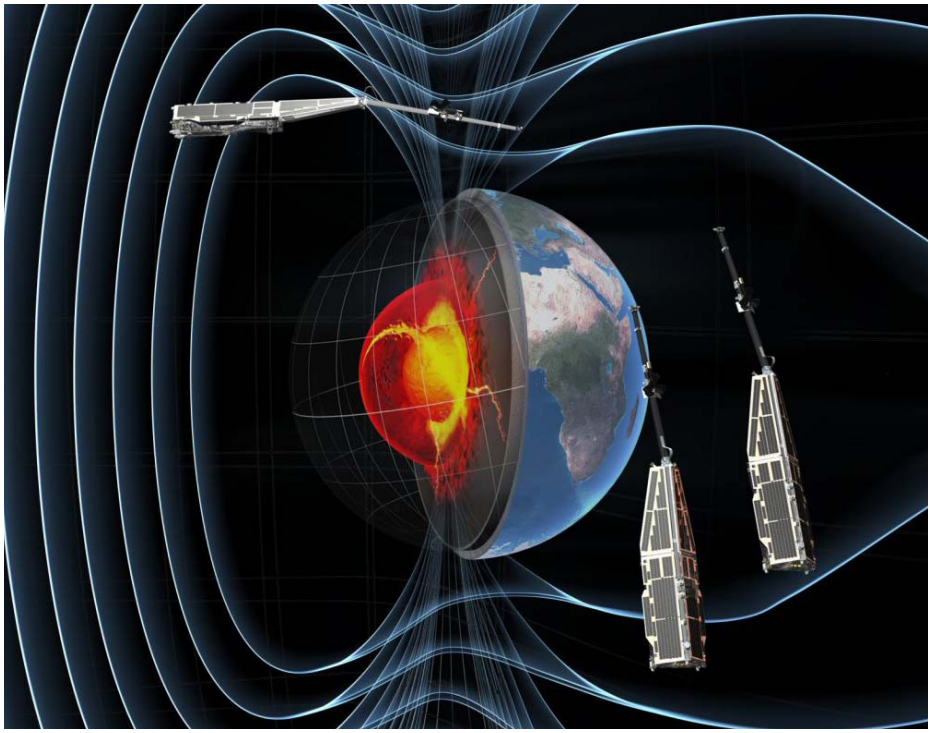
Swarm

Science and Validation Opportunity



DOCUMENT CHANGE RECORD

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TABLE OF CONTENTS

1. INTRODUCTION AND OVERALL OBJECTIVES

Swarm is the fifth Earth Explorer mission implemented by the European Space Agency as part of its Living Planet programme. The objective of the Swarm mission is to provide the best ever survey of the geomagnetic field and its temporal evolution, and gain new insights into improving our knowledge of the Earth's interior and climate.

The Swarm concept consists of a constellation of three satellites in three different polar orbits starting at approximately 490 and 530 km initial altitudes and naturally decaying thereafter. High-precision and high-resolution measurements of the strength, direction and variation of the magnetic field, complemented by precise navigation, accelerometer and electric field measurements will be provided by each satellite. In combination, they will provide the necessary observations that are required to model various sources of the geomagnetic field and to study the near-Earth current systems. The scientific focus of the mission is on:

- Studies of core dynamics, geodynamo processes, and core-mantle interaction,
- Mapping of the lithospheric magnetisation and its geological interpretation,
- Determination of the 3D electrical conductivity of the mantle,
- Identification of ocean circulation patterns by its magnetic signature
- Investigation of electric currents flowing in the magnetosphere and ionosphere,
- Quantification of the magnetic forcing of the upper atmosphere, including studies of thermosphere densities and winds.

The launch date is foreseen in mid 2012 with a planned operational lifetime of 48 months, after a 3-month commissioning phase.

1.1 Objectives of the Opportunity

In line with the European Space Agency's *free and open* data policy the present Swarm Science and Validation Opportunity is open to users of any category (scientific, operational, value-adding industries, etc.) worldwide. Two main objectives are addressed:

I. To engage expert groups in the **validation** of Level 1B data products.
II. To further develop the Swarm user community by announcing research opportunities using Level 1b and Level 2 data products from this new ESA mission.

Furthermore, information on the activities under preparation by the various user communities will allow the Agency to prepare for the operational phase and to size the expected demand for data products.

