

Space Weather International Collaboration and R2O2R in the ESA Space Safety Programme

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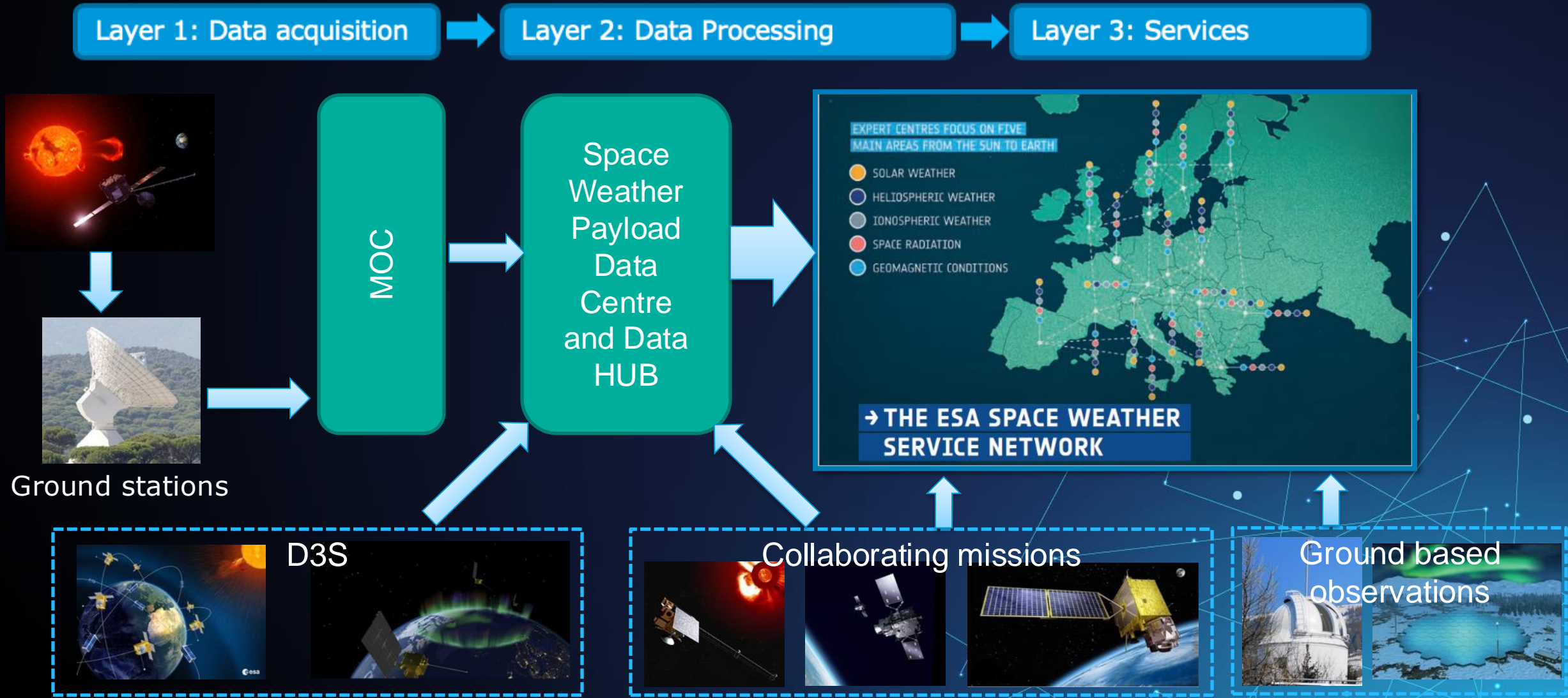
Space Weather in ESA S2P – Objectives

