System Impact of Reliability

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MIT Lincoln Laboratory

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Daniel J. Weidman

- **SB, Physics, MIT**
- **MS and Ph.D., EE, University of Maryland**
- **Author or co-author of more than**
  - **20 journal articles & technical reports in publications**
  - **60 conference presentations**
- **Co-inventor on patent US 5,051,659 for bulk plasma generation**
- **Senior Research Scientist, Science Research Lab**
- **Reliability Engineer in the semiconductor industry, TEL NEXX**
- **2012-2014 Chair of the IEEE Boston Reliability Chapter**
- **MIT LL Mission Assurance Engineer, Technical Staff, since 2009**

System Impact of Reliability: Abstract

Daniel J. Weidman, Ph.D.

MIT Lincoln Laboratory

Reliability is important in today's systems, because it can be the most difficult parameter to specify and quantify, either through analysis or testing. Basic reliability data and models are often not provided by electronics manufacturers especially at advanced technology nodes. Reliability becomes particularly important when a mission has a constrained schedule or budget, because there may not be resources or opportunity to recover from a problem. This presentation will explain reliability and related metrics, and how to flow down a reliability requirement from a top-level system to sub-systems. This presentation will explain how reliability information is rolled up from components and subsystems to larger systems. Some specific topics that contribute to reliability will be mentioned, and general reliability analyses, such as a Failure Modes and Effects Analysis, will be described. Electronics reliability will be the focus. All topics will emphasize practical techniques.

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Daniel J. Weidman, Ph.D.: present

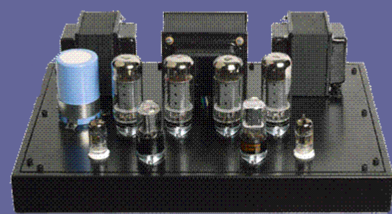
- **Daniel J. Weidman is a Mission Assurance Engineer at MIT Lincoln Laboratory working on reliability engineering testing and analysis for the Laboratory's most complex space projects. He supports all aspects of mission assurance, including safety, reliability, systems engineering, quality, and project management, throughout the life cycle of each project. Specifically, this includes applying systems engineering and reliability engineering techniques and analyses such as failure modes and effects analysis (FMEA or FMECA, similar to the description in MIL-STD-1629A Procedures for Performing a Failure Mode, Effects, and Criticality Analysis), and reliability prediction as described in MIL-HDBK-217F Reliability Prediction of Electronic Equipment. He presently is working on the largest "Level 1" program at MIT Lincoln Lab. In addition to these efforts specific to this program, he also helps improve those processes that are common to Lab programs. This position is part of the Safety and Mission Assurance Office, which reports to the Lincoln Laboratory Director.**
- **Dr. Weidman is an IEEE Senior Member and was Chair of the IEEE Boston Reliability Chapter Boston, which is a joint chapter with Providence, RI and New Hampshire. He was elected Chair for three years, 2012 through 2014. The Boston chapter has been ranked one of the top three IEEE Reliability Chapters in the world, according to the IEEE Reliability Society for the last several years.**

Daniel J. Weidman, Ph.D.: past

- Dr. Weidman started working as a Reliability Engineer 11 years ago in the semiconductor industry, where he led a project that that reduced the cost of the physical vapor deposition machine by $22,000 and reduced cost of ownership by $29,000/year, while increasing the average availability from less than 85% to more than 90%.
- Before that, he worked at two start-ups, testified as an expert witness in a federal lawsuit, won an SBIR (Small Business Innovative Research) grant from the NIH (National Institutes of Health), and conducted research at two Navy laboratories. He holds an S.B. in Physics from the Massachusetts Institute of Technology and an M.S. and Ph.D. in Electrical Engineering from the University of Maryland, College Park.
- Dr. Weidman is the author or co-author of more than 20 journal articles and technical reports in publications, and more than 60 conference presentations.

Evolution of System Reliability

Vacuum tubes and complex electronics, during and after WWII

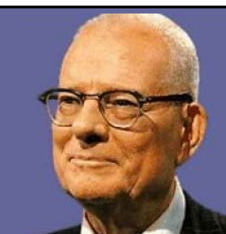


Human space missions, NASA

1906 — 1945 — 1950 — 1969 — 2013

Vilfredo Pareto and 80-20 rule

W. Edwards Deming and automotive industry, 14-point philosophy



Microsatellites

MIT Lincoln Laboratory

- **MIT LL is an FFRDC (Federally Funded R&D Center)**
- **Applies advanced technology to problems of national security**
- **R&D activities focus on long-term technology development as well as rapid system prototyping and demonstration**
  - **These efforts are aligned within key mission areas**
  - **Works with industry to transition new concepts and technology for system development and deployment**

Approved for public release; distribution is unlimited.

Today's Missions Require Reliability

- **State-of-the-Art Performance**
  - **Unproven**
  - **Paradigm shifting**
- **Complex systems**
- **Leading-edge Technology**
- **Different requirements**
  - **Space**
  - **Military**
  - **Ground Stations**
  - **Industrial**
  - **Commercial**

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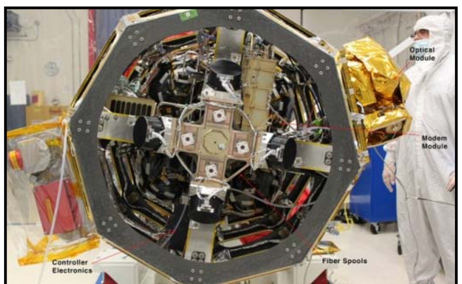
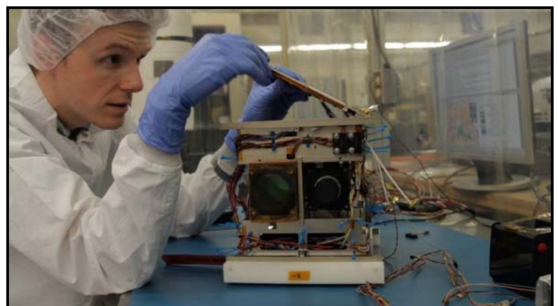
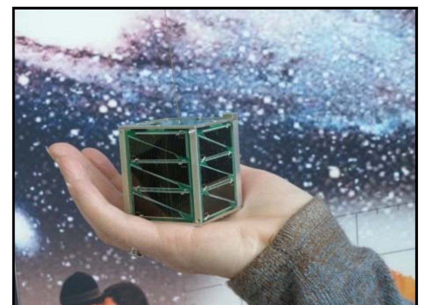
Size, Weight, and Power Reductions

- **Reduction in satellite size: microsats <200 lb., nanosat <20 lb.**
- **SWaP (Size, Weight, and Power) are being reduced, impacting various reliability mitigations, such as cooling by heat-sinking**





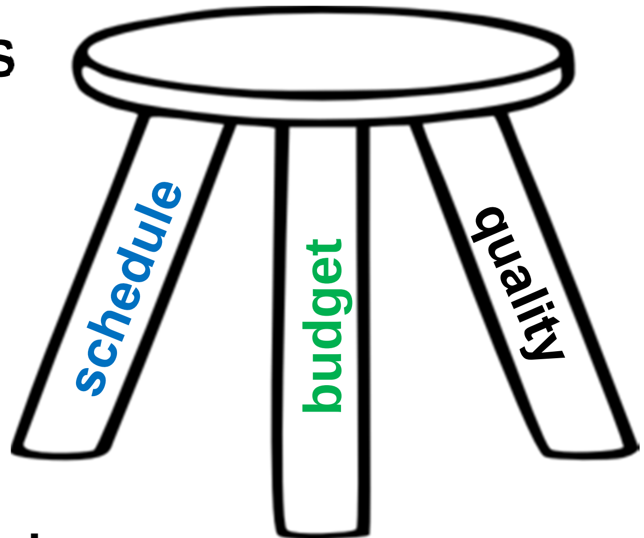


1990's **2013** **2015**

Approved for public release; distribution is unlimited.