2. VALIDATION OF LEVEL 1B DATA PRODUCTS

2.1 Objectives

The European Space Agency solicits proposals aimed at the full validation of Swarm Level 1B data products.

Validation takes place at several levels. Validation at Level 1B includes the comparison of Swarm data with other data sets available, either from satellite measurements or from in-situ ground (e.g. observatory) measurements. This may be based on external data, but also on the comparison of the internal data coming from the Swarm satellites or by using the information provided by the constellation of three spacecraft. Data sets required for all validation purposes are to be assembled by the expert groups.

Results (data products and reports) from the validation task can be used to support further scientific data exploitation, and also as feedback to the key elements of the Swarm ground segment responsible for the overall data quality and performance monitoring. Discovery of certain anomalies in the validation results may lead to a re-calibration or re-processing, and thus constitutes a possible operational feedback to the mission.

The Agency seeks the interest of institutes, research groups and scientists familiar with using one or multiple Level 1B Swarm products derived from the satellites and having ideas / capabilities and experience in validating against other independent data. Validation approaches making use of two or all three Swarm satellites can also be proposed. The AO is open to groups and individuals worldwide.

Following approval of the proposed validation project by ESA, Principal Investigators (PIs) will be invited to become members of the Swarm Validation Team (SVT). They shall be requested to sign the “Terms and Conditions for the Utilisation of Data under the ESA Category-1 scheme”, available via the Opportunity website given in section 7.

Members of the SVT may expect to participate in some, or all, of the following activities:

- Integration of their proposed work within a wider scientific and technical framework, and the establishment of collaborative linkages between specialists.
- Participation in post-launch data product and data retrieval algorithm validation, and on-going monitoring of satellite performance and data quality.
- Support the Agency in the definition, in the light of post launch experience, of reprocessing algorithms to be applied to Level 1B data.

Members of the SVT will be expected to play an active role in the validation activities. A description of their proposed contribution and experience forms part of the response to this Opportunity.

2.2 Organisation of activities

Following the evaluation of the responses to this Opportunity and the confirmation of the selected proposals, a Swarm Validation Team (SVT) will be established.

The SVT will be consisting of the selected expert groups each led by a Principal Investigator (PI). The expert groups are requested to plan and organise their efforts in close relation to the ESA-controlled elements of the Swarm Ground Segment.

A key aspect of the expert groups is the capacity to deliver fast feedback in a timely fashion and with the appropriate accuracy in support to the monitoring of Level 1B product quality. Consequently, successful proposals will have to indicate both interest and ability to commit to the timely and accurate delivery of data products and reports. This supporting activity is needed after the in orbit verification of the satellite and will be concluded with a Product Validation Review approximately 6 months after launch. Proposed activities extending beyond the product validation review will be considered as well.

2.3 Data Provision

In support of the validation activities, the Agency will make Swarm data available to the investigators selected. In line with ESA's data policy these data will be made available free of charge.

The data provision will be congruent with the activities outlined in the accepted proposal and in line with the objectives of this Opportunity. Test datasets for interface testing will also be provided by the Agency.

During the Swarm commissioning phase (and more generally during the initial data validation period), data access may be restricted to members of the SVT.

After finalisation of the Level 1B product validation activities, All scientists will be given access to the calibrated and validated Level 1B products according to the ESA data policy for Earth Explorers (ref.RD-3).

As part of the proposal submission, applicants are requested to indicate their needs for satellite data products (L1B products are defined in RD5, L2 products in RD9). Consequently SVT Members will be requested to refine their data requirements as part of the planning activity, also taking account of any constraints arising from the capabilities of the data processing and distribution facility.

In some cases, a proposed activity may require access to other data, e.g. third party information, auxiliary data etc., whose supply is beyond the capability of the proposers. While the Agency cannot in general undertake to provide such data, proposers are requested to identify the relevant data sets, so that, during the planning phase, the SVT and Agency may provide support to obtaining such data.

The provision of data to SVT Members (and to the scientific community in general) will need to satisfy the general ESA terms and conditions covering Earth Observation data. Satisfying these conditions (which are drawn up in agreement with ESA member states) is necessary for SVT Members the scientific community to receive data free of charge. It should be noted in particular that no data supplied in the framework of this Opportunity may be transferred, sold or given to third parties other

than approved co-investigators, without the written authorisation of the Agency. Prior to receiving data, SVT Members will need to provide:

- Confirmation of the funding of the project, where appropriate;
- Confirmation of their acceptance of the terms and conditions for receiving the data;
- Confirmation of agreement to the allocated data quantities and delivery conditions.

