Commercial service providers contribute to the R2O pipeline

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Disasters give us pause to assess, identify, and mitigate weather risks

Whether it is winds, fires, floods, snow, earthquakes, tornadoes, hurricanes, or coronal mass ejections, there are extreme natural phenomena that affect our lives

- ✓**Example – the SoCal fires in January 2025 showed that massive devastation evolved not from a Category 5 firestorm but from the result of many millions of ember casts**
- ✓**The lesson – small risks can rapidly become large and are often the foundation of extreme disasters**
- ✓**It is not necessarily the massive tsunami, "The Big One" earthquake, or the Carrington Event CME but the small risks that aggregate into, and create, larger events**

Space weather risk identification and mitigation

- SWAG User Needs Survey report provides guidance on path forward
  - The Space Weather Advisory Group (SWAG) User Needs Survey Report outlined 46 findings and 113 recommendations
  - Risk assessment surveyed across societal 7 sectors
  - Hazards related to space weather and steps by agencies, academia, and industry needed to mitigate those risks are detailed
- Here, we describe examples of ACSWA companies' instruments, models, and decision aid tools that are addressing the identification and mitigation of space weather hazards <u>where their activity is specifically guided by SWAG's findings and recommendations</u>

Aviation Sector

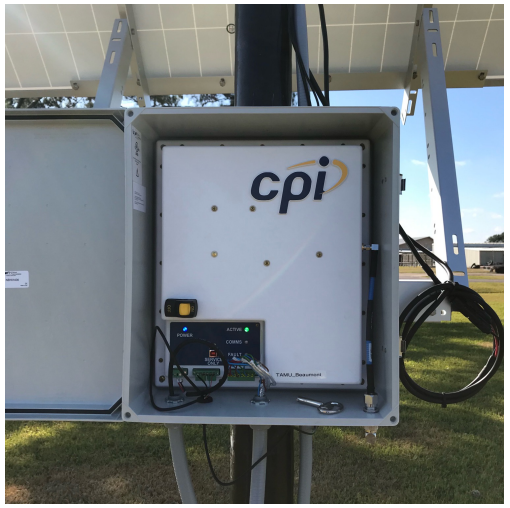
- **<u>Priority:</u>** surveyed participants wanted the ability to **measure, report, and educate radiation exposure** that can be used for tracking, reporting, and understanding radiation exposure at aviation altitudes
- **<u>Existing gap:</u>** aviation sector should clearly acknowledge crew members working in a high radiation environment and develop the guidelines, education, and regulatory framework to support work in this environment

<u>Solution:</u> SET's ARMAS/ARGOS
UAV radiation monitoring system will provide validated measurements for feeding the NASA NAIRAS data assimilative modeling and validating FAA's CARI model for:

- 24/7 radiation monitoring
- Supplying a real-time data feed
- Providing global dose rate flight data around the world for model validation and development

Electric Power Sector

- **<u>Priority:</u>** surveyed participants noted the ability to **perform measurement-based validation of GIC models** used for system and equipment vulnerability assessments and mitigation planning was important
- **<u>Existing gap:</u>** limited geographic coverage in North America from existing magnetometer network leaves many planners reliant on estimated geomagnetic field data for their areas, reducing the quality and accuracy of validations



<u>Solution:</u> CPI's MAGSTAR magnetometer network provides crucial measurements for feeding industry vulnerability assessment tools capable of:

- expansive risk analysis to the system from GIC
- Integrating with harmonic current modeling
- advancing earth conductivity models

