# ERFNet-DH: A Collaborative Environment for Advancing Space Radiation Research in Support of Human Exploration

## Workshop on Radiation Monitoring for the ISS (WRMISS) 2025

L. Scavarda PhD on behalf of ERFNet Team

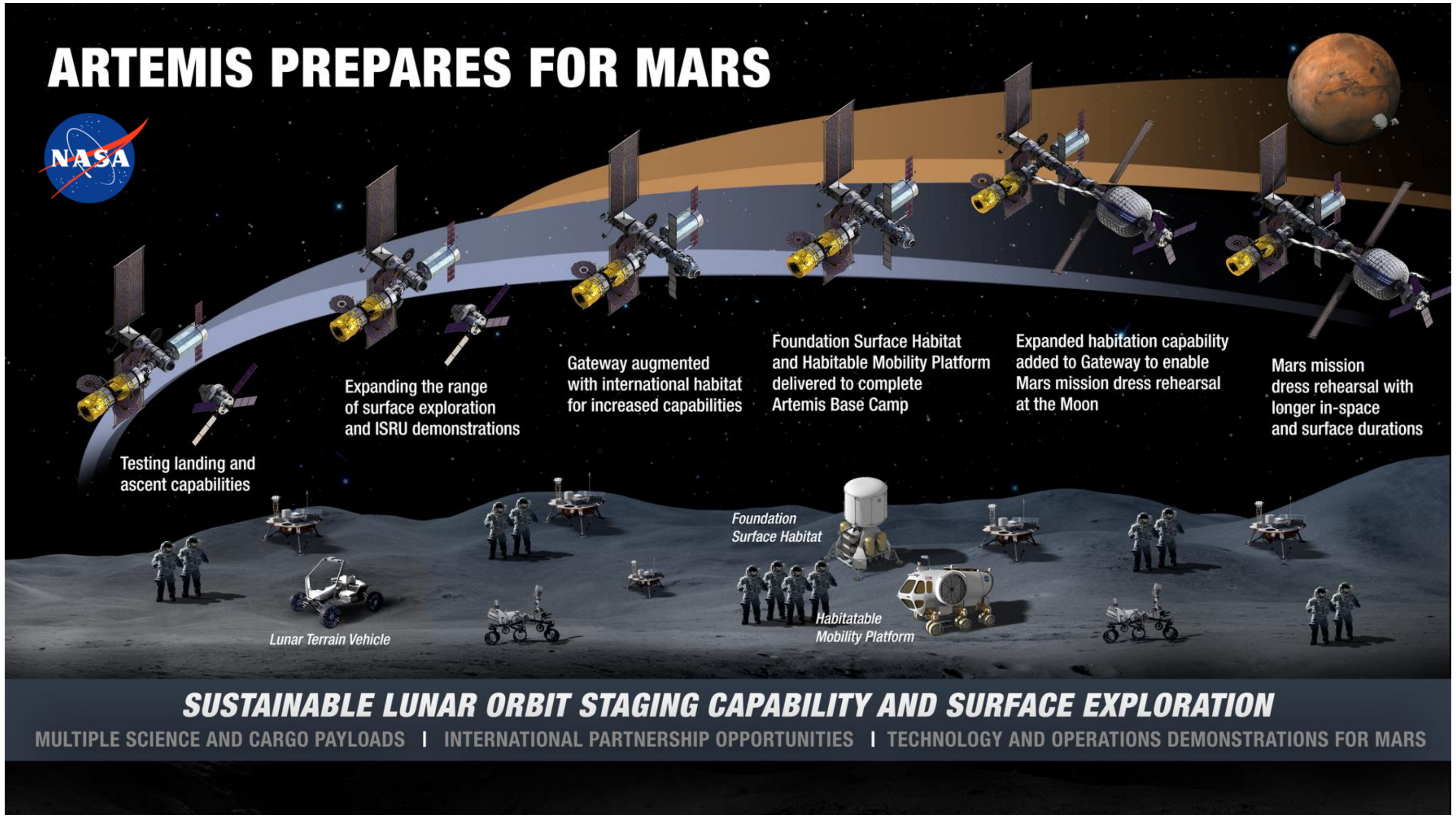
# Introduction

## Human Exploration Path

Human spaceflight is moving beyond LEO: Artemis will enable sustainable lunar exploration and prepare the path to Mars.

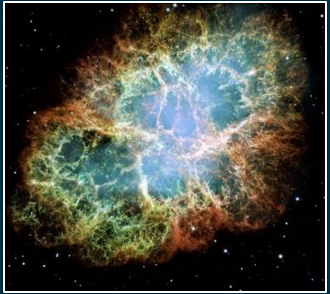
These missions open new scientific opportunities but also raise critical challenges for astronaut safety.

**The role of scientific community is essential**: advancing our knowledge, upgrading models, fostering collaboration, and designing innovative solutions to better protect future crews.

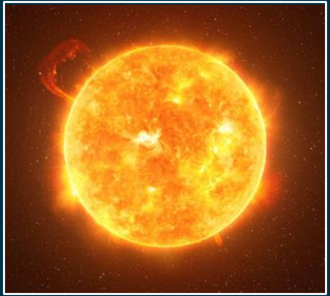



## Space Radiation Hazards

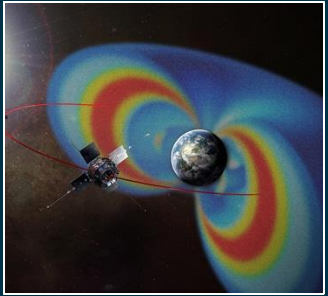
*Space radiation remains one of the main risks for long-duration missions*



GCR



SPE



Trapped Particles

# Open Questions

The shift from LEO to deep space has important implications for radiation research and there is the need to improve space radiological protection strategy and risk assessment for astronaut missions:

### Radiation Environment Measurement

- Enhance knowledge on radiation environment is fundamental for mission planning and design
- Particle quantities such as energy deposit spectra and fluxes are needed to validate and update models
- Development of new instrumentation

### Dosimetry and radiation risk estimation

- For exploration missions, actively powered radiation detectors for the crew are required
- Individual bio-dosimetry combined with the results of radiation detectors are fundamental for the radiation risk estimation

### Radiation propagation tools and models

- Radiation propagation tools provide calculated radiation data for a specific planned mission scenario and can be benchmarked with data from sensors
- Transport codes, based on Monte Carlo (GEANT4, FLUKA, PHITS) or on deterministic (HZETRN) codes need further developments including updates for missing data (such as nuclear cross section measurements)

### Radiation storm forecasting

- Forecasting SPEs is very important for deep space operations for efficient planning and use of countermeasures complying with the "As Low As Reasonable Achievable" (ALARA) principle for astronaut protection.
- Forecasting from physics based models lacks the accuracy needed for human protection.
- Now-casting, using real-time precursor measurements along with data from past SPEs, is currently the best method available for issuing timely warnings

*[Fogtman, A., Baatout, S., Baselet, B. et al. Towards sustainable human space exploration—priorities for radiation research to quantify and mitigate radiation risks. npj Microgravity 9, 8 (2023)]*

Only through a harmonized and cohesive Scientific Community we will be able to fill these gaps.