For proposals concerning *L1B Product Validation* it is emphasised that the data provided by the Agency for the purposes of this Opportunity are non-validated in a scientific sense. More specifically, prior to release of Level 1B products for validation purposes, the satellite data are internally calibrated and also validated to the maximum extent possible in the framework of the engineering activities, all performed by the ESA-controlled elements of the Swarm Payload Data Ground Segment.

2.4 Reporting

The progress and accomplishments of the validation projects will be monitored by ESA. All selected Principal Investigators/SVT members will be requested to submit monthly progress reports describing the status of the project and to prepare a final report prior to the Product Validation Review. Each expert group is requested to provide quality reports for all science products validated.

Results of projects may be provided in computer readable form to be defined by the Agency, so that they may be made available to other users.

Confidentiality can be requested when the proposal is submitted and should be supported by adequate justification. Confidentiality will be guaranteed during the course of the evaluation process. The Agency, however, retains the right to, under any circumstances, use the expert group results at its discretion for any further data processing and/or data exploitation purposes.

2.5 Evaluation Procedures

Evaluation Criteria

The following criteria will be used in the evaluation of the proposals:

- relevance of the proposed project to the objectives of the Swarm validation activity,
- contribution to the objectives of the Swarm validation activity,
- availability and quality of independent datasets,
- background and experience of the proposers and availability of key persons,
- feasibility (credible workplan) and probability of success, and
- credibility of proposed funding.

Evaluation and Selection Procedures

Proposals received in response to this Opportunity will be reviewed by panels composed of:

- Swarm Project,
- Swarm Mission Management,
- Swarm Mission Scientist together with external scientists with widely recognised expertise in science related to the mission.

For the date of notification of evaluation results to PIs: see section 6.

2.6 Funding

Funding of the activities solicited through this Opportunity shall be covered by national/institutional resources.

The Agency is in no way committed to negotiate any financial contribution to selected expert groups of the SVT. However, at its discretion it may nevertheless opt to do so in order to guarantee the funding of projects that are deemed to be of particularly high importance to the mission.

3. DATA EXPLOITATION

The European Space Agency announces the opportunity to conduct research and applications development exploiting validated Swarm Level 1B and Level 2 data products. While registration as a Swarm user can be done at any time, a response to the present Opportunity is deemed attractive for several reasons:

I. It allows a team of Principal Investigators and Co-Investigators to be built, information to be shared about the research application plans.

II. It allows Investigators to solicit national/institutional funding of their activities by making the participation in Swarm visible

III. It builds a comprehensive snapshot image of the current interest in the Swarm mission.

Following the response to the data exploitation Opportunity, ESA will be able to anticipate scientific domain of interest not addressed by the Opportunity and initiate ad-hoc actions. In addition the data exploitation Opportunity might reveal that a cluster of scientific institutes share the same research interest. In turn this may enable actions from ESA to optimise preparations for the joint exploitation of all Swarm data products

3.1 Data Provision

During phase E the Agency will make validated Level 1b and Level 2 Swarm data available to all registered users, free of charge.

During the Swarm commissioning phase (and more generally during the initial data validation period), data access may be restricted to members of the SVT. After finalisation of the Level 1B product validation activities, All scientists will be given access to the calibrated and validated Level 1B products according to the ESA data policy for Earth Explorer (ref.RD-3)

In some cases, a proposed activity may require access to other, third party data whose supply is beyond the capability of the proposers. While the Agency cannot generally undertake to supply such data, proposers are requested to identify such data, so that, during the planning phase, the SVT and Agency may provide support to obtaining such data. Data from other ESA missions are available to users under the same terms and conditions as the Swarm data.

3.2 Funding

Funding of the activities solicited through this Opportunity shall be covered by national/institutional resources.

4. DATA AVAILABILITY

Data will be provided free of charge.

4.1 Data Description

Data products to be provided to expert groups/users worldwide are described in [RD 5]. Level 1B algorithms are explained in [RD 4] and the characterisation and calibration database in [RD 6]. Information regarding product performances is provided in Annex D.

