

National Aeronautics and
Space Administration



Document Number: CII-CI-XXXX
Version: Rev A Draft

Common Instrument Interface Project

Hosted Payload Guidelines Document

Earth System Science Pathfinder Program Office
NASA Langley Research Center
Hampton, VA 23681

1
2

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 2 of 113

Submitted By:

Paul Speth
CII Project Manager

Date

Approved By:

Frank Peri
ESSP Program Director

Date

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 3 of 113

3

Change Log

Version	Date	Section Affected	Description
Rev A	11-26-2012	All	Incorporated GEO guidelines
Rev A	11-26-2012	All	Reorganized document to delineate Level 1 guidelines, Level 2 guidelines, and Best Practices
Rev A	11-26-2012	All	Added Hosted Payload Concept of Operations
Rev A	02-15-2013	All	Updated document based upon stakeholder feedback from December 2012 CII Working Group Meeting

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 4 of 113

Table of Contents

4		
5	1.0 OVERVIEW	8
6	1.1 Introduction	8
7	1.2 Nomenclature and Definitions	9
8	1.3 Methodology.....	9
9	1.4 Interpretation	10
10	1.5 Scope	11
11	1.6 Revisioning	12
12	1.7 Interaction with Other Agencies Involved with Hosted Payloads.....	12
13	2.0 LEVEL 1 DESIGN GUIDELINES	14
14	2.1 Assumptions	14
15	2.2 Guidelines.....	14
16	3.0 HOSTED PAYLOAD WORLDVIEW LEVEL 2 GUIDELINES	19
17	3.1 Mission Risk.....	19
18	3.2 Instrument End of Life	19
19	3.3 Prevention of Failure Back-Propagation.....	19
20	4.0 DATA LEVEL 2 GUIDELINES	20
21	4.1 Assumptions	20
22	4.2 Data Interface Guidelines	20
23	4.3 Data Accommodation Guidelines.....	21
24	5.0 ELECTRICAL POWER SYSTEM LEVEL 2 GUIDELINES	22
25	5.1 Assumptions	22
26	5.2 EPS Interface	24
27	5.3 EPS Accommodation	25
28	6.0 MECHANICAL LEVEL 2 GUIDELINES	28
29	6.1 Assumptions	28
30	6.2 Mechanical Interface Guidelines.....	28
31	6.3 Mechanical Accommodation Guidelines	28
32	7.0 THERMAL LEVEL 2 GUIDELINES.....	30
33	7.1 Assumptions	30
34	7.2 Thermal Interface	30
35	8.0 ENVIRONMENTAL LEVEL 2 GUIDELINES	32
36	8.1 Assumptions	32
37	8.2 Shipping/Storage Environment	32
38	8.3 Integration and Test Environment	34
39	8.4 Launch Environment	36
40	8.5 Operational Environment	43
41	9.0 REFERENCE MATERIAL / BEST PRACTICES	58
42	9.1 Data Interface Reference Material / Best Practices.....	58
43	9.2 Electrical Power Interface Reference Material / Best Practices	58

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 5 of 113

44	9.3	Mechanical Interface Reference Material / Best Practices -----	67
45	9.4	Thermal Interface Reference Material / Best Practices -----	74
46	9.5	Environmental Reference Material / Best Practices-----	77
47	9.6	Software Engineering Reference Material / Best Practices -----	77
48	9.7	Contamination Reference Material / Best Practices-----	78
49	9.8	Model Guidelines and Submittal Details -----	82
50			
51		Appendix A Acronyms.....	84
52		Appendix B Reference Documents	86
53		Appendix C Units of Measure and Metric Prefixes	89
54		Appendix D CII Hosted Payload Concept of Operations.....	90
55		Appendix E Supporting Analysis for LEO Guidelines	99
56		Appendix F Supporting Analysis for GEO Guidelines	103
57		Appendix G Instrument Modes	109
58		Appendix H Significant Differences among CII, ESA, and SMC Hosted Payload	
59		Guidelines	113
60			

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 6 of 113

List of Tables

61		
62	Table 5-1: Example of Power Source Impedance Function	24
63	Table 5-2: Instrument Power Allocation.....	26
64	Table 8-1: [GEO] Mass Acceleration Curve	38
65	Table 8-2: Sinusoidal Vibration Environment.....	39
66	Table 8-3: [LEO] Random Vibration Environment (derived from GEVS-SE, Table 2.4-4)	40
67	Table 8-4: [GEO] Random Vibration Environment	40
68	Table 8-5: Acoustic Noise Environment.....	42
69	Table 8-6: [GEO] Mechanical Shock Environment.....	43
70	Table 8-7: Thermal Radiation Environment	45
71	Table 8-8: [LEO] Total Ionizing Dose Radiation Environment	47
72	Table 8-9: [GEO] Total Ionizing Dose Radiation Environment.....	49
73	Table 8-10: [GEO] Particle fluxes in GEO w/ 100 mils of Aluminum Shielding.....	51
74	Table 8-11: Worst-case Micrometeoroid Environment	52
75	Table 8-12: [LEO] Worst-case Artificial Space Debris Environment.....	53
76	Table 8-13: [GEO] Worst-case Artificial Space Debris Environment	55
77	Table 9-1: Instrument Power Connector Pin Out Definition	65
78		
79	Table C-1: Units of Measure.....	89
80	Table C-2: Metric Prefixes.....	89
81	Table D-1:GEO/LEO Instrument Operating Modes Based Upon Mission Phase.....	97
82	Table E-1: Distribution of NICM Instruments Among Science Mission Directorate Divisions..	99
83	Table H-1: CII and ESA Hosted Payload Technical Guideline Differences	113
84		

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 7 of 113

List of Figures

85		
86	Figure 1-1: CII Scope.....	11
87	Figure 5-1: Spacecraft-Instrument Electrical Interface (Depicted with the optional Instrument	
88	side redundant Power Bus B interface).....	23
89	Figure 8-1: Shipping / Storage Environment.....	33
90	Figure 8-2: Integration and Test Environment.....	35
91	Figure 8-3: Launch Environment.....	37
92	Figure 8-4: Operational Environment.....	44
93	Figure 8-5: [LEO] TID versus Shielding Thickness.....	48
94	Figure 8-6: [GEO] TID versus Shielding Thickness.....	50
95	Figure 8-7: Worst-case Micrometeoroid Environment.....	53
96	Figure 8-8: [LEO]: Worst-case Artificial Space Debris Environment.....	54
97	Figure 8-9: [GEO] Worst-case Artificial Space Debris Environment.....	55
98	Figure 8-10: Atmospheric Atomic Oxygen density in Low Earth Orbit (Figure 2 from de Rooij	
99	2000).....	57
100	Figure 9-1: Instrument Side Power Bus #1 Circuit A & Circuit B.....	65
101	Figure 9-2: Instrument Side Power Bus #2 Circuit A & Circuit B.....	66
102	Figure 9-3: Instrument Side Survival Heater Power Bus Circuit A & Circuit B.....	66
103	Figure 9-4: Power Connector Keying.....	67
104		
105	Figure D-1: Geostationary Locations.....	91
106	Figure D-2: GOES-14 Image at 1000W.....	92
107	Figure D-3: Ground System Interfaces.....	93
108	Figure D-4: Summary of Transition to Normal Operations.....	93
109	Figure E-1: Instrument Mass vs. Development Cost.....	100
110	Figure E-2: Power as a Function of Mass.....	101
111	Figure E-3: Trend of Mean Instrument Data Rates.....	102
112	Figure G-1: Instrument Mode Transitions.....	109
113		

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 8 of 113

1.0 OVERVIEW

1.1 Introduction

These Common Instrument Interface (CII) Hosted Payloads Guidelines provide a prospective Instrument Developer with technical recommendations to help them design an Instrument that may be flown as a hosted payload either in Low Earth Orbit (LEO) or Geostationary Earth Orbit (GEO).

NASA Earth Science has implemented its Earth Venture Instrument (EVI) line of missions using a hosted payload model. Therefore, these guidelines primarily support stakeholders involved in NASA's EVI suite of investigations.

NASA competitively selects Principal Investigator (PI)-led EVI investigations via solicitations that "call for developing instruments for participation on a NASA-arranged spaceflight mission of opportunity to conduct innovative, integrated, hypothesis or scientific question-driven approaches to pressing Earth system science issues." The deliverables of a selected investigation includes "a flight qualified spaceflight instrument or instrument package ready for integration to a spacecraft, technical support for integration onto a NASA-determined spacecraft, and on-orbit operation of the instrument and delivery of science quality data." Prospective PI's propose their Instrument "without a firm identification of the spacecraft to accommodate it," and NASA deploys the selected Instrument on an existing planned spacecraft (Host Spacecraft).¹

This guideline document focuses on the technical aspects of flying an Earth Science Instrument on a Hosted Payload Opportunity (HPO). Because of the nature of the EVI acquisition strategy, Instrument Developers and Spacecraft Manufacturers proceed along the early stages of their respective product lifecycles independently. By vetting these technical parameters with space industry stakeholders, the CII team hopes to ensure maximum compatibility with the Earth-orbiting spacecraft market, leading to an increased likelihood of a successful Instrument to HPO pairing.

Instrument Developers are not required to comply with these guidelines. These guidelines are not met to replace Instrument Developer collaboration with Spacecraft Manufacturers, rather to provide familiarity of Spacecraft interfaces and accommodations in order to assist with such collaboration. Instrument parameters that exceed values specified in this guidance may very well be accommodated with additional resources that offset the impact to existing HPO designs (*e.g.*, investments enhancing Instrument capability) or that propose to enable compatibility after minor alterations to spacecraft performance (*e.g.*, investments enhancing Spacecraft capability). It is ultimately the responsibility of the Instrument Provider to investigate such cost-benefit considerations during proposal development.

¹ "Earth Venture Instrument-1," from Program Element Appendix (PEA) J of the Second Stand Alone Missions of Opportunity Notice (SALMON-2), 2012.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 9 of 113

1.2 Nomenclature and Definitions

The verb “should” denotes a recommendation. “Shall” denotes a requirement. “Will” denotes an expected future event.

Hosted Payload: a payload manifested on a spacecraft bus flying on a primary space mission.

Hosted Payload Opportunity: a spacecraft bus flying on a primary space mission with surplus resources to accommodate a hosted payload.

Instrument: the hosted payload of record that these guidelines describe.

Instrument Developer: the organization responsible for developing and building the Instrument itself.

Host Spacecraft: the Hosted Payload Opportunity spacecraft bus of record that these guidelines describe.

Host Spacecraft Manufacturer: the organization responsible for manufacturing the Host Spacecraft and the primary commercial payloads.

Satellite Operator: the organization responsible for on-orbit and ground operations throughout the Host Spacecraft’s lifetime.

Systems Integrator: the organization responsible for integrating the Instrument and Host Spacecraft.

1.3 Methodology

The content of this document is aggregated from several sources. The CII team used personal engineering experience, publicly available information, and privately held information shared by industry to define the primary technical components structuring this document and to establish its content. The CII team leveraged stakeholder feedback and numerous peer review workshops to guide efforts seeking to establish appropriate breadth and depth of the source material for the guidelines document. In order to increase the likelihood that a guideline-compliant Instrument design would technically fit within the accommodation space of an HPO, the CII team used an “all-satisfy” strategy. Specifically, for each technical performance measure, guidance is generally prescribed by the most restrictive value from the set of likely spacecraft known to operate in both the LEO and GEO domains. This strategy was again generally utilized to characterize environments, whereby the most strenuous environment expected in both the LEO and GEO domains inform best practices. Where considered necessary, the CII team based environmental guidance on independent modeling of particular low Earth orbits that are commonly considered advantageous in supporting Earth science measurements.

This methodology also allows for the sanitization of industry proprietary data. The set of expected LEO spacecraft is based upon the Rapid Spacecraft Development Office Catalog (<http://rsdo.gsfc.nasa.gov/catalog.html>), tempered by CII analyses of NASA databases and Communities of Practice. Smaller spacecraft (including microsatellites or secondary platforms)

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 10 of 113

are not precluded from host consideration. The set of expected GEO spacecraft is based upon industry responses to the *Request for Information for Geostationary Earth Orbit Hosted Payload Opportunities*.

One limitation of the “all-satisfy” strategy is that it constrains all instrument accommodation parameters to a greater degree than should be expected once the Instrument is paired with a Host Spacecraft. One size does not fit all in Hosted Payloads, especially in the GEO domain where the bus sizes vary among and within Spacecraft Manufacturers. Additionally, because a Spacecraft Manufacturer tailors its bus design to each Satellite Operator’s requirements, Instrument Developers may be able to negotiate an agreement for the Spacecraft Manufacturer to supply or for the Satellite Operator to require a larger bus or upgraded spacecraft performance than originally specified for the Satellite Operator. This enables the Host Spacecraft to accommodate more demanding Instrument requirements, given the application of enough resources. Because the Instrument to Host Spacecraft pairing occurs in the vicinity of Key Decision Point (KDP) C, certain knowledge of these available accommodation resources will be delayed well into the Instrument’s development timeline.

1.4 Interpretation

The content of this document represents recommendations, not requirements. These recommendations aid Instrument Developers proposing to EVI AO’s by documenting the CII team’s analysis of the interfaces and resource demands most likely to be accommodated on LEO and GEO HPO’s. While the EVI-1 AO references the CII guidelines and HPO database as “activities that document ... the types of opportunities that exist and the current interfaces and constraints that exist for each potential platform,” it does not state that compliance with the CII guidelines is mandatory.² The CII Team expects that future EVI AO’s will use the same model. The CII Team has limited the depth of guidelines to strike a balance between providing enough technical information to add value to a Pre-Phase A (Concept Studies) project and not overly constraining the Instrument design. This allows for a design sufficiently fungible to adapt to expected HPO’s and limits any (incorrectly inferred) compliance burdens.

While this document focuses on the technical aspects of hosted payloads, it is noteworthy that programmatic and market-based factors are likely more critical to the success of a hosted payload project than technical factors. When paired with commercial satellites, NASA can take advantage of the commercial space industries best practices and profit incentives to fully realize the benefits of hosted payloads. Because an EVI Instrument would neither be the primary payload or financial contributor on the Host Spacecraft, NASA may relinquish some of the oversight and decision rights it traditionally exerts in a dedicated mission. This leads to the “Do No Harm” concept explained in the Level 1 Design Guidelines. With this exception, programmatic and business aspects of hosted payloads are outside the scope of this document.

² “Earth Venture Instrument-1,” from Program Element Appendix (PEA) J of the Second Stand Alone Missions of Opportunity Notice (SALMON-2), 2012.

1.5 Scope

This document’s scope comprises five primary technical components of the Instrument to Host Spacecraft pairing: interface, accommodations, best practices, assumptions, and negotiated parameters. Figure 1-1 uses color to identify the scope: colored components are in scope; black components are out of scope.

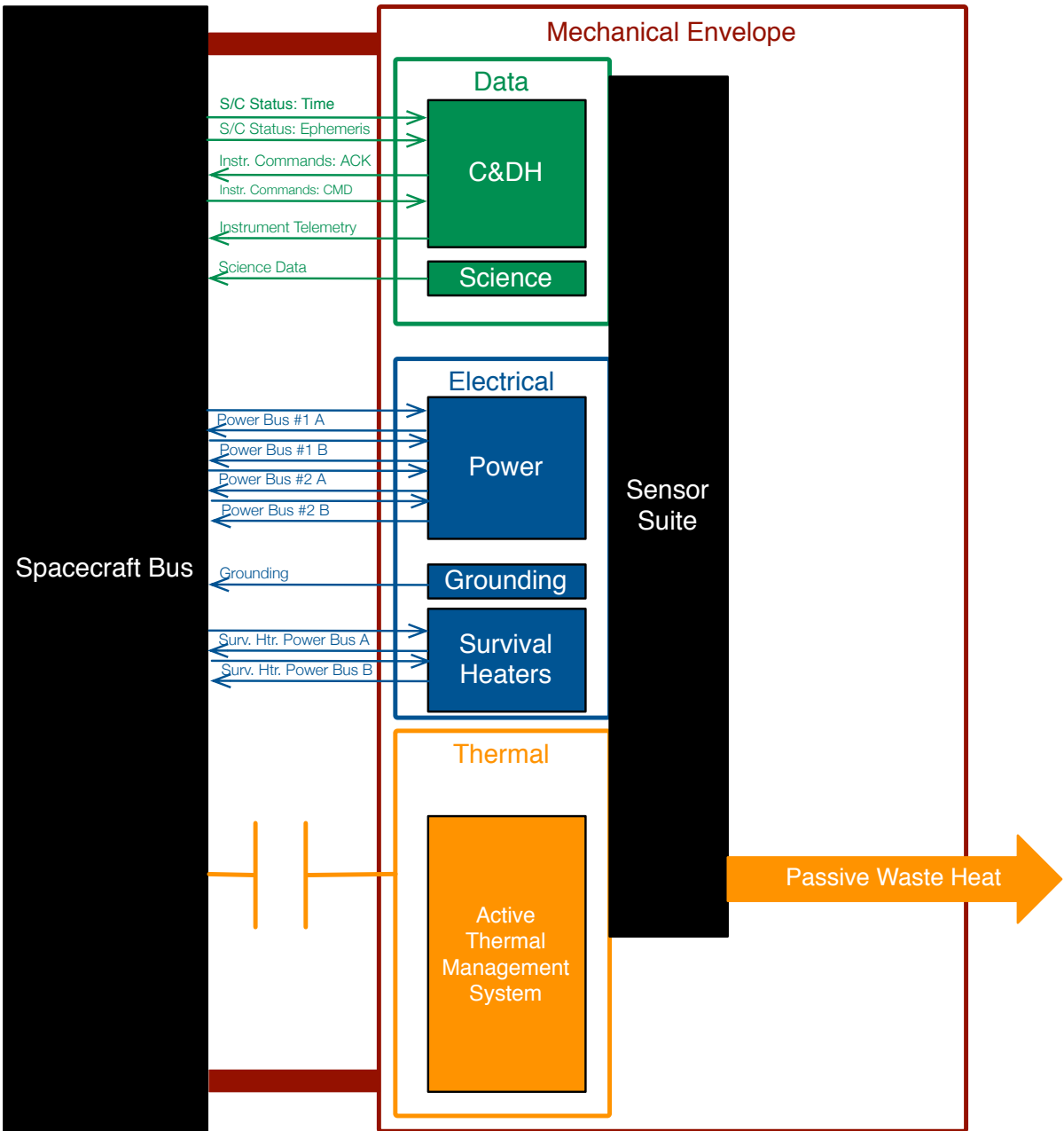


Figure 1-1: CII Scope

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 12 of 113

Interface guidelines describe the direct interactions between the Instrument and Host Spacecraft, such as physical connections and transfer protocols. Accommodation guidelines describe the constraints on the resources and services the Instrument is expected to draw upon from the Host Spacecraft, including size, mass, power, and transmission rates. While guidelines are not requirements—using the verb “should” instead of “shall”—they try to follow the rules of writing proper requirements, including providing rationale and maintaining traceability to higher level guidelines. This document provides two hierarchical levels of guidelines, because suggesting more specific technical details in the context of a hosted payload with not yet identified stakeholders is not credible.

The best practices capture additional technical information, less prescriptive than the guidelines, which an Instrument Developer might still find useful.

Assumptions are generally expectations of the characteristics and behavior of the Host Spacecraft and/or Host Spacecraft Manufacturer. Since Instrument requirement definition and design will likely happen prior to identification of the Host Spacecraft, these assumptions help bind the trade space.

Negotiated parameters reflect the effect of the Host Spacecraft and Instrument beginning development simultaneously and independently—some parameters will not be resolved prior to the Host Spacecraft to Instrument pairing. This document uses an Interface Control Document (ICD) construct as the means to record agreements reached among the Instrument Developer, Host Spacecraft Manufacturer, Launch Vehicle Provider, and Satellite Owner.

This document’s recommendations cover both the LEO and GEO domains. If a guideline or best practice is specific to one of the domains, it begins with either the [LEO] or [GEO] prefix. Guidelines or best practices without prefixes apply to both domains.

1.6 Revisioning

The Earth System Science Pathfinder (ESSP) Program Office released the Baseline version of CII guideline document, which only addressed interfaces for LEO platforms, in November 2011 in preparation for the EVI-1 AO. This Revision A version precedes the EVI-2 AO, providing more explicit definition of guideline scope and technical components, incorporating technical content for the GEO domain, and reducing design constraints on the Instrument Developer.

The CII Team plans to release updated guidelines preceding each future EVI AO release. This forward approach will ensure this document’s guidance reflects current technical interface capabilities of commercial spacecraft manufacturers and maintains cognizance of industry-wide design practices resulting from technological advances (*e.g.* xenon ion propulsion).

1.7 Interaction with Other Agencies Involved with Hosted Payloads

A measure of success for these guidelines is that they will have a broad acceptance among different communities and agencies. The Air Force Space and Missile Systems Center recently stood up a Hosted Payload Office (SMC/XRFH) to evaluate HPO’s as a distributed, resilient option within operational architectures. The European Space Agency’s (ESA) Future Missions

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 13 of 113

265 Division of their Earth Observation Program Directorate is also formulating a hosted payload
266 concept for their future missions. Both organizations are currently developing hosted payload
267 standards, although one important note is that the SMC and ESA elements will be prescriptive
268 requirements as opposed to the CII recommended guidelines.

269 The CII team has been working very closely with ESA over the past couple of years on a unified
270 set of guidelines for electrical power and data interfaces in the LEO domain. Due to different
271 sets of common practices in the American and European space industries, a small number of
272 technical differences exist between the CII and ESA guidelines.

273 Similarly, the CII team has been collaborating with SMC/XRFH to minimize the differences in
274 CII top-level guidelines and SMC requirements. The SMC requirements are currently in
275 development. Future versions of the CII document will summarize the differences with the SMC
276 requirements once they are finalized.

277 Appendix H summarizes these differences in tabular form.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 14 of 113

2.0 LEVEL 1 DESIGN GUIDELINES

The Common Instrument Interface has eleven Level 1 guidelines. These Level 1 guidelines are the highest guidelines in the hierarchy, and the rest of the lower-level guidelines depend on these.

2.1 Assumptions

2.1.1 Hosted Payload: The Host Spacecraft will have a primary mission different than that of the Instrument.

2.1.2 [GEO] Nominal Orbit: The Host Spacecraft will operate in GEO with an altitude of approximately 35786 kilometers and eccentricity and inclination of approximately zero.

2.1.3 [LEO] Nominal Orbit: The Host Spacecraft will operate in LEO with an altitude between 350 and 2000 kilometers with eccentricity less than 1 and inclination between zero and 180°, inclusive.

2.1.4 Responsibility for Integration: The Host Spacecraft Manufacturer will integrate the Instrument onto the Host Spacecraft with support from the Instrument Developer.

2.2 Guidelines

2.2.1 Hosted Payload Worldview

The Instrument should prevent itself or any of its components from damaging or otherwise degrading the mission performance of the Host Spacecraft or any other payloads.

Rationale: The most important constraint on a hosted payload is to “do no harm” to the Host Spacecraft or other payloads. The Satellite Operator will have the authority to remove power or otherwise terminate the Instrument should either the Host Spacecraft's available services degrade or the Instrument pose a threat to the rest of the Spacecraft. This guideline applies over the period beginning at the initiation of Instrument integration to the Host Spacecraft and ending at the completion of the disposal of the Host Spacecraft. It is important to note that most GEO communications satellites have a nominal mission lifetime in excess of 15 years or more while a hosted payload Instrument nominal lifetime is on the order of five years.

2.2.2 Data Interface

[LEO] The Instrument-to-Host Spacecraft data interfaces should use RS-422, SpaceWire, or MIL-STD-1553.

Rationale: RSS-422, SpaceWire, and MIL-STD-1553 are commonly accepted spacecraft data interfaces.

[GEO] The Instrument should use MIL-STD-1553 as the command and telemetry data interface with the Host spacecraft.

Rationale: The use of MIL-STD-1553 for command and telemetry is nearly universal across GEO spacecraft buses.

[GEO] The Instrument should send science data directly to its transponder via an RS-422, LVDS, or SpaceWire interface.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 15 of 113

315 Rationale: The use of RS-422, LVDS, or SpaceWire directly to a transponder for high-volume
316 payload data is a common practice on GEO spacecraft buses.

317 2.2.3 Data Accommodation

318 **[LEO] The Instrument should transmit less than 10 Mbps of data on average to the Host**
319 **Spacecraft. Data may be transmitted periodically in bursts of up to 100 Mbps.**

320 Rationale: CII analysis of the NICM Database (see Appendix E) shows 10 Mbps to be the upper
321 bound for instruments likely to find rides as LEO hosted payloads. Many spacecraft data buses
322 are run at signaling rates than can accommodate more than 10 Mbps. While this additional
323 capacity is often used to share bandwidth among multiple payloads, it may also be used for
324 periodic burst transmission when negotiated with the Host Spacecraft Providers and/or
325 Operators. When sizing Instrument data volume, two considerations are key: 1) The Instrument
326 should not assume the Host Spacecraft will provide any data storage (see guideline 4.3.1), and 2)
327 LEO downlink data rates vary considerably depending upon the antenna frequencies employed
328 (e.g. S-Band is limited to 2 Mbps while X-Band and Ka-Band may accommodate 100 Mbps or
329 more).

330 **[GEO] The Instrument should utilize less than 500 bps of MIL-STD-1553 bus bandwidth**
331 **when communicating with the Host Spacecraft.**

332 Rationale: The MIL-STD-1553 maximum 1 Mbps data rate is a shared resource. Most
333 spacecraft buses provide between 250 bps and 2 kbps for commanding and up to 4 kbps for
334 telemetry for all instruments and components on the spacecraft bus. Telemetry that is not critical
335 to the health and safety of either the Instrument or Host Spacecraft does not need to be monitored
336 by the Satellite Operator and therefore may be multiplexed with Instrument science data.

337 **[GEO] The Instrument should transmit less than 60 Mbps of science data to its**
338 **transponder.**

339 Rationale: Transponder bandwidth is a function of lease cost and hardware capability. Data rates
340 in the range of 60-80 Mbps for a single transponder are common. Higher data rates can be
341 achieved with multiple transponders (at an increased cost).

342 2.2.4 Electrical Power System Interface

343 **The Instrument should electrically ground to a single point on the Host Spacecraft.**

344 Rationale: The Instrument Electrical Power System (EPS) should ground in a way that reduces
345 the potential to introduce stray currents or ground loop currents into the Instrument, Host
346 Spacecraft, or other payloads.

347 2.2.5 Electrical Power System Accommodation

348 **[LEO] The Instrument EPS should draw less than or equal to 100W, averaged over the**
349 **orbit, from the Host Spacecraft.**

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 16 of 113

350 Rationale: CII analysis of the NICM Database (see Appendix E) shows 100 W to be the upper
351 bound for instruments likely to find rides as LEO hosted payloads.

352 **[LEO] The Instrument EPS should accept an unregulated input voltage of 28 ± 6 VDC.**

353 Rationale: The EPS architecture is consistent across LEO spacecraft bus manufacturers with the
354 available nominal voltage being 28 Volts Direct Current (VDC) in an unregulated (sun
355 regulated) configuration.

356 **[GEO] The Instrument should draw less than or equal to 300W of electrical power from
357 the Host Spacecraft.**

358 Rationale: The Host Spacecraft available electrical power varies significantly both by
359 manufacturer and by spacecraft bus configuration. 300 Watts represents a power level that all of
360 the Primary Manufacturers³ buses can accommodate, and requiring a power level less than this
361 increases the likelihood of funding a suitable Host Spacecraft.

362 **[GEO] The Instrument EPS should accept a regulated input voltage of 28 ± 3 VDC.**

363 Rationale: Host Spacecraft bus voltages vary by manufacturer, who design electrical systems
364 with the following nominal voltages: 28, 36, 50, 70, and 100 VDC. To maximize both voltage
365 conversion efficiency and available hosting opportunities, the Instrument should accept the
366 lowest nominal voltage provided, which is 28 VDC.

367 Note: this guideline may be superseded by Instruments that have payload-specific voltage or
368 power requirements or by “resistance only” power circuits (see below).

369 **[GEO] The Instrument payload primary heater circuit(s), survival heater circuit(s) and
370 other “resistance only” power circuits that are separable subsystems of the Instrument
371 payload EPS should accommodate the Host Spacecraft bus nominal regulated voltage and
372 voltage tolerance.**

373 Rationale: Host Spacecraft bus voltages vary by manufacturer, who design electrical systems
374 with the following nominal voltages: 28, 36, 50, 70, and 100 VDC. To minimize the amount of
375 power required to be converted to an input voltage of 28 ± 3 VDC and to maximize the available
376 hosting opportunities, an Instrument Developer should design “resistance only” power loads to
377 accept the spacecraft bus nominal voltage.

378 2.2.6 Thermal Interface

379 **The Instrument should be thermally isolated from the Host Spacecraft.**

³ In the context of this guideline, the Primary Manufacturers are the spacecraft manufacturers who responded to the CII RFI for GEO Hosted Payload Opportunities. They comprise more than 90% of the GEO commercial satellite market, based upon spacecraft either on-orbit or with publically-announced satellite operator contracts.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 17 of 113

Rationale: As a hosted payload, the Instrument should manage its own heat transfer needs without depending on the Host Spacecraft. The common practice in the industry is to thermally isolate the payload from the spacecraft.

2.2.7 Mechanical Interface

The Instrument should be capable of fully acquiring science data when directly mounted to the Host Spacecraft nadir deck.

Rationale: Assessments of potential LEO Host Spacecraft and the responses to the *CII RFI for GEO Hosted Payload Opportunities* indicate nadir-deck mounting of hosted payloads can be accommodated. Alternative mechanical interface locations or kinematic mounts are not prohibited by this guidance but may increase interface complexity.

2.2.8 Mechanical Accommodation

[LEO] The Instrument mass should be less than or equal to 100 kg.

Rationale: Analysis of the NICM database indicates that a 100kg allocation represents the upper bound for potential hosted payloads.

[GEO] The Instrument mass should be less than or equal to 150 kg.

Rationale: Analysis of the responses to the *CII RFI for GEO Hosted Payload Opportunities* indicate an instrument of up to 150 kg can be accommodated with minimal impact to existing spacecraft design and function. Instruments exceeding 150 kg can be accommodated but may require additional resources to address growing impacts to existing designs.

2.2.9 [GEO] Attitude Control System Pointing Accommodation

The Instrument 3σ pointing accuracy required should exceed 1440 seconds of arc (0.4 degrees) in each of the Host Spacecraft roll, pitch, and yaw axes.

Rationale: The Host Spacecraft bus pointing accuracy varies significantly both by manufacturer and by spacecraft bus configuration. 1440 arc-seconds represents a pointing accuracy that all of the Primary Manufacturers' buses can achieve. If an Instrument requires a pointing accuracy that is equivalent to or less stringent than this value, then the likelihood of finding a suitable Host Spacecraft increases significantly.

