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Hosted Payload Interface Guide for Proposers
CII for Earth Science Instruments Overview

Randy Regan

NASA CII Team

Chief Engineer

CII Overview Agenda

- CII Purpose and Goal
- Approach
- Workshop #3 Purpose and Goal
- Major Changes Since Last Guide
- CII Team
- Summary

CII Purpose and Goal

- **Common Instrument Interface (CII)**
- What is CII and what is CII's purpose?
  - NASA's Earth Science Division (ESD) will be developing secondary payloads under the Earth Venture Instrument (EVI) AOs. These Earth Science instruments will need to be matched up with Hosting Opportunities (Ideally, by PDR).
  - So, how can this matching be improved?
    - If these Earth Science instruments have common instrument to S/C interfaces then there would be a better possibility for this matching to occur.

CII Purpose and Goal (cont.)

- **Goal:**
- To develop a set of Common Instrument Interface (CII) guidelines for Secondary Earth Science instruments that will improve the match up with Hosting Opportunities and reduce instrument to spacecraft interface complexity.
  - This will also reduce the number of unique Interface Control Documents (ICDs)

CII Purpose and Goal (cont.)

- Products:
  - *The CII Project: HPIG* document. *A* draft version has been posted now. Feedback is due by Mar. 22, 2017 and the final copy will be posted by May 30, 2017.
    - This is a public document and others can use it to develop their own document.
      - NASA and the AF Hosted Payload Office (HoPS) share information and the AF has technically an identical document.
  - A Host Opportunities Database
    - http://cii.science.nasa.gov/
  - CII Web Page:
    - http://science.nasa.gov/about-us/smd-programs/earth-system-science-pathfinder/common-instrument-interface-workshop/

Approach

- A NASA CII Team was formed to work with industry, academia, and other government agencies to see how instrument interface guidelines could be developed to understand the key drivers that help or hinder the matching of these secondary payloads.

Approach (cont.)

- Approach:
  - Determine which interfaces could be common or cannot be common
  - If an interface cannot be common then look at additional options.
    - A Best Practices guide was developed to help developers during implementation

Approach (cont.)

- Approach:
  - Host CII Workshops once a year to receive feedback on the guide’s revisions
  - Participate in Satellite or Hosted Payload conferences.

CII Workshop #3 Purpose & Goal

- Give an overview of the CII project and our products
- Go over the changes since the last revision.
  - These revisions are the result of new information and feedback from industry and lessons learned from current hosted payload projects.
  - Hold private sessions, in the afternoon, with vendors to discuss any vendor specific questions comments.

General Guide Changes

- Level 1 and 2 combined to have only one level
- GEO and LEO were separated into two sections
- The NASA best practices were moved into a new document
- CII was based on handful of commercial companies(NASA RFI) and now the HPIG has wider participations

Discipline changes

- Data – No major changes
- Power
  - Streamlined to include only design guidelines
  - 2 level power limits for both GEO and LEO, compare to a single level in CII
- Mechanical
  - Streamlined to include only design guidelines
  - 2 levels of mass and volume for both GEL and LEO
- Thermal
  - Streamlined to include only design guidelines
  - Added solar panel reflectivity
- Environment
  - 2 levels of launch loads for both GEL and LEO

CII Org Chart

HQ
ESD Flight – Eric Ianson

ESSP Program Office
Program Manager/Dep. Program Manager – Greg Stover/Christina Motts-Xaiver

CII Manager – Lowell Primm (GSFC)

JPL

- JPL Lead/Systems Engineering - Dr. Benny Toomarian
- Data Interface Lead - Dr. Benny Toomarian
- Thermal Engineering Leads - Gaj Birur, Eric Sunada
- Mechanical Engineering Lead - Randy Hein
- Systems Integration - Dr. Margie Homer
- Launch & Space Environments Lead - Christine Farguson
- Electrical Lead - Donald Nieaeth
- Contamination Lead - Brain Blakkolb
- Opportunities Database Lead - Jim Hofman

ESSP PO Support to CII

- Chief Engineer - Randy Regan
- Consultant - John Rogers
- Business Manager - Cathy Murray-Wooddell
- Schedule Analyst - Ken Parkinson
- Logistics - Jenina Fitzpatrick
- Graphics - Dee Bullock

CII Team

- **ESSP PO Support to CII**
  - Chief Engineer - Randy Regan
  - Consultant - John Rogers
  - Business Manager - Cathy Murray-Wooddell
  - Schedule Analyst – Ken Parkinson
  - Logistics – Jenina Fitzpatrick
  - Graphics – Dee Bullock

- NASA GSFC
  - – CII Manager – Lowell Primm

CII Team (cont.)

