Metis INSTRUMENT
for the
Solar Orbiter Mission

Experiment Interface Document – Part B

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Change Log

date	issue	revision	Paragraphs	reason for change
15/01/2008	01	0	All	First Issue
30/06/2009	02	0	All	Second Issue - following the selection for the Assessment Study Phase (SRE-PS/01258, 20 March 2009)
28/10/2009	02	1	All	New release for IDSR meeting (11-12 Nov. 2009). New optical design with Inverted External Occulter and spectroscopic channel
	02	2	Tab. 2-1, 3.3&subs, 3.4, 4.4&subs, 4.5, 4.6&subs, 4.7&subs, 4.8&subs, 4.11.4, 5.1&subs, 5.2, 6.6.1.2&subs, 6.8.2	New release for delta-IDSR meeting (18-19 Feb. 2010).
	02	3	All	New release to close IDSR and D-IDSR actions items and RID's.
18/10/2010	02	4	Chap. 3.x and 4.x	Updated with the insertion of the ERM
			Ch. 1	Minor revisions
			4.6.1.7	Paragraph on internal harness added
			3.3.3.1	Revision of peak data rate and TC/TM paragraph
			3.3.5	Revision of off-pointing effects as function of the distance from the Sun
			4.6.4	Revision of Baffle system
			4.4.2	Revision of METIS Pointing Error
			2.x	Roles corrected
			Fig 4-5	MPPU external configuration drawings added
			4.7.3	Revision of thermal interfaces
01/03/2011	02	05	All	Complete revision according to ESA PO suggestion. Chapter organizations mirroring EID-A scheme.
11/11/2011	02	06	1.3	Rewording.
			3.2.1.2	"If needed" removed.
			Figure 3-2	Figure updated. Optical Bench renamed IFE
			3.2.2.1	"The diameter of the tube has to be optimized." Removed Some other rewording
			3.2.2.1.1	Reference to the Engineering Plan added
			3.2.2.3	Technical and material details removed
			3.2.2.4	Rewording of point 3
			3.2.2.4.1	Updated with new ERM concept
			3.2.2.4.2	Sentence removed because the IOM will be used
			3.2.2.4.3	Updated with new FIM concept
			3.2.3.1	Updated with the new design

date	issue	revision	Paragraphs	reason for change
			3.4.1	Removed
			3.4.2	Removed
			3.4.3	Removed
			4.2.3	Removed
			4.2.4	Point 3 reworded and point 4 removed
			4.2.5	Period specified in days
			4.2.6	Removed
			4.3.1.3	Removed
			4.3.1.4	Removed
			4.4.2.2	Removed
03/04/2012	02	7	All	General revision for the PDR. Most of paragraph have been renumbered to match EID-A chapter organization.
			All	METIS requirements renamed from REQ-xxxx to METIS-xxxx; obsolete requirements removed and remaining renumbered
14/03/2014	3	0	All	General revision for the D-PDR.
29/07/2014	3	1	1.1	Rewording: removed “, the Multi Element Telescope for Imaging and Spectroscopy investigation”
			2.1	List of institutes updated
			3.2.2.1.1	Reference to EUV focal plane removed from figure 3-5
			3.2.2.3.2	reference to the figure 3.10 corrected and changed to 3.9
			3.2.2.5	typo removed
			3.2.2.8	New chapter heading and text reworded
			4.2.7	reference to the req. METIS-4.2.7-1 corrected and changed to METIS-4.5.8-1 as per RID METIS-PDR-144
			4.4.2.1	LOS and ILS defined as per RID METIS_PDR_24 and PDR-OPS-06
			4.4.3	New chapter heading and rewording. Requirement 4.4.3-1 moved to section 5.2.1
			4.5.2	Mass Budget updated as per [RD-9]
			4.5.3	Harness physical properties added
			4.5.4	Harness physical properties added
			4.5.8	The req. METIS-4.5.8-1 has been modified adding the “light protection” functionality as per [AD-6]
			4.5.8	The req. METIS-4.5.8-2 modified as per RID METIS_PDR_158
			4.6.3.4	Text rephrased. Thermal boundary conditions (Table 4-5) updated
			4.6.3.5	Table 4-6 revised including also the information given in Table 4.7. Table 4.7 removed
			4.6.4.2	Decontamination heater operational temperature changed from 0 °C to 20-30 °C TBC

