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VIGIL MISSION

NASA INSTRUMENT OF OPPORTUNITY (NIO) INTERFACE REQUIREMENTS DOCUMENT

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APPROVAL

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CHANGE LOG

Reason for change	Issue Nr	Revision Number	Date
First issue	1	0	12/10/2022
Document updated: - to implement the comments received from NASA; - include direct references to the Airbus UK documents specifying the interfaces to the Vigil platform.	1	1	19/04/2023

CHANGE RECORD

Issue Number 1	Revision Number 0		
Reason for change	Date	Pages	Paragraph(s)
First issue	12/10/2022	All	All

Issue Number 1	Revision Number 1		
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Various editorial and format changes.	19/04/2023	All	All

Issue Number	1	Revision Number	1	
List if applicable, reference and normative documentation updated.		19/04/2023	7-9	s.2 and sub sections.
Typo: "The NIO will be accommodated outside the Spacecraft structure on the $-X_{MRF}$ panel", instead of "+X".		21	s.4	
Figure 3 replaced by a simplified diagram.		21	s.4	
Requirement VGL-NIO-IF-0005: created.		21	s.4	
Requirement VGL-NIO-IF-0020.c modified to include the STM to the model list.		22	s.4	
Requirement VGL-NIO-IF-0030, Note 1: typo about the referenced ECSS [VGL-ND-062] instead of [VGL-ND-04].		22	s.4	
Requirement VGL-NIO-IF-0040 updated to include reference to [ADS-05] and [ADS-06].		22	s.4	
Introduction paragraph added.		23	s.4.1	
Requirement VGL-NIO-IF-0060: modified; the requirement is made more generic.		25	s.4.1.2	
Figure 5 caption updated.		25	s.4.1.2	
Requirement VGL-NIO-IF-0220: Note 1 updated.		28	s.4.4	
Requirement VGL-NIO-IF-0265: Created.		29	s.4.5	
Requirement VGL-NIO-IF-0315: Created.		30	s.4.7	
Requirement VGL-NIO-IF-0335: Created.		32	s.4.7	
Introduction to s.4.8 created with the definition of nominal attitude for Vigil		32	s.4.8	
Requirement VGL-NIO-IF-0359: Created		32	s.4.8	

Issue Number	1	Revision Number	1
Requirement VGL-NIO-IF-0360: Note 2 added.		32	s.4.8
Requirement VGL-NIO-IF-0395: Created.		33	s.4.10
Section 4.12 created.		34	s.4.12

DISTRIBUTION

Name/Organisational Unit
Airbus Defence and Space (ADS), United Kingdom
National Aeronautics and Space Administration (NASA), Unites States

Table of Contents

1. INTRODUCTION

This document establishes a preliminary identification and requirements for the interfaces for the NASA Instrument of Opportunity that is expected to be accommodated on the Vigil Spacecraft.

In the course of the Vigil Spacecraft Design and Development (aka Phase B2), this document will be replaced by a more detailed Hosted Payload Requirement Document (or equivalent) to be established and maintained by the Vigil Space Segment Prime Contractor.

1.1. Mission Description

The Vigil Mission will position a spacecraft at the 5th Sun-Earth Lagrangian point (SEL5) with the objective to perform continuous observations of the Sun and the space between the Earth and the Sun to provide measurement data for space weather nowcasting and forecasting and for event-based warnings and alerts when solar events take place. The observations from SEL5 will enable more accurate space weather impact predictions and early warnings of potentially hazardous solar weather conditions emerging.

The field of view from SEL5 allows monitoring of the onset of Coronal Mass Ejections (CMEs) with a coronagraph from a different angle than coronagraphy from the Sun-Earth line. Vigil mission will also be able to monitor the entire space between Sun and Earth with a heliospheric imager allowing mid-course tracking of solar wind features including CMEs as they travel towards Earth. Magnetograph observations from SEL5 will provide fresh solar magnetic field data for numerical solar wind models used in CME propagation estimation and enable more precise predictions of the CME arrival times on Earth. Magnetograph data is also expected to improve the solar flare and CME onset forecasting accuracy.

In-situ measurements in SEL5 will allow monitoring of high-speed solar wind streams several days in advance before they rotate towards the Earth.

Vigil mission will demonstrate the benefits from space weather observations away from the Sun-Earth line for operational applications. The mission is required to carry out observations at all times including severe space weather events and to provide data about the current space weather conditions to the users continuously and with low latency.

1.2. Document Overview

This document is divided into chapters and sections as per Table of Content.

To ease traceability and verify compliance, all requirements have been assigned a unique identifier, formatted as follow:

VGL-NIO-IF-0000Requirement main clause/description.

a. Level 1 sub-clause.

   i. Level 2 sub-clause.

Note 1: Additional information for the interpretation of the requirement.

2. DOCUMENTATION

The complete list of applicable, normative and reference documents with their identifiers can be found in the Document Baseline List (DBL) VGL-LI-ESA-SS-0006 [VGL-AD-11].

If during the implementation of his work the Contractor should encounter conflicting, incomplete, missing or ambiguous requirements or information among the documents, He shall refer these to the Agency for formal resolution or clarification.

2.1. Applicable Documents

The following applicable documents belong the Vigil Space Segment document baseline:

ID	Reference	Title	Issue
VGL-AD-04	VGL-RS-ESA-PAS-0003	PA & Safety Requirements Document (PARD)	2.0
VGL-AD-06	VGL-RS-ESA-SC-0019	Tailoring and Verification Items for ECSS Engineering Standards (EETD)	1.0
VGL-AD-10	VGL-LI-ESA-SYS-0013	Terms, Definitions and Abbreviations (TDA)	1.0
VGL-AD-17	VGL-RS-ESA-SC-0008	Mission Environmental Specifications (MES)	1.0
VGL-RD-48	VGL-LI-ESA-INS-0017	Vigil Instrument Deliverable Documents List	1.0
VGL-ND-062	ECSS-E-ST-10-02C Rev.1	Verification	
VGL-ND-066	ECSS-E-ST-10-09C	Reference coordinate system	
VGL-ND-112	ECSS-E-ST-70-41C	Telemetry and telecommand packet utilization	
VGL-ND-097	ECSS-E-ST-50-12C Rev.1	SpaceWire – Links, nodes, routers and networks	
VGL-ND-100	ECSS-E-ST-50-51C	SpaceWire protocol identification	
VGL-ND-102	ECSS-E-ST-50-53C	SpaceWire – CCSDS packet transfer protocol	
VGL-ND-103	ECSS-E-ST-60-10C	Control performance	

In addition the following documents shall be considered as applicable:

ID	Reference	Title	Issue
[ADS-01]	LGL5-SC-ADSS-SP-1000941696	Payload General Design and Interface Requirements Tailoring	4
[ADS-02]	LGL5-SC-ADSS-SP-1000882707	Payload Requirements Document	7 draft
[ADS-03]	LGL5-SC-ADSS-TN-1000494493	Spacecraft and Subsystem Reference Coordinate Frame	5

