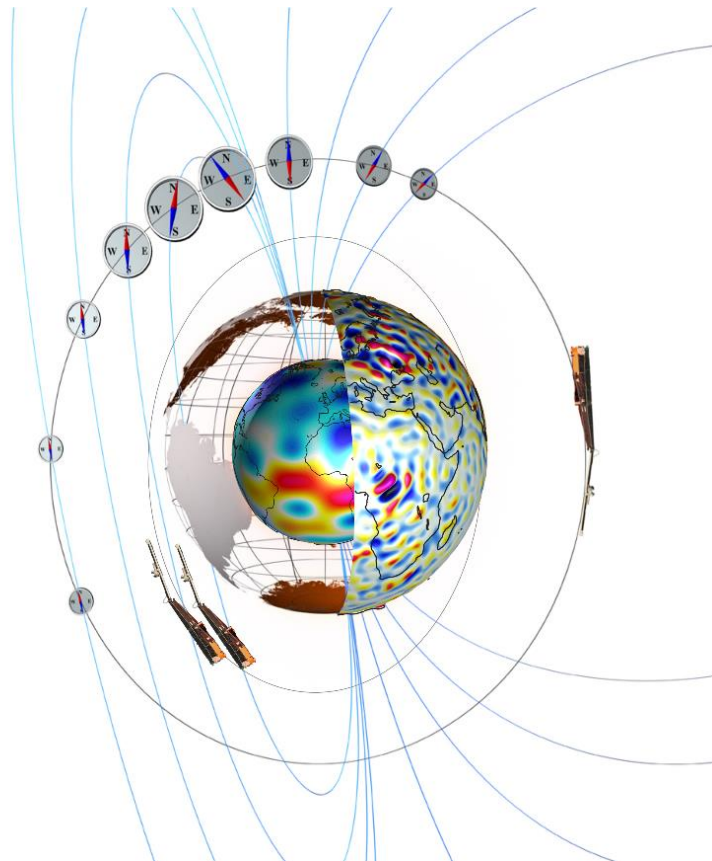# Statement of Work
Swarm DISC ITT 2.2
"Midlatitude Ionospheric Trough, Plasmapause and possibly related boundaries as determined from Swarm measurements"

Doc. no: SW-SW-DTU-GS-122, Rev: 1A

Record of Changes

Reason	Description	Rev	Date
Final version	Released for publication	1	25 Feb 2019
ICD update	Interface Control Document reference updated	1A	14 Mar 2019

Table of Contents

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 [RD-1].

1.1 Scope and applicability

This document describes the activity to be executed and the deliverables required under the Swarm DISC ITT 2.2 – "Midlatitude Ionospheric Trough, Plasmapause and possibly related boundaries as determined from Swarm measurements".

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-17 Swarm SPC to PDGS ICD v1.1

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]   Heilig, B., H. Lühr (2013) New plasmapause model derived from CHAMP field-aligned current signatures, Ann. Geophys., 31, 529-539, doi:10.5194/angeo-31-529-2013.

[RD-3]   Prölss, G. W. (2006), Subauroral electron temperature enhancement in the nighttime ionosphere, Ann. Geophys., 24, 1871–1885, doi:10.5194/angeo-24-1871-2006.

[RD-4]   Pedatella, N. M., and K. M. Larson (2010), Routine determination of the plasmapause based on COSMIC GPS total electron content observations of the midlatitude trough, J. Geophys. Res., 115, A09301, doi:10.1029/2010JA015265.

[RD-5]   SW-DS-GFZ-GS-001_AEBS_DPA – revision 1 draft A: Preliminary Description of the Processing Algorithm for *"Swarm-AEBS - Auroral Electrojet and auroral Boundaries estimated from Swarm observations"*

[RD-6]   SW-TN-UiO-GS-002_IPIR_TN-01_PDD rev. 1B: Product Definition Document for *"IPIR - Ionospheric Plasma Irregularities characterised by the Swarm satellites"*

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
CDM	Configuration and Data Management
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.
DISC	(Swarm) *Data, Innovation and Science Cluster* – a consortium of scientific and technical partners supporting the data processing for the ESA Swarm mission
DPA	Description of Processing Algorithm
DQW	Data Quality Workshop
DTU	Technical University of Denmark, DK
EOX	EOX IT services Gmbh, Austria – Developer and operator of the VirEs visualization platform
ESA	European Space Agency
ITT	Invitation To Tender
KO	Kick Off
PDD	Product Definition Document
PDGS	Payload Ground Data Segment
SLA	Service Level Agreement
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)
TBC	To Be Confirmed

Acronym *or abbreviation*	Description
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

Swarm is a constellation of satellites operated by ESA. The objective of the Swarm mission (https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/swarm) is to provide the best ever survey of the Earth's geomagnetic field and the near Earth's space environment. For this aim, the mission provides observations of the magnetic field, electron density and temperature, ion drift, and neutral density. These observations have been applied in many scientific studies and greatly advanced our understanding of the geomagnetic field and space physics – read more at https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/activities/publications.

