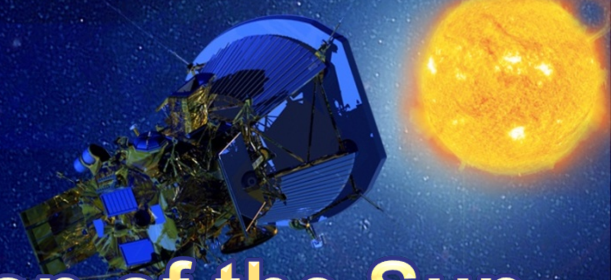
Solar Probe Plus

A NASA Mission to Touch the Sun



Integrated Science Investigation of the Sun Energetic Particles

Preliminary Design Review

05 – 06 NOV 2013

Systems Engineering

John Dickinson

Outline

- Instrument driving requirements
- Flow down of instrument performance requirements to major subsystems
- Instrument interfaces
  - Electrical
  - Mechanical
  - Thermal
- Environmental design and test requirements
- Resources allocated to the instrument
  - Mass, Power, Telemetry Volume, SSR Volume
- Instrument command and autonomy
- Major trades performed in Phase B
- Major changes since MDR

ISIS Systems Engineering Approach

- Distributed Systems Engineering
  - Both EPI-Hi and EPI-Lo have a dedicated SE
- ISIS SE role is to
  - Coordinate interactions with the project
  - Maximize use of shared resources
  - Provide oversight of technical tasks

SPP Req.s Doc. Architecture and Status

Solar Probe Plus
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Level 1

- L1 Requirements For The SPP Mission Appendix E to Living With a Star Program Plan

Level 2

- Solar Probe Plus (SPP) Level 2 Mission Requirements Document (MRD)

Level 3

- SPP Level 3 Payload Requirements Document (PAY)
- EDTRD
- EMECP
- CCP
- MPCP
- PCP
- SPP-ISIS ICD
- GI ICD
- MOC/SOC ICD

Level 4

- SPP ISIS Level 4 Instrument Requirements Document (IRD)

Status Key:

- Started
- Draft: Key Driving
- Draft: Complete
- Preliminary
- Baseline

Level Definitions

- L1 requirements are defined by NASA as advised by the SPP Science Working Group
  - This document belongs to **NASA**
  - "SPP mission shall"
  - **Program Level Requirements**
- L2s are APLs response to the L1s
  - This document belongs to **APL/Project Office**
  - "Mission shall"
  - **Mission Requirements Document**
- L3s are performance and functional requirements on individual mission elements
  - This document belongs to **APL/Project Office**
  - "Payload shall" or "ISIS suite shall"
  - **Payload Requirements Document**
- L4s are the payload response to L3s
  - This document belongs to **ISIS**
  - "EPI-Lo shall" or "EPI-Hi shall"
  - **Instrument Requirements Document**

Level\Owner	NASA HQ	APL	ISIS
Level 1 Program Level	SPP shall…		
Level 2 Mission Level		Mission shall…	
Level 3 Payload Level		Payload shall or ISIS shall…	
Level 4 Instrument / Subsystem Level			EPI-Lo shall or EPI-Hi shall…

SPP Requirements Documents

Project Requirements Document	Version	Date
NASA L1 Requirements For The SPP Mission Appendix E to Living With a Star Program Plan	Rev. -	9/6/2011
APL 7434-9047, Solar Probe Plus (SPP) Level 2 Mission Requirements Document (MRD)	Rev. C	8/30/2013
APL 7434-9051, SPP Level 3 Payload Requirements Document (PAY)	Rev. -	6/27/2013
APL 7434-9066, SPP General Instrument to Spacecraft ICD	Rev. -	10/3/2013
APL 7434-9058, SPP to ISIS ICD	Rev. -	[in review]
APL 7434-9078, SPP MOC to SOC ICD	Draft	[in review]
APL 7434-9039, SPP Environmental Design and Test Requirements Document	Rev. -	6/18/2013
APL 7434-9040, Electromagnetic Environment Control Plan (EMECP)	Rev. -	4/23/2013
APL 7434-9011, SPP Contamination Control Plan (CCP)	Rev. -	6/17/2013
APL 7434-9009, SPP Materials and Processes Control Plan (MPCP)	Rev -	6/11/2013
APL 7434-9001, SPP EEE Part Control Plan (PCP)	Rev. A	4/11/2013
JPL D-8545, JPL Derating guidelines	Rev. E	8/4/2006
Plus other Mission Assurance Documents		

ISIS Response Documentation

Number	Document	Released
16105-ISIS-IRD-01	ISIS Instrument Requirements Document	8/8/2013
16105-SPARES_PLAN-01	ISIS Spares Plan	10/15/2013
16105-[EPI-Hi/Lo/SOC]_SDP-01	EPI-Hi/Lo/SOC Software Development Plan	10/18/2013
16105-EPI-[HI/Lo]_SRD-01	EPI-Hi/Lo Software Requirements Document	8/8/2013
16105-ISIS_VVP-01	ISIS Verification and Validation Plan/Verification Matrix	10/8/2013
16105-ISIS_CMP-01	SwRI/APL/Caltech Configuration Management Plan	10/7/2013
16105-ISIS_CRMP-01	ISIS Risk Management Plan	10/7/2013
	EPI-Hi/Lo Contamination Control Plan	
16105-EPI-[HI/Lo]_FMEA-01	Inputs to SC Interface FMEA	10/7/2013
Number	**Drawings**	**Released**
7464-4001	EPI-Lo Event Board Schematic	
7464-1321	EPI-Lo Energy Board Schematic	
7464-3000	EPI-Lo Power Board Schematic	
	EPI-Hi Bias Supply Schematic	
	EPI-Hi DPU Schematic	
	EPI-Hi LET1 Telescope Board Schematic	
	EPI-Hi LET2 Telescope Board Schematic	
	EPI-Hi HET Telescope Board Schematic	

Reviewed Supporting Documents

- In addition to the Requirements documents, ISIS has provided feedback on the following documents/topics:

ISIS Input to Project
Limited Life Items List
Missile System Pre-Safety Package (MSPSP) Inputs
Materials and Processes List
Long Lead-Time Items List
Common Buy Item List
Instrument Thermal Model Supporting Information
Structural Analysis Documentation and Models
Instrument Mechanical Models
List of Planned Reviews
Comments on MOC-SOC Software ICD
Response on SPP Contamination Control
Reliability Plan Review

- ISIS has been responsive to inputs required by Project

Driving Requirements at L1/L2

- The Mission shall measure energetic electrons, as follows:
  - Energy range: ≤ 0.05 to ≥ 3 MeV
  - Highest cadence: ≤ 1s for selected rates
  - FOV: ≥ π/2 sr in sunward and anti-sunward hemispheres
  - Angular sectoring: ≤ 45 degree sectors
  - Composition: n/a
- The Mission shall measure energetic protons and heavy ions, as follows:
  - Energy range: ≤ 0.05 to ≥ 50 MeV/nucleon
  - Highest cadence: ≤ 5s for selected rates
  - FOV: ≥ π/2 sr in sunward and anti-sunward hemispheres
  - Angular sectoring: ≤ 30 degree sectors
  - Composition: at least H, He, 3He, C, O, Ne, Mg, Si, Fe
- Both EPI-Hi and EPI-Lo are required to meet all requirements at all energy ranges

Requirements Flowdown to L3

- L2: The Mission shall measure energetic electrons, as follows:
  - Energy range: ≤ 0.05 to ≥ 3 MeV
- L3:

3.1.4 Payload Energetic Particle Measurement Requirements

[PAY-76] Measurement: Energetic Electrons Energy Range (EPI-Lo)
EPI-Lo shall be capable of measuring energetic electrons over solar orbital distances of 9.86 R_S to 0.25 AU with an energy range of ≤ 0.05 MeV to 0.5 MeV (TBR).

Description/Clarification
It is presently thought that there will be no gap between the EPI-Lo and EPI-Hi energy coverages for electrons, but a factor of 2 (TBR) energy gap is allowed to take into account the possibility that the energy ranges actually achieved may differ slightly from those presently planned. If there were a gap it would be located near an energy of 0.5 MeV.

Rationale
-- This requirement meets Level 2 Mission Science Requirements. The overall ISIS electron energy range should extend from the suprathermal tail of the solar wind up to highly relativistic energies to allow studies of electron acceleration, to trace connectivity of the magnetic field back to structures on the Sun, and to determine release times of energetic particles from the Sun.

Parent Traceability
-- **MRD-96** : The Mission shall measure energetic electrons, as follows:
-- Energy range: ≤ 0.05 to ≥ 3 MeV
-- Highest cadence: ≤ 1s for selected rates
-- FOV: ≥ $\pi/2$ sr in sunward and anti-sunward hemispheres
-- Angular sectoring: ≤ 45 degree sectors
-- Composition: n/a

Requirement Allocation
ISIS

[PAY-200] Measurement: Energetic Electrons Energy Range (EPI-Hi)
EPI-Hi shall be capable of measuring energetic electrons over solar orbital distances of 9.86 R_S to 0.25 AU with an energy range of 0.5 MeV (TBR) to ≥ 3 MeV.

Description/Clarification
It is presently thought that there will be no gap between the EPI-Lo and EPI-Hi energy coverages for electrons, but a factor of 2 (TBR) energy gap is allowed to take into account the possibility that the energy ranges actually achieved may differ slightly from those presently planned. If there were a gap it would be located near an energy of 0.5 MeV. The lower bound on the EPI-Hi energy range might be changed later to maybe as high as 1.0 MeV, but the intent is to be as close to 0.5 MeV as possible].

Rationale
-- This requirement meets Level 2 Mission Science Requirements. The overall ISIS electron energy range should extend from the suprathermal tail of the solar wind up to highly relativistic energies to allow studies of electron acceleration, to trace connectivity of the magnetic field back to structures on the Sun, and to determine release times of energetic particles from the Sun.

Parent Traceability
-- **MRD-96** : The Mission shall measure energetic electrons, as follows:
-- Energy range: ≤ 0.05 to ≥ 3 MeV
-- Highest cadence: ≤ 1s for selected rates
-- FOV: ≥ $\pi/2$ sr in sunward and anti-sunward hemispheres
-- Angular sectoring: ≤ 45 degree sectors
-- Composition: n/a

Requirement Allocation
ISIS

- Traceability to L2 as well as more detail captured at L3
  - Description/Clarification, S/C Rationale, Parent Traceability, Requirement Allocation

Requirements Flowdown to L4

- L4:

3.1.4 Payload Energetic Particle Requirements

	Energetic Electrons Energy Range	ISIS-100	EPI-Lo Electron Energy Range	ISIS-200	EPI-Hi Electron Energy Range
PAY-76	**EPI-Lo** EPI-Lo shall be capable of measuring energetic electrons over solar orbital distances of 9.86 Rs to 0.25 AU with an energy range of ≤ 0.05 MeV to 0.5 MeV **(TBR)**.		The EPI-Lo instrument shall provide measurements of energetic electrons with an energy range of <=0.05MeV to >=0.5MeV.		The EPI-Hi instrument shall provide measurements of energetic electrons with an energy range from 0.5 **(TBR)** to 6 MeV **(TBR)**.
PAY-200	**EPI-Hi** EPI-Hi shall be capable of measuring energetic electrons over solar orbital distances of 9.86 Rs to 0.25 AU with an energy range of 0.5 MeV **(TBR)** to ≥ 3 MeV.		**Rationale:**		**Rationale:**
			The electron energy range should extend from the suprathermal tail of the solar wind up to highly relativistic energies to allow studies of electron acceleration, to trace connectivity of the magnetic field back to structures on the Sun, and to determine release times of energetic particles from the Sun. Combined with the EPI-Hi measurements, the electron energy range of the EPI-Lo instrument will provide an electron energy range of ≤ 0.05 to ≥ 3 MeV for the ISIS instrument suite.		The electron energy range should extend from the suprathermal tail of the solar wind up to highly relativistic energies to allow studies of electron acceleration, to trace connectivity of the magnetic field back to structures on the Sun, and to determine release times of energetic particles from the Sun. Combined with the EPI-Lo measurements, the electron energy range of the EPI-Hi instrument will provide an electron energy range of ≤ 0.05 to ≥ 3 MeV for the ISIS instrument suite.
			Notes:		**Notes:**
					Electron energy limits will be finalized once thresholds achievable with the SPP PHASIC have been measured.