4.2 Data Formats

Data products provided by the Payload Data Ground Segment adhere to the format specifications and follow the standards and conventions specified in [RD 7] [RD8].

4.3 Data Access for Users

In general, it shall be assumed that an expert group will have a secure and password-protected FTP-type interface to the PDGS, suitable for downloading data products and for uploading expert group results and data files. The data policy is outlined in [RD 3].

5. PROPOSAL SUBMISSION GUIDELINES

Two types of proposals can be submitted. In response to the

- Validation of L1b products
- Data Exploitation of validated Level 1B and Level 2 products

Detailed submission guidelines are available at: http://eopi.esa.int/SwarmSVO

The proposal should be submitted in electronic form using the ESA EOPI web site (see section 7) in a pre-defined format.

To facilitate assessment English is preferred, but French is also acceptable.

The deadline for submission is stated in section 6.

6. TIMETABLE

Release of the call (opening of Submission Website)	02 August 2011
Closing of the call (closing of Submission Website)	31 October 2011
Notification of the evaluation results to PIs	15 January 2012
Swarm launch	Mid July 2012
Start of Validation Campaign (Level 1B data delivery to SVT)	Launch + 1 months
Preliminary Validation Results (PIs presenting their preliminary results as an input to the Swarm In-Orbit Commissioning Review, IOCR)	Launch + 3 months
Product Validation Review (Projects completion and final reports),	Launch + 6 months
Start of Data Exploitation (Validated and calibrated Level 1B data delivery to accepted PIs)	Launch + 6 months
Start of Data Exploitation (Validated Level 2 data delivery to accepted PIs)	Launch + 6 months (TBC)
Symposia or Workshops	At several TBD occasions during phase E
Projects completion	Validation, research and exploitation activities are foreseen to continue throughout phase E and even beyond. Validation proposals should in any case provide a timely feedback to the Agency, with possibly the highest level of activity in the early phases of the mission.

7. REQUEST FOR FURTHER INFORMATION

Further information regarding this Opportunity can be found on the dedicated web site:

http:/eopi.esa.int/SwarmSVO

as well as from the EO Help Desk:

EO Helpdesk
ESRIN
Via Galileo Galilei – CP 64
00044 FRASCATI
ITALY

Tel: +39-6-941 80 666
Fax: +39-6-941 80 272
e-mail: eohelp@esa.int

8. ANNEX A: OVERVIEW OF THE SWARM MISSION

8.1 Mission Objectives and Description

The primary aim of the Swarm mission is to provide the best ever survey of the geomagnetic field and the first global representation of its variation on time scales from an hour to several years. The more challenging part, however, is to separate the contributions from the various sources. Swarm will simultaneously obtain a space-time characterisation of both the internal field sources in the Earth and the ionospheric-magnetospheric current systems.

The research objectives related to the Earth surface and its interior are:

- studies of core dynamics, geodynamo processes, and core-mantle interaction,
- mapping of the lithospheric magnetisation and its geological interpretation,
- determination of the 3-D electrical conductivity of the mantle,
- identifying the ocean circulation by its magnetic signature,

In addition research objectives related to the near-Earth electro-magnetic environment are:

- investigation of electric currents flowing in the magnetosphere and ionosphere
- quantifying the magnetic forcing of the upper atmosphere, including studies of thermosphere densities and winds.

Analysis of the Swarm data will greatly improve existing and provide new models of the near-Earth magnetic field of high resolution and authenticity compared to a single-satellite mission. This will provide the prospect of investigating hitherto undetected features of the Earth's interior.

A full description of the mission objectives is provided in ESA SP-1279(6) [RD 1] and in the Swarm Mission Requirements Document [RD 2].

8.2 Payload Configuration

In order to fulfil the mission objectives the Swarm space segment includes the following payload configuration on each of the three satellites:

- Absolute Scalar Magnetometer (ASM)
- Vector Field Magnetometer (VFM)
- Electrical Field Instrument (EFI)
- Startracker System (STR)
- GPS Receiver (GPSR)
- Accelerometer (ACC)
- Laser Retro Reflector (LRR)

Absolute Scalar Magnetometer

The ASM provides the ability of performing an in-flight calibration of the vector magnetometer, to maintain absolute accuracy in a multi-year geomagnetic field mission. The ability of performing an in-flight calibration of the vector magnetometer is needed. For this purpose and for obtaining the magnitude of the field with high accuracy an Absolute Scalar Magnetometer (ASM) is included in the payload.