Data from the Swarm mission are described in the *Swarm Data Handbook*:
https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/data-handbook

Studying the processes of the Ionosphere at Swarm altitudes is not only of importance to space science, but has highly practical impact on important societal activity such as transionospheric radio propagation (GNSS navigation, satellite and HF based communication, etc), as well as radiation safety of aviation and space operations, and (auroral) tourism activities.

The location and intensity of various disturbances or boundaries in the ionosphere are important to the evolving understanding of the physics involved as well as near real time space weather effects. Several projects such as

- AEBS - Auroral Electrojet and Auroral Boundaries Estimated from Swarm Observations
- AMPS - The average magnetic field and polar current system model
- IPIR - Ionospheric plasma irregularities and fluctuations based on Swarm data

(https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/activities/scientific-projects/disc)

are conducted under the umbrella of Swarm DISC (the Data, Innovation and Science Cluster supporting ESA's Swarm mission) , the purpose of which is to address new data products or models, which can characterize such phenomena and support an increase of our understanding of the physics involved.

So far no Swarm products specifically address the location and dynamics of the Midlattitude Trough and Plasmapause, which play important roles in space weather science, in particular since they are highly sensitive to geomagnetic activity.

3.2   Objective(s) of the Activity

The main objective of this activity is to produce and deliver new data products based on the Swarm satellites characterizing key ionospheric boundaries at Swarm altitudes, specifically the mid-latitude Ionospheric Trough and Plasmapause and possibly other related boundaries, avoiding to duplicate the efforts of ongoing projects such as AEBS and IPIR ([RD-5] and [RD-6]).

The proposers to this activity shall consider new or improved boundary detections and describe how they intend to derive and deliver data timeseries for the individual Swarm satellites, characterizing as a minimum the time and location of boundary crossings, boundary sharpness and a measure of the quality / reliability of the boundary detection on an orbit by orbit basis, which can then be visualized in VirES as comparison to time series of other Swarm measurements. No special developments of advanced visualizations are expected within this project.

The proposer shall in the proposal discuss how magnetic field and plasma measurements contribute to the boundary detection. Further, it shall be discussed how the multi satellite constellation will support boundary detection, characterization, or quality flagging of the product(s).

3.3   The Swarm data processing chain

All Swarm related data products are made 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 for Swarm' client (https://vires.services).
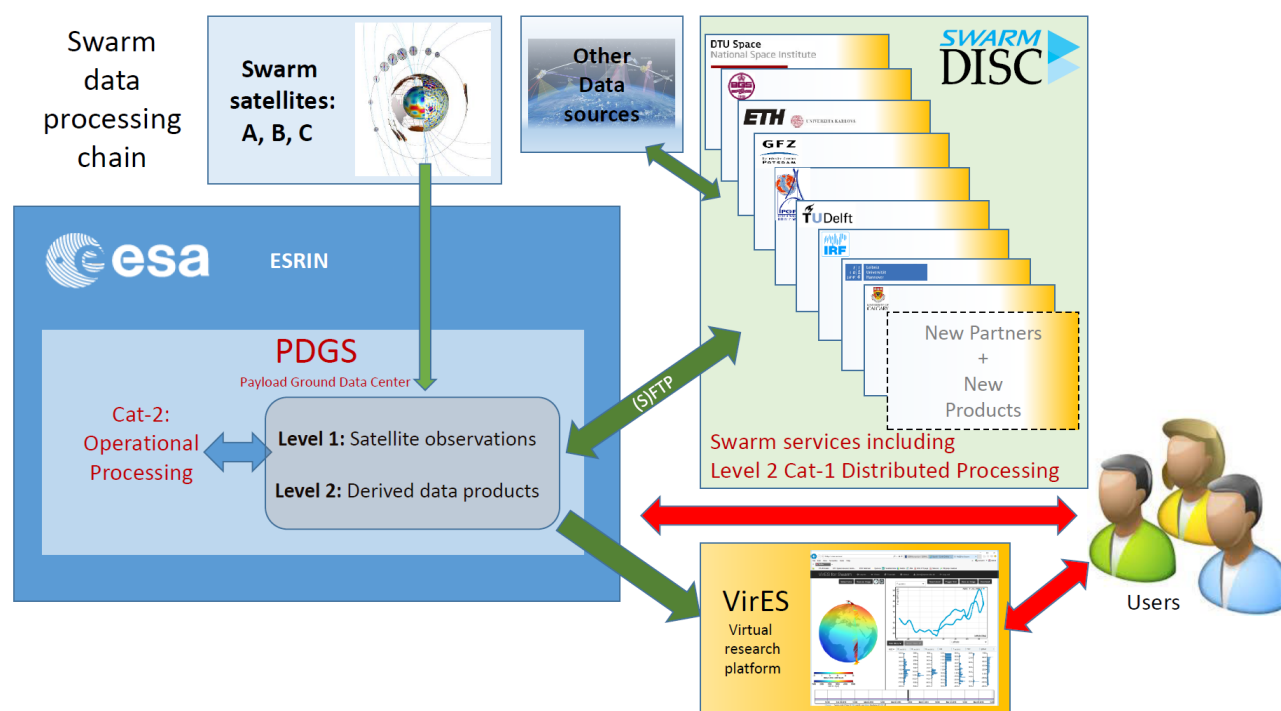
Figure 1 - Swarm data processing chain

