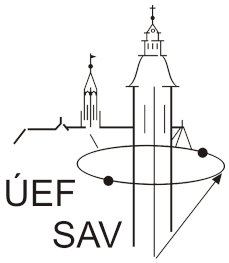

SK-AD03 Slovakia National Space Safety Programme (S2P) Study

ESA Subcontract No. ESA AO/1-10804/21/D/AP

Technical report 8

Mapping of Capabilities and Assets in Slovakia related to ESA SWE frameworks

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1) Introduction

This is Technical report 8 (TR-8) - Mapping of Capabilities and Assets in Slovakia related to Space Weather (SWE) frameworks document that contains a mapping between ESA entities and identified Slovak entities and assets that specialize in activities related to the ESA Space Safety Programme's frameworks Space Weather (SWE) and Vigil mission. This document is a compilation of information to be used as input for TN2 - Capabilities and Assets in Slovakia related to the ESA Space Safety Programme.

2) Applicable and reference documents

2.1) Applicable documents

[AD-1]	SK-S2P: TN1 Collection of Capabilities and Assets in Slovakia related to ESA Space Safety Programme

2.2) Reference document

[RD-01]	ESA Agenda 2025. Available online at: https://esamultimedia.esa.int/docs/ESA_Agenda_2025_final.pdf
[RD-02]	Draft Space Safety Period 2 programme proposal for the Council meeting at Ministerial level in 2022
[RD-03]	Space Weather Service Network. Available online at: https://www.esa.int/Safety_Security/Space_Weather_Service_Network
[RD-04]	Space Weather service Network web portal. Available online at: https://swe.ssa.esa.int/current-space-weather
[RD-05]	Vigil mission characteristics. Available online at: https://eoportal.org/web/eoportal/satellite-missions/v/vigil
[RD-06]	Kraft, S., Lupi, A., Luntama, J.P.: 2019, ESA's distributed space weather sensor system (D3S) utilizing hosted payloads for operational space weather monitoring, Acta Astronautica, 156, 157, https://doi.org/10.1016/j.actaastro.2018.01.020
[RD-07]	SK-AD03: TN1 Collection of Capabilities and Assets in Slovakia related to ESA Space Safety Programme
[RD-08]	TN: ESA Space Weather Network Service - Product Catalogue Portfolio (SSA-SWE-SSCC-TN-0011). Available online at: https://swe.ssa.esa.int/documents
[RD-09]	Mackovjak, Š., et al.: 2021b, Monthly Notices of the Royal Astro. Society, 508, 3, 3111, https://ui.adsabs.harvard.edu/abs/2021MNRAS.508.3111M/abstract
[RD-10]	e-CallistoInternational Network of Solar Radio Spectrometers. Available online at: https://www.e-callisto.org
[RD-11]	NMDB: the Neutron Monitor Database. Available online at: https://www.nmdb.eu
[RD-12]	ADEI: Advanced Data Extraction Infrastructure. Available online at: http://crd.yerphi.am/ADEI
[RD-13]	INTERMAG: International Real-time Magnetic Observatory Network. Available online at: https://intermagnet.github.io

3) Overview of ESA S2P activities in Space Weather

“In the mid-2020s, Europe’s first operational space weather observatory will be nearing launch. Together with NASA and NOAA assets, this mission will feed data into space weather services protecting European infrastructure and astronauts.” - quote from ‘Develop space for safety and security’ - the 3rd of five ESA priorities for Agenda 2025 [RD-01].

The Space Weather (SWE) is in high interest of ESA. The SWE activities within S2P are performed within 3 main frameworks:

- Space Weather Services Network
- Cornerstone space mission - Vigil
- Distributed space weather sensor system (D3S)

In what follows, we provide a brief description of these frameworks with references for a much more detailed description.

