



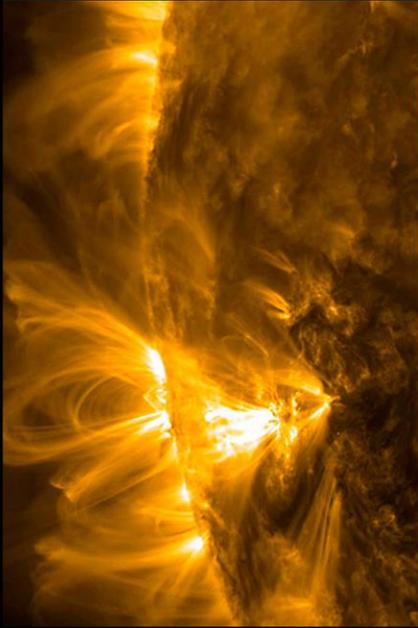
Heliophysics



*The Science of Space Weather
Space Weather Workshop 2016
27 April 2016
Steven W. Clarke, Director*



Science Mission Directorate



HELIOPHYSICS



EARTH SCIENCE



PLANETARY SCIENCE



ASTROPHYSICS



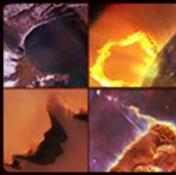
An Integrated Program of Science



The Science of Space Weather



- NASA formulates and implements a national research program for understanding the Sun and its interactions with the Earth and the Solar System and how these phenomena impact life and society.
 - Heliophysics research provides theory, data, and modeling development services to national space weather efforts through targeted research and leveraging the expertise of the Community Coordinated Modeling Center (CCMC), a multi-agency partnership to enable, support and perform the research and development for next-generation space science and space weather models.
- NASA fields a coordinated and complementary fleet of spacecraft to understand the Sun and its interactions with Earth and the solar system, including space weather.
- NASA enables the safe operations of its robotic and human missions using space weather research data and models.



NASA Heliophysics

Strategic Goal: Understand the Sun and its interactions with Earth and the solar system, including space weather

Solar Terrestrial Probes



Strategic Mission
Flight Programs

Living With a Star



Strategic Mission
Flight Programs

Solve the fundamental physics mysteries of heliophysics: Explore and examine the physical processes in the space environment from the sun to the Earth and throughout the solar system.

Build the knowledge to forecast space weather throughout the heliosphere: Develop the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.

Understand the nature of our home in space: Advance our understanding of the connections that link the sun, the Earth, planetary space environments, and the outer reaches of our solar system.