**ERFNet is an ESA and ASI coordinated and funded project**

## Collaboration

ERFNet fosters interdisciplinary collaboration, enabling experts in medicine, physics, biology, engineering, and other fields to exchange knowledge and insights, ultimately advancing our understanding of space radiation effects and enhancing our ability to mitigate risks for future space exploration missions.

## Network

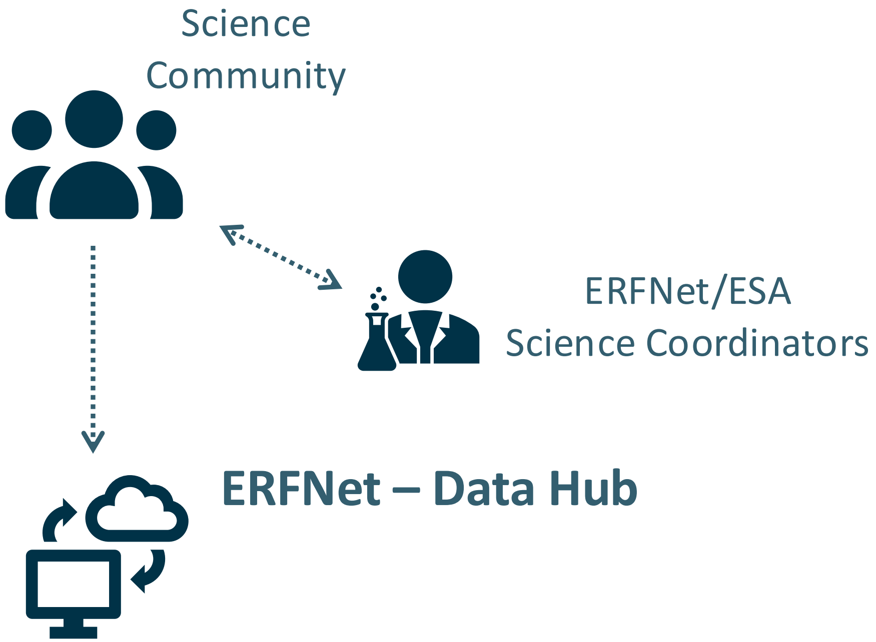
ERFNet serves as a framework for international partnerships, connecting researchers worldwide and facilitating the exchange of expertise and best practices in the field of Space Radiation research.

## Data Hub

ERFNet offers a collaborative Data Hub where scientists and researchers from diverse disciplines can come together to access and exploit data, write code, perform Monte Carlo simulations, and subsequently share data, projects, and results.

# ERFNet Scientific Environment

The scientific community directly accesses ERFNet, with dedicated Science Coordinators providing support, guidance, and alignment with program objectives.



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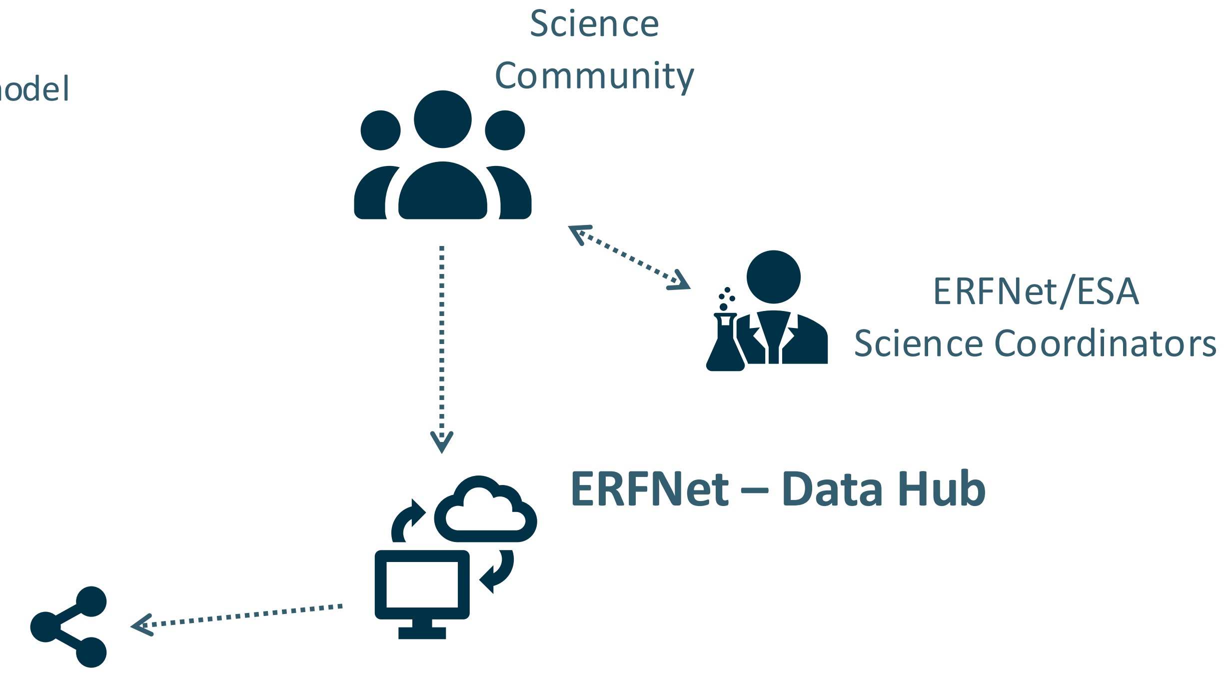