EPI-Lo (ISIS-100) verification:

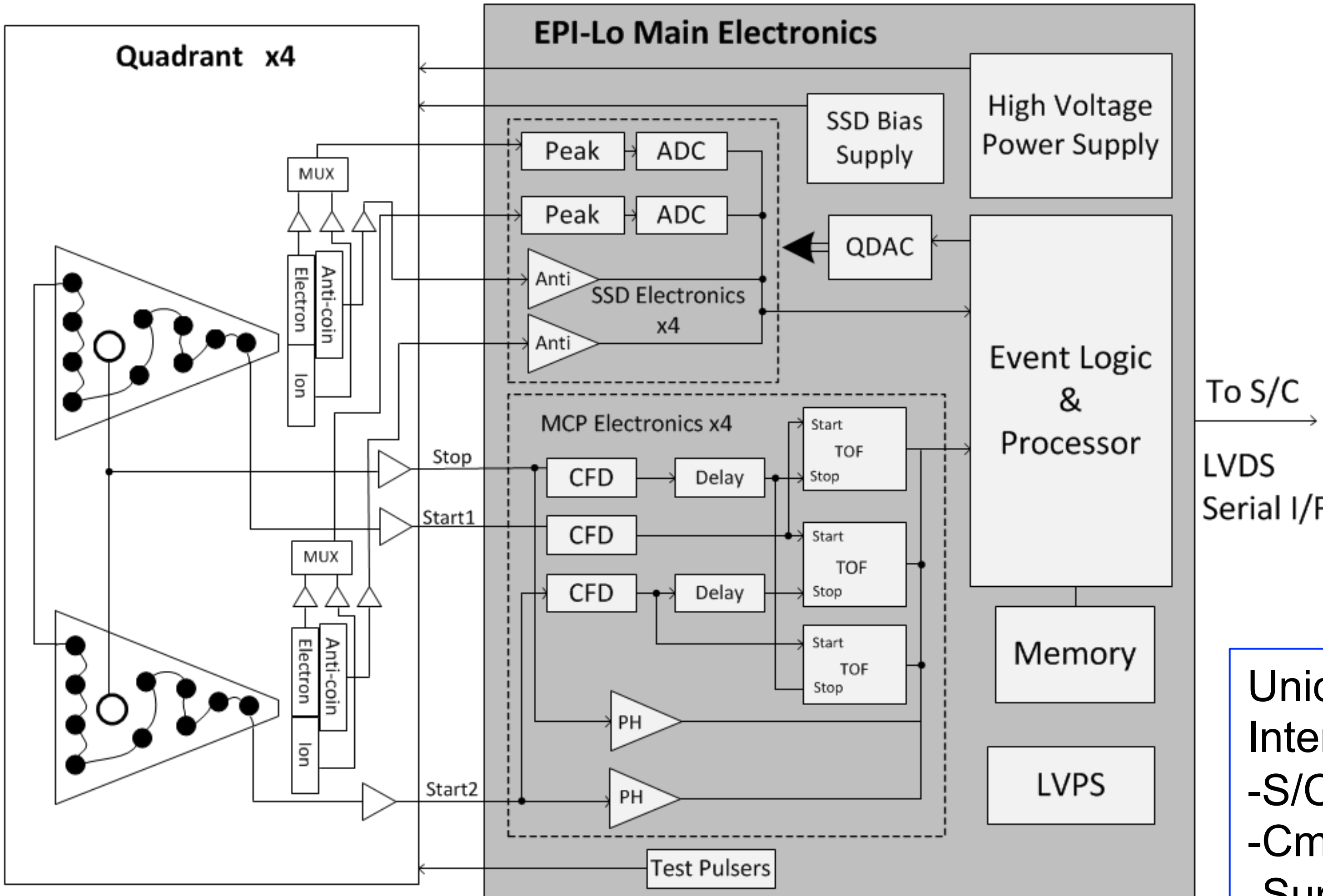
Verification Method	Verification Activity	Verification Result
Analysis & Test	Simulation and spot test using radiation sources.	

EPI-Hi (ISIS-200) verification:

Verification Method	Verification Activity	Verification Result
Analysis & Test	Monte Carlo simulation of response with spot checks using radioactive beta sources.	

- Traceability to L3, ISIS Rationale, Verification Method, and Verification Activity captured at L4

EPI-Lo Block Diagram



Unique EPI-Lo to S/C Interfaces include:
- S/C power
- Cmd/Tlm
- Survival Heaters
- S/C Temp Sensors

EPI-Lo mounted to shared ISIS Bracket

EPI-Hi Block Diagram

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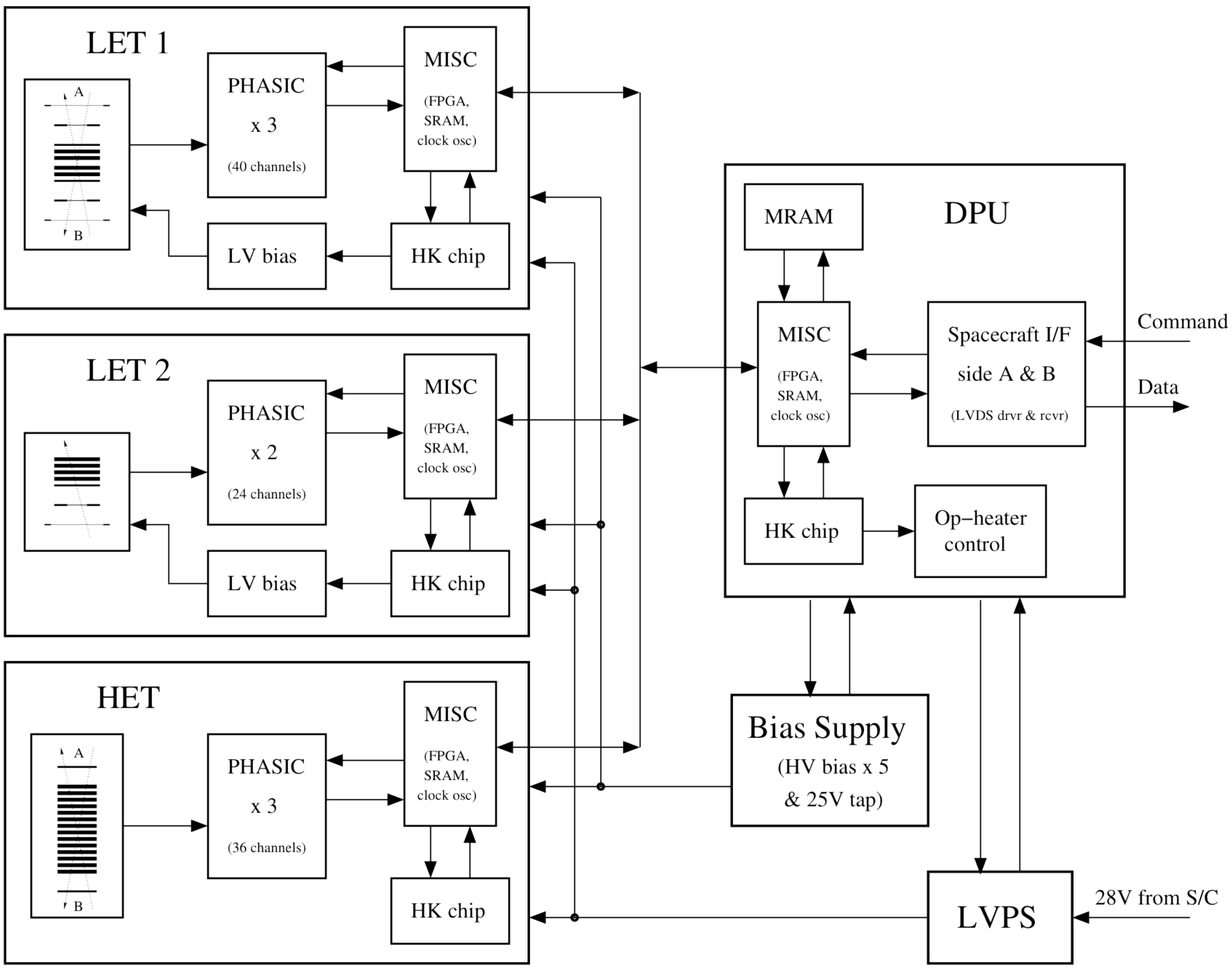
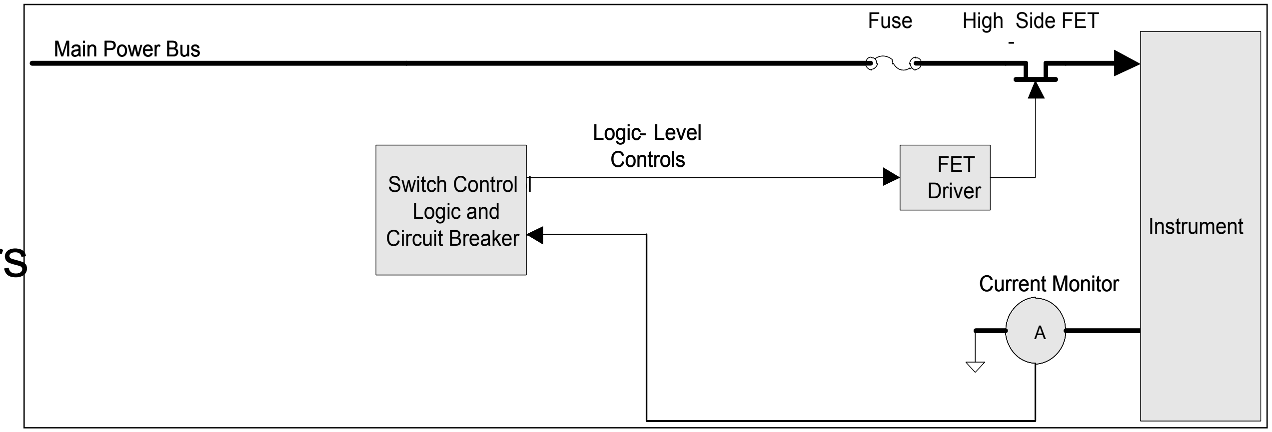