Explorers



Smaller flight programs,
competed science topics,
often PI-led

Research



Scientific research projects
utilizing existing data plus
theory and modeling



Heliophysics Budget

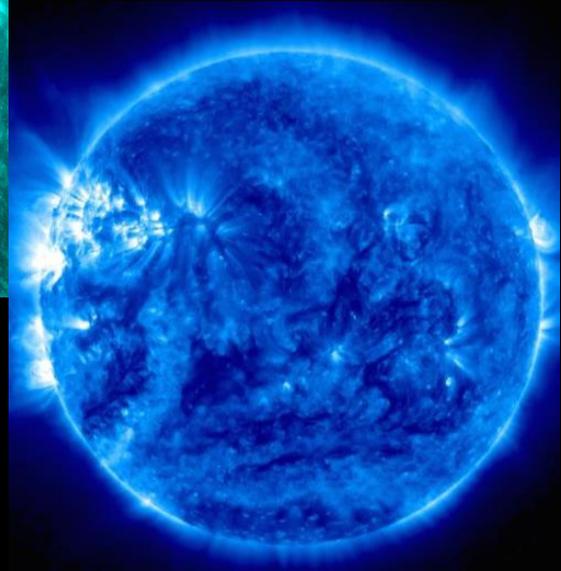
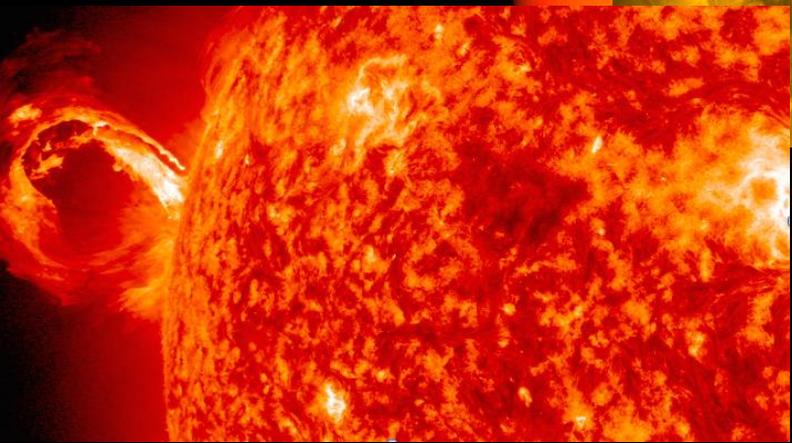
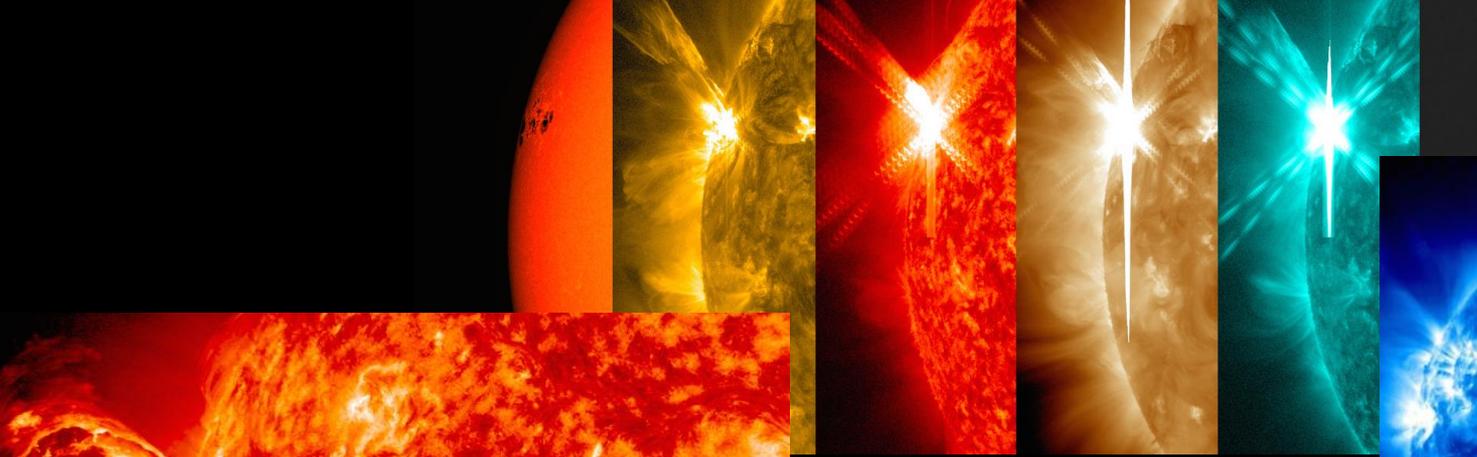
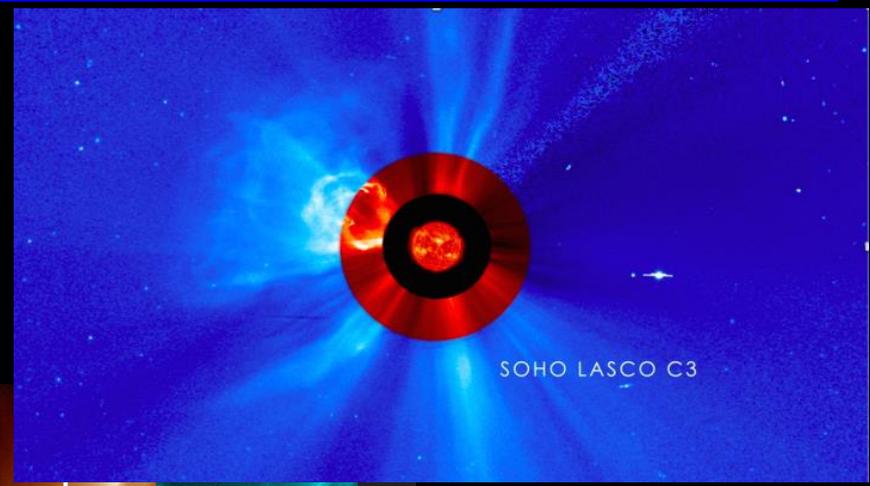
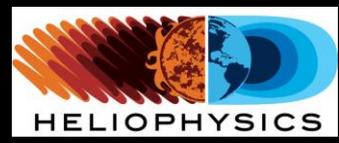


