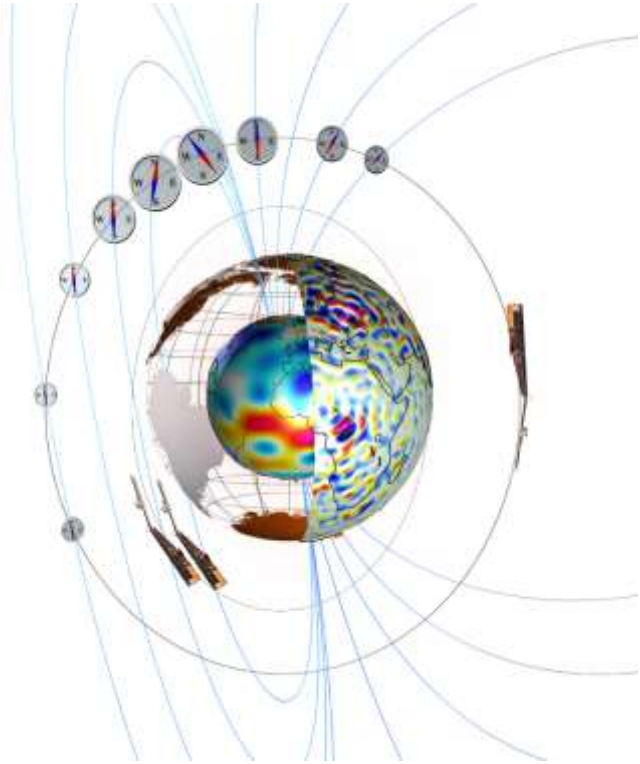
Statement of Work

Swarm DISC ITT 1.4

"Ionospheric irregularities and fluctuations based on Swarm data"



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1 Introduction

This Invitation to tender is issued by the Swarm DISC consortium on behalf of ESA within the reference frame of ESA contract 4000109587/13/I-NB, under the Swarm DISC Procurement Procedure described in [RD-1].

1.1 Scope and applicability

This document describes the activity to be executed and the deliverables required under the Swarm DISC ITT 1.4 – "Ionospheric irregularities and fluctuations based on Swarm data".

It will become part of the contract and shall serve as an applicable document throughout the execution of the work (with possible amendments recorded during the Negotiation meeting).

The document is structured as follows:

- Chapter 2 quotes applicable and reference documents (including applicable standards).
- Chapter 3 introduces the background and main objectives of the work, and presents the constraints on the system to be produced.
- Chapter 4 defines the work to be performed in the contract to produce the required output.
- Chapter 5 contains the requirements on deliverables and on general project management aspects.
- Chapter 6 contains schedule and milestones.

2 Applicable and Reference Documentation

2.1 Applicable Documents

The following documents are applicable to the definitions within this document.

[AD-1] ESA-EOPG-MOM-IF-0008 Swarm PDGS to SDPC Interfacing Control Documentversion 1.0

2.2 Reference Documents

The following documents contain supporting and background information to be taken into account during the activities specified within this document.

[RD-1] SW-RS-DTU-GS-003 rev. 1B, Swarm DISC Procurement Procedure

[RD-2] Goodwin, L. V. et al. (2015), Swarm in situ observations of F region polar cap patches created by cusp precipitation, *Geophysical Research Letters*, *42*(4), 996–1003, doi:10.1002/2014GL062610.

[RD-3] Buchert, S., F. Zangerl, M. Sust, M. André, A. Eriksson, J. E. Wahlund, and H. Opgenoorth (2015), SWARM observations of equatorial electron densities and topside GPS track losses, *Geophysical Research Letters*, *42*(7), 2088–2092, doi:10.1002/2015GL063121.

[RD-4] Park, J., M. Noja, C. Stolle, and H. Lühr (2013), The Ionospheric Bubble Index deduced from magnetic field and plasma observations onboard Swarm, *Earth Planet Sp*, *65*(11), 13–1344, doi:10.5047/eps.2013.08.005.

