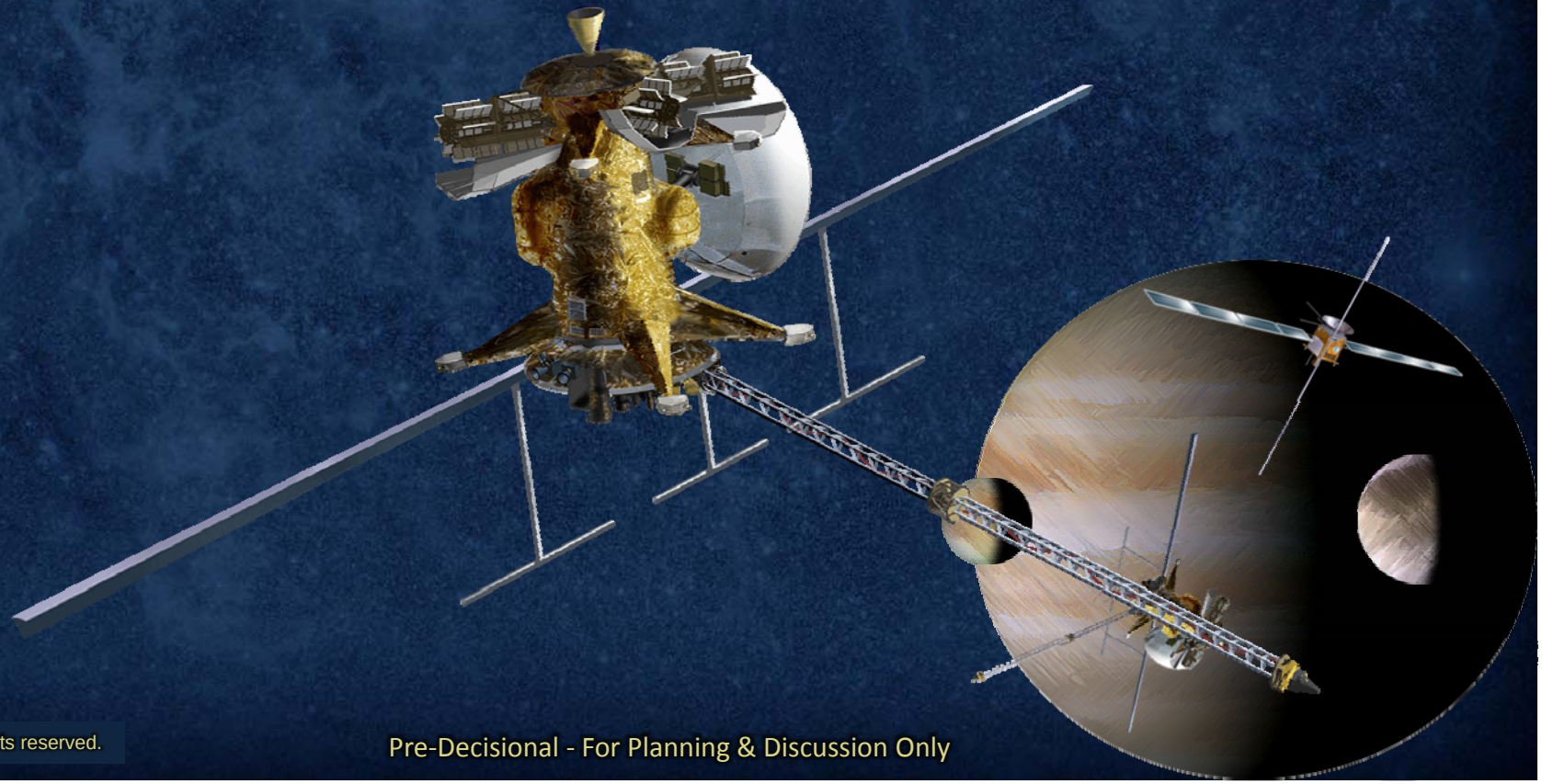
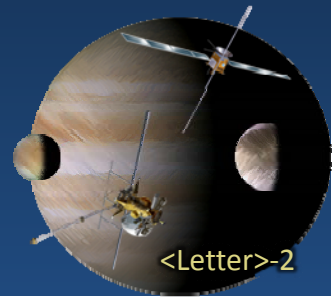
Jupiter Europa Orbiter