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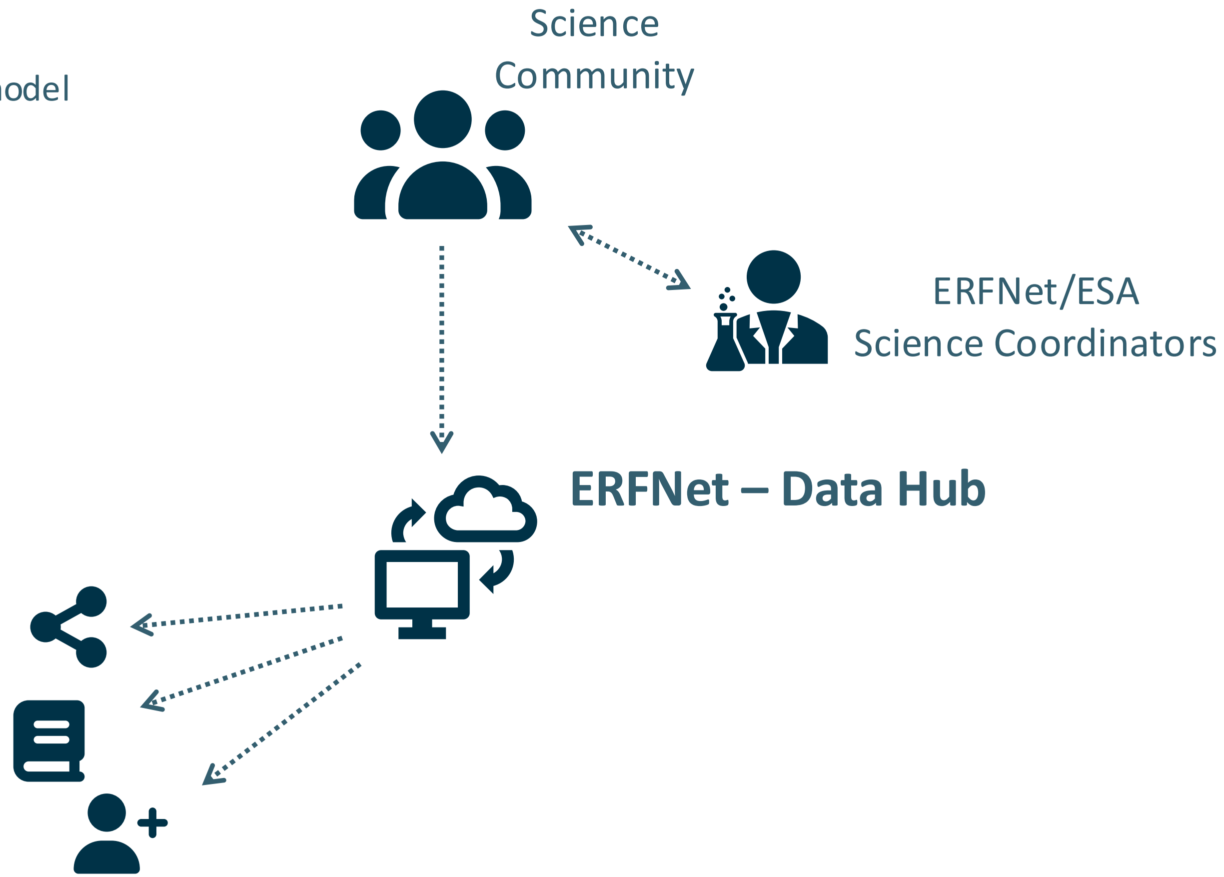

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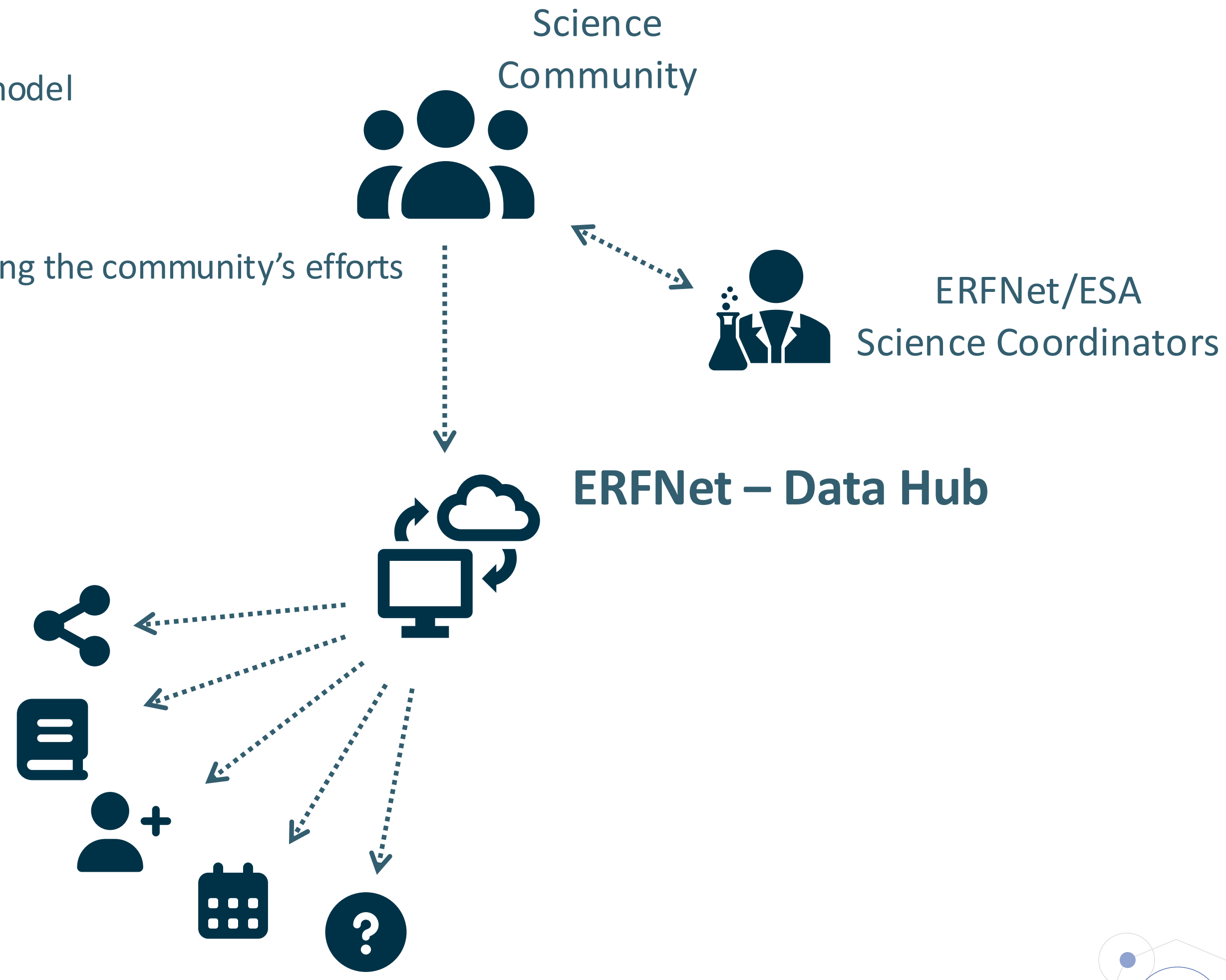