| \$M | FY15 | FY16 Enacted | FY17 | FY18 | FY19 | FY20 | FY21 |
|--------------|-------|-----------------|-------|-------|-------|-------|-------|
| Heliophysics | 636.1 | 647.2 | 698.7 | 684.0 | 698.3 | 714.8 | 723.9 |

- Missions in development fully funded
 - Space Environments Testbed-1 (SET-1) – March 2017
 - Ionospheric CONnection Explorer (ICON) – October 2017
 - Global Observation of the Limb and Disk (GOLD) – April 2018
 - Solar Probe Plus (SPP) – July 2018
 - Solar Orbiter Collaboration (SOC) – October 2018
- Future mission funding
 - Release Explorer mission AO/MoO in FY16
 - Release STP-5 mission AO/MoO in FY17
 - Release LWS-7 mission AO/MoO in FY18
- OMB Mandatory Spending (FY2017 only):
 - +\$10.0M for Heliophysics/Cubesat program
 - +\$10.0M for Heliophysics/Space weather research in support of the Space Weather Action Plan
 - +\$5.0M for Research & Analysis

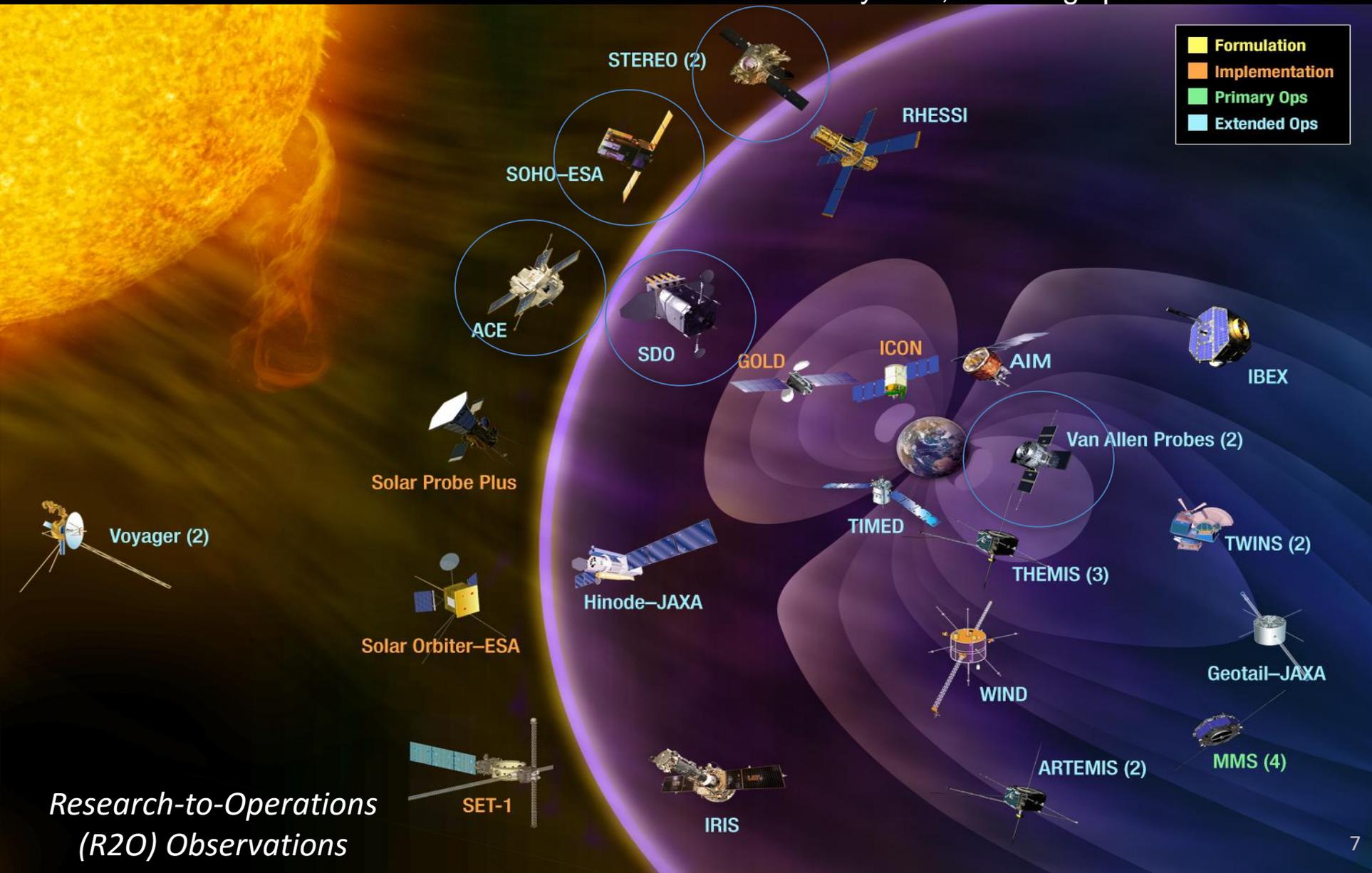


Observations



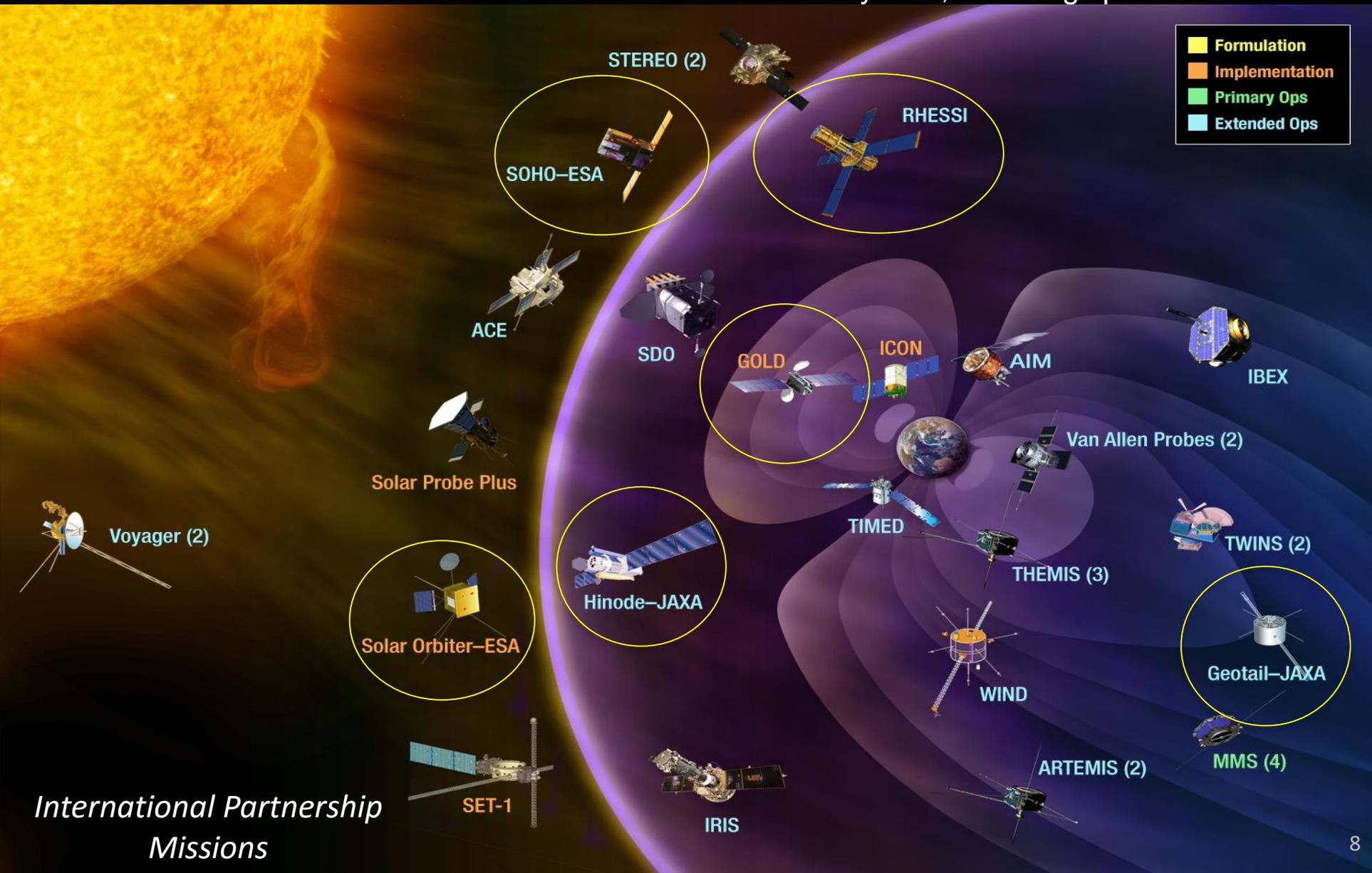
Heliophysics System Observatory

A coordinated and complementary fleet of spacecraft to understand the Sun and its interactions with Earth and the solar system, including space weather