Impacts to Reliability

- **Schedule pressure—cannot slip, use COTS**
- **Budget pressure—cannot overtest, COTS**
- **Quality—needs to work as intended, COTS**
- **SWaP (Size, Weight, and Power)**
- **Mitigate COTS (Commercial Off-The-Shelf) components risk by**
  - **screening and qualification to higher standards**
  - **design system to be "gentler" on components, such as temperature control to minimize excursions**



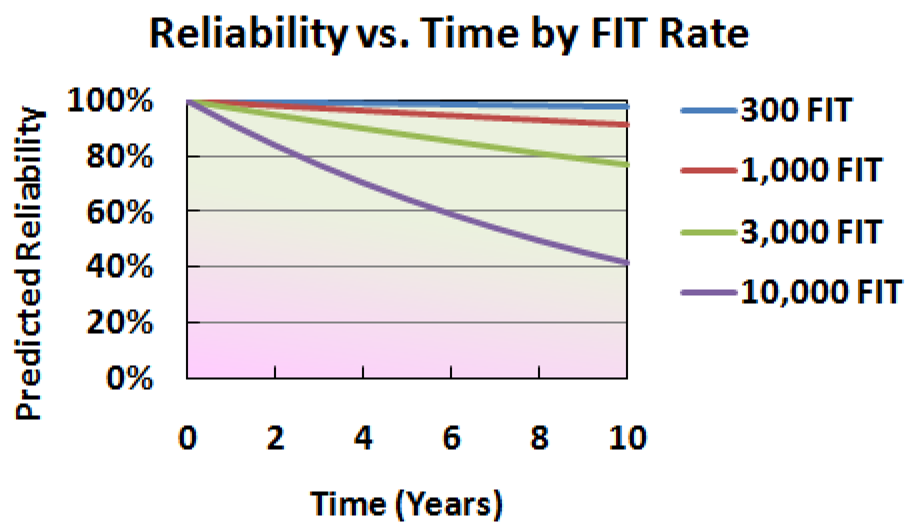
- **Reliability is a uniquely difficult performance parameter to test**
  - **Time dependent**
  - **May be more time consuming to measure than any other testing, such as functional, vibration, and even thermal, even with Highly Accelerated Life Testing and Stress Screening (HALT, HASS)**

Outline

- Introduction and Motivation
- General Reliability Concepts
- Flowdown of Reliability Requirements
- Roll-up of Data from Component and Sub-assembly Level
- Reliability Analyses
- Best Practices for Reliable Hardware
- Similarity and Heritage
- Summary of the System Impact of Reliability
- Future of System Reliability

System Reliability in General

- Program has a 5-year life requirement
  - 10-year design goal
- $R(t) = R_0 e^{-\lambda t}$ $\Leftrightarrow$ constant, random failure rate, λ is FIT rate
  - Rate of Failures In Time, or "FIT rate," or "FIT"
  - For reliable, individual components
    - per billion hours
    - ~0.1×10^{-9} or ~0.01×10^{-9}
  - For entire system
    - E.g., might want ~1000 FIT or less, if possible
    - E.g., might require ~3000 FIT, at most
    - Sometimes expressed as "per million hours"
  - MTBF (or MTTF) = 1 / λ , assuming constant λ (e.g., electronics, not bathtub curve with infant mortality or wearout)



Quantitative Definitions of Reliability

- **Reliability in the narrow sense**
  - **Specified at a certain time, e.g., *x*% at 6 months and slightly less at 12 months, or at 5 years**
  - **Typically exponential dependence with time, as on previous slide**
  - **Either MTBF (Mean Time Between Failures) or MTTF (Mean Time to Failure) applies, depending on whether the system is repairable**
- **Availability**
  - **Simply fraction of uptime out of all time**
  - **As in MIL-HDBK-338B and OPNAV Instruction 3000.12A (consistent with SEMI E10), which are comprehensive reliability references**
- **Degraded performance, need to define**
  - **E.g., *N* units in a group, & *M* triplets of 8; or *x*% of pixels of an image**
  - **Consider redundancy**
- **Survivability**

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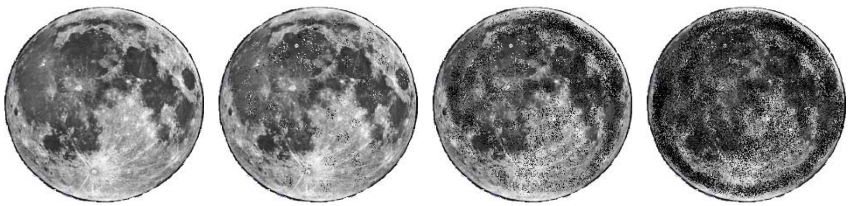

Allocation of Reliability

- **Flowdown of reliability requirements**
  - **Allocation of reliability across subsystems**
  - **Example "tree" is shown**

System	(6mo/12mo prob.)
Requirement	0.90 / 0.75
Current Estimate	0.948 / 0.905

Electronics	(probability)
Allocation	0.98 / 0.92
Current Est.	0.987 / 0.974

Pwr Supply	(probability)
Allocation	0.99 / 0.98
Current Est.	>0.994* / 0.994

Detector	(probability)
Allocation	0.95 / 0.87
Current Est.	0.967 / 0.936

Chassis	(probability)
Allocation	0.999 / 0 .995
Current Est.	0.999 / 0.999

* Power Supply vendor is calculating only a 12-month reliability

Reliability analysis completed per MIL-HDBK-217F

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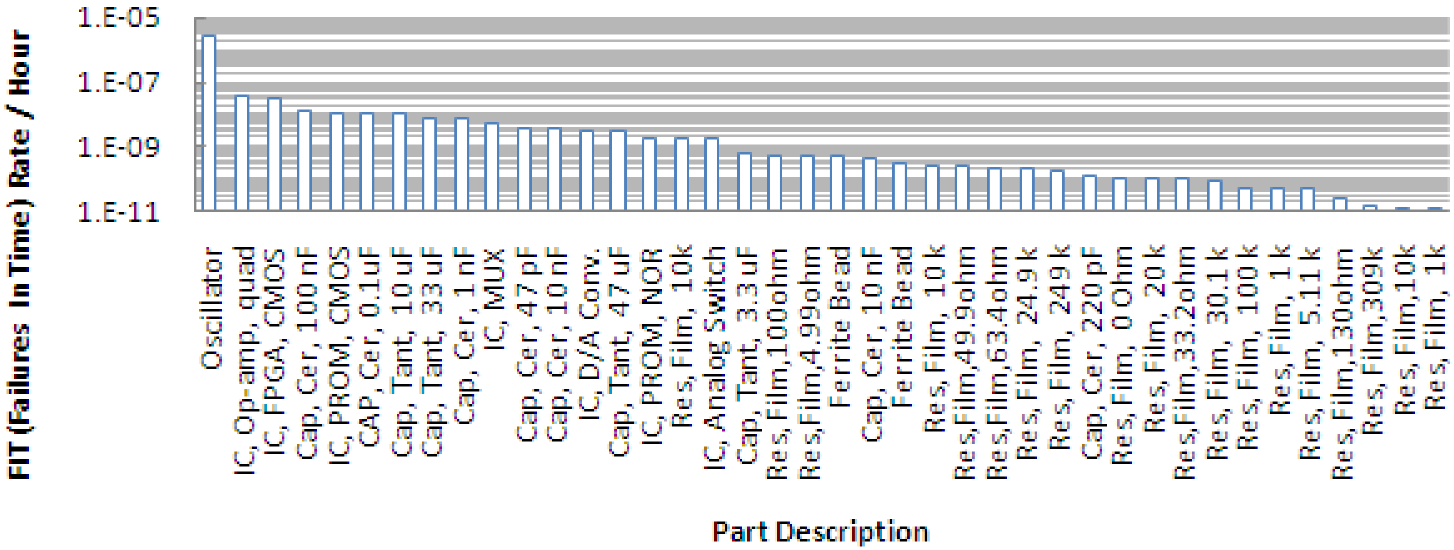
- **Future of System Reliability**

Roll-up of Data from Component Level

- **MIL-HDBK-217F for passives, Parts Stress Analysis Method**
- **Vendor reliability data (or in-house test) for active components**
- **FIT (Failures In Time) Rate per hour for each part type**
- **High FIT: ICs, incl. FPGA, and capacitors in large quantities**