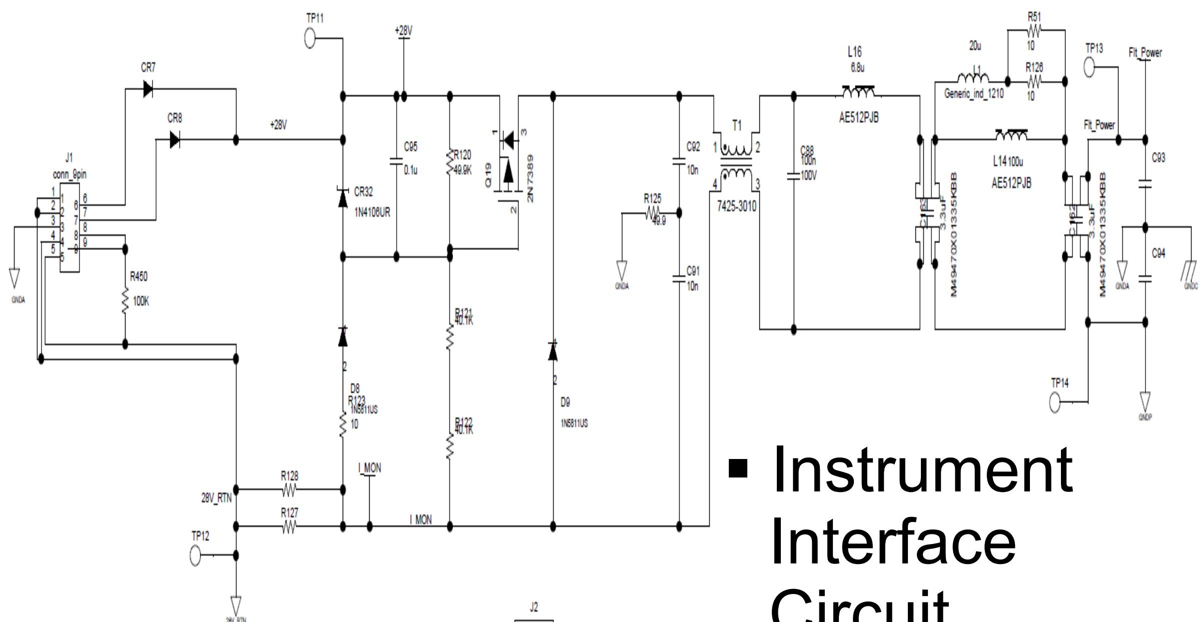
Unique EPI-Hi to S/C Interfaces include:
- S/C power
- Cmd/Tlm
- Survival Heaters
- Operational Heaters
- S/C Temp Sensors

EPI-Hi mounted to shared ISIS Bracket

Spacecraft Interfaces

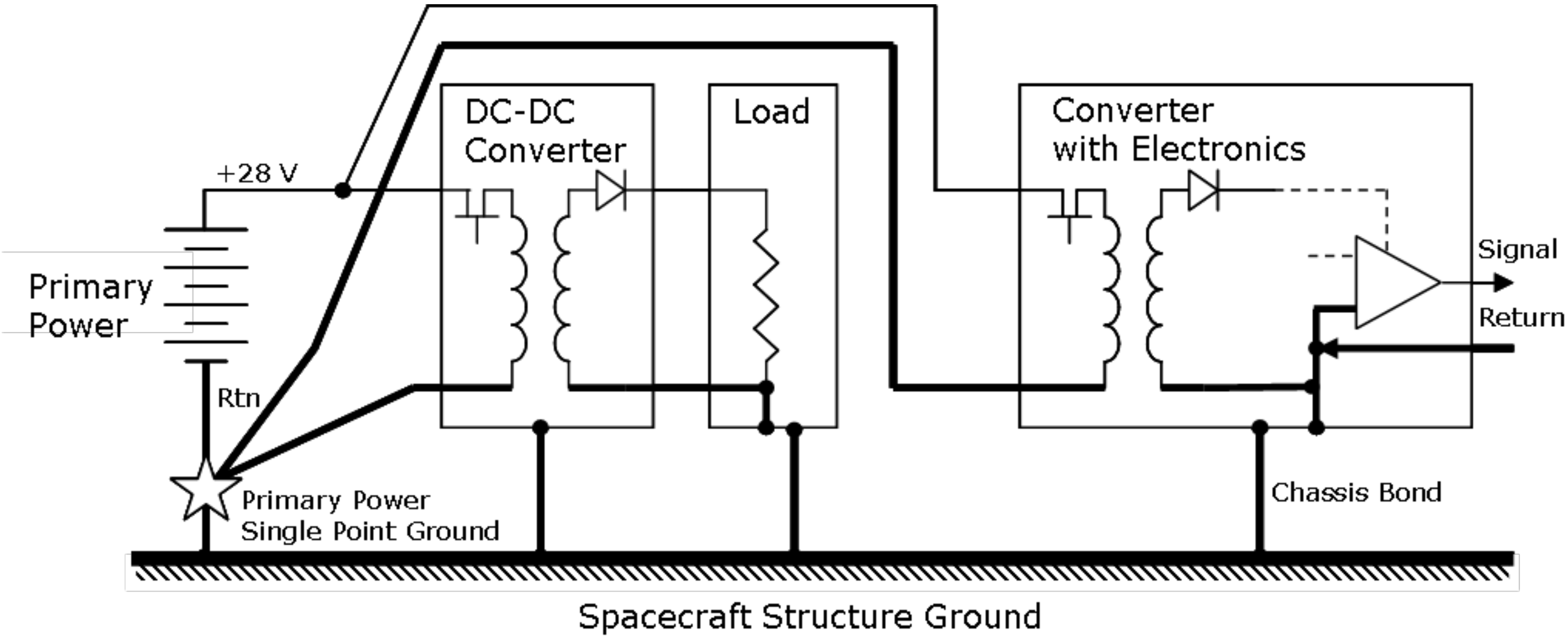
- Power
  - Main Instrument Power
  - Survival Heaters
  - Operational Heaters (EPI-Hi)
- Command & Telemetry
  - Side A/B LVDS UART
- Grounding
  - Chassis Ground
- Thermal
  - Heaters
  - Thermistors
  - Thermal Strap
- Captured in GI and SPP-ISIS ICDs





