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Contents

1 Description

1.1 Purpose

This document describes the interface between HFT developed by European consortium and PLM developed by JAXA.

1.2 Scope

Figure 1 shows preliminary work-sharing of LiteBIRD. Based on this work-sharing, there are JAXA ICDs as shown in Figure 2. The scope of this ICD is between HFT and PLM. The interaction between HFT and PLM has optical, thermal, physical/mechanical, and electromagnetic interfaces. Electrical or software interfaces are separately defined by other documents. The HFT includes following items,

1. HFT including polarization modulation units (PMU)
2. electrical drivers for PMU

Following tasks are assigned to JAXA.

1. 5K optical bench for HFT
2. Thermal straps for 0.1K, 0.3K, 1.8K and 4.8K

1.3 Related Documents and Definitions

1.3.1 Applicable Documents

The following documents are part of this document to the extent specified herein. If not explicitly stated differently, the latest issue of the document is valid.

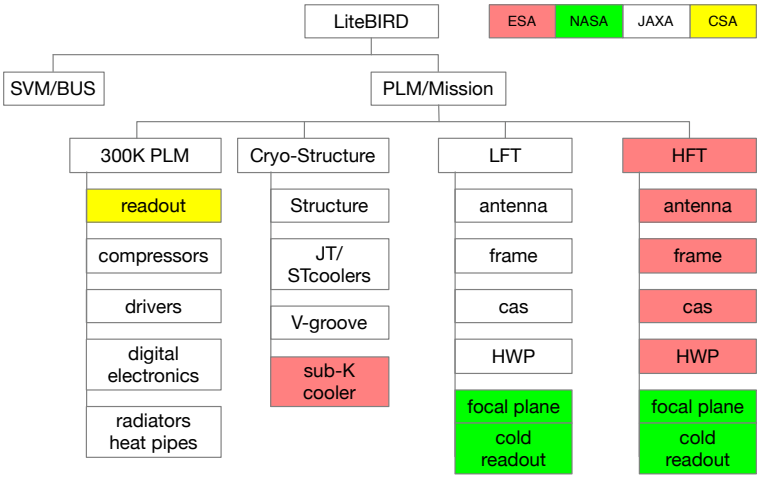

Figure 1. Block diagram and task sharing among agencies

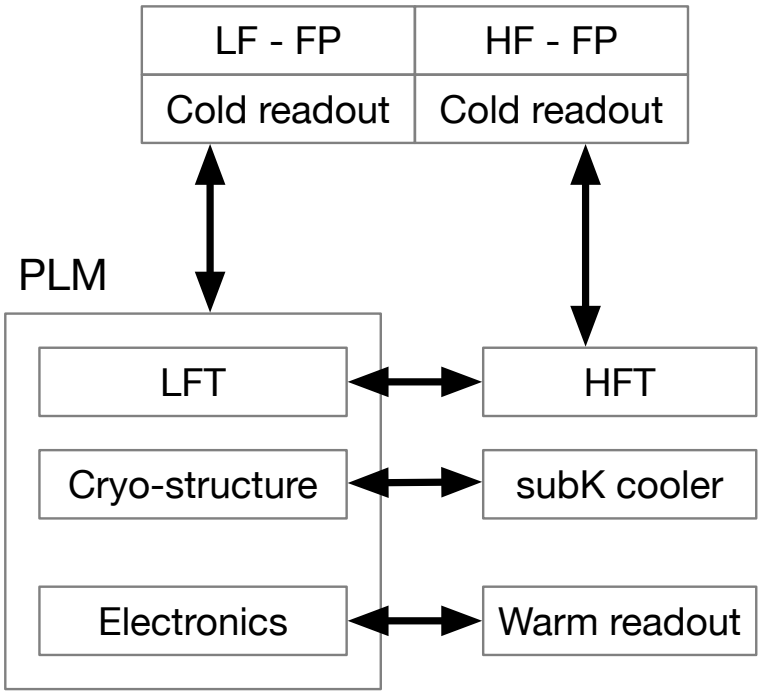

Figure 2. Interfaces among LiteBIRD sub-systems. This document defines the interfaces between HFT and PLM.