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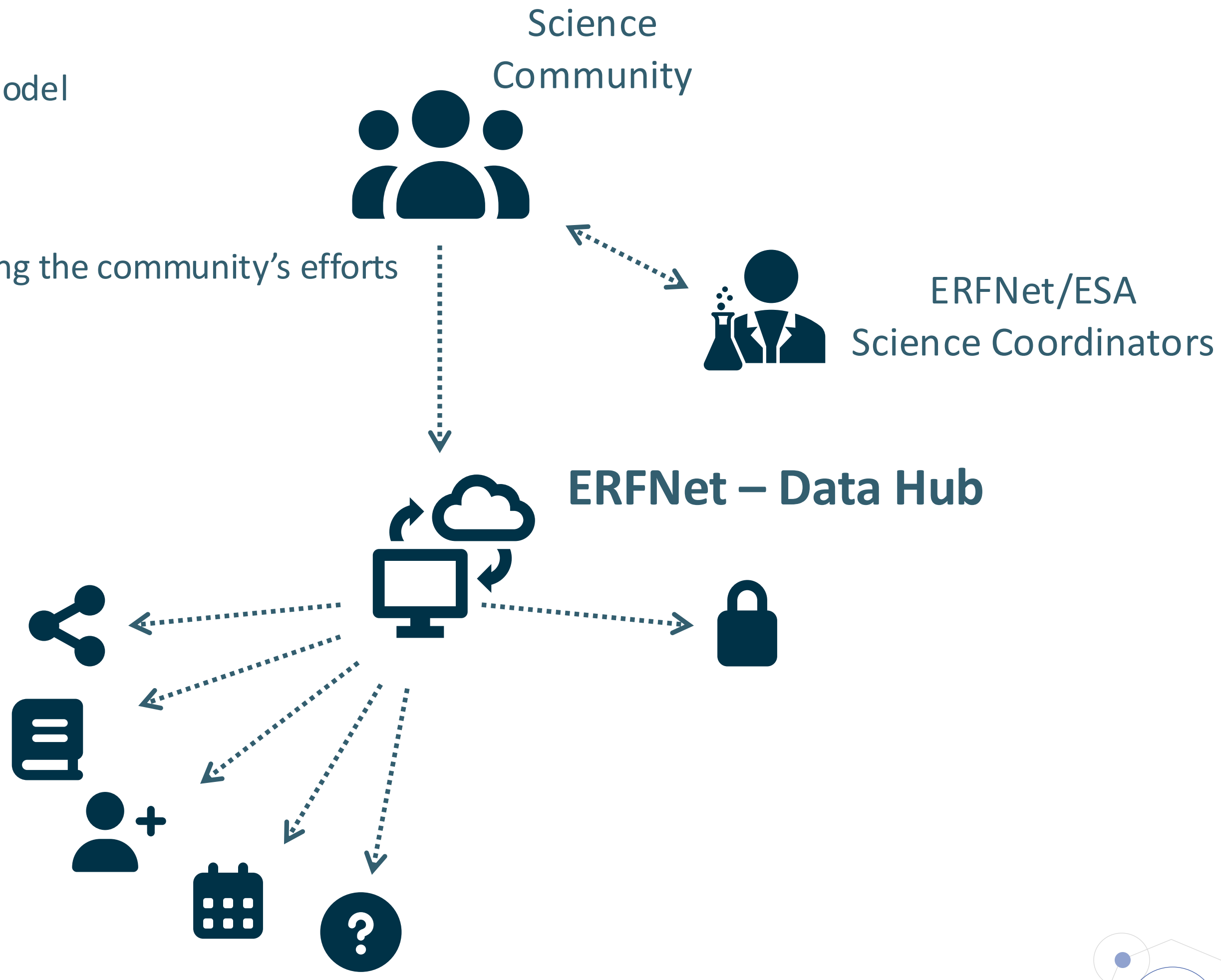

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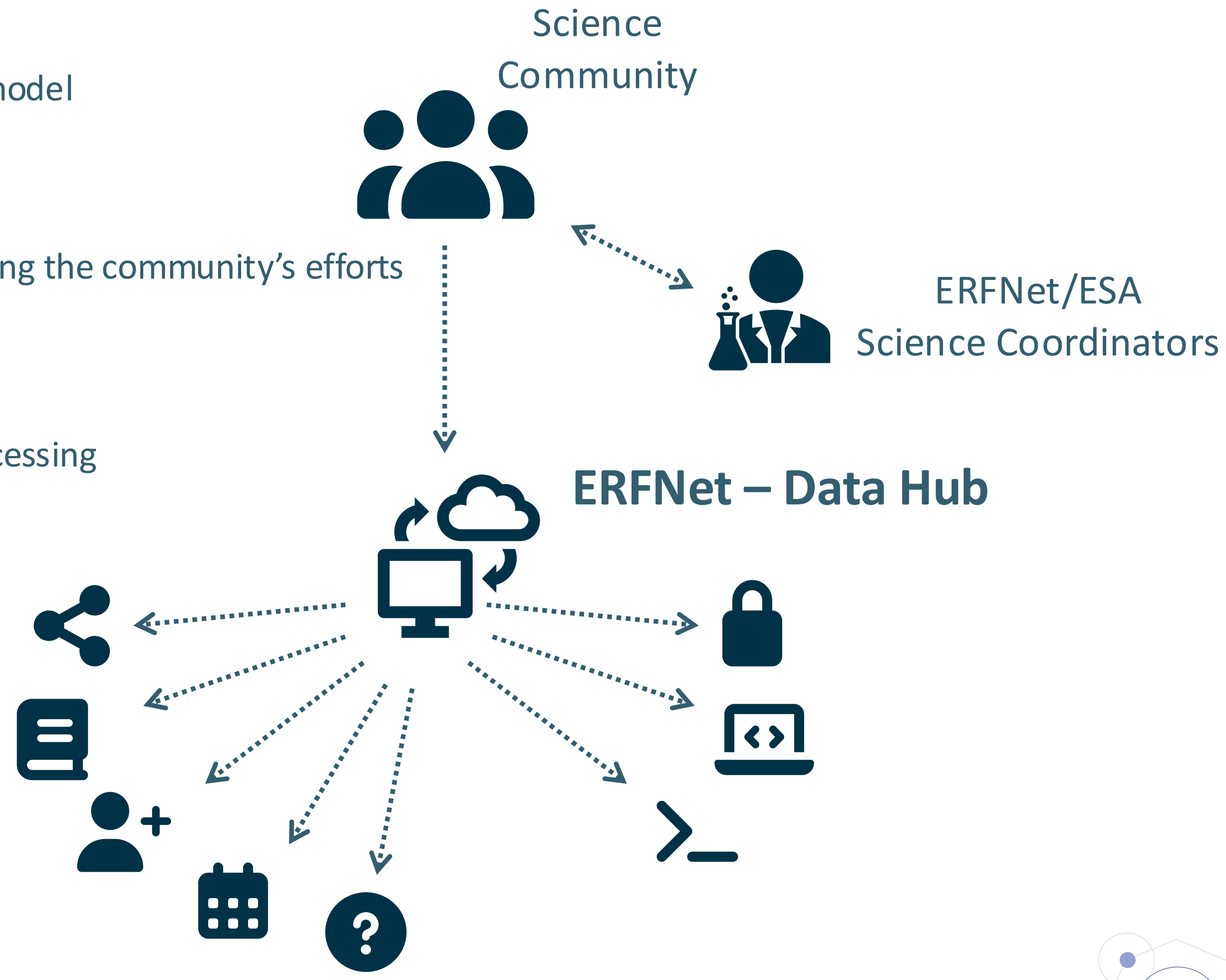