2.3 Terminology

In this document the term '*shall*' indicates requirements which the products must meet, while '*should*' indicates a desirable product features and '*may*' is used to indicate a suggested feature.

2.4 Abbreviations

Acronym ***or abbreviation***	***Description***
DTU	Technical University of Denmark, DK
Cat-1 / -2	Category-1 products are data products generated at a Swarm DISC partner, outside the PDGS, but published via the PDGS. Category-2 products are generated at the PDGS.
ESA	European Space Agency
ITT	Invitation To Tender
PDGS	Payload Ground Data Center
SVN	SVN Repository with server located at DTU. Presently, the following URLs apply: https://smart-svn.spacecenter.dk/svn/smart/SwarmESL-All https://smart-svn.spacecenter.dk/svn/smart/SwarmL2 (heritage from the L2PS Project)
Swarm	Constellation of 3 ESA satellites, http://www.esa.int/esaLP/ESA3QZJE43D_LPswarm_0.html
Swarm Data Handbook	https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/data-handbook New documentation site for Swarm Data Products
TBC	To Be Confirmed
TBD	To Be Defined
TDS	Test Data Set
TTO	Transfer To Operation
VirES	Virtual research platform https://vires.services
WBS	Work Breakdown Structure
WPD	Work Package Descriptions

3 Background and Objective(s)

3.1 Background

Sharp spatial changes (gradients) in the ionospheric plasma density cause problems for satellite-based communication as well as navigation services at a wide range of frequencies. In the equatorial regions, such gradients are often associated with so called equatorial plasma bubbles (EPBs), which appear in higher density plasma through convection of low density plasma regions from below [RD-4]. At high latitudes, and during geomagnetically disturbed periods even at mid-latitudes, plasma density gradients are associated with islands of high plasma density that drift through the low density background, forming what is known as polar cap patches (PCPs) [RD-2].

Currently, there is an official Swarm L2 product, the Ionospheric Bubble Index (IBI) which identifies low latitude plasma bubbles ([RD-4] and https://earth.esa.int/documents/10174/1514862/Swarm_L2_IBI_product_description).

Moreover, under the Swarm+ PCP project, polar cap patches have also been identified and sample data made available (http://www.mn.uio.no/fysikk/english/research/projects/swarm/).

Ionospheric scintillations of radio waves are one of the earliest known effects of space weather. With the development of global navigation satellite systems (GNSS) during the last few decades, scintillations of the L-band signal have been frequently observed and studied. It is known, for example, that ionospheric irregularities can affect the GPS propagation and this has been also observed with Swarm data [RD-3]. Scintillation indices are produced from the occultation receiver data of other satellite missions, such as PICOSat and COSMIC. Such indices can also be produced from Swarm data; however because Swarm only has a topside receiver, the indices derived from Swarm would represent the influence of the topside ionosphere, above the satellite.

It is clear that Swarm offers multiple methods and multiple instruments to study ionospheric irregularities. A combination of such existing methods, and perhaps also new ones, as a product that characterize these irregularities locally and globally, is desired.

