CLEAR Space Weather Center of Excellence: All-Clear Solar Energetic Particle Forecast
- Advancing Operational Space Weather Forecasting Across Earth–Moon–Mars

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CLEAR Mission

CLEAR Space Weather Center of Excellence (CLEAR Center) is a five-year (2024-2028) project funded by NASA to build an end-to-end, real-time, operational forecasting system for solar energetic particle (SEP) events. The CLEAR Center will deliver models that predict:

- pre-eruption and post-eruption probabilistic forecasts of SEP events
- post-eruption SEP event key parameters
- periods of proton intensities below a preset threshold to issue all-clear forecasts

The mission of the CLEAR Center will be accomplished through the integration of empirical, first-principles–based, and machine-learning models. **By providing actionable forecasts of SEP radiation, solar wind conditions, and coronal mass ejections, CLEAR enables risk-informed mission planning and operational decision making for human and robotic exploration throughout cislunar space and future Mars missions.**

WHY CLEAR Matters

- Provide forecasts of solar radiation hazards relevant to human exploration missions
- Deliver space weather information for cislunar and lunar surface operations
- Characterize space weather conditions along Earth–Moon and Earth–Mars transit trajectories
- Supply actionable forecast products to NASA, NOAA, and commercial spaceflight stakeholders

For detailed information on the CLEAR mission, forecasting capabilities, and research activities, please visit: clear.engin.umich.edu

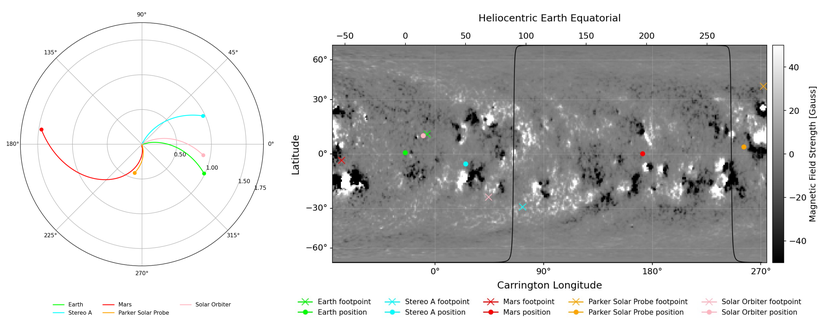
Acknowledgements

This work has been supported by the NASA Space Weather Center of Excellence program at the University of Michigan under award 80NSSC23M0191 (CLEAR Center).

References

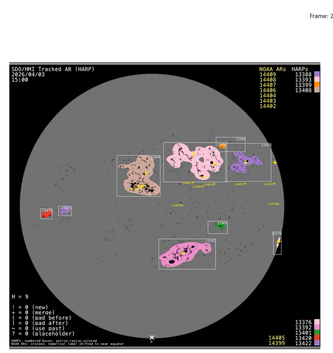
SEPNet: Yu, Y, et al. (2026), Space Weather
SOFIE: Zhao, L et al. (2023), Space Weather
AWSoMR: Sokolov, I. V. et al. (2021), The Astrophysical Journal

CLEAR Tool: Magnetic Connectivity

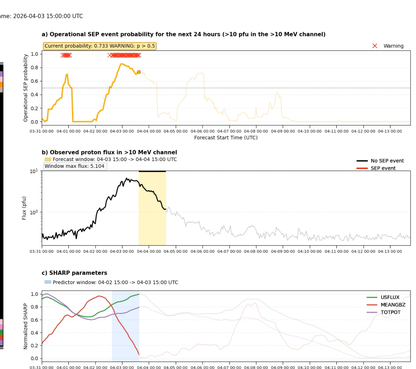


- Identifies magnetic pathways connecting solar eruptions to spacecraft, astronauts, and planetary destinations.
- Combines real-time solar wind simulations with magnetic field-line tracing throughout the inner heliosphere.
- Determines which assets are most likely to be impacted by an ongoing solar event.
- Provides critical context for SEP forecasting and radiation risk assessment