2.2.10 [GEO] Attitude Determination System Pointing Knowledge Accommodation

The Instrument 3σ pointing knowledge required should exceed 450 seconds of arc (0.125 degrees) in the Host Spacecraft roll and pitch axes and 900 seconds of arc (0.25 degrees) in the yaw axis.

Rationale: The Host Spacecraft bus pointing knowledge varies significantly both by manufacturer and by spacecraft bus configuration. 450 arc-seconds (roll/pitch) and 900 arc-seconds (yaw) represent a pointing knowledge that all of the Primary Manufacturers' buses can achieve. If an Instrument requires a pointing knowledge that is equivalent to or less stringent than this value, then the likelihood of finding a suitable Host Spacecraft increases significantly.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 18 of 113

2.2.11 [GEO] Payload Pointing Stability Accommodation

The Instrument should require a short term (≥ 0.1 Hz) 3σ pointing stability that is greater than or equal to 110 seconds of arc/second (0.03 degrees/second) in each spacecraft axis and a long term (Diurnal) 3σ pointing stability that is greater than or equal to 440 seconds of arc (0.12 degrees/second) in each spacecraft axis.

Rationale: Host Spacecraft pointing stability varies significantly both by manufacturer and by bus configuration. In order to maximize the probability of matching an available hosting opportunity, an instrument should be compatible with the maximum pointing stability defined for all responding Host Spacecraft Manufacturers' buses and configurations. According to information provided by industry, the level of short term (≥ 0.1 Hz) pointing stability available for secondary hosted payloads is ≤ 110 seconds of arc/second (0.03 degrees/second) in each of the spacecraft axes. The level of long term (Diurnal) pointing stability available for secondary hosted payloads is ≤ 440 seconds of arc/second (0.12 degrees/second) in each of the spacecraft axes. Therefore, an Instrument pointing stability requirement greater than these values will ensure that any prospective Host Spacecraft bus can accommodate the Instrument.

2.2.12 Environmental Interface

The Instrument should be compatible with and function according to its operational specifications in those environments encountered during Shipping/Storage, Integration and Test, Launch, and Operations as defined in Section 8.0.

Rationale: From the time the Instrument departs the facility in which it was constructed through on-orbit operations and decommissioning, it will encounter disparate environments with which it needs to be compatible with and function reliably and predictably.

2.2.13 Instrument Models

The Instrument Developer should submit finite element, thermal math, mechanical computer aided design, and mass models of the instrument to the Host Spacecraft manufacturer/integrator.

Rationale: The Host Spacecraft manufacturer/integrator requires models of all spacecraft components in order to complete the design portion of the spacecraft lifecycle.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 19 of 113

3.0 HOSTED PAYLOAD WORLDVIEW LEVEL 2 GUIDELINES

3.1 Mission Risk

The Instrument should comply with Mission Risk Class C safety and mission assurance requirements, in accordance with NPR 8705.4.

Rationale: NPR 8705.4 assigns Class C to medium priority, medium risk payloads, with medium to low complexity, short mission lifetime, and medium to low cost. The EVI-1 Announcement of Opportunity solicited "... proposals for science investigations requiring the development and operation of space-based instruments, designated as Class C on a platform to be identified by NASA at a later date."⁴

3.2 Instrument End of Life

The Instrument should place itself into a "safe" configuration upon reaching its end of life to prevent damage to the Host Spacecraft or any other payloads.

Rationale: The Instrument may have potential energy remaining in components such as pressure vessels, mechanisms, batteries, and capacitors, from which a post-retirement failure might cause damage to the Spacecraft Host or its payloads. The Instrument Developer should develop, in concert with the Host Spacecraft and the Satellite Operator, an End of Mission Plan that specifies the actions that the Instrument payload and Host Spacecraft will take to "safe" the Instrument payload by reduction of potential energy once either party declares the Instrument's mission "Complete."

3.3 Prevention of Failure Back-Propagation

The Instrument and all of its components should prevent anomalous conditions, including failures, from propagating to the Host Spacecraft or other payloads.

Rationale: The Instrument design should isolate the effects of Instrument anomalies and failures, such as power spikes, momentum transients, and electromagnetic interference so that they are contained within the boundaries of the Instrument system.

⁴ "Earth Venture Instrument-1," from Program Element Appendix (PEA) J of the Second Stand Alone Missions of Opportunity Notice (SALMON-2), 2012.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 20 of 113

4.0 DATA LEVEL 2 GUIDELINES

4.1 Assumptions

The CII data guidelines assume the following regarding the Host Spacecraft:

- 1) During the matching process, the Host Spacecraft Manufacturer/Systems Integrator and the Instrument Developer will negotiate detailed parameters of the data interface. The Data Interface Control Document (DICD) will record those parameters and decisions.

4.2 Data Interface Guidelines

4.2.1 Command Dictionary

The Instrument Provider should provide a command dictionary to the Host Spacecraft Manufacturer, the format and detail of which will be negotiated with the Host Spacecraft Manufacturer.

Rationale: Best practice and consistent with DICD. A command dictionary defines all instrument commands in detail, by describing the command, including purpose, preconditions, possible restrictions on use, command arguments and data types (including units of measure, if applicable), and expected results (*e.g.* hardware actuation and/or responses in telemetry) in both nominal and off-nominal cases. Depending on the level of detail required, a command dictionary may also cover binary formats (*e.g.* packets, opcodes, *etc.*).

4.2.2 Telemetry Dictionary

The Instrument Provider should provide a telemetry dictionary to the Host Spacecraft Manufacturer, the format and detail of which will be negotiated with the Host Spacecraft Manufacturer.

Rationale: Best practice and consistent with DICD. A telemetry dictionary defines all information reported by the instrument in detail, by describing the data type, units of measure, and expected frequency of each measured or derived value. If telemetry is multiplexed or otherwise encoded (*e.g.* into virtual channels), the telemetry dictionary will also describe decommutation procedures which may include software or algorithms. By their nature, telemetry dictionaries often detail binary packet formats.

4.2.3 SAFE mode

The Instrument should provide a SAFE mode.

The Instrument Safe mode is a combined Instrument hardware and software configuration meant to protect the Instrument from possible internal or external harm while making minimal use of Spacecraft resources (*e.g.* power).

4.2.4 Command (SAFE mode)

The Instrument should enter SAFE mode when commanded either directly by the Host Spacecraft or via ground operator command.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 21 of 113

504 Rationale: The ability to put the Instrument into SAFE mode protects and preserves both the
505 Instrument and the Host Spacecraft under anomalous and resource constrained conditions.

506 4.2.5 Command (Data Flow Control)

507 **The Instrument should respond to commands to suspend and resume the transmission of**
508 **Instrument telemetry and Instrument science data.**

509 Rationale: Data flow control allows the Spacecraft, Satellite Operator, and ground operations
510 team to devise and operate Fault Detection Isolation, and Recovery (FDIR) procedures, crucial
511 for on-orbit operations.

512 4.2.6 Command (Acknowledgement)

513 **The Instrument should acknowledge the receipt of all commands, in its telemetry.**

514 Rationale: Command acknowledgement allows the Spacecraft, Satellite Operator, and ground
515 operations team to devise and operate FDIR procedures, crucial for on-orbit operations.

516 4.3 **Data Accommodation Guidelines**

517 4.3.1 Onboard Science Data Storage

518 **The Instrument should be responsible for its own science data onboard storage capabilities.**

519 Rationale: Buffering all data on the Instrument imposes no storage capacity requirements on the
520 Spacecraft. This is consistent with the direct-to-transponder science data interface [GEO]. A
521 spacecraft need only enough buffer capacity to relay Instrument telemetry. Fewer resource
522 impacts on the Spacecraft maximize Instrument hosting opportunities.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 22 of 113

5.0 ELECTRICAL POWER SYSTEM LEVEL 2 GUIDELINES

5.1 Assumptions

The CII electrical power guidelines assume the following regarding the Host Spacecraft:

- 1) During the matching process, the Host Spacecraft Manufacturer/Systems Integrator and the Instrument Developer will negotiate detailed parameters of the electrical power interface. The Electrical Power Interface Control Document (EICD) will record those parameters and decisions.
- 2) [LEO] The Host Spacecraft will supply to the Instrument EPS unregulated (sun regulated) electrical power within the range of 28 ± 6 VDC, including ripple and normal transients as defined below, and power distribution losses due to switching, fusing, harness and connectors.
- 3) [GEO] The Host Spacecraft will supply to the Instrument EPS regulated electrical power within the range of 28 ± 3 VDC, including ripple and normal transients as defined below, and power distribution losses due to switching, fusing, harness and connectors.
- 4) [LEO] The Host Spacecraft will provide connections to two 50W (Orbital Average Power: OAP) power buses as well as a dedicated bus to power the Instrument's survival heaters. Each bus will have a primary and redundant circuit. For the purpose of illustration, this document labels these buses as Power Bus #1, Power Bus #2, and Survival Heater Power Bus. This document also labels the primary and redundant circuits as A and B, respectively. Figure 5-1 shows a pictorial representation of this architecture.
- 5) [GEO] The Host Spacecraft will provide connections to two 150W (Average Power: AP) power buses as well as a dedicated bus to power the Instrument's survival heaters. Each power bus will be capable of supporting both primary and redundant power circuits. For the purpose of illustration, this document labels these buses as Power Bus #1, Power Bus #2, and Survival Heater Power Bus. This document also labels the primary and redundant circuits as A and B, respectively. Figure 5-1 shows a pictorial representation of this architecture.
- 6) The Host Spacecraft will energize the Survival Heater Power Bus at 30% of the OAP [LEO]/AP [GEO] in accordance with the mission timeline documented in the EICD.
- 7) The Host Spacecraft Manufacturer will supply a definition of the maximum source impedance by frequency band. Table 5-1 provides an example of this definition.
- 8) The Host Spacecraft Manufacturer will furnish all Spacecraft and Spacecraft-to-Instrument harnessing.
- 9) The Host Spacecraft will deliver Instrument power via twisted conductor (pair, quad, etc.) cables with both power and return leads enclosed by an electrical overshield.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 23 of 113

- 10) The Host Spacecraft will protect its own electrical power system via overcurrent protection devices on its side of the interface.
- 11) The Host Spacecraft will utilize the same type of overcurrent protection device, such as latching current limiters or fuses, for all connections to the Instrument.
- 12) In the event that the Host Spacecraft battery state-of-charge falls below 50%, the Host Spacecraft will power off the Instrument after placing the Instrument in SAFE mode. Instrument operations will not resume until the ground operators have determined it is safe to return to OPERATION mode.
- 13) The Host Spacecraft will deliver a maximum transient current on any Power Feed bus of 100 percent (that is, two times the steady state current) of the maximum steady-state current for no longer than 50 ms.

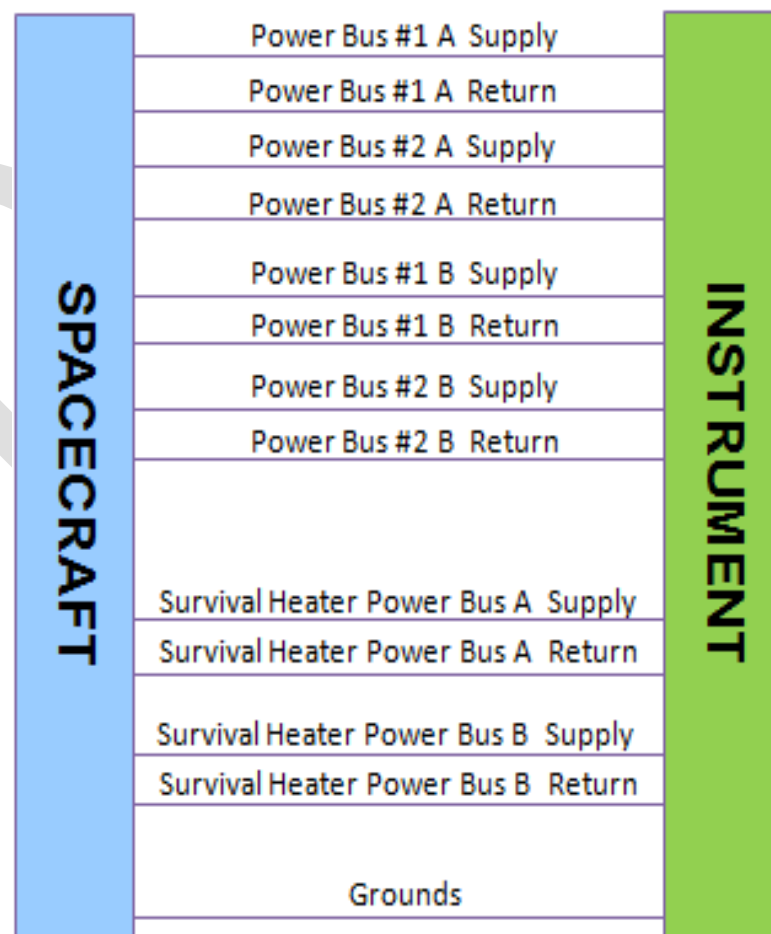


Figure 5-1: Spacecraft-Instrument Electrical Interface (Depicted with the optional Instrument side redundant Power Bus B interface)

Table 5-1: Example of Power Source Impedance Function

Frequency	Maximum Source Impedance [Ω]
1 Hz to 1 kHz	0.2
1 kHz to 20 kHz	1.0
20 kHz to 100 kHz	2.0
100 kHz to 10 MHz	20.0

5.2 EPS Interface

All guidelines in this section should be met at the electrical interface.

5.2.1 Power Bus Interface

The EPS should provide nominal power to each Instrument component via one or both of the Power Buses.

Rationale: The Power Buses supply the electrical power for the Instrument to conduct normal operations. Depending on the load, a component may connect to one or both of the power buses.

Note: The utilization of the redundant power circuits (Power Circuits B) by the Instrument is optional based upon instrument mission classification, reliability, and redundancy requirements.

5.2.2 Survival Heater Bus Interface

The EPS should provide power to the survival heaters via the Survival Heater Power Bus.

Rationale: The Survival Heaters, which are a member of the Thermal subsystem, require power to heat certain instrument components during off-nominal scenarios when the Power Buses are not fully energized. See Best Practices sections 9.2.3 and 9.4.2 for more discussion about survival heaters.

5.2.3 Grounding

The Instrument grounding architecture should comply with NASA-HDBK-4001.

Rationale: The Instrument grounding architecture must be established at the earliest point in the design process. The implementation of the subject level 1 guidance in conjunction with the consistent and proven design principles described in the ascribed reference will support a successful instrument development and integration to a Host Spacecraft and mission.

5.2.4 Grounding Documentation

The EICD will document how the Instrument will ground to the Host Spacecraft.

Rationale: It is necessary to define and document the Instrument to Host Spacecraft grounding interface architecture.

5.2.5 Bonding

The Instrument bonding should comply with NASA-STD-4003.

Rationale: The instrument bonding practices must be defined to support the instrument design and development process. The implementation of the subject reference will provide consistent

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 25 of 113

603 and proven design principles and support a successful instrument development, integration to a
604 Host Spacecraft and mission.

605 5.2.6 Mitigation of In-Space Charging Effects

606 **The Instrument should comply with NASA-HDBK-4002 to mitigate in-space charging**
607 **effects.**

608 Rationale: The application of the defined reference to the Instrument grounding architecture and
609 bonding practices will address issues and concerns with the in-flight buildup of charge on
610 internal spacecraft components and external surfaces related to space plasmas and high-energy
611 electrons and the consequences of that charge buildup.

612 5.2.7 Instrument Harnessing

613 **The Instrument Developer should furnish all Instrument harnessing.**

614 Rationale: The Instrument Developer is responsible for all harnesses that are constrained by the
615 boundaries of the Instrument as a single and unique system. This refers only to those harnesses
616 that are interconnections between components (internal and external) of the Instrument system
617 and excludes any harnesses interfacing with the Host Spacecraft or components that are not part
618 of the Instrument system.

619 5.2.8 Harness Documentation

620 **The EICD will document all harnesses, harness construction, pin-to-pin wiring, cable type,**
621 **connectors, ground straps, and associated service loops.**

622 Rationale: The EICD documents agreements made between the Host Spacecraft Manufacturer
623 and Instrument Developer regarding harness hardware and construction.

624 5.3 **EPS Accommodation**

625 This section specifies the characteristics, connections, and control of the Spacecraft power
626 provided to each Instrument as well as the requirements that each Instrument must meet at this
627 interface. This section applies equally to the Power Buses and the Survival Heater Power Buses.

628 5.3.1 Definitions

629 Average Power Consumption: the total power consumed averaged over any 180-minute period.

630 Peak Power Consumption: the maximum power consumed averaged over any 10 ms period.

631 5.3.2 Instrument Power Harness

632 **Instrument power harnesses should be sized to support the peak Instrument power level**
633 **and both Host Spacecraft and Instrument overcurrent protection devices.**

634 Rationale: Sizing all components of the Instrument power harness, such as the wires,
635 connectors, sockets, and pins to the peak power level required by the Instrument and Host
636 Spacecraft prevents damage to the power harnessing.

5.3.3 Allocation of Instrument Power

The EPS should draw no more power from the Host Spacecraft in each Instrument mode than defined in Table 5-2.

Rationale: The Level 1 guideline defines power allocation for the OPERATION mode. The assumption that the instrument requires 100% of the power required in the OPERATION mode defines the power allocation for the ACTIVATION mode. The assumption that the instrument requires 50% of the power required in the OPERATION mode defines the power allocation for the SAFE mode. The assumption that the instrument only requires survival heater power defines the power allocation for the SURVIVAL mode.

Note: Instrument and Instrument survival heater power should not exceed the defined power allocation at end-of-life at worst-case low bus voltage.

Note: The instrument modes are notional and based upon an example provided in Appendix G.

Table 5-2: Instrument Power Allocation

Mode	LEO		GEO
	Peak (W)	Average (W)	Average (W)
OFF/ SURVIVAL	0/60	0/30	0/90
ACTIVATION	200	100	300
SAFE	100	50	150
OPERATION	200	100	300

5.3.4 Unannounced Removal of Power

The Instrument should function according to its operational specifications when nominal power is restored following an unannounced removal of power.

Rationale: In the event of a Host Spacecraft electrical malfunction, the instrument would likely be one of the first electrical loads to be shed either in a controlled or uncontrolled manner.

5.3.5 Reversal of Power

The Instrument should function according to its operational specifications when proper polarity is restored following a reversal of power (positive) and ground (negative).

Rationale: This defines the ability of an instrument to survive a power reversal anomaly which periodically occurs during assembly, integration, and test (AI&T).

5.3.6 Power-Up and Power-Down

The Instrument should function according to its operational specifications when the Host Spacecraft changes the voltage across the Operational Bus from +28 to 0 VDC or from 0 to +28 VDC as a step function.

Rationale: A necessary practice to preclude instrument damage/degradation.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 27 of 113

5.3.7 Abnormal Operation Steady-State Voltage Limits

The Instrument should function according to its operational specifications when the Host Spacecraft restores nominal power following exposure to steady-state voltages from 0 to 50 VDC.

Rationale: Defines a verifiable (testable) limit for off-nominal input voltage testing of an instrument.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 28 of 113

6.0 MECHANICAL LEVEL 2 GUIDELINES

6.1 Assumptions

The CII mechanical guidelines assume the following regarding the Host Spacecraft:

- 1) During the matching process, the Host Spacecraft Manufacturer/Systems Integrator and the Instrument Developer will negotiate detailed parameters of the mechanical interface. The Mechanical Interface Control Document (MICD) will record those parameters and decisions.
- 2) The Host Spacecraft will accommodate fields-of-view (FOV) that equal or exceed the Instrument science and radiator requirements.
- 3) The Host Spacecraft Contractor will furnish all instrument mounting fasteners.

6.2 Mechanical Interface Guidelines

6.2.1 Functionality in 1 g Environment

The Instrument should function according to its operational specifications in any orientation while in the integration and test environment.

Rationale: As a hosted payload, the Instrument will attach to one of multiple decks on the Host Spacecraft. Its orientation with respect to the Earth's gravitational field during integration and test will not be known during the instrument design process. The function of the instrument and accommodation of loads should not depend on being in a particular orientation.

6.2.2 Stationary Instrument Mechanisms

The Instrument should cage any mechanisms that require restraint, without requiring Host Spacecraft power to maintain the caged condition, throughout the launch environment.

Rationale: As a hosted payload, the Instrument should not assume that the Host Spacecraft will provide any power during launch.

6.3 Mechanical Accommodation Guidelines

6.3.1 Dimensions

[LEO] The Instrument and all of its components should remain within the detailed instrument envelope of 400mm × 500mm × 850mm (H×W×L) during all phases of flight.

Rationale: Engineering analysis determined guideline payload volume based on mass guidelines and comparisons to spacecraft envelopes in the NASA Rapid Spacecraft Development Office (RSDO) catalog.

[GEO] The Instrument and all of its components should remain within the detailed instrument envelope of 1000mm × 1000mm × 1000mm (H×W×L) during all phases of flight.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 29 of 113

703 Rationale: Engineering analysis determined guideline payload volume based on mass guidelines
704 and comparisons to spacecraft envelopes in responses to the *CII RFI for GEO Hosted Payload*
705 *Opportunities and Accommodations.*

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 30 of 113

7.0 THERMAL LEVEL 2 GUIDELINES

7.1 Assumptions

The CII thermal guidelines assume the following regarding the Host Spacecraft:

- 1) During the matching process, the Host Spacecraft Manufacturer/Systems Integrator and the Instrument Developer will negotiate detailed parameters of the thermal power interface. The Thermal Interface Control Document (TICD) will record those parameters and decisions.
- 2) The Host Spacecraft will maintain a temperature range of between -40° C and 70°C on the Spacecraft side of the interface from the Integration through Disposal portions of its lifecycle.
- 3) The Spacecraft Manufacturer will be responsible for thermal hardware used to close out the interfaces between the Instrument and Spacecraft, such as closeout Multi-layer Insulation (MLI).

7.2 Thermal Interface

7.2.1 Thermal Design at the Mechanical Interface

The Instrument thermal design should be decoupled from the Spacecraft at the mechanical interface spacecraft and neighboring payloads as much as possible.

Rationale: As a hosted payload, the instrument should not interfere with the Host Spacecraft's functions. The common practice in the industry is to thermally isolate the payload from the spacecraft.

7.2.2 Conductive Heat Transfer

The conductive heat transfer at the Instrument-Host Spacecraft mechanical interface should be less than 15 W/m² or 4 W.

Rationale: A conductive heat transfer of 15 W/m² or 4 W is considered small enough to meet the intent of being thermally isolated.

7.2.3 Radiative Heat Transfer

The TICD will document the allowable radiative heat transfer from the Instrument to the Host Spacecraft.

Rationale: There is a limit to how much heat the Instrument should transmit to the Host Spacecraft via radiation, but that limit will be unknown prior to the thermal analysis conducted following Instrument-to-Host Spacecraft pairing. The TICD will document that future negotiated value.

7.2.4 Temperature Maintenance Responsibility

The Instrument should maintain its own instrument temperature requirements.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 31 of 113

740 Rationale: As a thermally isolated payload, the Instrument has to manage its own thermal
741 properties without support from the Host Spacecraft.

742 7.2.5 Instrument Allowable Temperatures

743 **The TICD will document the allowable temperature ranges that the Instrument will**
744 **maintain in each operational mode/state.**

745 Rationale: Defining the instrument allowable temperatures drives the performance requirements
746 for the thermal management systems for both the Instrument as well as the Host Spacecraft.

747 7.2.6 Thermal Control Hardware Responsibility

748 **The Instrument Provider should provide and install all Instrument thermal control**
749 **hardware including blankets, temperature sensors, louvers, heat pipes, radiators, and**
750 **coatings.**

751 Rationale: This responsibility naturally follows the responsibility for the instrument thermal
752 design and maintaining the temperature requirements of the instrument.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 32 of 113

8.0 ENVIRONMENTAL LEVEL 2 GUIDELINES

8.1 Assumptions

The CII environmental guidelines assume the following regarding the Host Spacecraft, launch vehicle, and/or integration and test facilities:

- 1) During the matching process, the Host Spacecraft Manufacturer/Systems Integrator and the Instrument Developer will negotiate detailed parameters of the environmental interface. The Environmental Interface Control Document (EICD) will record those parameters and decisions.

Note: the design of the Instrument modes of operation are the responsibility of the Instrument Developer. For purposes of illustration, the operational modes in this section are equivalent to the Instrument modes and states as defined in Appendix G.

8.2 Shipping/Storage Environment

The Shipping/Storage Environment represents the time in the Instrument's lifecycle between when it departs the Instrument Developer's facility and arrives at the facility of the Spacecraft Manufacturer/Systems Integrator. The Instrument is dormant and attached mechanically to its container (see Figure 8-1).

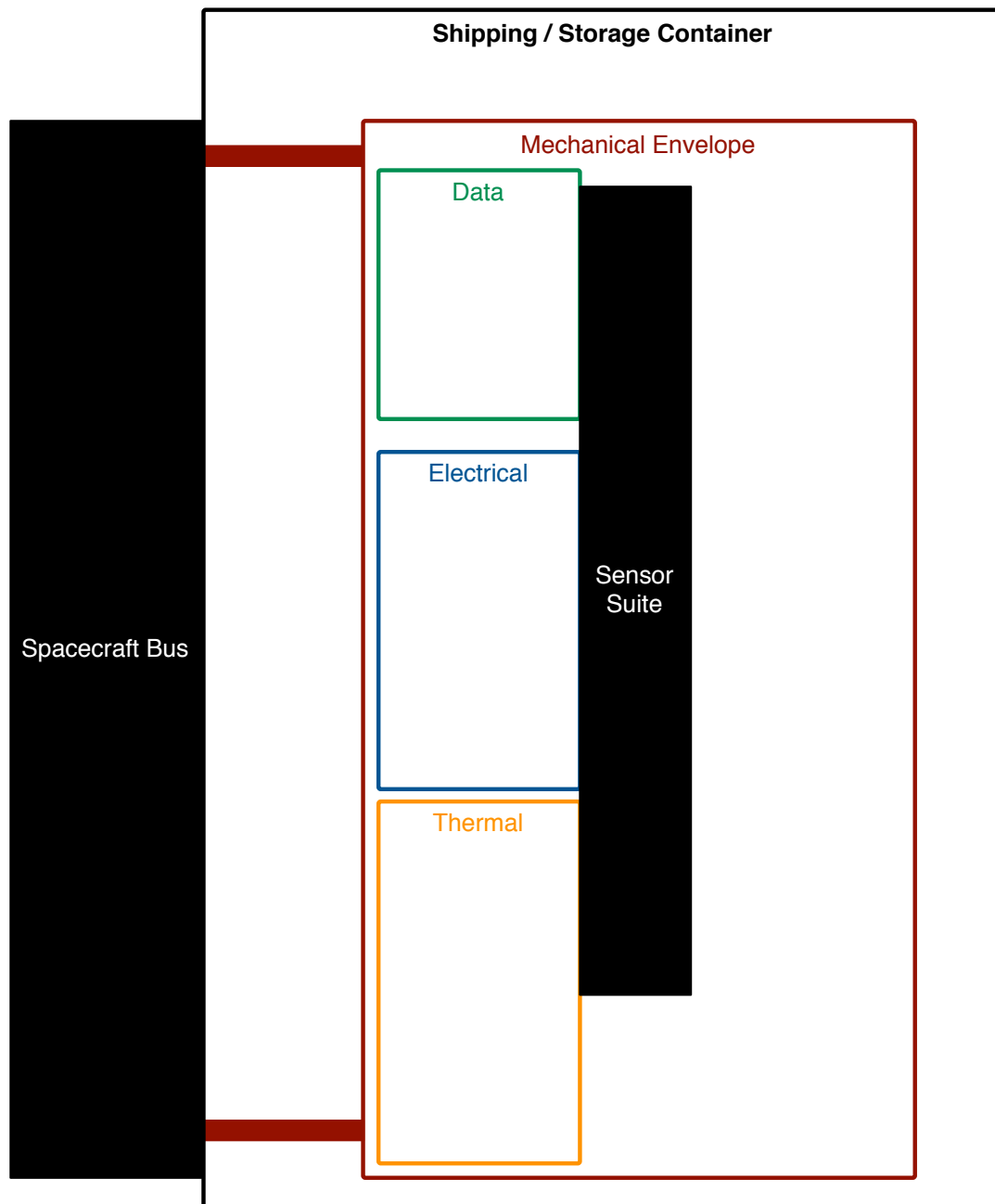


Figure 8-1: Shipping / Storage Environment

8.2.1 Documentation

The EICD will document the expected environment the Instrument will experience between the departure from the Instrument assembly facility and arrival at the Host Spacecraft integration facility.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 34 of 113

775 Rationale: The nature of the Shipping/Storage Environment depends upon the point at which
776 physical custody of the Instrument transfers from Instrument Developer to the Satellite
777 Contractor/Systems Integrator as well as negotiated agreements on shipping/storage procedures.

778 The interfaces associated with the shipping/storage environment include the allowable
779 temperatures and the characteristics of the associated atmosphere.

780 8.2.2 Instrument Configuration

781 **The EICD will document the configuration and operational state of the Instrument during**
782 **the Shipping/Storage phase.**

783 Rationale: Specifying the configuration of the Instrument during shipping/storage drives the
784 volume requirements for the container as well as any associated support equipment and required
785 services.

786 The Instrument will likely be in the OFF/SURVIVAL mode while in this environment.

787 8.3 **Integration and Test Environment**

788 The Integration and Test Environment represents the time in the Instrument's lifecycle between
789 when it arrives at the facility of the Spacecraft Manufacturer/Systems Integrator through payload
790 encapsulation at the launch facility. During this phase, the Host Spacecraft
791 Manufacturer/Systems Integration will attach the Instrument to the Host Spacecraft Bus and
792 verify that system performs as designed throughout various environmental and dynamics
793 regimes. The Instrument may be attached to the Host Spacecraft Bus or to various ground
794 support equipment that transmits power, thermal conditioning, and diagnostic data (see Figure
795 8-2).