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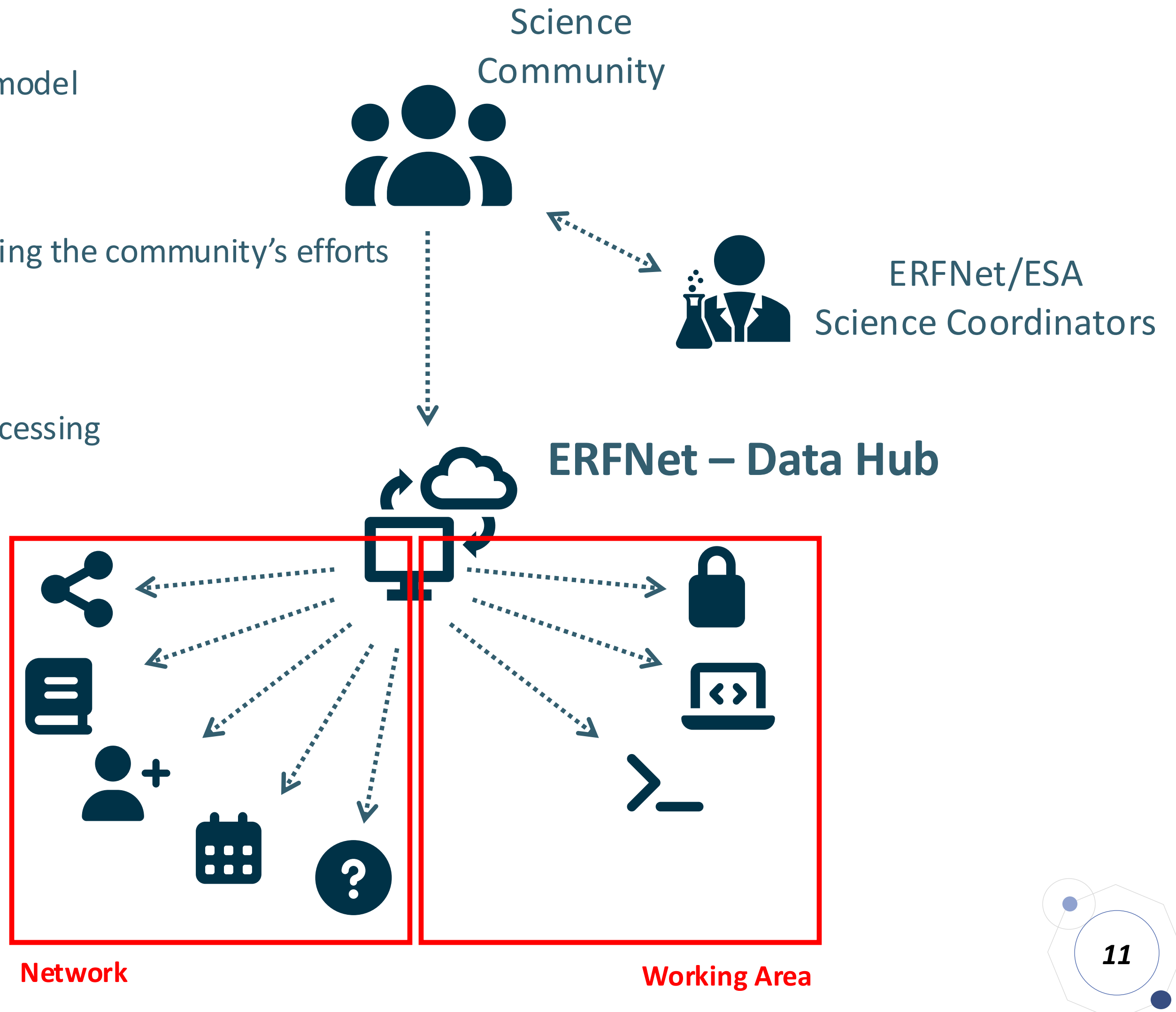
A single platform where data, tools, and collaboration converge to advance space radiation research

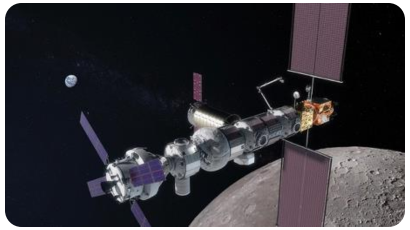


# Scientific Environment – Data Hub

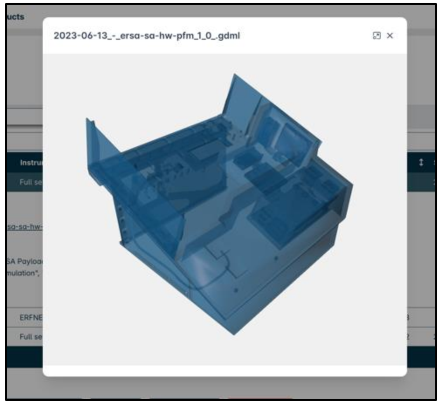
**Data-Hub**

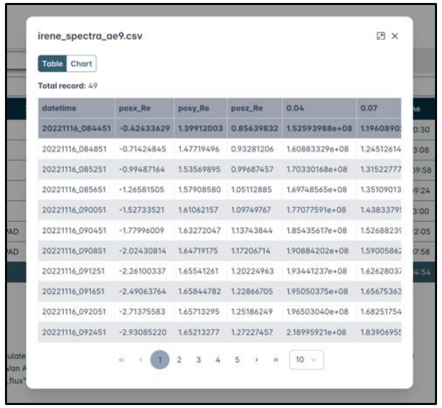
This capability aims at sharing data, software, and/or geometry models with other researchers.

