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

Alexi Glover, Juha-Pekka Luntama, Federico Da Dalt, Ralf Keil, Hannah Laurens, Judit Palacios
Space Weather Office, ESA Space Safety Programme Office
European Space Agency

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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

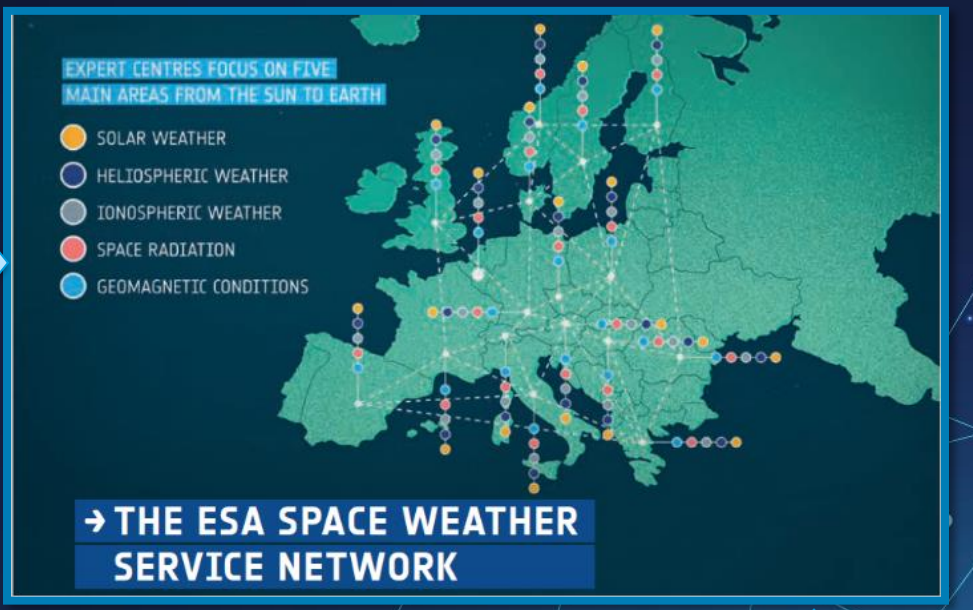
Development of Space Weather Capabilities in Europe

Layer 1: Data acquisition → Layer 2: Data Processing → Layer 3: Services

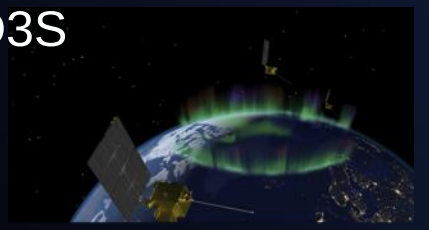
Ground stations

MOC

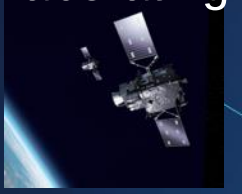
Space Weather Payload Data Centre and Data HUB



D3S

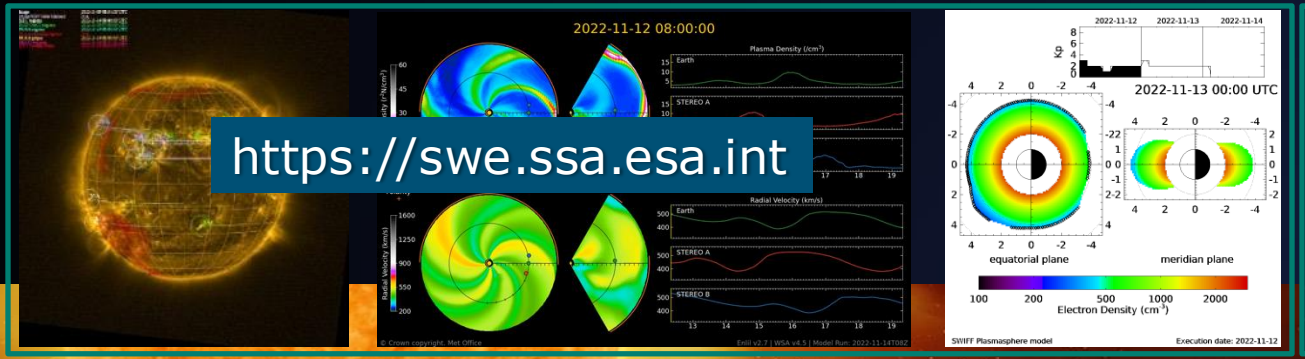


Collaborating missions



Ground based observations

ESA Space Weather Service Network



Who uses the services?