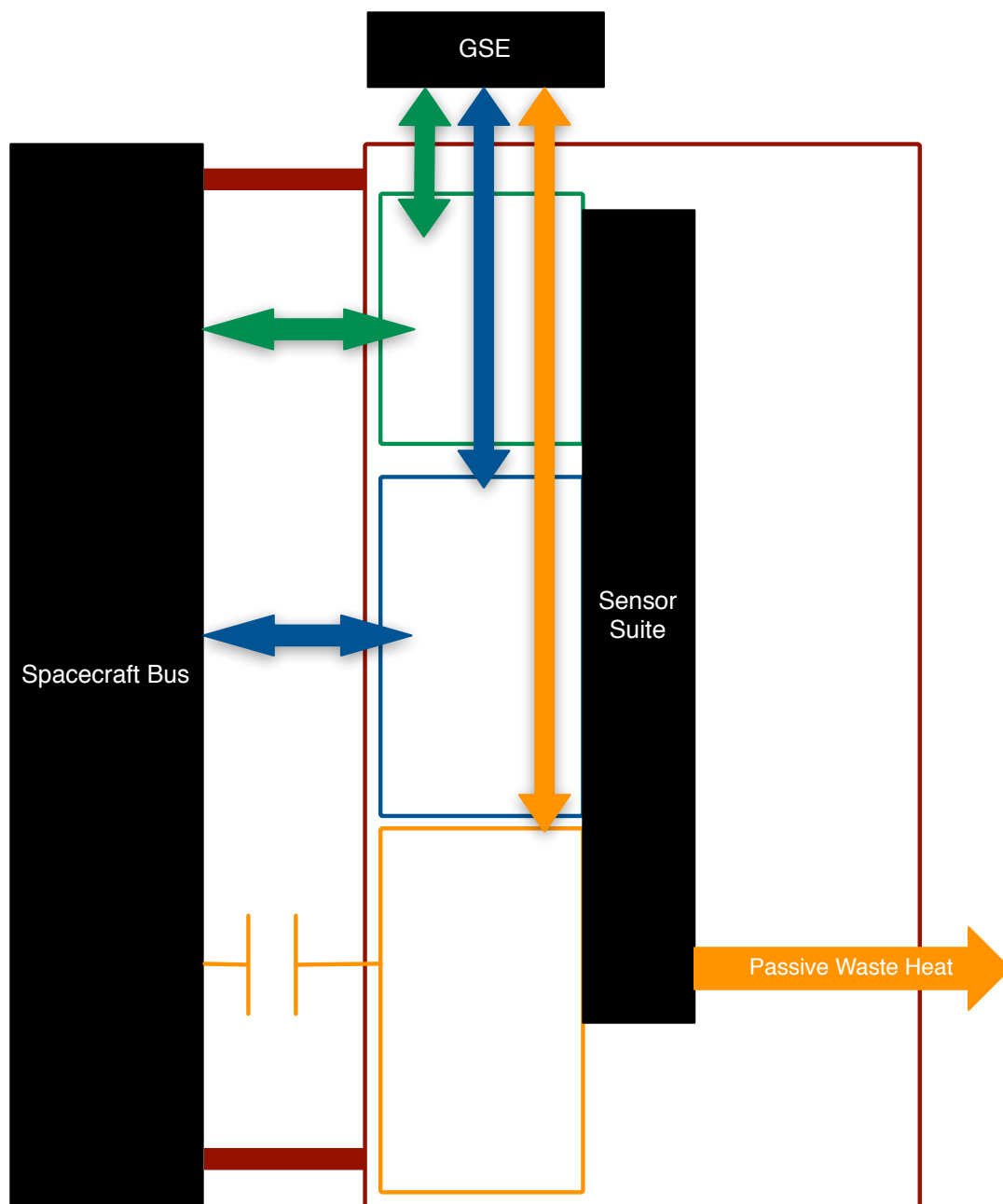


Figure 8-2: Integration and Test Environment

8.3.1 Documentation

The EICD will document the expected environments the Instrument will experience between arrival at the Host Spacecraft integration facility and Launch.

Rationale: The nature of the Integration and Test Environment depends upon the choice of Host Spacecraft and Launch Vehicle as well as the negotiated workflows at the Systems Integration and Launch facilities.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 36 of 113

804 Example environmental properties include the thermal, dynamic, atmospheric, electromagnetic,
805 radiation characteristics of each procedure in the Integration and Test process. The EICD may
806 either record these data explicitly or refer to a negotiated Test and Evaluation Master Plan
807 (TEMP).

808 8.3.2 Instrument Configuration

809 **The EICD will document the configuration and operational mode of the Instrument during**
810 **the Integration and Test phase.**

811 Rationale: Proper configuration of the Instrument during the various Integration and Test
812 procedures ensures the validity of the process.

813 8.4 **Launch Environment**

814 The Launch Environment represents that time in the Instrument's lifecycle when it is attached to
815 the launch vehicle via the Host Spacecraft, from payload encapsulation at the Launch facility
816 through the completion of the launch vehicle's final injection burn (see Figure 8-3).

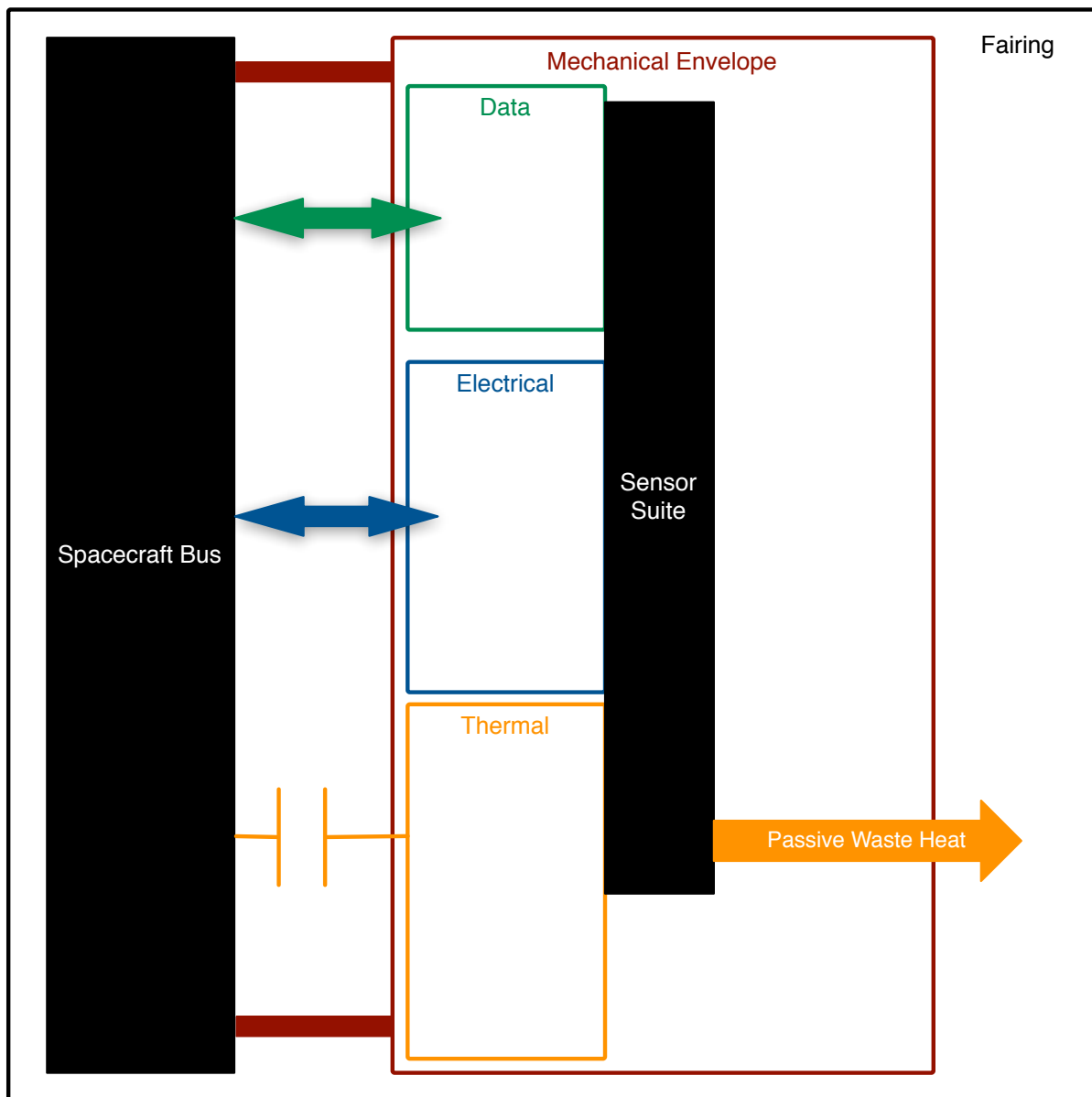


Figure 8-3: Launch Environment

8.4.1 Documentation

The EICD will document the expected environments the Instrument will experience between Launch and Host Spacecraft / Launch Vehicle separation.

Rationale: The nature of the Launch Environment depends upon the choice of Host Spacecraft and Launch Vehicle. Significant parameters related to the launch environment include temperature, pressure, and acceleration profiles.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 38 of 113

8.4.2 Instrument Configuration

The EICD will document the configuration and operational state of the Instrument during the Launch phase.

Rationale: The Launch phase is the most dynamic portion of the mission, and the Instrument configuration and operational mode are chosen to minimize damage to either the Instrument or Host Spacecraft. The Instrument will likely be in the OFF/SURVIVAL mode while in this environment.

The following guidelines are representative of a typical launch environment but may be tailored on a case-by-case basis.

8.4.3 Launch Pressure Profile

The Instrument should function according to its operational specifications after being subjected to an atmospheric pressure decay rate of 7 kPa/s (53 Torr/s).

Rationale: The Instrument must be able to withstand conditions typical of the AI&T, launch and on-orbit environments without suffering degraded performance or being damaged or inducing degraded performance of, or damage to, the Host Spacecraft or other payloads. This guidance represents the maximum expected pressure decay rate during launch ascent and applies to LEO and GEO launch vehicles. The GEO guideline is the all-satisfy strategy scenario, based upon CII analysis of the following sources of performance data: *CII RFI for GEO Hosted Payload Opportunities* responses, the *General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components (GEVS-SE)*, and *Geostationary Operational Environmental Satellite GOES-R Series General Interface Requirements Document (GOES-R GIRD)*.

8.4.4 Quasi-Static Acceleration

[GEO] The Instrument should function according to its operational specifications after being subjected to a launch vehicle-induced quasi-static acceleration environment represented by the MAC defined in Table 8-1.

Table 8-1: [GEO] Mass Acceleration Curve

Mass [kg]	Acceleration [g]
0 to 2.5	± 55
2.5 to 30	$= \pm (-1.273 \times \text{Mass} + 58.182)$
>30	± 20

Rationale: The Instrument must able to withstand conditions typical of the AI&T, launch and on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. This guidance represents the need to be compatible with the quasi-static loads that will be experienced during launch ascent. The GEO guideline is the all-satisfy strategy scenario, based upon CII analysis of the following sources of performance data: *CII RFI for GEO Hosted Payload Opportunities* responses, the *GEVS-SE*, and *GOES-R GIRD*.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 39 of 113

The “Mass” is the mass of the entire instrument or any component of the instrument. The MAC applies to the worst-case single direction, which might not be aligned with coordinate directions, to produce the greatest load component (axial load, bending moment, reaction component, stress level, etc.) being investigated and also to the two remaining orthogonal directions.

8.4.5 Sinusoidal Vibration

The Instrument should function according to its operational specifications after being subjected to a launch vehicle-induced transient environment represented by the sinusoidal vibration environment defined in Table 8-2.

Table 8-2: Sinusoidal Vibration Environment

Frequency (Hz)	Acceleration Amplitudes	
	Acceptance	Qualification
2 – 5	1.0 g peak	1.4 g peak
5 – 18	1.4 g peak	2.0 g peak
18 – 30	1.5 g peak	2.1 g peak
30 – 40	1.0 g peak	1.4 g peak
40 – 55	3.0 g peak	4.2 g peak
55 – 100	1.0 g peak	1.4 g peak
Acceptance Sweep Rate: From 5 to 100 Hz at 1.0 octaves/minute except from 40 to 55 Hz at 12 Hz/min		
Qualification Sweep Rate: From 5 to 100 Hz at 0.5 octaves/minute except from 40 to 55 Hz at 6 Hz/min		

Rationale: The Instrument must be able to withstand conditions typical of the AI&T, launch and on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. This guidance represents the need to be compatible with the coupled dynamics loads that will be experienced during ground processing and launch ascent. The GEO guideline is the all-satisfy strategy scenario, based upon CII analysis of all publicly available launch vehicle payload planner’s guides.

8.4.6 Random Vibration

[LEO] The Instrument should function according to its operational specifications after being subjected to a launch vehicle-induced transient environment represented by the random vibration environment defined in Table 8-3.

All flight article test durations are to be 1 minute per axis. Non-flight article qualification test durations are to be 2 minutes per axis.

Table 8-3: [LEO] Random Vibration Environment (derived from GEVS-SE, Table 2.4-4)

Zone/Assembly	Frequency (Hz)	Protoflight / Qualification	Acceptance
Instrument	20	0.026 g ² /Hz	0.013 g ² /Hz
	20 – 50	+6 dB/octave	+6 dB/octave
	50 - 800	0.16 g ² /Hz	0.08 g ² /Hz
	800 - 2000	-6 dB/octave	-6 dB/octave
	2000	0.026 g ² /Hz	0.013 g ² /Hz
	Overall	14.1 g _{rms}	10.0 g _{rms}

Table 8-3 represents the random vibration environment for instruments with mass less than or equal to 25 kg. Instruments with mass greater than 25 kg may apply the following random vibration environment reductions:

- 1) The acceleration spectral density (ASD) level may be reduced for components weighing more than 25 kg according to:

$$ASD_{new} = ASD_{original} * (25/M)$$

where M = instrument mass in kg

- 2) The slope is to be maintained at ± 6 dB/octave for instruments with mass less than or equal to 65 kg. For instruments greater than 65 kg, the slope should be adjusted to maintain an ASD of 0.01 g²/Hz at 20 Hz and at 2000 Hz for qualification testing and an ASD of 0.005 g²/Hz at 20 Hz and at 2000 Hz for acceptance testing.

[GEO] The Instrument should function according to its operational specifications after being subjected to a launch vehicle-induced transient environment represented by the random vibration environment defined in Table 8-4.

All flight article test durations are to be 1 minute per axis. Protoflight and non-flight article qualification test durations are to be 3 minutes per axis.

Table 8-4: [GEO] Random Vibration Environment

Zone/Assembly	Frequency (Hz)	Protoflight / Qualification	Acceptance
Instrument	20	0.2 g ² /Hz	0.14 g ² /Hz
	20 - 45	+6 dB/octave	+6 dB/octave
	45 - 500	1.0 g ² /Hz	0.71 g ² /Hz
	500 - 2000	-6 dB/octave	-6 dB/octave
	2000	0.06 g ² /Hz	0.04 g ² /Hz
	Overall	28.9 g _{rms}	24.2 g _{rms}

Table 8-4 represents the random vibration environment for all instruments

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 41 of 113

Rationale: The Instrument must be able to withstand conditions typical of the AI&T, launch and on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. This guidance represents the need to be compatible with the random vibration that will be experienced during launch ascent. The random vibration design guidelines are derived from: (a) launch vehicle-induced acoustic excitations during liftoff, transonic and max-q events; and (b) mechanically transmitted vibration from the engines during upper stage burns. The guidelines are the all-satisfy strategy scenario, based upon CII analysis of the following sources of performance data: *CII RFI for GEO Hosted Payload Opportunities* responses (GEO only), the *GEVS-SE* (LEO and GEO), and *GOES-R GIRD* (GEO only).

8.4.7 Acoustic Noise

The Instrument should function according to its operational specifications after being subjected to a launch vehicle-induced transient environment represented by the acoustic noise spectra defined in Table 8-5.

914

Table 8-5: Acoustic Noise Environment

1/3 Octave Band Center Frequency (Hz)"	Design/Qual/Protoflight (dB w/ 20 μ Pa reference)"	Acceptance (dB w/ 20 μ Pa reference)"
25	128.23	125.23
31.5	132	129
40	133.5	130.5
50	134	131
63	135	132
80	136.6	133.6
100	137.4	134.4
125	136.3	133.3
160	137.1	134.1
200	137.23	134.23
250	138.2	135.2
315	139	136
400	137.5	134.5
500	134.23	131.23
630	134.23	131.23
800	131.5	128.5
1000	129.23	126.23
1250	129.23	126.23
1600	124.8	121.8
2000	125	122
2500	124.23	121.23
3150	121.5	118.5
4000	120	117
5000	120	117
6300	118	115
8000	118	115
10000	119	116

915

916

917

918

919

920

921

922

923

924

Rationale: Acoustic design guidelines are based on maximum internal payload fairing sound pressure level spectra. The Instrument must be able to withstand conditions typical of the AI&T, launch and on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. This guidance represents the need to be compatible with the acoustic noise that will be experienced during launch ascent. The guideline is the all-satisfy strategy scenario, based upon CII analysis of the following sources of performance data: *CII RFI for GEO Hosted Payload Opportunities* responses, all publically available launch vehicle Payload Planers Guides (with the exception of the Long March LV) and the *GOES-R GIRD*.

925

926

927

The acoustic noise design requirement for both the instrument and its assemblies is a reverberant random-incidence acoustic field specified in 1/3 octave bands. The design / qualification / protoflight exposure time is 2 minutes; acceptance exposure time is one minute.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 43 of 113

8.4.8 Mechanical Shock

[GEO] The Instrument should function according to its operational specifications after being subjected to a spacecraft to launch vehicle separation or other shock transient accelerations represented by Table 8-6.

Table 8-6: [GEO] Mechanical Shock Environment

Frequency [Hz]	Acceleration [g]
100	115.1
600	2000
2000	5000
10000	5000

Rationale: The Instrument must able to withstand conditions typical of the AI&T, launch and on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. This guidance represents the need to be compatible with the mechanical shock that will be experienced during ground processing, launch ascent and on orbit. The GEO guideline is the all-satisfy strategy scenario, based upon CII analysis of the following sources of performance data: *CII RFI for GEO Hosted Payload Opportunities* responses, NASA GEVS and the GOES R GIRD. A quality factor (Q) of 10 is a typical value for a pyrotechnic separation system shock event. This value may be tailored based upon the shock environments anticipated/defined following the pairing of the Instrument and Host Spacecraft.

8.5 **Operational Environment**

The Operational Environment represents that time in the Instrument's lifecycle following the completion of the launch vehicle's final injection burn, when the Instrument is exposed to space and established in its operational orbit (Figure 8-4).

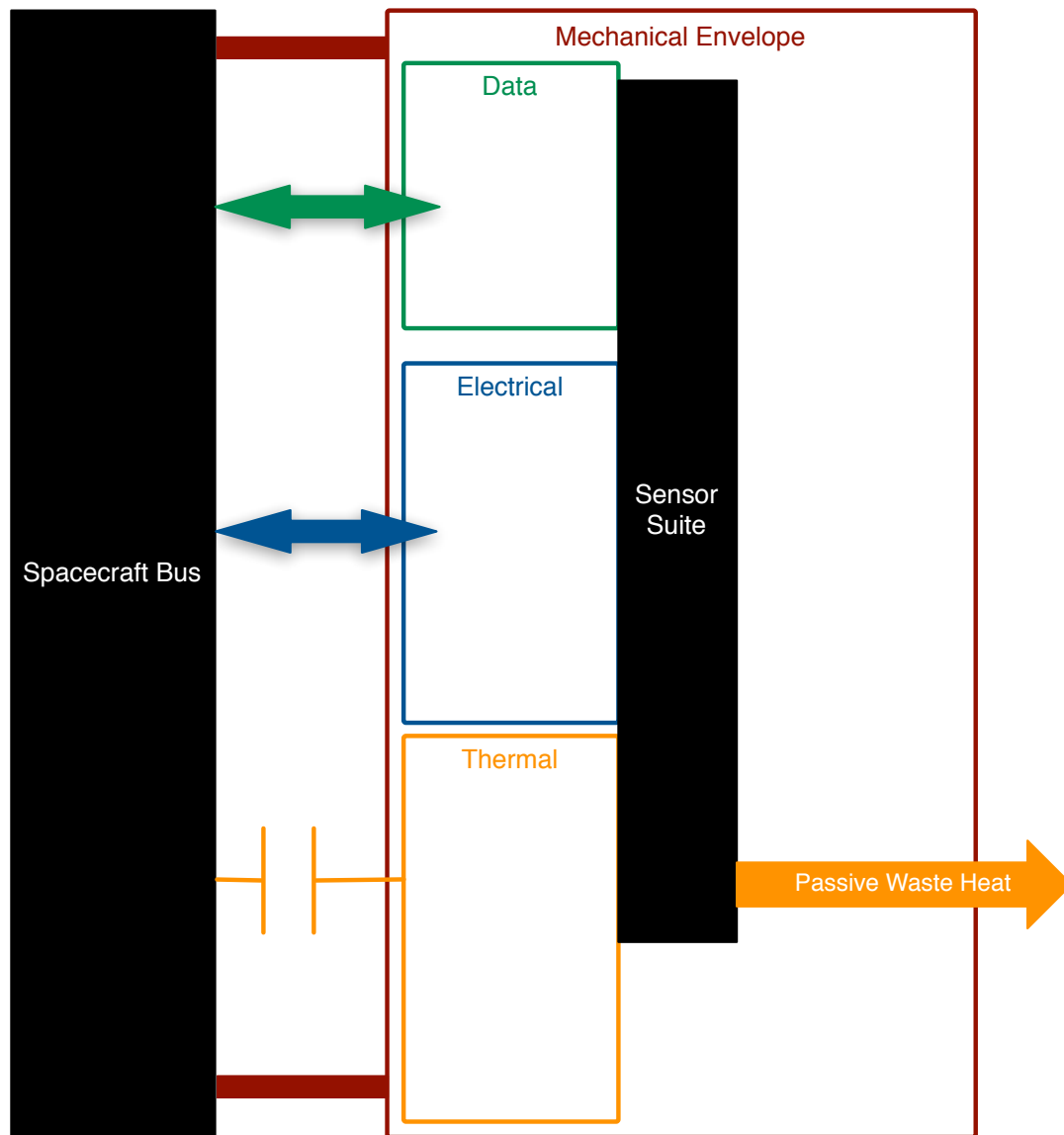


Figure 8-4: Operational Environment

Unless otherwise stated, the LEO guidelines are based upon a 98 degree inclination, 705 km altitude circular orbit. The GEO guidelines are based upon a zero degree inclination, 35786 km altitude circular orbit.

8.5.1 Orbital Acceleration

The Instrument should function according to its operational specifications after being subjected to a maximum spacecraft-induced acceleration of 0.04g.

Rationale: The Instrument in its operational configuration must be able to withstand conditions typical of the on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the Host Spacecraft or other payloads. This

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 45 of 113

guidance represents the need to be compatible with the accelerations that will be experienced on orbit. The guideline is the all-satisfy strategy scenario, based upon CII analysis of the following sources of performance data: *CII RFI for GEO Hosted Payload Opportunities* responses, the *GEVS-SE*, and *GOES-R GIRD*.

8.5.2 Corona

The Instrument should exhibit no effect of corona or other forms of electrical breakdown after being subjected to a range of ambient pressures from 101 kPa (~760 Torr) at sea level to 1.3×10^{-15} kPa (10^{-14} Torr) in space.

Rationale: The Instrument must be able to withstand conditions typical of the AI&T, launch and on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. This guidance represents the need to be compatible with the environment that will be experienced during ground processing, launch ascent and on orbit. The guideline is the all-satisfy strategy scenario, based upon CII analysis of the following sources of performance data: *CII RFI for GEO Hosted Payload Opportunities* responses, the *GEVS-SE*, and *GOES-R GIRD*.

8.5.3 Thermal Environment

The Instrument should function according to its operational specifications after being subjected to a thermal environment characterized by Table 8-7.

Table 8-7: Thermal Radiation Environment

Domain	Solar Flux [W/m ²]	Earth IR (Long Wave) [W/m ²]	Earth Albedo
LEO	1290 to 1420	222 to 243	0.275 to 0.375
GEO		Insignificant	Insignificant

Rationale: The Instrument must be able to withstand conditions typical of the on-orbit environment without suffering degraded performance or being damaged or inducing degraded performance of or damage to the spacecraft host or other payloads. While the Earth albedo and long wave infrared radiation are non-zero values at GEO, their contribution to the overall thermal environment is less than 0.05% of that from solar flux.

8.5.4 Radiation Design Margin

Every hardware component of the Instrument should have a minimum RDM value of two.

Rationale: Exposure to radiation degrades many materials and will require mitigation to assure full instrument function over the design mission lifetime. This guidance defines the need to carry 100% margin against the estimated amount of radiation exposure that will be experienced in Earth orbit in support of said mitigation.

A Radiation Design Margin (RDM) for a given electronic part (with respect to a given radiation environment) is defined as the ratio of that part's capability (with respect to that environment and its circuit application) to the environment level at the part's location.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 46 of 113

8.5.5 Total Ionizing Dose

The Instrument should function according to its operational specifications during and after exposure to the Total Ionizing Dose (TID) radiation environment based upon the specified mission orbit over the specified mission lifetime.

Table 8-8 shows the expected total ionizing dose for object in a 813 km, sun-synchronous orbit, for over the span of two years, while shielded by an aluminum spherical shell of a given thickness. Figure 8-5 plots the same data in graphical form. The data contain no margin or uncertainty factors.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 47 of 113

999

Table 8-8: [LEO] Total Ionizing Dose Radiation Environment

Shield Thickness [mil]	Trapped Electrons Rad [Si]	Bremsstrahlung Rad [Si]	Trapped Protons Rad [Si]	Solar Protons Rad [Si]	Total Rad [Si]
1	1.09E+06	1.84E+03	5.24E+04	6.52E+04	1.21E+06
3	5.23E+05	1.03E+03	1.70E+04	2.81E+04	5.69E+05
4	3.99E+05	8.30E+02	1.29E+04	2.18E+04	4.35E+05
6	2.44E+05	5.70E+02	8.86E+03	1.48E+04	2.68E+05
7	1.98E+05	4.87E+02	7.70E+03	1.29E+04	2.19E+05
9	1.38E+05	3.72E+02	6.30E+03	1.04E+04	1.55E+05
10	1.18E+05	3.32E+02	5.79E+03	9.47E+03	1.34E+05
12	9.04E+04	2.70E+02	5.01E+03	7.92E+03	1.04E+05
13	8.03E+04	2.46E+02	4.72E+03	7.31E+03	9.25E+04
15	6.45E+04	2.08E+02	4.28E+03	6.28E+03	7.53E+04
29	2.31E+04	9.80E+01	2.80E+03	2.96E+03	2.90E+04
44	1.23E+04	6.33E+01	2.18E+03	1.94E+03	1.65E+04
58	7.93E+03	4.75E+01	1.89E+03	1.47E+03	1.13E+04
73	5.24E+03	3.71E+01	1.70E+03	1.14E+03	8.12E+03
87	3.66E+03	3.06E+01	1.57E+03	9.30E+02	6.19E+03
117	1.81E+03	2.22E+01	1.39E+03	6.40E+02	3.86E+03
146	9.59E+02	1.76E+01	1.28E+03	4.52E+02	2.71E+03
182	4.38E+02	1.40E+01	1.19E+03	3.13E+02	1.95E+03
219	1.90E+02	1.17E+01	1.12E+03	2.47E+02	1.56E+03
255	8.38E+01	1.01E+01	1.06E+03	2.20E+02	1.38E+03
292	3.55E+01	8.97E+00	1.02E+03	1.98E+02	1.26E+03
365	5.72E+00	7.43E+00	9.34E+02	1.61E+02	1.11E+03
437	6.98E-01	6.46E+00	8.76E+02	1.38E+02	1.02E+03
510	4.96E-02	5.77E+00	8.32E+02	1.22E+02	9.60E+02
583	7.76E-04	5.26E+00	7.77E+02	1.05E+02	8.87E+02
656	1.06E-05	4.85E+00	7.38E+02	9.35E+01	8.36E+02
729	1.37E-07	4.49E+00	7.06E+02	8.50E+01	7.95E+02
875	0.00E+00	3.92E+00	6.42E+02	7.02E+01	7.16E+02
1167	0.00E+00	3.14E+00	5.42E+02	5.09E+01	5.96E+02
1458	0.00E+00	2.61E+00	4.67E+02	3.90E+01	5.09E+02

1000

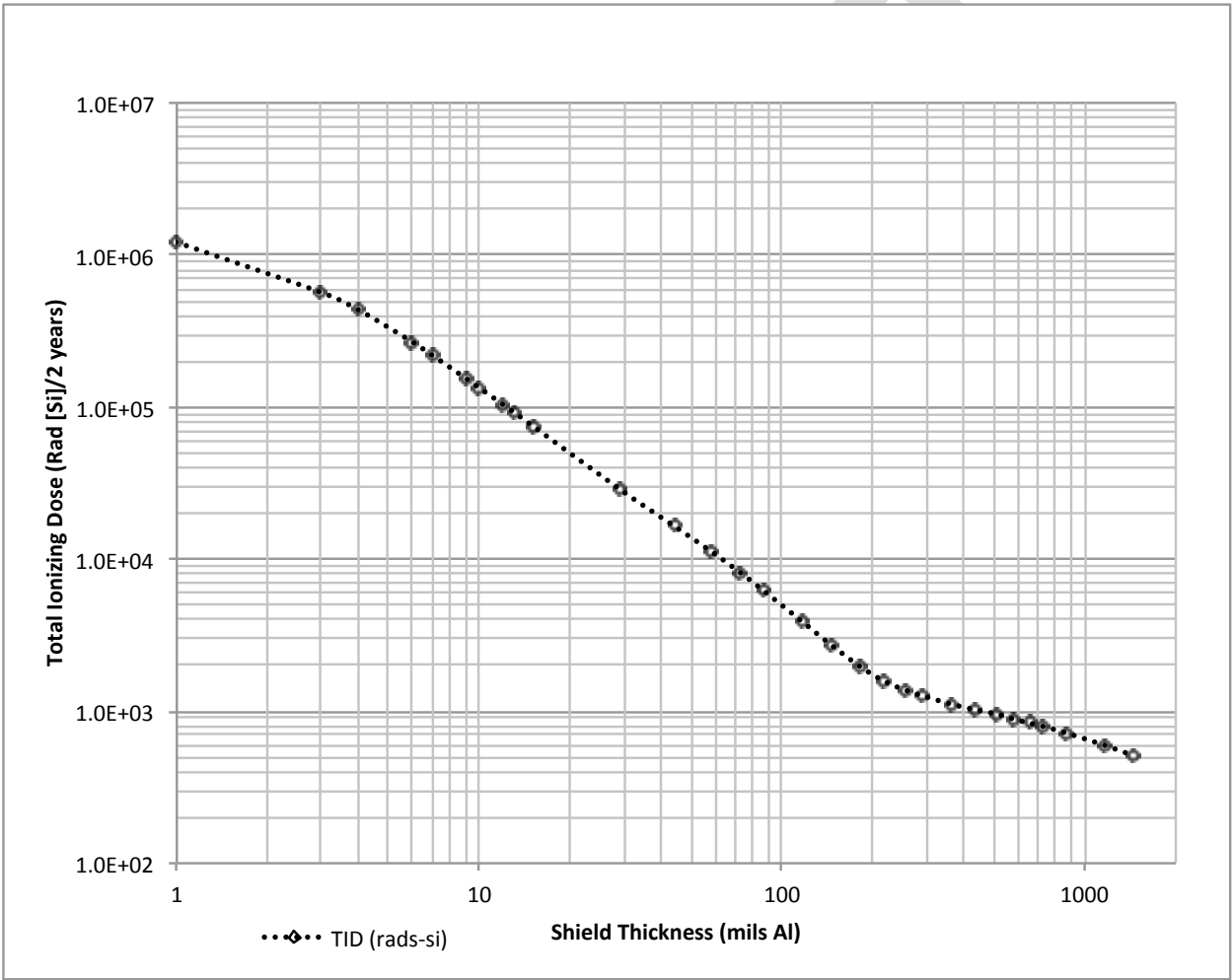


Figure 8-5: [LEO] TID versus Shielding Thickness

Table 8-9 shows the expected total ionizing dose for object in GEO, over the span of two years, while shielded by an aluminum spherical shell of a given thickness. Figure 8-6 plots the same data. The data contain no margin or uncertainty factors.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 49 of 113