ID	Reference	Title	Issue
[ADS-04]	LGL5-SC-ADSS-SP-1000628580	Finite Element Model Requirement Specification	3
[ASD-05]	LGL5-SC-ADSS-TN-1000533186	Instrument Mechanical Environmental Loads	6
[ADS-06]	LGL5-SC-ADSS-TN-1000704775	Instrument Thermal Environment Document	3
[ADS-07]	LGL5-SC-ADSS-SP-1000503731	Cleanliness Requirement Document (CRS)	4
[ADS-08]	LGL5-SC-ADSS-SP-1000950357	Payload Harness Requirement Specification	1
[ADS-09]	LGL5-SC-ADSS-SP-1000871277	SpaceWire Protocol Specification	3
[ADS-10]	ADS.E.1050	MICD specifications & CAD data exchange requirements	4
[ADS-11]	ADS.E.1158	Interface Thermal and Geometrical Model Spec	2
[ADS-12]	SPS_MSC-SP-1000191225	Airbus Packet Utilization Standard Interface Requirements Document Volume A	4
[ADS-13]	ASTN-SP-ADSF-1000843521	Astrobus Packet Utilization Standard Interface Requirements Document Volume B1 – Platform Configuration Tables	3
[ADS-14]	ADSS-SP-1000997258	Packet Utilization Standard IRD Volume B2	1

Note 1: The documents prepared by Airbus Defence and Space (ref [ADS-##]) defining the interfaces on at spacecraft level will be replaced by the latest versions after the kick-off of the Phase B2 of the development of the Vigil spacecraft.

2.2. Reference Documents

ID	Reference	Title	Issue
VGL-AD-05	VGL-RS-ESA-SC-0004	Space Segment Requirements Document (SSRD)	1.0
VGL-AD-03	VGL-TN-ESA-SYS-0015	Mission Architecture And Operations Concept	1.0
VGL-RD-17	ESSB-HB-E-003	ESA pointing error engineering handbook	1.0

2.3. Standards and Regulations

The normative documents include design, manufacturing, quality and verification standards that provide normative requirements to the execution of the work. The Normative Documents include the ECSS standards (2020 release) as well as standards established by other bodies (e.g. CCSDS, ESCC, ISO, MilBus, etc.).

In case of conflict between any of the Vigil Applicable Document and the Normative Documents the conflict shall be brought to the attention of the Agency for resolution.

- To download ECSS Standards, Handbooks, Technical Memoranda and the list of all ECSS DRDs refer to the internet address:

  www.ecss.nl

- To download CCSDS documents, refer to the internet address:

  www.ccsds.org

- To download documents in the area of EEE components specifications refer to the European Space Components Information Exchange System (ESCIES):

  https://escies.org

The tailoring of the product assurance and engineering normative documents is presented in [VGL-AD-04] and [VGL-AD-06] respectively.

3. GENERAL DESCRIPTION AND REQUIREMENTS

3.1. Mission Architecture

The main architectural elements of the Vigil Mission system, as depicted in Figure 1, are:

- The Space Segment, consisting of a single Spacecraft orbiting around the Sun-Earth Lagrangian point 5 (SEL5), 3-axis stabilised with respect to the Sun direction.
- The Spacecraft consists of a Platform carrying a Payload Suite comprising of:
  - 3 remote instruments: Compact Coronagraph (CCOR), Heliographic Imager (HI), Photo-Magnetospheric field Imager (PMI).
  - 2 in-situ instruments: plasma analyser (PLA), magnetometer (V-MAG).
  - 1 NASA instrument of opportunity (NIO).
- The Ground Segment, consisting of:
  - Mission Operation Centre (MOC) located in ESOC responsible for Spacecraft commanding, Spacecraft health monitoring, orbit control and on-board software configuration and maintenance.
  - The Payload Data Centre (PDC) located in ESOC responsible for mission data acquisition, processing, archiving and distribution to the customer/users, as well as mission planning.
  - Ground Station Network (GSN). The GSN shall be made up of a mix of ESA ESTRACK stations and commercial stations as Vigil has a specific need to maintain a 24/7 downlink capability, including over the pacific where there is a gap in ESTRACK coverage, therefore third party stations will be required. The typical station to be utilised is defined in the Vigil Space to Ground ICD Vol.1 [VGL-AD-22].
- The Launcher Service, to be procured by the Agency, baselined as Ariane 6, with Falcon 9 as back-up, in dual-launch configuration for injection in GTO.