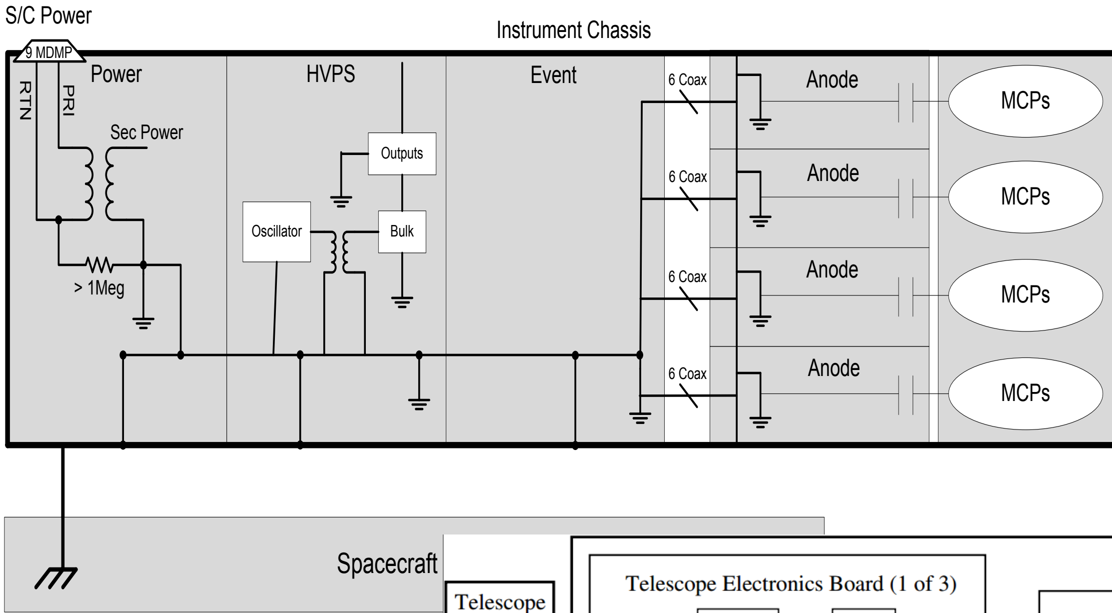
- Instrument Interface Circuit

Spacecraft Grounding Diagram

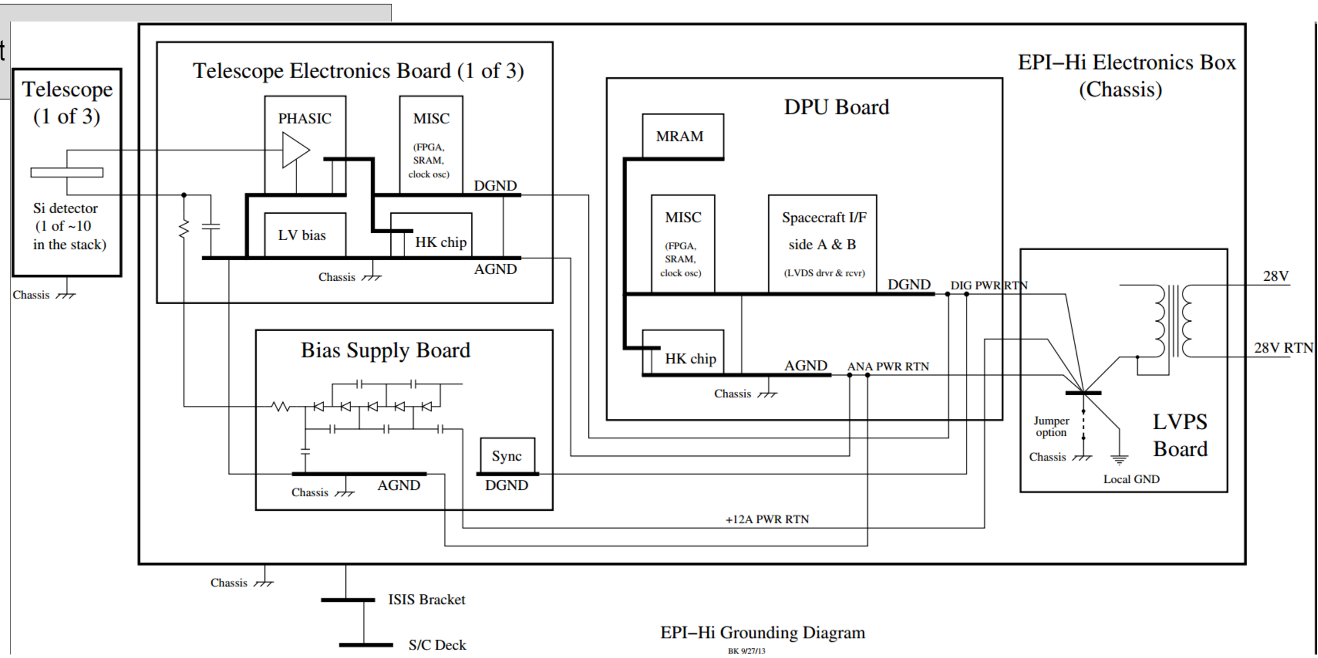


- Captured in GI ICD

Instrument Grounding Diagrams



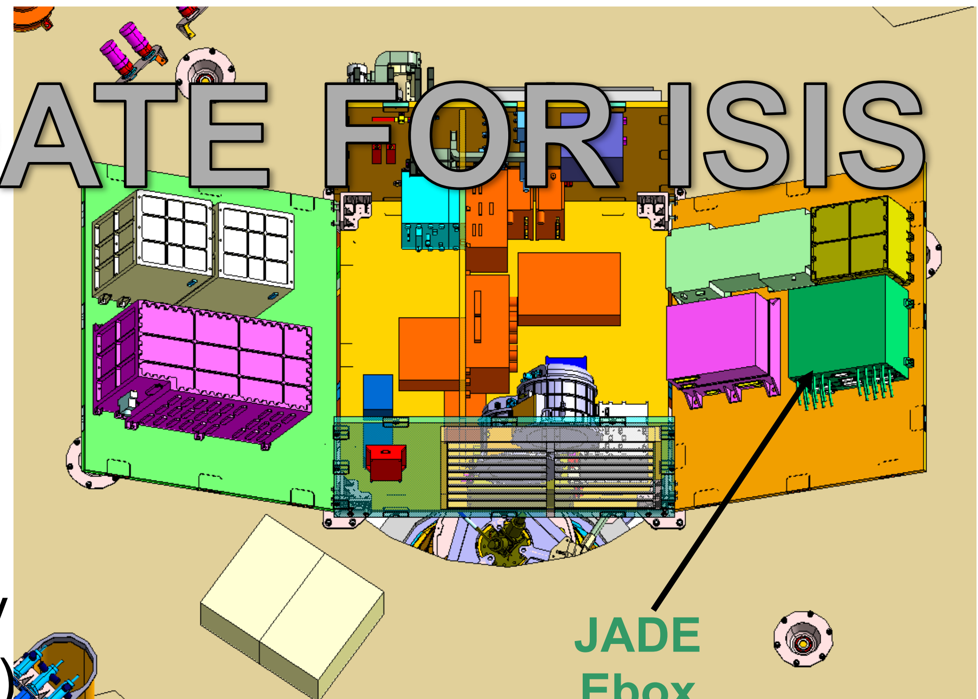
- EPI-Lo
- Captured in SPP-ISIS ICD



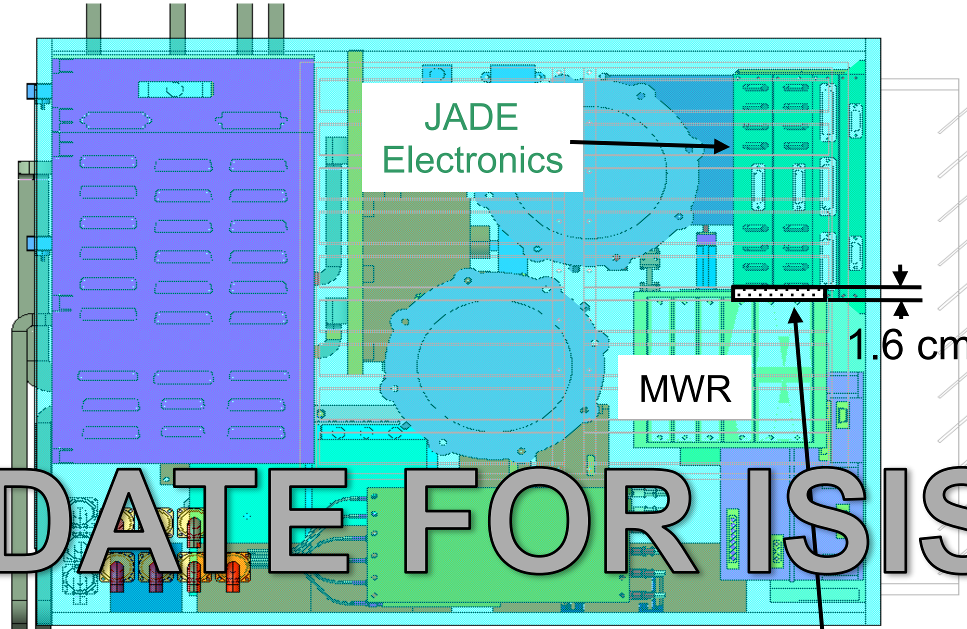
Mechanical Interfaces

- Mechanical - Vault
  - Electronics box location settled in vault
  - Vault cable feedthrough plate with mouseholes for HV cables in work with LM
  - Keep Out Zone at a corner of JADE box for clearance on cables to MWR box
  - Ebox thermally conducts through mounting
  - Latest Ebox Volume:
    - 28.37 x 22.86 x 18 cm
    - (11.169" x 9" x 7.085")
  - Max Ebox Volume:
    - 29.53 x 23.18 x 18 cm
    - (11.625" x 9.126" x 7.087")
  - Defined axis of growth – only in box +Z direction (s/c -X/-Y)

NEEDS UPDATE FOR ISIS

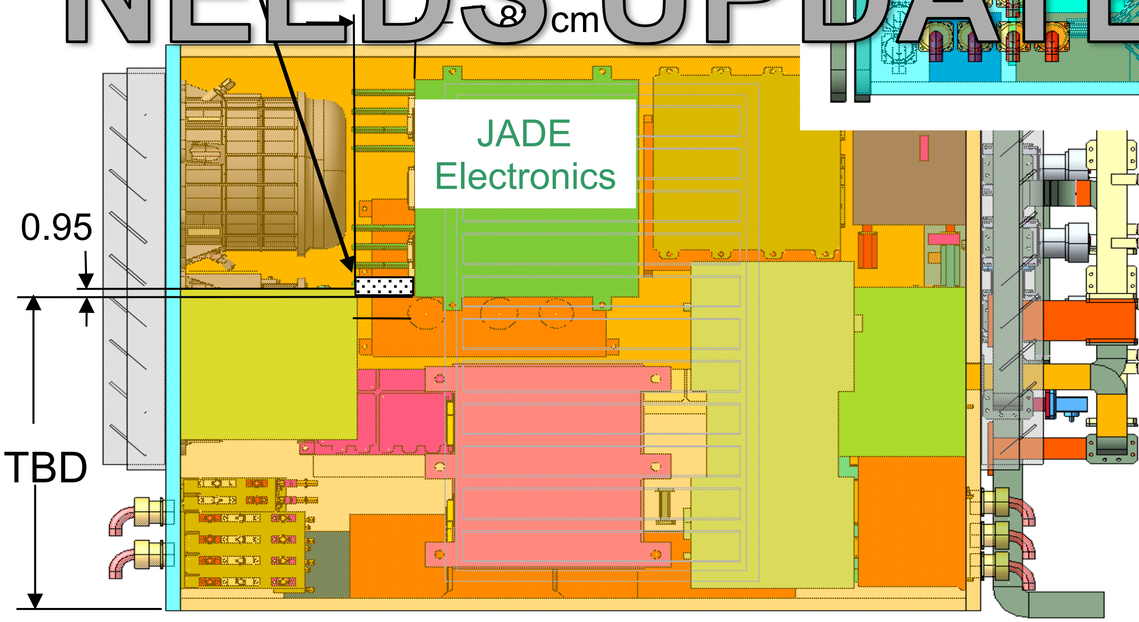


Spacecraft Sep Plane Keep Out Zone



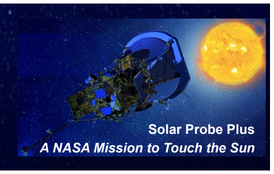
JADE harness Keep Out Zone, 5.82 cm x 1.6 cm