1006

Table 8-9: [GEO] Total Ionizing Dose Radiation Environment

Aluminum Shield Thickness [mil]	Total Dose [Rad]-Si
0	2.09E+08
10	2.62E+07
20	9.64E+06
30	4.78E+06
40	2.70E+06
50	1.60E+06
60	1.01E+06
70	6.60E+05
80	4.44E+05
90	3.19E+05
100	2.31E+05
110	1.69E+05
120	1.26E+05
130	9.37E+04
140	6.67E+04
150	5.26E+04
160	3.94E+04
170	2.87E+04
180	2.36E+04
190	1.88E+04
200	1.43E+04
210	1.17E+04
220	1.01E+04
230	8.57E+03
240	7.10E+03
250	5.96E+03
260	5.28E+03
270	4.63E+03
280	4.01E+03
290	3.41E+03
300	2.90E+03

1007

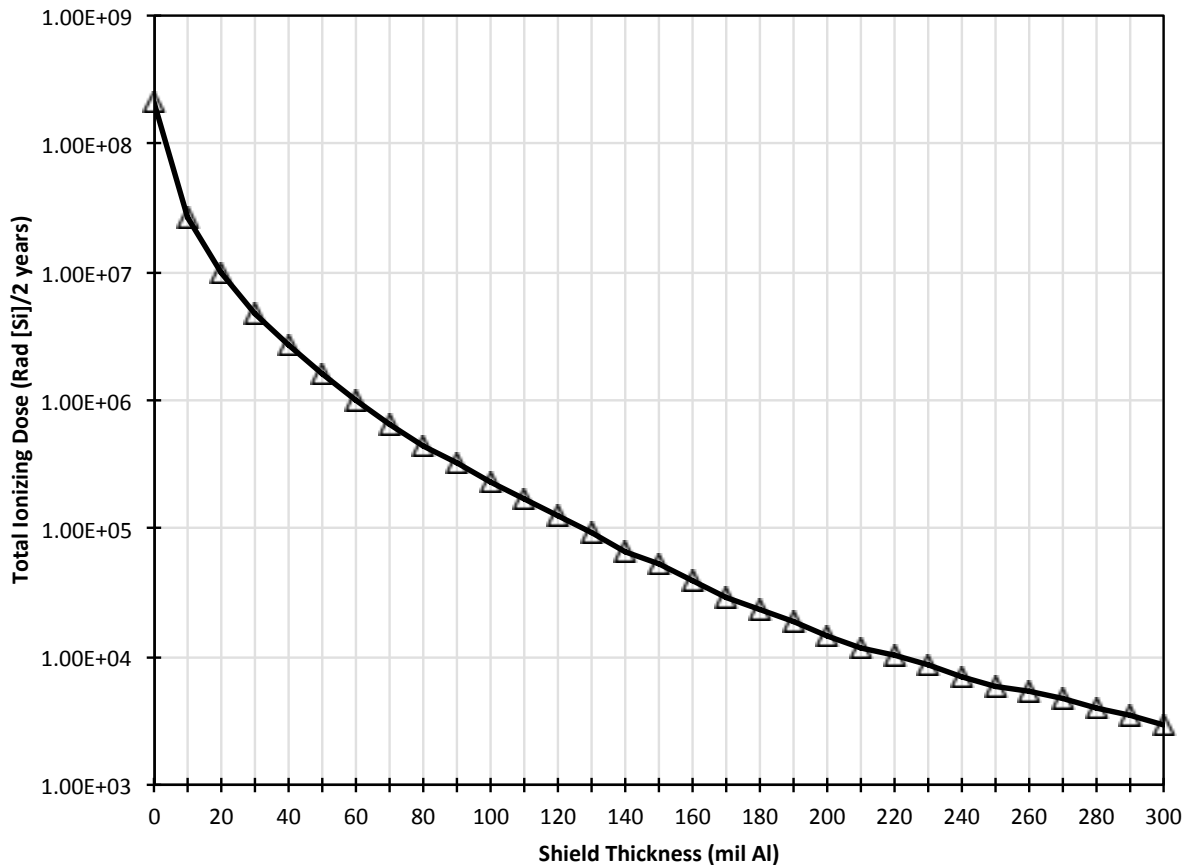


Figure 8-6: [GEO] TID versus Shielding Thickness

Rationale: Exposure to ionizing radiation degrades many materials and electronics in particular, and will require mitigation to ensure full instrument function over the design mission lifetime. Mitigation is typically achieved through application of the appropriate thickness of shielding. The LEO TID radiation environment is representative of exposure at an 813 km, sun-synchronous orbit. Analysis of dose absorption through shielding is based upon the SHIELDOSE2 model, which leverages NASA's Radiation Belt Models, AE-8 and AP-8, and JPL's Solar Proton Fluence Model. The GEO guideline is the all-satisfy strategy scenario, based upon CII analysis of the following sources of performance data: *CII RFI for GEO Hosted Payload Opportunities* responses and *The Radiation Model for Electronic Devices on GOES-R Series Spacecraft* (417-R-RPT-0027). The TID accrues as a constant rate and may be scaled for shorter and longer mission durations.

The LEO data represent conservative conditions for a specific orbit. While these data may envelop the TID environment of other LEO mission orbits (particularly those of lower altitude and inclination), Instrument Developers should analyze the TID environment for their Instrument's specific orbit. Since TID environments are nearly equivalent within the GEO domain, these data likely envelop the expected TID environment for GEO Earth Science

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 51 of 113

missions. The same caveat regarding Instrument Developer analysis of the TID environment also applies to the GEO domain.

8.5.6 [GEO] Instrument Interference

The Instrument should function according to specification in the operational environment when exposed to the particle fluxes defined by Table 8-10.

Rationale: The particle background causes increased noise levels in instruments and other electronics. No long term flux is included for solar particle events because of their short durations. This guidance is based upon “Long-term and worst-case particle fluxes in GEO behind 100 mils of aluminum shielding”, Table 4 of 417-R-RPT-0027.

Table 8-10: [GEO] Particle fluxes in GEO w/ 100 mils of Aluminum Shielding

Radiation:	Long-term flux [#/cm ² /s]	Worst-case flux [#/cm ² /s]
Galactic Cosmic Rays	2.5	4.6
Trapped Electrons	6.7×10^4	1.3×10^6
Solar Particle Events		2.0×10^5

8.5.7 Micrometeoroids

The Instrument Developer should perform a probability analysis to determine the type and amount of shielding to mitigate the fluence of micrometeoroids in the expected mission orbit over the primary mission.

Table 8-11 and Figure 8-7 provide a conservative micrometeoroid flux environment for both LEO and GEO.

Rationale: Impacts from micrometeoroids may cause permanently degraded performance or damage to the hosted payload instrument. This guidance provides estimates of the worst-case scenarios of micrometeoroid particle size and associated flux over the LEO and GEO domains. The data come from the Grün flux model assuming a meteoroid mean speed of 20 km/s. Of note, the most hazardous micrometeoroid environment in LEO is at an altitude of 2000 km. If a less conservative LEO environment is desired, the Instrument Developer should perform an analysis tailored to the risk tolerance.

Micrometeoroid and artificial space debris flux guidelines are separate due to the stability of micrometeoroid flux over time, compared to the increase of artificial space debris.

1051

Table 8-11: Worst-case Micrometeoroid Environment

Particle mass [g]	Particle diameter [cm]	Flux (particles/m ² /year)	
		LEO	GEO
1.00E-18	9.14E-07	1.20E+07	9.53E+06
1.00E-17	1.97E-06	1.75E+06	1.39E+06
1.00E-16	4.24E-06	2.71E+05	2.15E+05
1.00E-15	9.14E-06	4.87E+04	3.85E+04
1.00E-14	1.97E-05	1.15E+04	9.14E+03
1.00E-13	4.24E-05	3.80E+03	3.01E+03
1.00E-12	9.14E-05	1.58E+03	1.25E+03
1.00E-11	1.97E-04	6.83E+02	5.40E+02
1.00E-10	4.24E-04	2.92E+02	2.31E+02
1.00E-09	9.14E-04	1.38E+02	1.09E+02
1.00E-08	1.97E-03	5.41E+01	4.28E+01
1.00E-07	4.24E-03	1.38E+01	1.09E+01
1.00E-06	9.14E-03	2.16E+00	1.71E+00
1.00E-05	1.97E-02	2.12E-01	1.68E-01
1.00E-04	4.24E-02	1.50E-02	1.19E-02
1.00E-03	9.14E-02	8.65E-04	6.84E-04
1.00E-02	1.97E-01	4.45E-05	3.52E-05
1.00E-01	4.24E-01	2.16E-06	1.71E-06
1.00E+00	9.14E-01	1.02E-07	8.05E-08
1.00E+01	1.97E+00	4.72E-09	3.73E-09
1.00E+02	4.24E+00	2.17E-10	1.72E-10

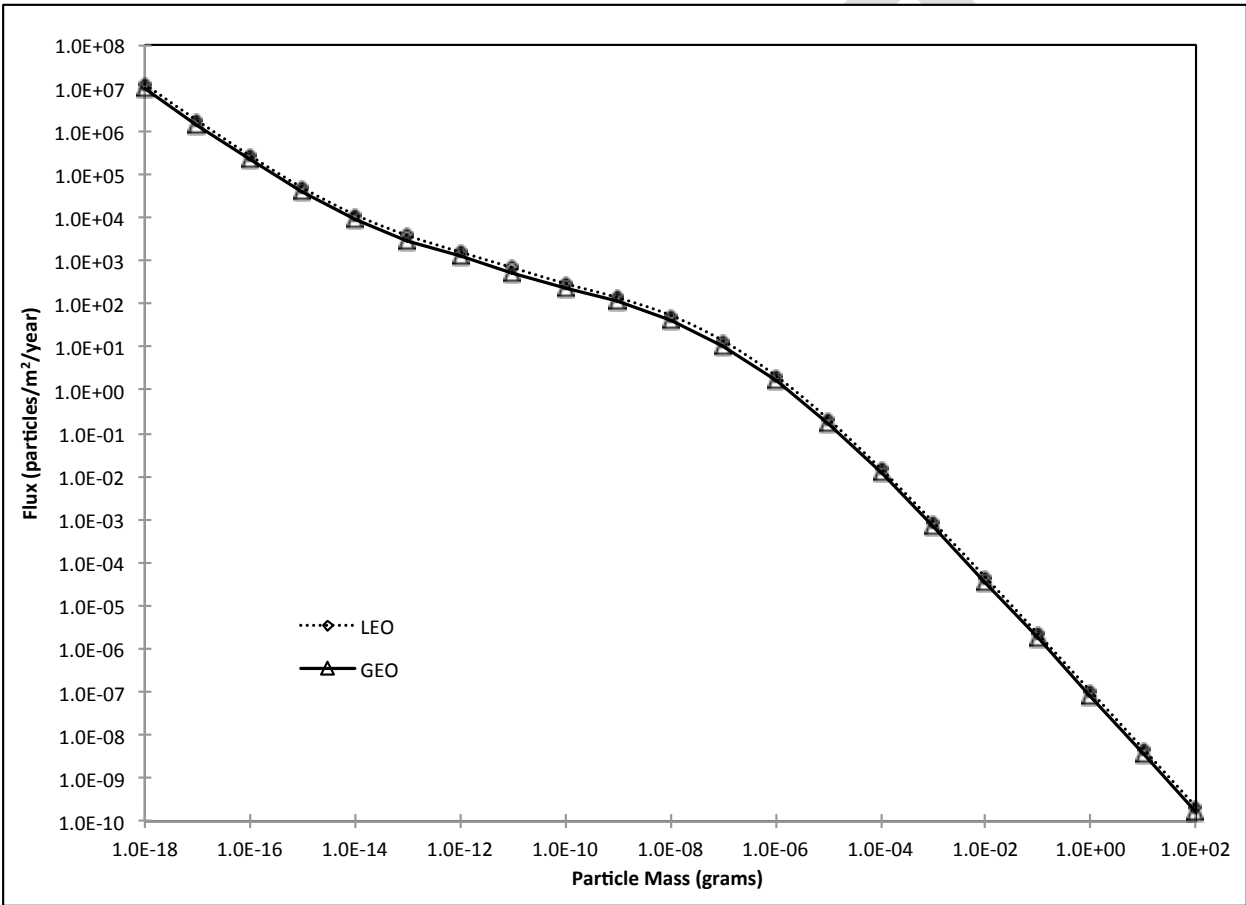


Figure 8-7: Worst-case Micrometeoroid Environment

8.5.8 Artificial Space Debris
The Instrument Developer should perform a probability analysis to determine the type and amount of shielding to mitigate the fluence of artificial space debris in the expected mission orbit over the primary mission.

Table 8-12, Figure 8-8, Table 8-13, and Figure 8-9 provide conservative artificial space debris flux environments for both LEO and GEO.

Table 8-12: [LEO] Worst-case Artificial Space Debris Environment

Object Size [m]	Flux [objects/m ² /year]	Object Velocity [km/s]
1.00E-05	4.14E+03	12.02
1.00E-04	4.10E+02	9.25
1.00E-03	3.43E-01	10.63
1.00E-02	1.50E-04	10.53
1.00E-01	6.64E-06	9.10
1.00E+00	2.80E-06	9.34
Average Velocity:		10.15

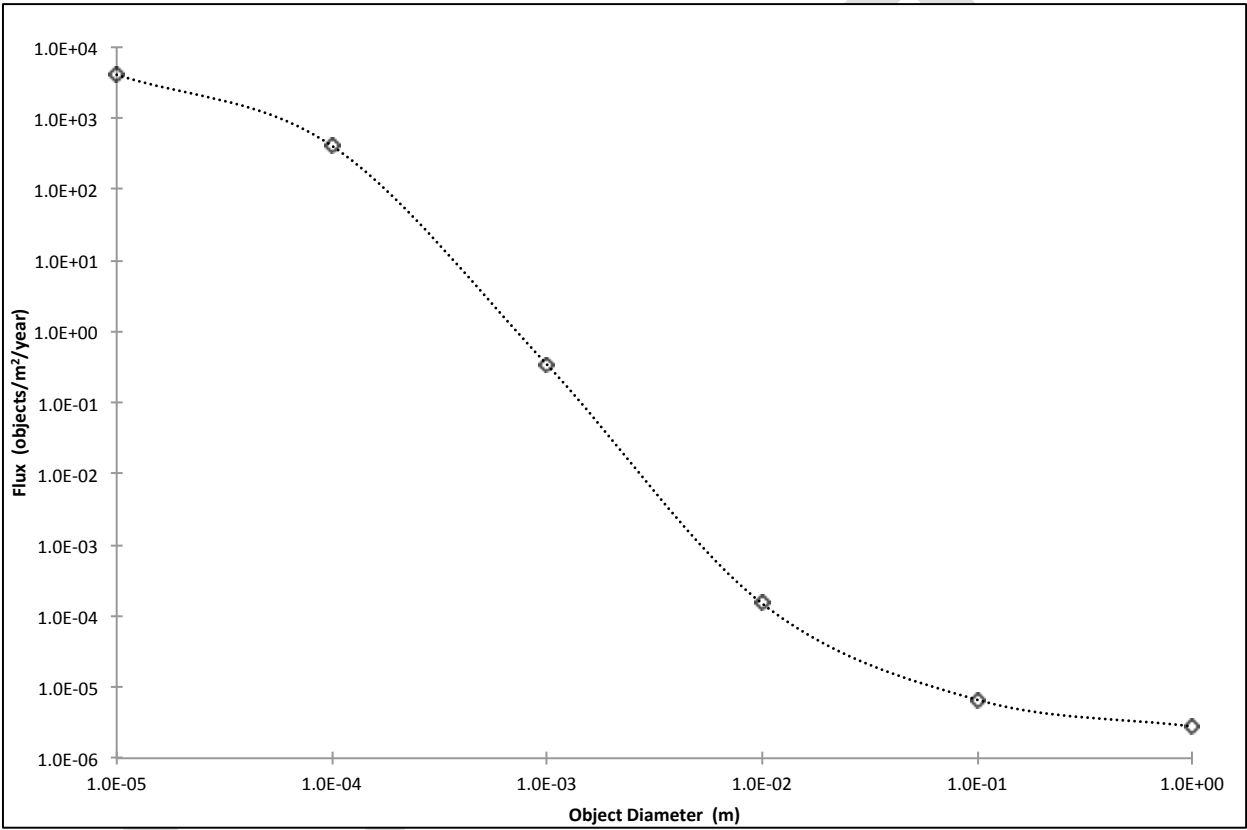
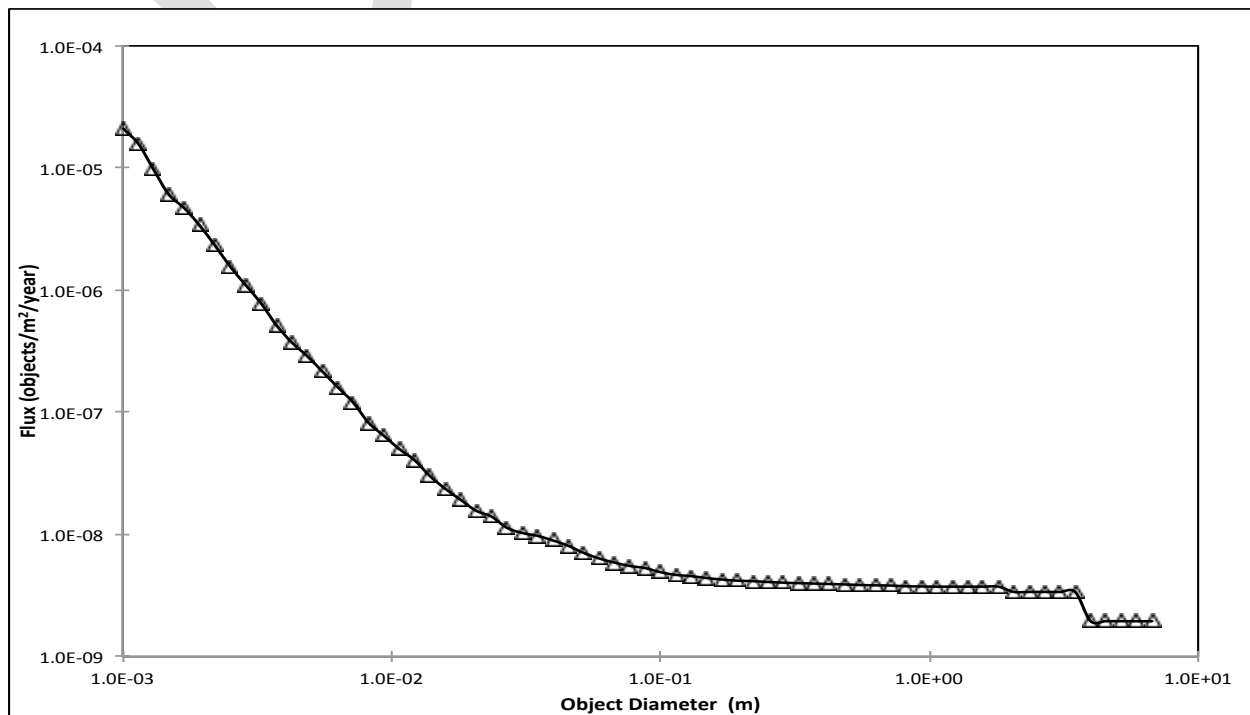


Figure 8-8: [LEO]: Worst-case Artificial Space Debris Environment

1064

Table 8-13: [GEO] Worst-case Artificial Space Debris Environment

Object Diameter [m]	Flux [objects/m ² /year]	Object Diameter [m]	Flux [objects/m ² /year]	Object Diameter [m]	Flux [objects/m ² /year]
1.00000E-03	2.08800E-05	2.06200E-02	1.56300E-08	4.25179E-01	3.93000E-09
1.14100E-03	1.58800E-05	2.35200E-02	1.40200E-08	4.84969E-01	3.89700E-09
1.30100E-03	9.74700E-06	2.68270E-02	1.13500E-08	5.53168E-01	3.85700E-09
1.48400E-03	6.06200E-06	3.05990E-02	1.02900E-08	6.30957E-01	3.83000E-09
1.69300E-03	4.70300E-06	3.49030E-02	9.74100E-09	7.19686E-01	3.81700E-09
1.93100E-03	3.38900E-06	3.98110E-02	8.92500E-09	8.20891E-01	3.76600E-09
2.20200E-03	2.32700E-06	4.54090E-02	8.07400E-09	9.36329E-01	3.75200E-09
2.51200E-03	1.55700E-06	5.17950E-02	7.06300E-09	1.06800E+00	3.73800E-09
2.86500E-03	1.10200E-06	5.90780E-02	6.36200E-09	1.21819E+00	3.73800E-09
3.26800E-03	7.81600E-07	6.73860E-02	5.88900E-09	1.38949E+00	3.73800E-09
3.72800E-03	5.16800E-07	7.68620E-02	5.52200E-09	1.58489E+00	3.73800E-09
4.25200E-03	3.73600E-07	8.76710E-02	5.30700E-09	1.80777E+00	3.73800E-09
4.85000E-03	2.88600E-07	1.00000E-01	4.91200E-09	2.06199E+00	3.38500E-09
5.53200E-03	2.15600E-07	1.14062E-01	4.66500E-09	2.35195E+00	3.38500E-09
6.31000E-03	1.60200E-07	1.30103E-01	4.56000E-09	2.68270E+00	3.38500E-09
7.19700E-03	1.20300E-07	1.48398E-01	4.39400E-09	3.05995E+00	3.38000E-09
8.20900E-03	8.21500E-08	1.69267E-01	4.27400E-09	3.49025E+00	3.37800E-09
9.36300E-03	6.42500E-08	1.93070E-01	4.18300E-09	3.98107E+00	1.95200E-09
1.06800E-02	5.00200E-08	2.20220E-01	4.14700E-09	4.54091E+00	1.95000E-09
1.21820E-02	4.05400E-08	2.51189E-01	4.08200E-09	5.17948E+00	1.94900E-09
1.38950E-02	3.00300E-08	2.86512E-01	4.02900E-09	5.90784E+00	1.94800E-09
1.58490E-02	2.36300E-08	3.26803E-01	3.99300E-09	6.73863E+00	1.94800E-09
1.80780E-02	1.92000E-08	3.72759E-01	3.96000E-09	7.68625E+00	1.36900E-13
Average Velocity (km/s)					1.3333



1065

1066

Figure 8-9: [GEO] Worst-case Artificial Space Debris Environment

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 56 of 113

1067 Rationale: Impacts from artificial space debris may permanently degrade performance or
1068 damage the Instrument. This guidance estimates the maximum artificial space debris flux and
1069 impact velocities an Instrument can expect to experience for both LEO and GEO domains during
1070 the Calendar Year 2015 epoch. Expected artificial space debris flux increases over time as more
1071 hardware is launched into orbit.

1072 The LEO analysis covers altitudes from 200 to 2000 km and orbital inclinations between 0 and
1073 180 degrees. The ORDEM2000 model, developed by the NASA Orbital Debris Program Office
1074 at Johnson Space Center, is the source of the data.

1075 Based upon analysis of ESA's 2009 MASTER (Meteoroid and Space Debris Environment)
1076 model, the GEO guidance aggregates the maximum expected artificial space debris flux, sampled
1077 at 20° intervals around the GEO belt.

1078 Micrometeoroid and artificial space debris flux guidelines are listed separately due to the
1079 stability of micrometeoroid flux over time, compared to the increase of artificial space debris.

1080 8.5.9 Atomic Oxygen Environment

1081 **The Instrument should function according to its specifications following exposure to the**
1082 **atomic oxygen environment, based on its expected mission orbit, for the duration of the**
1083 **Instrument primary mission.**

1084 Rationale: Exposure to atomic oxygen degrades many materials and requires mitigation to ensure
1085 full Instrument function over the design mission lifetime. Atomic oxygen levels in LEO are
1086 significant and may be derived using the Figure 8-10, which estimates the atomic oxygen flux,
1087 assuming an orbital velocity of 8 km/sec, for a range of LEO altitudes over the solar cycle
1088 inclusive of the standard atmosphere. Atomic oxygen levels in GEO are negligible and are only
1089 significant for GEO-bound Instruments that spend extended times in LEO prior to GEO transfer.

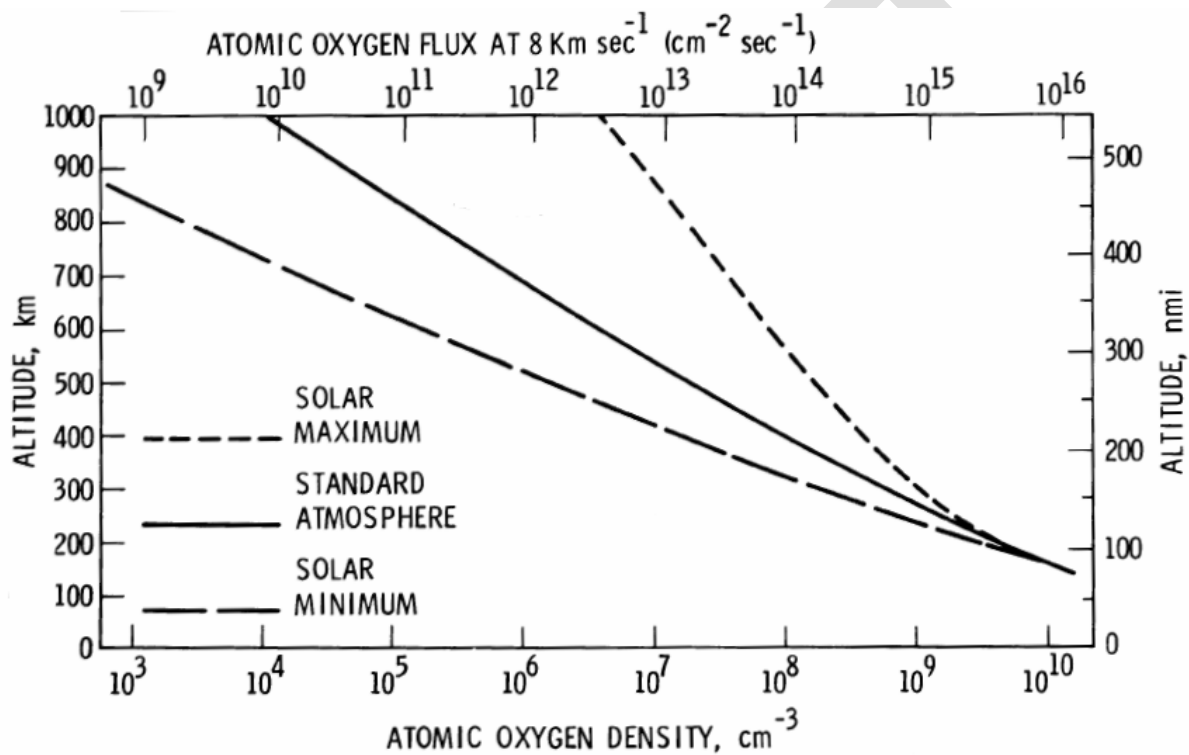


Figure 8-10: Atmospheric Atomic Oxygen density in Low Earth Orbit (Figure 2 from de Rooij 2000)

8.5.10 Electromagnetic Interference & Compatibility Environment

The Instrument should function according to its specification following exposure to the Electromagnetic Interference and Electromagnetic Compatibility (EMI/EMC) environments as defined in the applicable sections of MIL-STD-461.

Please note that the environments defined in MIL-STD-461 may be tailored in accordance with the Host Spacecraft, launch vehicle and launch range requirements.

Rationale: Exposure of the hosted payload instrument to electromagnetic fields may induce degraded performance or damage in the instrument electrical and/or electronic subsystems. The application of the appropriate environments as described in the above noted reference and in accordance with those test procedures defined in, or superior to, MIL-STD-461 or MIL-STD-462, will result in an instrument that is designed and verified to assure full instrument function in the defined EMI/EMC environments.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 58 of 113

9.0 REFERENCE MATERIAL / BEST PRACTICES

9.1 Data Interface Reference Material / Best Practices

9.1.1 CCSDS Data Transmission

The Instrument should transmit and receive all packet data using Consultative Committee for Space Data Systems (CCSDS) primary and secondary headers for packet sequencing and control.

Rationale: The use of CCSDS packets for data communication is common practice across aerospace flight and ground data systems.

9.1.2 Flight Software Update

Instrument control flight software should be updatable on orbit through ground command.

Rationale: On-orbit flight software updates are a best practice that facilitates improvements and/or workarounds deemed necessary through operational experience.

9.1.3 Flight Software Update (Partial)

Individual memory addresses of instrument control software should be updatable on orbit through ground command.

Rationale: On-orbit flight software updates are a best practice that facilitates improvements and/or workarounds deemed necessary through operational experience.

9.1.4 Use of Preexisting Communication Infrastructure

Instrument Developers should consider utilizing the communication infrastructure provided by the Host Spacecraft and Satellite Operator for all of the Instrument's space-to-ground communications needs.

Rationale: The size, mass, and power made available to the Instrument may not simultaneously accommodate a scientific Instrument as well as communications terminals, antennas, and other equipment. Additionally, the time required for the Instrument Developer to apply for and secure a National Telecommunications and Information Administration (NTIA) Spectrum Planning Subcommittee (SPS) Stage 4 (operational) Approval to transmit on a particular radio frequency band may exceed the schedule available, given the constraints as a hosted payload. A Satellite Operator will have already initiated the spectrum approval process that would cover any data the Instrument transmits through the Host Spacecraft. NPR 2570.1B, *NASA Radio Frequency (RF) Spectrum Management Manual*, details the spectrum approval process for NASA missions.

9.2 Electrical Power Interface Reference Material / Best Practices

9.2.1 Discussion

The following electrical power guidelines define a common basis for the provision of electrical power by spacecraft hosts to potential hosted payload Earth science instruments. This is necessary to progress both the design of any instrument prior to the selection of an HPO and launch vehicle and to progress the design of the host payload accommodations. The major sources from which these best practices were developed are the *General Interface Requirements Document (GIRD) for EOS Common Spacecraft/Instruments, Electrical Grounding Architecture*

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 59 of 113

1143 *for Unmanned Spacecraft*, (NASA-HDBK-4001), *Mitigating In-Space Charging Effects – A*
1144 *Guideline*, (NASA-HDBK-4002) and *Electrical Bonding for Launch Vehicles, Spacecraft,*
1145 *Payloads and Flight Equipment* (NASA-STD-4003).

1146 Note: This section assumes that the Host Spacecraft will provide access to its Electrical Power
1147 System using the interface defined in Section 5.1.

