Statement of Work

Swarm DISC ITT 1.2

"Strength and location of the auroral electrojets based on Swarm data"

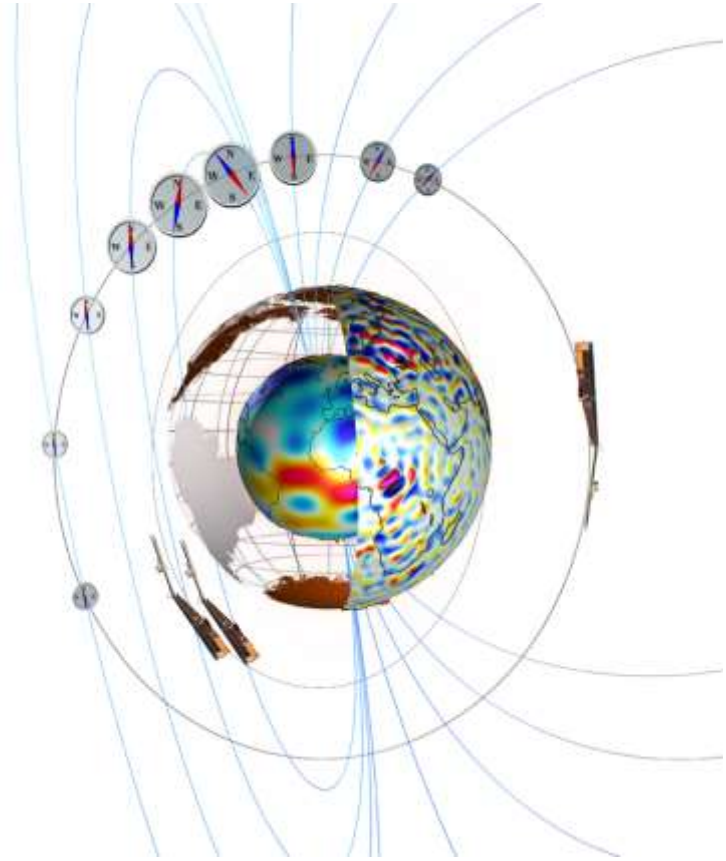

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Table of Contents

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 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 1.2 – "Strength and location of the auroral electrojets 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] Vennerstrom, S., and T. Moretto (2013), Monitoring auroral electrojets with satellite data, Space Weather, 11, 509–519, doi:10.1002/swe.20090.

[RD-3] Aakjær, C.D., Olsen N., and C. C. Finlay (2016), Determining polar ionospheric electrojet currents from Swarm satellite constellation magnetic data, Earth, Planets and Space, 68, 14, 10.1186/s40623-016-0509-y

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 Segment
PEJ	Polar Electrojet
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)
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

The best-known features of the aurora are the northern and southern ovals, which represent the regions receiving the main part of solar wind energy input. Viewed from space with a global imager, the aurora appears as diffuse, continuous, luminous bands that surround both magnetic poles at ionospheric altitudes. The boundaries of the auroral oval can be determined by ground-based radars, low-altitude satellite or optical imagers from high-altitude satellites. Auroral boundaries (both equatorward and poleward) can potentially also be derived from Field-Aligned Currents (FAC) observations as a regular Swarm product for each high-latitude segment of Swarm orbits. They may also be characterized by sudden discontinuous variations in the scalar or vector magnetic field measurements.

The auroral oval is characterized by a particular system of electric currents, the Polar ElectroJets (PEJ), which are among the most intense ionospheric sources, and have significant magnetic perturbations both on the ground and at satellite altitude. Additionally, they are notoriously difficult to predict due to the extremely complex and active interaction between the ionosphere and magnetosphere at high-latitudes. Providing estimates of these currents on a track-by-track basis would be invaluable to the high-latitude electrodynamics community which studies the many sources in this region.