EEE Parts and Materials Program



Materials

Paul Willis



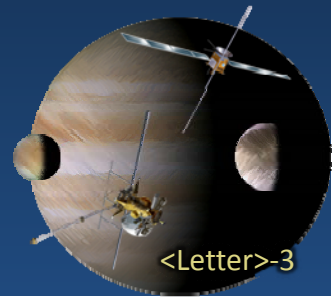
Materials Radiation Testing

Objectives

- Work with radiation testing facilities; test materials to JEO environments, compile data, address performance develop requirements, generate guidelines and add to approved materials list (APML)
- Assess critical components such as circuit boards, wire/cable, anti-reflective coatings, optical glasses, polymers, lubricants, insulators, etc. as a function of total dose and shielding

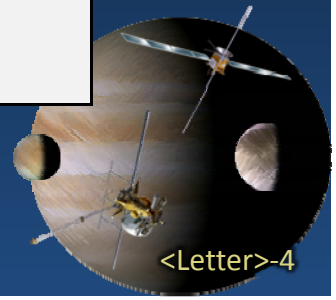
Benefits

- Reduce mission risk by compiling radiation damage data for candidate materials of construction for S/C bus and instruments
- Reduce mass and cost by establishing realistic performance requirements



Materials Radiation Test Status

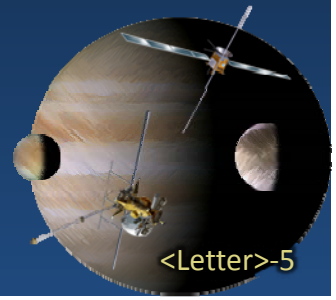
Adhesives	100 kRad	1 Mrad	10 MRad	30 Mrad	Comments (Co^{60} irradiation)
RTV 566					= Retained properties
Nusil 2510					Silicone adhesives survive well
Tapes					
Teflon Gasket Tape					= Damaged, unusable
DuPont 100XC					
3M 9203					Commercial tapes good to 30 Mrad exposure
Aluminized Polyimide					
Polymers					
Teflon FEP					
Teflon PTFE					Polymers good to 10 Mrad exposure, but none
Teflon PFA					survive the 30 Mrad exposure.
Silicone Rubber					Suspect most polymers good to 20 Mrad dose
Tefzel					Ultimate elongation *most* affected property
Kynar					Tensile strength retained fairly well
Polyaryl Sulfide					
Glasses					
Silica					
Zinc Selenide					Most optical glasses show some increase in
Magnesium Fluoride					absorption at low wavelengths (blue end)
Sapphire					Pure silica and sapphire show no changes
Zinc Sulfide					
Fused quartz					
Calcium Fluoride					
SF6G05					
NSF5					



Materials Radiation Test Status

Open items currently include:

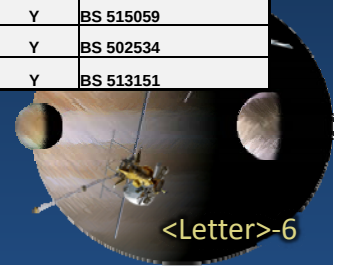
- Completion of radiation exposure of circuit boards (^{60}Co gamma)
- Update materials damage charts (continuing activity)
  - Replace risk number with actual dose, particle type, test temperatures, dose rates, damage/failure mode, applicable footnotes, etc.
  - Specify source; literature, JPL measurement, etc.
  - Includes DHMR (microbial reduction) assessments
  - Includes outgassing results (%TML, %CVCM)
  - Draft of Approved Materials List available now (60% complete)
  - Completed APML available 9 months before PDR
- Prepare summary report of all test results and methods
  - In progress, with complete charts of data in the appendix
- Final Report available end of July 2010
  - Revisions issued as further work completed