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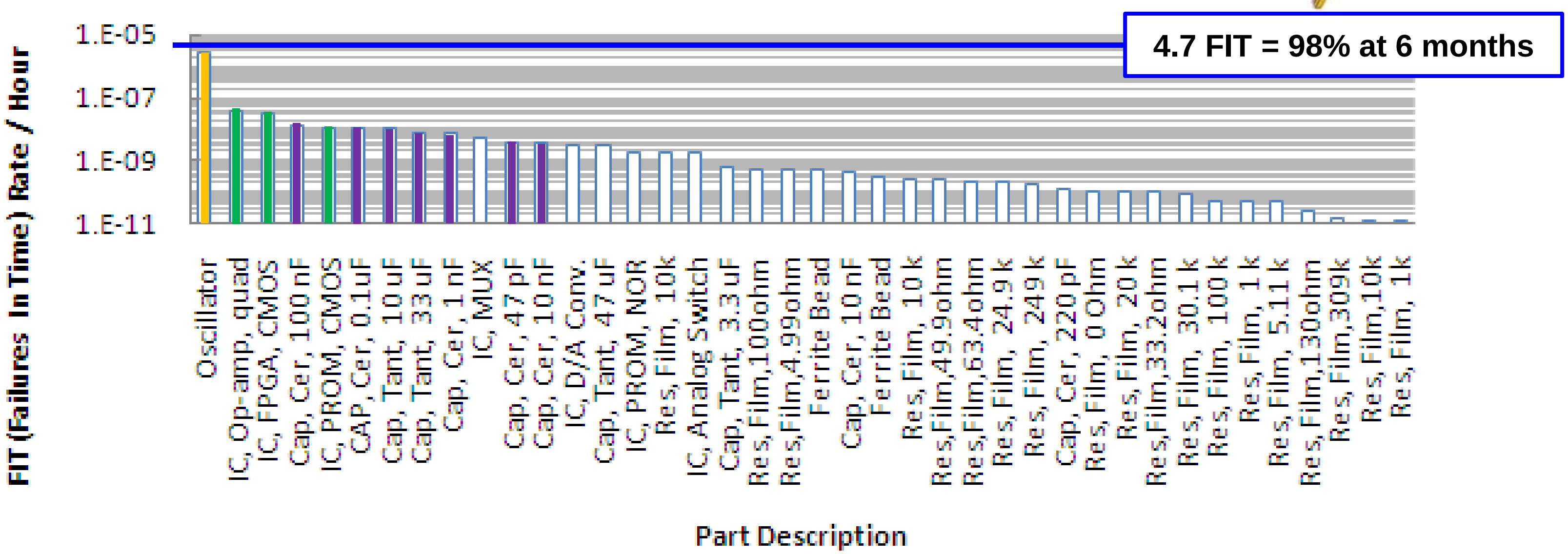
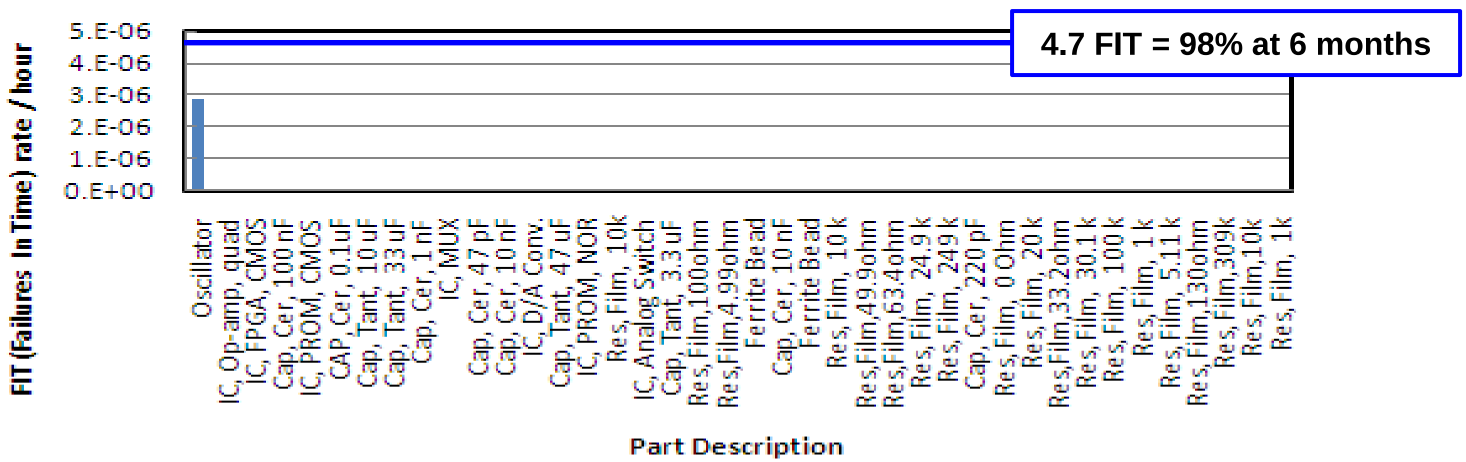


Roll-up of Data from Component Level

- $R(t) = R_0 e^{-\lambda t} \Rightarrow 0.98 = 1.00\ e^{-(4.7x10\text{-}6)\ (6\ \text{months x 4320 hours/month})}$
- **FIT rates add, so linear scale is more relevant than a log scale**
- **Oscillator dominates**
  - **2.9 FIT rate per million hours**
  - **From MIL-HDBK-217F of similar oscillator**



Roll-up of Data from Component Level

- **Electrical analysis such as MIL-HDBK-217F, including**
  - **Excel spreadsheet**