ESA will contribute in a coordinated European context to

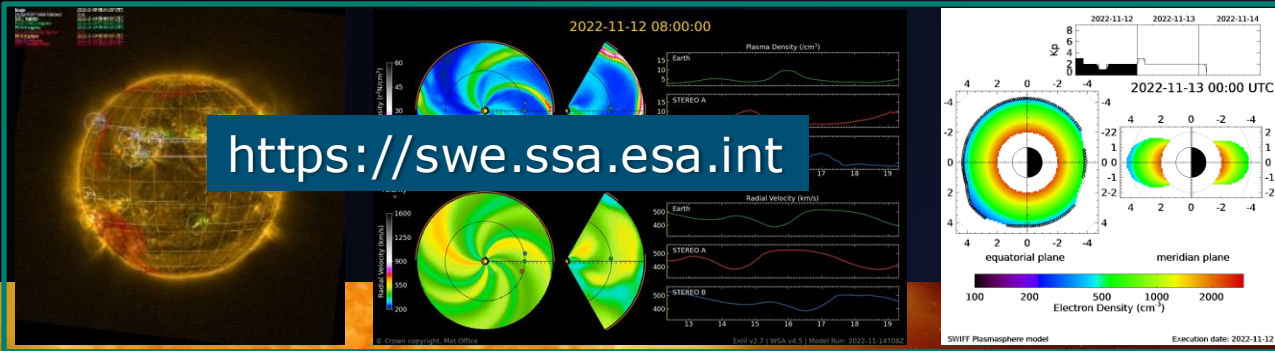
- Development of an operational space weather monitoring system
- Development of capability to provide services tailored to European user needs
- Definition of long term maintenance and enhancement plan
- Implementation of tested and exercised early warning system enabling prompt responses
- Development of world class R2O/O2R framework
- Support scientific research through open data policy



Development of Space Weather Capabilities in Europe



ESA Space Weather Service Network



SWE Service Network Provides:

- 29 services built on >300 data products & tools
- 95% overall availability & NWH helpdesk support
- Full Sun-Earth chain, coupled modelling
- Timely & reliable user tailored notifications & alerting

Who uses the services?