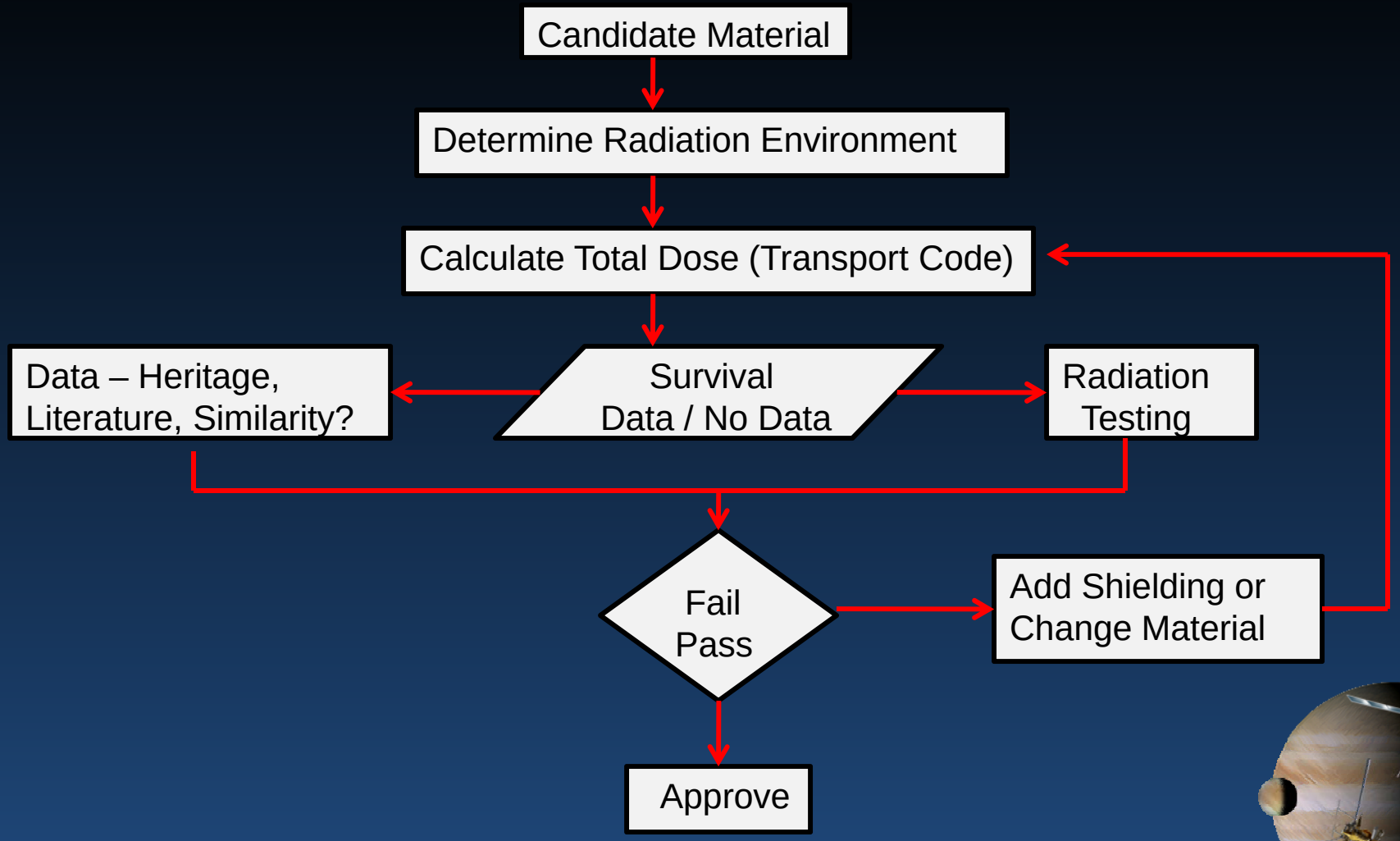
Approved Materials List (Example)

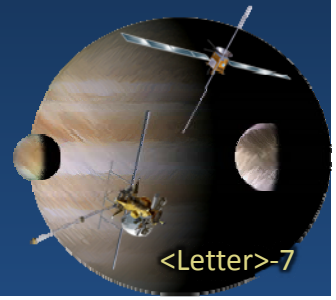
RADIATION RISK	DOSE	Risk Factor
None - no risk	> 100 Mrads	1
Low risk	10 Mrads	2
Medium risk	1 Mrad	3
Hi risk / Evaluate	100 Krads	4