Human Space Flight Sector

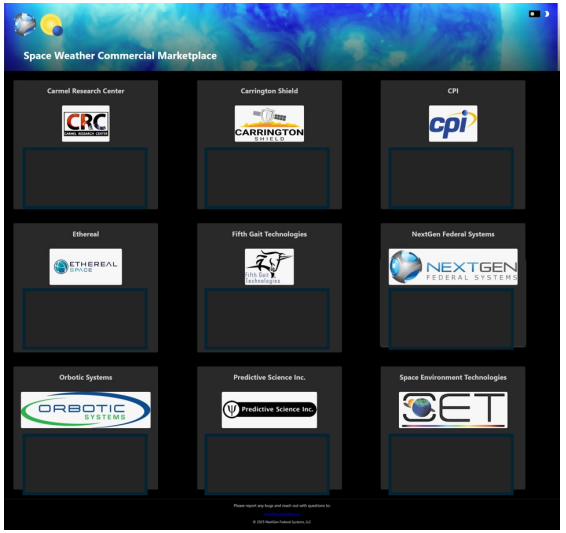
- **<u>Priority:</u>** surveyed participants noted that radiation measurements, modeling, tools are a priority for commercial HSF
- **<u>Existing gap:</u>** model and sensor development should cover LEO environments as well as highly elliptical orbits as seen with the recent SpaceX Inspiration4 Mission, i.e., the first all civilian mission to orbit in the radiation belts

<u>Solution:</u> SET's lunar lander ARMAS radiation monitoring system on Intuitive Machines Mission 2 to the lunar south pole region on Feb 27 to Mar 6, 2025:

- measured radiation from the Earth to the Moon and
- provided global dose rate flight data from deep space to the Moon that is valuable for assessing human risks

Operations Sector

- **<u>Priority:</u>** surveyed participants saw need for increased regionalization of forecast products and an indication of the potential impacts
- **<u>Existing gap:</u>** there is a need for engagement across sectors to further identify and prioritize forecasts and products that need longer lead times and specificity

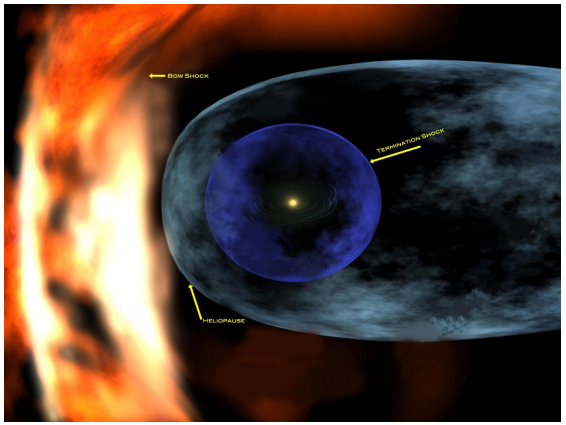


<u>Solution:</u> ACSWA's Commercial Marketplace hosted by NextGen Federal Systems provides validated models, data, and services for:

- Radiation monitors, magnetometers, and optical instruments
- Represents 10⁺ companies
- Deploys in January 2026

Research Sector

- **Priority:** surveyed participants saw the importance for focusing on the full R2O – O2R cycle that is critical to improving space weather nowcasting, forecasting, and mitigation
- **Existing gap:** there is a need for intentional and sustained investment in R2O and O2R infrastructure and processes to mature existing and future capabilities for operationsc



Solution: CRC's modeling network provides crucial information for understanding the Sun to beyond the heliosphere:

- Real-time and historical space weather modeling of coronal mass ejections, solar wind, shocks, magnetic fields, and energetic particles
- impact assessments across geomagnetic and heliospheric environments.

Space Traffic Management Sector

- **Priority:** surveyed participants identified the need by STM/C users for usable data and actionable neutral density model outputs and products
- **Existing gap:** there is a need for low-latency, i.e., hours time frame, neutral density observations between approximately 100–400 km

Solution: ORBOTICS's D3 drag device and WIND density measurements in the thermosphere will help de-orbit spacecraft and will feed data to assimilative density models for:

- LEO density monitoring
- A real-time data feed
- De-orbiting capabilities to mitigate debris collisions with active assets

Space Traffic Management Sector

- **Priority:** surveyed participants saw the need by STM/C users for usable data and actionable neutral density model outputs and products
- **Existing gap:** there is a need for a framework to validate and share inferred neutral density values where large constellation operators can share neutral density data

Solution: ORION's Dragster thermosphere density modeling system will use data in assimilative density models for:

- LEO density monitoring
- Representing the global density state
- Providing users with capabilities to mitigate collisions