**Multi-Domain Sources:** from space missions (ISS, Gateway) to ground accelerators (e.g. LHC, GSI)




**Flexible Sharing:** data can be kept private, team-shared, or made public




**Scientific Use Cases:**

- Experimental data: dosimetry, flux, cross section, detector performance
- Simulation outputs: Monte Carlo runs, validation datasets
- Software products: analysis scripts, configuration files, Monte Carlo simulation
- Geometry models: detectors, spacecraft, habitats for transport codes

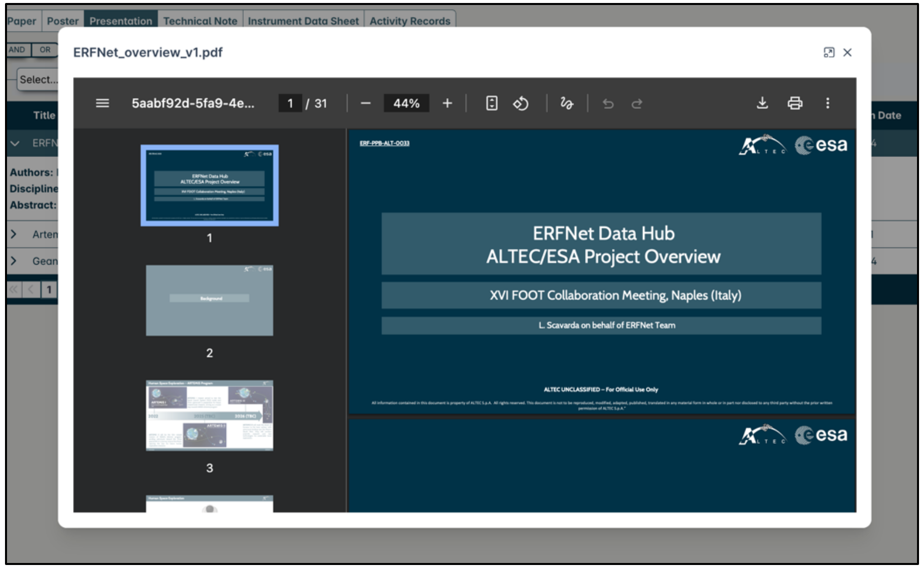
# Scientific Environment – Orienting Research

## Orienting Future Research

These capabilities aim to help researchers access, share, and align knowledge to advance space radiation studies.

### Bibliography Environment:

- Upload and share publications (PDF or links to journals).
- Fast filtering by keywords/tags to stay updated on specific topics (e.g. new cross-section measurements).
- Incrising visibility of their research

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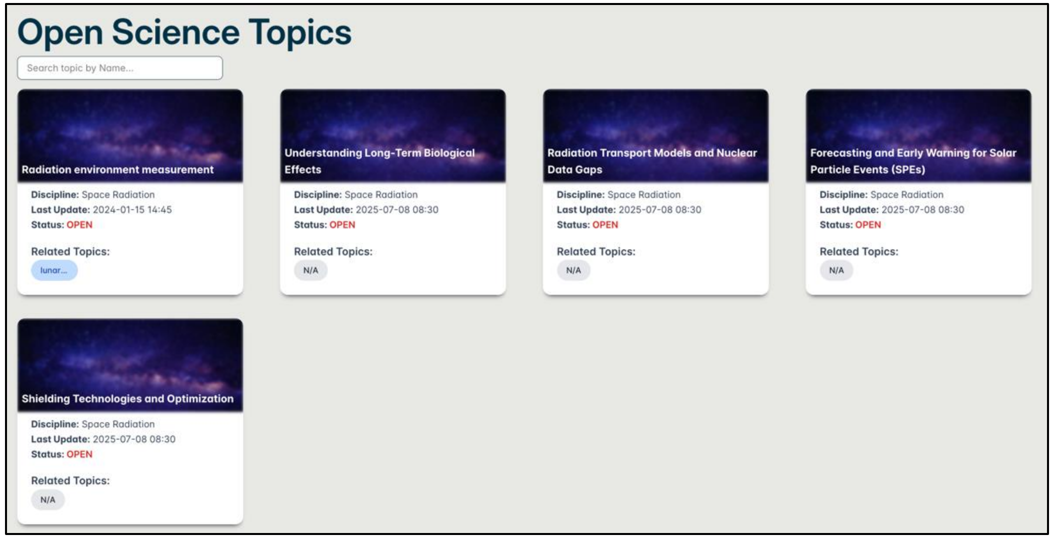
### Open Science Topics:

- Identify the big questions driving space radiation research
- Clarify what we need to understand and where we are going
- Provide a common framework to design new experiments and future missions
- Foster collaboration by aligning researchers around shared challenges.



# Scientific Environment – Working Area

## Virtual Workspace

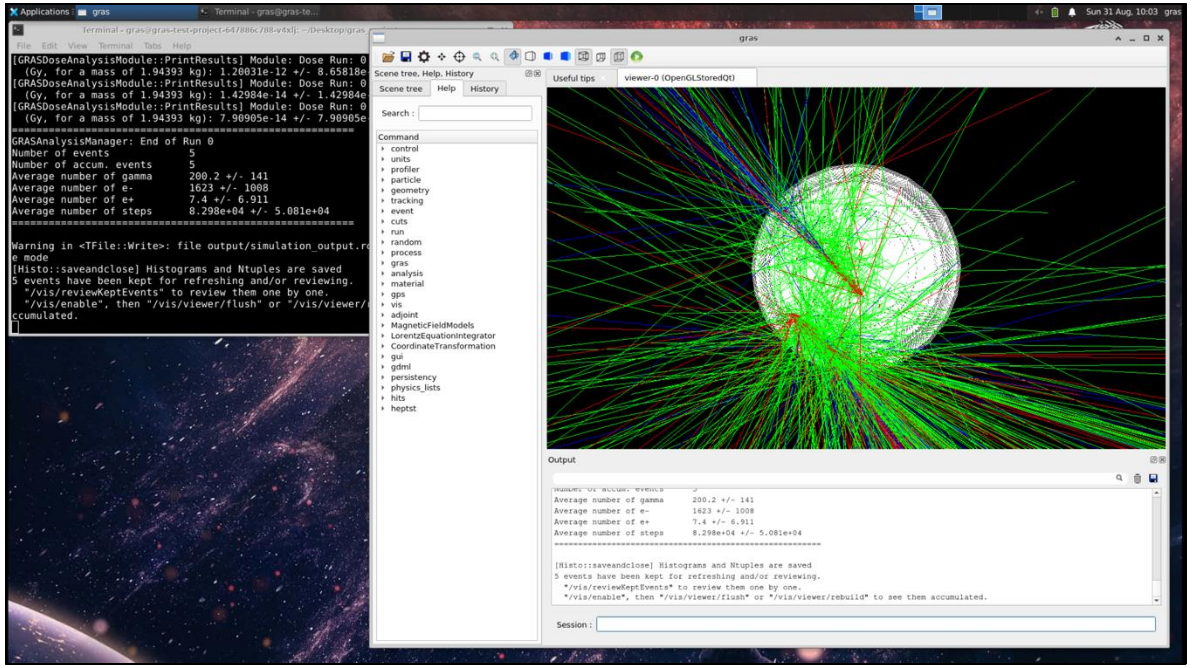
The Working Area provides each user with a personal computational environment, where projects can be created and customized with pre-installed tools for data analysis and Monte Carlo simulations.