DESCRIPTION / CLASS	MANUFACTURER	TYPICAL APPLICATION	RADIATION DAMAGE RISK FACTOR	LIMITING DOSE Rads [a]	SOURCE LITERATURE or JPL [b]	OUTGASSING TML %	OUTGASSING VCM %	TABLE SCC	M&P ACCEPT CLASS	MUA?	DHMR (125C 24 Hrs) Pass?	MATERIALS SPECIFICATION
METALS												
Aluminum 6061-T651	Unspecified	Mirror/mount	1	~ 1 E+16	L	n/a	n/a	1	1	N	Y	QQ-A-250/12
CRES 303	Unspecified	Screws/washers	1	~ 1 E+16	L	n/a	n/a	1	1	N	Y	ASTM-A582
Invar 36	Jorgenson	Fittings	1	~ 1 E+16	L	n/a	n/a	1	1	N	Y	BS 506336
Aluminum 6061-T6	Unspecified	Fittings	1	~ 1 E+16	L	n/a	n/a	1	1	N	Y	QQ-A-200/8
Titanium 6Al4V	Unspecified	Flexures	1	~ 1 E+16	L	n/a	n/a	1	1	N	Y	MIL-T-9046
COMPOSITES												
M55J/954-3 [0/45/90/135]s3	Unspecified	Face/Back skins	2	1 E+9	L	0.12	0.00	n/a	1	N	Y	BS 513087
K13C2U/954-3 [+45]s	Unspecified	Ribs	2	1 E+9	L	0.09	0.01	n/a	1	N	Y	BS 513087
M55J/954-3 [0/+15]s	Unspecified	Tubes	2	1 E+9	L	<0.50	<0.01	n/a	1	N	Y	BS 513087
GLASSES												
Corning 7940 Silica	Corning	Lenses	1	6 E+14	L	n/a	n/a	n/a	1	N	Y	
Soda Lime Glass	Nanofilm	Code disk	4	5 E+5	J	n/a	n/a	n/a	1	N	Y	BEI 636-0016
BK7 Glass	Schott	Lens	3	1 E+6	J	n/a	n/a	n/a	1	N	Y	BEI 635-0006
Quartz	Unspecified	Mixer substrate	1	1 E+14	J	n/a	n/a	n/a	1	N	Y	MIL-G-174
ADHESIVES												
EA-9394	Dexter Aerospace	Prism Bond	2	1 E+8	L	1.96	0.06	n/a	1	N	Y	BS 515059
EA-9395	Hysol Aerospace	Adhesive	2	1 E+8	L	1.14	0.00	n/a	2	Y	Y	BS 515059
EA-956	Dexter Aerospace	Adhesive	2	1 E+8	L	0.98	0.01	n/a	1	N	Y	BS 502534
Stycast 2850FT/24LV	Emerson-Cuming	PRT Bonding	2	1 E+8	L	1.00	0.00	n/a	1	N	Y	BS 513151



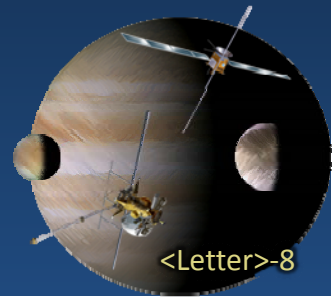
Materials Approval Flowchart





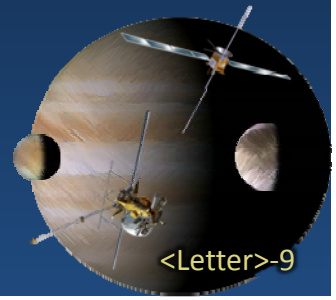
Materials Approval

- Delivered
  - Verified testing with gamma rays as substitute for electrons
  - Used transport codes to determine dose-depth profiles
  - Started testing of polymers, cables, glasses, etc.
  - Identified test facilities for very high energy radiation (if needed in future)
  - Completed current version Final Report
  - Completed draft of Approved Materials List (APML)
- Future
  - Continue materials testing
  - Determine refractive index changes in irradiated glasses
  - Test a new static dissipating conformal coating for circuit boards
  - Investigate models for surface erosion
  - Revise Final Report and Approved Materials List
  - All reports available 9 months before PDR