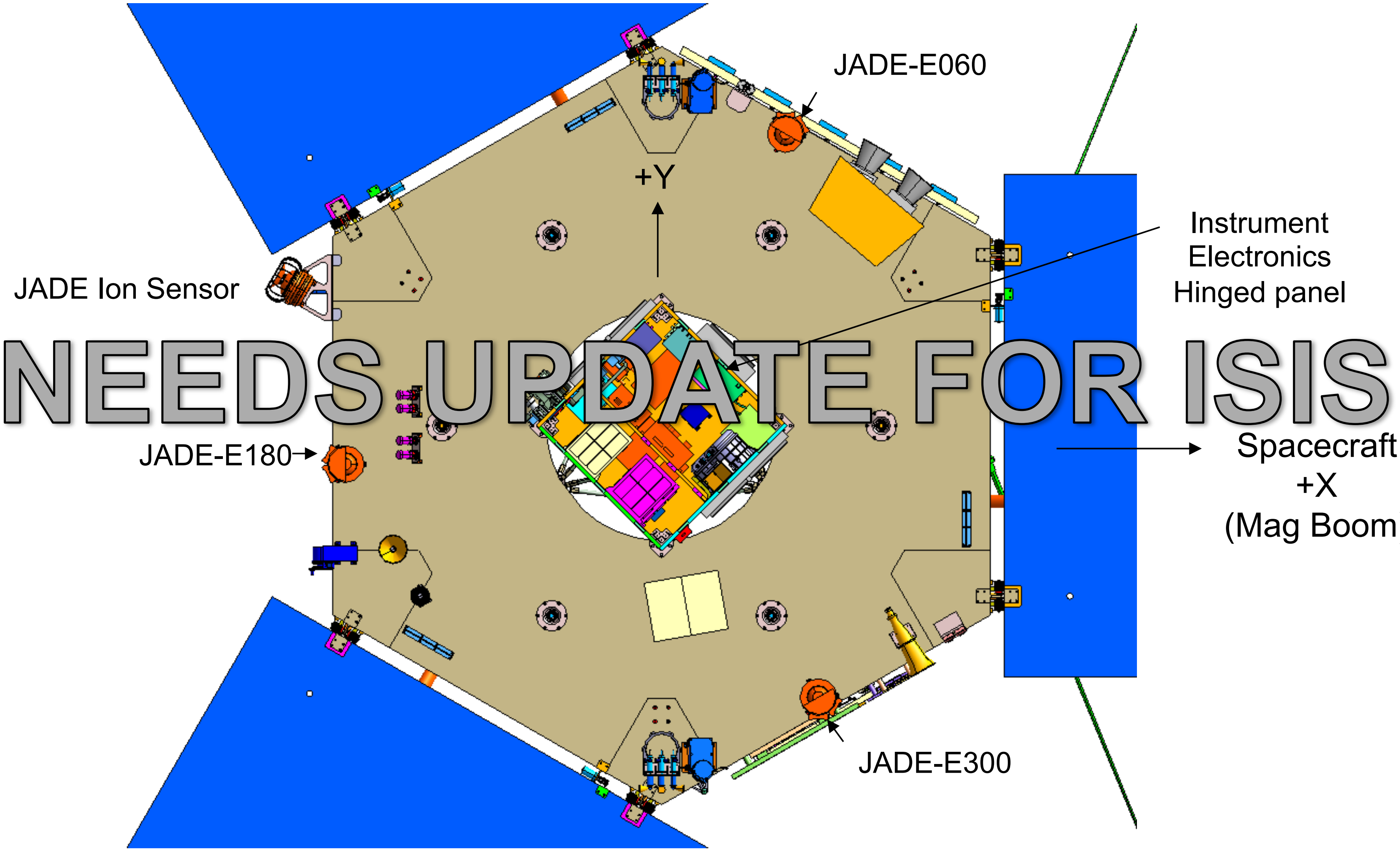
NEEDS UPDATE FOR ISIS



JADE harness KOZ, 7.1 cm x 1.6 cm

JADE Spacecraft Accommodations

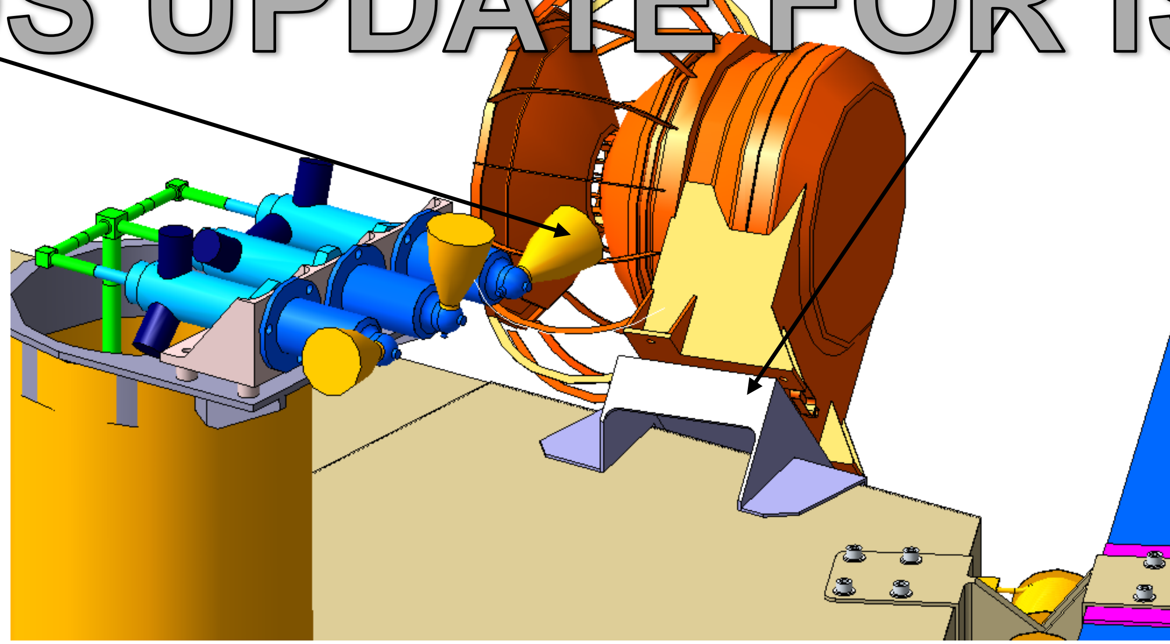




ISIS Instrument Mounting to Bracket

- New JADE Ion Proposed Bracket – To be worked with LM and documented in MICD
- Plume Shield will be implemented to minimize contamination in direction of s/c deck from thrusters

NEEDS UPDATE FOR ISIS



ISIS Mounting to Spacecraft Deck

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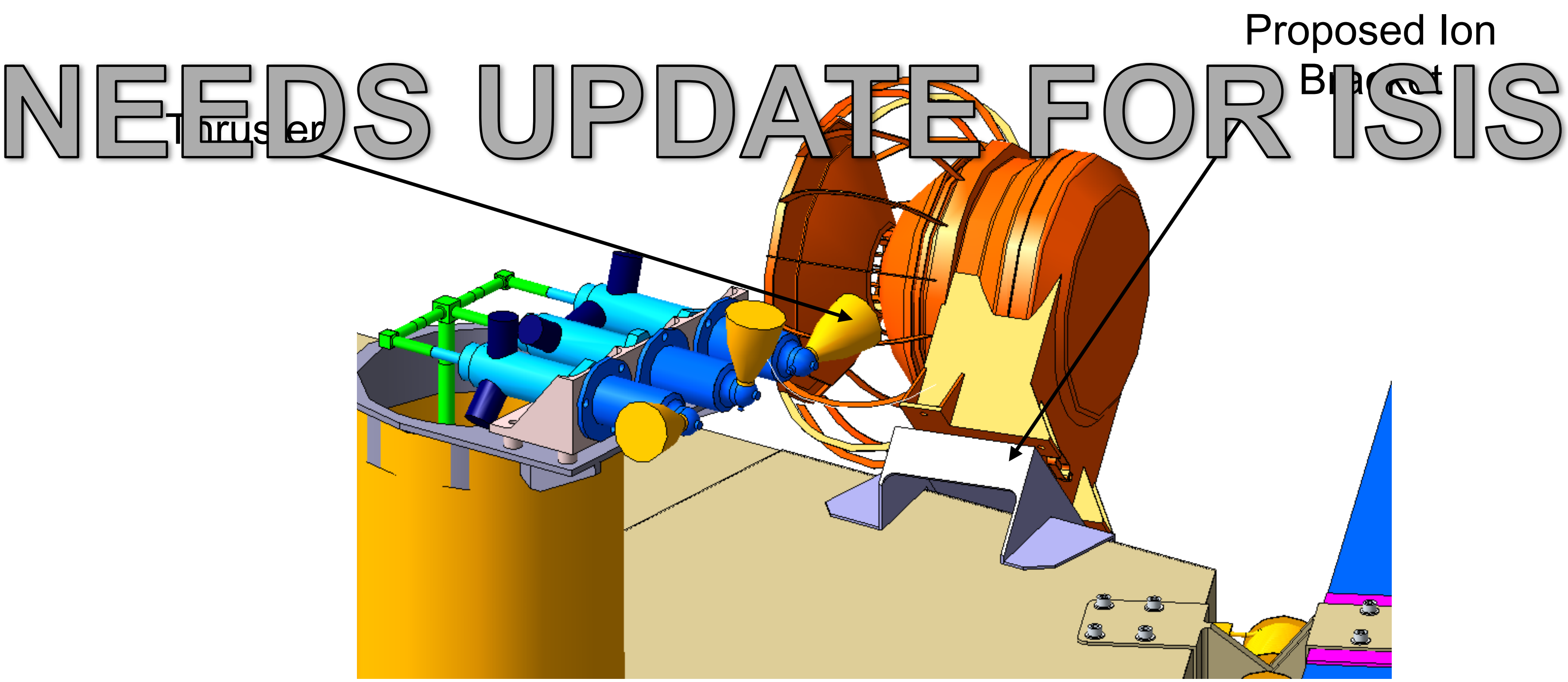
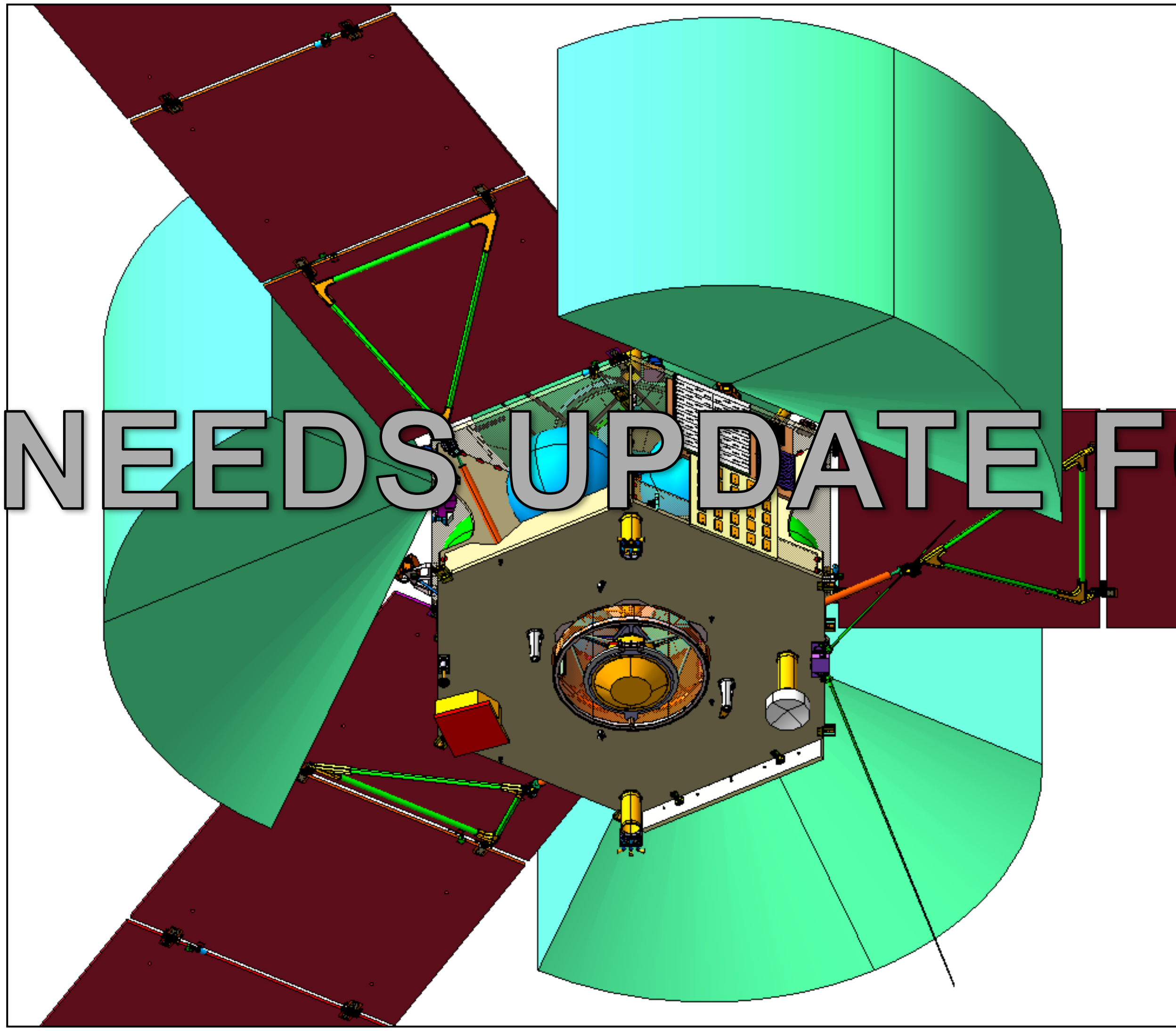
- New JADE Ion Proposed Bracket – To be worked with LM and documented in MICD
- Plume Shield will be implemented to minimize contamination in direction of s/c deck from thrusters