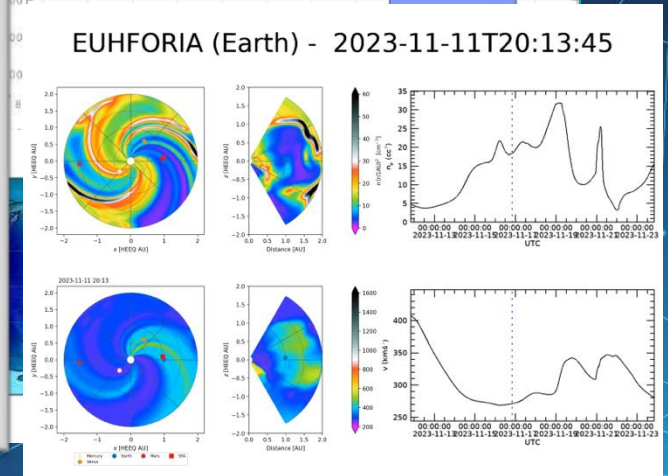
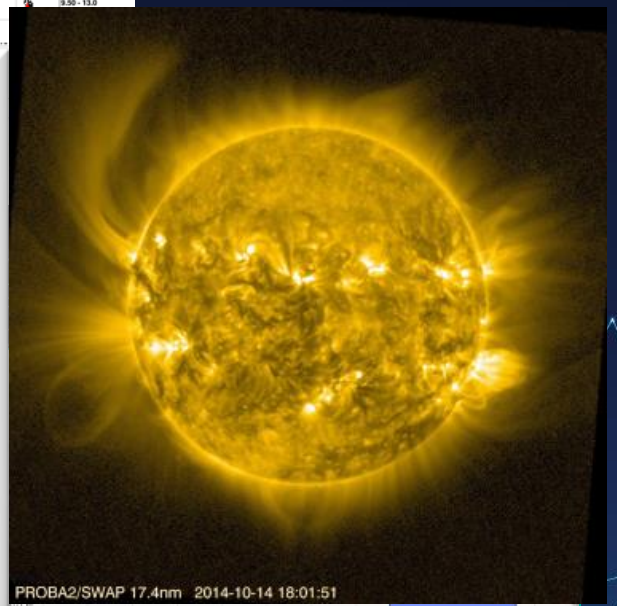
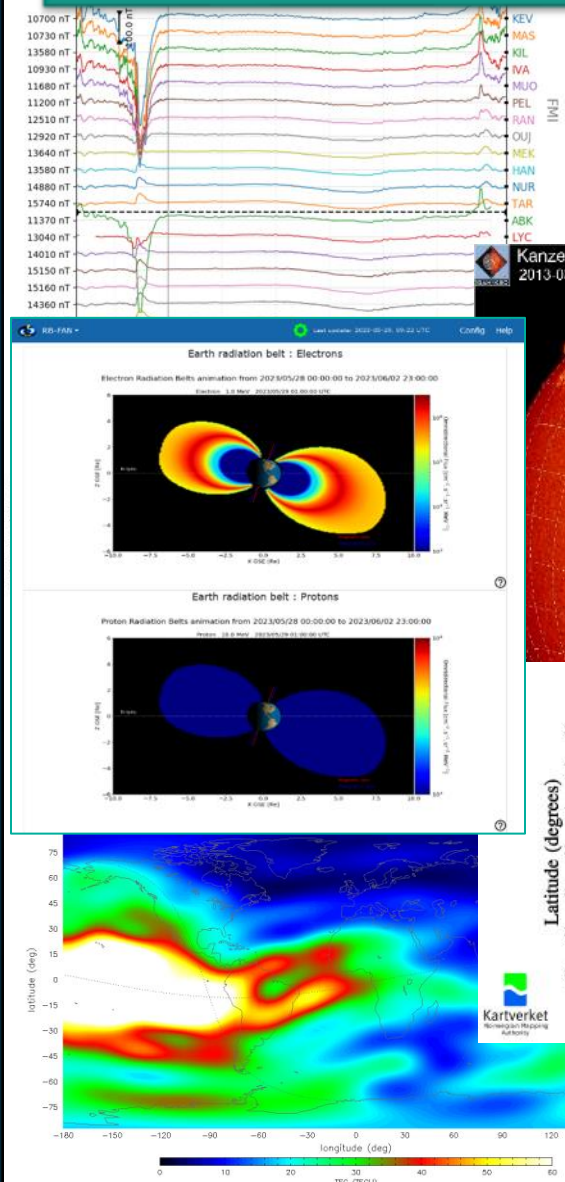