- NASA JPL
  - JPL Lead/Systems Engineering - Dr. Benny Toomarian
  - Data Interface Lead - Dr. Benny Toomarian
  - Thermal Engineering Leads - Gaj Birur, Eric Sunada
  - Mechanical Engineering Lead - Randy Hein
  - Systems Integration – Dr. Margie Homer
  - Launch & Space Environments Lead - Christine Farguson
  - Electrical Lead - Donald Nieaeth
  - Contamination Lead - Brain Blakkolb
  - Opportunities Database Lead - Jim Hofman

Summary

- Developing CII guidelines is a method to increase instrument compatibility with the spacecraft so that the maximum number of Hosted Payload Opportunities can be realized.
- NASA has made a long term commitment to developing CII guidelines for secondary Earth Science instruments
- CII Workshops provide a means to engage S/C and instrument developers in the development of these CII guidelines.

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Hosted Payload Interface Guide for Proposers
Data Guidelines

Nikzad “benny” Toomarian

NASA CII Team

LEO - Was & Is

- Data Interface
  - The Instrument-to-Host Spacecraft data interfaces should use RS-422, SpaceWire, LVDS, or MIL-STD-1553.
- Data Accommodation
  - The Instrument should transmit less than 10 Mbps of data on average to the Host Spacecraft. Data may be transmitted periodically in bursts of up to 100 Mbps.
- Onboard Science Data Storage
  - The Instrument should be responsible for its own science data onboard storage capabilities.

GEO – Was & Is

Data Interface

- *Command and telemetry*
  - The Instrument should use MIL – STD - 1553 as the command and telemetry data interface with the Host spacecraft.
- *Science*
  - The Instrument should send science data directly to its transponder via an RS-422, LVDS, or SpaceWire interface

Data Accommodation

- *Command and telemetry*
  - The Instrument should utilize less than 500 bps of MIL STD - 1553 bus bandwidth when communicating with the Host Spacecraft.
- *Science*
  - The Instrument should transmit less than 60 Mbps of science data to its transponder

Electrical Power System Guidelines - LEO

- Assumption
  - The Host Spacecraft will energize the Survival Heater Power Bus at approximately 30% (or possibly higher, as negotiated with the host provider) of the OAP in accordance with the mission timeline documented in the EICD.
  - The Host Spacecraft will provide connections to 100W (Orbital Average Power) power buses as well as a dedicated bus to power the Instrument's survival heaters.

Electrical Power System Guidelines - LEO

- Grounding
  - The Instrument should electrically ground to a single point on the Host Spacecraft.
- Power Supply Voltage
  - The Instrument EPS should accept an unregulated input voltage of 28 ± 6 VDC.

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Electrical Power System Guidelines - GEO

- Assumption
  - The Host Spacecraft will energize the Survival Heater Power Bus at approximately 30% (or possibly higher, as negotiated with the host provider) of the OAP in accordance with the mission timeline documented in the EICD.
- Accommodation
  - The Instrument should draw less than or equal to 300W of electrical power from the Host Spacecraft.
- Voltage
  - The Instrument EPS should accept a regulated input voltage of 28 +6/-3 VDC. (was 28 ± 3)
- Grounding
  - The Instrument should electrically ground to a single point on the Host Spacecraft.

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Hosted Payload Interface Guide for Proposers Mechanical Guidelines

Randy Hein

NASA CII Team

Mechanical Guidelines Assumptions (LEO)

- The CII mechanical guidelines assume the following regarding the Host Spacecraft:
- 1) ~~During the pairing 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. (It should be noted that FOV requests are best accommodated during the initial configuration of the host. Therefore, FOV may be a limiting factor in determining which host spacecraft is a viable candidate for your payload.)
- 3) The Host Spacecraft Manufacturer will furnish all instrument mounting fasteners.