Table 1. applicable documents

	title	date	
AD01	Basic policy on JAXA project implementation	2017/5/10	
AD02	Project management regulation	2017/6/27	JAXA regulation 29-28
AD03	Project management implementation procedure	2017/6/27	Chief engineer 29-1
AD04	Execution policy (final report) for task force recommendation in implementation of space science projects	2014/9/25	
AD05	ISAS reformation action plan after the Astro-H accident	2016/7/27	RSQ-16012A
AD06	ISAS CML checklist	2018/4/9	RPR-17009
AD07	Lesson Learned check list for projects	2017/9/8	BDB-14017A

In the event of a conflict between one of the before mentioned applicable documents and the contents of this document, the contents of the applicable document shall be considered as a superseding requirement.

1.3.2 References

The following documents contain additional information and are referenced in this document.

1.4 Abbreviations and Acronyms

A limited set of basic acronyms used in this document is given below.

FP focal plane for HFT and LFT

HFT High frequency telescope

LFT Low frequency telescope

1.5 Verb Convention

"Shall" is used when a specification is mandatory.

1.6 Requirements numbering

The requirements are numbered according to the following code:
[ICD-PLM-HFT-XXXXX-YY / Z]
Where:

- LB-ICD-PLM-HFT identifies the LiteBIRD/ICD-PLM-HFT;
- XXXXX is a combination of a section number and a consecutive number 03010, 03020, (the nine intermediate numbers remaining available for future revisions of this document);

Table 2. reference documents

RD01	On road map of space science and exploration	2013/9/19	
RD02	Strategic scenario of mid and long term plan of space science during next term	2018/3/28	
RD03	Guideline for phase transition reviews	2017/12/6	BDB-08013D
RD04	Guideline for success criteria description	2018/1/11	BDB-08012D
RD05	Guideline for utilization and operation concept document	2017/12/6	BDB-09008B
RD06	Guideline for mission requirement document	2017/12/27	BDB-09009A
RD07	Guideline for system requirement and specification document	2017/12/6	BDB-10002A
RD08	Guideline for cost estimation	2018/1/22	BDB-17008
RD09	Guideline for mission definition phase	2018/3/15	BDB-17013
RD10	On implementation procedure during ISAS mission exploration phase and mission definition phase	2018/6/15	
RD11	US CSR		
RD12	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment	ASTM E595 - 15	

- YY describes the requirement revision. It starts with 00 and is incremented by one with every requirement revision;
- Z describes the requirement verification method(s), where RT stands for Room Temperature Test, CT for cryogenic temperature test, I for Inspection, Rv for Review of design and A for Analysis. Multiple verification methods are allowed.

2 Operational definition

2.1 Observation mode

[ICD-PLM-HFT-03010-00 / CT] During observation mode, HWP shall be cooled to 5 K.

[ICD-PLM-HFT-03020-00 / A, CT] Dead time due to cosmic rays in the observation mode shall be less than 5 %.

2.2 Recycle mode

A sub Kelvin cooler needs recycle to restore the cooling capability. The recycle mode is defined as a period when the sub Kelvin cooler is recycled. The duty cycle (observation time/total time) shall be larger than 85 %.

2.3 Initial test mode

[ICD-PLM-HFT-03060-00 / I]
Initial test mode is defined as a period after the focal plane is cooled down to 100 mK after the launch. The test sequence shall be defined.

2.4 Ground test mode

[ICD-PLM-HFT-03070-00 / I]
Ground test mode is defined as a period in which HFT is tested with PLM before the launch.

2.5 Non-operational mode

[ICD-PLM-HFT-03080-00 / I]
HFT shall survive during non-operational mode which is kept in the temperature less than 313 Kelvin.

3 Requirements for PLM

3.1 Contamination control

[ICD-PLM-HFT-04010-00 / I]
All components shall not emit contaminations at all modes. (To be revised quantitatively)

3.2 Contamination protection

[ICD-PLM-HFT-04020-00 / I]
All components shall be protected from possible contamination at all modes. (To be revised quantitatively)

3.3 Ventilation

[ICD-PLM-HFT-04030-00 / I]
All sub-systems and components shall be ventilated to survive the acoustic shock at the launch.