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

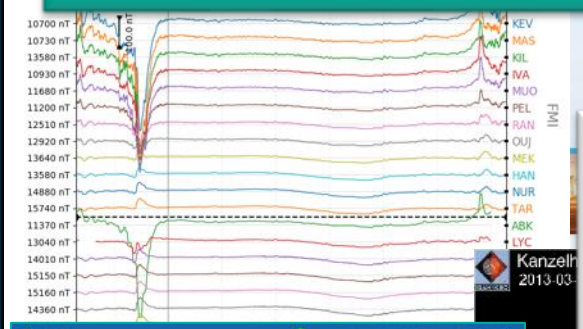
SWE Service Network Provides:

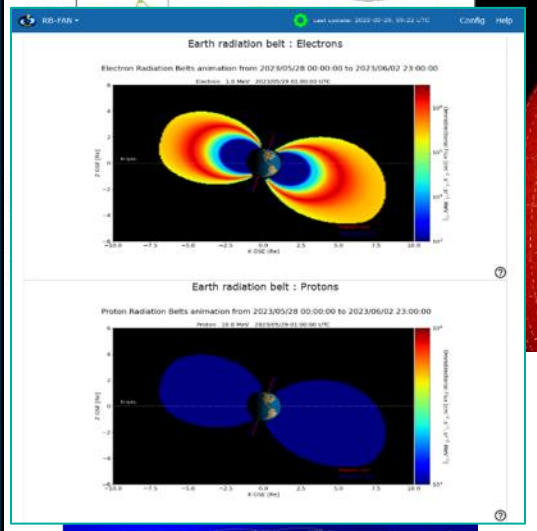
- 29 services built on >300 data products & tools
- 95% overall availability & NWH helpdesk support
- Full Sun-Earth chain, coupled modelling
- Timely & reliable user tailored notifications & alerting

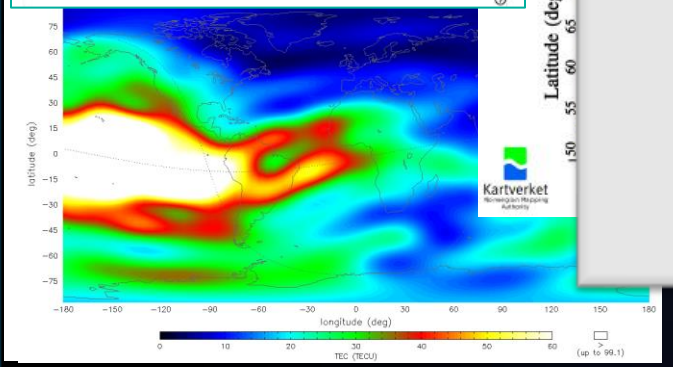
Who participates?

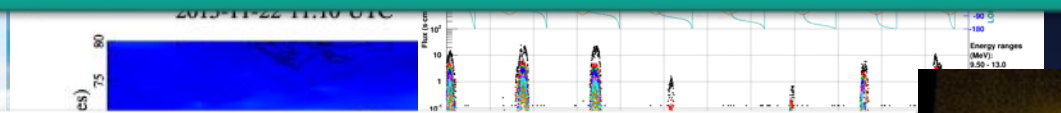
- >50 institutes, industry, academic groups
- Building on & strengthening European assets & expertise

