CII Thermal Guidelines

Gaj Birur
NASA CII Team

Thermal Interface Assumptions

- **Key assumptions**
  - 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

- A key thermal interface driver is the demand the instrument and spacecraft make on each other; lesser the demand, easier is the interface which leads to lower costs and better matching
  - The examples of these demands are: the survival heater power, instrument temperature monitoring by spacecraft, flight rules on orientation restrictions, etc.
- The required instrument radiator size can vary by a factor of four for depending on the location of the instrument on the LEO spacecraft
- Certain payload operating temperature requirements (e.g., very low temperature or very stringent thermal stability) can impose severe constraints on spacecraft operation

Thermal L1 Guideline

ID	Function	Guidelines	Rationale/Comment
2.2.6	Thermal Interface	The instruments should be thermally isolated form the Host Spacecraft	Causes minimal disturbance to spacecraft; makes it easier for the spacecraft to host HPL

Thermal L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
7.2.1	Thermal Design at the Mechanical I/F	The Instrument thermal design should be decoupled from the Spacecraft at the mechanical interface and neighboring payloads as much as possible.	As a hosted payload, the instrument should not interfere with the host spacecraft's functions.

Thermal L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
7.2.2	Conductive Heat Transfer	The conductive heat transfer at the Instrument-Host Spacecraft mechanical interface should be less than 15 W/m^2 or 4 W.	A conductive heat transfer of 15 W/m^2 or 4 W is considered small enough to meet the intent of being thermally isolated.

Thermal L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
7.2.3	Radiative Heat Transfer from the instrument	The TICD will document the allowable radiative heat transfer from the Instrument to the Host Spacecraft.	After pairing, the spacecraft details will be known; TICD can document instrument's radiative isolation from spacecraft and other payload

Thermal L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
7.2.4	Temperature Maintenance Responsibility	The Instrument should maintain its own instrument temperature requirements.	As a thermally isolated payload, the Instrument has to manage its own thermal properties without support from the Host Spacecraft.

Thermal L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
7.2.5	Instrument Allowable Temperatures	The TICD will document the allowable temperature ranges that the Instrument will maintain in each operational mode/state.	The allowable temperatures drive the requirements for the Instrument and S/C thermal systems

Thermal L2 Guidelines

ID	Function	Guidelines	Rationale/Comment
7.2.6	Thermal Hardware Responsibility	The Instrument Provider should provide and install all Instrument thermal control hardware including blankets, temperature sensors, louvers, heat pipes, radiators, and coatings.	This function naturally follows the responsibility for the instrument thermal design and maintaining its temperature requirements. The Host Spacecraft will provide only the closeout thermal hardware for the interface such as MLI blanket or the S/C provided heat pipes

Thermal Best Practices

ID	Function	Guidelines	Rationale/Comment
9.4.1.1	Heat Transfer Hardware	The Instrument should be thermally isolated from the Host spacecraft	This is the key assumption made for better matching of the instrument with a Host Spacecraft
9.4.1.2	Survivability at Very Low Temperature	The Instrument Developer should consider using components that can survive at -55° C.	This is to minimize the survival power demands on the Spacecraft

Thermal Best Practices

ID	Function	Guidelines	Rationale/Comment
9.4.1.3	Implementation of Cooling Function	Consider using thermoelectric coolers or mechanical coolers for cryogenic temperature requirement	This will reduce restrictions on the placement and size of radiators
9.4.1.4	Implementation of High Thermal Stability	Consider using high thermal capacity hardware such as phase change material (PCM) to increase thermal stability	PCM is an example of an useful technology for low mass optical components

Thermal Best Practices

ID	Function	Guidelines	Rationale/Comment
9.4.2.1	Survival Heater Responsibility	Instrument Provider should provide and install all instrument survival heaters	Survival heaters are part of the Instrument
9.4.2.2	Mechanical Thermostats	The Instrument should control instrument survival heaters via mechanical thermostats	Mechanical thermostats allow control of heaters while the instrument is not operating

Thermal Best Practices

ID	Function	Guidelines	Rationale/Comment
9.4.2.3	Survival Heater Documentation	The TICD will document survival heaters characteristics and mounting details	To capture the agreement between Host Spacecraft and Instrument Developer
9.4.2.4	Minimum Turn-on Temperature	Maintain the component temperature above that required to safely energize & operate the component	Some electronics require this minimum temperature to safely operate

Thermal Best Practices

ID	Function	Guidelines	Rationale/Comment
9.4.3.1	Surviving Arbitrary Pointing Orientations	[LEO] The instrument should survive four orbits of arbitrary pointing orientation with survival power w/o permanent degradation	Typical NASA earth orbiting science instrument survival requirement
9.4.3.2	Documentation of Temperature Limits	The TICD will document temperature limits for Instrument components during ground test and on-orbit scenarios	Needed for Integration and Test (I&T) engineers to monitor and safely manage it during I&T

Thermal Best Practices

ID	Function	Guidelines	Rationale/Comment
9.4.3.3	Documentation of Temperature Monitoring Locations	The TICD will document the locations of all Instrument temperature sensors	This is standard means to document the agreement between the Spacecraft & Instrument
9.4.3.4	Temperature Monitoring during Off Mode	The Spacecraft may not be able to provide temperature monitoring of the payload when it is Off	This limits the demand the Instrument may place on the Host Spacecraft

Thermal Best Practices

ID	Function	Guidelines	Rationale/Comment
9.4.3.5	Thermal Control Hardware Documentation	The TICD will document Instrument thermal control hardware	This is standard means to document the agreement between the Spacecraft & Instrument
9.4.3.6	Thermal Performance Verification	The Instrument Developer should verify the thermal control system's ability to meet Instrument requirements either by test or analysis	These verification methods ensure the instrument's thermal performance meeting the TICD agreements

Summary of Thermal Guidelines

- **2.0 Level 1 Design Guidelines**
  2.2.6 Thermal Interface

- **7.0 Thermal Level 2 Guidelines**
  7.2.1 Thermal Design at Mechanical Interface
  7.2.2 Conductive Heat Transfer
  7.2.3 Radiative Heat Transfer
  7.2.4 Temperature Maintenance Responsibility
  7.2.5 Instrument Allowable Temperature
  7.2.6 Thermal Control Hardware Responsibility

- **9.4 Thermal Interface Reference Material / Best Practices**
  9.4.1 Heat Management Techniques
    9.4.1.1 Heat Transfer Hardware
    9.4.1.2 Survivability at Very Low Temperature
    9.4.1.3 Implementation of Cooling Function
    9.4.1.4 Implementation of High Thermal Stability
  9.4.2 Survival Heaters
    9.4.2.1 Survival Heater Responsibility
    9.4.2.2 Mechanical Thermostats
    9.4.2.3 Survival Heater Documentation
    9.4.2.4 Minimum Turn-on Temperatures

Summary of Thermal Guidelines

- **9.4 Thermal Interface Reference Material / Best Practices (Cont'd)**

9.4.3 Thermal Performance and Monitoring

9.4.3.1 Surviving Arbitrary Pointing Orientations
9.4.3.2 Documentation of Temperature Limits
9.4.3.3 Documentation of Monitoring Locations
9.4.3.4 Temperature Monitoring during OFF Mode
9.4.3.5 Thermal Control Hardware Documentation
9.4.3.6 Thermal Performance Verification