EPI-Hi Field Of View

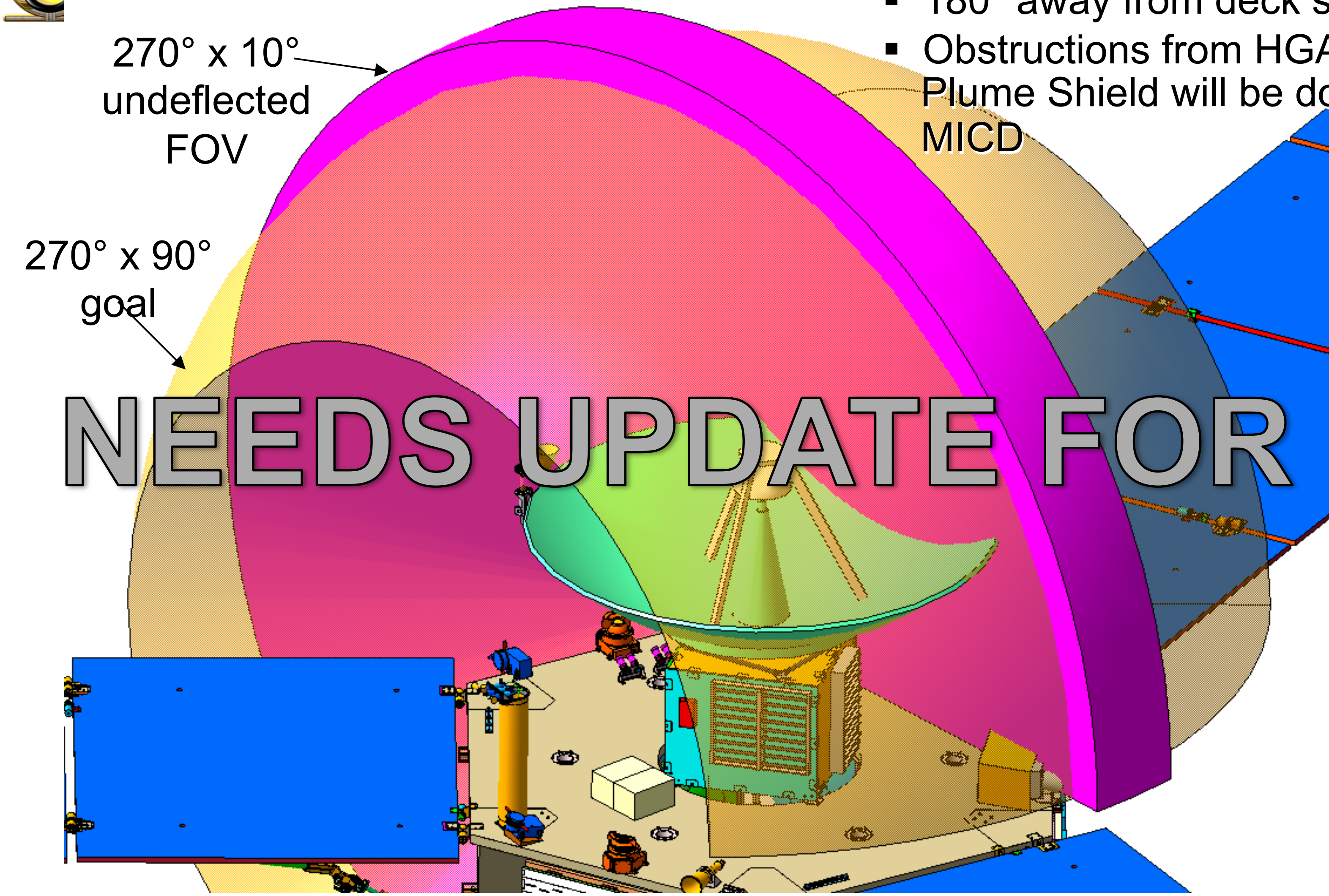


Jade 60 X 120
Keep Out FOV

NEEDS UPDATE FOR ISIS

EPI-Lo Field Of View

- 180° away from deck should be clear
- Obstructions from HGA and Thrusters/ Plume Shield will be documented in MICD



Thermal Interfaces

- EPI-Hi:
  - Both survival and operational heater services from the spacecraft
  - Instrument controls operational heater
  - Spacecraft controls survival heater
  - Has 5 temp sensors monitored by spacecraft
- EPI-Lo:
  - Has a dual use survival/operational heater, used during survival conditions, instrument pre-on warm-up, and in low power modes
  - EPI-Lo has 2 temp sensors
- Individual thermal straps to spacecraft deck

Instrument Subsystem	Design / Test Operating Temperture Range (C)	Non-op Survival Temperature Range (C)	Survival Heater Resistance (Ohms)	Set Point Temperature Range (C)
EPI-Hi HET	-25 / +30	-40 / +50	TBD	---
EPI-Hi LET1	-25 /+30	-40 / +50	TBD	---
EPI-Hi LET2	-25 / +30	-40 / +50	TBD	---
EPI-Hi Electronics	-25 / +40	-40 / +50	TBD	-35 to -32
EPI-Lo Detectors	-30 / +35	-45 / +50	---	---
EPI-Lo Electronics	-30 / +55	-45 / +65	---	---
EPI-Lo Dome	-30 / +55	-45 / +65	TBD	-40 to -37

Resources - Power

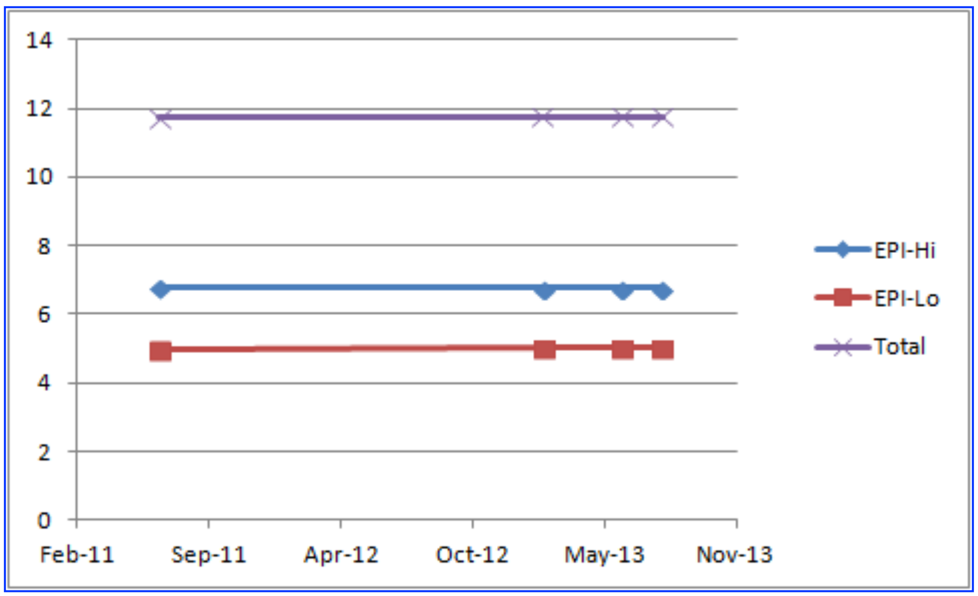
ISIS	Hi CBE	Hi Uncty	Hi Total	Lo CBE	Lo Uncty	Lo Total	ISIS Total
Instrument Power (W)	5.81	0.96	**6.77**	4.17	0.83	**5.00**	**11.77**
Operational Heaters (W)	0.48	0.07	**0.55**	0.00	0.00	**0.00**	**3.47**
Survival Heaters (W)	3.81	0.57	**4.38**	2.45	0.37	**2.82**	**7.20**
Totals:	**10.10**	**1.60**		**6.62**	**1.20**		

Function	Power Service	Peak Current	Max Load Dissipation (CBE+Uncertainty) by Mode				
		(A)	(W)				
		EPI-Lo Modes:	*Survival*	*WarmUp*	*Boot*	*Non-Encounter*	*Encounter*
EPI-Lo	Main Power	0.208 @ 24V	0.00	0.00	2.00	5.00	5.00
	Survival Heater Power, 121 Ω eq. res.	0.271 @ 33V	2.82	5.56	3.00	0.00	0.00
		EPI-Hi Modes:	*Survival*	*WarmUp*		*Non-Encounter*	*Encounter*
EPI-Hi	Main Power	0.282 @ 24V	0.00	0.00		6.77	6.77
	Survival Heater Power, 87 Ω eq. res.	0.378 @ 33V	4.38	7.74		0.00	0.00
	Operational Heater Power, 1056 Ω eq. res.	0.031 @ 33V	0.00	0.00		0.55	0.55

- ISIS Current Best Estimates and Uncertainties
- ISIS Power by Mode and service
- EPI-Lo has a low-power Boot safe-hold mode in which survival heaters are used as operational heaters to maintain instrument above Cold Op. temps
- EPI-Hi is either on or off
- During Survival, heater power is duty cycled to ensure instrument stays above survival temperature
- During Warm-up, heater has a 100% duty cycle to warm the instrument prior to normal operations (Encounter Mode)

Resource – Power (Trend)

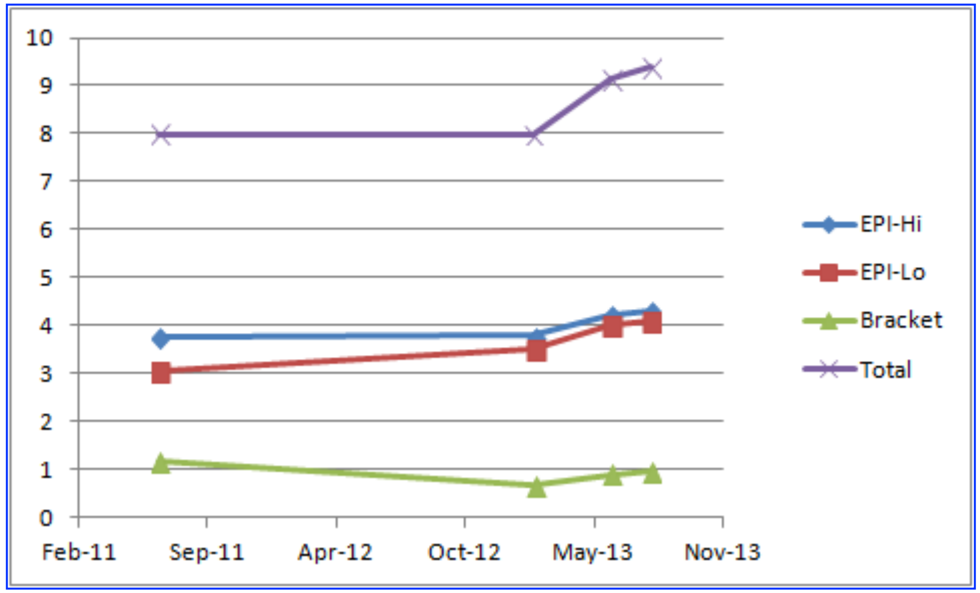
- Because all resources on SPP are tightly constrained, mass and power estimates have been rigorously maintained based on heritage instruments from the beginning
- As a result of this attention to rigorous estimation, there has been no change in instrument power allocation over time



Resources - Mass

	Hi CBE	Hi cont.	Lo CBE	Lo cont.	Bracket	cont.	Total
Mass (kg)	3.628	0.692	3.435	0.656	0.817	0.156	**9.384**

- With the S/C orbit change, the Instruments were asked to choose key areas to increase mass to reduce risk (in June, 2013)
- This increased instrument allocation by 1.5 kg.