3.1) Space Weather Services Network (SWESNET)

ESA Space Weather Services Network (SWESNET) provides timely and accurate information about all main components of space weather (SWE). Its ambition is to use as much as possible ground-based and space-based measurements to provide the nowcast and forecast necessary for SWE warning services. The network consists of five expert service centers (ESC):

- ESC Solar Weather
- ESC Heliospheric Weather
- ESC Space Radiation
- ESC Ionospheric Weather
- ESC Geomagnetic Conditions

The ESCs provide services for the following service domains:

- Spacecraft Design
- Spacecraft Operation
- Human Spaceflight
- Launch Operation
- Transionospheric Radio Link
- Space Surveillance and Tracking
- Power Systems Operation
- Aviation
- Resource Exploitation System Operation
- Pipeline Operation
- Auroral Tourism
- General Data Service

All services can be accessed via the web portal [RD-04]. There is a fully-functional dashboard for each domain to present an overview of the various services and products that are available for the particular domain. The web portal contains a Technical Library that consists of detailed

documentation of all available SWE products and services. Currently, 29 services provide over 200 products addressing around 50% of the requirements. The web portal is used by more than 2000 registered users with 1.5 - 2.0 M hits per month [RD-02]. The map of more than 50 space weather services providers by country and by ESC is displayed in Figure 3.1.1.

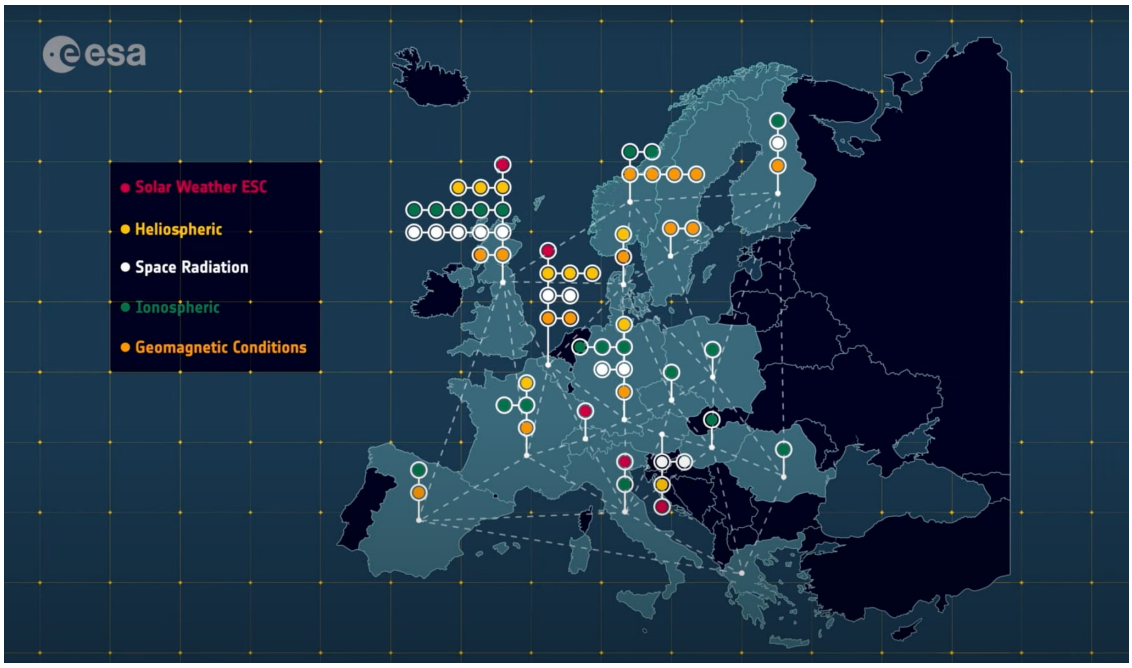

Figure 3.1 – ESA SWE services network (Credit: ESA)

3.2) Vigil mission

Vigil is a planned space weather mission, formerly known as Lagrange 5 mission. It is a Cornerstone space mission within the Space Safety Programme (S2P). Its aim is to monitor SWE and provide near real-time data of potentially dangerous events for vulnerable technologies and astronauts. The Vigil will be located in the L5 vantage point to observe solar structures before they will be faced towards Earth's direction. Even more, it will provide a side-view of the propagation of plasma emitted by the Sun toward the Earth. The instrumentation would consist of: Heliospheric Imager, Magnetograph, Compact Coronograph (provided by NOAA), Plasma Analyser (PLA), and Magnetometer (MAG). Phase B2 will be re-issued in 2022 [RD-02]. The patch of the Vigil mission is displayed in Figure 3.2.1. The name is derived from Latin ‘vigilis exceptus’ which means sentry, or guard, while ‘vigilia’ means wakefulness and the act of keeping a devoted watch. The main characteristics can be found in [RD-05] and references therein.