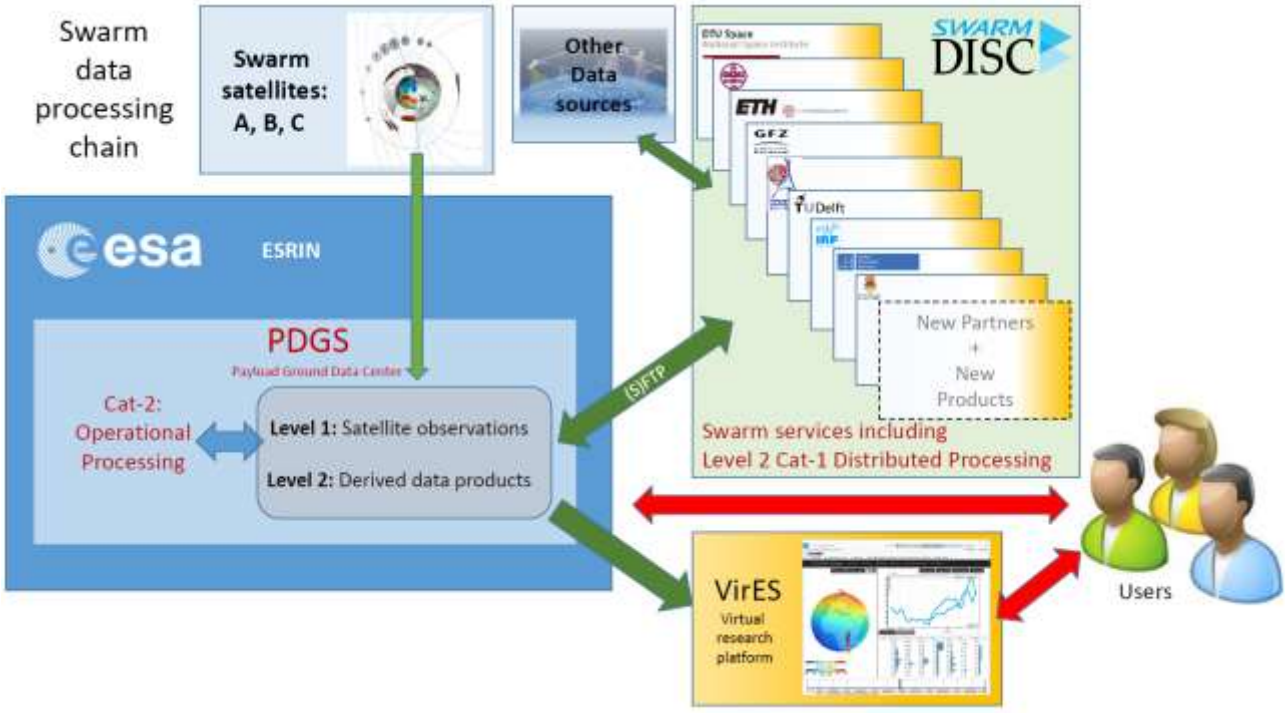

Figure 1 - Swarm data processing chain

The Swarm mission management intends to expand the delivery of Swarm related products that will have high impact and best benefit from the mission's data and its objectives. This ITT seeks to deliver a new product in the Swarm data processing chain.

Swarm mission's objectives, as well as already existing Swarm products are disseminated and described through https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/swarm and included links.

New products in the Swarm Level 2 data processing chain (see **Error! Reference source not found.**Figure 1) are uploaded via FTP to the Payload Data Ground Segment (PDGS) at ESA. All Swarm related data products are available to users through the PDGS. Swarm data products available are described on the Swarm Data Handbook and visualizations of most Swarm data products are available via the interactive 'VirES' Virtual research platform (https://vires.services).

Tenderers are encouraged to visit VirES, to get an impression of the capabilities available.

Note: Questions related to VirES can be directed to EOX (the implementers of VirES): Gerhard Triebnig (gerhard.triebnig@eox.at) or Daniel Santillan (daniel.santillan@eox.at). Please note that they will not answer questions directly related to this ITT, nor be committed to respond to your questions within any certain deadline.

3.2 Objective(s) of the Activity

The objective of the project is to produce a new product characterizing ionospheric density irregularities at all latitudes, and their effect on magnetic field variability and GPS performance, using an optimized combination of Swarm data and methods.

The data product shall fulfill the following requirements:

1. The data product should represent irregularities occurring at all latitudes.
2. Data should be time-tagged and geolocated using both geodetic and geomagnetic coordinates.