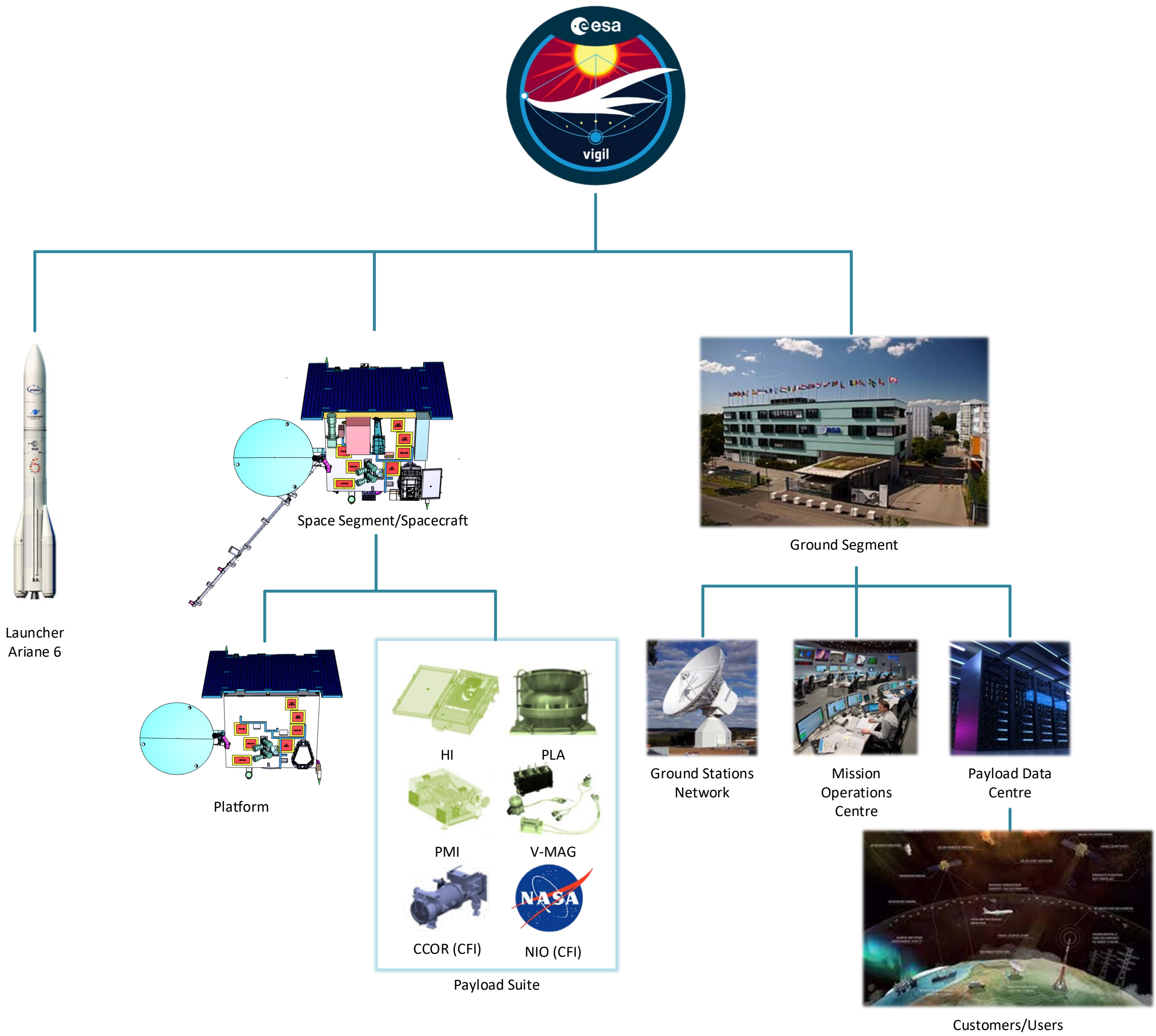

Figure 1:Vigil Mission Architecture

3.2. Mission Objectives

The Vigil mission will perform continuous observations to provide low latency data on the current space weather conditions to the user community. Being an operational mission, Vigil targets an availability of the service above 97%, with a chance of less than 1% of a temporary interruption during the most extreme Space Weather Event observed in the last 100 years (e.g. Carrington Event).

The observations from L5 will enable more accurate space weather impact predictions and early warnings of potentially hazardous solar weather conditions. Vigil mission objectives can be grouped in two main categories:

- Nowcasting with the aim to provide an early warning about solar flares and the onset of a Coronal Mass Ejections (CMEs) using a coronagraph, a heliospheric imager and a magnetograph observing the Sun from a different angle than from the Sun-Earth line (e.g. L1 mission). Thanks to the side view from L5, the Vigil mission will also be able improve the accuracy of the predicted arrival CME arrival time on Earth by 2 to 4 hours compared to the current capabilities; this will be achieved by monitoring the space between Sun and Earth with a heliospheric imager allowing mid-course tracking of CME and in general solar wind features as they travel towards Earth.
- Forecasting up to 4 to 5 days of the developing solar activity thanks to the monitoring of active region development beyond the East limb not visible from Earth. In-situ measurements in L5 will allow monitoring of high-speed solar wind streams and magnetic field several days in advance before they reach the Earth, allowing, for instance, to forecast the events that might provoke the charging of geostationary Spacecrafts.

3.3. Spacecraft Mission Phases and Operations

The baseline mission timeline and the required phases set, from Pre-Launch phase to routine operation, for the Vigil mission are shown in Figure 2. The figure is a schematic drawing and does not show the specifics such as transfer trajectories and different Ground Stations necessary for the required coverage.

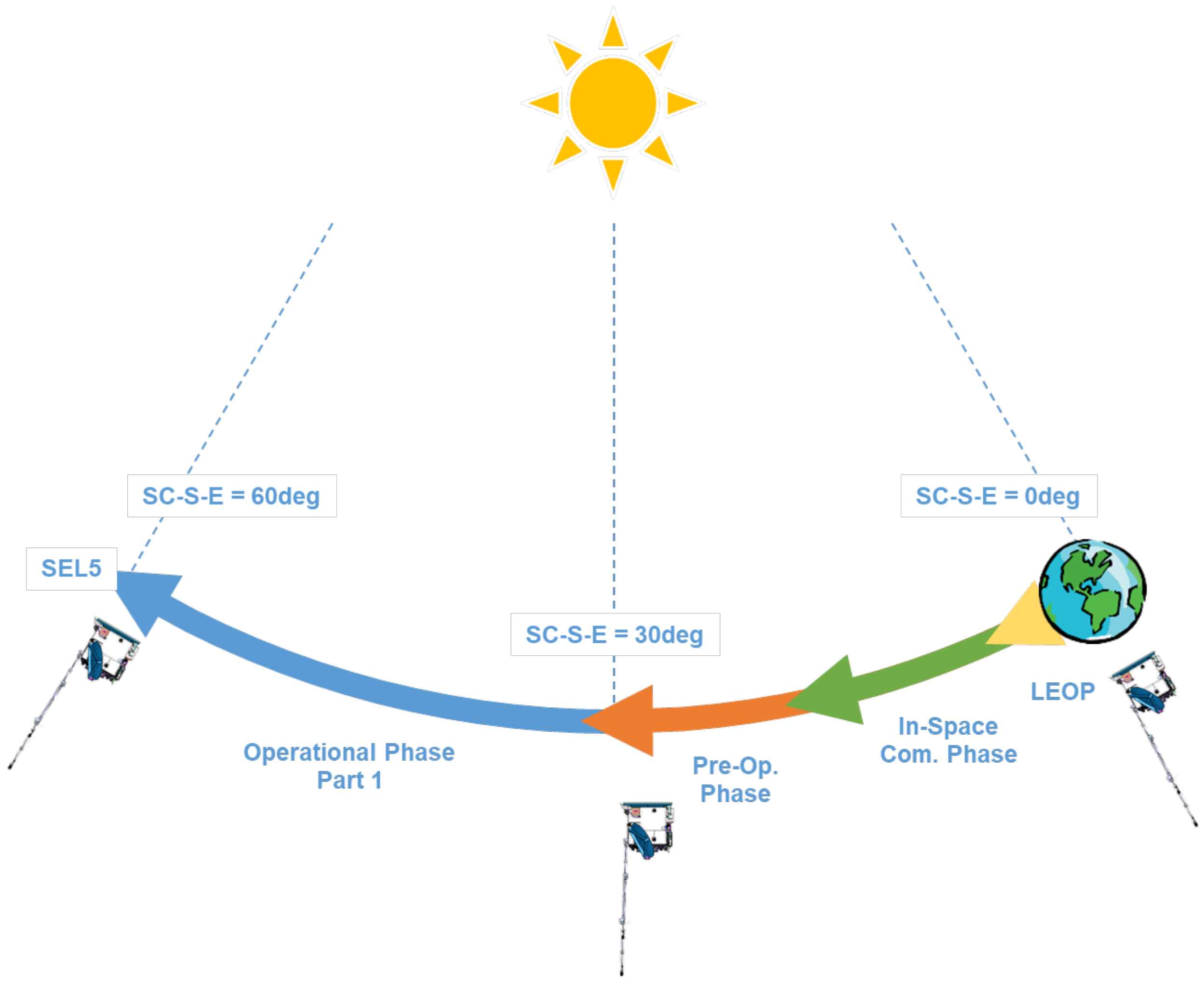

Figure 2: Outline of the mission timeline.

The duration of each phase depends on the selected strategy to reach SEL5; currently two approached are considered: via GTO (baseline) by direct injection.