Mechanical Interface (LEO)

- The Instrument *should* be capable of fully acquiring science data when directly mounted to the Host Spacecraft nadir deck.
- The Instrument should be capable of fully acquiring science data when directly mounted to the Host Spacecraft. If precision mounting is required, the Instrument Provider should assume supplying a mounting plate to meet those requirements. Such an accommodation could affect the Instrument Providers mass budget.

Mechanical Interface (LEO)

(Volume)

- [LEO] The Instrument and all of its components *should* remain within the detailed Instrument envelope of 400mm x 500mm x 850mm (HxWxL) during all phases of flight.
- The Instrument and all of its components should remain within a volume of 0.15 m^3 during all phases of flight.

Mechanical Interface (LEO)

(Minimum Fixed-Base Frequency)

- The Instrument should have a fixed-base frequency greater than 50 Hz.
- The Instrument should have a fixed-base frequency greater than 70 Hz.

(In Reference Material/Best Practices)

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Mechanical Guidelines Assumptions (GEO)

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- 3) The Host Spacecraft Manufacturer will furnish all instrument mounting fasteners.

Mechanical Interface (GEO)

(Volume)

- [GEO] The Instrument and all of its components *should* remain within the detailed Instrument envelope of 1000mm x 1000mm x 1000mm (HxWxL) during all phases of flight.
- The Instrument and all of its components should remain within a volume of 1 m^3 during all phases of flight.

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Mechanical Interface (GEO)

(Minimum Fixed-Base Frequency)

- The Instrument should have a fixed-base frequency greater than 50 Hz.
- The Instrument should have a fixed-base frequency greater than 100 Hz.

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Air Force & NASA Hosted Payload Forum

Hosted Payload Interface Guidelines - Thermal

Gaj Birur/Eric Sunada

NASA CII Team

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Thermal Interface Assumptions (NO CHANGES)

- <u>Key Assumptions</u>
  - Once paired, the Host Spacecraft and the Instrument Developer work out the implementation details between them and record them in Thermal Interface Control Document (TICD)
  - The Host Spacecraft will maintain its side of the interface at temperatures between -40 C and 70 C from Integration through Disposal portions of its life cycle
  - The Host Spacecraft is responsible for the thermal hardware used to close out the interface between the Spacecraft and the instrument such as closeout MLI blanket; Instrument is responsible for all other thermal hardware on it

Thermal Interface Drivers

- **Conductive Heat transfer**
  - The conductive heat transfer at the Instrument-Host S/C mechanical I/F should be less than 15 W/m^2 or 4 W.
- **Radiative Heat Transfer**
  - The TICD will document the allowable radiative heat transfer from the Instrument to the Host Spacecraft.
- **Backloading**
  - Instrument requiring cold radiator should evaluate the effect of backloading from S/C hot parts (solar panels)

(This is an addition in the new document)

Justification for Change

TEMPO Hosting Experience

- During the matching up TEMPO instrument with a host GEO satellite the instrument radiator had too much backloading from the S/C solar panel led to heritage radiator being not adequate
- The backloading from GEO satellites was over 44 W/sq. m while the TEMPO heritage radiator was designed 25 W/sq. m
- As a thermally isolated payload, TEMPO had to manage its own heat transfer needs without support from the Host Spacecraft
- The TEMPO radiator design was too late to change; this led to instrument heat rejection responsibility moved to spacecraft

Backloading on the Radiator

- Another type of radiative input is backloading from one part of the spacecraft to another or to a third surface (like the shuttle). Two surfaces that view each other will interchange energy in the Infrared range.

$$\text{Backloading}_{1\text{-}2} = A \; \mathcal{SF} \, \sigma (T_1^4 - T_2^4)$$