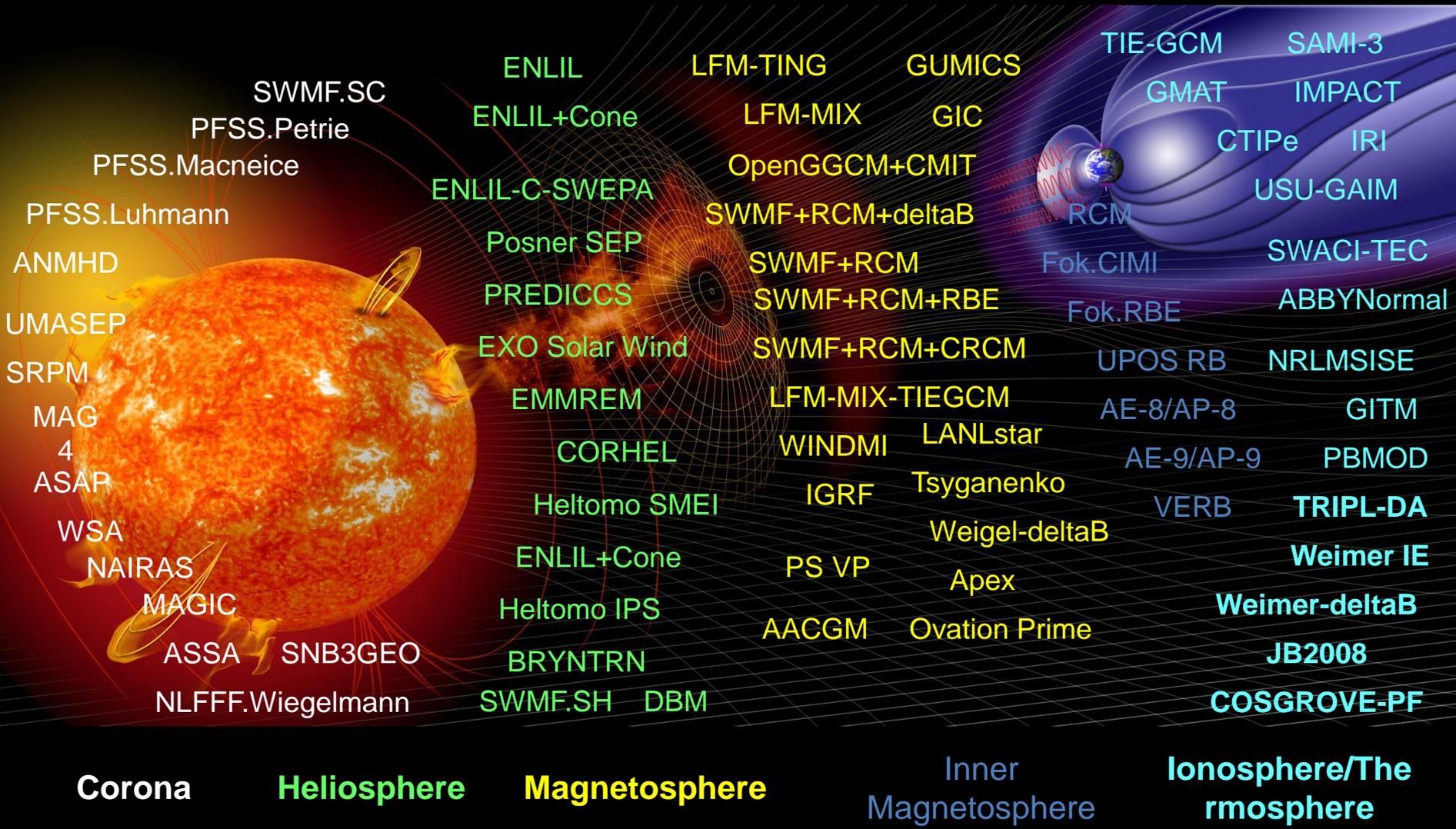
Heliophysics System Observatory

A coordinated and complementary fleet of spacecraft to understand the Sun and its interactions with Earth and the solar system, including space weather



Numerous Community Research Models

[List of those hosted at Community Coordinated Modeling Center (CCMC)]



Focus is on research - despite quantity of excellent models few are applicable to operational needs.





Heliophysics Research Grants



NASA Heliophysics implements a program to achieve three overarching science goals through research grants for flight data analyses, theory and modeling:

- *Explore the physical processes in the space environment from the Sun to the Earth and throughout the solar system*
- *Advance our understanding of the connections that link the Sun, the Earth, planetary space environments, and the outer reaches of our solar system*
- *Develop the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth*