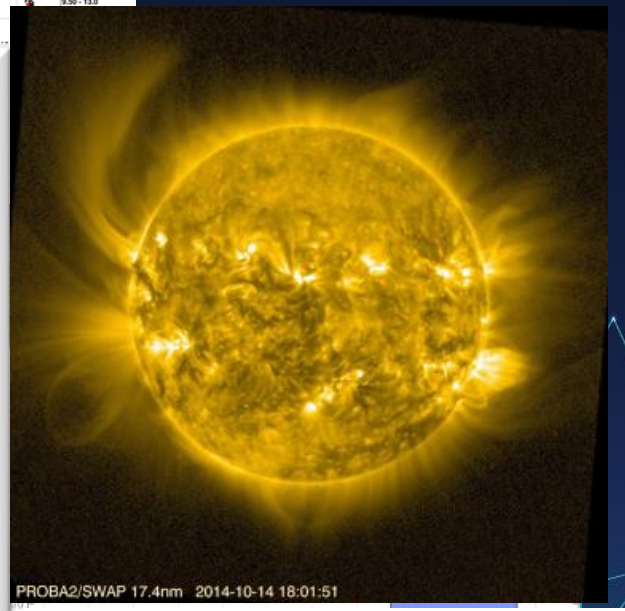
Space Weather Capability Development

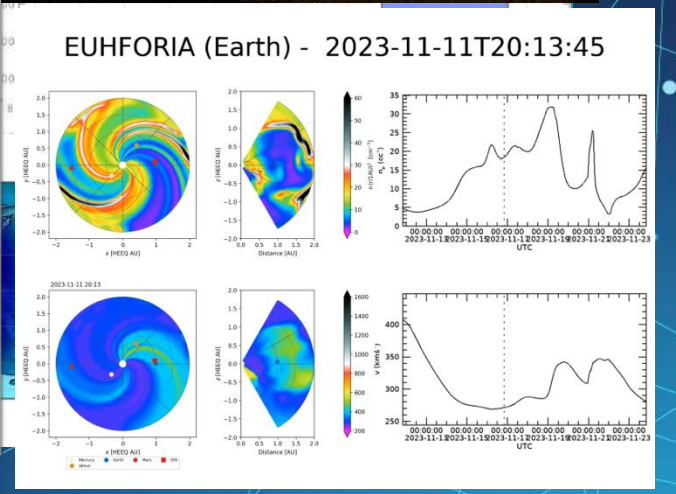








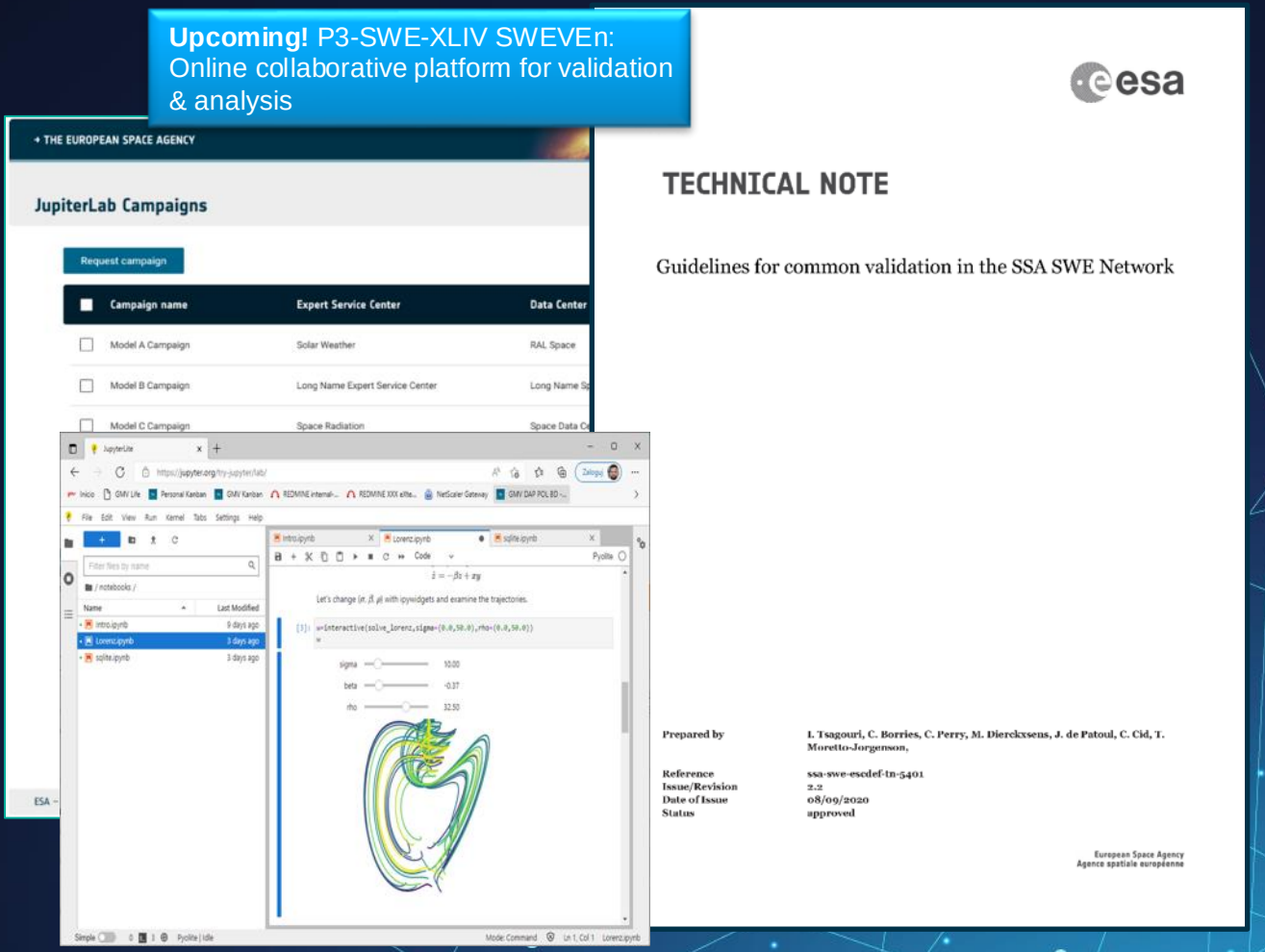




Validation, Verification and Performance Assessment

- 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 wide range of conditions
  - *Results may be different but both are necessary for operational transition!*
- Towards consistent validation & verification as a <u>community standard</u>
  - Recommended validation methodologies
    - Methods & metrics
  - Guidelines for validation campaigns
  - Continuous validation post deployment