3. The data product shall be made available as soon as feasible after data reception as a Level 2 Cat-1 product (i.e. delivered via FTP to PDGS – see figure 1 and refer to [AD-1] and Swarm Data Handbook for further details).
4. Where possible, the product should contain relevant information on quality, uncertainty and availability of input data (e.g. quality flags, error estimate).
5. The new product shall be based on multiple Swarm instruments and/or data sources. Data sources other than Swarm may be used, but the need for any other data sources must be well justified.

The project shall deliver:

- A development plan for a processor software, to produce a dataset of global ionospheric scintillations and fluctuations.
- Implementation and verification of the processor at the contractor's premises.
- A validation report for the new data product, against a relevant set of independent data or models.
- Delivery of the data product, including historical data since the beginning of availability of Swarm input data.
- Documentation and user support, concerning the new data products.
- Use cases that define relevant visualizations and user interaction for the VirES Visualization User Interface.

A first iteration of the development plan should be included in the proposal.

It is envisaged that visualization of new Swarm products shall be made available to users through the virtual research platform VirES (https://vires.services). While implementation of this web visualization is not part of this ITT, the Tenderer shall allocate time to hand over visualization use cases, sample data sets and assist EOX in specifying and testing relevant web visualization(s).

During the project at least one peer reviewed publication and one presentation to a Swarm Data Quality Workshop are expected.

Public Outreach opportunities that the Tenderer anticipate to arise from this new product shall be described in the Tender, and included in the proposed workplan.

During Swarm operations, the processors will be enhanced and improved triggering the reprocessing of the full mission data and the subsequent release of such new product baseline. Furthermore, data quality assessment processes may reveal anomalies that could lead to the re-generation and replacement of a specific group of already existing data products with an updated file counter. Your proposal shall describe which steps you will take in both the reprocessing or re-generation scenarios in order to ensure the data quality of your output products.

3.3 Assumptions and Constraints

Official Swarm products made available by the Swarm PDGS shall be used by the project.

In case information from other sources is needed, the need for these products shall be defined and justified.

File naming convention and file format of the new product shall be in compliance with [AD-1].

Approval of deliverables will normally require 14 days for review by Swarm DISC Project Office. Approval of payment milestones is subject to approval of the related deliverables. Approval will be provided with the monthly progress report (mid month), to match the payment approval cycle of Swarm DISC.

4 Work to be performed

4.1 Work Logic

The work to be performed shall be divided into:

- A definition phase
- An implementation phase
- A preparation for operations phase
- An initial operations phase

The different phases will be reflected in the task descriptions below.

Time shall be assigned to collaborate with the third party implementers of VirES on the specification of relevant visualizations during the preparation for operations phase, as well as validating such visualizations. Verification of the visualizations shall also take place during the preparation for operations.

4.2 Definition phase

4.2.1 Task 1: Product definition

4.2.1.1 *Input*

- Statement of Work (this document)
- Scientific literature
- Swarm data products and product documentation
- Proposal (should include a first iteration of the product definition and work plan)

4.2.1.2 *Task Description*

Based on a review of the existing scientific literature and documentation of existing Swarm data products, the contractor shall define a new high-level data product on sources of ionospheric scintillations and irregularities. The sources that are to be included in the product encompass both low latitude plasma bubbles and high-latitude polar cap patches. The definition of the product shall be based on clearly defined requirements from both scientific users, interested in improving the understanding of ionospheric irregularities, and operational users of systems affected by these irregularities, such as users of high-end GNSS precise point positioning.

The contractor shall document the definition of the product. The product definition shall include information on the required input products, a definition of the data fields and metadata to be contained in the output product, information on the expected accuracy, time representation, temporal sampling and data volume of the product, as well as latency for availability of the product.

The contractor shall propose a work plan for the implementation, validation and operation of the processor that is to be developed for producing the new product. The proposed work plan shall be supported by preliminary analysis results. The work plan shall include the identification of the Swarm data and meta-data required for the analysis, as well as independent data or models to be used for validation. One or more representative periods for initial testing and validation of the processor and resulting product shall be defined in the work plan. If any supplementary data from sources other than existing Swarm products are required,

these shall be identified in the work plan, along with a justification for their need, and a description of the means to access this supplementary data.