The strength of the PEJs are monitored on a routine basis by the AE-index, which is derived from magnetic data obtained by a set of geomagnetic ground observatories located in the auroral oval. Due to the rather uneven distribution of the observatories it is likely that the ionospheric currents comprising the PEJ are from time to time located at different latitude (i.e. either to the South or to the North) to the ground stations, leading to a biased measure of the PEJ strengths. As a consequence of this, the strength of the PEJ is often not properly determined by the AE-index.

Satellites in LEO orbit, like Swarm with its unique constellation, provide excellent global coverage along a profile essentially in North-South direction, allowing for a determination not only of the strength of the PEJ but also of its location and width, at the time and longitude of the satellite crossing, without the limitations of the AE index. We wish to take advantage of the more than three years' worth of data that exist to determine these parameters both in the past and from current operational data.

The "Location and Strength of the auroral electrojets based on Swarm data" shall deliver new products into the Swarm data processing chain (see Figure 1). The data will be delivered to the user community via the Payload Ground Data Segment (PDGS) which currently supports the issuance of Level1b and Level 2 products to the scientific community.

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

New products in the Swarm Level 2 data processing chain (see 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.

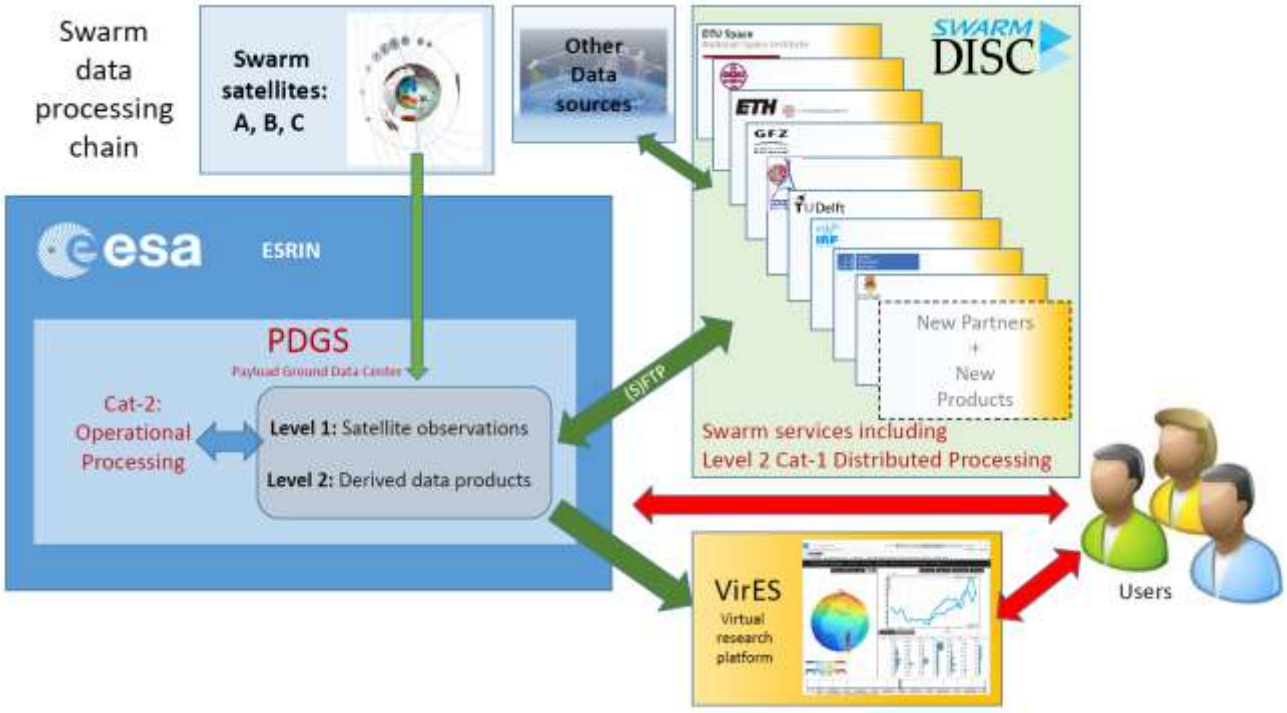

Figure 1 - Swarm data processing chain

3.2 Objectives of the Activity

The requirements of the "Strength and Location of auroral electrojets based on Swarm data" activity *shall* be as follows:

- Produce one or more products based on Swarm data to characterize the strength and location of auroral electrojets in both hemispheres and their boundaries, as Level 2 Cat-1 products. Tenderers are addressed to [AD-1] for a detailed description of the interface to ESA for data transfer, the expected packaging of data and name conventions; the full description of the existing Swarm Level 2 products, can be found in the Swarm Data Handbook (https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/data-handbook)
- Deliver daily product files (i.e. covering each day from 00:00:00 until 23:59:59) with a latency of less than 5 days using Swarm operational data, on a best-effort basis in an initial operation phase until end of project.
- Deliver daily product(s) covering the period from the start of the Swarm mission to the present.
- The product(s) to include the strength of the electrojet current, and the location in geographic and geomagnetic latitude and longitude, Universal Time (UT) and Magnetic Local Time (MLT) of the position(s) of the peak of the electrojets detected in both hemispheres.
- The product(s) to include the geographic and geomagnetic latitude and longitude, Universal Time (UT) and Magnetic Local Time (MLT) of the auroral electrojet boundary crossings in both hemispheres.
- Produce documentation explaining how the algorithm works, and the production and operation of the processor in detail.

The product(s) *should* meet the following requirements:

- Provide robust output which always give values for the southern and northern location of the auroral electrojet boundaries for each pass across the north and south polar regions. Hence, on each full

orbit per satellite there should be eight boundary points. If no definitive boundary is detected, an empty value or flag (such as NaN) should be entered.

- Provide robust output for the strength and location of the current peak. If no current peak is detected an empty value or flag (such as NaN) should be entered.
- Provide a relative or absolute uncertainty to be attached to the estimate of current strength within the product.
- Provide general uncertainties on the location of the auroral boundaries (e.g. within the user notes or manual).

The product(s) *may*:

- Incorporate data from other satellites (e.g. e-POP, DMSP) where appropriate.

In order to validate the product(s), the provider *should*:

- Provide evidence from tests comparing the boundaries detected in space to those from ground-based observatory, radar or other datasets.
- Provide convincing evidence that a majority of the orbital passes tested produce a reliable detection of a boundary or current strength.

In addition, it is required that the provider *shall*:

- Produce use-cases that define relevant visualizations and user interaction with the VirES Visualization User Interface

  It is envisaged that visualization of these new products shall be made available to users also 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 the visualization Use Cases, sample data sets and assist EOX in specifying and testing relevant web visualization(s).

- During the project, deliver at least one peer-reviewed publication and one presentation to a Swarm Data Quality Workshop.

It is required that the provider should:

- Harness Public Outreach opportunities that the Tenderer anticipate to arise from this new product.
- During Swarm operations, the Level1b processors may be enhanced and improved, triggering the reprocessing of the full mission data and the subsequent release of 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 should 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

The following assumptions and constraints apply:

- It will be assumed that existing Swarm Level1b, and/or Level 2 CAT-1 and/or CAT-2 products are required for the derivation of the “Strength and location of the auroral electrojets based on Swarm data” products.
- If other daily production chains of Level1b, and/or Level 2 CAT-1/CAT-2 products are interrupted, then the auroral processing chain may also be unable to complete.

- 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:

- An Implementation phase
- An Initial Operation phase

Time shall be assigned to collaborate with EOX (implementers of VirES) on the specification of relevant visualizations during Implementation phase, as well as validating such visualizations. Verification shall also take place during Initial Operation.

4.2 Implementation

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.

4.2.1 Task 1: Implementation of algorithm(s) in processor(s)

4.2.1.1 *Input*

None

4.2.1.2 *Task Description*

Implementation of Algorithms for generation of the new products.