**Lowering entry barriers**: pre-configured tools allow non-expert users to start simulations without complex installation.

**Data Hub integration:** direct access to datasets, software, and geometry models stored in ERFNet

**Flexibility for experts:** upload and test custom macros, workflows, or simulation setups in a ready-to-use environment.

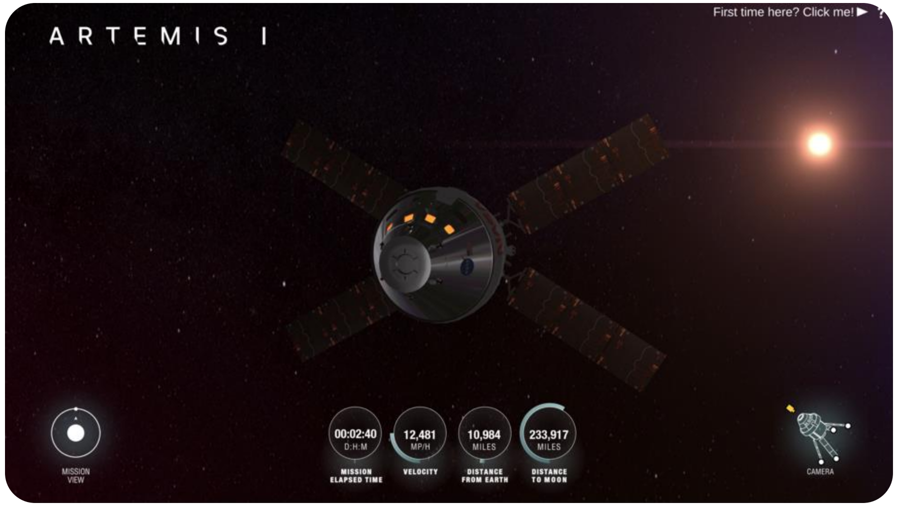
**Collaboration & training:** projects can be shared between users, supporting real-time collaboration, debugging, or teaching activities (e.g. PhD schools).

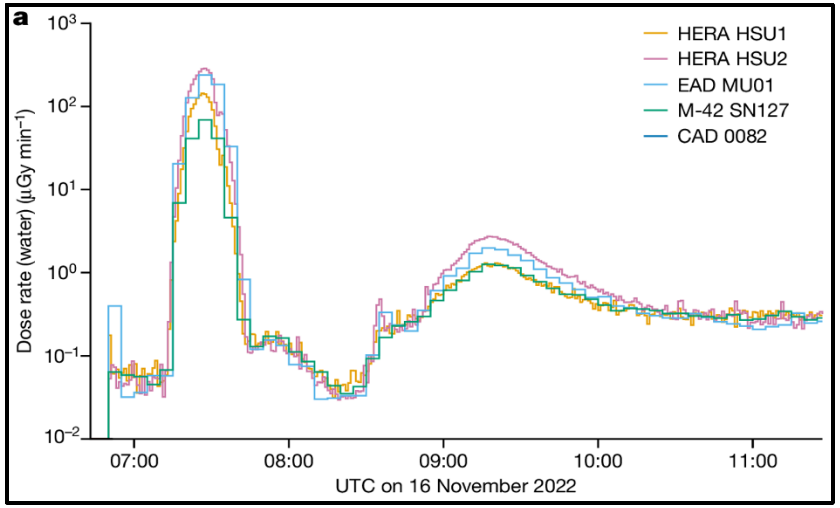


# Use Case: Artemis I Van Allen Belt Dosimetry

## Within the Space It Up program, ERFNet is used to reproduce the Orion capsule dose profile measured during Artemis I

*ASI Funding Contract No. 2024-5-E.0 – Unique Project Code I53D24000060005 – Project SPACE IT UP*




*[George, S.P., Gaza, R., Matthiä, D. et al. Space radiation measurements during the Artemis I lunar mission. Nature 634, 48–52 (2024). https://doi.org/10.1038/s41586-024-07927-7]*

## ERFNet supports the full research cycle: from running simulations to sharing results and fostering collaborative validation

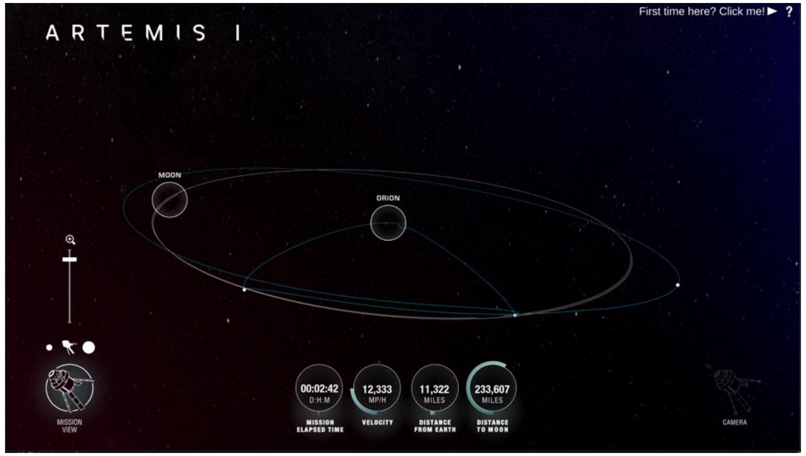
### Working & Analysis

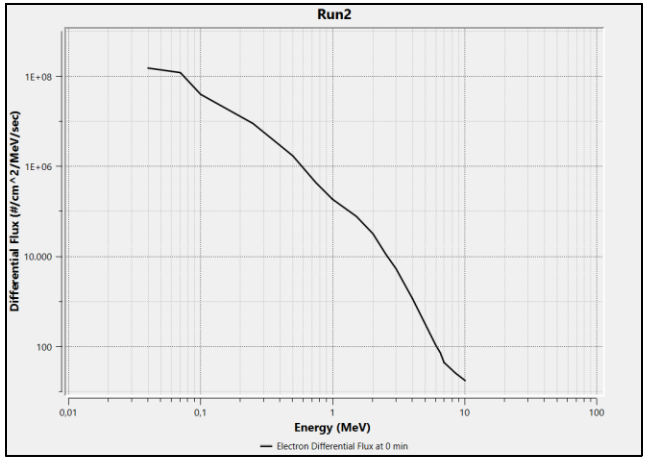
- Import geometry models and particle spectra
- Run Monte Carlo simulations
- Compare simulated dose profiles with in-flight measurements