3.4 Outgassing

[ICD-PLM-HFT-04040-00 / RT, Rv, I]
All materials used in PLM shall be TML (total mass loss) of less than 1 % and CVCM (Collected Volatile Condensable Materials) of less than 0.1 %. Test methods of TML and CVCM refer to ASTM E595-15 [RD].

3.5 Discharge

[ICD-PLM-HFT-04050-00 / Rv, CT]
All components shall be avoided to electrically charged (To be revised quantitatively).

3.6 Radiation Tolerance

[ICD-PLM-HFT-04060-00 / Rv]

The integrated radiation dose at L2 over three years of observation shall not degrade instrument sensitivity below the requirement.

4 Sensitivity

4.1 Frequency band definition

[ICD-PLM-HFT-05010-00 / Rv, CT]

The observation frequency bands are defined as shown in Table 3. LF focal plane shall cover these frequency bands.

Table 3. Frequency bands and detector configuration. The CO lines are avoided with planar notch filters. This table shows only optical TESs. There are additional dark TESs for the monitor purpose.

	Type	Center [GHz]	BW	Low [GHz]	High [GHz]	Num. of wafers	TES channels Opt/wf	Total
LFT 34 - 161 GHz	1	40	0.30	34	46	3	14	42
		60	0.23	53	67	3	14	42
		78	0.23	69	87	3	14	42
	2	50	0.30	43	58	4	14	56
		68	0.23	60	76	4	14	56
		89	0.23	79	99	4	14	56
	3	68	0.23	60	76	3	38	114
		89	0.23	79	99	3	38	114
		119	0.30	101	137	3	38	114
	4	78	0.23	69	87	3	38	114
		100	0.23	89	112	3	38	114
		140	0.30	119	161	3	38	114
HFT 89 - 448 GHz	5	100	0.23	89	112	3	74	222
		140	0.30	119	161	3	74	222
		195	0.30	166	224	3	74	222
	6	119	0.30	101	137	2	74	148
		166	0.30	141	191	2	74	148
		235	0.30	200	270	2	74	148
	7	235	0.30	200	270	1		
		337	0.30	286	388	1	338	338
	8	280	0.30	238	322	1	338	338
		402	0.23	356	448	1	338	338
Total								3102
LFT								978
HFT								2124

5 Optical interfaces

Bore-sight angle (β) of HFT shall be 50 degree.

The field of view of HFT shall not interact with V-groove passive radiators.

6 Physical and mechanical Interfaces

6.1 Volume

[ICD-PLM-HFT-07030-00 /I]

HFT is mechanically placed on the 5 K part of PLM. Drawing of the interface shall be defined.

6.2 Mass and center of gravity

[ICD-PLM-HFT-07010-00 /I, RT]

The total mass of HFT added to the 5 K part of PLM shall be less than 100 kg.

[ICD-PLM-HFT-07020-00 / A, Rv]

The center of gravity of HFT shall be positioned as follows with respect to the optical coordinate system:

Table 4. Location of center of gravity

X	0 mm ± 10 mm
Y	0 mm ± 10 mm
Z	xx mm ± yy mm

6.3 Life time

[ICD-PLM-HFT-07040-00 /Rv, CT]

HFT shall survive longer than 3 years in the L2 orbit.

6.4 Eigen frequency

[ICD-PLM-HFT-07050-00 / RT]

HFT shall have eigen frequencies:

- 1st eigen frequency in the vertical direction (Z) of the satellite coordinate shall be higher than 100 Hz. (TBC)
- 1st eigen frequency in the horizontal directions (X, Y) of the satellite coordinate shall be higher than 50 Hz. (TBC)

6.5 Launch load

[ICD-PLM-HFT-07060-00 / RT]

FP shall survive the launch load of 20 G in the vertical direction (Z) and 10 G in the horizontal directions (X, Y) of the satellite coordinate. (TBC)

6.6 Alignments

6.6.1 Static alignment

[ICD-PLM-HFT-07080-00 / Rv, CT]

HFT shall be placed in the following position and angle between the optical axis and the rotation axis.