Vector Field Magnetometer

The Vector Field Magnetometer (VFM) accomplishes high precision, high linearity and low noise measurements of the Earth's magnetic field vector components.

Electrical Field Instrument

The Electric Field Instrument (EFI) makes in-situ measurements of the plasma. It is composed of two Thermal Ion Imagers (TII) and two Langmuir Probes (LP). Key parameters that can be determined by these instruments are ion arrival angle, drift velocity, ion density, ion temperature, electron density, electron temperature and spacecraft potential. These parameters are used to calculate the local electric field.

Star Tracker System

The STR system delivers 3 axis highly accurate attitude data. The STR is mounted together with the VFM on a rigid mechanical interface to get the knowledge of the VFM sensor axes orientation. This mechanical interface between STR and VFM is called optical bench.

GNSS Receiver

The GNSS receiver will provide autonomous and real time satellite positioning and timing information. Precise orbit determination will be computed during post processing at Level 2. By using the precise timing information contained in each navigation solution in combination with a synchronisation pulse delivered every second by the receiver, a common time scale can be established for all the satellites and their instruments.

Accelerometer

An accelerometer (ACC) takes measurements of the non-gravitational accelerations acting on the spacecraft caused by air density, solar wind, Earth albedo, attitude and orbit control actuators etc.

Laser Retro Reflector

The LRR allows precise range measurements from ground based satellite laser ranging stations.

8.3 Calibration Activities during the Commissioning Phase

The launch vehicle will place all three satellites in the same injection orbit. From there, the spacecraft will each be manoeuvred to its own operational orbit. This manoeuvring will be done in steps throughout the 3 month In-Orbit Commissioning (IOC) Phase.

The satellite and instrument health-checks, verification activities as well as the calibration activities will also be executed during the Commissioning Phase and thus interleaved with be orbit acquisition manoeuvres. Currently the detailed planning of these activities among all three spacecraft is not frozen.

The Level 1B data products provided to the validation expert groups will be calibrated using parameters from the Characterisation and Calibration Data Base (CCDB, see RD6) as they have been determined pre-flight during on-ground calibration campaigns.

The Level 1B products provided to the data exploitation expert groups will be validated and calibrated using parameters as established during the in-orbit calibration activities.

The Level 2 products provided to the data exploitation expert groups will have also been validated.

In this section an overview of the in-orbit calibration activities is provided. Scientists involved within the satellite prime contract perform most of them during the In-Orbit Commissioning Phase, while others are repeated on a regular basis during the routine phase E.

Please note that some instrument calibrations require the satellite attitude to be changed which may lead to an unavailability of measurements from other instrument.

Accelerometer

- Scale factor determination (x- and y-axis) via thruster pulses. This is an interim calibration to gain confidence in the characterisation performed on-ground. The final calibration will be run during the Level 2 data processing. This calibration will be performed during the IOC Phase and will involve small attitude changes due to dedicated thruster activations.
- Offset determination using 180 degrees slew manoeuvre. This is an interim calibration to gain confidence in the characterisation performed on-ground. The final calibration will be run during the Level 2 data processing. This calibration will be performed during the IOC Phase and will involve an attitude change by 180 degrees, i.e. the spacecraft is flying “backwards”. During this manoeuvre the EFI instrument will not provide measurement data.
- Scale factor determination (x- and y-axis) considering response to solar radiation pressure. This is an interim calibration to gain confidence in the characterisation performed on-ground. The final calibration will be run during the Level 2 data processing. This calibration will be performed during the IOC Phase and comprises data analysis only. No specific attitude manoeuvres are required.

- Offset determination considering atmospheric co-rotation. This is an interim calibration to gain confidence in the characterisation performed on-ground. The final calibration will be run during the Level 2 data processing. This calibration comprises data analysis only and will be performed during the IOC Phase. No specific attitude manoeuvres are required.
- Distance verification between spacecraft CoM and centre of Accelerometer proof mass. This verification will be performed during the IOC Phase and comprises data analysis only.
- Scale factor and bias determination with adapted POD procedure within Level-2 processor. This calibration will be performed after the IOC Phase.