- SWE Service Network provides <u>unique opportunity for testing, demonstration and collaboration towards community</u> consensus on current capabilities and <u>benchmarking</u>

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



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

- Tailored to a subset of use cases or domain on request
- How to navigate & utilise key tools
- At users premises or online webinars

- Bespoke dashboards
- Content tailored together with test users
- Individual product adaptation

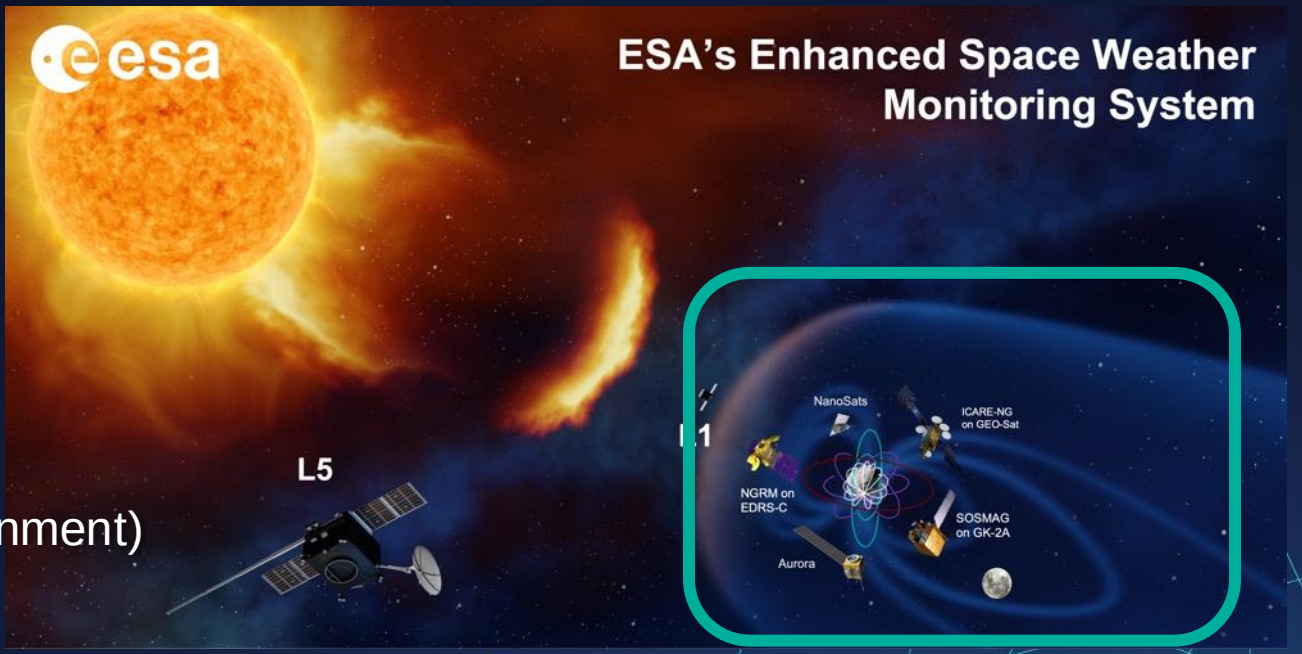
- Outreach to registered user community following major release
- Feedback on service content and presentation