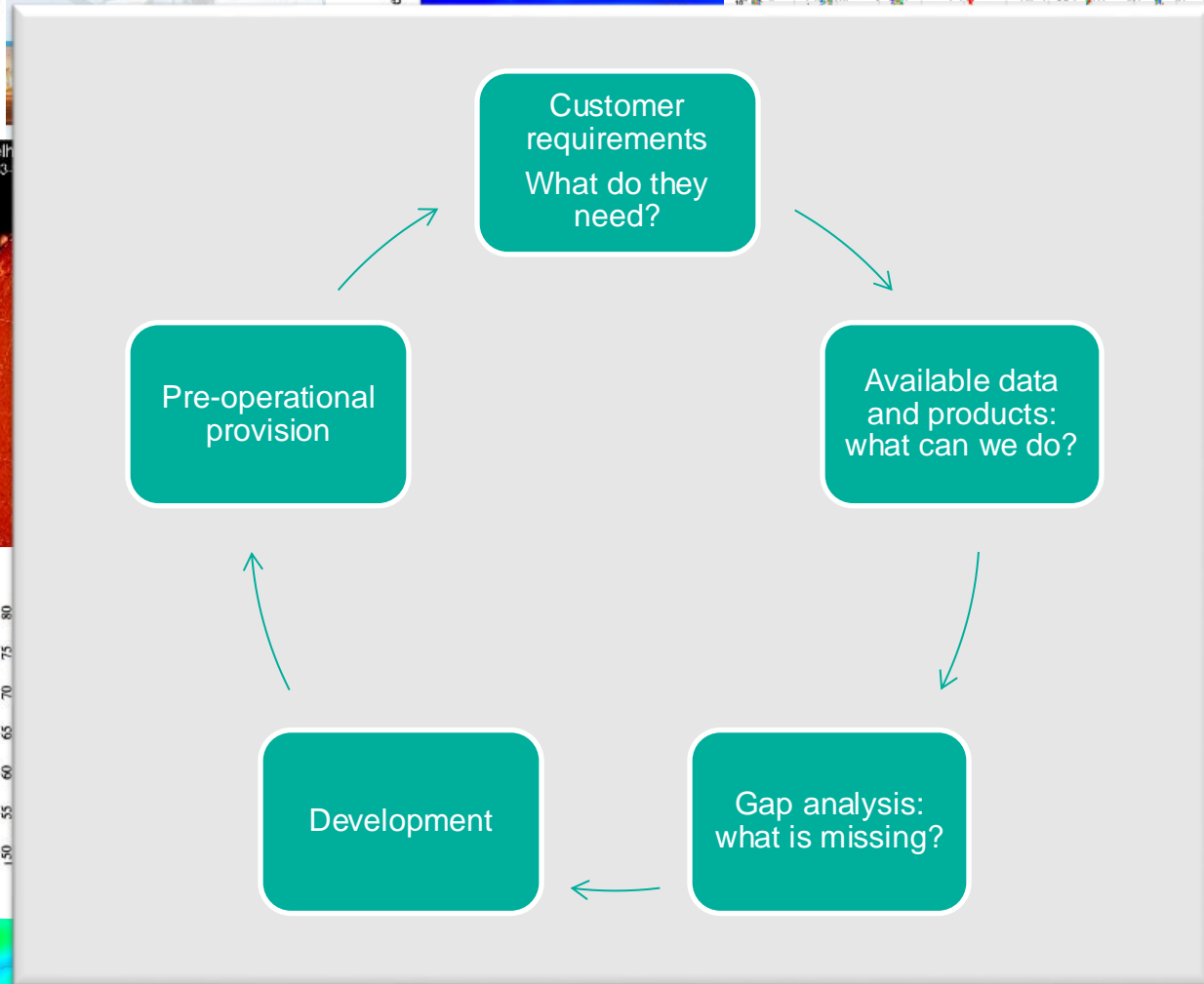
- >4500 registered users
- >2M hits on portal monthly
- All affected sectors, plus national & regional agencies