Figure 3.2 – ESA Vigil mission patch. (Credit: ESA)

3.3) Distributed Space Weather Sensor System (D3S)

The main objective of the D3S is to monitor SWE directly in the space environment [RD-06]. The observations consist of in-situ and imaging observations of the magnetic field, neutral/charged particles, auroral oval, upper atmosphere, and other parameters needed for SWE services. D3S utilizes hosted SWE payloads (as SOSMAG, NGRM) on satellites, SmallSat missions, and nanosatellites. The development of these new instruments is in coordination with the ESA Technology Programmes. One of the most important activities within D3S is the development of Aurora - constellation (4 - 6) of SmallSats with a wide field of view imagers dedicated to monitoring aurora and so the interconnection of magnetosphere-ionosphere-thermosphere in the polar region. Another cost-effective approach is the location of radiation monitors, magnetometers, and other in-situ detectors on the nanosatellites platforms. The particular nanosatellite missions will be considered based on resources and funding [RD-02].

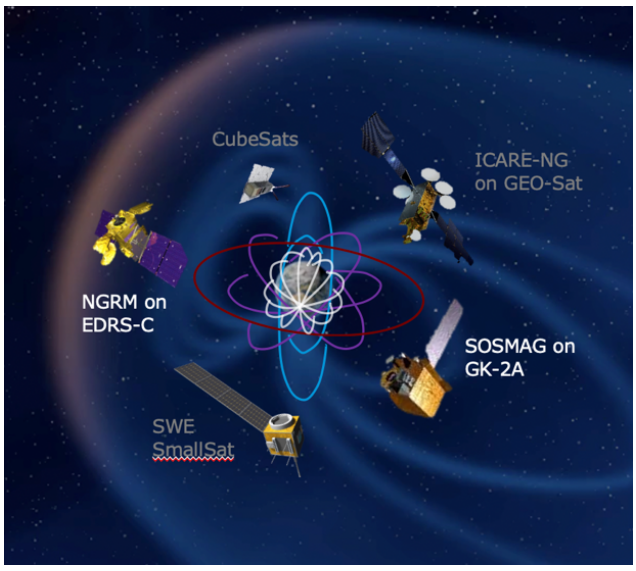

Figure 3.3 – Illustration of Distributed Space Weather Sensor System (D3S) (Credit: ESA)

4) Identified capabilities list

This section contains all identified Slovak capabilities listed in [RD-07] and additional capabilities identified during writing of this report that could be related to the SWE activities presented in Section 3. For each capability, an overview is provided and references to the sources used for the data compilation.

Table 4.1: List of identified Slovak SWE capabilities related to ESA SWE activities (capabilities are in order according to Section 3).

Capability / Asset	OPERATOR	TYPE	SWE framework
Halpha Solar images*	Slovak Central Observatory Hurbanovo (SUH)	Product	SWESNET - Solar Weather
White light Solar images*	SUH	Product	SWESNET - Solar Weather
Sunspot number*	Astronomical Observatory Prešov (AOP)	Product	SWESNET - Solar Weather
CoMP-S	Astronomical Institute, Slovak Academy of Sciences (AI SAS)	Product	SWESNET - Solar Weather
eCallisto*	SUH	Product	SWESNET - Solar Weather
SCSS-Net*	Institute of Experimental Physics, Slovak Academy of Sciences (IEP SAS)	Service	SWESNET - Solar Weather
Neutron monitor	IEP SAS	Product	SWESNET - Space Radiation
SEVAN	IEP SAS	Product	SWESNET - Space Radiation
Models of energetic astroparticles	IEP SAS	Product	SWESNET - Space Radiation
ASPIS	IEP SAS	Service	SWESNET - Ionospheric Weather
MSTID*	IEP SAS	Product	SWESNET - Ionospheric Weather
AMON-ES, AMON-net	IEP SAS	Product	SWESNET - Ionospheric Weather / Geomagnetic Conditions
Data-driven prediction services*	Faculty of Electrical Engineering and Informatics, Technical University of Košice (FEI, TUKE)	Service	SWESNET - Geomagnetic Conditions
INTERMAGNET	Earth Science Institute, Slovak Academy of Sciences (ESI SAS)	Product	SWESNET - Geomagnetic Conditions
Geomagnetic measurements	Faculty of Mathematics, Physics and Informatics, UK (FMPI)	Product	SWESNET - Geomagnetic Conditions
Space R&D infrastructure	IEP SAS	Service	Vigil, D3S
Vigil data processing system*	IEP SAS	Service	Vigil
Space data center*	IEP SAS	Service	SWESNET, Vigil, D3S