EEE Parts

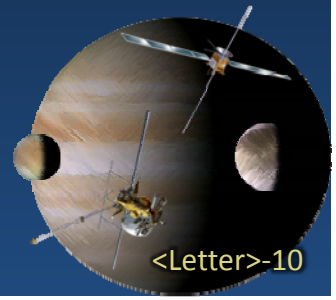
Harald Schone



Reducing Risk is Paramount

- Mission needs to survive highest radiation levels ever flown in space.
- Best chance of success lies in identifying suitable parts before the start of design activities.
- Substituting all your circuits with radiation hardened parts is insufficient.
  - You need, among others, recognize part use restrictions, adhere to new design rules; adopt system level mitigations, etc.
- The JEO team is gathering this information for you and is creating a list of parts, which have:
  - Passed an extensive list radiation/ reliability test and qual screens
  - A complete complement of data and use information
- Creating such a list is very costly and demands we limit the list to a minimal, workable set of parts.

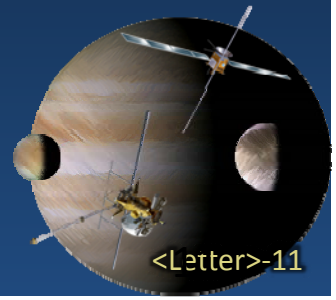
The Approved Parts & Materials List (APML) serves as the repository of information



JEO EEE Parts Policies

Except for custom components, only EEE parts listed on the JEO Approved Parts & Materials List (APML) shall be used.

EEE Part shall be used in accordance with all the application notes and use restrictions.



EEE Parts Requirements

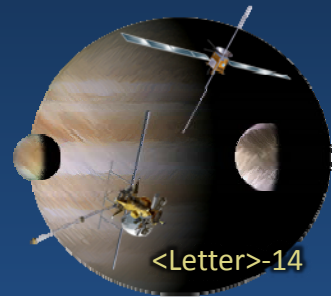
- Part quality level are defined in JEO's Project Parts Requirements document
- Reliability:
  - Microcircuits: MIL-PRF-38535, Level V
  - Hybrids: MIL-PRF-38534, Level K
  - Semiconductors: MIL-PRF-19500, Level JANS
  - Passives: Established reliability levels R, S & T Intended for space applications (e.g. MIL-PRF-123 capacitors)
- Radiation requirements
  - TID: As specified by ERD (for APML inclusion, the minimum is 300 krad(Si), Goal 1 Mrad(Si))
  - ELDRS: Averaged mission dose rate of 40 mrad(Si)
  - Displacement Damage $3x10^{11}$ p/cm^2 or $1.3x\ 10^9$ MeV/gm in silicon
  - Single event effects: Upset; Latch up; Fault interruption; Gate Rupture; Burn out; Transients

Custom components: FPGAs

- A limited number of FPGAs will be on the APML
  - To date, only the Aeroflex UT6325 is a viable candidate
- FPGAs are unique EEE part as the programming step modifies reliability and radiation performance.
  - JEO will require design reviews at various project milestones and will impose use restrictions
  - JEO specific requirements documents are under development
- FPGAs in need of support chips such as boot ROMs will be approved as a chip set
- All designs require the insertion of an on-chip synthesized function generator and logic analyzer for a more comprehensive code V&V

Custom components: ASICs

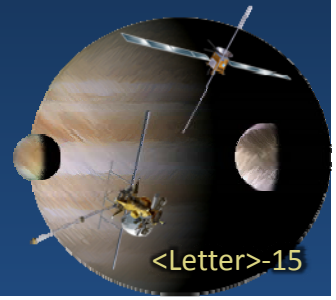
- The final reliability and radiation performance of a Custom ASIC depends on:
  - Design implementation
  - Choice of cell library
  - Rad Hard By Design implementation
- The APML will list manufacturers with approved fabrication lines only.
- JEO is establishing a guideline for generating a custom ASIC through the intermediary step of an FPGA.
- The final custom ASIC is required to meet all the applicable JEO reliability, quality and radiation requirements.
- Embedded IP will be reviewed



Custom components: RF & Sensors

- Sensors & ROICs have additional design and technology specific radiation responses:
  - Charged particle induced noise – electrons, protons, heavy ions, secondary showers (x-ray, electrons, neutrons)
  - Localized dose or displacement – electrons, protons, heavy ions
- Parts requirements need to be tailored to each sensor type. The choice of a sensor is closely linked to a instrument design, making an APML-like standard part impractical.
- RF components vary greatly by process and by design to the point that a “standard” RF part definition is difficult.