3.3.1. Pre-Launch

The Pre-Launch phase starts from the integration of the Spacecraft on the Launcher to the start of power provision from spacecraft internal battery.

The Pre-Launch phase includes:

- Final check-out of the Spacecraft in the pre-launch mode,

- Dress Rehearsal tests between the Spacecraft and the launch site,
- Verification of the Count-Down and Go/No-Go procedures

3.3.2. Launch and Early Orbit Phase (LEOP)

The Launch and Early Orbit Phase (LEOP) starting at the switchover from ground-supplied power to the Spacecraft internal batteries is considered completed when Spacecraft has achieved its intended attitude and it is ready to execute the first Apogee Raising Manoeuvre (ARM).

The nominal LEOP duration is 3 days include the following events (not necessarily in this order):

- Internally powered phase during the count-down;
- Launch phase, from the lift-off until separation of the Spacecraft from the launcher
- Acquisition phase, including but not limited to:
    - Establishing the post-separation configuration (e.g. enabling the reaction control system);
    - Attitude rate reduction, initial attitude acquisition;
    - Solar array deployment and rotation start (if applicable);
    - Instrument and other appendage deployments (possibly excluding some specific instrument deployments to be performed later);
    - Delivery of power from the solar array.
- Switch-ON phase, during which communication is established the Ground Segment, and the spacecraft services are brought into operation.

3.3.3. Transfer Phase

The Transfer phase begins at the end of the LEOP with the first burn for escaping the Earth orbit and ends once the Spacecraft reaches SEL5 orbit.

The Transfer Phase duration and sequence of activities vary significantly depending on the launch scenario (e.g. GTO, direct injection).

The Transfer Phase overlaps with the In-Space Commissioning Phase (ISCP), the Pre-Operational Phase (Pre-OP) and the Operational Phase (OP) until reaching SEL5.

3.3.4. In-Space Commissioning Phase (ISCP)

During the In-Space Commissioning Phase the overall Spacecraft, including the Platform and Instrument, will be brought into a fully operational state. Relevant adjustments may be made to the Instrument operational parameters or software to optimise performance. During the Commissioning Phase the end-to-end measurements of the Vigil system will be calibrated and validated such that the performances and measurement quality are known and controlled. The necessary manoeuvres to acquire the operational orbit shall also be performed during ISCP.

The In-Space Commissioning Phase, can divided into 2 major sub-phases as follows:

<u>Spacecraft In-Space Verification (SIOV) Sub-phase</u>

During this phase the Instruments are brought into initial operation. Any deployments remaining after the LEOP are also performed during this phase.

During SIOV, payload data reception ground stations (X-band) are verified and commissioned in terms of RF links and data stream acquisition.

Specific SIOV activities will include:

- Spacecraft functional checkout, in which overall Spacecraft basic functions and health are verified;
- verification of Instrument data generation and handling;
- verification of Instrument measurements;
- characterisation of Instruments performances;
- setting of Platform and Instruments parameters;
- implementation of on-board operations.

<u>Calibration and Validation (Cal/Val) Sub-phase</u>

After completion of the SIOV phase, the Spacecraft, including Platform and Instrument will be functioning nominally and the measurement data being generated can be used for Cal/Val activities. Specific Cal/Val activities will include:

- implementation of nominal Spacecraft operations;
- optimisation of instrument operating parameters;
- calibration of the instrument (including dedicated attitude manoeuvres);
- validation of mission data products;
- validation of end-to-end system functionalities and performances.

The end of this phase is marked by the In-Space Commissioning Review and conclude the Phase E1 of the Space Segment.

3.3.5. Pre-Operational Phase (Pre-OP)

Between the end of the In-Space Orbit Commissioning and the start of the Operational Phase, all instruments of the Payload suite can be put into function for collecting data in advance to their nominal use.

This phase is not considered as operational, since it cannot be guaranteed that all mission performances could be met. For instance, with respect to availability, observations would have to be periodically interrupted to allow the data link of the data after re-pointing of the Spacecraft main antenna.

3.3.6. Operational Phase (OP)

During the Operational Phase the Spacecraft and the Payload Suite shall operate at their nominal performance.

The Operational Phase can be divided in two sub-phases:

- Part 1: starting before reaching SEL when the Spacecraft has reached a 30 degrees separation from Earth with respect to the Sun (goal) or as soon as all Vigil instruments can be operated at nominal performances and the data latency requirements can be met. The only admissible interruptions to the service are the those for the necessary trajectory adjustment for the final injection around SEL5 except in case of trajectory correction manoeuvres.

Table 1: Mission parameters Operation Phase part 1.

Orbital Parameter		**Variation during transfer: 30 degrees Earth separation to L5 (3 revolution baseline)**
Earth Range	Minimum (at 30 deg. separation)	75 Mkm
	Maximum	154 Mkm
Sun Range	Minimum	148 Mkm
	Maximum	162 Mkm
Declination relative to the ecliptic		$\pm$0.5 degrees
Z_{SC} axis rotation (yaw)		$\pm$0.9 degrees

- Part 2: starting from the final injection in the operational orbit around SEL5 until the end of the mission.

Table 2: Mission parameters Operation Phase part 2

Orbital Parameter		**Variation in orbit around L5**
Earth Range	Minimum	146 Mkm
	Maximum	154 Mkm
Sun Range	Minimum	146 Mkm
	Maximum	154 Mkm
Sun-SC-Earth angle		60 $\pm$ 0.3 degrees
Earth-Sun-EC angle		60 $\pm$ 0.5 degrees
Declination relative to the ecliptic		$\pm$0.5 degrees
Z_{SC} axis rotation (yaw)		$\pm$0.3 degrees

3.3.7. Disposal Phase

At the end of the mission, the Spacecraft should release the SEL5 orbit by performing a disposal manoeuvre such that the resulting orbital evolution does also not lead to interference with known operational Spacecrafts orbiting around the Earth in the foreseeable future.

3.4. Spacecraft Operational Modes

The Vigil spacecraft will be able to support at least the following operational modes:

1) Pre-Launch Modes for configuration of the spacecraft for launch and ground testing;
2) Launch and Early Operations (LEOP) Mode
3) Nominal Model
4) Trajectory/Orbit Control Mode
5) Safe Mode
6) Survival Mode

For more information about of the Vigil Operational Modes refer to Vigil SSRD [VGL-AD-05].

3.5. Spacecraft Attitude Determination and Control

During nominal operations the Vigil Spacecraft will be 3-axis stabilised with the solar array directly facing the Sun and the High Gain Antenna pointed toward Earth. Deviations from the nominal attitude could occur during trajectory corrections, orbit maintenance and the instruments calibration.

In case of a major failure leading to a Survival Mode, the spacecraft attitude will be spin-stabilised around the Sun direction stabilised with the solar array directly facing the Sun.

3.6. Lifetime, Reliability & Availability

3.6.1. Lifetime

The Spacecraft will have a nominal in-space lifetime longer than 7.5 years with the possibility of a 5-year extension.