* These specific Capabilities / Assets were identified after submission of [RD-07] thanks to review of ESA needs. They represent extension of already mentioned capabilities or additional capabilities for already mentioned entities in [RD-07].

- **Halpha Solar images**: Solar chromosphere images in H-alpha spectral line (656 nm) are product that can be provided by Slovak Central Observatory Hurbanovo (SUH) and also by

observatories in Prešov and Rimavská Sobota. Images are acquired on the daily basis according to weather conditions. Coordination of the measurements among observatories might increase the duty cycle.

- **White light Solar images**: Solar photosphere images are product that can be provided by Slovak Central Observatory Hurbanovo (SUH) and also by observatories in Prešov and Rimavská Sobota. Images are acquired on the daily basis according to weather conditions. Coordination of the measurements among observatories might increase the duty cycle.

- **Sunspot number**: The international sunspot number measurements are product that can be provided by the Astronomical Observatory in Prešov - the coordinator of these measurements in Slovakia. The sunspot number is calculated on the daily basis according to weather conditions. Coordination of the measurements among observatories might increase the duty cycle.

- **CoMP-S**: Coronal Multi-Channel Polarimeter is dedicated to the observation of solar corona in visible and IR spectral range by ground-based coronagraphs located at high altitude observatory Lomnicky stit (LSO). The products might be valuable for the Solar weather domain as there are not yet any ground-based coronographs in the SWESNET. Refer to [RD-07] for technical details of possible products.

- **eCallisto**: Radio solar spectrometer (45 – 800 MHz) that provides radio spectrograms as a product of an international network [RD-10]. The data are already included in the Solar weather domain.

- **SCSS-Net**: Solar Corona Structures Segmentation by the deep neural network is a service that requires images of the solar corona as input and provides automatic segmentation of solar corona structures (e.g. coronal holes, active regions) as output. The segmentation can be expressed as e.g. total area within the solar disc, heliographic coordinates, lifetime, etc. The approach is based on deep neural networks and all details are presented in [RD-09].

- **Neutron monitor:** This is a continuous measurement of secondary cosmic rays at high altitude observatory Lomnicky stit (LSO). Cutoff rigidity is ~ 4 GV. It is a component of the international network of neutron monitors that provide important data for the Space Radiation domain. All the details are available online [RD-11].

- **SEVAN:** Space Environmental Viewing and Analysis Network detects changing fluxes of different species of secondary cosmic rays at different altitudes and latitudes, thus turning into a powerful integrated device used to explore solar modulation effects. The SEVAN located at LSO is one of seven operating instruments that provide data available online via ADEI [RD-12].

- **Models of energetic astroparticles:** Theoretical models of the dynamics of low energy cosmic rays (CR) and of suprathermal cosmic particles, as well as high energy CR based on measurements in space and on the ground. They are focused on the modulation of CR at very high energies of 50, 100, 150, and 200 GeV per 1 AU.

- **ASPIS:** Autonomous Service for Prediction of Ionospheric Scintillations is a service that requires adequate space weather as an input and provides predictions of the occurrence of ionospheric scintillations as output for a particular location. The development of ASPIS is in progress within ESA / PECS SK6-29 activity. The proof-of-concept is expected to be demonstrated in Q2 / 2023.