1148 9.2.2 Electrical Interface Definitions

1149 9.2.2.1 *Power Bus Current Rate of Change*

1150 **For power bus loads with current change greater than 2 A, the rate of change of current**
1151 **should not exceed 500 mA/μs.**

1152 Rationale: This describes the maximum nominal rate of change for instrument electrical current
1153 to bound nominal and anomalous behavior.

1154 9.2.2.2 *Power Bus Isolation*

1155 **All Instrument power buses (both operational and survival) should be electrically isolated**
1156 **from each other and from the chassis.**

1157 Rationale: Circuit protection and independence.

1158 9.2.2.3 *Power Bus Returns*

1159 **All Instrument power buses (both operational and survival heater) should have**
1160 **independent power returns.**

1161 Rationale: Circuit protection and independence.

1162 9.2.3 Survival Heaters.

1163 9.2.3.1 *Survival Heater Power Bus Circuit Failure*

1164 **The Instrument survival heater circuit should prevent a stuck on condition of the survival**
1165 **heaters due to internal failures.**

1166 Rationale: A stuck-on survival heater could lead to excessive power draw and/or over-
1167 temperature events in the Instrument or Host Spacecraft. This is normally accomplished by
1168 using series-redundant thermostats in each survival heater circuit.

1169 9.2.3.2 *Survival Heater Power Bus Heater Type*

1170 **The Instrument should use only resistive heaters (and associated thermal control devices)**
1171 **to maintain the Instrument at survival temperature when the main power bus is**
1172 **disconnected from the Instrument.**

1173 Rationale: This preserves the survival heater power bus for exclusive use of resistive survival
1174 heaters, whose function is to maintain the Instrument at a minimum turn-on temperature when
1175 the Instrument Power Buses are not energized.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 60 of 113

1176 9.2.3.3 *Survival Heater Power Bus Design*
1177 **The system design should be such that having both primary and redundant survival heater**
1178 **circuits enabled does not violate any thermal or power requirement.**

1179 Rationale: This precludes excessive power draw and/or over-temperature events in the
1180 Instrument or Host Spacecraft. This is normally accomplished via the application of thermostats
1181 with different set points in each redundant survival heater circuit.

1182 9.2.4 Voltage and Current Transients

1183 9.2.4.1 *Low Voltage Detection*

1184 **A voltage excursion that causes the spacecraft Primary Power Bus to drop below 22 VDC**
1185 **in excess of four seconds constitutes an under-voltage condition. In the event of an under-**
1186 **voltage condition, the spacecraft will shed various loads without delay, including the**
1187 **Instrument. A ground command should be required to re-power the load.**

1188 Rationale: Bounds nominal and anomalous design conditions. Describes “typical” spacecraft
1189 CONOPS to the noted anomaly for application to design practice.

1190 9.2.4.2 *Bus Undervoltage and Overvoltage Transients*

1191 **Derating factors should take into account the stresses that components are subjected to**
1192 **during periods of undervoltage or overvoltage, including conditions which arise during**
1193 **ground testing, while the bus voltage is slowly brought up to its nominal value.**

1194 Rationale: Describes a “standard” design practice.

1195 9.2.4.3 *Bus Undervoltage and Overvoltage Transients*

1196 **The Instrument should not generate a spurious response that can cause equipment damage**
1197 **or otherwise be detrimental to the spacecraft operation during bus voltage variation, either**
1198 **up or down, at ramp rates below the limits specified in the sections below, and over the full**
1199 **range from zero to maximum bus voltage.**

1200 Rationale: the Instrument needs to be able to tolerate appropriate electrical transients without
1201 affecting the Host Spacecraft.

1202 9.2.4.4 *Abnormal Transients Undervoltage*

1203 **An abnormal undervoltage transient event is defined as a transient decrease in voltage on**
1204 **the Power Bus to no less than +10 VDC, maintaining the decreased voltage for no more**
1205 **than 10 ms, and returning to its previous voltage in less than 200 ms.**

1206 9.2.4.5 *Abnormal Transients Tolerance*

1207 **The Instrument should ensure that overstress does not occur to the unit during an**
1208 **undervoltage event.**

1209 Rationale: The Instrument needs to tolerate the abnormal voltage transients, which can be
1210 expected to occur throughout its mission lifetime.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 61 of 113

1211 9.2.4.6 *Abnormal Transients Recovery*

1212 **Units which shut-off during an undervoltage should return to a nominal power-up state at**
1213 **the end of the transient.**

1214 Rationale: The Instrument needs to tolerate the abnormal voltage transients, which can be
1215 expected to occur throughout its mission lifetime.

1216 9.2.4.7 *Abnormal Transients Overvoltage*

1217 **An overvoltage transient event is defined as an increase in voltage on the Power Bus to no**
1218 **greater than +40 VDC, maintaining the increased voltage for no more than 10 ms, and**
1219 **returning to its previous voltage in less than 200 ms.**

1220 Rationale: A necessary definition of an Abnormal Transient Overvoltage

1221 9.2.4.8 *Instrument Initial In-rush Current*

1222 **After application of +28 VDC power at t_0 , the initial inrush (charging) current due to**
1223 **distributed capacitance, EMI filters, etc., should be completed in 10 μ s with its peak no**
1224 **greater than 10 A.**

1225 Rationale: Bounds nominal and anomalous behavior.

1226 9.2.4.9 *Instrument Initial In-rush Current Rate of Change*

1227 **The rate of change of inrush current after the initial application of +28V power should not**
1228 **exceed 20 mA/ μ s.**

1229 Rationale: Bounds nominal and anomalous behavior.

1230 9.2.4.10 *Instrument In-rush Current after 10 μ s*

1231 **After 10 μ s, the transient current peak should not exceed three times the maximum steady**
1232 **state current.**

1233 Rationale: Bounds nominal and anomalous behavior.

1234 9.2.4.11 *Instrument Steady State Operation*

1235 **Steady state operation should be attained within 50 ms from turn-on or transition to**
1236 **OPERATION mode, except for motors.**

1237 Rationale: Bounds nominal and anomalous behavior with a maximum transient duration of 50
1238 ms.

1239 9.2.4.12 *Instrument Turn-off Peak Voltage Transients*

1240 **The peak voltage of transients generated on the Instrument side of the power relay caused**
1241 **by inductive effects of the load should fall within the -2 VDC to +40 VDC range.**

1242 Rationale: Bounds nominal behavior.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 62 of 113

1243 9.2.4.13 *Instrument Turn-off Transient Suppression*
1244 **The Instruments should use suppression devices, such as diodes, across all filter inductors,**
1245 **relay coils, or other energy sources that could induce transients on the power lines during**
1246 **turn-off.**

1247 Rationale: Describes design “standard practice.”

1248 9.2.4.14 *Reflected Ripple Current – Mode Changes*
1249 **The load current ripple due to motor rotation speed mode changes should not exceed 2**
1250 **times the steady state current during the period of the motor spin-up or spin-down.**

1251 Rationale: Bounds nominal behavior.

1252 9.2.4.15 *Instrument Operational Transients Current Limit*
1253 **Operational transients that occur after initial turn-on should not exceed 125% of the peak**
1254 **operational current drawn during normal operation.**

1255 Rationale: Bounds nominal behavior.

1256 9.2.4.16 *Instrument Reflected Ripple Current*
1257 **The peak-to-peak load current ripple generated by the Instrument should not exceed 25%**
1258 **of the average current on any Power Feed bus.**

1259 Rationale: Bounds nominal behavior.

1260 9.2.5 Overcurrent Protection

1261 9.2.5.1 *Overcurrent Protection Definition*

1262 **The analysis defining the overcurrent protection device specification(s) should consider**
1263 **turn-on, operational, and turn-off transients.**

1264 Rationale: Describes conditions necessary for inclusion in the “standard” design practice.

1265 9.2.5.2 *Overcurrent Protection – Harness Compatibility*
1266 **Harness wire sizes should be consistent with overcurrent protection device sizes and de-**
1267 **rating factors.**

1268 Rationale: Describes a “standard” design practice.

1269 9.2.5.3 *Overcurrent Protection Device Size Documentation*

1270 The agreed-upon type, size, and characteristics of the overcurrent protection device(s) should be
1271 documented in the Spacecraft to Instrument ICD.

1272 **The EICD will document the type, size, and characteristics of the overcurrent protection**
1273 **devices.**

1274 Rationale: Describes “standard practice” EICD elements.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 63 of 113

1275 9.2.5.4 *Instrument Overcurrent Protection*

1276 **All Instrument overcurrent protection devices should be accessible at the Spacecraft**
1277 **integration level without any disassembly of the Instrument.**

1278 Rationale: Accessible overcurrent protection devices allow Systems Integrator technicians to
1279 more easily restore power to the Instrument in the event of an externally-induced overcurrent.

1280 9.2.5.5 *Instrument Fault Propagation Protection*

1281 **The Instrument and spacecraft should not propagate a single fault occurring on either the**
1282 **“A” or “B” power interface circuit, on either side of the interface, to the redundant**
1283 **interface or Instrument.**

1284 Rationale: This preserves redundancy by keeping faulty power circuits from impacting alternate
1285 power sources.

1286 9.2.5.6 *Testing of Instrument High-Voltage Power Supplies in Ambient Conditions*

1287 **Instrument high-voltage power supplies should operate nominally in ambient atmospheric**
1288 **conditions.**

1289 Rationale: This allows simplified verification of the high-voltage power supplies.

1290 **If the high-voltage power supplies cannot operate nominally in ambient conditions, then**
1291 **the Instrument should enable a technician to manually disable the high-voltage power**
1292 **supplies.**

1293 Rationale: This allows verification of the Instrument by bypassing the HV power supplies that do
1294 not function in ambient conditions.

1295 9.2.5.7 *Instrument High-Voltage Current Limiting*

1296 **The output of each Instrument's high-voltage supply should be current limited to prevent**
1297 **the supply's discharge from damaging the Spacecraft and other Instruments.**

1298 Rationale: This prevents the power supply's discharge from damaging the Host Spacecraft or
1299 other payloads.

1300 9.2.6 Connectors

1301 The following best practices apply to the selection and use of all interface connectors.

1302 9.2.6.1 *Instrument Electrical Power System Connector and Harnessing*

1303 **The Instrument electrical power system harnessing and connectors should conform to**
1304 **GSFC-733-HARN, IPC J-STD-001ES and NASA-STD-8739.4.**

1305 Rationale: Describes the appropriate design practices for all Instrument electrical power
1306 connections and harnessing.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 64 of 113

1307 9.2.6.2 *Connector Savers*

1308 **Throughout all development, integration, and test phases, connector savers should be used**
1309 **to preserve the mating life of component flight connectors.**

1310 Rationale: This practice serves to preserve the number of mate/de-mate cycles any particular
1311 flight connector experiences. Mate/de-mate cycles are a connector life-limiting operation. This
1312 practice also protects flight connects form damage during required connector mate/de-mate
1313 operations.

1314 9.2.6.3 *Connector Separation*

1315 **Separate harness interface connectors should be provided on all components for each of the**
1316 **following functions:**

1317 **The Instrument should physically separate the electric interfaces for each of the following**
1318 **functions using distinct connectors:**

- 1319 1) +28 VDC bus power and return
- 1320 2) Telemetry and command signals with returns
- 1321 3) Deployment actuation power and return (where applicable)

1322 Rationale: A “standard” design practice to preclude mismating and to simplify test and anomaly
1323 resolution.

1324 9.2.6.4 *Command and Telemetry Returns*

1325 **Telemetry return and relay driver return pins should reside on the same connector(s) as**
1326 **the command and telemetry signals.**

1327 Rationale: A “standard” design practice to simplify testing and anomaly resolution.

1328 9.2.6.5 *Connector Usage and Pin Assignments*

1329 **Harness side power connectors and all box/bracket-mounted connectors supplying power**
1330 **to other components should have female contacts.**

1331 Rationale: Unexposed power supply connector contacts preclude arcing, mismating, and contact
1332 shorting.

1333 9.2.6.6 *Connector Function Separation*

1334 **Incompatible functions should be physically separated.**

1335 Rationale: A “standard” design practice to ensure connector conductor self-compatibility that
1336 precludes arcing and inductive current generation.

1337 9.2.6.7 *Connector Derating*

1338 **Instrument and Spacecraft should derate electrical connectors using *Electronic Parts,***
1339 ***Materials, and Processes for Space and Launch Vehicles (MIL-HDBK-1547A)* as a guide.**

1340 Rationale: A “standard” design practice.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 65 of 113

1341 9.2.6.8 *Connector Access*

1342 **At least 50 mm of clearance should exist around the outside of mated connectors.**

1343 Rationale: Ensures the ability to perform proper connector mate/de-mate operations.

1344 9.2.6.9 *Connector Engagement*

1345 **Connectors should be mounted to ensure straight and free engagement of the contacts.**

1346 Rationale: This precludes mismating connectors.

1347 9.2.6.10 *Power Connector Type*

1348 **The Instrument power connectors should be space-flight qualified MIL-DTL-24308, Class**
1349 **M, Subminiature Rectangular connectors with standard density size 20 crimp contacts and**
1350 **conform to GSFC S-311-P-4/09.**

1351 Rationale: Connector sizes and types selected based upon familiarity, availability, and space
1352 flight qualification.

1353 9.2.6.11 *Power Connector Size and Conductor Gauge*

1354 **The Instrument power connectors should be 20 AWG, 9 conductor (shell size 1) or 15**
1355 **conductor (shell size 2) connectors.**

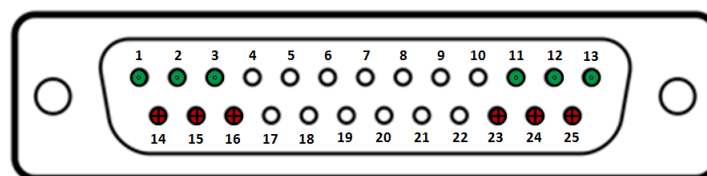
1356 Rationale: Application of stated design practices to the CII instrument power bus connectors.

1357 9.2.6.12 *Power Connector Pin Out*

1358 The Instrument power connectors should utilize the supply and return pin outs defined in Table
1359 9-1 and identified in Figure 9-1 thru Figure 9-3. *Note that the connectors are depicted with the*
1360 *instrument side of the connector (pins) shown while the spacecraft side of the connector (sockets)*
1361 *is the mirror image.*

1362 **Table 9-1: Instrument Power Connector Pin Out Definition**

Power Bus	Circuit	Supply Conductor Position	Return Conductor Position
#1	A & B	14,15,16,23,24,25	1,2,3,11,12,13
#2	A & B	9,10,11,13,14,15	1,2,3,6,7,8
Survival Heater	A & B	6,7,8,9	1,2,4,5



1363

1364 **Figure 9-1: Instrument Side Power Bus #1 Circuit A & Circuit B**

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 66 of 113

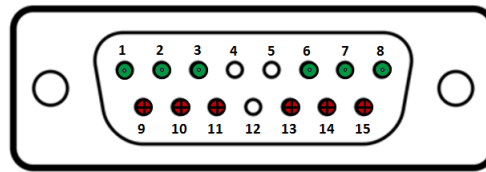


Figure 9-2: Instrument Side Power Bus #2 Circuit A & Circuit B

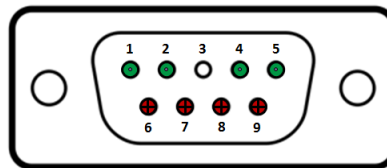


Figure 9-3: Instrument Side Survival Heater Power Bus Circuit A & Circuit B

9.2.6.13 *SpaceWire Connectors and Harnessing*

The Instrument SpaceWire harnessing and connectors should conform to ECSS-E-ST-50-12C.

Rationale: Describes the appropriate design practice for all SpaceWire connections and harnessing.

9.2.6.14 *Power Connector Provision*

The Instrument Provider should furnish all instrument power mating connectors (Socket Side) to the Spacecraft Manufacturer for interface harness fabrication.

Rationale: Describes the appropriate design practice for all SpaceWire connectors.

9.2.6.15 *Power Connector Conductor Size and Type*

The Instrument should have size 20 socket crimp contacts on the Instrument side power connectors and size 20 pin crimp contacts on the Spacecraft side power connectors.

Rationale: Application of the conductor size and type selected for the CII instrument power bus connectors to the corresponding instrument power connectors.

9.2.6.16 *Power Connector Keying*

The instrument power connectors should be keyed as defined in Figure 9-4.

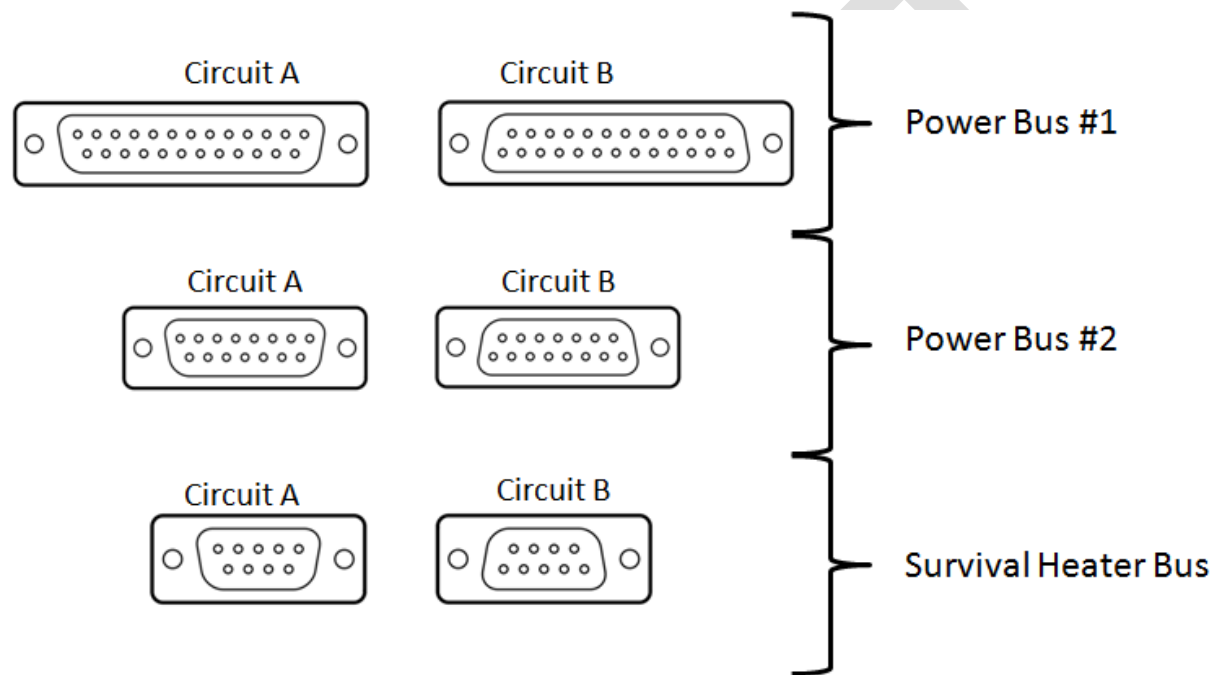


Figure 9-4: Power Connector Keying

9.2.6.17 *Connector Type Selection*

All connectors to be used by the Instrument should be selected from the Goddard Spaceflight Center (GSFC) Preferred Parts List (PPL).

Rationale: Utilizing the GSPC PPL simplifies connector selection, since all of its hardware is spaceflight qualified.

9.2.6.18 *Flight Plug Installation*

Flight plugs requiring installation prior to launch should be capable of being installed at the Spacecraft level.

Rationale: Ensures necessary access.

9.2.6.19 *Test Connector Location and Types*

Test connector and coupler ports should be accessible without disassembly throughout integration of the Instrument and Host Spacecraft.

Rationale: This reduces the complexity and duration of integrated testing and simplifies preflight anomaly resolution.

9.3 **Mechanical Interface Reference Material / Best Practices**

9.3.1 Minimum Fixed-Base Frequency

The Instrument should have a fixed based frequency greater than 50 Hz.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 68 of 113

1404 Rationale: This minimum fixed-based frequency exceeds the composite guidance of publically
1405 available Launch Vehicle Payload Planner's Guidebooks as applicable to primary spacecraft
1406 structures operating in both LEO and GEO regimes. To some extent, the Instrument will affect
1407 the spacecraft frequency depending on the payload's mass and mounting location. Spacecraft
1408 Manufacturers may negotiate for a greater fixed-based frequency for hosted payloads until the
1409 maturity of the instrument can support Coupled Loads Analysis.

1410 9.3.2 Mass Centering

1411 **The Instrument center of mass should be less than 5 cm radial distance from the $Z_{instrument}$**
1412 **axis, defined as the center of the Instrument mounting bolt pattern.**

1413 Rationale: Engineering analysis determined guideline Instrument mass centering parameters
1414 based on comparisons to spacecraft envelope in the *STP-SIV Payload User's Guide*.

1415 **The Instrument center of mass should be located less than half of the Instrument height**
1416 **above the Instrument mounting plane.**

1417 Rationale: Engineering analysis determined guideline Instrument mass centering parameters
1418 based on comparisons to spacecraft envelope in the *STP-SIV Payload User's Guide*.

1419 9.3.3 Documentation of Mechanical Properties

1420 9.3.3.1 Envelope

1421 **The MICD will document the Instrument component envelope (including kinematic**
1422 **mounts and MLI) as "not to exceed" dimensions.**

1423 Rationale: Defines the actual maximum envelope within which the instrument resides.

1424 9.3.3.2 Mass

1425 **[LEO] The MICD will document the mass of the Instrument, measured to $\pm 1\%$.**

1426 **[GEO] The MICD will document the mass of the Instrument, measured to less than 0.2%.**

1427 Rationale: To ensure that accurate mass data is provided for analytic purposes.

1428 9.3.3.3 Center of Mass

1429 **[LEO] The MICD will document the launch and or-orbit centers of mass of each**
1430 **Instrument, references to the Instrument coordinate axes and measured to ± 5 mm.**

1431 **[GEO] The MICD will document the launch and on-orbit centers of mass of each**
1432 **Instrument, referenced to the Instrument coordinate axes and measured to ± 1 mm.**

1433 Rationale: To ensure that accurate CG data is provided for analytic purposes.

1434 9.3.3.4 Moment of Inertia

1435 **[LEO] The MICD will document the moments of inertia, measured to less than 10%**

1436 **[GEO] The MICD will document the moments of inertia, measured to less than 1.5%.**

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 69 of 113

1437 Rationale: To ensure that accurate moments of inertia data is provided for analytic purposes.

1438 9.3.3.5 *Constraints on Moments of Inertia*

1439 **The MICD will document the constraints to the moments and products of inertia available**
1440 **to the Instrument.**

1441 Rationale: To define the inertial properties envelope within which the Instrument may operate
1442 and not adversely affect spacecraft and primary instrument operations.

1443 9.3.4 Dynamic Properties

1444 9.3.4.1 *Documentation of Dynamic Envelope or Surfaces*

1445 **The MICD will document the initial and final configurations, as well as the swept volumes**
1446 **of any mechanisms that cause a change in the external envelope or external surfaces of the**
1447 **Instrument.**

1448 Rationale: To define variations in envelope caused by deployables.

1449 9.3.4.2 *Documentation of Dynamic Mechanical Elements*

1450 **The MICD will document the inertia variation of the Instrument due to movable masses,**
1451 **expendable masses, or deployables.**

1452 Rationale: Allows spacecraft manufacturer to determine the impact of such variations on
1453 spacecraft and primary payload.

1454 9.3.4.3 *Caging During Test and Launch Site Operations*

1455 **Instrument mechanisms that require caging during test and launch site operations should**
1456 **cage when remotely commanded.**

1457 Rationale: To allow proper instrument operation during integration and test.

1458 **Instrument mechanisms that require uncaging during test and launch site operations**
1459 **should uncage when remotely commanded.**

1460 Rationale: To allow proper instrument operation during integration and test.

1461 **Instrument mechanisms that require caging during test and launch site operations should**
1462 **cage when accessible locking devices are manually activated.**

1463 Rationale: To allow proper instrument operation during integration and test.

1464 **Instrument mechanisms that require uncaging during test and launch site operations**
1465 **should uncage when accessible unlocking devices are manually activated.**

1466 Rationale: To allow proper instrument operation during integration and test.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 70 of 113

1467 9.3.5 Instrument Mounting

1468 9.3.5.1 *Documentation of Mounting*

1469 **The MICD will document the mounting interface, method, and geometry, including ground**
1470 **strap provisions and dimensions of the holes for mounting hardware.**

1471 Rationale: To ensure no ambiguity of mounting interface between instrument and spacecraft.

1472 9.3.5.2 *Documentation of Instrument Mounting Location*

1473 **The MICD will document the mounting location of the Instrument on the Host Spacecraft.**

1474 Rationale: To ensure no ambiguity of mounting location on spacecraft.

1475 9.3.5.3 *Metric Units*

1476 **The MICD will specify whether mounting fasteners will conform to SI or English unit**
1477 **standards.**

1478 Rationale: Metric hardware are not exclusively used industry wide. Choice of unit system likely
1479 will be set by spacecraft manufacturer.

1480 9.3.5.4 *Documentation of Finish and Flatness Guidelines*

1481 **The MICD will document finish and flatness guidelines for the mounting surfaces.**

1482 Rationale: To ensure no ambiguity of finish and flatness requirements at instrument interface.

1483 9.3.5.5 *Drill Template Usage*

1484 **The MICD will document the drill template details and serialization.**

1485 Rationale: Drill template details will be on record.

1486 **The Instrument Developer should drill spacecraft and test fixture interfaces using the**
1487 **MICD defined template.**

1488 Rationale: A common drill template will ensure proper alignment and repeatability of mounting
1489 holes.

1490 9.3.5.6 *Kinematic Mounts*

1491 **The Instrument Provider should provide all kinematic mounts.**

1492 Rationale: If the instrument requires kinematic mounts, they should be the responsibility of the
1493 instrument provider due to their knowledge of the instrument performance requirements.

1494 9.3.5.7 *Fracture Critical Components of Kinematic Mounts*

1495 **Kinematic mounts should comply with all analysis, design, fabrication, and inspection**
1496 **requirements associated with fracture critical components as defined by NASA-STD-5019.**

1497 Rationale: Kinematic mount failure is a potential catastrophic hazard to the Instrument and the
1498 Host Spacecraft.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 71 of 113

1499 9.3.6 Instrument Alignment

1500 9.3.6.1 *Documentation of Coordinate System*

1501 **The MICD will document the Instrument Reference Coordinate Frame.**

1502 Rationale: To ensure there is no ambiguity between instrument and spacecraft manufacturers
1503 regarding the Instrument Reference Coordinate System.

1504 9.3.6.2 *Instrument Interface Alignment Cube*

1505 **If the Instrument has critical alignment requirements, the Instrument should contain an**
1506 **Interface Alignment Cube (IAC), an optical cube that aligns with the Instrument Reference**
1507 **Coordinate Frame.**

1508 **The Spacecraft should contain an IAC that aligns with the Instrument Reference**
1509 **Coordinate Frame.**

1510 Rationale: To aid in proper alignment of the instrument to the spacecraft during Integration and
1511 Test.

1512 9.3.6.3 *Interface Alignment Cube Location*

1513 **The Instrument Developer should mount the IAC such that it is visible at all stages of**
1514 **integration with the Spacecraft from at least two orthogonal directions.**

1515 Rationale: Observation of IAC from at least two directions is required for alignment.

1516 9.3.6.4 *Interface Alignment Cube Documentation*

1517 **The MICD will document the location of all optical alignment cubes on the Instrument.**

1518 Rationale: To have a record of the IAC locations.

1519 9.3.6.5 *Instrument Boresight*

1520 **The Instrument Developer should measure the alignment angles between the IAC and the**
1521 **Instrument boresight.**

1522 Rationale: Since this knowledge is critical to the instrument provider they should be responsible
1523 for taking the measurement.

1524 **The MICD will document the alignment angles between the IAC and the Instrument**
1525 **boresight.**

1526 Rationale: To record the actual alignment angle in case it is needed for later analysis.

1527 9.3.6.6 *Pointing Accuracy, Knowledge, and Stability*

1528 **The MICD will document the Host Spacecraft's required pointing accuracy, knowledge,**
1529 **and stability capabilities in order for the Instrument to meet its operational requirements.**

1530 Rationale: To establish that spacecraft's pointing accuracy, knowledge and stability
1531 specifications meet requirements of instrument operation.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 72 of 113

1532 9.3.7 Integration and Test

1533 9.3.7.1 *Installation/Removal*

1534 **The Instrument should be capable of being installed in its launch configuration without**
1535 **disturbing the primary payload.**

1536 **The Instrument should be capable of being removed in its launch configuration without**
1537 **disturbing the primary payload.**

1538 Rationale: Primary payload safety.

1539 9.3.7.2 *Mechanical Attachment Points*

1540 **The Instrument should provide mechanical attachment points that will be used by a**
1541 **handling fixture during integration of the instrument.**

1542 Rationale: The handling fixtures will be attached to the Instrument while in the Integration and
1543 Test environment.

1544 **The MICD will document details of the mechanical attachment points used by the handling**
1545 **fixture.**

1546 Rationale: To ensure handling fixture attachment points are properly recorded.

1547 9.3.7.3 *Load Margins*

1548 **Handling and lifting fixtures should function according to their operational specifications**
1549 **at five (5) times limit load for ultimate.**

1550 **Handling and lifting fixtures should function according to their operational specifications**
1551 **at three (3) times limit load for yield.**

1552 **Handling fixtures should be tested to two (2) times working load.**

1553 Rationale: All three load margins maintain personnel and instrument safety.

1554 9.3.7.4 *Responsibility for Providing Handling Fixtures*

1555 **The Instrument Provider should provide proof-tested handling fixtures for each**
1556 **component with mass in excess of 16 kg.**

1557 Rationale: This guideline protects personnel safety.

1558 9.3.7.5 *Accessibility of Red Tag Items*

1559 **All items intended for pre-flight removal from the Instrument should be accessible without**
1560 **disassembly of another Instrument component.**

1561 Rationale: Instrument safety.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 73 of 113

1562 9.3.7.6 *Marking and Documentation of Test Points and Test Guidelines*

1563 **All test points and I&T interfaces on the Instrument should be visually distinguishable**
1564 **from other hardware components to an observer standing 4 feet away.**

1565 Rationale: Clear visual markings mitigate the risk that Integration and test personnel will attempt
1566 to connect test equipment improperly, leading to Instrument damage. Four feet exceeds the
1567 length of most human arms and ensures that the technician would see any markings on hardware
1568 he intends to connect test equipment to.

1569 **The MICD will document all test points and test guidelines.**

1570 Rationale: To ensure no ambiguity of Integration and Test interfaces and test points and to aide
1571 in developing I&T procedures.

1572 9.3.7.7 *Orientation Constraints During Test*

1573 **The MICD will document instrument mechanisms, thermal control, or any exclusions to**
1574 **testing and operations related to orientations.**

1575 Rationale: This documents any exceptions to the 1g functionality described in section 6.2.1

1576 9.3.7.8 *Temporary Items*

1577 **All temporary items to be removed following test should be visually distinguishable from**
1578 **other hardware components to an observer standing 4 feet away.**

1579 Rationale: Any preflight removable items need to be obvious to casual inspection to mitigate the
1580 risk of them causing damage or impairing spacecraft functionality during launch/operations.