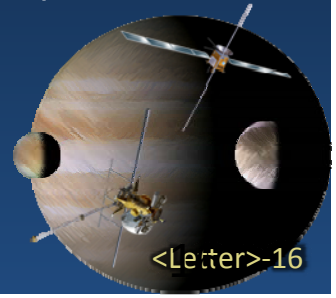
Custom Parts are shall meet all EEE part requirements in addition to component specific requirements



Approved Parts & Materials List

- General comments:
  - Limited number of commonly used active & passive EEE parts and materials
  - All parts will meet or exceed 300krad(Si) total dose survivability. The goal is 1Mrad(Si)
  - Parts will have passed full complement of screening, lot qualification inspection and radiation lot acceptance tests
  - Passive parts will be Established Reliability (levels R, S & T) rated or intended for space applications (e.g. MIL-PRF-123 capacitors)
  - Each active part will have a complete specification sheet, derating guidelines, Worst Case Analysis (WCA) sheet, screening & radiation test data as well as radiation design guidelines.
  - JEO will manage GIDEP alerts and part obsolescence.
  - No further part reviews required, provided final design review is completed!

You can find the APML at:
http://radcentral/APML/



Anatomy of the APML

Device Type	Generic Part No.	Part Description	Flight Part #	Parts Status	SEL/ SEGR / SEB	SEU	SET	SEFI	DD	50K	100K	300K	1000K
Memory	28F256LVQLE	PROM, 32K X 8-BIT, 3.3 V, 65 NS ACCESS TIME	5962H0151704VXC	A	A	A	S	A	A	A/WCD	A/WCD	A/WCD	A/WCD
Transceiver	54ACS164245	IC, 16-bit Transceiver	5962R9858002VXC	A	A	A	A	A	A	A/WCD	A/WCD	T	N

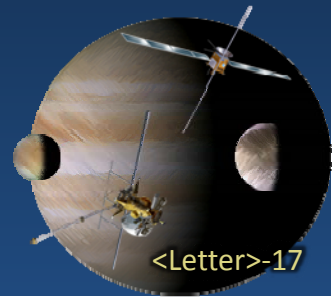
Legend

A – Approved meets requirements
S – Requires application mitigation/ analysis
A/WCD – Approved, design tolerance must meet WCD
T – Additional testing required
N – Not approved

Part/Radiation Approvals

Links to worst case design data

- Current version: Spreadsheet with 4 tabs: Diodes, Transistors, Microcircuits, Materials
  - Most current APML will be posted to the JEO website quarterly
- Future implementation will be as web based part management system (review, procurement, test data repository, data base)



Worst Case Datasheet

- Provides worst case design data
  - Radiation
  - Aging
  - Temperature
- Provided for all active devices on the APML after completion of characterization
- Initial versions will include extreme value worst case design parameters
  - Later revisions may include statistical worst case design parameters

JPL — **Part Variation Worksheet for Worst Case Analysis**

Program name:	JEO
Part Number(s):	RH1499M
Generic part type:	RH1499M
Description:	LINEAR, 10MHz, 6V/us, Quad RAIL-TO-RAIL INPUT AND OUTPUT PRECISION C-load OP AMP

Conditions of use: Min Temp (°C): -55; Max Temp (°C): 85; Radiation Dose (K rad): 300; Service Life (months): 60; [redacted] Max Temp (°C): [redacted]

Parameter: Input Offset Voltage — **Symbol:** VIO — Vcm=0V, Vs=+/-14.5V
Nominal Value: 200 — **Units:** uV — Vcm=V+, V-

	Deterministic variation Min	Deterministic variation Max	Random variation (+/-)		Data Source	Notes
Initial	-800.00	800.00			mfr spec	
Low temp.	-300.00	300.00			mfr spec	
High temp.	-180.00	180.00			mfr spec	
Radiation	-150.00	150.00			JPL data and mfr spec	up to 200K
End-of-life	-184.41	184.41			est	

Worst Case Minimum: -1434.406 uV — **Worst Case Maximum:** 1434.41 uV

Parameter: Input Offset Current — **Symbol:** Ios — Vcm=0V, Vs=+/-14.5V
Nominal Value: 6 — **Units:** nA — Vcm=V+,V-