- **MSTID:** Medium Scale Travelling Ionospheric Disturbances activity will be measured by the ionospheric Doppler sounder located in East Slovakia. It will operate in coincidence with AMON-ES measurements and with MSTID service over Czechia provided by the Department of Ionosphere and Aeronomy (IAP CAS). Initial installation is planned for Q3 / 2022.

- **AMON-ES, AMON-net**: Airglow Monitor - Extended Station and Airglow Monitor - Network is technology dedicated to the observation of airglow and so variation in the thermosphere. The following airglow emissions can be monitored: UV (300 - 480, generated by molecular oxygen), green (557.7 nm, generated by atomic oxygen), red (630.0 nm, generated by atomic oxygen), IR (700 - 900 nm, generated by hydroxyl molecules). The technology works as standalone products that acquire data and store them in a database for further usage. The products are developed and tested within ESA / PECS SK2-09 activity.

- **Data-driven prediction services**: The services are based on state-of-the-art machine learning techniques that employ long-term measurements of geomagnetic conditions - such as the Dst index (Disturbance storm time). The basic principles have been observed and the application has been formulated. When the proof-of-concept will be demonstrated for Dst, utilization of the service for other indices will be considered and explored.

- **INTERMAGNET**: It is a global, real-time, permanent geomagnetic observatory network, which is recognized as a key Earth observation system and which provides data that serves scientific research into the Earth, from its deep interior to space, and supports operational services benefiting society. More details can be found online [RD-13].

- **Geomagnetic measurements**: The measurements of Earth's magnetic field and magnetometric products are provided by the Astronomical and Geophysical Observatory in Modra. The premises of the observatory are suitable for the installation of new geomagnetic detectors.

- **Space R&D infrastructure:** The infrastructure can be used for the development and testing of HW and SW components. It consists of the specialized space engineering laboratories for electronics and mechanical design, construction and testing (PCB prototype manufacturing in CNC machine, soldering, thermal-vacuum testing, physical calibration/clean room, vibration testing, EMC testing), software development (workstations with software for electronics CAD - Altium designer, mechanical 3D design - SolidWorks, development tools for many microcontrollers and FPGA platforms), measuring instruments (high-speed multi-channel mixed-signal oscilloscopes, signal generators, high-speed counters, precision multimeters, laboratory power supplies, high voltage power

supply, etc.). The mechanical laboratory is fully equipped for mechanical manufacturing (manual milling and drilling machines, lathes, etc.).

- **Vigil data processing system:** The identified Slovak contribution to the Vigil mission would consist of data processing, which would imply ground segment and specifically PDC/expert group processing systems.
- **Space data center:** The data center is used for gathering, processing, and storage of data generated by IEP SAS assets. It allows access to archived data via the web interface to visualize and download data for a specific time period. The data center might be extended to handle data from other Slovak assets and to provide a straightforward connection to the ESA SWESNET portal. According to the plan, the system will be refactored with the help of IT entities located in Košice (GlobalLogic Slovakia, SPACE::LAB startup, FEI TUKE).

5) Technology readiness levels assessment

This section contains the TRL assessment of each identified space weather capability and asset that was mentioned in Section 4. Each capability is also described with regard to specific ESA technology.

Table 5.1: List of identified Slovak SWE capabilities and assets with regard to particular ESA SWE technology.

Slovak SWE technology			**ESA technology**	
Capability / Asset	**TRL**	**Description with regard to ESA technology**	**Capability / Asset**	**TRL**
Halpha Solar images	5	The verification in the relevant environment has been demonstrated. It can provide additional information to various products within Solar Weather ESC.	S.103 SIDC/USET Halpha Solar images, S.107a UGraz/KSO Halpha Solar images, S.122 INAF/OACT Halpha Solar images. Refer to [RD-08] for a detailed description and links to technology operation.	7
White light Solar images	5	The verification in the relevant environment has been demonstrated. It can provide additional information to various products within Solar Weather ESC.	S.104 SIDC/USET White light Solar images, S.107e UGraz/KSO White light Solar images, S.121 INAF/OACT White light Solar images. Refer to [RD-08] for a detailed description and links to technology operation.	7
Sunspot number	6	The system has been demonstrated in a relevant environment. It can provide additional information to product S.108 SIDC/SILSO International sunspot number	S.108 SIDC/SILSO International sunspot number. Refer to [RD-08] for a detailed description and links to technology operation.	7
CoMP-S	4	The functional verification of solar corona polarimetry has been performed. It can provide unique information to Solar Weather Expert Service Center (ESC) specifically spectral profiles of the emission lines from prominences and the solar corona.	S.051a Maps of the thermal structure of the solar corona. Refer to [RD-08] for a detailed description and links to technology operation.	7