1581 **The MICD will document all items to be installed prior to or removed following test and all**
1582 **items to be installed or removed prior to flight.**

1583 Rationale: To ensure no ambiguity of installed and/or removed items during Integration and Test
1584 through documentation.

1585 9.3.7.9 *Temporary Sensors*

1586 **The Instrument should accommodate temporarily installed sensors and supporting**
1587 **hardware to support environmental testing.**

1588 Rationale: To facilitate environmental testing.

1589 Example sensors include acceleration sensors and thermal monitors.

1590 9.3.7.10 *Captive Hardware*

1591 **The Instrument Developer should utilize captive hardware for all items planned to be**
1592 **installed, removed, or replaced during integration, except for Instrument mounting**
1593 **hardware and MLI.**

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 74 of 113

1594 Rationale: Captive hardware reduces the danger to the Host Spacecraft, Instrument, and
1595 personnel from fasteners dropped during integration.

1596 9.3.7.11 *Venting Documentation*

1597 **The MICD will document the number, location, size, vent path, and operation time of**
1598 **Instrument vents.**

1599 Rationale: This eliminates ambiguity regarding venting the Instrument and how it may pertain to
1600 the Host Spacecraft and primary instrument operations.

1601 9.3.7.12 *Purge Documentation*

1602 **The MICD will document Instrument purge guidelines, including type of purge gas, flow**
1603 **rate, gas purity specifications, filter pore size, type of desiccant (if any), and tolerable**
1604 **interruptions in the purge (and their duration).**

1605 Rationale: This ensures compatibility of instrument purging procedures with respect to the Host
1606 Spacecraft and primary instrument.

1607 9.3.7.13 *Combined Structural Dynamics Analysis Results*

1608 **The Spacecraft Manufacturer should furnish the combined structural dynamics analysis**
1609 **results to the respective Instrument Provider.**

1610 Rationale: To ensure the combined structural dynamics does not impede instrument operations.

1611 9.3.7.14 *Non-Destructive Evaluation*

1612 **Kinematic mount flight hardware should show no evidence of micro cracks when inspected**
1613 **using Non-Destructive Evaluation (NDE) techniques following proof loading.**

1614 Rationale: To ensure kinematic mounts meet load requirements without damage.

1615 **The MICD will document the combined structural dynamics analysis.**

1616 Rationale: Record maintenance.

1617 **9.4 Thermal Interface Reference Material / Best Practices**

1618 9.4.1 Heat Management Techniques

1619 9.4.1.1 *Heat Transfer Hardware*

1620 **The Instrument Developer should consider implementing heat pipes and high thermal**
1621 **conductivity straps to transfer heat within the Instrument.**

1622 Rationale: A spacecraft would likely more easily accommodate an instrument whose thermal
1623 design is made more flexible by the inclusion of heat transfer hardware.

1624 9.4.1.2 *Survivability at Very Low Temperature*

1625 **The Instrument Developer should consider using components that can survive at -55° C to**
1626 **minimize the survival power demands on the Spacecraft.**

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 75 of 113

1627 Rationale: -55° C is a common temperature to which space components are certified. Using
1628 components certified to this temperature decreases the survival heater power demands placed
1629 upon the Host Spacecraft.

1630 9.4.1.3 *Implementation of Cooling Function*

1631 **The Instrument Developer should consider implementing thermoelectric coolers or**
1632 **mechanical coolers if cryogenic temperatures are required for the instrument to ease the**
1633 **restrictions on Instrument radiator orientations.**

1634 Rationale: Thermoelectric or mechanical coolers provide an alternative technique to achieve very
1635 low temperatures that do not impose severe constraints on the placement of the radiator.

1636 9.4.1.4 *Implementation of High Thermal Stability*

1637 **The Instrument Developer should consider implementing high thermal capacity hardware,**
1638 **such as phase change material, in order to increase the Instrument's thermal stability.**

1639 Rationale: Some optical instruments require very high thermal stability and given the relatively
1640 low masses expected in CII Instruments, incorporating phase change material for thermal storage
1641 is a useful technique.

1642 9.4.2 Survival Heaters

1643 The use of survival heaters is a technique to autonomously apply heat to an Instrument in the
1644 event that the thermal subsystem does not perform nominally, either due to insufficient power
1645 from the Host Spacecraft or an inflight anomaly.

1646 9.4.2.1 *Survival Heater Responsibility*

1647 **The Instrument Provider should provide and install all Instrument survival heaters.**

1648 Rationale: Survival heaters are a component of the Instrument.

1649 9.4.2.2 *Mechanical Thermostats*

1650 **The Instrument should control Instrument survival heaters via mechanical thermostats.**

1651 Rationale: Mechanical thermostat allows control of the survival heaters while the instrument
1652 avionics are not operating.

1653 9.4.2.3 *Survival Heater Documentation*

1654 **The TICD will document survival heater characteristics and mounting details.**

1655 Rationale: This will capture the agreements negotiated by the Spacecraft Manufacturer and
1656 Instrument Developer.

1657 9.4.2.4 *Minimum Turn-On Temperatures*

1658 **The Instrument should maintain the temperature of its components at a temperature no**
1659 **lower than that required to safely energize and operate the components.**

1660 Rationale: Some electronics require a minimum temperature in order to safely operate.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 76 of 113

1661 9.4.3 *Thermal Performance and Monitoring*

1662 9.4.3.1 *Surviving Arbitrary Pointing Orientations*

1663 **The Instrument should be capable of surviving arbitrary pointing orientations without**
1664 **permanent degradation of performance for a minimum of four (4) orbits with survival**
1665 **power only.**

1666 Rationale: This is a typical NASA earth orbiting science instrument survival requirement.

1667 9.4.3.2 *Documentation of Temperature Limits*

1668 **The TICD will document temperature limits for Instrument components during ground**
1669 **test and on-orbit scenarios.**

1670 Rationale: This will provide values for the Integration and Test technicians to monitor and
1671 manage.

1672 9.4.3.3 *Documentation of Monitoring Location*

1673 **The TICD will document the location of all Instrument temperature sensors.**

1674 Rationale: This is the standard means to documents the agreement between the spacecraft and
1675 instrument

1676 9.4.3.4 *Temperature Monitoring During OFF Mode*

1677 **The Instrument Designer should assume that the Host Spacecraft will monitor only one**
1678 **temperature on the spacecraft side of the payload interface when the payload is off. During**
1679 **extreme cases such as host anomalies, however, even this temperature might not be**
1680 **available.**

1681 Rationale: This limits the demands that the Instrument may place on the Host Spacecraft.

1682 9.4.3.5 *Thermal Control Hardware Documentation*

1683 **The TICD will document Instrument thermal control hardware.**

1684 Rationale: This is the standard means to documents the agreement between the spacecraft and
1685 instrument

1686 9.4.3.6 *Thermal Performance Verification*

1687 **The Instrument Developer should verify the Instrument thermal control system's ability to**
1688 **maintain hardware within allowable temperature limits either empirically by thermal**
1689 **balance testing or by analysis for conditions that cannot be ground tested.**

1690 Rationale: These verification methods ensure that the Instrument's thermal performance meets
1691 the guidelines and agreements documented in the TICD.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 77 of 113

1692 **9.5 Environmental Reference Material / Best Practices**

1693 9.5.1 Introduction

1694 The following environmental best practices provide potential Earth Science instrument and HPO
1695 spacecraft manufacturers a common design and analysis basis in order to progress the design of
1696 instrument prior to selection of a Host Spacecraft and launch vehicle.

1697 9.5.2 Radiation-Induced SEE

1698 The following best practices describe how the Instrument should behave in the event that a
1699 radiation-induced SEE does occur.

1700 9.5.2.1 *Temporary Loss of Function or Loss of Data*

1701 **Temporary loss of function or loss of data is permitted, provided that the loss does not**
1702 **compromise instrument health and full performance can be recovered rapidly.**

1703 Rationale: Identifies that a temporary loss of function and/or data is permissible in support of
1704 correcting anomalous operations. This includes autonomous detection and correction of
1705 anomalous operations as well as power cycling.

1706 9.5.2.2 *Restoration of Normal Operation and Function*

1707 **To minimize loss of data, normal operation and function should be restored via internal**
1708 **correction methods without external intervention.**

1709 Rationale: Identifies that autonomous fault detection and correction should be implemented.

1710 9.5.2.3 *Irreversible Actions*

1711 **Irreversible actions should not be permitted. The hardware design should have no parts**
1712 **which experience radiation induced latch-up to an effective LET of 75 MeV/mg/cm² and a**
1713 **fluence of 10⁷ ions/cm².**

1714 Rationale: Identifies limitations for radiation induced latch-up and prescribes both a LET and an
1715 ion fluence immunity level

1716 **9.6 Software Engineering Reference Material / Best Practices**

1717 **The Instrument System's software should comply with Class C software development**
1718 **requirements and guidelines, in accordance with NPR 7150.2A**

1719 Rationale: NPR 7150.2A Appendix E assigns Class C to "flight or ground software that is
1720 necessary for the science return from a single (non-primary) instrument." NASA Class C
1721 software is any flight or ground software that contributes to mission objectives, but whose
1722 correct functioning is not essential to the accomplishment of primary mission objectives. In this
1723 context, primary mission objectives are exclusively those of the Host Spacecraft.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 78 of 113

1724 **9.7 Contamination Reference Material / Best Practices**

1725 **9.7.1 Assumptions**

- 1726 1) During the matching process, The Host Spacecraft Owner/Integrator and the Instrument
1727 Developer will negotiate detailed parameters regarding contamination control. The
1728 Contamination Interface Control Document (CICD) will record those parameters and
1729 decisions.
- 1730 2) The Instrument Developer will ensure that any GSE accompanying the Instrument is
1731 cleanroom compatible in accordance with the CICD.
- 1732 3) The Instrument Developer will ensure that any GSE accompanying the Instrument into a
1733 vacuum chamber during Spacecraft thermal-vacuum testing is vacuum compatible in
1734 accordance with the CICD.
- 1735 4) The Host Spacecraft Manufacturer/Systems Integrator will attach the Instrument to the
1736 Host Spacecraft such that the contamination products from the vents of the Instrument do
1737 not directly impinge on the contamination-sensitive surfaces nor directly enter the
1738 aperture of another component of the Spacecraft system.
- 1739 5) The Host Spacecraft Manufacturer/Systems Integrator will install protective measures as
1740 provided by the Instrument Provider to protect sensitive Instrument surfaces while in the
1741 Shipment, Integration and Test, and Launch environments.
- 1742 6) The Launch Vehicle Provider will define the upper limit for the induced contamination
1743 environment. This is typically defined as the total amount of molecular and particulate
1744 contamination deposited on exposed spacecraft surfaces from the start of payload fairing
1745 encapsulation until the upper stage separation and contamination collision avoidance
1746 maneuver (CCAM).

1747 **9.7.2 Instrument Generated Contamination**

1748 **9.7.2.1 Verification of Cleanliness**

1749 **The Instrument Developer should verify by test the cleanliness of the instrument exterior**
1750 **surfaces documented in the CICD, prior to delivery to the Spacecraft**
1751 **Manufacturer/Systems Integrator.**

1752 Rationale: The Instrument must meet surface cleanliness requirements that are consistent with
1753 the cleanliness requirements as specified for the Host Spacecraft by the Spacecraft Manufacturer.
1754 A record of the cleanliness verification should be provided to the Host Spacecraft Manufacturer
1755 prior to Instrument integration with the Host Spacecraft.

1756 **9.7.2.2 Instrument Sources of Contamination**

1757 **The CICD will document all sources of contamination that can be emitted from the**
1758 **Instrument.**

1759 Rationale: This determines the compatibility of the Instrument with the Host Spacecraft and
1760 mitigate the risk of Instrument-to-Host-Spacecraft cross contamination.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 79 of 113

1761 9.7.2.3 *Instrument Venting Documentation*

1762 **The CICD will document the number, location, size, vent path, and operation time of all**
1763 **Instrument vents.**

1764 Rationale: Mitigation of Instrument-to-Host-Spacecraft cross contamination (See 9.7.2.2)

1765 9.7.2.4 *Flux of outgassing products*

1766 **The CICD will document the flux (g/cm²/s) of outgassing products issuing from the**
1767 **primary Instrument vent(s).**

1768 Rationale: Mitigation of Instrument-to-Host-Spacecraft cross contamination (See 9.7.2.2)

1769 9.7.2.5 *Sealed Hardware*

1770 **The Instrument should prevent the escape of actuating materials from Electro-explosive**
1771 **devices (EEDs), hot-wax switches, and other similar devices.**

1772 Rationale: Mitigation of Instrument-to-Host-Spacecraft cross contamination (See 9.7.2.2)

1773 9.7.2.6 *Nonmetallic Materials Selection*

1774 **The Instrument design should incorporate only those non-metallic materials that meet the**
1775 **nominal criteria for thermal-vacuum stability: Total Mass Loss (TML) ≤ 1.0 %, Collected**
1776 **Volatile Condensable Material (CVMC) ≤ 0.1 %, per ASTM E595 test method.**

1777 Rationale: Host Spacecraft Manufacturers generally require that all nonmetallic materials
1778 conform to the nominal criteria for thermal-vacuum stability. A publicly accessible database of
1779 materials tested per ASTM E595 is available at: www.outgassing.nasa.gov Note: Some Host
1780 Spacecraft Manufacturers may require lower than the nominal levels of TML and CVMC.

1781 9.7.2.7 *Wiring and MLI Cleanliness Guidelines*

1782 **The CCID will document thermal vacuum bakeout requirements for Instrument wiring**
1783 **harnesses and MIL.**

1784 Rationale: Thermal vacuum conditioning of materials and components may be necessary to
1785 meet Spacecraft contamination requirements.

1786 9.7.2.8 *Particulate Debris Generation*

1787 **The Instrument design should avoid the use of materials that are prone to produce**
1788 **particulate debris.**

1789 Rationale: Host Spacecraft Manufacturers generally prohibit materials that are prone to produce
1790 particulate debris, either from incidental contact or through friction or wear during operation.
1791 Therefore, such materials, either in the construction of the payload or ground support equipment,
1792 should be avoided. Where no suitable alternative material is available, an agreement with the
1793 Host Spacecraft will be necessary and a plan to mitigate the risk posed by the particulate matter
1794 implemented.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 80 of 113

1795 9.7.2.9 *Spacecraft Integration Environments*

1796 **The Instrument should be compatible with processing in environments ranging from IEST-**
1797 **STD-1246 ISO-6 to ISO-8.**

1798 Rationale: Spacecraft integration facilities may vary in cleanliness and environmental control
1799 capabilities depending on the Spacecraft Manufacturer and integration/test venue. Instruments
1800 and associated ground support equipment should be compatible with protocols contamination
1801 control of ISO-6 cleanroom environments. Instruments should be compatible with operations in
1802 up to ISO-8 environments, employing localized controls such as bags, covers, and purges to
1803 preserve cleanliness; such controls must be integrated into the spacecraft integrations process.

1804 9.7.3 Accommodation of Externally Generated Contamination

1805 9.7.3.1 *Protective Covers: Responsibility*

1806 **The Instrument Developer should provide protective covers for any contamination-**
1807 **sensitive components of the Instrument.**

1808 Rationale: Preservation of Instrument cleanliness during Spacecraft I&T.

1809 9.7.3.2 *Protective Covers: Documentation*

1810 **The CICD will document the requirements and procedures for the use of protective covers**
1811 **(such as bags, draping materials, or hardcovers).**

1812 Rationale: Preservation of Instrument cleanliness during Spacecraft I&T.

1813 9.7.3.3 *Instrument Cleanliness Requirements*

1814 **The CICD will document the cleanliness goals for all contamination-sensitive instrument**
1815 **surfaces that will be exposed while in the Integration and Test Environment.**

1816 Rationale: Enables the Spacecraft Manufacturer and Instrument Provider to negotiate appropriate
1817 and reasonable instrument accommodations or determine the degree of deviation from the
1818 defined goals.

1819 9.7.4 Instrument Purge Requirements

1820 **The CICD will document Instrument purge requirements, including type of purge gas, flow**
1821 **rate, gas purity specifications, filter pore size, type of desiccant (if any), and whether**
1822 **interruptions in the purge are tolerable.**

1823 Rationale: The Spacecraft Manufacturer generally will provide access to a gas supply of the
1824 desired type, purity, and flow rate. The Instrument provider is responsible to provide the
1825 necessary purge interface ground support equipment (See 9.7.4.1).

1826 9.7.4.1 *Instrument Purge Ground Support Equipment (GSE)*

1827 **The Instrument Provider should provide purge ground support equipment (GSE)**
1828 **incorporating all necessary filtration, gas conditioning, and pressure regulation**
1829 **capabilities.**

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 81 of 113

1830 Rationale: The Instrument provider is responsible for control of the gas input to the instrument
1831 during Spacecraft Integration & Test. This purge GSE is the interface between the Instrument
1832 and the gas supply provided by the Spacecraft Manufacturer.

1833 9.7.4.2 *Spacecraft to Instrument Purge Interface*

1834 **The MICD will document any required mechanical interface of the Instrument purge**
1835 **between the Instrument and Spacecraft.**

1836 Rationale: If the Instrument Purge requires a mechanical interface with the Spacecraft, that
1837 interface shall be documented in the MICD. The Spacecraft Manufacturer will negotiate with
1838 the Launch Vehicle Provider any resultant required purge interface between the Spacecraft and
1839 Launch Vehicle.

1840 9.7.4.3 *Instrument Inspection and Cleaning During I&T: Responsibility*

1841 **The Instrument Provider should be responsible for cleaning the Instrument while in the**
1842 **Integration and Test Environment.**

1843 Rationale: The Instrument Provider is responsible for completing any required inspections during
1844 I&T. The Instrument Provider may, upon mutual agreement, designate a member of the
1845 Spacecraft I&T team to perform inspections and cleaning.

1846 9.7.4.4 *Instrument Inspection and Cleaning During I&T: Documentation*

1847 **The CIGD will document any required inspection or cleaning of the Instrument while in**
1848 **the Integration and Test Environment.**

1849 Rationale: Instrument inspections and cleaning consume schedule resources and must be
1850 conducted in coordination with other Spacecraft I&T activities.

1851 9.7.4.5 *Spacecraft Contractor Supplied Analysis Inputs*

1852 **The CIGD will document the expected Spacecraft-induced contamination environment.**

1853 Rationale: Mitigate the risk of Instrument-Spacecraft cross contamination. The Spacecraft
1854 Contractor may perform analyses or make estimates of the expected spacecraft-induced
1855 contamination environment, which will be documented in CIGD. The results of such
1856 assessments may include a quantitative estimate of the deposition of plume constituents to
1857 Instrument surfaces and be used to determine the allowable level of contamination emitted from
1858 the Instrument.

1859 9.7.4.6 *Launch Vehicle Contractor Supplied Analysis Inputs*

1860 **The CIGD will document the Launch Vehicle-induced contamination environment**

1861 Rationale: Most Launch Vehicle Providers are able to provide nominal information regarding the
1862 upper bound of molecular and particulate contamination imparted to the Spacecraft Payload
1863 surfaces; frequently such information is found in published User Guides for specific Launch
1864 Vehicles. Spacecraft and Instrument Providers should use this information in developing

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 82 of 113

1865 mitigations against the risk of contamination during integrated operations with the Launch
1866 Vehicle.

1867 9.8 Model Guidelines and Submittal Details

1868 9.8.1 Finite Element Model Submittal

1869 **The Instrument Developer should supply the Spacecraft Manufacturer with a Finite**
1870 **Element Model in accordance with the GSFC GIRD.**

1871 Rationale: The GIRD defines a NASA Goddard-approved interface between the Earth Observing
1872 System Common Spacecraft and Instruments, including requirements for finite element models.
1873 As of the publication of this guideline document, Gird Rev B is current, and the Finite Element
1874 Model information is in Section 11.1.

1875 9.8.2 Thermal Math Model

1876 **The Instrument Developer should supply the Spacecraft Manufacturer with a reduced**
1877 **node geometric and thermal math model in compliance with the following sections.**

1878 Rationale: The requirements and details for the Thermal Model submittal listed in this section are
1879 based on commonly used NASA documents such as GSFC GIRD and JPL spacecraft instrument
1880 interface requirement documents.

1881 9.8.2.1 *Model Format*

1882 Model format should be in Thermal Desktop version 5.2 or later or NX Space Systems Thermal
1883 version 7.x or later.

1884 9.8.2.2 *Units of Measure*

1885 Model units should be SI.

1886 9.8.2.3 *Radiating Surface Element Limit*

1887 Radiating surface elements should be limited to less than 200.

1888 9.8.2.4 *Thermal Node Limit*

1889 Thermal nodes should be limited to less than 500.

1890 9.8.2.5 *Model Verification*

1891 The Geometric Math Model and Thermal Math Model should be documented with a benchmark
1892 case in which the Spacecraft Developer may use to verify the model run.

1893 9.8.2.6 *Steady-State and Transient Analysis*

1894 The model should be capable of steady-state and transient analysis.

1895 9.8.2.7 *Reduced Node Thermal Model Documentation*

1896 The Instrument Provider should supply the Spacecraft Developer with documentation describing
1897 the reduced node thermal model. The documentation should contain the following:

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 83 of 113

- 1898 9.8.2.1.7 Node(s) Location
1899 The node(s) location at which each temperature limit applies.
- 1900 9.8.2.2.7 Electrical Heat Dissipation
1901 A listing of electrical heat dissipation and the node(s) where applied.
- 1902 9.8.2.3.7 Active Thermal Control
1903 A listing of active thermal control, type of control (*e.g.*, proportional heater), and the node(s)
1904 where applied.
- 1905 9.8.2.4.7 Boundary Notes
1906 A listing and description of any boundary nodes used in the model.
- 1907 9.8.2.5.7 Environmental Heating
1908 A description of the environmental heating (Beta angle, heliocentric distance, planetary albedo,
1909 planetary emissive power, *etc.*).
- 1910 9.8.2.6.7 User Generated Logic
1911 A description of any user generated software logic
- 1912 9.8.3 Thermal Analytical Models
1913 The Instrument Provider should furnish the Spacecraft Manufacturer with a written report
1914 documenting the results of the detailed thermal analysis and the comparison of results to the
1915 reduced node model, including a high-level energy balance and heat flow map.
- 1916 9.8.4 Mechanical CAD Model
1917 9.8.4.1 *Model Format*
1918 **The Instrument Provider should provide Mechanical CAD models that have been created**
1919 **in a file format compatible with the spacecraft vendor, i.e. in the same program and version**
1920 **of the spacecraft vendor or in a neutral file format such as IGES or STEP.**
- 1921 Rationale: The Spacecraft Manufacturer may need Mechanical CAD models for hosted payload
1922 assessment studies.
- 1923 9.8.5 Mass Model
1924 9.8.5.1 *Instrument Mass Model*
1925 **The Instrument Provider should provide all physical mass models required for spacecraft**
1926 **mechanical testing.**
- 1927 Rationale: The Spacecraft Manufacturer may fly the mass model in lieu of the Instrument in the
1928 event that Instrument delivery is delayed.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 84 of 113

1929

Appendix A Acronyms

AI&T	Assembly, Integration, and Test
AP	Average Power
ASD	Acceleration Spectral Density
AWG	American Wire Gauge
CCSDS	Consultative Committee for Space Data Systems
CE	Conducted Emissions
CICD	Contamination ICD
CII	Common Instrument Interface
COTS	Commercial Off The Shelf
CS	Conducted Susceptibility
CVCM	Collected Volatile Condensable Material
DICD	Data ICD
EED	Electro-explosive Device
EICD	Electrical Power ICD
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EOS	Earth Observing System
EPS	Electrical Power System
ESA	European Space Agency
EVI	Earth Venture Instrument
FDIR	Fault Detection, Isolation, and Recovery
FOV	Field of View
GCR	Galactic Cosmic Ray
GEO	Geostationary Earth Orbit
GEVS	General Environmental Verification Standard
GIRD	General Interface Requirements Document
GOES	Geostationary Operational Environmental Satellites
GSE	Ground Support Equipment
GSFC	Goddard Spaceflight Center
GTO	Geostationary Transfer Orbit
HPO	Hosted Payload Opportunity
HPOC	Hosted Payload Operations Center
HSOC	Host Spacecraft Operations Center
I&T	Integration and Test
IAC	Interface Alignment Cube
ICD	Interface Control Document
KDP	Key Decision Point
LEO	Low Earth Orbit
LET	Linear Energy Transfer
LVDS	Low Voltage Differential Signaling
MAC	Mass Acceleration Curve

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 85 of 113

MICD	Mechanical ICD
MLI	Multi-layer Insulation
NDE	Non-Destructive Evaluation
NICM	NASA Instrument Cost Model
NPR	NASA Procedural Requirement
NTIA	National Telecommunications and Information Administration
OAP	Orbital Average Power
PI	Principal Investigator
PPL	Preferred Parts List
RDM	Radiation Design Margin
RE	Radiated Emissions
RFI	Request for Information
RS	Radiated Susceptibility
RSDO	Rapid Spacecraft Development Office
SEE	Single Event Effect
SI	Système Internationale
SMC	US Air Force Space and Missile Systems Center
SMC/XRFH	SMC Hosted Payload Office
SPS	Spectrum Planning Subcommittee
SRS	Shock Response Spectrum
TEMP	Test and Evaluation Master Plan
TICD	Thermal ICD
TID	Total Ionizing Dose
TML	Total mass Loss
VDC	Volts Direct Current

1930

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 86 of 113

Appendix B Reference Documents

- 1931
- 1932 417-R-GIRD-0009, *Geostationary Operational Environmental Satellite GOES-R Series General*
- 1933 *Interface Requirements Document (GOES-R GIRD).*
- 1934 Arianespace, *Ariane 5 User's Manual, Issue 5, Revision 1*, July 2011, available at:
- 1935 [http://www.arianespace.com/launch-services-](http://www.arianespace.com/launch-services-ariane5/Ariane5_users_manual_Issue5_July2011.pdf)
- 1936 [ariane5/Ariane5_users_manual_Issue5_July2011.pdf](http://www.arianespace.com/launch-services-ariane5/Ariane5_users_manual_Issue5_July2011.pdf).
- 1937 Arianespace, *Soyuz User's Manual, Issue 2, Revision 0*, March 2012, available at:
- 1938 [http://www.arianespace.com/launch-services-soyuz/Soyuz-Users-Manual-March-](http://www.arianespace.com/launch-services-soyuz/Soyuz-Users-Manual-March-2012.pdf)
- 1939 [2012.pdf](http://www.arianespace.com/launch-services-soyuz/Soyuz-Users-Manual-March-2012.pdf).
- 1940 Arianespace, *Vega User's Manual, Issue 3, Revision 0*, March 2006, available at:
- 1941 <http://www.arianespace.com/launch-services-vega/VEGAUsersManual.pdf>.
- 1942 ASTM E595-07, *Standard Test Method for Total Mass Loss and Collected Volatile Condensable*
- 1943 *Materials from Outgassing in a Vacuum Environment*, ASTM International, 2007.
- 1944 Barth, J. L., Xapsos, M., Stauffer, C., and Ladbury, R., *The Radiation Environment for*
- 1945 *Electronic Devices on the GOES-R Series Satellites*, NASA GSFC 417-R-RPT-0027,
- 1946 March 2004.
- 1947 Bilitza, D., *AE-8/AP-8 Radiation Belt Models*, NASA Space Physics Data Facility, Goddard
- 1948 Space Flight Center, available at: <http://modelweb.gsfc.nasa.gov/models/trap.html>.
- 1949 de Rooij, A., "CORROSION IN SPACE," ESA-ESTEC, *Encyclopedia of Aerospace*
- 1950 *Engineering*, John Wiley & Sons Ltd, 2010, available at:
- 1951 http://esmat.esa.int/Publications/Published_papers/Corrosion_in_Space.pdf.
- 1952 Earth Venture Instrument – 1 solicitation (NNH12ZDA006O-EVI1), February 2012, available at:
- 1953 <https://www.fbo.gov/spg/NASA/HQ/OPHQDC/NNH12ZDA006O-EVI1/listing.html>.
- 1954 ECSS-E-ST-50-12C, *SpaceWire Links, Nodes, Routers, and Networks, European Cooperation*
- 1955 *for Space Standardization (EECS)*, July 2008.
- 1956 European Space Agency, *Meteoroid and Space Debris Terrestrial Environment Reference*
- 1957 *(MASTER) 2009*, available at: <http://www.master-model.de/>.
- 1958 Feynman, J., A. Ruzmaikin, and V. Berdichevsky, "The JPL proton fluence model: an update",
- 1959 *JASTP*, 64, 1679-1686, 2002.
- 1960 Goddard Space Flight Center, *General Environmental Verification Specification for STS & ELV*
- 1961 *Payloads, Subsystems, and Components (GEVS-SE), Revision A*, June 1996.
- 1962 Grün, E., H.A. Zook, H. Fechtig, R.H. Giese, "Collisional balance of the meteoritic complex,"
- 1963 *Icarus* 62, 244-272, 1985.
- 1964 GSFC 422-11-122-01, Rev. B, *General Interface Requirements Document (GIRD) for EOS*
- 1965 *Common Spacecraft/Instruments*, August 1998.
- 1966 GSFC S-311-P-4/09 Rev. C, *Connectors, Electrical, Polarized Shell, Rack and Panel, for Space*
- 1967 *Use*, June 1991, available at: https://nepp.nasa.gov/files/22992/S-311-P-4_09C.pdf.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 87 of 113