date	issue	revision	Paragraphs	reason for change
			4.7.1.4	Better definition of long/short peak power Detailed subsystem by subsystem power budget removed (par. From 4.7.1.5 → 4.1.7.10) Tables 4-11 4-12 and 4-13 deleted
			4.7.1.11	Table 4-11 updated Table 4-12 updated Table 4-13 updated (as per RID METIS_PDR_72 and AI PDR-OPS-17) Table 4-14 inserted (as per RID METIS_PDR_72 and AI PDR-OPS-17)
			4.7.1.12	The req. METIS-4.7.1-1 deleted as per RID METIS_PDR_103 and AI PDR-ELE-006
			4.8.1.1	Typo corrected: Carriage Return between “Stand-By” and “Safe” removed Figure 4-5 updated
			4.8.1.2	Table 4-16 updated.
			4.8.8	Paragraph rewritten as per RID METIS_PDR-108 - AI PDR-ELE-16
			5.2.1	The structure of this paragraph has been changed including the following sub-paragraphs: 5.2.1.1 General pointing requirement 5.2.1.2 External Door closing 5.2.1.3 External door opening 5.2.1.4 External Door status
			5.2.1	“(e.g. > 9 arcmin at 0.28 AU)” deleted
			5.2.1.1	new requirement METIS-5.2.1-0 inserted. It is a modification of req. METIS-4.4.3-1 of EID-B Issue 3.0 as requested by per RID METIS_PDR-24 ii) and PDR-25 and PDR-153.
			5.2.1.1	Definition of Alpha_MAX added. In the EID-B 3.1 draft Alpha a typo in the definition of AlphaMax was present and has been corrected.
				Requirement METIS-5.2.1-2 now relies on BetaMax (TBC) instead of AlphaMax
			5.2.1.3	Plot of alpha_MAX modified including both alpha_max and beta_max and moved at the end of the paragraph.
			5.2.1.3	Requirement METIS-5.2.1.-4 updated and expressed in function of beta_MAX
			5.2.1.3	Definition of beta_MAX added.
			5.2.1.4	Requirement METIS-5.2.1-5 on door status added.
			6.6.1.1.3	Typo to reference document corrected as per RID-71 Modes acronyms added
			9.1 & 9.2	References to other docs updated
			Appendix –A	Added
19/09/2014	3	2	4.2.7	Paragraph rewritten
			4.4.3	APE requirement introduced as METIS-4.4.3-2; table 4-3 updated accordingly

date	issue	revision	Paragraphs	reason for change
			4.5.1	Requirement METIS-4.5.1-1 added
			4.5.2	Mass Budget (Table 4-4) updated
			4.5.7	In METIS-4.5.7-1 the word “will” is replaced bay “shall”. Requirement METIS-4.5.7-2 reworded
			4.5.7.1	Requirement METIS-4.5.7-3 reworded
			4.5.8	Requirements METIS-4.5.8-2 and METIS-4.5.8-3 reworded
			4.6.3	Reference to the relevant documents modified
			4.6.3.5	Clarification about table 4-6 (for information only) added
			4.6.4.2	Requirements METIS-4.6.4-1
			4.7	Reference to the EICD [AD-10] corrected
			4.7.1.8	Clarification on heater duty cycle added
			4.11.4	Requirements METIS-4.11.4-1, METIS-4.11.4-2 and paragraph text reworded. TBC removed from METIS-4.11.4-3 Requirement METIS-4.11.4-4 added.
			5.2.1.1	Requirements METIS-5.2.1-0 and METIS-5.2.1-1 reworded.
			5.2.1.2	Requirement METIS-5.2.1-2 reworded.
			5.2.1.3	First requirement of the paragraph demoted to descriptive text.
			5.3	First compilation (it was TBW)
			5.4	First compilation (it was TBW)
			5.5	First compilation (it was TBW)
			6.4.7	Requirement METIS-6.4.7-1 reworded
			9.1	References of AD-7, AD-8 and AD-10 updated
			9.2	References of RD-3, RD-6, RD-7, RD-11, RD-12, RD-13 and RD-14 updated. Reference to RD-18, RD-19, RD-20, RD-21 added.
30/09/2014	3	3	4.6.3.5	Table 4.6 removed.
			5.2.1.1	In req. 5.2.1-1 “when Alpha max is exceeded” added
			5.2.1.2	In req. 5.2.1-2 included condition on Beta max
			5.2.1.3	Requirement 5.2.1-4 deleted and transformed in descriptive text.
30/06/2015	3	4	2.1	Vincenzo Andretta added as Scientific Operations Coordinator
			3.2.1.2	Sentence corrected (Metis is not any longer on an optical bench)
			3.2.2	Paragraph reworded in order to describe the physical units. Figure 3-2 updated
			3.2.2.3.1	description of the structure updated. Dimensions and section of the inner hole of M2 updated. Figures 3-7 and 3-8 updated
			3.2.2.3.2	Reference to INVAR collar added, figure 3.9 updated
			3.2.2.5	Figure 3.11 updated