Who participates?

- >50 institutes, industry, academic groups
- Building on & strengthening European assets & expertise



Space Weather Capability Development



- Needed at multiple stages in R2O(2R) process
 - Validate underpinning models and algorithms: limited cases, usually a reflection of “best case” scenario during early development
 - Verify product provision in (pre-)operational context: performance assessment with uncorrected real-time data for a wide range of conditions
 - *Results may be different but both are necessary for operational transition!*
- Towards consistent validation & verification as a community standard
 - Recommended validation methodologies
 - Methods & metrics
 - Guidelines for validation campaigns
 - Continuous validation post deployment
- SWE Service Network provides unique opportunity for testing, demonstration and collaboration towards community consensus on current capabilities and benchmarking

Upcoming! P3-SWE-XLIV SWEVEN:
Online collaborative platform for validation & analysis

The image shows a screenshot of the ESA website. On the left, there is a 'JupyterLab Campaigns' section with a table listing campaigns. On the right, there is a 'TECHNICAL NOTE' document titled 'Guidelines for common validation in the SSA SWE Network'. Below the table is a screenshot of a JupyterLab interface showing a notebook with a plot of trajectories.

Campaign name	Expert Service Center	Data Center
<input type="checkbox"/> Model A Campaign	Solar Weather	RAJL Space
<input type="checkbox"/> Model B Campaign	Long Name Expert Service Center	Long Name S
<input type="checkbox"/> Model C Campaign	Space Radiation	Space Data C

TECHNICAL NOTE
Guidelines for common validation in the SSA SWE Network

Prepared by: I. Tsagouri, C. Borries, C. Perry, M. Dierckxens, J. de Patoul, C. Cid, T. Moretto-Jorgenson,
Reference: ssa-swe-escldef-tn-5401
Issue/Revision: 3.2
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European Space Agency
Agence spatiale européenne

<https://swe.ssa.esa.int/documents>

Implementation of standardised R2O(2R) process

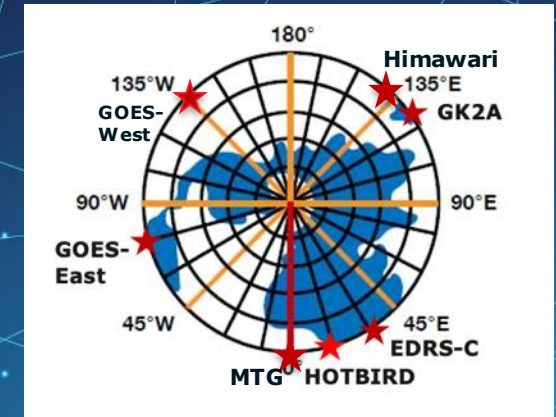
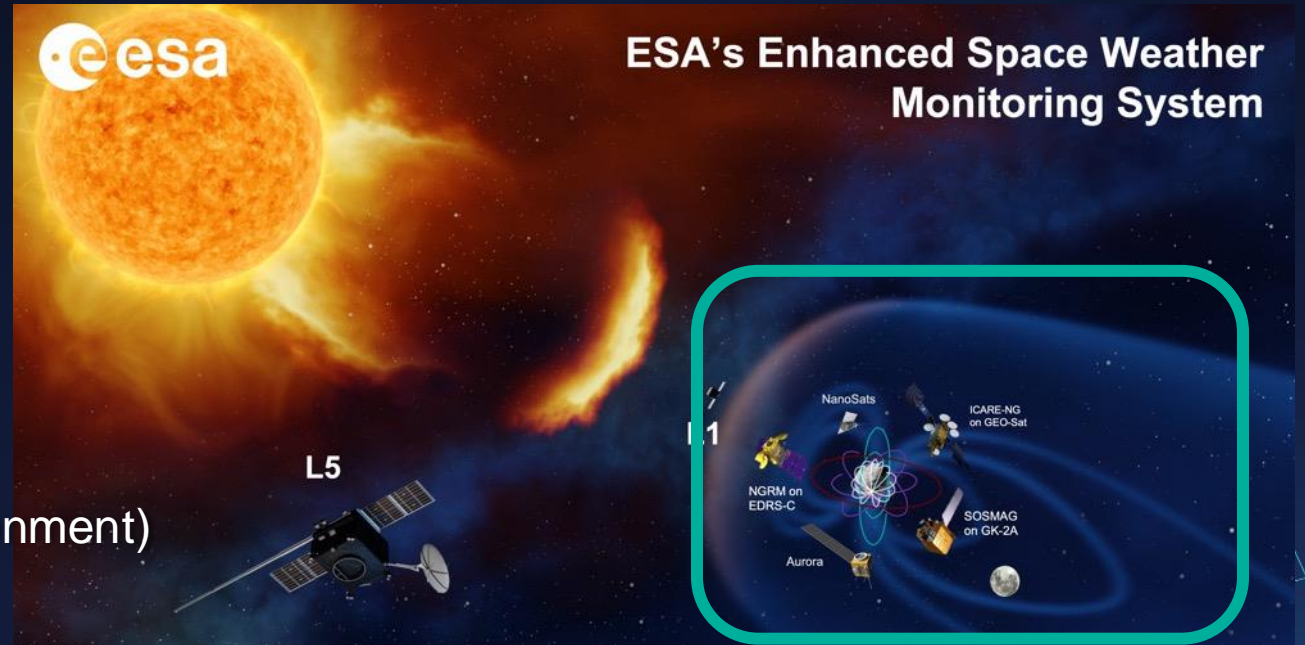
- User engagement from the start of the development process through to testing of end results
 - Builds on continuous reliable provision with end user in the loop
- Consistent validation & verification approach as a community standard at different stages in the development & implementation process
 - Builds on standardised methodologies, metrics & tools
- Recognition that users have different needs & levels of expertise and are looking for different types of information accordingly.
 - R2O: development of tailored capabilities
 - O2R: feedback on needs, usability, user workflows & procedures