	A	C	D	F	G	H	I	J	K	L	M	N	O	P	U	V	W	X	Y	Z	AA	AC	AD	AE
1	Part type	SAP Part Number "Item #"	Description	Capacitance (in pF) for caps, resistance in Mohms	Package	Qty per Board in	Flex print 11/20/	Estimated Lead Time	Flight Part Number	Manufacturer	Governing Spec	TID	ESD	Package	Data Provided (If MIL-217, the λp)	MIL-217F temperature factor	MIL-217F capacitance factor πc for capacitors	MIL-217F voltage stress factor	MIL-217F factor πs	MIL-217F quality factor	MIL-217F environmental factor πE = S_F, which "Earth	Failure Rate (per hour) per p	MTTF (hours)	Failure Rate (per hour) p
151	Resistor, film	523	Resistor, 49.9K OHM, 1/8W, 1%, 0705 SMD	0.049900	0705	20			M55342K06B49E9S	Per QPL				0705	2.10E-09	1	1.0			0.03	0.2	1.26E-11		1.26E
152	Resistor, film	524	Resistor, 57.6K OHM, 1/8W, 1%, 0705 SMD	0.057600	0705	2			M55342K06B57E6S	Per QPL				0705	2.10E-09	1	1.0			0.03	0.2	1.26E-11		1.26E
153	Resistor, film	525	Resistor, 68.1K OHM, 1/8W, 1%, 0705 SMD	0.068100	0705	1			M55342K06B68E1S	Per QPL				0705	2.10E-09	1	1.0			0.03	0.2	1.26E-11		1.26E
154	Resistor, film	526	Resistor, 71.5K OHM, 1/8W, 1%, 0705 SMD	0.071500	0705	1			M55342K06B71E5S	Per QPL				0705	2.10E-09	1	1.0			0.03	0.2	1.26E-11		1.26E
155	Resistor, film	527	Resistor, 100K OHM, 1/8W, 0.1%, 0705 SMD	0.100000	0705	24			M55342K06B100BS	Per QPL				0705	2.10E-09	1	1.1	1	1	0.03	0.2	1.39E-11		1.39E
156	Resistor, film	528	Resistor, 105K OHM, 1/8W, 1%, 0705 SMD	0.105000	0705	7			M55342K06B105ES	Per QPL				0705	2.10E-09	1	1.1			0.03	0.2	1.39E-11		1.39E
157	Resistor, film	529	Resistor, 110K OHM, 1/8W, 1%, 0705 SMD	0.110000	0705	2			M55342K06B110ES	Per QPL				0705	2.10E-09	1	1.1			0.03	0.2	1.39E-11		1.39E
158	Resistor, film	530	Resistor, 140K OHM, 1/8W, 1%, 0705 SMD	0.140000	0705	5			M55342K06B140ES	Per QPL				0705	2.10E-09	1	1.1			0.03	0.2	1.39E-11		1.39E
159	Resistor, film	531	Resistor, 200K OHM, 1/8W, 1%, 0705 SMD	0.200000	0705	3			M55342K06B200ES	Per QPL				0705	2.10E-09	1	1.1			0.03	0.2	1.39E-11		1.39E
160	Resistor, film	532	Resistor, 499K OHM, 1/8W, 1%, 0705 SMD	0.499000	0705	4			M55342K06B499ES	Per QPL				0705	2.10E-09	1	1.1			0.03	0.2	1.39E-11		1.39E
161	Resistor, film	533	Resistor, 5.62 OHM, 1/4W, 1%, 1206 (Metric) SMD	0.000006	1206M	6			D55342K07B5D62S	Per QPL				1206M	2.10E-09	1	1.0	1	1	0.03	0.2	1.26E-11		1.26E
162	Resistor, film	538	Resistor, 9.31K OHM, 1/8W, 1%, 0705 SMD	0.009310	0705	12			M55342K06B9E31S	Per QPL				0705	2.10E-09	1	1.0			0.03	0.2	1.26E-11		1.26E
163	Resistor, film	610	Resistor, 162K OHM, 1/8W, 1%, 0705 SMD	0.162000	0705	4			M55342K06B162ES	Per QPL				0705	2.10E-09	1	1.1			0.03	0.2	1.39E-11		1.39E
164	Resistor, film	611	Resistor, 825 OHM, 1/8W, 1%, 0705 SMD	0.000825	0705	1			M55342K06B825DS	Per QPL				0705	2.10E-09	1	1.0			0.03	0.2	1.26E-11		1.26E
165	Resistor, film	612	Resistor, 8.25K OHM, 1/8W, 1%, 0705 SMD	0.000008	0705	3			M55342K06B8E25S	Per QPL				0705	2.10E-09	1	1.0			0.03	0.2	1.26E-11		1.26E
166	Resistor, film	613	Resistor, 9.09K OHM, 1/8W, 1%, 0705 SMD	0.909000	0705	1			M55342K06B9E09S	Per QPL				0705	2.10E-09	1	1.1			0.03	0.2	1.39E-11		1.39E
167	Resistor, film	614	Resistor, 14K OHM, 1/8W, 1%, 0705 SMD	0.014000	0705	1			M55342K06B14E0S	Per QPL				0705	2.10E-09	1	1.0			0.03	0.2	1.26E-11		1.26E
168	Resistor, film	615	Resistor, 15.4K OHM, 1/8W, 1%, 0705 SMD	0.015400	0705	2			M55342K06B15E4S	Per QPL				0705	2.10E-09	1	1.0			0.03	0.2	1.26E-11		1.26E
169	Resistor, film	616	Resistor, 249K OHM, 1/8W, 1%, 0705 SMD	0.249000	0705	1			M55342K06B249ES	Per QPL				0705	2.10E-09	1	1.1			0.03	0.2	1.39E-11		1.39E
170			4) International Rectifier power converters. IR lists Mil-Hdbk-217 based estimates I think on the order of 10 million hours MTBF. [10 million hours MTBF <--> 100 FIT per billion hours, dju 3/17/2011.] A key question is what do we think is the actual reliability at our use																						
171			See PowerPoint presentation about IR's dc-to-dc converters, and many emails, dju 6/30/2011.							7/8/2011, 11:17 AM, dju: About 200 FIT (per billion hours) at 35C.														
172			5) "Generic" space qualified ICs. As two specific examples, you could look into the Aeroflex UT54ACS138EUVAG demultiplexer and the Analog Devices OP470AT/QMLR op amp.																					
173	IC		Aeroflex UT54ACS138 EUVAG demultiplexer (3:8 Decod		16 pin Flatpack				5962R9654403VXA													2.00E-10		####
174			Aeroflex UT54ACS164245 SEIUCCR IC, Transceiver, 16		48 pin Flatpack				5962R9858006VXC													2.00E-10		####
175			Aeroflex UT8SDMQ64M40 -75XEC IC, SDRAM, 2.5Gb		128 pin Flatpack				5962R1022901QXC															
176	IC		Analog Devices OP470AY/QMLR op amp		8 pin DIP				5962R9468002VPA															
177	IC																							
178	IC																							
179			6) "Generic" space qualified discrete components. As two specific examples, you could look at the JANTXV2N5005 transistor and the JANTXV1N4153-1 diode.																					
180																								
181			7) Upscreened commercial electronics. These include the Hittite and Inphi parts that we have discussed recently.																					
182																								
183			8) The Virtex-5 FPGA																					
184	IC	2021954	IC, FPGA, 96 Cell, CMOS, RH		717pin Cer	1		up to 36 wks	XQR2V3000-4CG717V	Xilinx												3.07E-08		####
185			9) The Aeroflex UT699-ZYC Leon processor																					
186																								
187			10) Clock oscillators (e.g. the Vectron and Symmetricom oscillators that we have on order). These also seem to have ~10 million hour MTBF based on Mil-HDBK-217.																					
188	IC		IC, Custom Dual Oscillator		16pin	1		6 mos	MTI 011XXX-XXXX	MTI Millirom													8.40E+05	####
189			Quartz crystal from MIL-HDBK-217, Section 19			1									3.00E-08					1	0.5	1.50E-08		1.50E-
190			SAW (Surface Acoustic Wave) device per MIL-HDBK			1									2.10E-06					0.1	0.5	1.05E-07		1.05E-
191																								
192		2012468	Shielding Bead, Chip, Ferrite, 30 Ohm			31		8-10 wks	03024-018K	QPL	DESC 03024	N/A			1.10E-09		1			0.03	0.5	1.65E-11		1.65E
193		2022743	Shielding Bead, Chip, Ferrite, 30 Ohm			20		8-10 wks	03024-010K	QPL	DESC 03024	N/A			1.10E-09		1			0.03	0.5	1.65E-11		1.65E
194																								
195																								
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203					Total:	4758																1.67E-07		####
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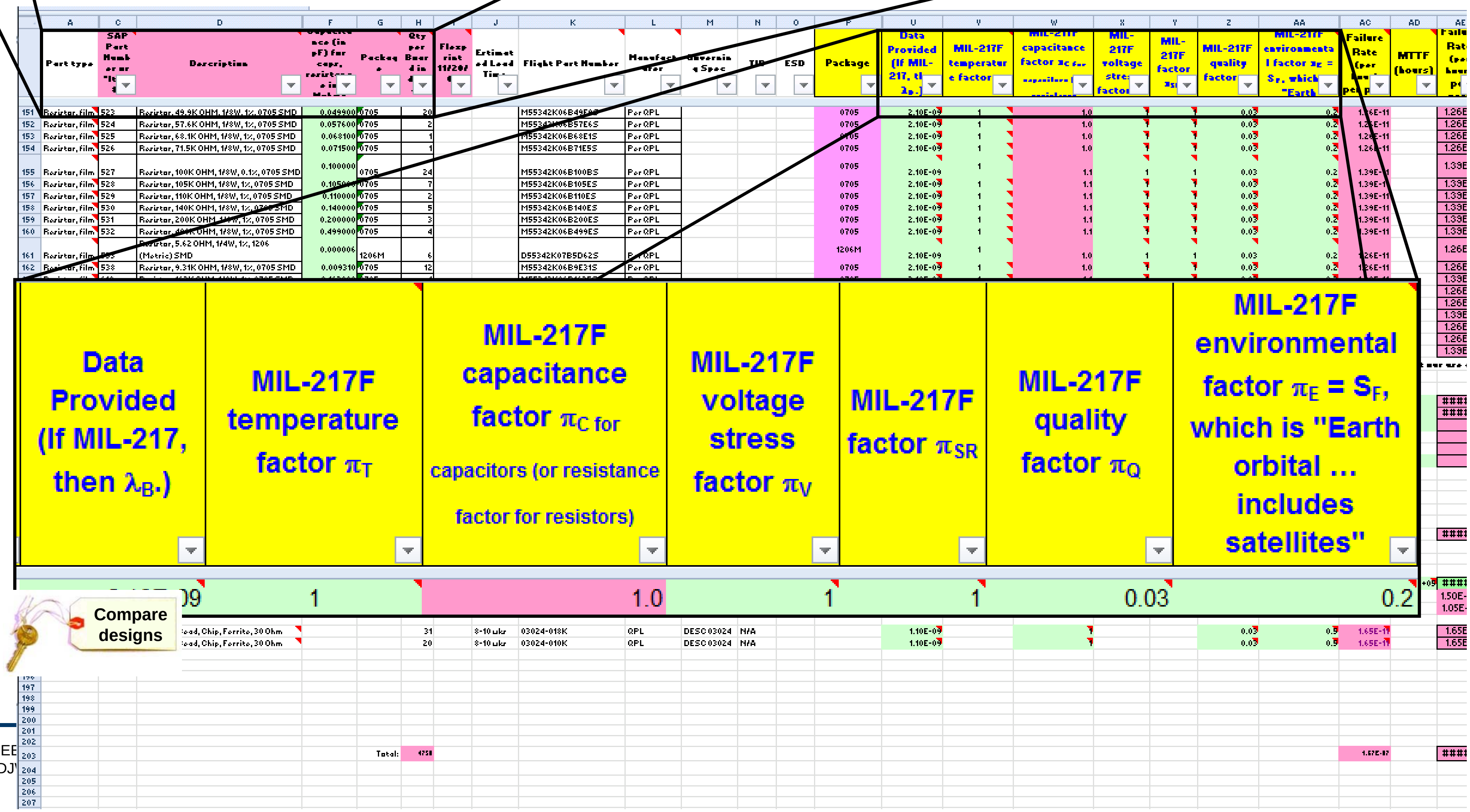
– **Excel spreadsheet**