3.6.2. Reliability

The Spacecraft and all the instruments will be designed, manufactured and qualified to provide an in-space operational reliability of each chain (instrument + platform) larger than 80% at the end of the nominal lifetime.

3.6.3. Availability

The Spacecraft and all the instruments will be designed, manufactured and qualified to provide an in-space operational availability of each chain (instrument + platform) larger than 98% on a monthly basis, including any outage (planned and unplanned) over the nominal operational lifetime, excluding permanent instrument or platform failure and excluding the occurrence of a 1-in-100-years Space Weather Event as defined in [VGL-AD-17].

The Spacecraft and all the instruments will be designed, manufactured and qualified to provide an in-space operational availability of each chain (instrument + platform) larger than 96% in case of a 1-in-100-years Space Weather Event lasting up to 1 week during the nominal in-space operational lifetime, excluding permanent Instrument or Platform failure.

In case of a 1-in-100-years Space Weather Event lasting up to 1 week during the nominal in-space operational lifetime, the probability for the Spacecraft to enter into a mode/state requiring MOC intervention to resume nominal observations shall be less than 1%.

4. REQUIREMENTS

The NIO will be accommodated outside the Spacecraft structure on the -X_{MRF} panel together with the optical instruments of the Vigil mission (Compact Coronagraph, Photospheric Magnetic field Imager, and Heliospheric Imager).

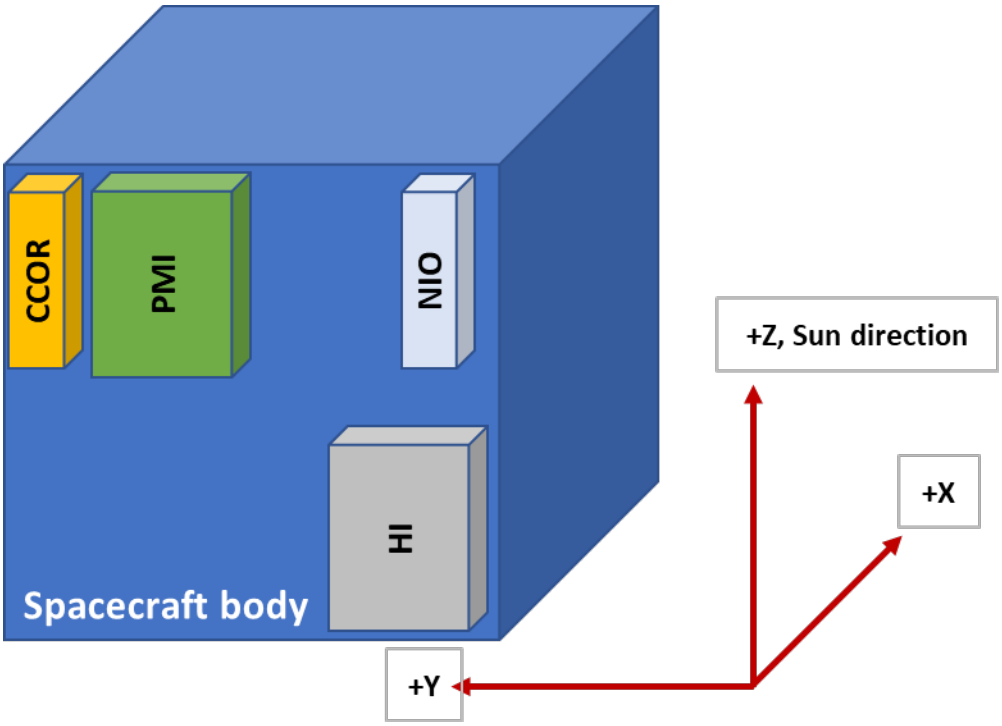

Figure 3: Schematics of the Vigil spacecraft layout showing the location of NIO.

All resource requirements (e.g. mass, power, data rate, etc.) shall be assumed as current best estimates plus sufficient equipment design maturity margin. No additional margin may be expected. It is assumed that the instrument will be provided with its Control and Data Processing Unit (CDPU).

VGL-NIO-IF-0005

The Instrument shall be designed in accordance to [ADS-01].

VGL-NIO-IF-0010

The Instrument shall use in all drawings, specifications and engineering data the International System of Unit (SI), extended to the officially accepted Non-SI units.

VGL-NIO-IF-0020

The instrument shall unambiguously identify each item of delivered hardware by a Unit Identification Code composed as follows:

a. identifier for the instrument (e.g. NIO),

b. identifier for the unit identification, (e.g. Digital Processing Unit, DPU, Optics unit, OU),

c. identifier for the model identification (e.g. STM for Structural Thermal Model, EM for Engineering Model, QM for Qualification Model, FM for Flight Model, FS for Flight Spare Model, PFM for Proto-flight Model).

VGL-NIO-IF-0030

The instrument shall apply the following maturity margins (beyond the sum of the engineering best estimate) for mass and electrical power consumption and thermal power dissipation:

a. 30% for harness mass and harness electrical losses;

b. 20% for new units/equipment design;

c. 10% for modified units/equipment (ECSS Category C) or units/equipment/harness passed PDR;

d. 5% for recurrent units/equipment (ECSS Category A/B) or units/equipment/harness passed QR/CDR;

Note 1: For the definition of the ECSS Qualification Status Category refer to Table 7-1 in [VGL-ND-062].

VGL-NIO-IF-0040

The instrument hardware shall survive under the worst feasible combination of mechanical and thermal loads for the complete lifetime of the Spacecraft, as specified in the environmental requirements [ADS-05] and in [ADS-06].

Note 1: The complete lifetime includes manufacturing, assembly, testing, transport, launch and in-space operations.

VGL-NIO-IF-0050

The instruments operate nominally under the following assumptions, unless otherwise specified:

a. after in-space commissioning and calibration;

b. end of the 7.5 years nominal operational lifetime conditions;

c. with a confidence level of 99.7%;

d. during a 1-in-100-years Space Weather Event as defined in [VGL-AD-17].

4.1. Reference Frames

The following definitions and requirements for the reference frames are in accordance with [ADS-03].

The diagrams in this document as the referenced ones label the axes of the reference frames either as +/-X, Y, Z or P/M X, Y, Z.

4.1.1. Spacecraft Mechanical Reference Frame (MRF)

The Spacecraft Mechanical Reference Frame REF_{MRF} = {O_{MRF}; X_{MRF}, Y_{MRF}, Z_{MRF}} is a right-handed orthogonal body-fixed system of axes which defines the design of the spacecraft:

a. The origin O_{MRF} of the REF_{MRF} reference frame is located at the centre of the launch vehicle interface ring, located in the spacecraft/launcher separation plane at the bottom of the Spacecraft (interface with Launcher);

b. Z_{MRF}: perpendicular to the spacecraft/launcher separation plane, +Z away from the launcher interface towards the Spacecraft top floor;

c. Y_{MRF}: parallel to the Spacecraft/launcher separation plane, +Y towards the panel on which the High Gain Antenna is stowed;

d. X_{MRF}: parallel to the Spacecraft/launcher separation plane completing the orthonormal right-handed reference frame, +X towards the panel on which the in-situ instruments are accommodated.