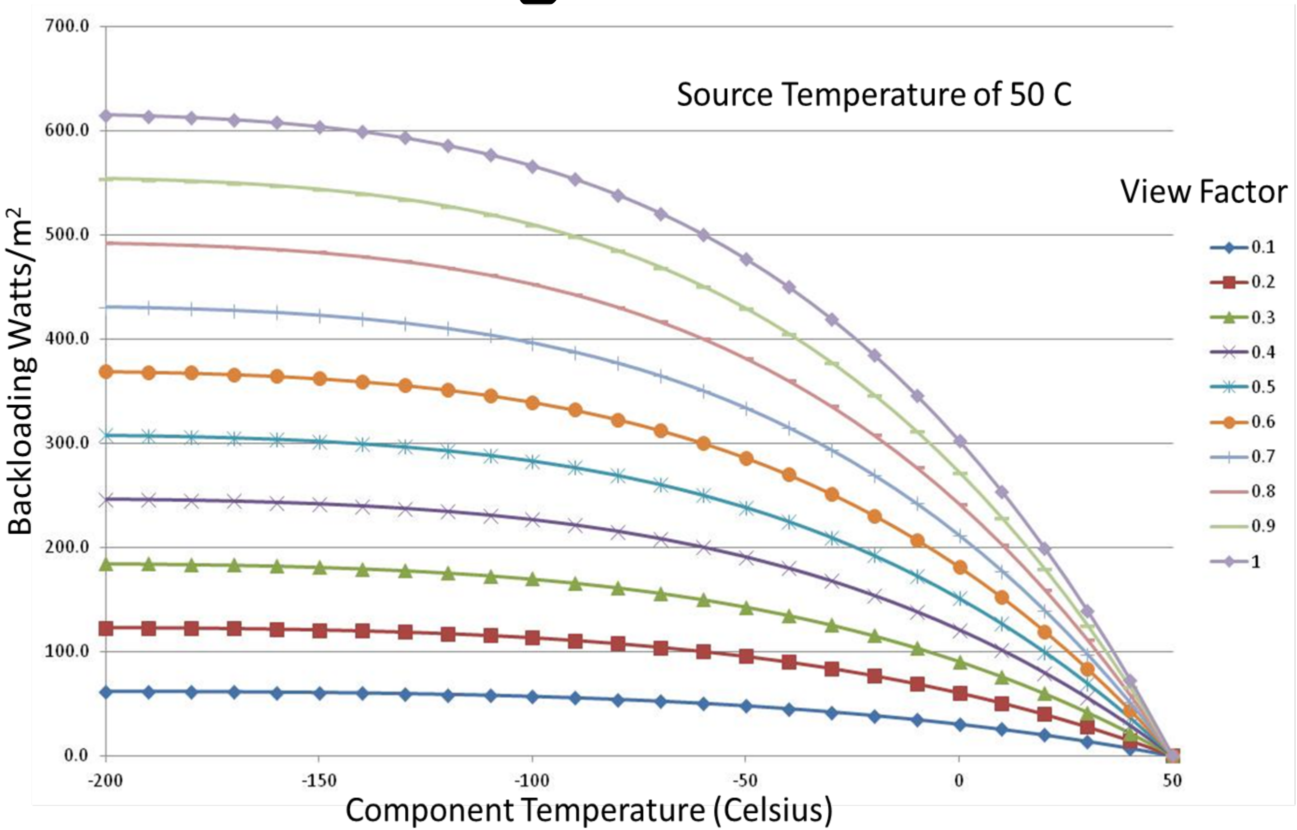
Where:

A - area

SF - script F

σ - Stefan Boltzmann Constant

Backloading from a 50 C Source



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Hosted Payload Interface Guide for Proposers
Environmental Guidelines

Christine Farguson
Kelly Collette
NASA CII Team

Summary

- This presentation only covers changes from CII to the new HPIG document.
- HPIG document includes changes to the following environments:
  - Quasi-Static - decreased
  - Sinusoidal Vibration - increased
  - Random Vibration - decreased
  - Acoustics - decreased
  - Shock - decreased
  - Orbital Acceleration - decreased
- New specifications are somewhat less conservative (except sine) and may not cover all possible hosting S/C. Some sections also provide additional higher spec for the "all satisfy" hosting opportunities.

Integration and Test Environments

- New: The instrument should be designed to minimize integrated tests with the spacecraft during the system level I&T phase. This is especially important during test activities in the environmental chambers. To the extent practical for the instrument, all performance testing should be performed prior to arrival at the spacecraft facility. Interface compatibility should be tested and the instrument should be powered down for the majority of spacecraft system level activities.