Part type	SAP Part Number or "Item #"	Description	Capacitance (in pF) for caps, resistance in Mohms for resistors	Package	Qty per Board in design
Resistor, film	523	Resistor, 49.9K OHM, 1/8W, 1%, 0705 SMD	0.049900	0705	20



Data Provided (If MIL-217, then λ_B.)	MIL-217F temperature factor π_T	MIL-217F capacitance factor π_C for capacitors (or resistance factor for resistors)	MIL-217F voltage stress factor π_V	MIL-217F factor π_{SR}	MIL-217F quality factor π_Q	MIL-217F environmental factor π_E = S_F, which is "Earth orbital … includes satellites"
…09	1	1.0	1	1	0.03	0.2

Reliability Testing of Components

- **Radiation analyses and part selections are done to a required lifetime (e.g., 5 years), with margin (e.g., 2x or 3x)**
- **Life testing of moving components**
  - **Rotary actuators (outside vendor)**
  - **Flexprint (Kapton polyimide)**
  - **Piezoelectric actuators life tested**
- **Tight focus on one component by large cross-functional team**
- **Electronics testing, such as by vendors on their components or third-party lot qualification and screening, as well as standard practice**
  - **Example: MIL-PRF-123 testing of capacitors rated at <100V used at <10V**

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- Introduction and Motivation
- General Reliability Concepts
- Flowdown of Reliability Requirements
- Roll-up of Data from Component and Sub-assembly Level
- **Reliability Analyses**
  - **Pro-active Reliability Analyses**
  - **Reactive Reliability Analyses**
- **Best Practices for Reliable Hardware**
- **Similarity and Heritage**
- **Summary of the System Impact of Reliability**
- **Future of System Reliability**

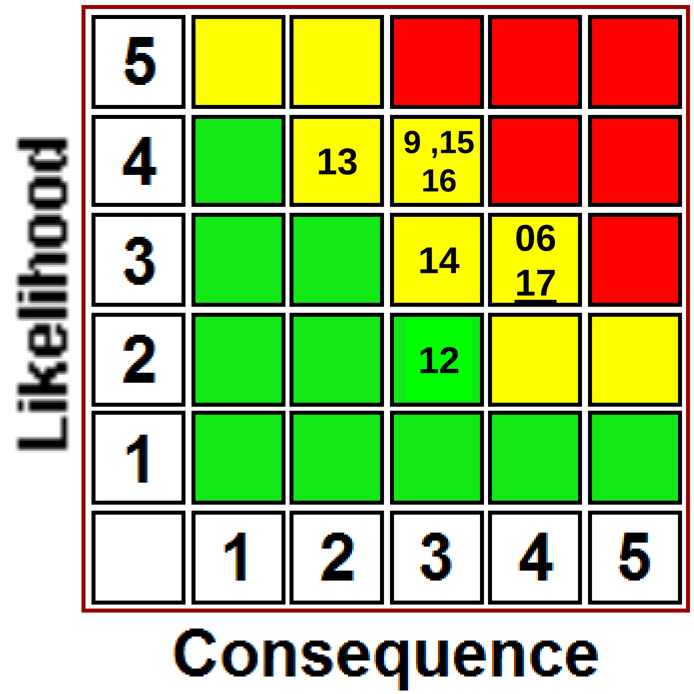
Pro-Active Reliability Analyses

- **More general and comprehensive analyses—that are pro-active**
  - **FMEA or SFP like MIL-STD-1629A—time and people are required!**

A	B	E	F	G	H	J	K	L	M	O	P
ID #	Date of Failure Identification	Include in Single Failure Point list?	Risk Title	*Potential Failure Mode & Causes*	Initial Likelihood	*Potential Local Effects / Consequence*	*Next Higher Level Effects / Issue Type*	*End effects*	Initial Consequence	Initial Risk color	*Recommended Failure Mitigatic Changes*
F3	6/1/2012	yes	Ring terminal	If the nickel-plated ring terminal is bent and the plating flakes,	5	then we will expose copper and have nickel FOD,	and we may have a short circuit causing system failure.	performance	4	9.2	Email that I sent on 5/30/2012 includes c that the tin-plated terminal will be bent ar plated, not the nickel-plated terminal.
F5	6/1/2012	yes	RTV mixing process	If the RTV is not thoroughly mixed properly,	4	then there may not be a full cure and the RTV may be too low viscosity to cure in the correct geometry,	and the RTV may form beyond edges.	performance	2	6.0	6/1/2012: emails entitled "SSG bonding" this question, but SSG now states that e fine. In an internal meeting this morning, telecon to SSG on another topic, I said th should ask what changes they've made t such sudden confidence, and I mentioned email to be sent at the end of the day toc
F6	6/1/2012	yes	Gold mitigation on connectrs (Tx & Rx Clck Brds)	If there is too much gold on the connectors of the Tx Clock Board and the Rx Reference Board,	3	then the solder joints will be brittle,	and the connection may open during vibration.	performance	3	5.9	Two emails on 5/25/2012 indicate that th a small enough amount of gold not to be but a follow-up email to be sent by me or indicates that we have not yet closed this completely.
F7	6/1/2012	yes	Thin walls	If the walls of the chassis are too thin,	3	then they may be affected by vibration,	and structural integrity may be compromised.	performance	3	5.9	This is my notes from a 5/15/2012 meetir this program were made thicker than on a program.

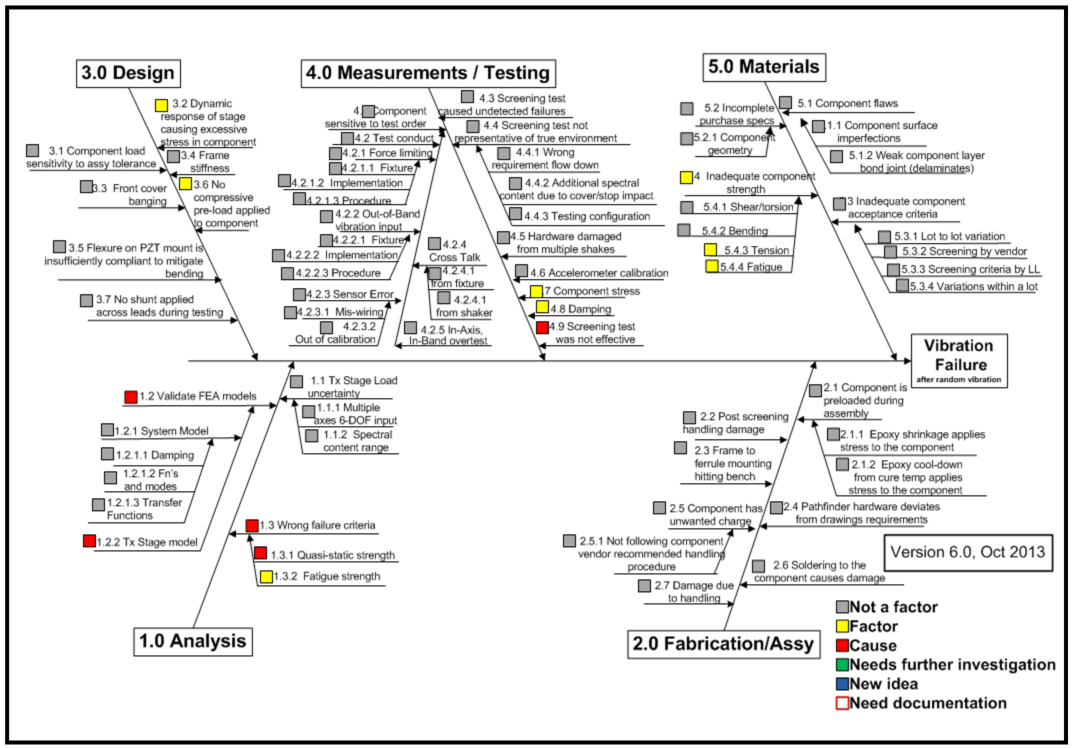
Plot for FMEA or SPF Results

- **FMEA (Failure Modes and Effects Analysis), or SFP (Single Failure Point) Analysis, or Risk management in accordance with MIL-STD-1629A**
  - **Process identifies & balances these aspects:**
    - **Cost / budget**
    - **Schedule**
    - **Technical, Performance, Quality**