This project shall deliver its data products as part of the Level 2 distributed processing network, as a new product in the Swarm data processing chain (see Figure 1). It shall be generated on a regular basis pending availability of the required input data products and upload via SFTP to the Payload Data Ground Segment (PDGS) at ESA for publication.

Although the Swarm mission currently does not deliver its observation data in a near real time mode, the proposer should – considering the possible near real time Space Weather applications of the product – discuss the feasibility of providing the products in a near real time mode in the proposal, pending availability of the required input data.

During Swarm operations, the Level1b processors may 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 regeneration and replacement of a specific group of already existing data products with an updated file counter. The proposal shall support versioning of the output data products and describe which steps will be taken in order to ensure

the data quality of the output products, should new releases of the input data become available in both the re-processing or re-generation scenarios.

3.4 Assumptions and Constraints

Official Swarm products made available by the Swarm PDGS shall be used by the project. In case data from other sources are needed for processing purposes these products need to be defined and described in detail.

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.

4 Work to be performed

All deliverables in the form of Technical Notes described here will require an informal review – reviewer to be appointed by the Swarm DISC technical representative – and subsequent written approval.

The following sections describe the tasks anticipated to complete this project. Required output deliverables are listed in chapter 5.

4.1 Work Logic

The work to be performed should as a guideline cover the following tasks: Definition of the product and scientific validation, development of an implementation as a new Level 2 product in the SWARM processing chain, verification and validation of the product performance, plus preparation of the product for provision in an operational setting.

Immediately after Kick-off, the proposer is expected to provide a brief summary (about 200 words) to be published on the Swarm mission website https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/activities/scientific-projects/disc.

4.1.1 Task 1: Product definition

4.1.1.1 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)

4.1.1.2 Task Description

Based on a review of the existing scientific literature (see, for example, [RD-2], [RD-3], [RD-4]) and documentation of existing or recent Swarm data products (see https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/data-handbook, [RD-5] and [RD-6]), the Contractor shall define a new high-level data product at least including regions where the mid-latitude Ionospheric Trough and Plasmapause are expected, and possibly other related boundaries. The definition of the product shall be based on its usefulness for improved understanding of regions in geospace and their dynamics. Furthermore, the definition shall consider how magnetic field and plasma measurements contribute to the boundary detection and how the multi satellite constellation will support boundary detection, characterization, or quality flagging of the product(s).

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.

4.1.1.3 *Deliverables*

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

4.1.2 Task 2: Processor implementation

4.1.2.1 *Input*

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

4.1.2.2 *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 is strongly encouraged to adopt an open source approach for the code development. 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.

4.1.2.3 *Deliverables*

- TN-03: Description of the processing algorithms and preferably submission of code to open source repository
- DL-01: First test data set

4.1.3 Task 3: Product validation

4.1.3.1 *Input*

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

4.1.3.2 *Task description*

The Contractor shall compare the new data product with independent data or models, to demonstrate the validity of the data set, and to the extent 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.

In order to assist the visualisation of the new data set in VirES, the Contractor shall develop visualization use cases and test data sets. The Contractor is encouraged to interact as early as possible with EOX in support of their implementation of the product visualization.