	Deterministic variation Min	Deterministic variation Max	Random variation (+/-)		Data Source	Notes
Initial	-70.00	70.00			mfr spec	
Low temp.	0.00	0.00			mfr spec	
High temp.	-138.00	138.00			mfr spec	
Radiation	FALSE	0.00			JPL data	UP TO 200K
End-of-life	-16.14	16.14			est	

Worst Case Minimum: -224.14 nA — **Worst Case Maximum:** 224.14 nA

Parameter: Input Bias Current — **Symbol:** IIB — Vcm=0V, Vs=+/-15V
Nominal Value: 250 — **Units:** nA

	Deterministic variation Min	Deterministic variation Max	Random variation (+/-)		Data Source	Notes
Initial	-715.00	715.00			mfr spec	
Low temp.	-485.00	0.00			mfr spec	
High temp.	0.00	291.00			mfr spec	
Radiation	-450.00	450.00			mfr spec	up to 200K
End-of-life	-16.48	16.48			est	

Worst Case Minimum: -1666.48 nA — **Worst Case Maximum:** 1472.48 nA

Parameter: Common Mode Rejection Ratio — **Symbol:** CMRR — Vcm=±14.5V (incl mismatch)
Nominal Value: 90 — **Units:** dB

	Deterministic variation Min	Deterministic variation Max	Random variation (+/-)		Data Source	Notes
Initial	84.00	103.00			mfr spec	min is est
Low temp.	0.00	0.00			mfr spec	
High temp.	-1.80	0.00			mfr spec	
Radiation	-7.00	7.00			mfr spec	up to 200K
End-of-life	-0.97	0.00			est	

Worst Case Minimum: 74.23 dB — **Worst Case Maximum:** 110.00 dB

Worst Case Datasheet

Part Variation Worksheet for Worst Case Analysis

Worst case design parameters

Program name	JEO
Part Number(s)	RH1499M
Generic part type	RH1499M
Description	LINEAR, 10MHz, 6V/us, Quad RAIL-TO-RAIL INPUT AND OUTPUT PRECISION C-load OP AMP

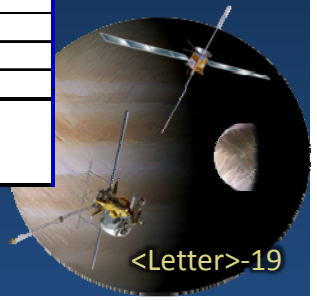
Conditions of use:					
Min Temp (°C):	-55		Max Temp (°C):	85	
Radiation Dose (K rad):	300		Service Life (months):	60	
Shelf Life Max Temp (°C):	25		Shelf Life (months):	12	

Parameter:	Input Offset Voltage			**Symbol:**	VIO	Vcm=0V, Vs=+/-14.5V	
Nominal Value:	200	**Units:**	uV		Vcm=V+, V-		
	Deterministic variation			**Random variation**			
		Min	**Max**		**(+/-)**	**Data Source**	**Notes**
Initial		-800.00	800.00			mfr spec	
Low temp.		-300.00	300.00			mfr spec	
High temp.		-180.00	180.00			mfr spec	
Radiation		-150.00	150.00			JPL data and mfr spec	up to 300K
End-of-life		-184.41	184.41			est	

Worst Case Minimum: -1434.406 uV **Worst Case Maximum:** 1434.41 uV

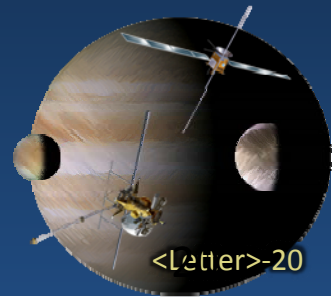
Parameter:	Input Offset Current			**Symbol:**	Ios	Vcm=0V, Vs=+/-14.5V	
Nominal Value:	6	**Units:**	nA		Vcm=V+,V-		
	Deterministic variation			**Random variation**			
		Min	**Max**		**(+/-)**	**Data Source**	**Notes**
Initial		-70.00	70.00			mfr spec	
Low temp.		0.00	0.00			mfr spec	
High temp.		-138.00	138.00			mfr spec	
Radiation		-50.00	50.00			JPL data	up to 300K
End-of-life		-16.14	16.14			est	