Ishikawa Diagram (Fishbone)

- **Ishikawa diagram / Fishbone / Cause-and-Effect diagram**
  - **6 M's for manufacturing**
    - **Methods (policies, procedures, rules, laws)**
    - **Mother Nature (Environment)**
    - **Manpower (People)**
    - **Measurements & Testing**
    - **Machines (Fab & Assy)**
    - **Materials**
  - **Alternative**
    - **Measurements & Testing**
    - **Machines (Fab & Assy)**
    - **Materials**
    - **Analysis**
    - **Design**

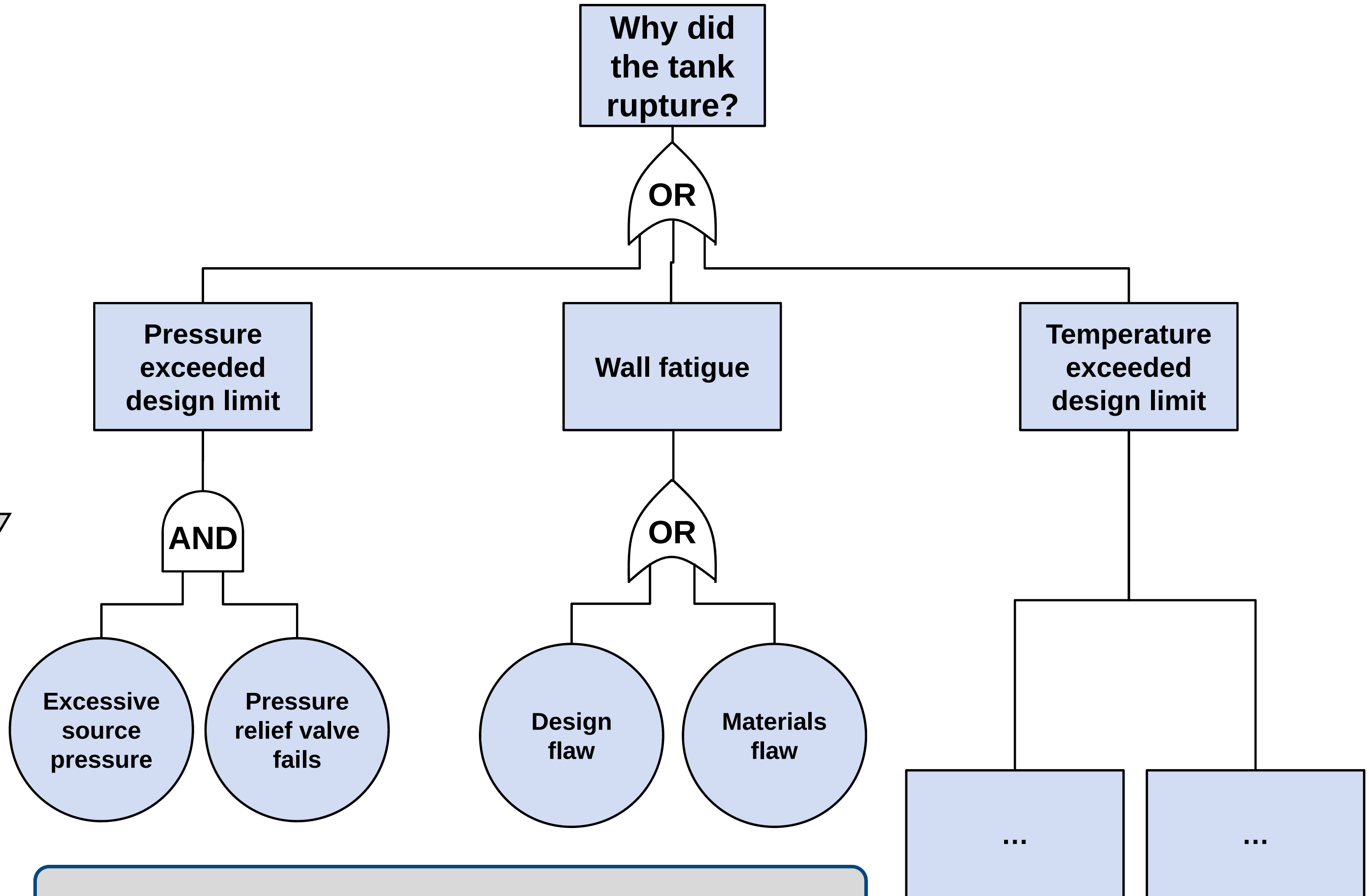


Fault-Tree Analysis example

Start with "Why did xxx fail?" or "Why did xxx occur?"

Work from top down by asking, "Why?"

Continue down to root cause of each branch



Fault-Tree Analysis can be a pro-active analysis

Outline

- Introduction and Motivation
- General Reliability Concepts
- Flowdown of Reliability Requirements
- Roll-up of Data from Component and Sub-assembly Level
- Reliability Analyses
  - Pro-active Reliability Analyses
  - Reactive Reliability Analyses
- **Best Practices for Reliable Hardware**
- **Similarity and Heritage**
- **Summary of the System Impact of Reliability**
- **Future of System Reliability**

Best Practices Contribute to Reliability
Design and Fabrication

- Design to NASA EEE-INST-002, including deratings therein
- Parts are space-rated to NASA EEE-INST-002 "Grade 1"
  - Purchased as such, or upscreened to space standards
  - Lot qualifications include Group C life testing
- Printed-circuit boards
  - Fabricated and assembled to IPC-6012B
    - With solder-paste jet printer (not stencils) for higher precision
    - With state-of-the-art pick-and-place (not by hand)
    - With vapor-phase reflow oven with vacuum (not convection oven)
    - ESD (Electrostatic Discharge) sensitive devices: use proper protocols
  - Soldering done to space standards: IPC J-STD-001ES
  - Workmanship inspected to IPC-A-610E

Qual & upscreen

Solder-Paste Printer

Vapor-Phase Reflow Oven

Mydata Pick-and-Place

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Best Practices Contribute to Reliability
Inspections and Other Checks

- **Check for…**
  - **<u>Prohibited materials</u>**
    - **Lead-free components**
    - **Material on terminations, and mitigate when needed**
      - **Gold, to avoid embrittlement**
      - **Pure tin (x-ray fluorescence), to avoid tin whiskers**
  - **Floating metal, and tie to ground or a voltage rail**
    - **Lids on hybrids**
    - **"NC" leads that are not internally connected**
  - **<u>Counterfeit components</u>**
    - **Manufacturers and distributors from Approved Supplier List**
    - **Visual incoming inspection**
  - **<u>GIDEP</u> (Government-Industry Data Exchange Program)**
    - **Alerts and Advisories**
    - **Individual parts or batched**
    - **One-time check or repeated ("auto batch match")**
  - **<u>Limited Life Items</u> and expiration dates**

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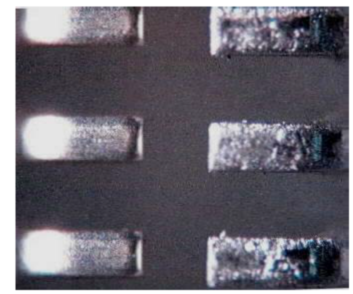
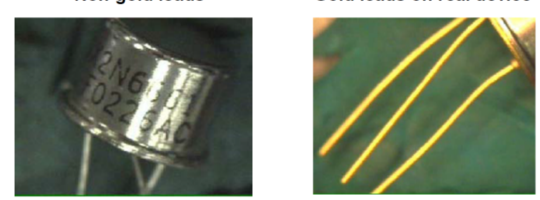
New versus
Refurbished leads



Non-gold leads — Gold leads on real device



Similarity

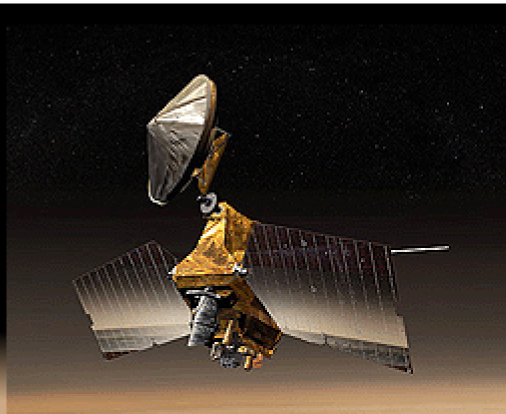
- **A part can be considered qualified if all of the following:**
  - **Part is similar to a part for which qualification test data exists**
  - **Test data satisfy requirements specified for applicable part level**
  - **Test data available**
  - **Test data less than 2 years old relative to lot date code of parts**
- **In order to be considered similar, the part shall be:**
  - **Made by the same manufacturer on the same manufacturing line, or**
  - **On a line with only minor differences, and these differences shall be documented and shown to represent no increased reliability risk**
- **Above is from NASA EEE-INST-002**