date	issue	revision	Paragraphs	reason for change
			3.2.2.6	The IEO is now without coating on the external surfaces, it is bare titanium Figure 3-13 deleted
			3.2.2.8	Figure 3-15 updated.
			3.2.2.9	Paragraph reworded, figure 3-16 updated.
			3.2.3.1	MPPU description updated. Figure 3-19 updated
			3.2.3.2	MPPU description updated. Figures 3-20, 3-21 updated, figure 3-22 deleted.
			3.2.4.1	Ops ranges of VLD APS and proximity electronics inserted in place of the cold finger interface temperature ranges.
			3.2.4.2	Ops ranges of the UVD APS and proximity electronics inserted in place of the cold finger interface temperature ranges. Table 3-2 added.
			3.2.5	Metis OBSW description updated,Figure 3-29 updated. Tables 3-3, 3-4 and 3,5 added
			4.1	Sentence reworded.
			4.1.1	Paragraph renamed, lasttable removed.
			4.2.4	Sentence reworded
			4.2.6	Sentence reworded
			4.2.7	Specific reference to Metis req. inserted in bullet 1
			4.4.1	Sentence reworded , Figure 4-2 deleted
			4.4.2.1	AKE added in the definitions list
			4.4.3	AKE added in the description text Requirement METIS-4.4.3-2 reworded (it refers only to in-flight contribution) Requirement METIS-4.4.3-3 added (it refers only to ground and ground-to-space contribution)
			4.5.1	Requirement METIS-4.5.1-1 modified and reworded accordingly to the CR about the SORA redesign.
			4.5.2	Mass budget (Table 4-4) updated
			4.5.3	CoM values removed, reference to the MICD's inserted
			4.5.4	MoI values removed, reference to the MICD's inserted
			4.5.7	Requirement METIS-4.5.7-1 relaxed from 10% to 12%
			4.6.3	Section reduced and simplified. Specific reference to the relevant RFD inserted. Paragraphs 4.6.3.1 through 4.6.3.5 deleted.
			4.6.4.2	Requirement 4.6.4-1 reworded in function of the CE I/F temperature.
			4.6.4.3.1	VLDA and UVDA heaters removed from table 4-7
			4.6.4.3.2	Table 4-8 updated
			4.6.5.1	Sentence on ground operations removed. Requirement METIS 4.6.5-1 added
			4.7.1.11	Power budget tables updated (merged all modes in Table 4-9, tables 4-10, 4-11 and 4-12 deleted. Text afterwards removed

date	issue	revision	Paragraphs	reason for change
			4.8.6	Sentence reworded.
			4.11.4	Requirement METIS-4.11.4-1 reworded. Text and requirement METIS-4.11.4-4, related to integration of MCAP, have been removed.
			5.2.1.1	Requirements METIS-5.2.1-0 and METIS-5.2.1-1 deleted. Their text demoted to sentence.
			5.2.1.2	Requirement 5.2.1-2 reworded. Requirement 5.2.1-35 added.
			5.2.1.4	Requirement 5.2.1.5 deleted (see email from M. Romoli to F. Marliani of 06 March 2015).
			9.1	AD-1, ….., updated to the latest issue
			9.2	RD-2, RD-5, RD-9, RD-18, RD-21 updated to the latest issue
09/10/2015	4	0	4.4.3	Requirements METIS-4.4.3-2 and METIS-4.4.3-3 reworded (see [RD-23])
			4.5.2	Mass budget (Table 4-4) updated
			4.5.8	Requirements METIS-4.5.8-1 and METIS-4.5.8-3 modified (see [RD-23)
			4.7.1.11	Power budget (Table 4-9) updated
			4.10.4	Magnetic budget paragraph added, table 4-14 added
			4.11.2	Requirement METIS-4.11.2-1 on cleaniness added, text reworded and table 4-15 added.
			4.11.2.1	Paragraph added with the list of Metis Sensitive surfaces.
			4.11.4	In the requirements METIS-4.11.4-1 and METIS-4.11.4-2 the nitrogen purity has been modified to 99.995% (see [RD-23)
			5.2.1.2	Requirements METIS-5.2.1-2 and 5.2.1-35 reworded
12/11/2015	4	1	4.5.2	Mass budget table removed, reference to the Detailed Budget Report [RD-9] included.
			4.6.3	Table 4-5 added with the requested thermal interface temperatures as function of heliocentric distance
			4.7.11	Power budget table removed, reference to the Detailed Budget Report [RD-9] included.
			4.10.4	Magnetic breakdown updated with MPPU contribution
			4.11.2	Requirement 4.11.2-1 reworded and Table 4-15 changed: it contains only the cleanliness requirements for the exterior sensitive surfaces. Figure 4-6 updated
			4.11.4	Typo in the requirements METIS-4.11.4-1 corrected.
15/12/2015	4	2	all	METIS acronym replaced by Metis
			1.1, 1.2, 1,3, 2.1, 3.2.1.2, 3.2.2, 3.2.2.1, 3.2.2.2, 3.2.2.3.2, 3.2.2.7, 3.2.2.9, 3.2.3.2	Descriptive text reworded