- Rationale: This approach minimizes schedule, cost, and complexity with the host

Quasi-Static Environment (Mass Acceleration Curve)

- Reduction in Quasi-Static Acceleration Levels for payloads >5kg.
- New levels are still "all satisfy strategy"

NOW:

Mass [kg]	Limit Load [g] (any direction)
1	68.0
5	49.0
10	39.8
20	31.2
40	23.8
60	20.2
80	17.8
100	16.2
125	14.7
150	13.5
175	12.6
200 or Greater	12.0

WAS:

Mass [kg]	Acceleration [g]
0 to 2.5	± 55
2.5 to 30	= ± (-1.273×Mass + 58.182)
>30	± 20

Sine Vibration

- Sine Vibration levels increased.
- Generic environment for preliminary design, represents coupled dynamic loads
- Notching to MAC allowed

WAS:

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		

NOW:

Frequency (Hz)	Amplitude	
	Flight Level	Protoflight/ Qual Level
5 – 20	12.7 mm (double amplitude)	16 mm (double amplitude)
20 – 100	10.0	12.5 g
Protoflight/Qual Sweep Rate: From 5 to 100 Hz at 4 octaves/minute Flight Level Sweep Rate: From 5 to 100 Hz at 2 octaves/minute except from 40 to 55 Hz at 6 Hz/min Input levels may be notched to limit component CG response to the design limit loads specified in Table 2-1		

Random Vibration

- GEO: Random Vibration levels reduced. LEO: no change.
- Source: GEVS, includes reduction criteria for P/L mass >25kg
- Previously GEO levels were based on "all Satisfy criteria". New spec adds higher levels of 30.9 GRMS (GEO) and 23.1 Grms (LEO) for all hosting criteria.
- Hardware with resonant frequencies below 80 Hz may be designed using only the MAC design loads

WAS (GEO):

Zone/Assembly	Frequency (Hz)	Protoflight / Qualification	Acceptance
Instrument	20	0.4 g^2/Hz	0.2 g^2/Hz
	20 – 50	+3 dB/octave	+3 dB/octave
	50 - 500	1.0 g^2/Hz	0.5 g^2/Hz
	500 - 2000	-4 dB/octave	-4 dB/octave
	2000	0.16 g^2/Hz	0.08 g^2/Hz
	Overall	32.1 g_{rms}	22.7 g_{rms}

NOW:
(GEO & LEO)

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}

Acoustic Environment

- Overall reduction.
- Previous spec met the "all Satisfy criteria".
- Rule of thumb added for h/w susceptibility guidance
  - Surface to weight ratio of > 150 in2/lb

Updated Spectrum:

Table 2-7: Acoustic Noise Environment

1/3 Octave Band Center Frequency (Hz)"	Design/Qual/Protoflight (dB w/ 20 μPa reference)"	Acceptance (dB w/ 20 μPa reference)"
20	129.5	126.5
25	130.7	127.7
31.5	130.0	127.0
40	131.5	128.5
50	133.0	130.0
63	134.5	131.5
80	135.5	132.5
100	136.0	133.0
125	136.8	133.8
160	136.7	133.7
200	136.0	133.0
250	136.0	133.0
315	136.0	133.0
400	134.0	131.0
500	132.0	129.0
630	131.4	128.4
800	131.6	128.6
1000	129.9	126.9
1250	126.1	123.1
1600	121.3	118.3
2000	119.5	116.5
2500	118.0	115.0
3150	116.1	113.1
4000	115.5	112.5
5000	114.8	111.8
6300	114.0	111.0
8000	113.0	110.0
10000	112.1	109.1

Shock

- Previously shock was only specified for GEO and was based on "all Satisfy criteria".
- Shock spectrum now identical for GEO and LEO
- New document also includes maximum spectrum of up to 5000 G (1600 to 10000 Hz) for more hosting opportunities.

WAS(GEO) :

Table 8-6: [GEO] Mechanical Shock Environment

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

NOW (GEO and LEO):

Table 2-8: Shock Response Spectrum (Q=10)

Frequency (Hz)	Acceptance Level (g)	Protoflight/Qualification (g)
100	160	224
630	1000	1400
10000	1000	1400
	The shock levels given assume that a component is located at least 60 cm (2 ft) from a shock source	The shock levels given assume that a component is located at least 60 cm (2 ft) from a shock source

Orbital Acceleration

- The Instrument should function according to its operational specifications after being subjected to a maximum spacecraft-induced acceleration of 0.15g (was 0.4 g)
- The guideline is the all-satisfy strategy scenario.