simple functional tests |
| Documentation | Complete BOMs and test documentation | some traceability<br>Some test documentation | Minimal |

# Notional Piece Part choices, Testing

| Requirement | Low Risk/high confidence | med-low Risk/Med-high confidence | med-high Risk/Med-low confidence | High risk/low confidence |
|---|---|---|---|---|
| Lot acceptance | Per QPL/QML req'ts when possible. Upscreen part when no QPL/QML equivalent available | Optional Per QPL/QML req'ts | Not required | Not required |
| Temperature cycling | Per QPL/QML req'ts when possible. Upscreen part when no QPL/QML equivalent available | Optional Per QPL/QML req'ts | Not required | Not required |
| Serialization | Not required. Any serializing of key components done by supplier's judgement. | Not required | Not required | Not required |
| Burn-in | Per QPL/QML req'ts when possible. Upscreen part when no QPL/QML equivalent available | Optional Per QPL/QML req'ts | Not required | Not required |
| Radiation | Mission TID analysis required. Optional TID testing. Optional SEL part screening to 37 MeV. Optional customer review and approval of EEE parts. | Expected mission TID must be below 20k RAD after shielding. Optional customer review and approval of EEE parts. | Optional customer review and approval of EEE parts. No testing required. | Not required |
| Derating Analysis | Analysis required, customer furnished requirements | Analysis, supplier determined requirements | Analysis, supplier determined requirements | Not required, derating may not be required |

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# Notional Component Choices, Testing

| Requirement | Low Risk/high confidence | med-low Risk/Med-high confidence | med-high Risk/Med-low confidence | High risk/low confidence |
|---|---|---|---|---|
| Thermal cycling | Optional cycles | Optional cycles | Not required | Not required |
| Serialization | Board and subsystem level | Board and subsystem level | Subsystem level | Optional subsystem level |
| Burn-in | 72 hours at room temperature plus thermal testing | 72 hours at room temperature plus thermal testing | 72 hours at room temperature plus thermal testing | Implied by operational testing |
| Thermal testing | +10C above max, -10C below min expected operating temp, 24 hours each | +5C above max, -5C below min expected operating temp, 24 hours each | expected operating temp, 24 hours each | Must operate over expected operating temp |
| Vacuum operation testing | Components screened to not outgas | Components screened to not outgas | Not required | Not required |
| Soldering | J-STD-001 certified soldering. | Must pass intent of J-STD-001 | Must pass intent of J-STD-001 | Not required |
| Vibe/shock testing | Optional | Optional | Vibe only | Not required |
| Acceptance test plan | Extensive, operating parameters recorded | Comprehensive, time and cost efficient, operating parameters recorded | Operating parameters recorded | Must operate in relevant thermal environment |

# *Other supplier comments*

- It is unlikely that a university would even be looking at the questions in Appendix A, nor would their suppliers have any answers
- In this case building good relations even for small part orders is advisable
- Incoming tests at the board level is also advisable
  - *In particular, given the experiences by a number of SmallSat integrators with boards arriving from suppliers defective, reference the presentation comments made by Michael Johnson at the 2017 SmallSat conference*
  - *Buying more parts/boards needed in this case would be a very good idea as it makes it easy to swap out if issues with test failures and workmanship arise*

## *Wrap up*

- These examples outlined here show possible implementations of best practices for different mission types.
- Most important thing is to determine top level requirements and scope, all other decisions flow from that
- As we learn more we would like to meet with industry representatives to ensure the final product is useful to both industry and the Government

***Seeking further inputs from industry and universities***

## *Appendix A, List of Questions for parts suppliers*

By Allyson Yarbrough PhD, and Sung Hong PhD
Electronics and Sensors Division
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Aerospace Corporation

# *Appendix A, Questions to ask part and component suppliers*

- This section is an excerpt from "Key Questions to Ask When Considering Alternate-Grade EEE (Electrical, Electronic and Electromechanical) Parts for Small Satellite Missions" by Dr. Sung Hong and Dr. Allyson Yarbrough both of Aerospace Corporation
  - ***Supplier Data:***
    - **Test Data from Supplier**
  - *3. To what data or insight do you have access that demonstrates lot homogeneity and device consistency between lots (e.g., lot screening data)?*
  - *4. Many manufacturers' data sheets state that specified parameters and performance are subject to change without notice. What measures do you have in place to ensure that what you procure today is identical to what you procure in the future?*
  - *8. Do the supplier's reliability test criteria for new technology or devices satisfy the requirements of your mission?*
  - *9. Are the advertised FIT (failures in time) rates consistent with the mission's requirements?*
  - *19. Does the supplier perform testing to failure to confirm that design margins meet your mission's requirements?*
  - *22. What measures does the supplier employ to identify and eliminate potential causes of defects? Do these meet your mission requirements?*