Electric Field Instrument (EFI)

- The EFI Thermal Ion Imager (TII) map detector gain response will be calibrated by dedicated yaw and pitch manoeuvres. For both manoeuvres the satellite attitude will be slewed through a range of +/- 10 degrees around the nominal attitude. This calibration will be performed during the IOC Phase and involves attitude changes.
- The EFI Langmuir Probe (LP) calibration will involve a set of operational modes. This calibration will be performed during the IOC Phase. No specific attitude manoeuvres are required.
- The EFI TII detector centre and the direction cosine determination via 'circle fit algorithm'. This calibration comprises data analysis only and will be executed during the IOC Phase as well as during Routine Phase. No specific attitude manoeuvres are required.

GPS Receiver

- Verification of the derived GPS orbits. This calibration comprises data analysis only. This calibration will be performed during the IOC Phase. No specific attitude manoeuvres are required.

Torquer Correction Manoeuvre

- The torquer correction matrix for the VFM and ASM instruments is determined during the on-ground satellite magnetic test. In order to verify the derived values in orbit under flight conditions, a series of predetermined torquer activations will be performed. This calibration will be performed during the IOC Phase. No specific attitude manoeuvres are required and the attitude change due to the magnetorquer activations will be small.

Precise Datation Manoeuvre

- The relative timing of the epochs of measurements between the vector instruments (STR, VFM, EFI, ACC) is derived from on-ground tests, however shall be verified in orbit. STR, EFI and ACC require their space environment (star background, ion flow, accelerations within measurements range) to provide

reliable data. The stimulation of synchronous variations at all the individual instruments shall be performed by activating the roll axis thruster pairs in alternating directions at predefined times in order to generate harmonic oscillations at known and fixed frequency. From the relative phases of these signals, datation differences between the instruments can be deduced. This calibration will be performed during the IOC Phase with dedicated attitude manoeuvres.

Star Trackers

The Euler angles describing the transformation between the reference systems of the three star sensors, the VFM and the Combined STR Reference Frame (CRF) are characterised on-ground at an astronomical observatory. However the measurement accuracy for this on-ground determination is limited. Therefore, dedicated procedures to determine these angles in space are foreseen in the Level 1B and Level 2 Data Processors. During the Commissioning Phase a comparison is planned between on-ground determined Euler angles and in-orbit determined Euler angles. The differences will be compared to the uncertainty of the on-ground calibration. No specific attitude manoeuvres are required.

Vector Field Magnetometer

- Due to the near polar orbits the spacecraft fly mainly along the lines of the geomagnetic field. Therefore one of the VFM instrument axes senses a much smaller range of the magnetic field. This hampers the determination of long-term variations of offset, sensitivity and non-orthogonality of that axis.

  Rotating the S/C by an angle of e.g. 70° in yaw, thus flying sideways, the VFM y-axis will experiences a considerably larger range of magnetic field variations over an orbit.

  The duration of this manoeuvre is 12 hours and will be performed during the IOC Phase and repeated once per year during the Routine Phase.

9. ANNEX B: DEFINITIONS AND ACRONYMS

Calibration — The process of quantitatively defining the system responses to known, controlled signal inputs

Validation — The process of assessing, by independent means, the quality of the data products derived from the system outputs

ACC	Accelerometer
AO	Announcement of Opportunity
ASM	Absolute Scalar Magnetometer
CCDB	Characterisation and Calibration Data Base
CoM	Centre of Mass
EFI	Electric Field Instrument
EO	Earth Observation
GPSR	GPS Receiver
ICRF	International Celestial Reference Frame
IOC	In-Orbit Commissioning Phase
IOCR	In-Orbit Commissioning Review
ITRF	International Terrestrial Reference Frame
LP	Langmuir Probe
LRR	Laser Retro-Reflector
MOD	Medium Orbit Determination
NEC	North/East/Centre (coordinate system)
PDGS	Payload Data Ground Segment
PI	Principal Investigator
POD	Precise Orbit Determination
S/C	Spacecraft
SDET	Swarm Data Exploitation Team
SRD	System Requirements Document
STR	Star Tracker System
SVT	Swarm Validation Team
TBC	To be confirmed
TBD	To be defined
TII	Thermal Ion Imager
VFM	Vector Field instrument

10. ANNEX C: REFERENCE DOCUMENTS

The following documents provide background information for this Announcement of Opportunity.