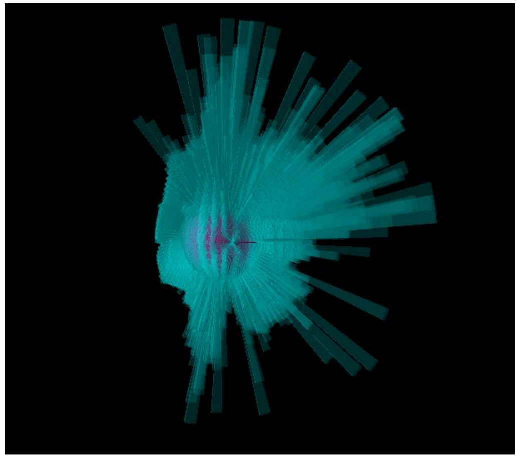
### Sharing & Collaboration

- Publish results as datasets, simulation outputs, geometry files or particle spectra
- Provide reusable inputs for the scientific community (e.g. geometry model, particle spectra)
- Link outcomes to publications for community validation and benchmarking

# Use Case: Artemis I Van Allen Belt Dosimetry (2)



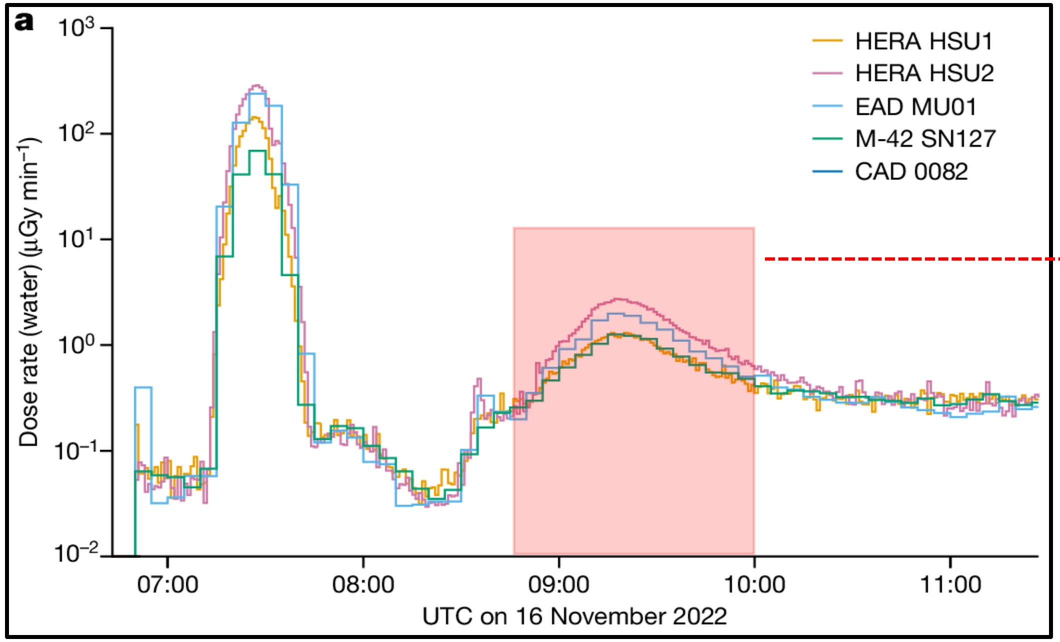



As input for the simulation, the Orion's OEM data were provided as input to IRENE to generate particle spectra in the Van Allen belts using the AE9 model, for the time interval between 08:45 and 12:00 UTC on November 16, 2022

- PMM ISS module geometry used as a proxy for Orion, simplified via ray-tracing into a mass–thickness distribution
- Dose scored into an ICRU

# Use Case: Artemis I Van Allen Belt Dosimetry (3)

## Preliminary simulation results comparison with absorbed dose data measured by Orion during the ARTEMIS 1 mission

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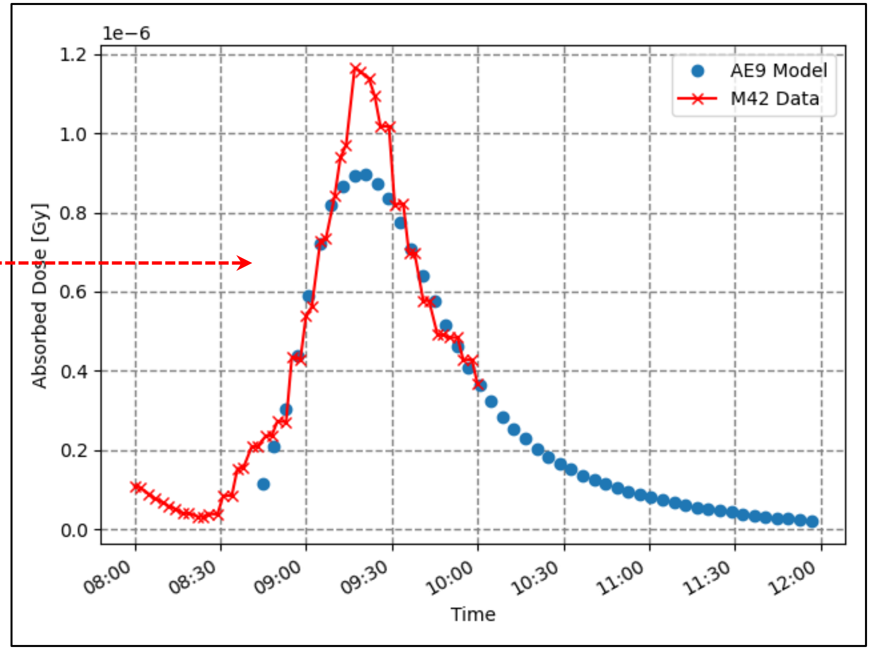


Discrepancy in the peak ~ 25%

### Work Ongoing & Next Step

1. Reproduce dose profile of the first peak (AP9)
2. Improve input geometry (Orion mass-thickness geometry)?
3. Test AE8/AP8 model
4. Reproduce dose profile of GCR

Input mass-thickness distribution geometry
and AE9 spectra available in ERFNet
Dose profile results coming soon

# Conclusions

## Ambitious and challenging goal:

ERFNet aims at becoming a support tool for scientist and researches involved in the Space Radiation/Radioprotection fields to face the upcoming challenges (to the Moon and beyond). ERFNet wants to boost the Scientific Community cohesiveness, in order to work towards answering the questions still open in the field.

## A Community-Driven Effort

ERFNet is not only a support tool, it is a community-driven effort. Its success depends on the active contributions of researchers: sharing data, publications, open questions, and software. The more we put into it, the more it can give back to all of us.

## ERFNet V1 released: **23/07/2025**


*https://ekb.ersse.altecspace.it/*

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**THANK YOU FOR YOUR ATTENTION!**