4.2.1.3 *Deliverables*

- TN-01: Product definition document
- TN-02: Work plan

4.3 Implementation phase

4.3.1 Task 2: Processor implementation

4.3.1.1 *Input*

- TN-01: Product definition document
- TN-02: Work plan
- Swarm data products and documentation

4.3.1.2 *Task description*

The contractor shall implement the processor at its premises, according to the work plan. The processor shall be implemented to produce the data set, in accordance with the product definition document. The contractor shall document the algorithms that are applied in the processor in a technical note. The contractor shall collect all necessary input data to run the processor for a test period, and generate and deliver a first test data set.

4.3.1.3 *Deliverables*

- TN-03: Description of the processing algorithms
- DL-01: First test data set

4.3.2 Task 3: Product validation

- TN-01: Product definition document
- TN-02: Work plan

4.3.2.1 *Task description*

The contractor shall compare the new data product with independent data or models, to demonstrate the validity of the data set, and if possible assess the accuracy of the data. The output of the activity shall be documented in a validation report, which shall be delivered along with the preliminary dataset used in the validation.

The contractor shall interact with EOX to discuss options for the visualisation of the new data set in VirES. Based on this, the contractor shall develop visualization use cases and test data sets and deliver these to EOX. The contractor shall assist EOX in developing recommendations for a tutorial or help text to guide users of the visualization of the product where relevant.

4.3.2.2 *Deliverables*

- TN-04: Validation report
- DL-02: Preliminary dataset used for validation
- TN-06: Technical note including use cases for visualisation and recommendations for tutorial or help text for VirES

4.4 Preparations for operations phase

4.4.1 Task 4: Preparation for transfer of data to PDGS

4.4.1.1 *Input*

- TN-01: Product definition document
- TN-02: Work plan
- [AD-1]

4.4.1.2 *Task description*

Implement functions for operational transfer of data to PDGS – i.e. data products uploaded to ESA FTP server in correct file format, etc., see [AD-1]. The Swarm DISC System Manager will offer Unix scripts that exemplifies generation of header and dissemination files.

The contractor shall allocate time to validate visualizations developed by the VirES team.

The contractor shall identify a person that will be available to answer user questions during the operational phase.

4.4.1.3 *Deliverables*

- TN-01 - published on the Swarm Data Handbook.
- TN-05: Technical note documenting implementation of data transfer functionality.

4.5 Initial operations phase

4.5.1 Task 6: Initial operations

4.5.1.1 *Input*

- Processor
- Swarm products

4.5.1.2 Task description

The contractor shall collect all necessary input data, and use the processor as implemented at its premises, to deliver data since the beginning of availability of Swarm data to PDGS. The contractor shall continue to produce and deliver these data products, as new Swarm input data comes in, until the end time of the contract. The contractor shall be fully responsible for the data content quality before any data transfer.

The contractor shall provide expert support to users of the data, responding to user questions that the ESA helpdesk cannot answer, via e-mail on a best effort basis

A scientific description of the product and its benefits shall submitted to a peer-reviewed journal, and this shall be presented at a relevant science meeting – Swarm Data Quality Workshop or similar event in Europe to be agreed with the Swarm DISC project office.

Finally, all project documentation shall be delivered to Swarm DISC in searchable PDF format.

4.5.1.3 *Deliverables*

- DL-03: Historical data set.
- DL-04: Data set based on new incoming data until end of project.
- DL-05: Publication submitted to journal publication
- DL-06: Presentation of results at Swarm Data Quality Workshop
- DL-07: Replies to user support questions
- DL-08: All project documentation delivered electronically to the Swarm DISC Project Office in searchable PDF format

5 Requirements for Management, Reporting, Meetings and Deliverables

The following are the requirements for Management, Reporting, Meetings and Deliverables applicable to the present activity.