eCallisto	7	The system is fully operational and products are provided within S.105b eCallisto Solar radio spectrograms.	S.105b eCallisto Solar radio spectrograms. Refer to [RD-08] for a detailed description and links to technology operation.	7
SCSS-Net	2-3	The application has been formulated and proof-of-concept has been partially demonstrated [RD-09]. It can provide additional and more precise information to product S.126 based on SPoCA suite software and to product S.101c SIDC Solarmap.	S.126 (Solar Influences Data analysis Center) SIDC Automated coronal hole detection. S.101c SIDC Solarmap. Refer to [RD-08] for a detailed description and links to technology operation.	7
Neutron monitor	7	The system is fully operational and products are provided within R.108 Multi-station neutron monitor data.	R.108 Multi-station neutron monitor data. Refer to [RD-08] for a detailed description and links to technology operation.	7
SEVAN	6	The system has been demonstrated in a relevant environment. It can provide an additional product to Space Radiation ESC.	R.108 Multi-station neutron monitor data. Refer to [RD-08] for a detailed description and links to technology operation.	7
Models of astroparticles	3	It can provide additional information to R.140 Static radiation model of energetic protons at LEO.	R.140 Static radiation model of energetic protons at LEO. Refer to [RD-08] for a detailed description and links to technology operation.	7
ASPIS	2	The development towards demonstration of proof-of-concept is in progress. It can provide additional information to Ionospheric Scintillation Monitoring service I.122.	I.122 Ionospheric Scintillation Monitoring service. Refer to [RD-08] for a detailed description and links to service operation.	7
MSTID	1	The network operated by IAP CAS will be extended also in Slovakia. The measurements will provide additional information to I.136 MSTID activity over Czechia.	I.136 MSTID activity over Czechia Refer to [RD-08] for a detailed description and links to technology operation.	7
AMON-ES, AMON-net	4	The functional verification is ongoing. It can provide additional information to Auroral Visible Imaging and to Thermosphere Expert Center that is planned for the future.	G.146 Auroral data from Kiruna, G.166 Auroral images (Scotland). Refer to [RD-08] for a detailed description and links to service operation.	7
Data-driven prediction services	2	The basic principles have been observed and the application for the forecast purposes has been formulated. It can provide additional information to G.128 Geomagnetic Storm Occurrence and G.135 Forecast of Dst.	G.128 Geomagnetic Storm Occurrence G.135 Forecast of Dst Refer to [RD-08] for a detailed description and links to service operation.	7
INTERMAGNET	7	The system has been demonstrated in a relevant environment. It can provide additional information to G.113 Forecasts of dB/dt.	G.113 Forecasts of dB/dt Refer to [RD-08] for a detailed description and links to service operation.	7

Geomagnetic measurements	5	The magnetometer has been verified in the relevant environment. It can provide additional information to G.101 Magnetogrammes from North(West) Europe and Greenland.	G.101 Magnetogrammes from North(West) Europe and Greenland. Refer to [RD-08] for a detailed description and links to service operation.	7
Space R&D infrastructure	5	The infrastructure has been used for the development, construction, and testing of the JDC detector for ESA mission JUICE. It can be used for the development of sub-components for Vigil mission and/or for components within D3S.	Vigil mission D3S - Distributed Space Weather Sensor System	9
Vigil data processing system	1	The initial idea has been formulated by the Vigil mission team as an opportunity for Slovak participation in Vigil mission.	Vigil mission	N/A
Space data center	4	Data center is used for gathering, processing, and storage of data from Neutron monitor, SEVAN, AMON-net, and other detectors. It can be used for data handling from other Slovak assets for a direct connection to SWESNET. It can be also used for data handling from Vigil and D3S sensors.	SWESNET Vigil D3S	7

ESA products and services listed in Table 5.1 are described in detail in [RD-08]. Here we provide very basic characteristics extracted from this Product Catalogue to simplify the navigation through documents.