- 1968 GSFC-733-HARN Rev. C, *Design and Manufacturing Standard for Electrical Harnesses*, July
1969 2003, available at: <http://eed.gsfc.nasa.gov/docs/harness/harness.html>.
- 1970 GSFC-PPL-21, *Goddard Space Flight Center Preferred Parts List, Notice 1*, May 1996,
1971 available at: <http://nepp.nasa.gov/docuploads/AA0D50FD-18BE-48EF-ABA2E1C4EFF2395F/ppl21notice1.pdf>.
1972
- 1973 GSFC-STD-7000, *General Environmental Verification Standard (GEVS) For GSFC Flight*
1974 *Programs and Projects*, April 2005.
- 1975 IEST-STD-1246D, *Product Cleanliness Levels and Contamination Control Program*.
- 1976 ILS, *Proton Mission Planner's Guide, Revision 7*, July 2009, available at:
1977 <http://www.ilslaunch.com/sites/default/files/pdf/Proton%20Mission%20Planner%27s%20Guide%20Revision%207%20%28LKEB-9812-1990%29.pdf>.
1978
- 1979 IPC J-STD-001ES, *Joint Industry Standard, Space Applications Hardware Addendum to J-STD-*
1980 *001E, Requirements for Soldered Electrical and Electronic Assemblies*, December 2010,
1981 available at: http://www.ipc.org/4.0_Knowledge/4.1_Standards/IPC-J-STD-001ES.pdf.
- 1982 Kosmotras, *Dnepr Space Launch System User's Guide, Issue 2*, November 2001, available at:
1983 <http://www.kosmotras.ru/upload/dneprlv.zip>.
- 1984 MIL-DTL-24308, *General Specification for Connectors, Electric, Rectangular,*
1985 *Nonenvironmental, Miniature, Polarized Shell, Rack and Panel, w/ Amendment 1,*
1986 *Revision G*, January 2011.
- 1987 MIL-HDBK-1547A, *Department of Defense Handbook: Electronic Parks, Materials, and*
1988 *Processes for Space and Launch Vehicles*, July 1998.
- 1989 MIL-STD-461F, *Requirements for the Control of Electromagnetic Interference Characteristics*
1990 *of Subsystems and Equipment*, December 2007.
- 1991 MIL-STD-462, *Measurement of Electromagnetic Interference Characteristics*, July 1967.
- 1992 NASA Orbital Debris Program Office, *Orbital Debris Engineering Models (ORDEM2000)*,
1993 available at: <http://www.orbitaldebris.jsc.nasa.gov/model/engrmodel.html>.
- 1994 NASA-HDBK-4001, *Electrical Grounding Architecture for Unmanned Spacecraft*, February
1995 1998, available at: <https://standards.nasa.gov/documents/detail/3314876>.
- 1996 NASA-HDBK-4002, Rev A, *Mitigating In-Space Charging Effects-A Guideline*, March 2011,
1997 available at: <https://standards.nasa.gov/documents/detail/3314877>.
- 1998 NASA-STD-4003, *Electrical Bonding for Launch Vehicles, Spacecraft, Payloads and Flight*
1999 *Equipment*, September 2003, available at:
2000 <https://standards.nasa.gov/documents/detail/3315121>.
- 2001 NASA-STD-5019, *Fracture Control Requirements for Spaceflight Hardware*, January 2008,
2002 available at: <https://standards.nasa.gov/documents/detail/3315593>.
- 2003 NASA-STD-8739.4, *Crimping, Interconnecting Cables, Harnesses, and Wiring*, February 1998,
2004 available at: <https://standards.nasa.gov/documents/detail/3314921>.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 88 of 113

2005	NPR 2570.1B, <i>NASA Radio Frequency (RF) Spectrum Management Manual</i> , December 2008,
2006	available at: https://standards.nasa.gov/documents/detail/3315383 .
2007	NPR 7150.2A, <i>NASA Software Engineering Requirements</i> , November 2009, available at:
2008	https://standards.nasa.gov/documents/detail/3315720 .
2009	NPR 8705.4, <i>Risk Classification for NASA Payloads</i> , June 2004, available at:
2010	https://standards.nasa.gov/documents/viewdoc/3315479/3315479 .
2011	Orbital Sciences Corporation, <i>Minotaur I User's Guide</i> , Release 2.1, January 2006, available at:
2012	http://www.orbital.com/NewsInfo/Publications/Minotaur_Guide.pdf .
2013	Orbital Sciences Corporation, <i>Minotaur IV User's Guide</i> , Release 1.1, January 2006, available
2014	at: http://www.orbital.com/NewsInfo/Publications/Minotaur_IV_Guide.pdf
2015	Orbital Sciences Corporation, <i>Pegasus User's Guide, Release 7.0</i> , April 2010, available at:
2016	http://www.orbital.com/NewsInfo/Publications/pegasus_ug.pdf .
2017	<i>Rapid III Contract Catalog</i> , NASA Rapid Spacecraft Development Office, available at:
2018	http://rsdo.gsfc.nasa.gov/catalog.html .
2019	<i>Request for Information and Geostationary Earth Orbit Hosted Payload Opportunities and</i>
2020	<i>Accommodations</i> , April 2012, available at:
2021	https://www.fbo.gov/spg/NASA/LaRC/OPDC20220/CII-GEO/listing.html . RFI
2022	Responses are proprietary.
2023	Sea Launch Company, <i>Sea Launch User's Guide, Revision D</i> , February 2008, available at:
2024	http://www.sea-launch.com/customers_webpage/sluw/doc_src/SectionALL.pdf .
2025	<i>Space Test Program – Standard Interface Vehicle (STP-SIV) Payload User's Guide</i> , June 2008.
2026	SpaceX, <i>Falcon 1 Launch Vehicle Payload User's Guide, Revision 7</i> , May 2008, available at:
2027	https://spacex.com/Falcon1UsersGuide.pdf .
2028	SpaceX, <i>Falcon 9 Launch Vehicle Payload User's Guide, Revision 1</i> , 2009, available at:
2029	https://spacex.com/Falcon9UsersGuide_2009.pdf .
2030	United Launch Alliance, <i>Atlas V Launch Services User's Guide</i> , March 2010, available at:
2031	http://www.ulalaunch.com/site/docs/product_cards/guides/AtlasVUsersGuide2010.pdf .
2032	United Launch Alliance, <i>Delta II Payload Planners Guide</i> , December 2006, available at:
2033	http://www.ulalaunch.com/site/docs/product_cards/guides/DeltaIIPayloadPlannersGuide2
2034	007.pdf .
2035	United Launch Alliance, <i>Delta IV Payload Planners Guide</i> , September 2007, available at:
2036	http://www.ulalaunch.com/site/docs/product_cards/guides/DeltaIIPayloadPlannersGuide2
2037	007.pdf .

Appendix C Units of Measure and Metric Prefixes

Table C-1: Units of Measure

Abbreviation	Unit
A	ampere
Arcsec	arc-Second
B	bel
bps	bits per second
eV	electron-volt
F	farad
g	gram
Hz	hertz
J	joule
m	meter
N	newton
Pa	pascal
Rad [Si]	radiation absorbed dose \equiv 0.01 J/(kg of Silicon)
s	second
T	tesla
Torr	torr
V	volt
Ω	ohm

Table C-2: Metric Prefixes

Prefix	Meaning
M	mega (10^6)
k	kilo (10^3)
d	deci (10^{-1})
c	centi (10^{-2})
m	milli (10^{-3})
μ	micro (10^{-6})
n	nano (10^{-9})
p	pico (10^{-12})

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 90 of 113

Appendix D CII Hosted Payload Concept of Operations

D.1 INTRODUCTION

This CII Hosted Payloads Concept of Operations (CONOPS) provides a prospective Instrument Developer with technical recommendations to help them design an Instrument that may be flown as a hosted payload either in LEO or GEO. This document describes the systems, operational concepts, and teams required to develop, implement, and conduct a hosted payload mission. More specifically, this CONOPS document primarily supports stakeholders involved in NASA Science Mission Directorate (SMD) Earth Science Division's investigations. What follows is a CONOPS applicable to those ESD payloads to be hosted as a secondary payload, including those developed under the EVI solicitation.

D.1.1 Goals and Objectives

The CONOPS documents the functionality of a hosted payload mission and defines system segments, associated functions, and operational descriptions. The CONOPS represents the operational approaches used to develop mission requirements and provides the operational framework for execution of the major components of a hosted payload mission.

The CONOPS is not a requirements document, but rather, it provides a functional view of a hosted payload mission based upon high-level project guidance. All functions, scenarios, figures, timelines, and flow charts are conceptual only.

D.1.2 Document Scope

The purpose of this CONOPS document is to give an overview of LEO and GEO satellites operations, with an emphasis on how such operations will impact hosted payloads.

This CONOPS is not a requirements document and will not describe the Instrument Concept of Operation in detail or what is required of the Instrument to operate while hosted on LEO/GEO satellites.

D.2 COMMON INSTRUMENT INTERFACE PHILOSOPHY

This CONOPS supports the "Do No Harm" concept as described in section 2.2.1.

D.3 LEO/GEO SATELLITE CONCEPT OF OPERATIONS SUMMARY

This section is intended to be a summary of the Concept of Operations for both Low Earth Orbit Satellites [LEO] and Commercial Geostationary Communications Satellites [GEO], to give the Instrument provider an idea of what to expect when interfaced to the Host Spacecraft.

D.3.1 General Information

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 91 of 113

2074 [LEO] Nominal Orbit: The Host Spacecraft will operate in a Low Earth Orbit with an altitude
2075 between 350 and 2000 kilometers with eccentricity less than 1 and inclination between zero and
2076 180°, inclusive (see section 2.1.3). LEO orbital periods are approximately 90 minutes.

2077 [LEO] The frequencies used for communicating with LEO spacecraft vary, but S-Band (2–4
2078 GHz) with data rates up to 2 Mbps are typical. Since communication with ground stations
2079 requires line-of-site, command uplink and data downlink are only possible periodically and vary
2080 considerably depending on the total number of prime and backup stations and their locations on
2081 Earth. Communication pass durations are between 10–15 minutes for a minimum site angle of
2082 10°.

2083 [GEO] Nominal Orbit: The Host Spacecraft will operate in a Geostationary Earth Orbit with an
2084 altitude of approximately 35786 kilometers and eccentricity and inclination of approximately
2085 zero (see section 2.1.2.) GEO satellites remain in the same fixed location over the ground
2086 location for the life of the mission. Station keeping is required on a regular basis to maintain that
2087 fixed position. Current commercial communication satellite locations are as shown in Figure
2088 D-1. If full continental United States coverage is desired, a location of around 95°W - 100°W
2089 may be desired as shown in Figure D-2.

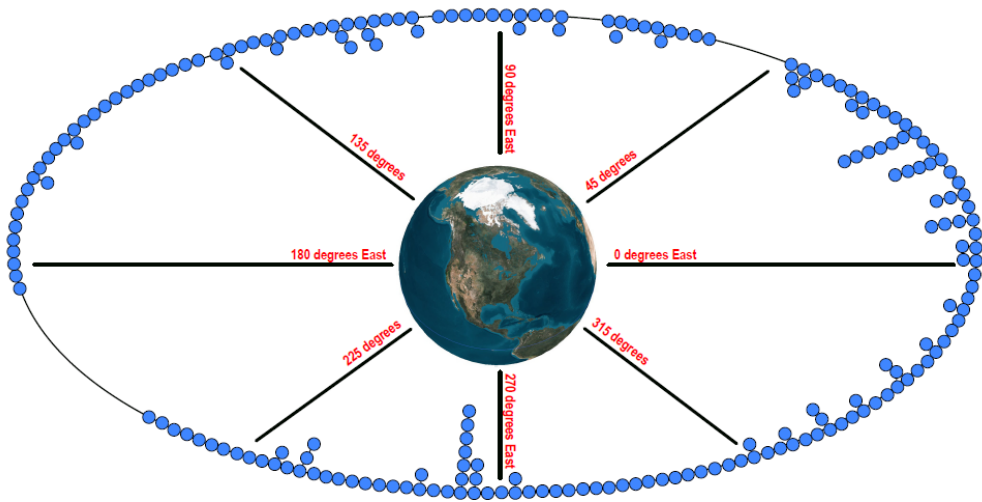


Figure D-1: Geostationary Locations

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 92 of 113

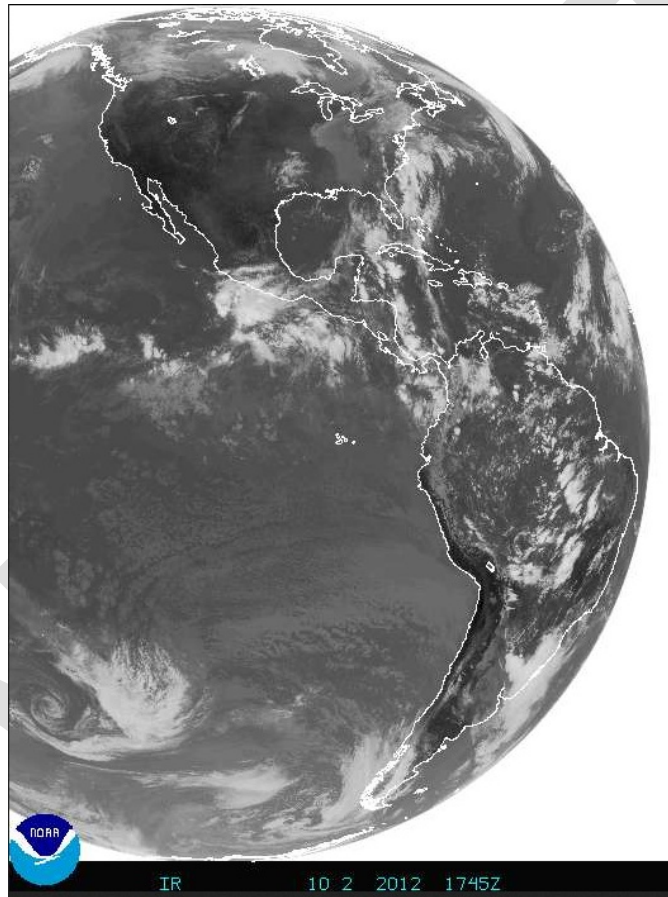


Figure D-2: GOES-14 Image at 100°W

[GEO] The Instrument approach provides the advantage of utilizing the Commercial Satellite's location, features, and services. Due to the location, the Instrument will have minimal data latency due to continuous real-time bi-directional communications links. As older commercial communications satellites are going out of service, newer more sophisticated satellites are replacing them.

[GEO] The Instrument will have the option to either purchase command and/or telemetry and/or data services from the Host Spacecraft or provide their own. The Instrument will have continuous direct data transfer to/from the Host Spacecraft during normal operations. The Instrument will have continuous direct data broadcast with the ground via the Host Spacecraft ground system during normal operations, as shown in Figure D-3.

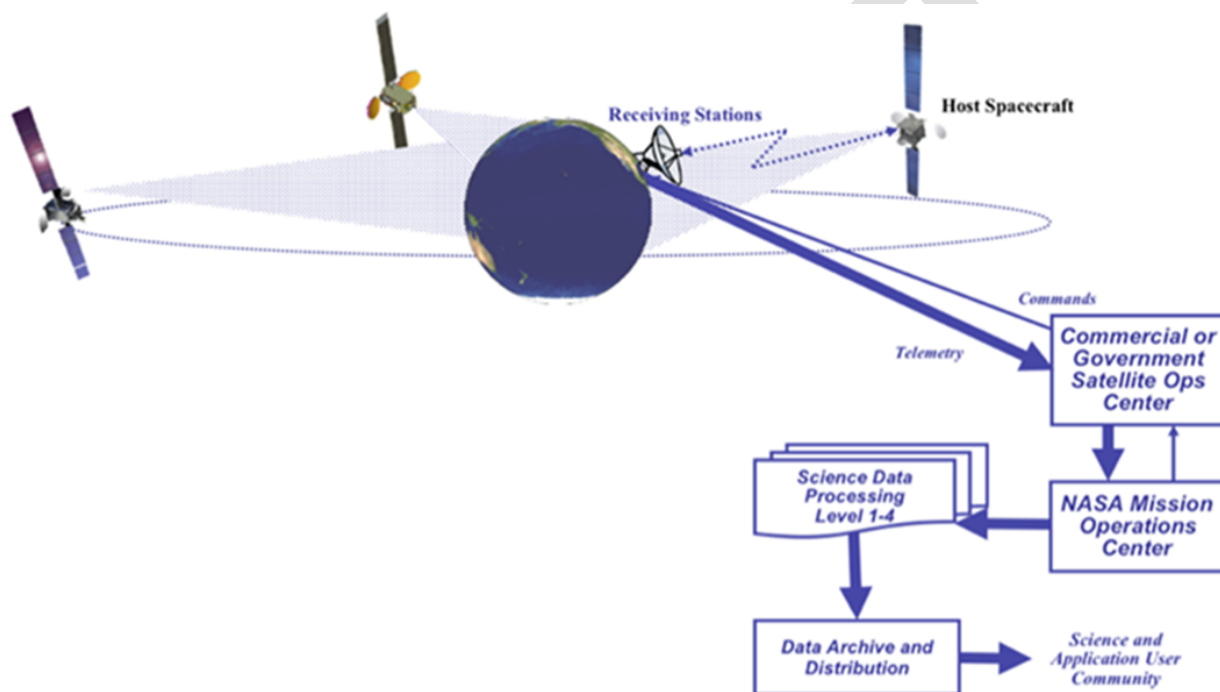


Figure D-3: Ground System Interfaces

D.3.2 Phases of Operation

The Host Spacecraft will have numerous phases of operation, which can be described as launch & ascent, [GEO] Geostationary Transfer Orbit (GTO), checkout, normal operations, and safeshold. The Instrument will have similar phases that occur in parallel with the Host Spacecraft. A summary of the transition from launch to normal operations is as shown in Figure D-4.

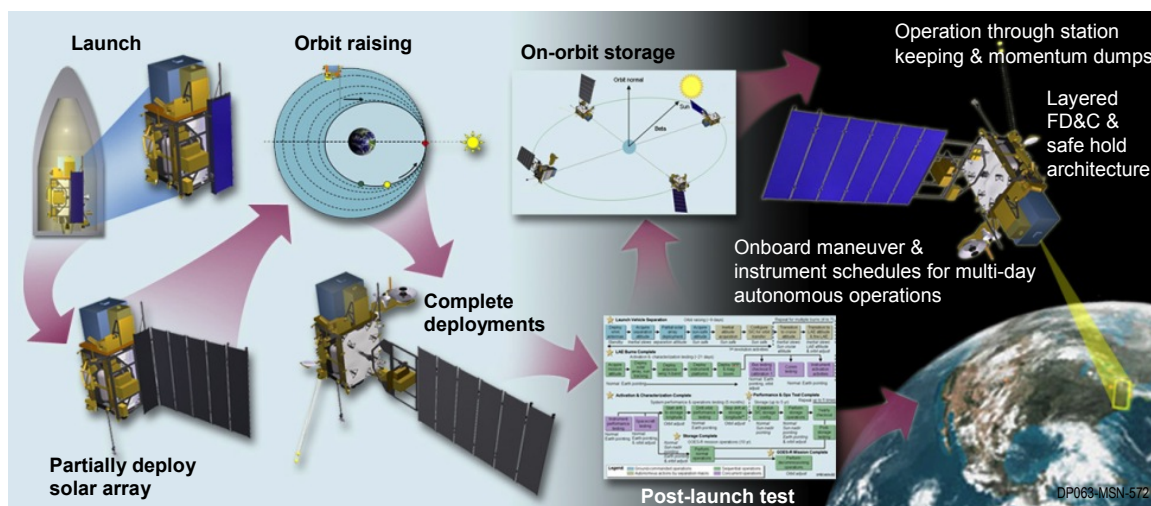


Figure D-4: Summary of Transition to Normal Operations

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 94 of 113

2114 Launch and Ascent

2115 During this phase, the satellite is operating on battery power and is in a Standby power mode,
2116 minimal hardware is powered on, e.g., computer, heaters, RF receivers, etc.

2117 Heaters, the RF receiver and the satellite computer will be powered on collecting limited health
2118 and status telemetry and when the payload fairing is deployed, the RF transmitter may
2119 automatically be powered on to transmit health and status telemetry of the satellite, this is vendor
2120 specific.

2121 *Instrument Launch and Ascent*

2122 The Instrument will be powered off, unless it is operating on its own battery power and the Host
2123 Spacecraft has agreed to allow it to be powered. No commutations between the Instrument and
2124 the Host Spacecraft or the ground (in the event the Instrument has a dedicated RF transponder)
2125 will take place. The Host Spacecraft may provide survival heater power to the Instrument during
2126 this phase, as negotiated with the Host Spacecraft.

2127 Orbit Transfer ([GEO] GTO)

2128 [GEO] During this phase, the satellite is in transition to its orbital location and will take several
2129 days, depending on the method of transfer and the propulsion. Conventional propulsion systems
2130 can take up to 10 days, while electric propulsion systems can take up to 6 months. Typically,
2131 prior to the first burn, the solar array is partial deployed to allow more satellite hardware to be
2132 powered, provide power to the electric propulsion system if used and charge the batteries, as
2133 shown in Figure D-4.

2134 [LEO] The satellite will be injected directly into its orbit location as part of the launch and
2135 ascent phase.

2136 *Instrument Orbit Transfer*

2137 The Instrument will be powered off and no commutations between the Instrument and the Host
2138 Spacecraft or the ground (in the event the Instrument has a dedicated RF transponder) will take
2139 place, unless negotiated otherwise with the Host Spacecraft due to the science data to be
2140 collected. If the Instrument is powered off, the Host Spacecraft will provide survival heater
2141 power, as negotiated.

2142 If the Instrument is powered on during this phase, the Host Spacecraft will provide primary
2143 power as negotiated.

2144 On-Orbit Storage

2145 [GEO] The satellite may inject into a storage location to either perform its checkout or if the
2146 operational satellite hasn't been decommissioned. The checkout for the Host Spacecraft as well
2147 as the instrument will be performed at this location. At the appointed time, the satellite will
2148 perform a series of maneuvers to re-locate to the operational location.

2149 [LEO] An on-orbit storage location may be used if the Host Spacecraft is part of a constellation
2150 and the current operational spacecraft hasn't been decommissioned. The satellite may inject into
2151 this location to perform its checkout, as will the instrument. Upon completion of the checkout or

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 95 of 113

2152 if the operational satellite has been decommissioned, the Host Spacecraft will perform a series of
2153 maneuvers to re-locate into its location within the constellation.

2154 Checkout

2155 After orbit transfer and the final burn is completed and the orbital location has been successfully
2156 achieved, full solar array deployment will take place and the satellite check process will begin.
2157 Each subsystem will be fully powered and checked out in a systematic manor. Once the satellite
2158 is successfully checked-out and operational, the communication payload checkout begins, also in
2159 a systematic manor. When both the satellite and communications payload are successfully
2160 checked-out, the owner/operator will transition to normal operations.

2161 Normal Operations

2162 The satellite is in this phase as long as all hardware and functions are operating normally and
2163 will remain in this phase for the majority of its life.

2164 Once the transition to normal operations is achieved, only then is the hosted payload powered on
2165 and the checkout process begun.

2166 *Instrument Checkout*

2167 After the Host Spacecraft has achieved normal operations, the Instrument will be allowed to
2168 power on and begin its checkout process. Calibration of the Instrument would be during this
2169 phase as well. Any special maneuvering required of the Host Spacecraft will be negotiated.

2170 *Instrument Normal Operations*

2171 The Instrument will remain in this phase as long as all hardware and functions are operating
2172 normally and will remain in this mode for the majority of its life.

2173 Safehold

2174 While not technically an operational phase, this mode is achieved when some sort of failure of
2175 the Host Spacecraft has occurred. This mode can be achieved either autonomously or manually.
2176 During this mode, all non-essential subsystems are powered off, the communications payload
2177 maybe powered off, depending on the autonomous trigger points programmed in the flight
2178 software, the hosted payload will be powered off, and the satellite will be maneuvered into a
2179 power-positive position. When the Host Spacecraft enters Safehold the Instrument may be
2180 commanded into Safehold, but will most likely be powered-off.

2181 After the failure has been understood and it is safe to do so, the owner/operator Mission
2182 Operations Center will transition the Host Spacecraft back to normal operations. After normal
2183 operations have been achieved, the hosted payload will be powered back on.

2184 *Instrument Safehold*

2185 The Instrument will go into this mode one of two ways, either due to a Host Spacecraft failure or
2186 an Instrument failure. In the event the Host Spacecraft experiences a failure, the Host Spacecraft
2187 will immediately cut the power to the Instrument and the Instrument will have to be able to
2188 successfully recover from this event.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 96 of 113

2189 In the event the Instrument experiences a failure of some sort, it will have to autonomously move
2190 into this mode without manual intervention. The Instrument Mission Operations Center will
2191 manually perform the trouble shooting required and manually transition the Instrument back to
2192 normal operations.

2193 *Instrument Safehold Recovery*

2194 If Host Spacecraft operations require the Instrument to be powered off with no notice, the
2195 Instrument must autonomously recover in a safe state once power has been restored. Once health
2196 and status telemetry collection and transmission via the Host Spacecraft has been restored, the
2197 Instrument operations center may begin processing data.

2198 Host Spacecraft Normal Operations After Instrument End of Life

2199 Commercial spacecraft are designed to have operational lifetimes of typically less than 10 years
2200 in LEO, while GEO lifetimes of 15 years or more are common. Instrument lifetimes are
2201 prescribed by their mission classification (Class C, no more than 2 years). The Instrument
2202 lifetime may be extended due to nominal performance and extended missions may be negotiated
2203 (Phase E). Since the Host Spacecraft may outlive the Instrument, especially commercial GEO
2204 satellites, the Instrument must be capable of safely decommissioning itself.

2205 During the end of life phase, the Instrument will be completely unpowered, unless survival
2206 heaters are required to assure host satellite safety, and, essentially, inert. This may involve the
2207 locking of moving parts and the discharge of any energy or consumables in the payload. This
2208 process will be carried out such that it will not perturb the Host Spacecraft in any way. Upon
2209 completion, the Host Spacecraft will consider the Instrument as a simple mass model that does
2210 not affect operations.

2211 De-commissioning

2212 At the end of the Host's mission life, it will perform a series of decommissioning maneuvers to
2213 de-orbit to clear the geostationary location. The Instrument will have been configured into the
2214 lowest possible potential energy state and then powered down at the end of its mission. The host
2215 maneuvers may span several days to relocate where it will be powered down and its mission life
2216 will end.

2217 **D.4 HOSTED PAYLOAD OPERATIONS**

2218 The Host Spacecraft will have a primary mission different than that of the Instrument. The
2219 Instrument's most important directive is to not interfere or cause damage to the Host Spacecraft
2220 or any of its payloads, and to sacrifice its own safety for that of the Host Spacecraft.

2221 The Host Spacecraft has priority over the Instrument. Special or anomalous situations may
2222 require temporary suspension of Instrument operations. Instrument concerns are always
2223 secondary to the health and safety of the Host Spacecraft and the objectives of primary payloads.
2224 Suspension of Instrument operations may include explicitly commanding the Instrument to Safe
2225 mode or powering it off. The Host Spacecraft operator may or may not inform the Instrument
2226 operators prior to suspension of operations.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 97 of 113

D.4.1 Instrument Modes of Operation

Table D-1 shows the command and control responsibilities of the commercial Host Spacecraft Operations Center (HSOC) and Hosted Payload Operations Center (HPOC) for hosted payload missions. Hosted payload power control will be performed by HSOC commands to the commercial satellite with hosted payload commanding performed by the HPOC after power is enabled. Operation of the hosted payload will be performed by the HPOC. In case of any space segment anomalies, the HSOC and HPOC will take corrective actions with agreed upon procedures and real-time coordination by the respective control teams.

Table D-1:GEO/LEO Instrument Operating Modes Based Upon Mission Phase

Instrument Mission Phase	Launch	Orbit Transfer	On Orbit Storage	Checkout	Nominal Operations	Anomalous Operations	End of Life
Survival Power	OFF/ON	ON	ON	ON	ON	ON	ON/OFF
Instrument Power	OFF	OFF	OFF	OFF/ON	ON	ON	ON/OFF
Mode	OFF/ SURVIVAL	OFF/ SURVIVAL	OFF/ SURVIVAL	INITIALIZE/ OPERATION/ SAFE	OPERATION	SAFE	SAFE/ OFF/ SURVIVAL
Command Source	NA	NA	NA	HPOC	HPOC	HPOC	HPOC/ NA
<i>Note: Host Spacecraft controls Instrument power.</i>							

The following are a set of short descriptions of each of the basic modes of operation. A more detailed set of guidance regarding these basic modes and transitions may be found in Appendix G.

OFF/SURVIVAL Mode

In the OFF/SURVIVAL Mode, the Instrument is always unpowered and the instrument survival heaters are in one of two power application states. In the survival heater OFF state of the OFF/SURVIVAL mode, the survival heaters are unpowered. In the survival heater ON state of the OFF/SURVIVAL Mode, the survival heaters are powered. The spacecraft should verify that the power to the survival heaters is enabled after the command to enter the survival heater ON state of the OFF/SURVIVAL mode has been actuated. Nominal transitions into the OFF/SURVIVAL mode are either from the INITIALIZATION mode, the SAFE mode or the OPERATION mode with the preferred path being a transition from the SAFE mode. The only transition possible out of the OFF/SURVIVAL mode is into the INITIALIZATION mode.

It is important to note that the Instrument should be capable of withstanding a near instantaneous transition into the OFF/SURVIVAL mode at any time and from any of the other three Instrument modes. Such a transition may be required by the Spacecraft host and would result from the sudden removal of operational power. This could occur without advance warning or notification and with no ability for the Instrument to go through an orderly shutdown sequence. This sudden removal of instrument power could also be coupled with the near instantaneous activation of the survival heater power circuit(s).

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 98 of 113

INITIALIZATION Mode

When first powered-on, the Instrument transitions from the OFF/SURVIVAL mode to the INITIALIZATION mode and conducts all the internal operations that are necessary in order to transition to the OPERATION mode or to the SAFE mode. These include, but are not limited to, activation of command receipt and telemetry transmission capabilities, initiation of health and status telemetry transmissions and conducting instrument component warm-up/cool-down to nominal operational temperatures. The only transition possible into the INITIALIZATION mode is from the OFF/SURVIVAL mode. Nominal transitions out of the INITIALIZATION mode are into the OFF/SURVIVAL mode, the SAFE mode or the OPERATION mode.

OPERATION Mode

The Instrument should have a single OPERATION mode during which all nominal Instrument operations occur. It is in this mode that science observations are made and associated data are collected and stored for transmission at the appropriate time in the spacecraft operational timeline. Within the OPERATION mode, sub-modes may be defined that are specific to the particular operations of the Instrument (*e.g.* STANDBY, DIAGNOSTIC, MEASUREMENT, etc.). When the Instrument is in the OPERATION mode, it should be capable of providing all health and status and science data originating within the instrument for storage or to the Spacecraft for transmission to the ground operations team. Nominal transitions into the OPERATION mode are either from the INITIALIZATION mode or the SAFE mode. Nominal transitions out of the OPERATION mode are into either the OFF/SURVIVAL mode or the SAFE mode.

SAFE Mode

The Instrument SAFE mode is a combined Instrument hardware and software configuration that is intended to protect the Instrument from possible internal or external harm while using a minimum amount of Spacecraft resources (*e.g.* power). When the instrument is commanded into SAFE mode, it should notify the Spacecraft after the transition into this mode has been completed. Once the Instrument is in SAFE mode, the data collected and transmitted to the HPOC should be limited to health and status information only. Nominal transitions into the SAFE mode are either from the INITIALIZATION mode or the OPERATION mode. Nominal transitions out of the SAFE mode are into either the OFF/SURVIVAL mode or the OPERATION mode.

D.4.2 Instrument Interfaces

The instrument should refer to the referenced Guidelines document for all Instrument/Host Spacecraft interfaces.

Appendix E Supporting Analysis for LEO Guidelines

In order to provide Level 1 guidelines for future hosted payload instruments, we have examined the NASA Instrument Cost Model (NICM) remote sensing database to identify instrument characteristic parameters. The database has information on 102 different instruments that launched before 2009 from all four divisions of the Science Mission Directorate (SMD), as depicted in Table E-1. There are two significant characteristics of the data set that limit its statistical power to draw conclusions about Earth Science instruments. The first is the small sample size of Earth Science instruments ($n=28$). The second is that since more than half of the NICM instruments are Planetary, which tend to be smaller overall, the data are skewed. Nonetheless, analyzing the entire 102-instrument set provides some useful insight.