ESA S2P Space Weather Monitoring Missions

Missions Overview:

- Hosted Payloads (radiation environment, plasma, magnetic field)
- Nanosat constellations (LEO radiation environment, upper atmosphere)
- Aurora (Auroral oval)
- ERSa, MiniRMU/Lunar Pathfinder (radiation environment)
- SWORD (Radiation belts)
- Deep space: Vigil mission to L5



Vigil Mission – Collaboration in Solar Monitoring



Coronagraphy:
CCOR

Heliospheric
Imaging: HI

Magnetography: PMI



EUV imaging:
JEDI

Solar wind:
PLA

IMF: MAG



- Continuous observations of Sun and heliosphere between Earth and the Sun from L5 vantage point
- Data availability in near real-time => operational applications + bonus science
- Launch: **2031**
- Complementing SWFO L1/SWFO Next L1 observations from Sun-Earth line
- When can we add L4 observations?

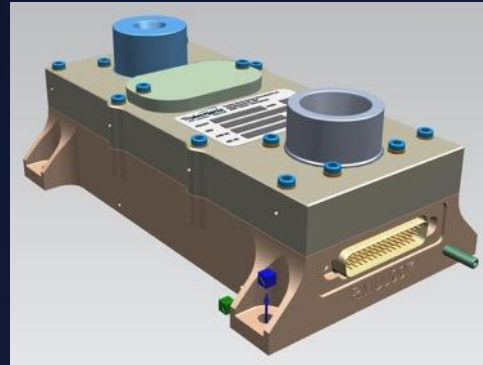


https://www.esa.int/Space_Safety/Vigil

Cislunar Hosted Payload Missions

- MiniRMU on Lunar Pathfinder

- Monitoring of high energy electrons and protons
- Planned launch in 2025

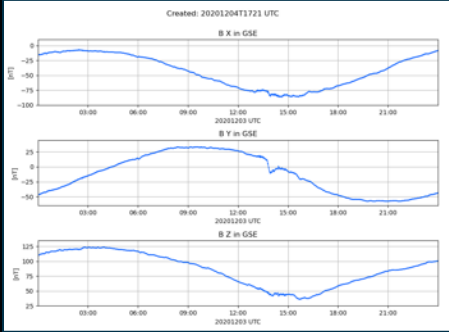


- ERSA on Lunar Gateway

- Comprised of several radiation monitors, dosimeters and magnetometers
- Close collaboration with NASA solar physics HERMES payload
- Planned launch end 2025



Collaboration with International Partners and Industry



NGRM – Next Generation Radiation Monitor on EDRS-C

NGRM data is provided as part of the ESA Service Network's General Data Service. Access it via the ESA Data Browser or the ESA API.

The Instrument

NGRM is the second Space Weather instrument flying as part of ESA's Distributed Space Weather Sensor System (DS3). It is hosted on the European Data Relay System - C (EDRS-C) spacecraft, located in GEO at 31° East.

Figure 1: Illustration of DS3 Distributed Space Weather Sensor System payload elements to be received through several payload modules as well as dedicated small satellite missions.

NGRM entails two particle sensors, the electron detector (ED) consisting of 16 circular silicon strip detectors with a circular strip collimator on top, and the stacked detector (SD) comprising an assembly of seven silicon detectors layered with several aluminum and tantalum degraders. Incident charged particles are registered according to the detector logic in one of 14 electron or one of 18 proton channels. (J. Desorgher et al., 2013)

Figure 2: The NGRM flight model with the detector system in the right of the instrument and the data handling and I/O electronics in the left part. ED and SD have been calibrated with both experimental and numerical means. The electron (proton) response functions (RF) of ED and SD have been derived using An and linear beam GEANT4 simulations slightly to experimental results based on the work experimental calibration at the Fermi Irradiation and the Electron Microstructural Facilities at Paul Scherrer Institute, Switzerland.