date	issue	revision	Paragraphs	reason for change
			3.2.4.1, 3.2.5, 3.3, 4.4.1, 4.4.2.1, 4.5.7.1, 4.6.4.2, 4.7.1.4, 4.8.1.1, 5.2.1.3	Descriptive text reworded
			3.1.1	Spatial resolution updated in Table 3-1
			3.2.2.1	Figure 3-4 updated
			3.2.4.1	Table 3-2 deleted
			4.11.2.1	TBC/TBD removed
			6.6.1.1.3	Reference to the Ops Concept document replaced with the User Manual
			6.6.2	TBC removed
			9.1, 9,2	Some reference updated
			10	Acronyms updated
18/03/2017	5	0		
			4.6.3	Thermal design requirements are not function of the S/C heliocentric distance any longer. Requirement METIS-4.6.3-1 added as per RID METIS-CDR-1 and Action OPS-11
			4.8.1.1	Figure 4-5 updated
			4.9.3	Reference to [RD-03] and [RD-27] added.
			5.1	First update
			5.2	paragraph updated with references to [RD-3] and [AD-4]
			5.3.1	Definition of modified accordingly to [RD-25]
			5.5	Reference to [AD-1] added
			6.6.1.1.3	Paragraph revised as per CDR OPS-03 including the details of the in-flight calibration procedures and requirements. Requirements METIS-6.6.1-1 and METIS-6.6.1-2 added
			9.1	References updated as per PFM Acceptance Data Package and CIDL
			9.2	References updated as per PFM Acceptance Data Package and CIDL

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1 General Introduction

1.1 Background

Solar Orbiter will provide the next major step forward in the exploration of the Sun and the heliosphere after the successful ESA missions Ulysses and SOHO, as well as the NASA missions, TRACE, RHESSI, STEREO and SDO, and the ISAS mission, Hinode. Solar Orbiter is a key element of the International Living with a Star program, focused on the space research that has the objective of understanding the processes governing the connected Sun-heliosphere system.
Solar Orbiter was proposed in 2000 by the European solar scientific community with the aim of exploring the circumsolar region, obtaining unique quasi helio-synchronous observations and performing the first out-of-ecliptic imaging and spectroscopic observations of the solar poles and the first equatorial corona observations from high altitudes.

Metis benefits from the heritage of the scientific knowledge and experimental experience that has been arising in the last decades from the technology developments and data analysis and interpretation related to the SOHO coronagraphs and spectrometers. The investigation also benefits from the successful launch of the prototype of Metis, which is the Sounding-rocket Coronagraphic Experiment, SCORE, on the 14th of September 2009.

1.2 Summary of Investigation Objectives

The design of Metis, conceived to perform off-limb, near-Sun coronagraphy, is motivated by the aim of addressing the three key scientific questions identified as the focus of the Solar Orbiter mission. These questions concern: the origin and heating/acceleration of the solar wind streams; the origin, acceleration and transport of the solar energetic particles; and the transient ejection of coronal mass and its evolution in the inner heliosphere (coronal mass ejections, CME's).

The crucial tests for addressing and solving these still open issues can be achieved by combining the instrument's versatility with the uniqueness of the Solar Orbiter mission profile, which allows: 1) a close approach to the Sun thus leading to a significant improvement in spatial resolution; 2) quasi co-rotation with the Sun, which allows one to nearly freeze for several days both the on-disk inner corona and the outer corona in the plane of the sky and, thus, disentangle the evolution of coronal structures and solar rotational effects on medium-term time scales; and 3) an out-of-ecliptic view of the Sun.