4.1.3.3 *Deliverables*

- TN-04: Validation report
- DL-02: Preliminary dataset used for validation
- TN-06: Technical note including use cases and test data and format specification for visualisation.

4.1.4   Task 4: Preparation and transfer of data to PDGS

4.1.4.1   *Input*

- TN-01: Product definition document
- TN-02: Work plan
- **Error! Reference source not found.**: Interfacing Control Document

4.1.4.2 *Task description*

The Contractor shall implement functions capable of transfer of data to PDGS – i.e. uploading data products to ESA FTP server in correct file format, etc., see **Error! Reference source not found.**. The Swarm DISC System Manager will offer Unix scripts that exemplifies generation of header and dissemination files.

The Contractor shall produce the output data in the final product format and upload it to PDGS. First data should be delivered at least 2 month prior to project finalization. Full mission data from the beginning of the Swarm mission shall be delivered by Final Presentation.

The Contractor shall prepare a plan for how continued operational provision of the data product could be supported beyond the end of the contract. This plan shall describe the support needed for maintaining operational production including answering user questions received by ESA EO helpdesk in the event that a future operational phase is to be negotiated.

4.1.4.3 *Deliverables*

- TN-05: Technical note documenting implementation of data transfer functionality.
- DL-03: PDD (TN-01) published on the Swarm Data Handbook.
- DL-04: First data delivered to PDGS
- DL-05: Plan for continued operation
- DL-06: Full mission data delivered to PDGS

4.1.5   Task 5: Final presentation

4.1.5.1   *Input*

- All outcomes from the project

4.1.5.2 *Task description*

- Preparation and submission of peer reviewed publication about the outcome of this project
- Presentation of project achievements at a Swarm Data Quality Workshop or similar event to be agreed with the Swarm DISC Project Office towards the end of the project.
- Delivery of all documentation to Swarm DISC

4.1.5.3 *Deliverables*

- DL-07: One Peer reviewed publication submitted
- DL-08: A presentation of project achievements made during a Swarm DQW.
- DL-09: Final 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

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

MG-03. 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
> Centrifugevej, Building 356
> 2800 Kgs. Lyngby
> Denmark
> Fax: +45 4525 9701

5.2 Reporting

RP-01. The Contractor shall submit all documents to the DISC Project Office in searchable, non-protected PDF format, as well as their native format.

RP-02. The Contractor shall ensure that electronic documents do not contain any harmful code (e.g. virus)

RP-03. The Contractor shall ensure that short minutes of meeting are produced, recording participants and any decisions made during the Kick Off meeting as well as status report meetings, and send a copy of these to the Swarm DISC project office, not later than three days after these meetings.

RP-04. The Contractor shall produce a short quarterly (or other interval as agreed) progress report, which is sent via e-mail to the Swarm DISC project office. This report shall contain highlights of recent achievements, status on work progress, references to publications or presentations, new challenges, etc. Swarm DISC will provide a Progress Reporting template.

5.3 Technical Documentation

TN-01. PDD – Product Definition Document

TN-02. Workplan

TN-03. DPA – Description of the processing algorithms and preferably submission of code to open source repository

TN-04. Validation Report

TN-05. Technical note documenting implementation of data transfer functionality

TN-06. Use-case document describing visualization in the context of ViRES

5.4 Meetings

ME-01. The Contractor shall organize a kick off meeting via teleconference where key persons are introduced and the project schedule is presented.

ME-02. The Contractor shall upon request - and at least at the Mid Term Review - present the project status to the Swarm DISC project office via teleconference. 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 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. Presentation draft to be provided to Swarm DISC Project Office and ESA 5 working days before the event.

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. PDD (TN-01) published on the Swarm data handbook

DL-04. First data delivered to PDGS

DL-05. Plan for continued operation

DL-06. Full mission data delivered to PDGS (from start of mission until most recent input data)

DL-07. One Peer reviewed publication submitted

DL-08. Presentation of project achievements to Swarm DQW

DL-09. Final project documentation delivered electronically to the Swarm DISC Project Office in searchable PDF format

6   Schedule and Milestones

This activity is expected to start as soon as possible in 2019, with a planned duration of up to one year.

6.1   Schedule

SC-01. The Contractor shall establish a schedule that is consistent with the planned start of work and the draft 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. 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	TN-01, TN-02	KO+3
MIL-03	Mid Term Review: TN-03, DL-01, TN-06	KO+6
MIL-04	TN-04, TN-05, DL-02	KO+9
MIL-05	Final Presentation: DL-03, DL-04, DL-05, DL-06, DL-07, DL-08, DL-09	KO+12