Heritage

- **The part must satisfy all of the following:**
  - **Used successfully**
  - **Used in an application identical or more severe than planned**
  - **Used 2 years minimum total operation in orbit**
  - **Built by the same manufacturer**
  - **Built in the same facility**
  - **Built using the same materials and processes to an equivalent SCD**
- **User's responsibility to have such evidence documented**
- **"History" is in NASA EEE-INST-002**

Heritage example

- **One vendor listed eight missions for flight heritage**
  - **Two are classified, so we don’t know if they have been successful**
  - **One of them (ICE) has not yet been launched**
  - **Another to launch 12/12, not ’09 [science.nasa.gov/missions/iris/]**
  - **Juno has been in orbit for less than 2 years**
- **That leaves only three of eight launched more than 2 years ago**
  - **MRO (Mars Reconnaissance Orbiter), GeoEye-1, and Worldview-2**
  - **All three have been successful**



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System Impacts of Reliability: Summary

- Challenges to reliability
  - State-of-the-art technology
  - Reductions in Size, Weight, and Power further challenge reliability
  - Fast schedules and tight budgets
  - COTS (Commercial Off-The-Shelf) components
  - Uniquely difficult to measure reliability
- Reliability estimates can be allocated from the top-level
- Reliability can be estimated by rolling up component data
- Be wary of similarity and heritage

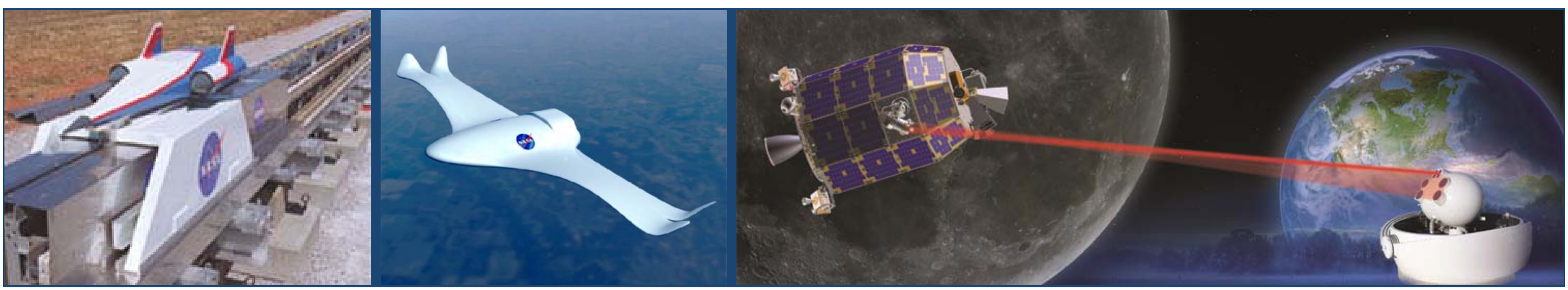
Improving Reliability: Summary

Improving reliability

- Various pro-active analyses during design
  - Identify weaknesses and Single Failure Points
    - Improve
    - Consider redundancy
  - Compare reliability of different designs
  - Compare component reliability or Class levels
  - Estimate reliability requirement at subsystem level
- Various reactive analyses during testing and prototyping
- Best practices
  - Lot qualification
  - Screening
  - ESD (Electrostatic Discharge) sensitivity: use proper protocols
  - Counterfeit components: procurement process and inspection

Possible Future of System Reliability

- **Positive and negative impacts to reliability may be in the future**
  - **System reliability relies on component reliability**
    - **Electronics sensitive to ESD (electrostatic discharge)**
    - **<u>Counterfeit electronics</u> (Nat. Defense Auth. Act signed 12/31/2011)**
  - **Redundancy mitigates system reliability shortcomings**
    - **Multiple missions to reduce risk and cost—each with reduced reliability**
    - **Redundancy within a system, such as multiple cameras, multiple lasers**
  - **Computer modeling**
  - **Testing and spiral techniques for hardware and software**
  - **Improved MIL-HDBK-217**
  - **Political factors: NDAA, budgets, RoHS, manufacturing sources**



IEEE Reliability Society’s Boston Chapter

Boston Reliability Chapter

Joint with New Hampshire and Providence, RI

http://www.ieee.org/BostonRel

- ***Daniel J. Weidman, Ph.D.***
- **IEEE Senior Member**
- **Chapter Chair 2012-2014**
- ***DanWeidman@ieee.org***

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MIT Lincoln Laboratory

Mission Assurance Office

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System Impact of Reliability

Thank you

Reference Material

Counterfeit Parts, LWP-5

- **This motivates the need for**
  - **ASL**
  - **GIDEP**
  - **Incoming inspections**
    - **Visual**
    - **XRF—e.g.: solder joints from vendor**

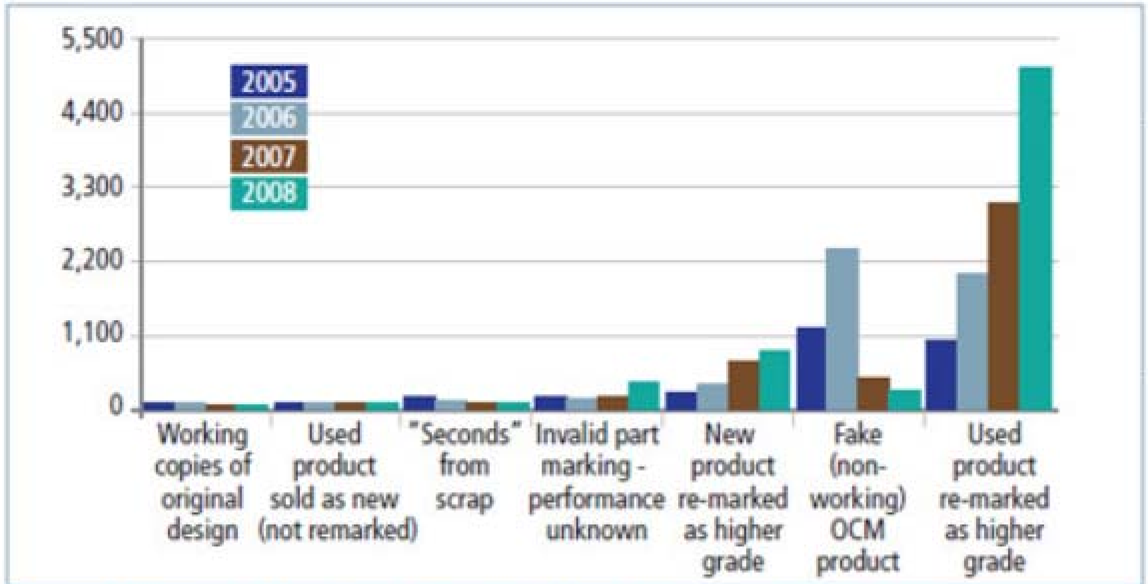

Figure 1. Counterfeit Incidents by Type of Problem - Microcircuits (2005-2008). (Source: U.S. Department of Commerce, Office of Technology Evaluation, Counterfeit Electronics Survey, November 2009.)