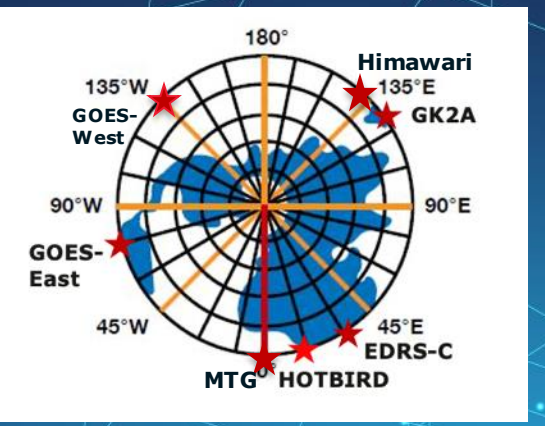
- At users' premises or part of a conference or workshop e.g. European Space Weather Week

ESA S2P Space Weather Monitoring Missions

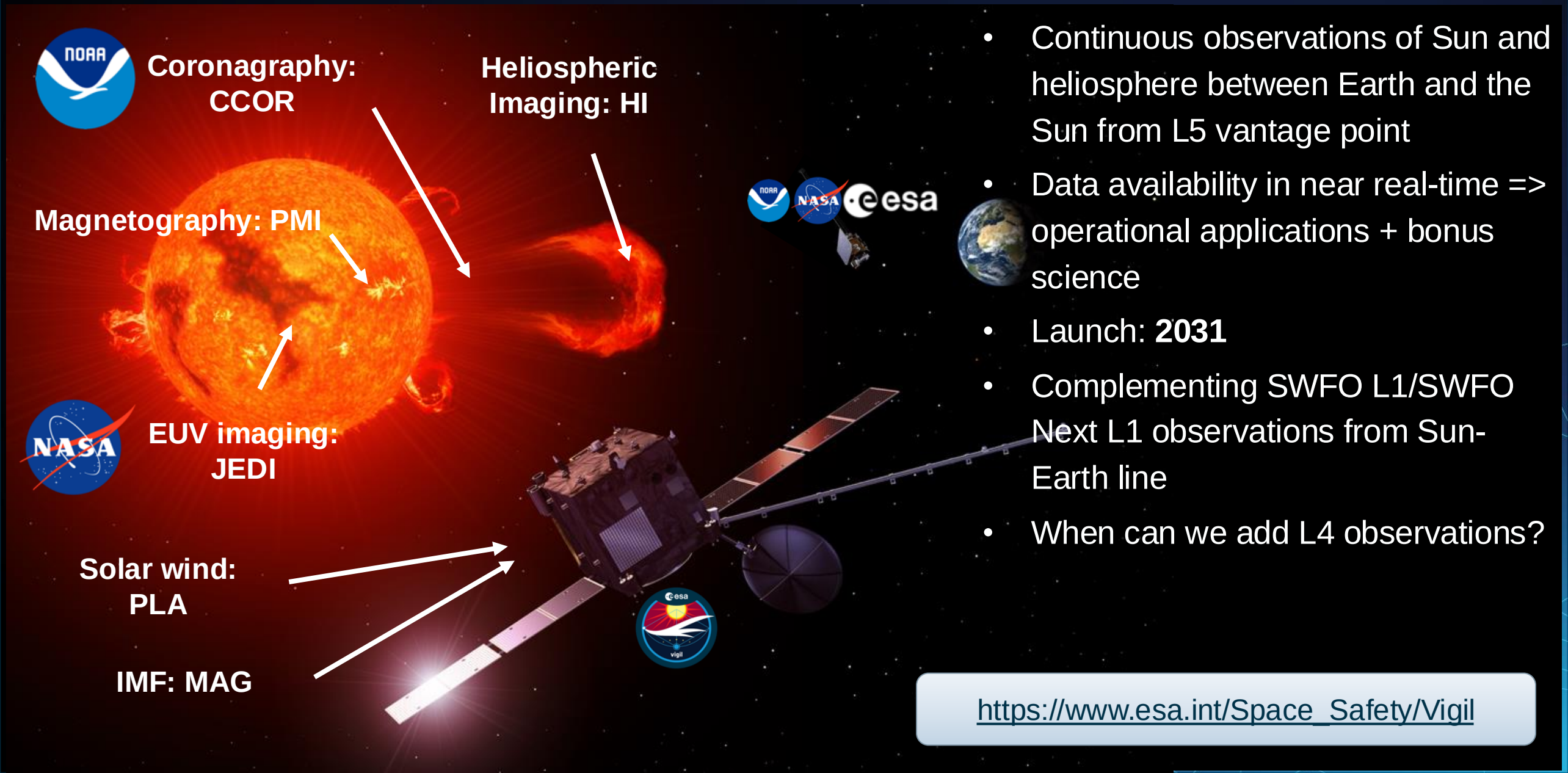
Missions Overview:

- 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

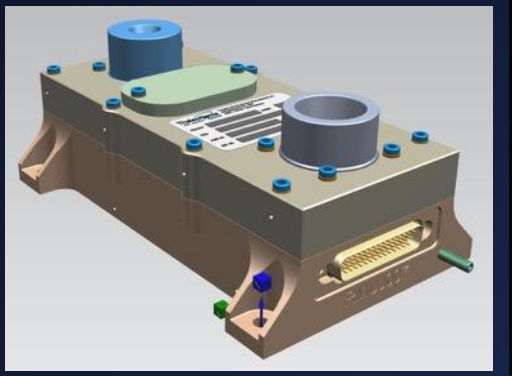


- Continuous observations of Sun and heliosphere between Earth and the Sun from L5 vantage point
- Data availability in near real-time => operational applications + bonus science
- Launch: **2031**
- Complementing SWFO L1/SWFO Next L1 observations from Sun-Earth line
- When can we add L4 observations?

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

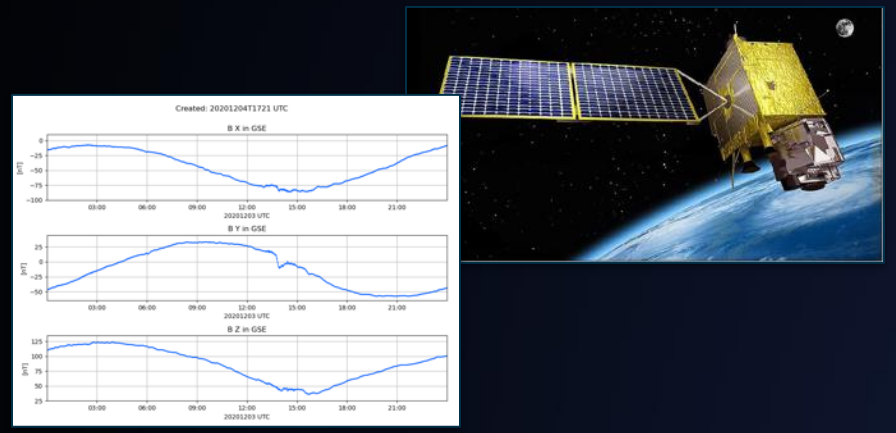
Cislunar Hosted Payload Missions

- MiniRMU on Lunar Pathfinder
  - Monitoring of high energy electrons and protons
  - Planned launch in 2025



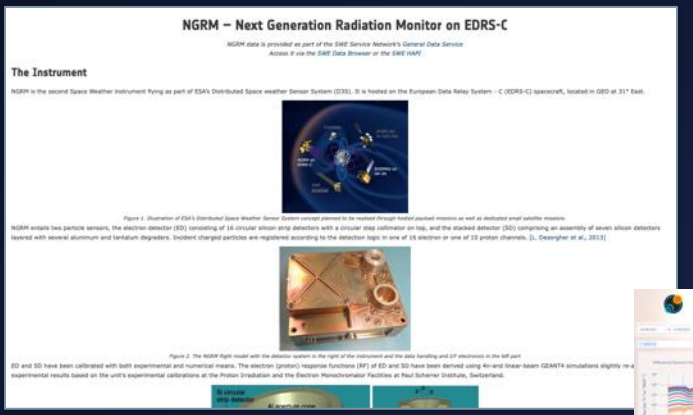
- ERSA on Lunar Gateway
  - Comprised of several radiation monitors, dosimeters and magnetometers
  - Close collaboration with NASA solar physics HERMES payload
  - Planned launch end 2025