- **S.103 SIDC/USET Halpha Solar images**: H-alpha solar chromosphere images produced by the Solar Influences Data analysis Center (SIDC) local observing facilities (Uccle Solar Equatorial Table). SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/sidc-S103-federated
- **S.107a UGraz/KSO Halpha Solar images**: H-alpha solar chromosphere images produced by Kanzelhöhe Observatory every day from about 8:00 to 16:00 CET/CEST. SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/kso-S107a-federated
- **S.122 INAF/OACT Halpha Solar images**: H-alpha solar chromosphere images produced by Catania Astrophysical Observatory. SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/catania-S122-federated
- **S.104 SIDC/USET White light Solar images**: Solar white light images of photosphere produced by the Solar Influences Data analysis Center (SIDC) local observing facilities (Uccle Solar Equatorial Table). SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/sidc-S104-federated
- **S.107e UGraz/KSO White light Solar images**: Solar white light images of photosphere produced by Kanzelhöhe Observatory every day from about 8:00 to 16:00 CET/CEST. SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/kso-S107e-federated

- **S.121 INAF/OACT White light Solar images**: Solar white light images of photosphere produced by Catania Astrophysical Observatory. SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/catania-S121-federated

- **S.108 SIDC/SILSO International sunspot number**: The World Data Centre for the International Sunspot Number collects observations of sunspots from a network of about 85 observers around the world and produces the daily International Sunspot number and its monthly and yearly means. SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/sidc-S108-federated

- **S.051a Maps of the thermal structure of the solar corona**: This service provides maps of parameters of a Differential Emission Measure (DEM) model as a function of temperature: temperature (T), Emission Measure (EM), width of the DEM, and goodness of fit ($\chi 2$). These maps are derived from SDO/AIA observations. SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/medoc-S051a-federated

- **S.105b eCallisto Solar radio spectrograms**: The e-Callisto Network provides solar radio spectrograms from observing stations spread around the globe. The data are used for the identification of radio bursts as indications of Solar phenomena driving Space Weather. SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/ecallisto-federated

- **S.126 SIDC Automated coronal hole detection**: The coronal holes are automatically detected in EUV solar images from SDO/AIA data at 193Å using the SPoCA suite software. SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/sidc-S126-federated

- **S.101c SIDC Solarmap**: This service allows the user to display solar features (such as sunspots, coronal holes, filaments, etc.) on the solar disc. SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/sidc-S101c-federated

- **R.108 Multi-station neutron monitor data**: The multi-station Neutron Monitor data provides continuous measurements of galactic cosmic rays from neutron monitors located around the world. SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/anemos-federated

- **R.140 Static radiation model of energetic protons at LEO:** A static radiation model for protons at LEO for regions covered by the high quality PROBAV/EPT data. SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/csr-ept-federated

- **I.122c-m Ionospheric Scintillation Monitoring service (ISM)**: Near-real-time nowcast and forecast worldwide and continental map and error map of phase scintillation index, based on GISM model and assimilated data from dedicated scintillation receivers (MONITOR) and geodetic GNSS receivers (IGS, SOPAC, CORS). SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/ism-public/

- **I.136 MSTID activity over Czechia**: Detection of Medium Scale Travelling Ionospheric Disturbances (MSTID) activity in the ionosphere from the ionospheric Doppler sounder measurements. SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/cas-iap-federated

- **G.146 Auroral data from Kiruna**: The product provides access to all-sky images from IRF

Kiruna digital all-sky camera (DASC) for both real-time and from the archive with 1-minute resolution. SWESNET portal entry point: https://swe.ssa.esa.int/irf-aurora-federated