Counterfeit Parts, LWP-5

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    - **Visual**
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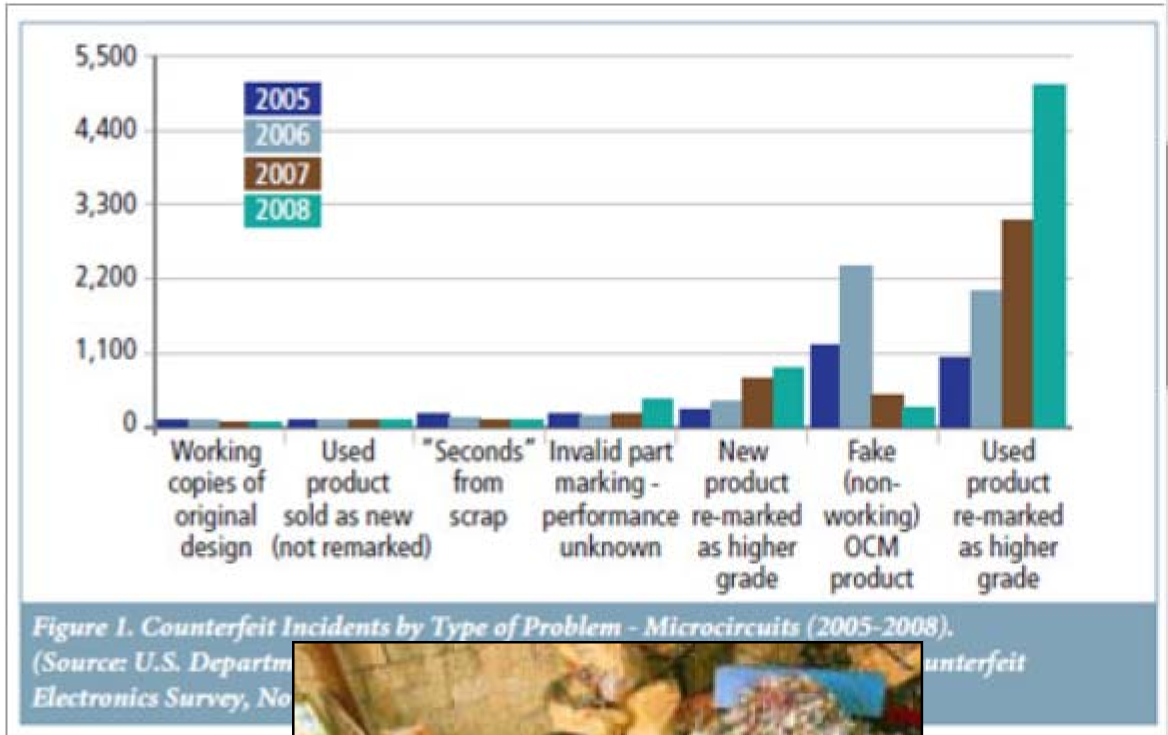
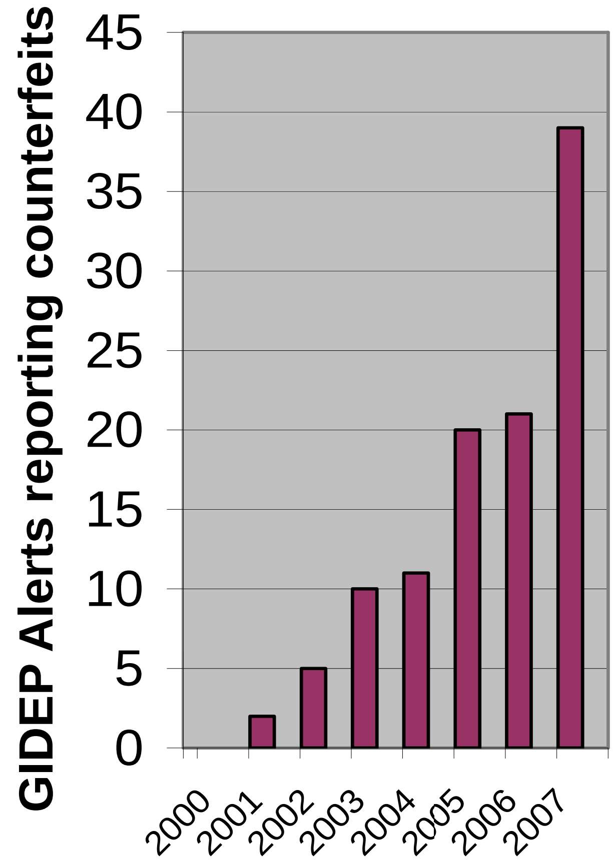


Figure 1. Counterfeit Incidents by Type of Problem - Microcircuits (2005-2008). (Source: U.S. Departm… unterfeit Electronics Survey, No…

GIDEP Alerts

- **Government-Industry Data Exchange Program**
  - **Many participating organizations**
    - **FFRDC's like MIT LL**
    - **Private companies, such as Boeing, BAE**
  - **Problems reported so others are alerted**
- **MAE checks parts list against GIDEP alerts**
  - **Important to know lots/date codes**
  - **Results within four business days**
  - **MIT LL has four people with GIDEP access**
- **GIDEP checks for any out-of-spec issues, e.g.:**
  - **Not all screens, e.g., skipped bond-pull test**
  - **Parts may have <3% lead on terminations**
  - **A/D converter delay > spec at high end of temp range**
  - **New cement caused resistance < spec on connectors**



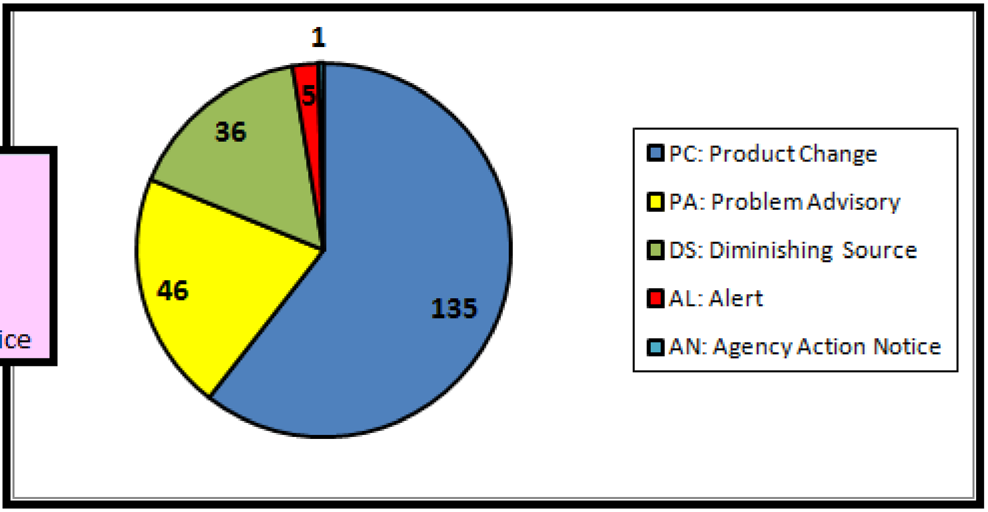
<u>Counterfeiting</u> accounts for more than 8% of global merchandise trade and is equivalent to lost sales of as much as $600B and will grow to $1.2T by 2009

US Dept of Commerce

GIDEP Summary Example

- GIDEP: Government-Industry Data Exchange Program
- Five GIDEP Alerts
- 223 GIDEP Notices of various types: Advisories, etc.
- Individual parts or batched
- One-time check or repeated (“auto batch match” service)

135	Product Change	PC: Product Change
46	**Problem Advisory**	PA: Problem Advisory
36	Diminishing Source	DS: Diminishing Source
5	***Alert***	AL: Alert
1	Agency Action Notice	AN: Agency Action Notice



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7.1.1 Prohibited Materials: Sample List

- Cadmium (including plating) and compounds, except for alloys <1% Cd by weight
- Pure zinc (including plating) and zinc alloys, except for alloys <1% zinc by weight
- Mercury and compounds
- Nylon
- Copper alloys with tellurium and lead
- Brasses containing lead
- Bronzes containing sulfur, selenium, and lead
- Steels containing sulfur, selenium, and lead
- Stainless steels containing sulfur, selenium, and lead
- Aluminum alloys containing lead and bismuth
- Magnesium or selenium
- Pure tin and tin alloy coatings and finishes containing less than 3% lead by weight
- Organic acid solder fluxes
- Materials that exhibit or are known to exhibit natural radioactivity such as uranium, potassium, radium, thorium, and/or any alloys thereof
- Corrosive sealants and adhesives
- High volatility compounds that are free to migrate onto sensitive surfaces
- Finish materials that evolve particles as a result of handling or oxidation, especially bare silver
- Plated metal where intended rotational interface may cause particulates

7.1.8 Limited Life Items: Typical List

- Polymeric materials that have a limited shelf-life will be controlled by a process that identifies the start date (manufacturer's processing, shipment date, or date of receipt, etc.), the storage conditions associated with a specified shelf-life, and expiration date.
- Materials such as O-rings, rubber seals, tape, uncured polymers, lubricated bearings and paints will be included except for those used in rotary actuators.
- The use of materials whose date code has expired requires that MIT LL verifies, by means of appropriate tests, analysis or other means, that the properties of the materials have not been compromised for their intended use.
- LLI items may be defined as an item whose expected life is less than twice that of the mission duration.