Request	NTE (kg)	Risk Addressed
ISIS Bracket Change to Follow Umbra at TPS Shift	0.300	APL proposal. Also hold 0.100 kg as lien.
Increase Size of Four EPI-HI Boards	0.336	Mitigate board area allocation risk.
Heavier Than Expected MCPs	0.900	Realized mass growth.
Total	1.536	

Resource - Telemetry

		Total ISIS	12 Gbits	r < 0.25 AU and burst only, include compression, packetization, but not contingency				
			13.3253022	0.89894993				
		bps	# of secs	total raw bits	total (Gbits)	*0.75 comprss	*1.05 Packt	
EPI-Hi	r < 0.25 AU	3640.747218	902545.7301	3655310207	3.655310207	2.741482655	2.878556788	
	r > 0.25 AU						n/a	
EPI-Lo	r < 0.25 AU	11271.03423	902545.7301	11316118364	11.31611836	8.487088773	8.911443212	
	r > 0.25 AU						n/a	
	Burst					0.2	0.21	
							12	Gbits/orbit

- ISIS Telemetry request is unchanged since Phase A

Instrument	Gbit / orbit	+ 30%	Avg. Rate <0.25 AU 11 days	Continuous Data Rate	Peak Data Rates (3 Hours)
WISPR	23	30	30 kbps	260 kbps	350 kbps 8 kbps
FIELDS 1 & 2	20	26	26 kbps		80 kbps 80 kbps
SWEAP	20	26	26 kbps		80 kbps
ISIS	12	16	16 kbps		80 kbps 80 kbps
Science campaign "data bank"	10	13	13 kbps		NA
	85 Gbit	111 Gbit	111 kbps	341 kbps	758 kbps

CCSDS APIDs

Allocation	APID Range (Hex) - Low	APID Range (Hex) - High	Assignment
64	0x490	0x4CF	EPI-Lo
64	0x440	0x47F	EPI-Hi

APID (Decimal)	APID (Hex)	Assignment
1180 TBR	0x49C TBR	EPI-Lo Critical Housekeeping Packet
1088 TBR	0x440 TBR	EPI-Hi Critical Housekeeping Packet

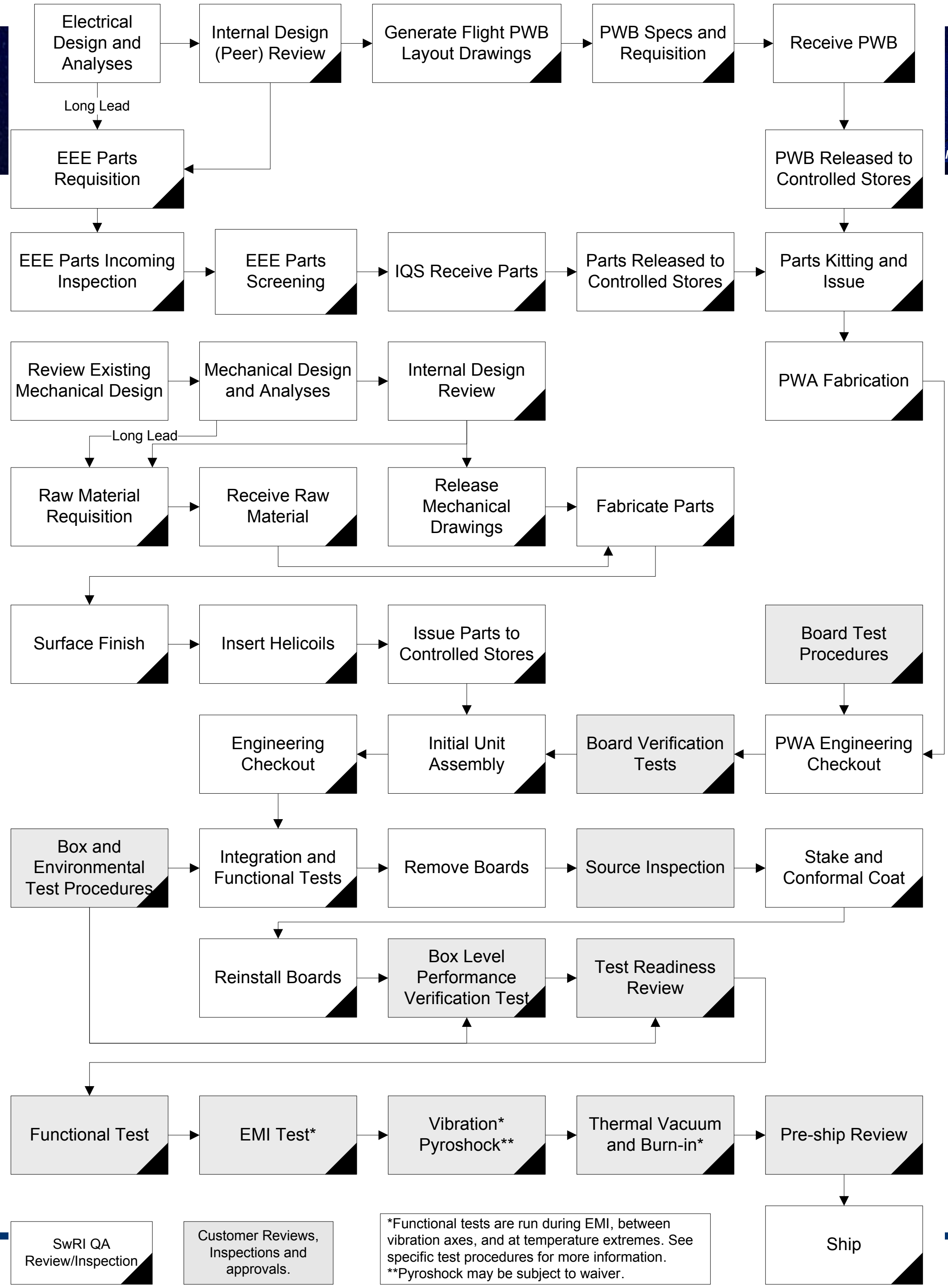
- CCSDS APIDs assigned in SPP-ISIS ICD
- EPI-Lo and EPI-Hi have each been allocated a contiguous range of 64 APIDs for CCSDS telecommand and telemetry packets.

Autonomy Summary

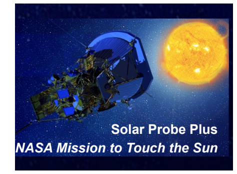
The spacecraft will monitor and respond to:

- ISIS Power requests instrument critical housekeeping telemetry packet:
  - instrument power-down (response = power-down)
  - instrument power-cycle (response when < 0.25 AU = power-cycle; response when >= 0.25 AU = power-down)
- ISIS Stale aliveness status as determined from the sequence count in the ITF (response when < 0.25 AU = power-cycle; response when >= 0.25 AU = power-down)
- Excessive instrument power levels as determined from spacecraft Power Distribution Unit (PDU) telemetry (response = power-down)
- Excessive instrument temperature as determined from spacecraft Remote Interface Units (RIUs) (response = power-down)

ISIS AI&T



*Functional tests are run during EMI, between vibration axes, and at temperature extremes. See specific test procedures for more information.
**Pyroshock may be subject to waiver.



Environmental Requirements & Tests

- Key Environmental Requirements set in EDTRD:
  - Duration: 7 years
  - Orbits: 24
  - Solar Illumination: 1 sun on any aperture
  - TID: 70 kRad behind 60 mils Al [CHECK THIS???]
  - SEL: >80 MeV-cm2/mg
  - Dust: Probability of no damage >95%
    - EPI-Lo: 124.3 um particle diameter
    - EPI-Hi: 68.5 um particle diameter
  - Stiffness: >80 Hz Res. Freq.
  - Shock: 40G @ 100 Hz at separation interface

Test	Subsystem / Instrument Requirement
Magnetic Field (test magnetic hardware)	X[b]
Hermeticity (tanks, cooling system)	*
Comprehensive Performance Test	X
EMI/EMC	X
Initial Optical Alignment	*
Mass Properties	X[a]
Pre Vibration Survey	X
Sinusoidal Vibration	X
Random Vibration	X
Pressure Profile	
Shock (self induced)**	*
Acoustic	*
Strength	X
Post Vibration Survey	X
Deployments	*
Performance Test	X
Thermal Vacuum Balance	*
Thermal Vacuum Cycle	X
Bake-out	X
Final Optical Alignment	*
Comprehensive Performance Test	X

X Test is required

* Test is conditionally required, see relevant sections

ISIS Concept of Operations

- Commissioning – 2 days for ISIS alone
  - Initial Turn-on and Checkout with Real-Time Telemetry
- Multi-Instrument Commissioning – 5 days for Instrument Suite
  - EPI-Hi & EPI-Lo performs statistics gathering for calibration
- Calibration goal: at least 1d of data during significant SEP event on orbit 1-2
- Spacecraft-Sun Distance R<0.25 AU (Normal Science Mode)
  - Full nominal power
  - High data collection rate and burst mode
- Spacecraft-Sun Distance: 0.25< R<0.76 AU (Low-rate Science Mode)
  - Full power when not downlinking
  - Full power or low-power mode when downlinking
  - Reduced data collection rate
  - Commanding window should be scheduled late in the series of telemetry passes, although it may not be used every orbit
  - Minimize power cycling the HV supplies

Major Changes Since MDR

- Mission Orbit Change
- Embraced Quadrant Architecture on EPI-Lo
- Added Anti-Coincidence in EPI-Lo

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Trade Studies

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Trade	Description	Status	Closure Date
Hi: PHASIC Approach	Improve PHASIC TID: 1) Passive Shielding 2) RadHard respin of STEREO PHASIC by Aeroflex	EM Components fabricated, tested, and meet requirements	PDR (closed)
Hi: Thin Silicon Detectors	Process for making thin ion-implanted detectors that simultaneously meet all of the specifications for the EPI-Hi LET telescopes have not yet been demonstrated.	Thin detectors have been fabricated, tested, and meet requirements	PDR (closed)
Hi: Thin Windows	Because of the thin front detectors on the EPI-Hi LETs, it would be useful to make the windows at the LET apertures thinner than those used in heritage STEREO/LET instrument. (Note: Fall back to flight-proven 1/5 mil Kapton meets Level 1 Reqs)	Thin windows fabricated and tested at CU	PDR (closed)
Lo: RIO Chip	APL has developed an ASIC that performs housekeeping functions called the Remote IO (RIO) chip. Component may be useful as Housekeeping chip for ISIS (EPI-Hi and EPI-Lo).	EM Components fabricated, tested, and meet requirements	PDR (closed)
Lo: Wedge-to-TOF Chip Ratio	Time-of-Flight can be derived in several configurations of MCP wedges and TOF chips (start/stop inputs), i.e. 1 or 2 wedges with direct or daisy chained TOF chips. Minimizing mass without sacrificing measurement quality is the goal.	Quadrant approach implemented	PDR (closed)
Lo: ASIC Lot Selection	The use of new generation TOF/CFD timing chips and RIO housekeeping chips alleviates the availability concern due to depletion of existing flight stocks. However, new designs might not be available in time.	EM Components fabricated, tested, and meet requirements	PDR (closed)
ISIS: Harness Approach	We wish to lower the mass and heat leak penalties of existing discrete wiring. The harness design also impacts the sensor noise and high voltage breakdown immunity.		PDR (closed)

Summary

- ISIS takes a comprehensive and distributed approach to systems engineering
- ISIS requirements are approached with flowdown and verification in mind
  - Requirements flowdown is easily traceable and well understood
  - **ISIS design meets or exceeds all Level 3 requirements**
- ISIS to Spacecraft electrical, mechanical, and thermal interfaces are well described in the ICDs
- ISIS Resource estimates are within spacecraft allocations
  - ISIS has cultivated a reputation as a good steward of mission resources
- Plans are in place for Environmental Testing and AI&T
- ISIS has demonstrated tremendous design maturation and clarification throughout Phase B

- Next steps
  - Continue with EM builds and testing

Requirements Verification

- Verification Planning
  - Inspection, Analysis, Test
  - Specs lead to VTP where individual requirements are checked off
  - Completing VTP's in EM so we have the documents ready for FM build
  - Linking specs and VTP's / As-Run tests in DOORS
  - Verification Matrix shows how each requirement will be verified, and links to the appropriate test procedure
  - Reviewing Juno Verification and Validation Plan, D-34004