Table E-1: Distribution of NICM Instruments Among Science Mission Directorate Divisions

SMD Division	Directed	Competed	Non-NASA	Total
Earth	18	5	5	28
Planetary	35	18	1	54
Heliophysics	5	3	1	9
Astrophysics	10	1	0	11
Total	68	27	7	102

In analyzing the data, one may easily conclude that the development cost of an instrument is a function of multiple parameters such as: mass, power, data rate, year built, SMD division and acquisition strategy. With further analysis, one will realize that these parameters are not independent of each other and are implicitly functions of mass. For example, Planetary Science instruments tend to be smaller than Earth Science instruments, and competed instruments tend to be smaller than their directed counterparts. As technology improves with time, the instruments get smaller and more capable. With this information, we have plotted the instrument cost as a function of mass as shown in Figure E-1.

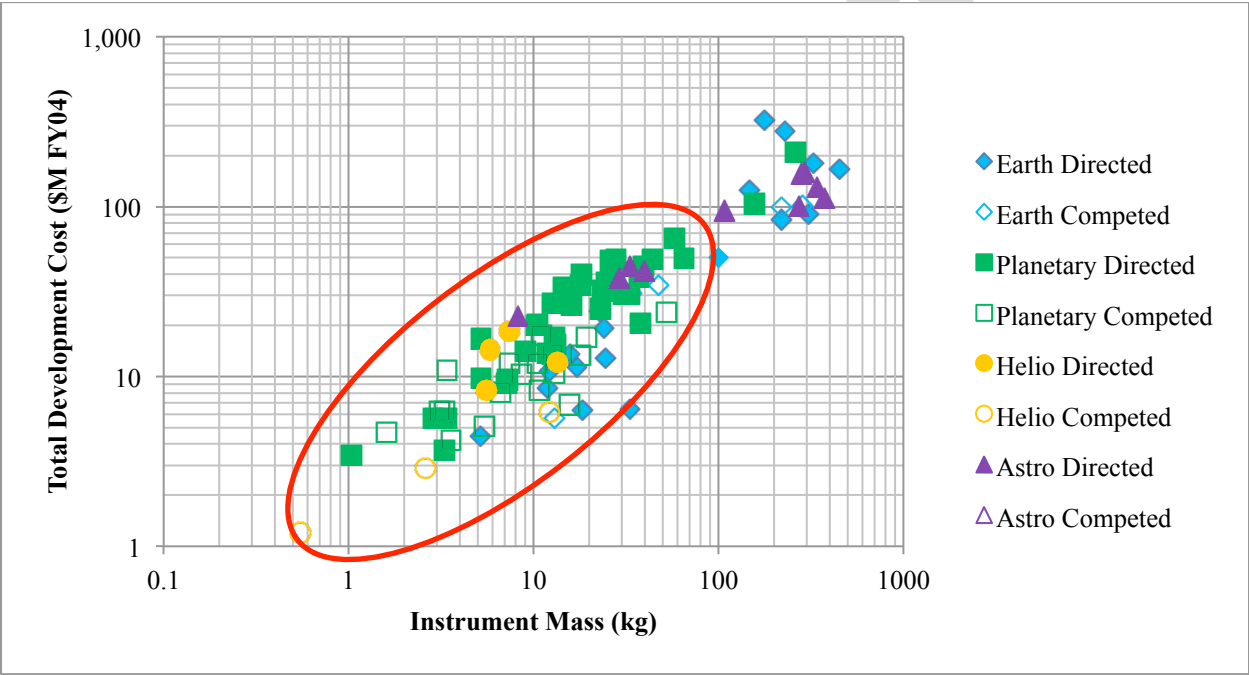


Figure E-1: Instrument Mass vs. Development Cost

In further examination of the data, specifically the Earth Science instruments that are outside the ellipse in Figure E-1, one realizes that they were primary instruments that the mission were built around, for example, the Aura mission with the MLS and TES instruments. Given that this document deals with instruments that are *classified as hosted payloads* without knowledge of what mission or spacecraft they will be paired with, the CII WG *allocates 100 kg for the Level 1 mass guideline*. Therefore, every effort should be made to keep the mass to less than 100 kg to increase the probability of matching up with an HPO.

Figure E-2 shows the relationship between power and mass. The power consumed by an instrument is also approximately linearly correlated to the mass of the instrument. On this basis, *we allocate 100 W for the Level 1 power guideline* for a 100 kg instrument.

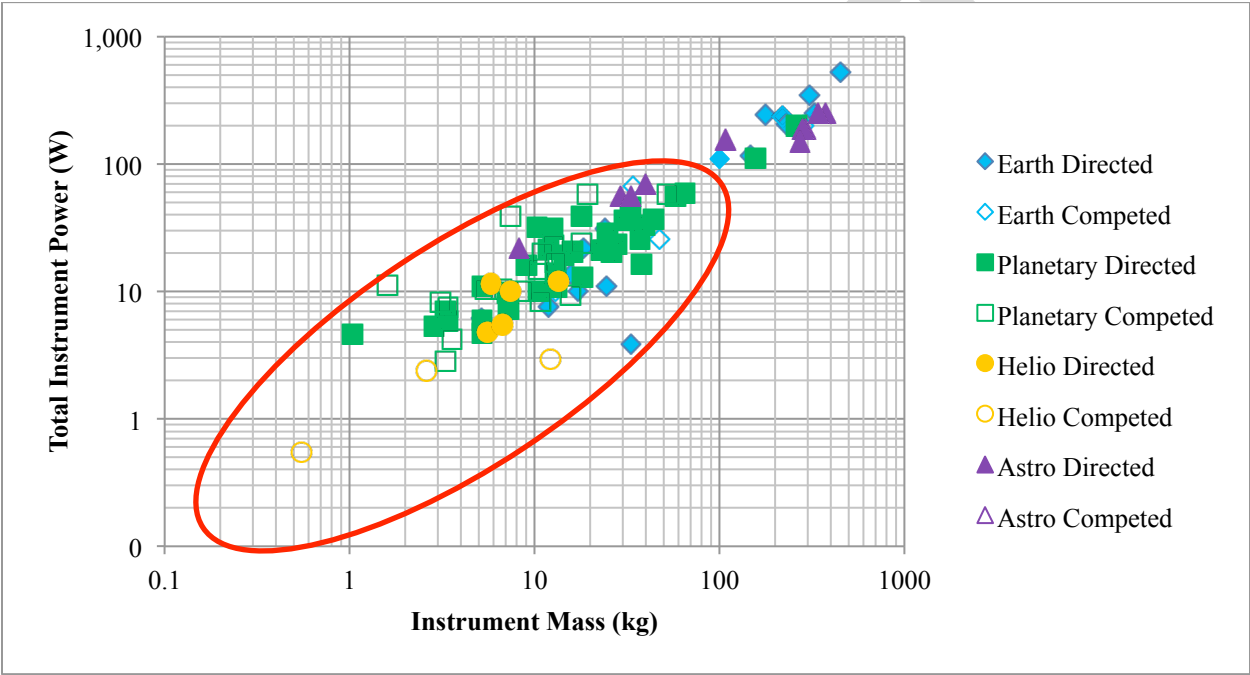


Figure E-2: Power as a Function of Mass

As stated earlier, instruments over time have become smaller and more capable. Specifically, in Earth Science instruments this translates into generating more and more data. Figure E-3 shows the data rates for all SMD instruments. This graph indicates that the data rate has increased by about an order of magnitude over two decades. Based upon this observation *we set the Level 1 data rate guideline at 10 Mbps*. It is clear that some instruments will generate more than 10 Mbps. This implies that the instruments should have the capability of on-board data analysis and or data compression or the capability of fractional time data collection. As with all guidelines contained within this document, once the instrument is paired with an HPO, the agreement between the two will supersede these guidelines.

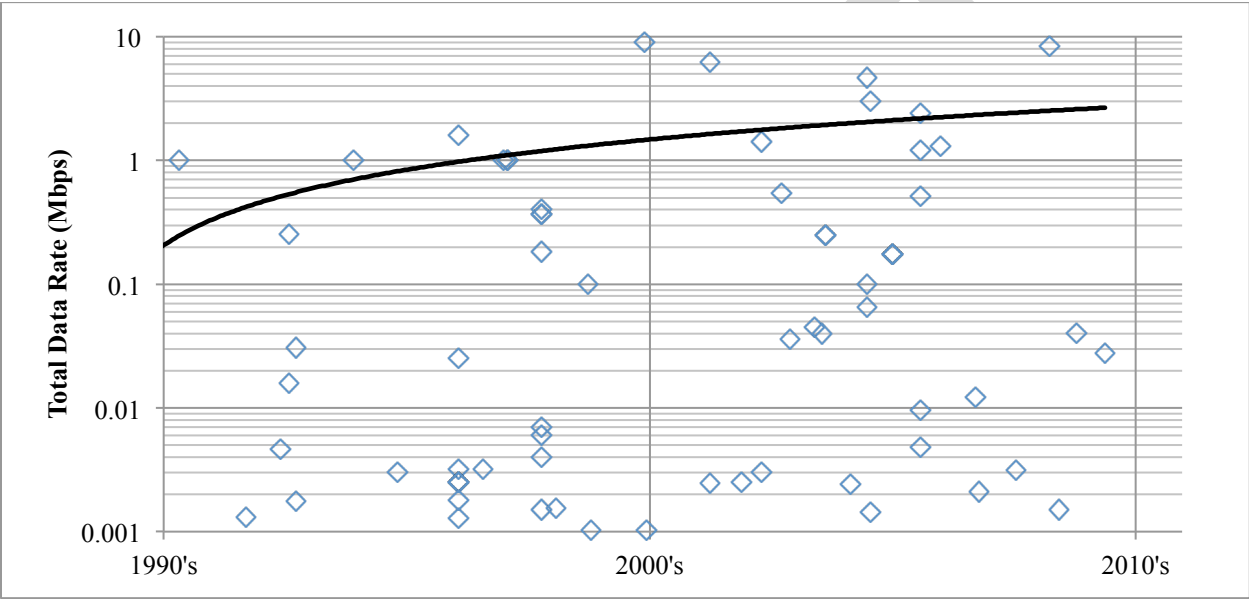


Figure E-3: Trend of Mean Instrument Data Rates

Categorization of the instruments as hosted payloads implies that these instruments have a mission risk level of C as defined in NPR 8705.4. This in turn defines the 2-year operational life and software classification.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 103 of 113

Appendix F Supporting Analysis for GEO Guidelines

On 29 March 2012, NASA Langley Research Center released a *Request for Information (RFI) for Geostationary Earth Orbit (GEO) Hosted Payload Opportunities (HPO) and Accommodations*, upon whose responses the CII Team primarily established our GEO guidelines.

NASA Langley Research Center is hereby soliciting information about potential sources for Geostationary Earth Orbit (GEO) Hosted Payload Opportunities (HPO) and Accommodations.

Background

NASA's Earth Science Division (ESD) will be developing Earth Science Instruments, some of which may be suitable to fly as hosted payloads on HPO's. The development of the instruments as well as the HPO's will be conducted independently of each other with the goal of matching a specific instrument with a specific HPO by the instrument Preliminary Design Review (PDR) timeframe.

In an effort to facilitate matching instruments to HPO's, ESD initiated the Common Instrument Interface (CII) Project. The charter for the CII Project is to work with industry, academia, and other governmental agencies to develop a set of common instrument-to-spacecraft interfaces that could serve as guidelines for instrument developers. If used properly by instrument developers, these guidelines would help produce instruments that have a less complex interface and would improve the probability of matching a given instrument with a HPO or platform.

The CII Project has recently completed a draft set of Low Earth Orbit (LEO) guidelines and a draft HPO Database document. Additional information on the CII project may be found at this website: <http://science.nasa.gov/about-us/smd-programs/earth-system-science-pathfinder/common-instrument-interface-workshop/>. Current CII Guideline and HPO database documents may be found on the Earth Venture Instruments 1 Program Library: http://essp.larc.nasa.gov/EV-I/evi_programlibrary.html

Current Intention

The CII Project is now interested in identifying HPO's, and their associated accommodations, for future GEO missions in order to develop a draft set of GEO guidelines to complement our LEO guidelines, and to update the publically-available HPO database document. Additionally, the CII Project is investigating flying and operating a hosted payload on an upcoming GEO HPO as a pathfinder initiative (hereafter described as the "Initiative") to better understand the programmatic and

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 104 of 113

technical challenges for a commercially-hosted NASA science payload. The CII Project would document lessons learned from conducting the GEO pathfinder initiative and feed them back into the GEO guidelines document to help developers intending to fly a payload on a future GEO HPO.

The purpose of this RFI is to:

- 1) Identify the GEO HPO's for the period from 2013-2023;
- 2) Obtain a description of available HPO payload accommodations on future GEO HPO's; and
- 3) Obtain information on all of the steps required to fly the "Initiative" as described later in this RFI.

The CII Project can accommodate responses containing properly-marked proprietary information. The CII Project will safeguard the proprietary information on hosted payload opportunities (Requested Information #1) and payload accommodations (Requested Information #2) within the Project organization. The CII Project intends to utilize the non-proprietary portions of Requested Information #1 to update the publicly available HPO database. The CII Project intends to use Requested Information #2 to bound/envelope the payload accommodation parameters that will inform the future GEO Guidelines Document. NASA may also use Requested Information #1 and #2 to assess the suitability of hosted payload-to-spacecraft matches associated with future NASA Earth Science missions.

The CII Project will use the requested information for the GEO pathfinder initiative (Requested Information #3 above) to assess the feasibility of such an Initiative, to provide an overview of the hosted payload process in the future GEO Guidelines Document, and to inform future Earth Science hosted payload planning and programming activities.

Requested Information

1. Please identify your organization's HPO's for the period of 2013-2023 with their associated mission parameters including but not limited to:

- Mission Name
- Launch Date
- Owner/Operator
- Primary Customer
- Spacecraft Bus Manufacturer
- Spacecraft Bus Model
- Launch Vehicle
- Orbital Longitude

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 105 of 113

If the data are not available beyond your current business cycle, please suggest a technique for the CII Project to obtain those data once they do become available.

2. Please describe what Payload Accommodation and Interface resources your HPO's can provide to a prospective hosted payload without significant modifications to your nominal manufacturing, integration, test and launch processes. Please also describe the environment the prospective hosted payload might expect to encounter:

- Payload Accommodation Parameters and Interface
 - Maximum Payload Mass Available without System Redesign [kg]
 - Maximum Payload Orbital Average Power without System Redesign [W]
 - Maximum Payload Peak Power without System Redesign [W]
 - Main Bus Nominal Voltage [V]
 - Volume (l x w x h) [mm x mm x mm]
 - Sensor Mounting Location on Spacecraft (e.g. Nadir, Zenith, Ram, Wake, North, South, East, West, ...)
 - Command and Control Interface (1553B, RS-422, SpaceWire, etc.) with average and peak data rates [kbps]
 - Payload-to-Transponder Interface (RS-422, SpaceWire, etc.) for Science Data Transmission with average and peak data rates [Mbps]
 - Host spacecraft constraints or preferences for digital formats most suitable for conversion to RF in system architecture
 - Payload command and control encryption requirements
 - Pointing Control [arcsec]
 - Pointing Knowledge [arcsec]
 - Pointing Stability [arcsec / sec]
 - Spacecraft absolute position accuracy, each axis [m]
 - Spacecraft absolute velocity accuracy, each axis [m/s]
 - Limitations with respect to payload-induced uncompensated torques [N x m] by frequency [Hz]
 - Limitations with respect to payload-induced uncompensated forces [N] by frequency [Hz]
 - Typical Integration and Test Facility Cleanliness [Cleanroom Class]
 - Thermal Rejection With Heat Pipes [W]
 - Thermal Rejection Without Heat Pipes [W]
- Payload Environment
 - Temperature Range

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 106 of 113

- 2467 ○ Quasi-static loads
- 2468 ○ Minimum resonant frequency
- 2469 ○ Random vibration and acoustic loads
- 2470 ○ Shock environment
- 2471 ○ Disturbance torque
- 2472 ○ RF Field EMI/EMC/ESD
- 2473 ○ Molecular contamination as a function of mission
- 2474 elapsed time and hosted payload location
- 2475

2476 3. As a specific potential near term opportunity, please
2477 provide information on all of the programmatic and technical
2478 steps required to fly a GEO Pathfinder Initiative on your HPO's
2479 as described below.

2480 GEO Pathfinder Initiative Information

2481 The Initiative will also provide NASA with experience with the
2482 commercially-hosted payload process. The Initiative will also
2483 mitigate space environmental risks to future GEO missions by
2484 measuring vibration and contamination of an Instrument Suite
2485 hosted on a commercial GEO spacecraft. Both objectives will
2486 reduce risk on future commercially-hosted GEO Earth Science
2487 missions. See attached Figure 1 for an example of a notional
2488 Instrument Suite, which the CII Project will develop and
2489 provide, with the following characteristics:

- 2490 • Mass: 50 kg
- 2491 • Power: 125 W
- 2492 • Volume: 1000 x 500 x 500 mm
- 2493 • Data Rate: 60 Mbps
- 2494 • Thermal Control: Electronics thermally isolated, with
- 2495 exterior boxes insulated with multi-layer insulation (MLI).
- 2496 • The Instrument Suite is presumed to be mounted on the host
- 2497 spacecraft nadir deck.
- 2498 • The Instrument Suite has a nominal operational lifetime of
- 2499 3 years
- 2500

2501 Note: The Initiative is designed to exercise the GEO hosted
2502 payload process whose parameters are a subset and likely smaller
2503 than those of a typical future science flight mission.

2504 GEO Pathfinder Initiative Requested Information

2505 Please provide information related to the accommodation of the
2506 Instrument Suite by your mission:

- 2507 • Date the contract needs to be signed relative to Launch
- 2508 Date

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 107 of 113

2509 • Government-provided technical / programmatic deliverables
2510 required (e.g. mass and thermal models)
2511 • Instrument Suite delivery date required relative to Launch
2512 Date
2513 • Rough Order of Magnitude Price Estimate to fly and operate
2514 the Initiative. In addition to the Total price, please
2515 estimate the following components:
2516 ◦ Integration, Test, and Launch
2517 ◦ Operations
2518 • Any concerns with FAR Part 12 terms and conditions:
2519 <https://acquisition.gov/far/html/FARTOCP12.html>
2520 • Concept of operating hosted payload, including
2521 communications architecture
2522 • Safety and mission assurance requirements levied upon
2523 hosted payload
2524 • The level of NASA participation allowed during spacecraft
2525 development and instrument integration (e.g. spacecraft
2526 design reviews, environmental tests, etc.)
2527

2528 NASA is seeking capability statements from all interested
2529 parties, including Small, Small Disadvantaged (SDB), 8(a),
2530 Woman-owned (WOSB), Veteran Owned (VOSB), Service Disabled
2531 Veteran Owned (SD-VOSB), Historically Underutilized Business
2532 Zone (HUBZone) businesses, and Historically Black Colleges and
2533 Universities (HBCU)/Minority Institutions (MI) for the purposes
2534 of determining the appropriate level of competition and/or small
2535 business subcontracting goals.

2536 No solicitation exists; therefore, do not request a copy of the
2537 solicitation. If a solicitation is released it will be
2538 synopsized in FedBizOpps and on the NASA Acquisition Internet
2539 Service. It is the potential offeror's responsibility to
2540 monitor these sites for the release of any solicitation or
2541 synopsis.

2542 Vendors having the capabilities necessary to meet or exceed the
2543 stated requirements are invited to submit appropriate
2544 documentation, literature, brochures, and references.

2545 Please advise if the requirement is considered to be a
2546 commercial or commercial-type product. A commercial item is
2547 defined in FAR 2.101.

2548 This synopsis is for information and planning purposes and is
2549 not to be construed as a commitment by the CII Project nor will
2550 the CII Project cover any costs for information submitted in
2551 response to the RFI.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 108 of 113

2552 Technical questions should be directed to Craig Jones at
2553 Craig.D.Jones@nasa.gov. All other questions should be directed
2554 to Brad Gardner at Robert.B.Gardner@nasa.gov. All responses
2555 shall be submitted to Brad Gardner at Robert.B.Gardner@nasa.gov
2556 and to Craig Jones at Craig.D.Jones@nasa.gov no later than May
2557 11, 2012. Respondents may e-mail files up to 10MB in size to
2558 Brad Gardner; respondents shall submit larger files on optical
2559 storage media (CD/DVD) via postal mail to the following address:

2560 Brad Gardner
2561 Office of Procurement
2562 Building 2101, MS 12
2563 NASA Langley Research Center
2564 Hampton, VA 23681

2565 Please reference CII-GEO in any response.

Appendix G Instrument Modes

This section shows one way to set up a notional Instrument mode scheme and also provides context for those guidelines, especially data and electrical power, which reference various modes.

G.1 MODE GUIDELINES

Basic Modes

Instruments should support four basic modes of operation: OFF/SURVIVAL, INITIALIZATION, OPERATION, and SAFE (see Figure G-1). Within any mode, the Instrument may define additional sub-modes specific to their operation (*e.g.* STANDBY, DIAGNOSTIC, MEASUREMENT, etc.).

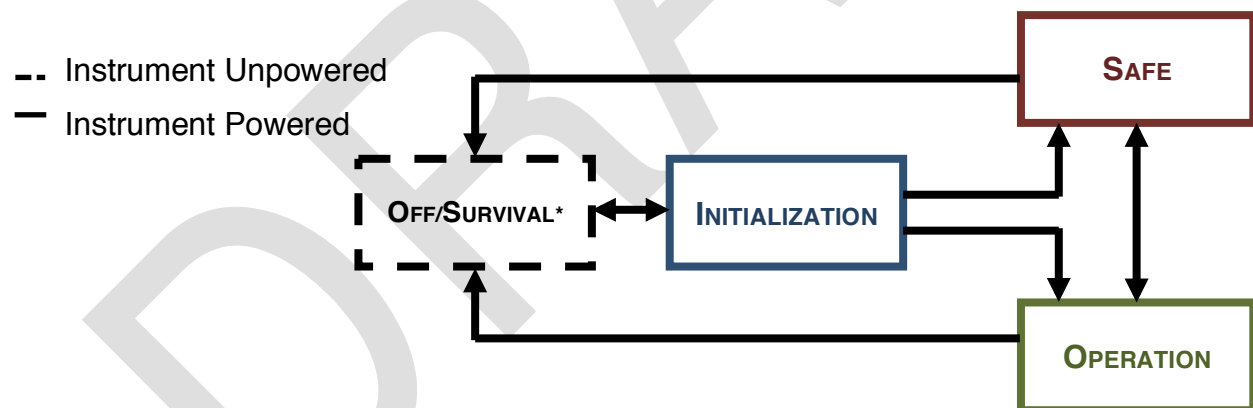


Figure G-1: Instrument Mode Transitions

OFF/SURVIVAL Mode, Survival Heater OFF State

The Instrument is unpowered, and the survival heaters are unpowered in survival heater OFF state of the OFF/SURVIVAL mode.

OFF/SURVIVAL Mode Power Draw

The Instrument should draw no operational power while in OFF mode.

Instrument Susceptibility to Unanticipated Power Loss

The Instrument should be able to withstand the sudden and immediate removal of operational power by the Spacecraft at any time and in any instrument mode. This refers specifically to the sudden removal of operational power without the Instrument first going through an orderly shutdown sequence.

OFF/SURVIVAL Mode, Survival Heater ON State

The Instrument is unpowered, and the survival heaters are powered-on in the survival heater ON state of the OFF/SURVIVAL mode.

Spacecraft Verification of Instrument Survival Power

The Spacecraft should verify Instrument survival power is enabled upon entering the survival heater ON state of the OFF/SURVIVAL mode.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 110 of 113

2593 *Post-Launch Instrument Survival Circuit Initiation*

2594 The Spacecraft should enable power to the Instrument survival heater circuit(s) within 60
2595 seconds after spacecraft separation from the launch vehicle, unless precluded by Spacecraft
2596 survival. The amount of time defined from spacecraft separation to enabling of the instrument
2597 survival heater circuit should be reviewed and revised as necessary after pairing with the host
2598 mission CONOPS, spacecraft and launch vehicle..

2599 *Instrument Susceptibility to Unanticipated Transition to SURVIVAL Mode*

2600 The Instrument should be able to withstand the sudden and immediate transition to instrument
2601 OFF/SURVIVAL mode by the Spacecraft at any time and in any Instrument mode. This refers
2602 specifically to the sudden removal of operational power without the Instrument first going
2603 through an orderly shutdown sequence and the sudden activation of the survival heater power
2604 circuit(s).

2605 INITIALIZATION Mode

2606 When first powered-on, the Instrument enters INITIALIZATION mode and conducts all internal
2607 operations necessary in order to eventually transition to OPERATION (or SAFE) mode.

2608 *Power Application*

2609 The Instrument should be in INITIALIZATION mode upon application of electrical power.

2610 *Thermal Conditioning*

2611 When in INITIALIZATION mode, the Instrument should conduct Instrument component warm-up
2612 or cool-down to operating temperatures.

2613 *Command and Telemetry*

2614 When in INITIALIZATION mode, the command and telemetry functions of the Instrument should
2615 be powered up first.

2616 *Health and Status Telemetry*

2617 When in INITIALIZATION mode, the Instrument should send the Spacecraft health and status
2618 telemetry.

2619 OPERATION Mode

2620 The Instrument OPERATION mode covers all nominal Instrument operations and science
2621 observations.

2622 *Science Observations and Data Collection*

2623 The Instrument should have one OPERATION mode for science observations and data collection.
2624 Within the OPERATION mode, an instrument may define additional sub-modes specific to their
2625 operation (e.g. STANDBY, DIAGNOSTIC, MEASUREMENT, etc.).

2626 *Data Transmission*

2627 When in OPERATION mode, the Instrument should be fully functional and capable of providing
2628 all health and status and science data originating within the instrument to the Spacecraft and
2629 ground operations team.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 111 of 113

- 2630 *Resources*
- 2631 When in OPERATION mode, the Instrument should have all allocated Spacecraft resources
- 2632 available to it.
- 2633 SAFE Mode
- 2634 The Instrument SAFE mode is a combined Instrument hardware and software configuration meant
- 2635 to protect the Instrument from possible internal or external harm while making minimal use of
- 2636 Spacecraft resources (e.g. power).
- 2637 *Data Collection and Transmission*
- 2638 When in SAFE mode, the Instrument should limit data collection and transmission to health and
- 2639 status information only.
- 2640 *Notification*
- 2641 The Instrument should notify the Spacecraft when it has completed a transition to SAFE mode.
- 2642 **G.2 MODE TRANSITIONS**
- 2643 Impacts to other instruments and the Host Spacecraft bus
- 2644 The Instrument should transition from its current mode to any other mode without harming itself,
- 2645 other instruments, or the Host Spacecraft bus.
- 2646 Preferred Mode Transitions
- 2647 The Instrument should follow the mode transitions depicted in Figure G-1. The preferred
- 2648 transition to OFF/SURVIVAL mode is through SAFE mode. All other transitions to OFF/SURVIVAL
- 2649 are to be exercised in emergency situations only.
- 2650 SURVIVAL Mode Transitions
- 2651 *Trigger*
- 2652 The Spacecraft should transition the Instrument to OFF/SURVIVAL mode in the event of a severe
- 2653 Spacecraft emergency.
- 2654 *Instrument Operational Power*
- 2655 The Spacecraft should remove Instrument operational power during transition to OFF/SURVIVAL
- 2656 mode.
- 2657 *Instrument Notification*
- 2658 Transition to SURVIVAL mode should not require notification or commands be sent to the
- 2659 Instrument.
- 2660 INITIALIZATION Mode Transitions
- 2661 *Transition from OFF Mode*
- 2662 The Instrument should transition from OFF mode to INITIALIZATION mode before entering either
- 2663 OPERATION or SAFE modes.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 112 of 113

2664 *Exiting initialization Mode*

2665 When in INITIALIZATION mode, the Instrument should remain in INITIALIZATION mode until a
2666 valid command is received from the Spacecraft or ground operations team to transition to
2667 OPERATION (or SAFE) mode.

2668 SAFE Mode Transitions

2669 *Command Trigger*

2670 The Instrument should transition to SAFE mode upon receipt of a command from the Spacecraft
2671 or ground operations team.

2672 *Missing Time Message Trigger*

2673 The Instrument should transition to SAFE mode upon the detection of 10 consecutive missing
2674 time messages.

2675 *On-Orbit Anomaly Trigger*

2676 The Instrument should transition to SAFE mode autonomously upon any instance of an
2677 Instrument-detected on-orbit anomaly, where failure to take prompt corrective action could result
2678 in damage to the Instrument or Spacecraft.

2679 *Orderly Transition*

2680 The Instrument should conduct all transitions to SAFE mode in an orderly fashion.

2681 *Duration of SAFE Mode Transition*

2682 The Instrument should complete SAFE mode configuration within 10 seconds after SAFE mode
2683 transition is initiated.

2684 *Instrument Inhibition of SAFE Mode Transition*

2685 The Instrument should not inhibit any SAFE mode transition, whether by command from the
2686 Spacecraft or ground operations team, detection of internal Instrument anomalies, or lack of time
2687 messages from the Spacecraft.

2688 *Deliberate Transition from SAFE Mode*

2689 When in SAFE mode, the instrument should not autonomously transition out of SAFE mode,
2690 unless it receives a mode transition command from the Spacecraft or ground operations team.

2691 OPERATION Mode Transitions

2692 *Trigger*

2693 The Instrument should enter OPERATION mode only upon reception of a valid OPERATION mode
2694 (or sub-mode) command from the Spacecraft or ground operations team.

2695 *Maintenance of OPERATION Mode*

2696 When in OPERATION mode, the Instrument should remain in the OPERATION mode until a valid
2697 command is received from the Spacecraft or ground operations team to place the Instrument into
2698 another mode, or until an autonomous transition to SAFE mode is required due to internal
2699 Instrument anomalies or lack of time messages from the Spacecraft.

Common Instrument Interface Project		
Document No: CII-CI-XXXX	Effective Date: 02/15/2013	Version: Rev A Draft
		Page 113 of 113

Appendix H Significant Differences among CII, ESA, and SMC Hosted Payload Guidelines

Table H-1: CII and ESA Hosted Payload Technical Guideline Differences

Interface	NASA	ESA	Comments
Data Interface	SpaceWire, RS422, Mil-STD-1553	SpaceWire	
On-board data storage	Instrument	Spacecraft	
Power	28 ± 6 VDC	18 to 36 VDC	
Discrete PPS line	Optional	Required	
Redundancy	Optional	Required	Data, power, Survival Heaters
EMI/EMC	Tailored MIL-STD-461F Based on inputs	Will be tailored from MIL-STD-461F	Inputs from RFI responders
Overcurrent protection	Open	Latching Current Limiters (LCL)	