5.1 Management

5.1.1 General

MG-01	The contractor shall assign a responsible project manager as point of contact with the DISC project office / the Agency.
MG-02	A point of contact shall be assigned for subcontractors, if any, but generally any correspondence with the project will be via the project manager assigned in MG-01

5.1.2 Communications

MC-01	All correspondence between the project and the Agency must be via – or if agreed by DTU in copy to – the Swarm DISC project office: Swarm DISC Project office DTU Space, Building 371 Diplomvej 2800 Kgs. Lyngby Denmark Fax: +45 4525 9701

5.2 Reporting

5.2.1 General reporting requirements

GR-01	The contractor shall submit all documents to the DISC Project Office in searchable, non-protected PDF format, as well as their native format (MS Word 2010 or compatible format).
GR-02	The contractor shall ensure that electronic documents do not contain any harmful code (e.g. virus)

5.2.2 Minutes of Meeting

MM-01	The contractor shall produce short minutes of meeting, recording participants and any decisions made during meetings, and send a copy of these to the Swarm DISC project office, not later than two days after these meetings.

5.2.3 Progress Reports

PR-01	The contractor shall produce a short monthly progress report, which is sent via e-mail to the Swarm DISC project office.

5.3 Technical Documentation

TN-01	Product definition document, published on Swarm Data Handbook
TN-02	Work plan
TN-03	Description of the processing algorithm
TN-04	Validation report
TN-05	Technical note documenting implementation of data transfer functionality
TN-06	Technical note including use cases for visualisation and recommendations for tutorial or help text for VirES

5.4 Meetings

ME-01	The Contractor shall organize a kick off meeting via WebEx where key persons are introduced and the project schedule is presented.
ME-02	The Contractor shall present the project status regularly to the Swarm DISC project office via Teleconference – at least quarterly. The status report shall be provided to DTU one week before the teleconference. The Agency reserves the right to participate.
ME-03	The Contractor shall prepare a presentation of the final result (DL-06) and present it to the Swarm DISC community at a suitable event (Data Quality Workshop or conference) in Europe to be agreed with the Swarm DISC Project Office..
ME-04	The Swarm DISC project office and the Agency reserves the right to call up ad hoc meetings at any time for justified reasons.

5.5 Other deliverables

DL-01	First test data set.
DL-02	Preliminary dataset used for validation
DL-03	Historical data set.
DL-04	Data set based on new incoming data until end of project.
DL-05	One Peer reviewed publication submitted or accepted
DL-06	Presentation of results at Swarm Data Quality Workshop
DL-07	E-mail replies to 2nd level support questions forwarded from ESA EO helpdesk
DL-08	All project documentation delivered electronically to the Swarm DISC Project Office in searchable PDF format

6 Schedule, Milestones and Deliverables

6.1 Schedule

SC-01	The Contractor shall establish a schedule that is consistent with the planned start of work and the milestones in section 6.2. Any deviation shall be identified and duly justified.
SC-02	The Contractor shall during execution monitor the major milestone schedule. Any deviations shall be and reported to the DISC project office with justification.
SC-03	In the event that delays to milestone deliveries are anticipated, this shall be reported to the Swarm DISC project office As Soon As Possible.

6.2 Milestones

Milestone	Description	Event timeline (months)
MIL-01	Project Kick Off	KO
MIL-02	Delivery of work plan (TN-02)	KO+1m
MIL-03	Delivery of algorithm description (TN-01, TN-03, DL-01)	KO+5m
MIL-04	Payment milestone 1: Acceptance of validation report plus preliminary data set used for validation (TN-04, DL-02, TN-06)	KO+7m
MIL-05	Delivery of first data to PDGS (TN-06).	KO+8m
MIL-06	Payment milestone 2: Acceptance of data set from start of availability of Swarm data until one year after the start of the project.(DL-03, DL-04, DL-05, DL-06, DL-07, DL-08)	KO+12m