- **G.166 Auroral images**: A selection of auroral images captured automatically by a camera at Lerwick observatory. SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/BGS-federated
- **G.128 Geomagnetic Storm Occurrence**: Geomagnetic storm alert predicting a variation greater than 50 nT, provided by Universidad de Alcalá. SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/uah-senmes-federated
- **G.135 Forecast of Dst**: Forecast of Dst index with up to 2 hours lead-time, provided by Swedish Institute of Space Physics. SWESNET portal entry point: https://swe.ssa.esa.int/irf-federated
- **G.113 Forecasts of dB/dt**: Forecast of the 30-minute maximum of horizontal|dB/dt| with lead times between 20 to 80 minutes depending on solar wind speed, provided by Swedish Institute of Space Physics. SWESNET portal entry point: https://swe.ssa.esa.int/irf-federated
- **G.101 Magnetogrammes from North(West) Europe and Greenland**: This product provides magnetograms from several ground magnetometer stations, sorted by the responsible institute. Each station measures the variations in the Earth's magnetic field in three directions orthogonal on each other. SWESNET portal entry point: https://swe.ssa.esa.int/web/guest/nrt-mag-federated

6) Overview of international collaboration

This section contains current international cooperation in the area of space weather. The international partners with active contacts are presented for each Slovak entity listed in [RD-07].

Table 6.1: List of Slovak SWE entities and their active international partners within ESA.

Slovak Entity	Domain	Partner	Country	Partner's contact person
Institute of Experimental Physics, Slovak Academy of Sciences (IEP SAS)	Heliospheric weather, Ionospheric weather	Institute of Atmospheric Physics, Czech Academy of Sciences https://www.ufa.cas.cz/en/homepage-en/	CZ	Prof. Ondřej Santolík, Dr. Jaroslav Chum
	Heliospheric weather	Swedish Institute of Space Physics https://www.irf.se/en/	SE	Prof. Stas Barabash
	Heliospheric weather	Space Technology Ireland https://www.maynoothuniversity.ie/	IE	Prof. Susan McKenna-Lawlor
	Heliospheric weather	Faculty of Mathematics and Physics, Charles University https://www.mff.cuni.cz/en	CZ	Assoc. Prof. Lubomír Přech

	Ionospheric weather	Ionosphere Monitoring and Prediction Center, German Aerospace Center (DLR) https://impc.dlr.de	DE	Dr. Martin Kriegel
	Ionospheric weather	German Remote Sensing Data Center, DLR https://www.dlr.de/eoc/en/desktopdefault.aspx/tabid-5289/9001_read-16754	DE	Prof. Michael Bitner
	Solar weather	Institute for Data Science, FHNW - University of Applied Sciences Northwestern Switzerland https://www.fhnw.ch/en/about-fhnw/schools/school-of-engineering/institutes/institute-for-data-science	CH	Prof. André Csillaghy
	Solar weather	Astronomical Institute, Czech Academy of Sciences https://www.asu.cas.cz/en/about/about-the-institute	CZ	Dr. Jaroslav Dudík, Dr. Elena Dzifčáková
	Space radiation	Nuclear Physics Institute, Czech Academy of Sciences http://www.ujf.cas.cz/en/	CZ	Dr. Iva Ambrožová
	Space radiation	Faculty of Mathematics and Natural Sciences, Kiel University https://www.mnf.uni-kiel.de/en, https://www.nmdb.eu/impressum/	DE	Dr. Christian Steigies
Astronomical Institute, Slovak Academy of Sciences (IEP SAS)	Solar weather	Astronomical Institute, Czech Academy of Sciences https://www.asu.cas.cz/en/about/about-the-institute	CZ	Dr. M. Bárta
	Solar weather	University of Graz, Institute of Physics, Graz, Austria https://physik.uni-graz.at/en/igam/	AT	Dr. A. Veronig
Slovak Central Observatory Hurbanovo (SUH)	Solar weather	Geophysical and Astronomical Observatory, University of Coimbra https://www.uc.pt/	PT	Dr. R. Gafeira
Earth Science Institute, Slovak Academy of Sciences (ESI SAS)	Geomagnetic conditions	Institute of Geophysics of the Czech Academy of Science https://www.ig.cas.cz/en/	CZ	Dr. Pavel Hejda