Collaboration with International Partners and Industry



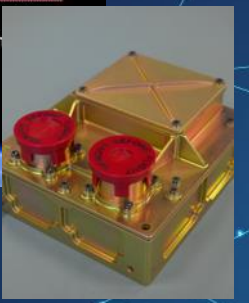
GEO-KOMPSAT-2A

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



EDRS-C

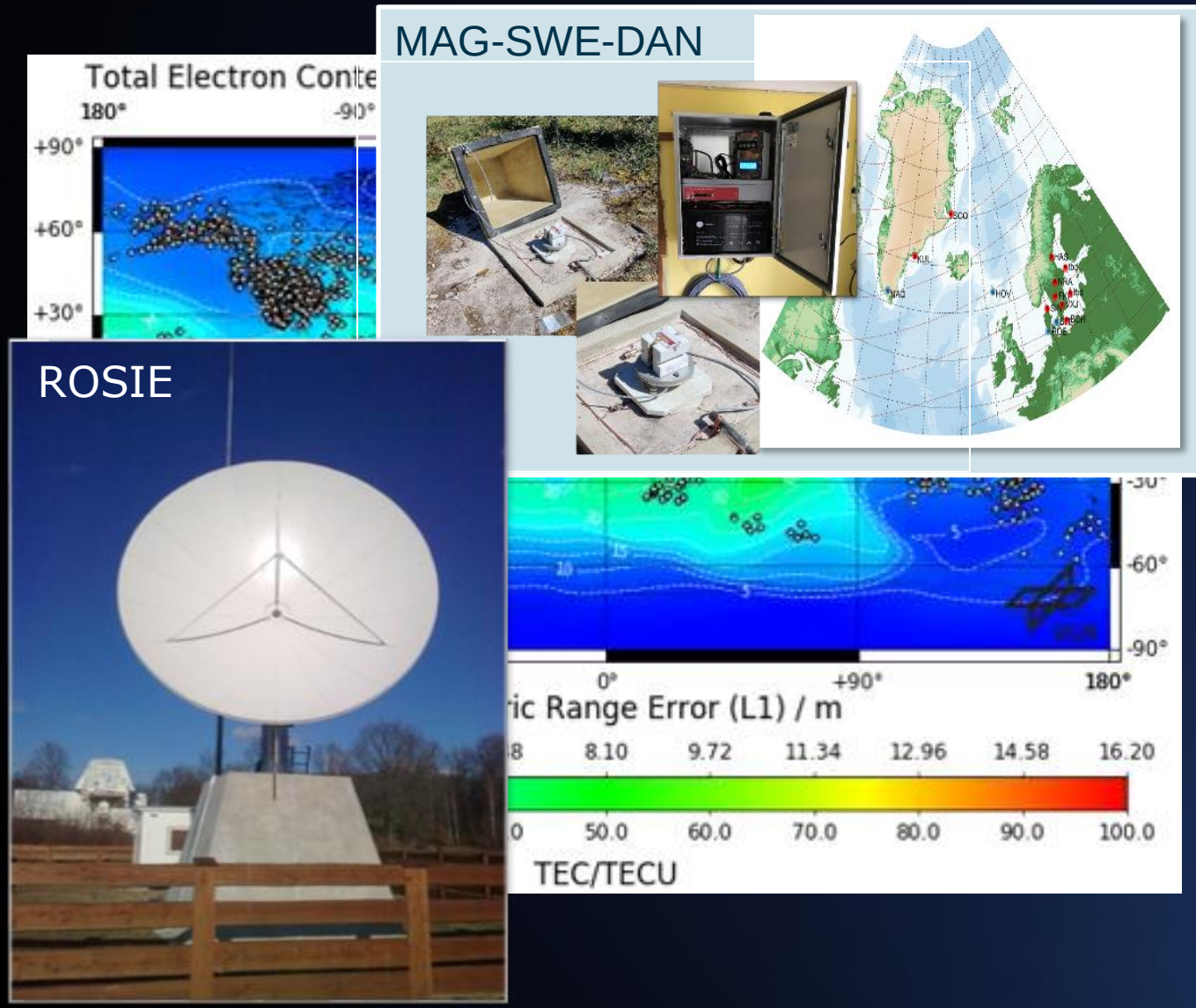
- NGRM radiation monitor as hosted payload



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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