The following technical notes will be required for the product:

- TN-01: A Technical note describing the Algorithmic Process, including relevant references to peer-reviewed articles that document the scientific basis of the implementation
- TN-02: A Product Definition Documentation describing the data product(s) – to be included in Swarm Data Handbook (https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/data-handbook)

The Proposal is expected to contain preliminary drafts of relevant visualizations for the topic at hand. Tenderers are encouraged to visit the VirES website for inspiration.

- TN-03: A Technical note including use cases that describe user interaction with a visualization User Interface as well as examples (mock-ups) of relevant visualizations, and relevant example data set.

If the resulting data product output by the algorithm cannot be visualized directly (e.g. if the output consists of coefficients defining a model instance) and needs further processing for generating visualization and/or validation data, an implementation of the necessary processing shall be provided (i.e. primarily to help with the VirES visualization software):

- SW-01: An implementation of computational generation of model output data, based on input parameters (e.g. position/time), enabling visualization of the model.

In this case, TN-03 shall also contain a Software documentation section providing information on the use of the software (SW-01), dependencies and references to used algorithms or solutions

Preferred coding languages are Python, C / C++ or Fortran. The choice of other coding languages is permitted, but shall be described in the Tender.

The SW-01 software shall be provided under a license providing Swarm DISC and ESA access and usage rights for the software including the Source Code (e.g. https://opensource.org/licenses/MIT or similar license). Swarm DISC and ESA shall be granted access and usage rights for all used software dependencies.

An example of code that produces field values on a regular grid is the IGRF forward code, available in Fortran and C, at https://www.ngdc.noaa.gov/IAGA/vmod/igrf.html

Another example implementation of model harmonics expansion is provided as Open Source on Github:

https://github.com/ESA-VirES/MagneticModel/

It is based on the WMM (World Magnetic Model): https://www.ngdc.noaa.gov/geomag/WMM/soft.shtml). Reuse of such software (and their extension) might be beneficial in reducing implementation efforts.

4.2.1.3 *Deliverables*

- TN-01
- TN-02
- TN-03
- SW-01 (if applicable)

4.2.2 Task 2: Validation of Processor

4.2.2.1 *Input*

TN-01, TN-02

4.2.2.2 *Task description*

The Tender shall describe relevant validation activities that will be performed during this task.

- TN-04: A Validation Report of the product proving the requirements have been met in Section 3.2 with reference to independent datasets.

4.2.2.3 *Deliverables*

- TN-04 (version 1)

4.2.3 Task 3: Collaboration with VirES

4.2.3.1 *Input*

TN-02, TN-03 (draft versions), SW-01 (if applicable)

4.2.3.2 *Task description*

A joint workshop related to the collaboration on evolving visualizations of new products will be arranged between EOX (the VirES team) and a group of Swarm DISC subcontractors for new products during the Swarm Data Quality Workshop on October 9th-12th 2017, in Delft. Tenderer shall include this workshop in the workplan. Apart from this workshop, collaboration with VirES is primarily expected to take place via Teleconferences.

A first meeting with EOX aiming to refine mutual expectations shall take place during Task 1. Tenderer shall provide initial draft versions of TN-02 and TN-03 and sample data sets to the VirES team in advance and the VirES team may comment and request clarifications.

During Task 2, time shall be allocated to hand over the final version of TN-02, SW-01 and TN-03 including the visualization Use Cases and relevant test data sets to EOX. Time shall also be allocated to collaborate with EOX on specification and validation of relevant visualizations. The Tenderer can expect EOX to make available a password protected Staging Service Environment within VirES - a 'sandbox' where new services can be tested prior to publication.

The contractor shall assist in developing recommendations on tutorial or help text to guide users of the visualization of the product where relevant.

TN-04 shall be updated with a section covering validation and verification of the visualizations in VirES.

During Initial Operation Phase, any remaining activities related to validation of the visualizations in VirES not completed during Task 2 shall be finalized. Verification of visualizations related to samples of the regular updates of the data products provided to PDGS shall be conducted.