Worst Case Minimum: -274.14 nA **Worst Case Maximum:** 274.14 nA



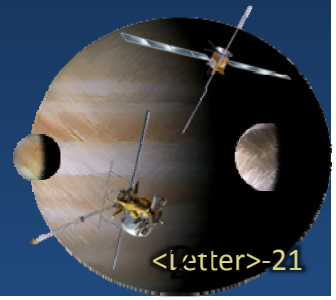
Notional APML Schedule

- EEE Parts goals:
  - 85% of likely JEO part candidates will be identified by AO release
  - 95% of likely JEO part candidates will be identified by 1 year after AO release
  - 50% of candidates will have complete set of background information such as WCA, derating, radiation tests, etc.
  - Completed APML 9 months prior to PDR
- Web based parts review and APML management tool will be in place by January 2012



Your Part or Material is not on the APML! What Now?

- JEO team will try to identify an APML listed part or material that meets your design
  - The JEO team will work with you to identify modified designs that use APML elements
  - The JEO team will evaluate other system trades before considering your part
- If an APML part or material is not feasible:
  - Your submission will start with filling out an extensive JEO Part Specification
  - A statement describing a clear impact on the science objective is required
  - The submission deadline is 6 months prior to PDR
  - JEO team will review your part and material for reliability, quality, radiation susceptibility, etc.
  - Electronic parts will have to meet or exceed 100krad(Si) at the die level.
  - Part shielding will be evaluated
  - JEO team will review your radiation test plan and/or test the parts for you
- You will have to carry the significant cost of part review and testing:
  - Schedule: Part review + procurement + qual/rad tests → On average 2 years
  - Cost: Depending on part complexity $200K to >$2,000K
- Your part and material may be added to APML. Part Control Board will decide if it:
  - Meets all quality, reliability and radiation requirements
  - Adds new functional capabilities
  - Can be used on multiple subsystems without any restriction



Non Standard Part Approval
Typically ASIC's. custom hybrids, RF IC's

Design Engineer submits part with justification and supporting data (JEO Part Specification)

JEO Part Control Board (PCB) considers system trades & APML based alternates

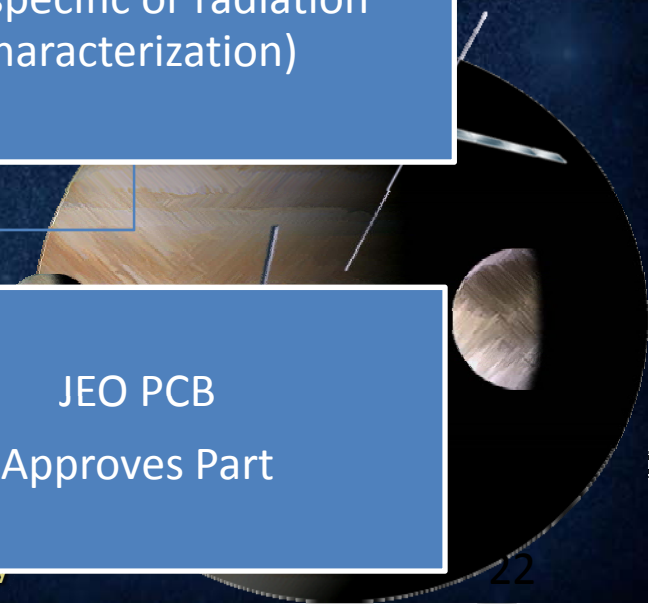
If justification is approved, JEO Parts Engineering proceeds with review and identifies additional testing as required

Perform testing as indicated (Lot specific or radiation characterization)

JEO Parts Engineering reviews test data

JEO PCB

Approves Part



Parts Control Board Activities

- JEO Parts Control Board (PCB) roles
  - Addresses GIDEP, NASA advisory, general industry issues
  - Procurement issues (group buys, delivery issues) before step 2 proposal
  - Provides overall parts status for approval, qualification and tests
  - Final part approval authority
- The EEE Parts Control Board will consist of:
  - JEO Project EEE Parts Engineering Lead & Deputy
  - JEO Parts Radiation Effects Lead Engineer
  - Engineering Representative
  - EEE Parts Specialists
  - The Project Scientist & System Engineer may be consulted to determine the loss of science impact for non-standard EEE parts or materials submitted for JEO consideration