Table 5. Static alignment of FP

X	0 mm ± 1 mm
Y	0 mm ± 1 mm
Z	xx mm ± 1 mm
Angle (X)	0.2 degrees ± 0.1 degree
Angle (Y)	0.2 degrees ± 0.1 degree

6.6.2 Dynamic alignment

[ICD-PLM-HFT-07090-00 / Rv, CT]

HFT shall keep their dynamic alignment (to be revised quantitatively).

6.7 Physical interfaces for thermal strap

[ICD-PLM-HFT-07100-00 / Rv]

Physical interfaces for thermal straps shall be defined

0.1K 4 times M2.5 bolts (TBC)

0.3 K 4 times M2.5 bolts (TBC)

1.8 K 4 times M2.5 bolts (TBC)

4.7 K 8 times M4 bolts (TBC)

7 Thermal Interface

7.1 Interface temperature

[ICD-PLM-HFT-08010-00 / CT]

Temperatures of conductive and radiative interfaces of HFT on both 5 K and 2 K stages are defined in Table 6.

Table 6. Temperatures of conductive and radiative interfaces of HFT

	5 K stage		2 K stage	
	conductive	radiative	conductive	radiative
operation mode	4.7 K or less	5.0 K or less	1.8 K or less	2.0 K or less
re-cycle mode	5.5 K or less	6.0 K or less	2.0 K or less	2.5 K or less

7.2 Heat load

[ICD-PLM-HFT-08020-00 / CT]
The heat load of HFT shall comply those shown in Table 7.

Table 7. heat loads of HFT

	Stability	HFT heat load
100 mK	82 nK/sqr(Hz)	(1 uW)
300 mK	TBC	(20 uW)
1.8 K	10 mK in one minute	0.8 mW
4.8 K	5 mK in one minute	1 mW

7.3 Surface emissivity

[ICD-PLM-HFT-08080-00 / Rv]
The surface emissivity of the outside of HFT shall be defined in Table (To be prepared).

7.4 Temperature measurement points

[ICD-PLM-HFT-08090-00 / CT]
Temperature measurements points of HFT shall be defined in Table (To be prepared).

8 Electromagnetic Interface

8.1 Magnetic field

[ICD-PLM-HFT-09010-00 / Rv, CT]
HFT shall have its performance under circumstance of variation of DC magnetic field of xx μT (TBC).

[ICD-PLM-HFT-09020-00 / Rv, CT]
HFT shall have its performance under circumstance of AC magnetic field of xx μT (TBC).

8.2 EMI/EMC

[ICD-PLM-HFT-09030-00 / Rv, CT]
HFT shall have its performance under circumstance of EMI/EMC of . (TBD).

9 Electrical Interface

9.1 Ground interface

[ICD-PLM-HFT-10010-00 / Rv]
Ground diagram of HFT is shown in Figure

9.2 Wire harness between cold readout and Warm Readout

9.2.1 Wire harness definition

[ICD-PLM-HFT-10020-00 / Rv]
Wire harness between HFT and warm readout electronics shall be defined as tabulated in Table 8.

Table 8. wire harness between the cold readout at 5 K and warm readout

	# of wire/SQUID	impedance [Ω]	material
SQUID output	2	R < 20	BeCu Dia. 0.1mm (12 Ω/meter)
SQUID (0.1K) bias	2	100 <R < 270	manganin Dia. 0.1mm (60 Ω/meter)
SQUID (4.5K) bias	2	100 < R < 270	manganin Dia. 0.1mm (60 Ω/meter)
TES bias	2	100 < R < 270	manganin Dia. 0.1mm (60 Ω/meter)
SQUID heater	1	100 < R < 270	manganin Dia. 0.1mm (60 Ω/meter)
Ground	1/telescope	R < 20	BeCu Dia. 0.1mm (12 Ω/meter)

9.2.2 Cross talk

[ICD-PLM-HFT-10030-00 / RT, CT]
Cross talk of wire harness between HFT and warm readout electronics shall be less than 0.03 % (TBC).