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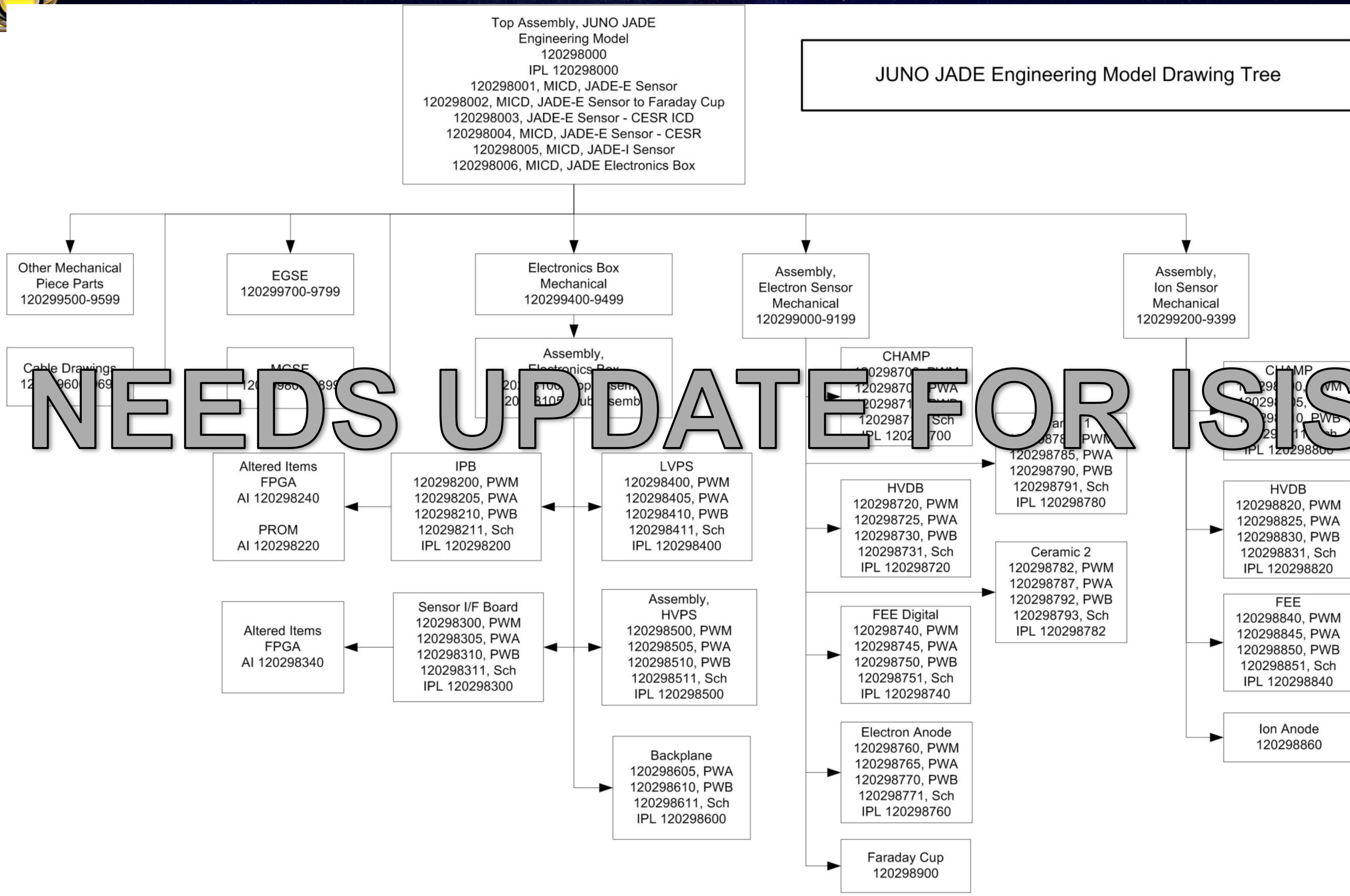
EM Drawing Tree



JADE Operations

- JADE Hardware Modes
  - Boot
    - Instrument has been turned on and is booting up, not ready to respond to commands
  - Low Voltage Engineering
    - Low power mode, no high voltage. Initial post-boot state.
    - Functional testing, initial low voltage turn-on and checkout.
  - High Voltage Engineering
    - Allows direct control of high voltage via commands.
    - Allows for initial checkout of high voltage performance, as well as specific calibration activities.
    - No automatic sweeping of high voltage.

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  - High Voltage Survey
    - Low rate science data collection mode that is active for most of the 11-day nominal science orbit, outside of the +/- 3 hr perijove prime observation period.
  - High Voltage Science
    - High rate science data collection mode. Active during the +/- 3 hr around perijove region in a nominal science orbit.
  - High Voltage Science + Burst
    - Burst data collection is active in addition to high voltage science mode.
    - Burst data is the uncollapsed data products produced by each sensor, sent out over the dedicated High Speed Synchronous (HSS) RS-422 data line to be collected in buffers by the spacecraft. Occurs over the north and south polar regions of Jupiter only, within the prime science observation region.

Pointing: Level 3 Requirements

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L3-PRD-35 (flowed from L2-PS-796)

ISIS Control to Nominal Pointing		BIAS
REQ	0.548 deg	0.100
CBE	0.387 deg	0.100
ALLOWABLE OFFSET	0.400 deg	
Note: Desire 1 degree requirement?		
Total		
REQ	**0.96 deg**	
CBE	**0.80 deg**	

ISIS Internal Calibration

ISIS Internal Calibration		BIAS
REQ	0.20 deg	0.000
CBE	0.20 deg	0.000
Note: TBD		

ISIS Angular Measurement Accuracy/Resolution		
REQ	0.200 deg	
CBE	0.200 deg	
		UNVERIFIED
Note: Provided by ISIS Team		

Initial ISIS Control to SC Body Frame

Initial ISIS Control to SC Body Frame		BIAS
REQ	0.24 deg	
CBE	0.24 deg	
Note: TBD		

ISIS Csys knowledge to Mech Ref Features		
REQ	0.100 deg	
CBE	0.100 deg	
		UNVERIFIED
Note: Provided by ISIS Team		

ISIS Mech Ref Features to SC frame knowledge		
REQ	0.200 deg	
CBE	0.200 deg	
		UNVERIFIED
Note: Measurement Accuracy		

SC body frame knowledge		
REQ	0.100 deg	
CBE	0.100 deg	
		UNVERIFIED
Note: Measurement Accuracy of Csys		

Allowable offset from nominal pointing		
REQ	deg	
CBE	deg	
		UNVERIFIED
Note: 0.4 deg - see final summation box		

ISIS Control Changes from initial sett

ISIS Control Changes from initial sett		BIAS
REQ	0.20 deg	0.100
CBE	0.20 deg	0.100
Note:		

Shock & Vibe Shifts		
REQ	0.050 deg	
CBE	0.050 deg	
		UNVERIFIED
Note:		

ADD

Shipping shift		
REQ	0.050 deg	
CBE	0.050 deg	
		UNVERIFIED
Note:		

ADD

Shock & Vibe in flight		
REQ	0.100 deg	
CBE	0.100 deg	
		UNVERIFIED
Note: TBD		

Mech. Therm. Distortion		BIAS
REQ	deg	0.100
CBE	deg	0.100
		UNVERIFIED
Note:		

SC Pointing and Knowledge

SC Pointing and Knowledge		BIAS
REQ	0.40 deg	0.000
CBE	0.10 deg	0.000
Note: TBD		

SC Attitude Control Error		
REQ	0.400 deg	
CBE	0.100 deg	
		UNVERIFIED
Note: SCRD-166 2 deg. for ISIS		

JADE Prelim Test Verification Matrix

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JADE Component	Testing to Protoflight Levels												System Testing				
	Static Loads	Acoustics	Random Vibration	Pyroshock	Thermal Vacuum	Thermal Cycle, 1 atm	Thermal Shock	Pressure Profile	Magnetics	Radiation, TID & DDD	Radiation, SEE	Micrometeoroid	Bakeout	SW Module Verification Test	Functional Test	Verification Test Plan	Calibration
JADE Flight Instrument															X	X	
JADE Ion Sensor	A	[illegible]	T	T	[illegible]	[illegible]	-	A	T	A	A	A	X		X	[illegible]	[illegible]
Electro-Optics													X				X
Microchannel Plates													X				X
Ceramics													X				X
Front End Electronics													X		X	X	
JADE Electron Sensor	A	-	T	T (1)	T	-	-	A	T	A	A	A	X		X	X	X
Electro-Optics													X				X
Microchannel Plates													X				X
Faraday Cups													X				X
Front End Electronics													X		X	X	
JADE Electronics Box	A	-	T	T	T	-	-	A	T	A	A	-	X		X	X	
LVPS													X		X	X	
IPB													X		X	X	
JSIB													X		X	X	
HVPS													X		X	X	
Flight Software														X		X	
Cabling													X		X	X	

Contamination Requirements

- L2-PS-813 Pressure at JADE aperture; HV On
  - The Juno Project shall limit in-flight pressure at the JADE sensors' apertures to less than 1x10E^{-6} Torr during operation of its detector high voltage level. The MCPs within the instrument can be degraded if their high voltage is operated at pressures above this level.
  - Verification – Inspection (MICD / Ideas / at ATLO) Analysis (outgassing pressures)

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- L2-PS-814 Thruster line-of-sight to the JADE Sensor Aperture
  - The Juno project shall eliminate direct line-of-sight between the nozzle opening of any RCS engine and the entrance aperture of any JADE sensor (excluding the Faraday Cups), as defined in the JADE-Spacecraft ICD.
  - Verification – Inspection (MICD / Ideas / At ATLO)

Contamination Budget

- L3-PLS-381: The Juno Payload shall meet the instrument exterior surface contamination levels listed in L2-PS-809.

Contamination Source	External Surface Levels	
	Delivery to ATLO	EOL (L2-PS-809)
Particulate	500	550
NVR	A/2	A (100 Å thick)

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- Fabrication and Assembly on Class 100 flow bench of critical detector components (MCPs and carbon foil)
- Testing and calibration in Class 10,000 clean rooms
- Witness plates used to monitor facilities with flight hardware

JADE Operations and Operability

- Flight Operations
  - Initial HV checkout after over 1 month Flight System outgassing time
  - Earth Flyby Operations – latest temperatures show JADE will be within operating temperature limits at EFB and will be available to take data
  - Cruise Operations – solar wind in flight calibration
  - Calibrations – once a month preferred during cruise, once an orbit at Jupiter
    - Voltage-gain curve
    - Solar wind measurement during cruise
    - Cross calibrate with Faraday Cups, other Juno instruments
    - L3-PLS-472: Calibration over the ascending magnetic equator crossing of the flight system on at least 5 science orbits.
  - Designed for automated ops on-orbit except for calibration period where we may upload new lookup tables to tweak parameters such as MCP gain or integration times

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NOVICE results

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- Preliminary mass optimization study on electron sensor NOVICE results
- Based on noise and flux analysis, JADE is aiming for ~8.5 g/cm^2 shielding – light-medium blue on figure
- Other areas have more shielding than we need

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