[RD 1] Swarm – The Earth's Magnetic Field and Environment Explorers, ESA SP-1279(6)
Available at: http://esamultimedia.esa.int/docs/SP_1279_6_Swarm.pdf

[RD 2] Swarm Mission Requirements Document for Phases B, C/D, E1, SW-MD-ESA-SY-001

[RD 3] ESA Data Policy, ESA/PB-EO(2010)54

[RD 4] Swarm Level1B Algorithms, SW-RS-DSC-SY-0002

[RD 5] Swarm Level1B Product Definition, SW-RS-DSC-SY-0007

[RD 6] Swarm Level1B Processor Characterisation and Calibration Data Base, SW-TN-DSC-SY-0005

[RD 7] Earth Explorer Ground Segment File Format Standards, PE-TN-ESA-GS-0001

[RD 8] Tailoring of the Earth Explorer File Format Standard for the Swarm Ground Segment SW-TN-ESA-GS-0074

[RD 9] Product specification for L2 Products and Auxiliary Products, SW-DS-DTU-GS-0001

11. ANNEX D: LEVEL 1B PRODUCT PERFORMANCE

These performance requirements apply for each single satellite and are valid for an altitude between 530 km and 300 km. Note that several performance numbers for products derived from the electric field instrument relate to a simulation environment and within mentioned environmental boundary conditions. The instrument can also measure outside some of the given ranges but for these cases no performance specification is provided here.

PER-1 The in-situ magnitude of the magnetic field shall be determined with a random error better than 0.3 nT (2σ, σ being the standard deviation), for signals encompassing all scales from global to 50 km (full wavelength).

PER-2 The stability in time of the magnitude of the magnetic field shall be better than 0.12 nT over 3 months (2σ) for the slow variations.

PER-3 The magnetic field vector components in the local North, East, Centre (NEC) frame shall be determined with a random error better than 1 nT (2σ), for signals encompassing all scales from global to 2 km (full wavelength).

PER-4 The stability in time of the magnetic field vector components in the NEC frame shall be better than 1 nT/year (2σ) for the slow variations.

PER-5 The vector electric field components in the NEC frame shall be determined with an accuracy better than 10mV/m (2σ) - 5mV/m (2σ) target - for plasma densities greater than $1x10^{10}$ m^{-3} and for ion temperature between 0.1 eV and 1 eV for signals encompassing all scales from global to 10 km (full wavelength)

PER-6 The stability in time of the electric field vector components in the NEC frame shall be better 1mV/m/month (2σ) for the slow variations.

PER-7 The measurement accuracy (2σ) of the plasma density shall be better than 20% between $1x10^{9}$ and $1x10^{11}$ m^{-3} and better than 5% for densities greater than $1x10^{11}$ m^{-3} for signals encompassing all scales from global to 10 km (full wavelength).

PER-8 The air drag acceleration vector components in International Celestial Reference Frame (ICRF) shall be determined with a random error better than $5*10^{-8}$ ms^{-2} (2σ) in each direction for signals encompassing all scales from global to 200 km (full wavelength).

PER-9a The ion temperature shall be determined with an accuracy better than 20% for temperatures between 0.1 eV and 1 eV for densities greater than $1x10^{10}$ m^{-3} and encompassing all scales from global to 200 km (full wavelength) for periods up to 3 months. The ion temperature shall be determined with an accuracy better than 10% for plasma condition specified by the IRI model.

PER-9b The electron temperature shall be determined with an accuracy better than 20% for temperatures between 0.1 eV and 1 eV for densities greater than $1x10^{9}$ m^{-3} and encompassing all scales from global to 200 km (full wavelength) for periods up to 3 months. The electron temperature shall be determined with an accuracy better than 5% for plasma condition specified by the IRI model.

PER-10 The ion drift velocity vector components in the NEC frame shall be determined with a random error better than 200 m/s (2σ) - 100 m/s target - encompassing all scales from global to 10 km (full wavelength) for periods up to 3 months for densities greater than $1x10^{10}$ m^{-3} and for ion temperature between 0.1 eV and 1 eV.

PER-11 The satellite position (from Medium Orbit Determination, MOD) shall be better than 1.5 m RMS in all directions in ICRF and International Terrestrial Reference Frame (ITRF).

PER-12 The satellite attitude knowledge (a-posteriori absolute measurement error) shall be better than 0.1 deg (2σ) in the ICRF and NEC frame.