Metis will be capable of obtaining for the first time simultaneous imaging of the full corona in polarized visible-light (580-640 nm) and narrow-band ultraviolet HI Ly α (121.6 nm).

These measurements will allow a complete characterization of the most important plasma components of the corona and the solar wind, i.e., electrons and protons, and will diagnose, with unprecedented temporal coverage and spatial resolution (down to about 4000 km, sampling element), the structure and dynamics of the full corona in the range from 1.6 to 3.0 solar radii ($R_\odot$) at minimum perihelion (0.28 AU), and from 2.8 to 5.5 $R_\odot$ at 0.5 AU. This region is crucial in linking the solar atmosphere phenomena to their evolution in the inner heliosphere, and the study of its properties is very important in meeting the Solar Orbiter fundamental science goals.

The coronagraph is based on a novel externally occulted design, in which light enters through a circular inverted external occulter located at the outside panel of the S/C heat shield. The inverted external occulter is supported by a suitable truss, which protrudes from the S/C instrument bay inside the heat shield. Two different coronal light wavelength bands are acquired: visible (580-640 nm), collected by a visible detector after passing through a polarizer, and ultraviolet (HI 121.6 nm) line emission collected by a UV detector.

1.3 Document Concept and Architecture

The EID-B defines the PI response to the technical requirements in part A, specifying in detail the interface information applicable to Metis. Furthermore, in this document, the Metis requirements versus the S/C are univocally identified and numbered.
Part B will form the sole formal and binding document for all technical and programmatic agreements between the ESA Solar Orbiter Project Office and the Principal Investigator.
The EID A and B will be placed under formal configuration and change control once signed and thus any change requires formal agreement between ESA and the PI.
The EID- B will become one of the applicable documents to the Solar Orbiter prime contractor.

Since the EID-B will accompany Metis until its realization, we have chosen to introduce the description of the interfaces with the S/C and some sections have been added to describe l the optical characteristics and the performance of the instrument.

2 Key Personnel and Responsibilities

2.1 Metis Consortium

The Metis investigation is proposed by an International Consortium under the responsibility of the Principal Investigator, Ester Antonucci, INAF-Osservatorio Astrofisico di Torino. The Experiment Manager of the Metis project is Giampiero Naletto, University of Padua. The Metis Experiment Scientist is Silvano Fineschi, INAF-Osservatorio Astrofisico di Torino, and the Instrument Scientist is Marco Romoli of the University of Florence. The Metis project is supported by the Italian Space Agency (ASI) as Leading Funding Agency.
The consortium is formed by the following Italian institutions:
Istituto Nazionale di Astrofisica (INAF),
Universities of Florence, Padua, and Politecnico of Turin,
Consiglio Nazionale delle Ricerche (CNR) Institute for Photonics and Nanotechnology, Padova, Italy,
and the following foreign institutions:
Astronomical Institute of the Academy of Sciences, Czech Republic,
Max-Planck-Institut für Sonnensystemforschung (MPS), Goettingen, Germany,
Laboratoire d'Astrophysique de Marseille (LAM), France (during phase B), and
Naval Research Laboratory (NRL), USA.

Scientific collaboration is provided by the following institutes:
Universities of Calabria, Catania, L'Aquila, Palermo, Perugia, Rome II, Urbino, Institute d'Astrophysique Spatiale (IAS), France, Jet Propulsion Laboratory, US, Mullard Space Science Laboratory, UK, Royal Observatory of Belgium, Bruxelles, Belgium, University of Athens, Greece, University of Michigan, US, and University of St. Andrews UK.

INAF is the leading scientific institute and ASI is the leading national space agency funding the Metis project.
In the tables hereafter, the Metis key personnel are listed.

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Table 1. Key Metis personnel list.

Other key personnel, the relative responsibility, consortium organization, and detailed list of Co-I's and Associate Scientists can be found in the Metis – Science Team Management Plan [AD-4].

Metis will be realized by a "Temporary Enterprise Association" (ATI), which involves the following companies:

OHB, Compagnia Generale per lo Spazio, Via Gallarate 150, Milano, Italy
Thales Alenia Space Italia, Strada Antica di Collegno, 253 – 10146 Torino TO, Italy

The ATI Management Plan can be found in [AD-5].

Mirrors and detector assemblies contributions to Metis are provided by:

- Toptec, Sobotecka 1660, Turnov 51101, Czech Republic
- Max Planck Institut fuer Sonnensystemforschung – MPS – Goettingen - Germany

respectively.