CLEAR Tool: Machine Learning SEP Prediction



Magnetic field of the sun



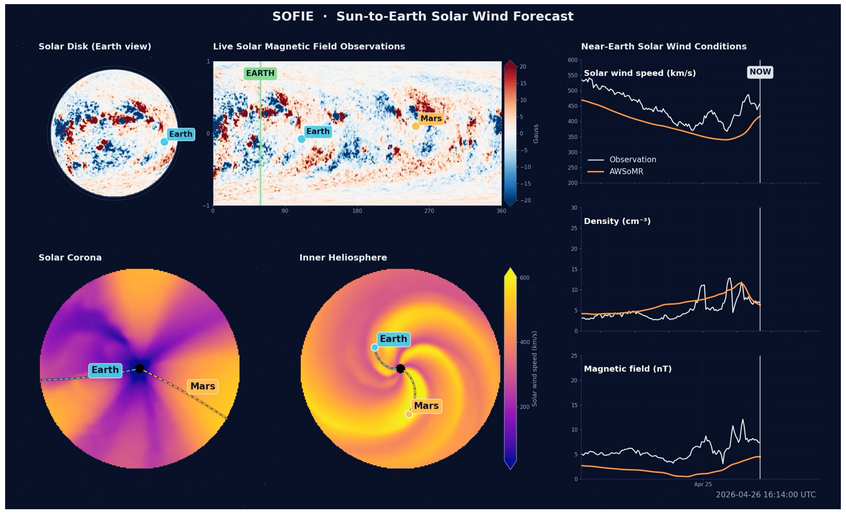
SEPNet

SEPNet was running 24/7 and providing SEP probability prediction during Artemis II mission.

- Provides real-time probabilistic forecasts of SEP events from solar observations and space weather data.
- Delivers early warning of potential radiation storms before energetic particles arrive at exploration assets.
- Produces forecast products that complement physics-based models and operational space weather monitoring.

CLEAR Tool: Real-time Solar Wind

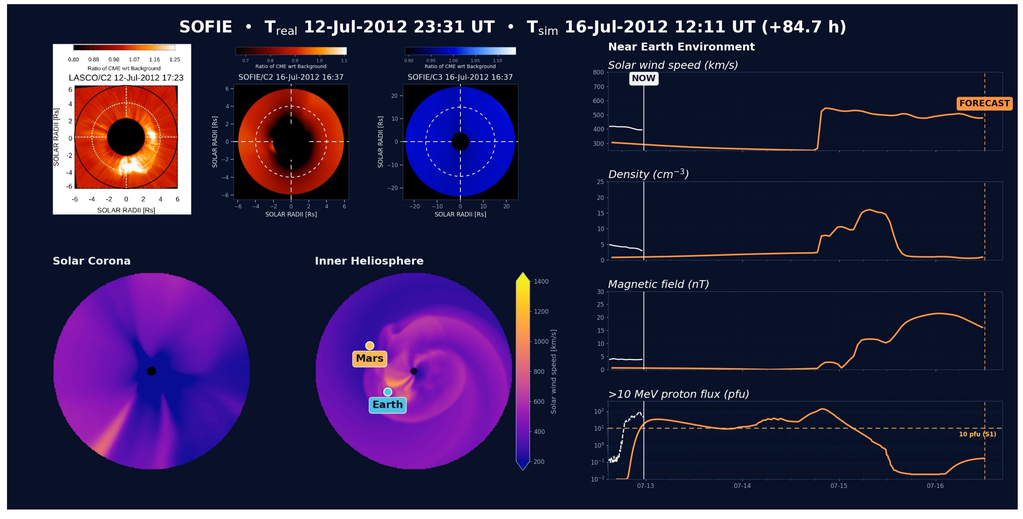
The real-time solar wind capability is provided by running the 3D AWSoMR model driven by the hourly updated magnetic field of the sun. Solar wind property at any location of the heliosphere are extracted. The real-time pipeline has been running 24/7 since November 2025. All results are streamed to https://solarwind.engin.umich.edu/pipeline/



- Maintains a real-time representation of heliospheric conditions across the inner solar system.
- Provides predictions of ambient solar wind conditions and magnetic connectivity throughout the Earth–Moon–Mars system.
- Serves as the operational foundation for CME, SEP, and radiation hazard forecasting within CLEAR.

CLEAR Tool: Real-time SEP Prediction

The SOFIE real-time pipeline simulates the propagation of coronal mass ejections and the associated solar energetic particles through the real-time solar wind background. SOFIE is triggered by the CME entry in the CCMC DONKI database. The image above shows the timing of the predicted >10 MeV proton flux by SOFIE compared with observations. The real-time SOFIE pipeline has been running 24/7 since February, 2026.



- Operates as a fully automated, real-time SEP forecasting pipeline driven by continuous solar observations and CMEs.
- Forecasts CME propagation, arrival of ICMEs, and SEP radiation hazards within a unified framework.
- Provides integrated forecast products for space weather monitoring and operational decision-making throughout the Earth–Moon–Mars system.