This reference frame is used for geometrical configuration, design drawings and dimensions. The Spacecraft mechanical reference frame is shown in the following figure.

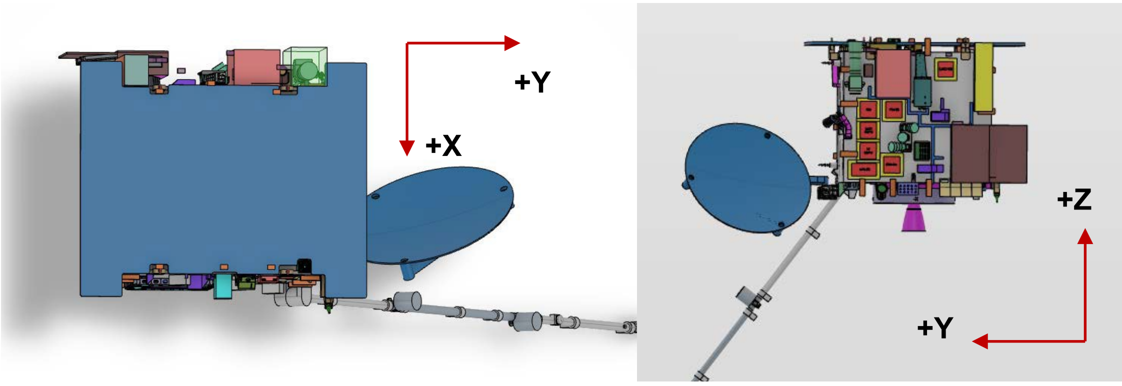

Figure 4: Spacecraft Mechanical Reference Frame

4.1.2. Instrument Reference Frame

VGL-NIO-IF-0060

The Instrument supplier shall define the Instrument Reference Frame REF_{IRF}= {O_{IRF}; X_{IRF}, Y_{IRF}, Z_{IRF}} as body-fixed, orthogonal, right-handed.

Note 1: According to the guidelines in [ADS-03] the preferred definition should have:

a. Origin O_{IRF} of the REF_{IRF} is located in the centre of a reference position on the interface plane, preferably in correspondence of one the mounting holes and clearly identified in the interface drawings;

b. X_{IRF} shall be parallel to (and preferably oriented like) X_{MRF};

c. Y_{IRF} shall be parallel to (and preferably oriented like) Y_{MRF};

d. Z_{IRF} shall be parallel to and oriented like Z_{MRF};

For an instrument like NIO to be mounted on the -X_{MRF} the following is expected

X_{IRF} // -X_{MRF}

Y_{IRF} // -Y_{MRF}

Z_{IRF} // Z_{MRF}

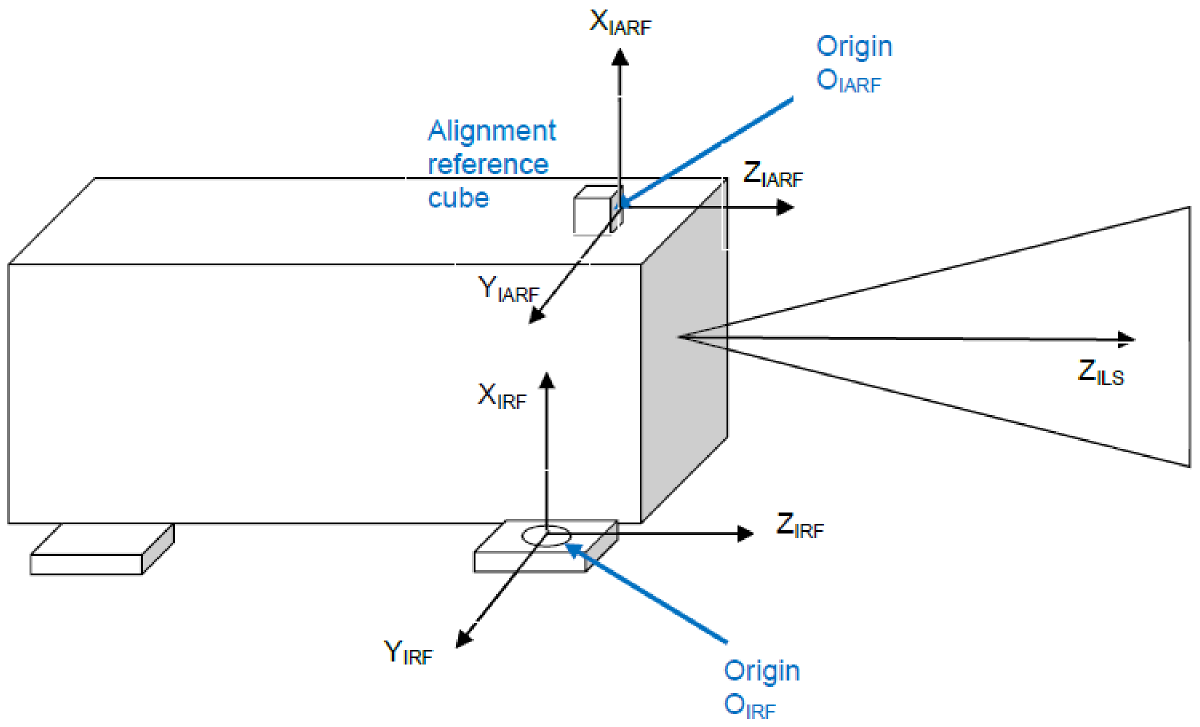

Figure 5: Instrument Reference Frame, Instrument Alignment Reference Frame and LOS direction (Z_{ILS}) for a generic unit or equipment.

VGL-NIO-IF-0070

Any additional reference frame shall be uniquely and unambiguously defined with respect to the Instrument Reference Frame.

Note 1: For the normative requirements concerning the definition of reference frames, refer to ECSS-E-ST-10-09C [VGL-ND-066].

VGL-NIO-IF-0080

The Instrument physical properties (e.g. dimensions, CoG, MoI) shall be defined using the Instrument Reference Frame.

VGL-NIO-IF-0090

The Instrument Alignment Reference Frame REF_{IARF}= {O_{IARF}; X_{IARF}, Y_{IARF}, Z_{IARF}} shall be instrument body-fixed, orthogonal, right-handed and defined by:

a. Origin O_{IARF} of the REF_{IARF} is located in the centre of the Instrument Alignment Reference Cube face.

b. X_{IARF} shall be parallel to and oriented like X_{IRF};

c. Y_{IARF} shall be parallel to and oriented like Y_{IRF};

d. Z_{IARF} shall be parallel to and oriented like Z_{IRF}.

Note 1: Exceptions to be agreed by the Agency

VGL-NIO-IF-0100

The Instrument Alignment Reference Frames shall be used for alignment measurements with respect to the platform and the other instruments:

VGL-NIO-IF-0110

The Instrument supplier shall define the Instrument Line-Of-Sight Reference Frames (ILS).