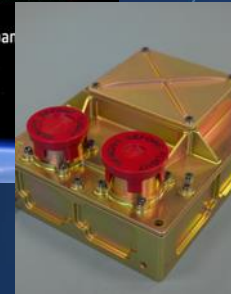
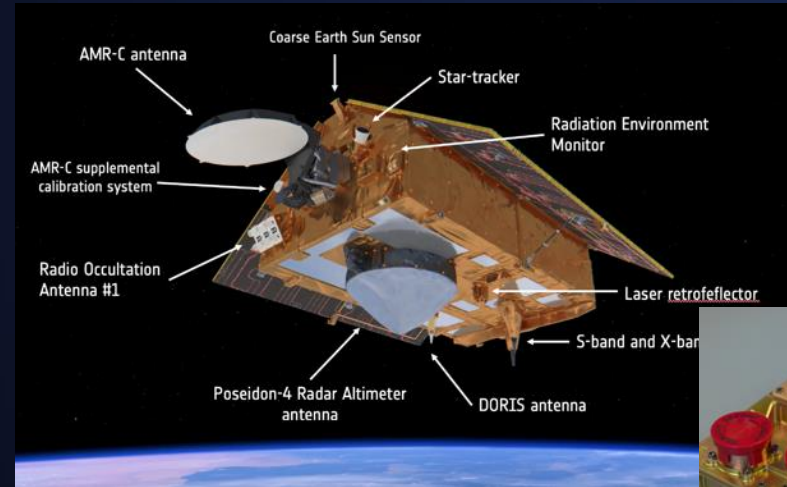
EDRS-C

- NGRM radiation monitor as hosted payload



GEO-KOMPSAT-2A

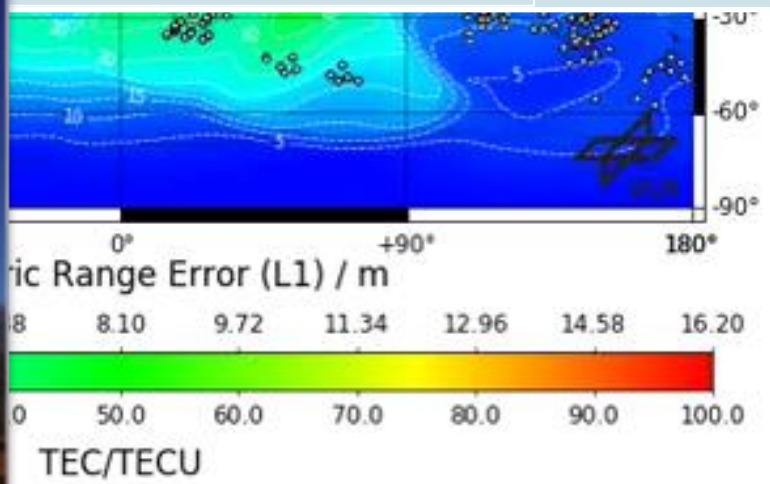
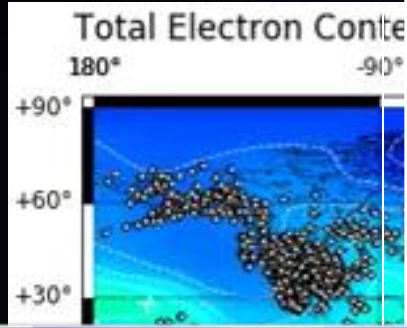
- SOSMAG magnetometer in KSEM instrument package
- Excellent collaboration with KMA since 2018
- Collaboration in future GK missions in planning



Sentinel-6

- Collaboration with EUMETSAT
- ESA managing and processing RMU data
- Utilising synergy from NGRM

Global Collaboration in Ground Based Observations



- Ground based global observation networks mandatory for space weather applications
- Examples of international networks:
 - IGS, EUREF
 - INTERMAGNET
 - NMDB
 - MIRACLE network
 - SuperDARN
- Many national and regional networks are being developed and enhanced
- How to
 - Improve user access to these data?
 - Ensure long-term availability of the networks?

THANK YOU

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