# *Appendix A, Questions to ask part and component suppliers*

- **Supplier Auditing/Check**

- 6. Is it possible to audit the device supplier, should you need to do so? What guidelines would be used for the audit (i.e. ISO/TS16949: Quality Management Systems – Automotive Suppliers – Particular Requirements for the Application of ISO 9001:2008? Or internal requirements?)
- 12. Have you and the supplier agreed upon a category or level of change that triggers notification to you, the user?
- 13. Do you include either the International Automotive Task Force's ISO/TS 16949 (Quality Management Systems – Automotive Suppliers – Particular Requirements for the Application of ISO 9001:2008), the Automotive Electronics Council's AEC Q100 (Failure Mechanism Based Stress Test Qualification for Integrated Circuits), Q101 (Failure Mechanism Based Stress Test Qualification for Discrete Semiconductors in Automotive Applications), Q200 (Stress Test Qualification for Passive Components), or the Automotive Industry Action Group's PPAP (production part approval process) requirement in your supply contracts?
- 14. As a customer/user, do you have the right of approval over your changes to the supplier's product including fabrication, assembly, testing, marking and packing processes?
- 15. As a customer/user, do you receive priority problem resolution and advance end-of-life notifications?

# *Appendix A, Questions to ask part and component suppliers*

- **Supplier Auditing/Check**
- 16. If you procure your devices through a third party (e.g., a distributor), what data and/or processes do you review to ensure the devices are authentic (not counterfeit) and have not been tampered with?
- 18. How frequently does your supplier verify product families to AEC Stress Test Qualification standards?  Does this satisfy the needs of your program?
- 20. Where are the devices under consideration designed, manufactured, packaged, and tested? Are these facilities certified to TS 16949: Quality Management Systems – Automotive Suppliers – Particular Requirements for the Application of ISO 9001:2008?
- 21. Does the supplier employ part average testing, statistical yield limit and statistical bin limit per AEC-Q001 - Guidelines For Part Average Testing and AEC-Q002 - Guidelines For Statistical Yield Analysis to identify statistically different parts and lots?
- 24. Does the supplier employ any type of Lessons Learned database or Reach Across Alert system to ensure continuous improvement and failure containment?

# *Appendix A, Questions to ask part and component suppliers*

- **Mission Requirements:**
- 1. What are the mission's radiation requirements, if any, and have you reviewed test data that demonstrates the devices meet your mission's requirements?
- 10. Does an assessment of the supplier's existing, qualified device data demonstrate that the similar device you are considering will satisfy mission requirements?
- 17. If the qualification of the devices being considered do not meet mission requirements (e.g., was performed over a temperature range narrower than your application requires, contains no radiation data), do you have a means by which to augment or translate test conditions to those more representative of your mission?
- 23. Are the parts used in an application that is a single-point failure or is mission-critical? If so, what mitigations are in pace to ensure failure of the device is not mission-ending?
- 25. Does the supplier's corrective action process and preventive action process meet your program's requirements?
- 26. Does the supplier's failure modes, effects, and analysis (FMEA) process meet your program's requirements?
- 28. In the special cases of high-reliability, ultra-short duration (<24 hours) missions, demonstrating successful turn-on may not be sufficient to show that it will perform for the rest of the mission. What scope of power-on/turn-on data do you review for the devices being considered and do the results meet your requirements?

# *Appendix A, Questions to ask part and component suppliers*

- **Vehicle Manufacturer's Data**

- 2. What flight heritage do the parts being considered have in your specific mission type (e.g., earth imaging, communication, weather monitoring) and duration?
- 7. Do you have access to data regarding failure mechanisms in the parts being considered and the results of the stress tests that were performed to qualify the parts? Do the results satisfy your mission requirements?
- 11. What data regarding burn-in, screening, test conditions and pass/fail criteria for the parts being considered did you review? What were the results and do they satisfy the requirements of your mission? In other words, how does the screen affect the Consumer's Risk vs the Producer's Risk?
- 27. When a manufacturer's disclaimer states that parts are not qualified for space applications (e.g., SmallSats), and your designers include those parts in units, what technical data do you use to substantiate their use?
- 29. Has all test data been reviewed for trends, oddities, "out-of-family" values, and other indicators of anomalies?