Note 1: Typically the origin is placed at the centre of the detector, the Z-axis of the such frame is chosen parallel to the boresight axis, the X- and Y-axis are parallel to the plane of the detector.

4.2. Physical Envelope

VGL-NIO-IF-0120

The instrument shall have dimensions of less than 330 mm (X) x 260 mm (Y) x 1000 mm (Z).

Note 1: If a separate volume is required for the CDPU (e.g. inside the Spacecraft and close to the instrument) this shall be proposed by the instrument supplier for verification and approval by Spacecraft Prime.

VGL-NIO-IF-0130

The instrument shall have a footprint of less than 860 mm (Z) x 260 mm (Y).

Note 1: The top (+Z) 140 mm of the instrument allowable volume shall not be used for the mechanical interfacing. This accounts for the space available for the mounting of the instrument on the Spacecraft panel (see Figure 2 – left).

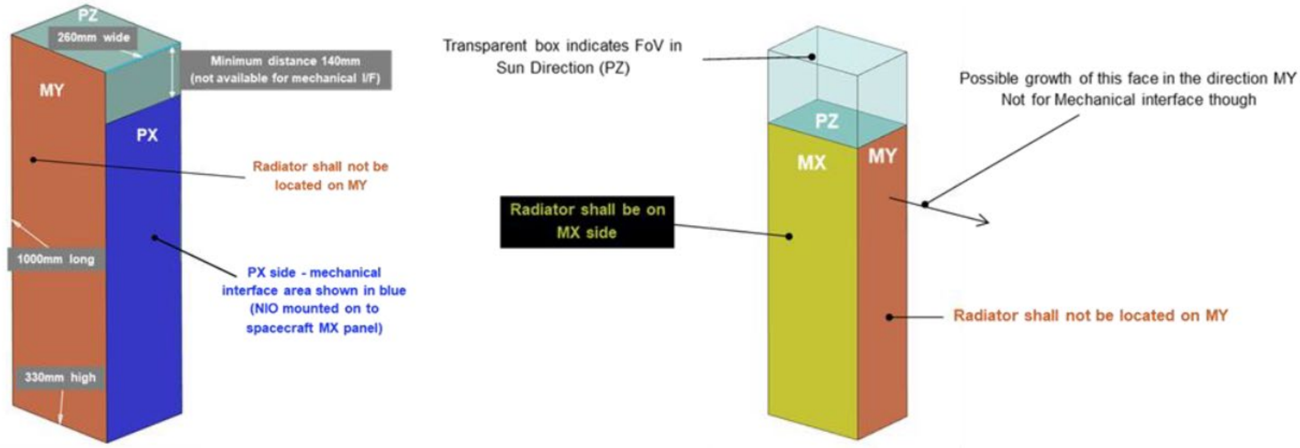

Figure 6: Outline of the accommodation specifics of the NIO instrument (left: Dimensions, right: Field of view indication, radiator location and indication of grows potential).

4.3. Mass Properties

VGL-NIO-IF-0140

The instrument shall have a mass of less than 25 kg including harness, MLI blankets and the respective maturity margins.

Note 1: The instrument mass budget includes the CDPU and its harness to the instrument.

4.4. Thermal Control

VGL-NIO-IF-0150

When switched ON, the instrument shall ensure its own thermal control (e.g. autonomous regulation of the heaters) by using the power delivered by the Spacecraft power bus.

VGL-NIO-IF-0160

For non-operating modes, the instrument shall be compatible with the platform interface temperature, under the assumptions that the monitoring of the instrument survival temperature sensors is ensured by the platform.

VGL-NIO-IF-0170

The instrument shall be conductively and radiatively decoupled from the surrounding instruments and platform.

Note 1: The CDPU, if integrated inside the Spacecraft, would be thermally coupled.

VGL-NIO-IF-0180

The instrument shall implement sensors in order to allow temperature monitoring both in-space and on-ground.

VGL-NIO-IF-0190

The instrument shall allow each individual heater control loop to be enabled or disabled by the platform.

VGL-NIO-IF-0200

The instrument shall allow adjustment of the temperature control thresholds of each individual heater control loop by the platform.

Note 1: This prohibits the use of thermostats for thermal control.

VGL-NIO-IF-0210

It shall be assumed that both survival heaters and decontamination heaters (if required) will be controlled by the platform.

VGL-NIO-IF-0220

The normal of the radiator shall be pointed towards the $–X_{MRF}$ axis.

Note 1: See Figure 2 (right) for illustration, where $-X_{MRF}$ is denoted at MX.

VGL-NIO-IF-0230

The view factor of the radiator may be assumed to be close to 2 π.

VGL-NIO-IF-0240

The field of view of the instrument is assumed to be not restricted.

4.5. Electrical Power Control

VGL-NIO-IF-0250

The instrument shall have a power consumption of less than 30 Watts including margin.

VGL-NIO-IF-0260

It shall be assumed that a regulated power line will be provided by the platform with voltages between 26.8 V and 28.2 V.

VGL-NIO-IF-0265

The Instrument harness shall be designed according to [ADS-08].

4.6. Data Handling

VGL-NIO-IF-0270

The data rate of downlinked observational and housekeeping data shall be less than 20 kbps including margin.

Note 1: The data volume generated is assumed without headers.

Note 2: In addition to these observational and housekeeping data forming the baseline measurements for operational space weather applications, it is intended to enable, bandwidth permitting, the transmission of additional measurement data without timeliness requirements.

VGL-NIO-IF-0280

The cadence of the data or images shall be less or equal to 5 minutes for one acquisition.

VGL-NIO-IF-0290

The instrument latency of the data shall be less of equal to 5 minutes.

Note 1: This corresponds to the time that is needed to acquire and process the data by the instrument. With this assumption it is expected that the data can be transferred to *ground within 30 minutes. Assumptions are to be confirmed and adjusted to the actual acquisition scheme.*

4.7. Functional Interface

VGL-NIO-IF-0300

The discrete interfaces shall be based on a typical cross strapping configuration to allow each instrument DC/DC converter to be switched ON and OFF from either nominal or redundant side of the Remote Interface Unit (RIU). The Standard High Power (SHP) ON and SHP OFF commands are separated: SHP: 4N (Nominal) + 4R (Redundant)

a. NIO DC/DC converter N: SHP On N, SHP On R, SHP Off N, SHP Off R

b. NIO DC/DC converter R: SHP On N, SHP On R, SHP Off N, SHP Off R

Note 1: If SHPs are needed for other functionalities (e.g. off-pointing warning signal) then these would be in addition to the 4N and 4R detailed above.

VGL-NIO-IF-0310

The Relay Status Acquisitions shall be monitored by the following interface lines: RSA: 1N + 1R

a. Status of NIO DC/DC converter N

b. Status of NIO DC/DC converter R

VGL-NIO-IF-0320

The instrument CDPU shall use the PUS-C standard [VGL-ND-112] for communication, data transfer and interfacing to the Spacecraft.

VGL-NIO-IF-0315

The implementation of PUC-C shall be done according to the tailoring provided in [ADS-12], [ADS-13], [ADS-14].