4.2.3.3 *Deliverables*

- TN-04 (version 2)

4.2.4 Task 4: Operational preparation

4.2.4.1 *Input*

TN-02

4.2.4.2 *Task description*

Implement functions for operational transfer of data – 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.

- TN-05: A Technical Note documenting implementation of data transfer functions, providing the information required to initiate Transfer To Operation in compliance with Appendix A of [AD-1].

4.2.4.3 *Deliverables*

- TN-05

4.3 Initial Operation

4.3.1 Task 5: Transfer to Operation

4.3.1.1 *Input*

TN-01, TN-02 and TN-05

4.3.1.2 *Task description*

Initiation of Transfer To Operation in collaboration with Swarm DISC System Manager and Integration Specialist.

TN-02 to be published on the Swarm Data Handbook.

First transfer of full data set to be completed and verified. The contractor shall be fully responsible for the data content quality before any data transfer.

4.3.1.3 *Deliverables*

- DL-01: TN-02 posted on Swarm Data Handbook
- DL-02: First delivery of data products to PDGS

4.3.2 Task 6: Operations

4.3.2.1 *Input*

TTO (Task 5) completed

4.3.2.2 *Task description*

Regular delivery of product(s). The contractor shall be fully responsible for the data content quality before any data transfer.

Second-level support - responding to user questions that the ESA helpdesk cannot answer in relation to Swarm gravity field products, via e-mail on a best effort basis.

Delivery of products from start of mission.

Assist verification of visualizations in VirES.

4.3.2.3 *Deliverables*

- DL-03: Regular delivery of data products until end of project.
- DL-04: E-mail replies to 2nd level support questions forwarded from ESA EO helpdesk.
- DL-05: Delivery to PDGS of all data products from start of mission to operational initiation.
- DL-06: Visualizations of VirES have been verified - or a list of recommended action items for improvements approved by Swarm DISC.

4.3.3 Task 8: Final presentation

4.3.3.1 *Input*

All tasks completed

4.3.3.2 *Task description*

The Tenderer shall include at least one peer-reviewed publication on the outcome of this project.

The Tenderer shall prepare and deliver at least one 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

4.3.3.3 *Deliverables*

- DL-07: One peer-reviewed publication submitted
- DL-08: A presentation of project achievements made during a Swarm DQW.
- DL-09: 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 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 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	Technical note describing the Algorithmic Processor(s)
TN-02	Product Definition Documentation
TN-03	Technical note including use-cases for visualisation
TN-04	Validation Report for the product(s)
TN-05	Technical Note documenting implementation of data transfer functionality

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 bimonthly present the status report to the Swarm DISC project office via WebEx. 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.
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 Software deliverables

SW-01 (if applicable)	An implementation of computational generation of model output data, based on input parameters (e.g. position/time), enabling visualization of model – if applicable

5.6 Other deliverables

These are the deliverables beyond the technical documentation listed in Section 5.3:

DL-01	TN-02 posted on Swarm Data Handbook
DL-02	First delivery of data products to PDGS
DL-03	Regular delivery of data products until end of project
DL-04	E- mail replies to 2nd level support questions forwarded from ESA EO helpdesk
DL-05	Delivery to PDGS of all data products from start of mission to operational initiation.
DL-06	Visualizations of VirES have been verified - or a list of recommended action items for improvements approved by Swarm DISC
DL-07	One peer-reviewed publication submitted
DL-08	A presentation of project achievements made during a Swarm DQW
DL-09	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. 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

Mile-stone	Description	Event timeline (months)
MIL-01	Project Kick Off	KO
MIL-02	Delivery 1: TN-01; TN-02; TN-03; TN-04 (version 1); (SW-01)	KO+6
MIL-03	Delivery 2: TN-04 (version 2); TN-05; DL-01; DL-02	KO+8
MIL-04	Final Delivery: DL-03; DL-04; DL-05; DL-06; DL-07; DL-08; DL-09	KO+12