VGL-NIO-IF-0330

The data processing and compression shall be performed by the CDPU of the instrument.

VGL-NIO-IF-0340

All control functions other than survival heating and decontamination heating shall be performed by the CDPU of the instrument.

VGL-NIO-IF-0350

The bus interface of the instrument shall be based on the ESA SpaceWire standards ([VGL-ND-097], [VGL-ND-100], [VGL-ND-102]).

VGL-NIO-IF-355

The SpaceWire interface shall implemented according to [ADS-09].

4.8. In-Flight Attitude

During nominal operations the Vigil spacecraft will maintain a 3-axis stabilised attitude with the $+Z_{MRF}$ axis pointed toward the Sun.

In occasion of trajectory control manoeuvres, high-gain antenna pointing slews, instrument calibrations the spacecraft attitude will deviate from the nominal attitude typically in the following range: Azimuth angle = 0°, Elevation angle = 180° to 360°, where the reference vector is the Sun direction.

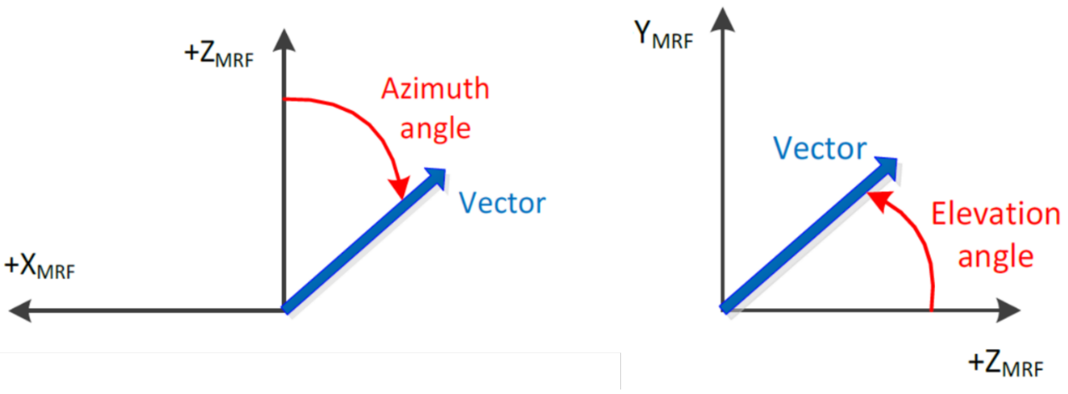

Figure 7: definition of Azimuth and Elevation.

It is left to the NIO Supplier to indicate any attitude constraint or the need to achieve a specific attitude for instance for calibration purposes

VGL-NIO-IF-0359

The Instrument shall survive without degradation of performance to deviation from the nominal spacecraft attitude in the following range: Azimuth angle = 0°, Elevation angle = 180° to 360°,

Note 1: during this events the instrument is expected to be non-operational.

VGL-NIO-IF-0360

The Instrument shall be compatible with the Vigil Spacecraft pointing performance given in Table 4.

Table 3: Vigil Spacecraft Pointing/Knowledge Performances

Performance Metrics	X/Y Component	Z Component	Remarks
Absolute Pointing Error (APE)	> 3 arcmin	> 30 arcmin	Temporal interpretation at 99.7% confidence level.
Absolute Knowledge Error (AKE) before calibration.	> 0.5 arcmin	> 5 arcmin	Temporal interpretation to 99.7% confidence level.
Absolute Knowledge Error (AKE) after calibration.	> 0.5 arcmin	> 5 arcmin	Mixed interpretation to 99.7% confidence level.
Relative Pointing Error (RPE)[1]	> 1.2 arcsec over 1.82 sec	> 12 arcsec over 1.82	Temporal interpretation to 99.7% confidence level.
Pointing Drift Error (PDE)	TBD	TBD	Temporal interpretation to 99.7% confidence level.
Knowledge Drift Error (KDE) after calibration	TBD	TBD	Mixed interpretation to 99.7% confidence level.

[1] This performance is indicative of the Platform capabilities; it will have to be reassessed based on the averaging and observation times stated by the Instrument Supplier.

Note 1: Refer to [VGL-ND-103] for the definitions of the Performance Metrics and the statistical interpretations (i.e. Temporal and Mixed).

Note 2: The allocations for the windowed error metrics (e.g. PDE, KDE) will be defined once the Instrument supplier has provided the respective end-to-end requirement.

4.9. Space Environment

VGL-NIO-IF-0370

The Instrument shall meet the performance requirements in the radiation environment as defined in [VGL-AD-17].

VGL-NIO-IF-0380

The Instrument shall meet the performance requirements in the plasma environment as specified in [VGL-AD-17].

VGL-NIO-IF-0390

The Instrument shall meet the performance requirements in the particulate environment as specified in [VGL-AD-17].

4.10. Contamination Control and Cleanliness

VGL-NIO-IF-0395

The instruments shall be compatible cleanliness and contamination requirements established in [ADS-07].

VGL-NIO-IF-0400

The instrument shall be compatible with use of a nitrogen purge gas with the properties given in Table 5 during spacecraft Assembly, Integration and Test.

Table 4: Purge Gas Properties

Gas Species Specification	Concentration
Hydrocarbons	< 1.1 ppm
Water	< 5 ppm
Oxygen	< 3ppm

VGL-NIO-IF-0410

If the instrument requires purging (e.g. due to cleanliness or storage) it shall integrate a 1/4" Swagelok tube male fitting into the instrument unit.

VGL-NIO-IF-0420

The instrument shall survive in an ISO 8 environment with a purge interruption of:

a. 1 hour (Covers / bags off);

b. 2 hours (Covers / bags on).

Note 1: For verification of this requirement, instrument teams are required to determine a maximum outage time they can tolerate without damage, with clear justification. Exceptions are to be agreed with the Spacecraft prime.

Note 2: No purge is available after launcher encapsulation, or Thermal Vacuum testing including pump down and re-pressurisation.

VGL-NIO-IF-0430

The instrument shall tolerate, without damage, pressure spikes of up to 0.03 bar/min at the instrument purge interface.

4.11. Electromagnetic Combability

One of the objectives of the Vigil mission is to characterize the intergalactic magnetic field using magnetometer.

VGL-NIO-IF-0440

the instrument magnetic moment shall be less than 100 mAm^2.

Note 1: The instrument design should limit the use soft magnetic alloys such as Invar and elements that will generate a magnetic moment.

4.12. Mathematical Models format for Exchange

4.12.1. CAD and FEM Models

VGL-NIO-IF-0450

The Instrument Geometric Mathematical CAD model shall comply with the requirements in [ADS-10].

VGL-NIO-IF-0460

The Instrument Finite Element Model (FEM), both detailed and condensed, shall comply with the requirements in [ADS-04]

4.12.2. Thermal Models

VGL-NIO-IF-0470

The Instrument Thermal and Geometrical Model shall comply with the requirements in [ADS-11].

Note 1: Model formats and level of detail are to be agreed with the Agency.