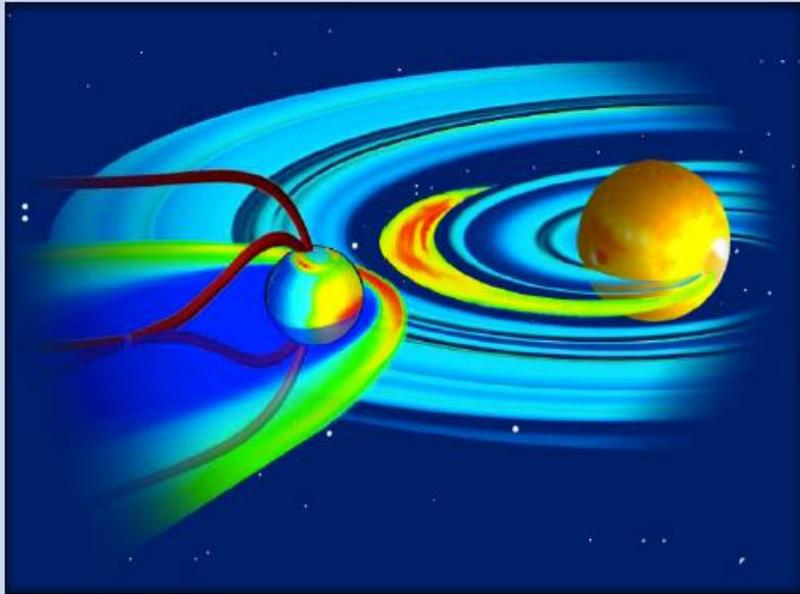


NSF/NASA LWS Strategic Capability Space Weather Modeling (2013-2018)



8 continuing awards, \$1.5M/yr (NSF), \$2.5M/yr (NASA) for 5 years:

Collaborative Space Weather Modeling



A Model of Community Coordinated Modeling Center (CCMC)

NASA NSF Partnership for Collaborative Space Weather Modeling supports large-scale space weather modeling efforts that require collaborative community teamwork. This joint effort has been significantly enhanced by our capabilities in the modeling and prediction of solar eruptions, particle acceleration in the corona and solar wind, small scale physics effects in global magnetosphere models, and upper atmosphere dynamics.

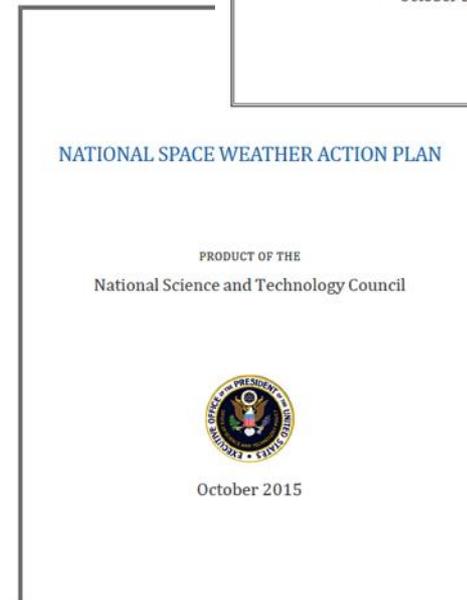
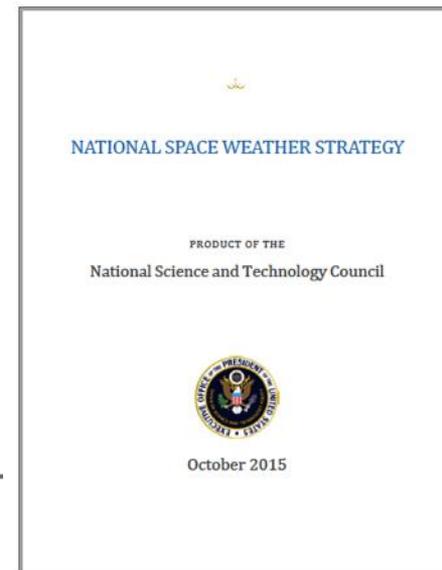
- Fisher; UC Berkeley, Stanford, Lockheed; [Coronal global evolutionary model](#)
- Schunk; Utah State, JPL, U of Southern CA, [1st principles-based data assimilation model for the global ionosphere](#)
- Bhattacharjee, Princeton, GSFC, LANL, UCSD; [Kinetic Effects in Global Magnetosphere Models](#)
- Mansour, [Real-time heliospheric space weather modeling](#)
- Odstroil, UMD, GMU, UCB; [Magnetic flux emergence and transport](#)
- Antiochus; UMich, NASA, NRL; [Modeling of flares, coronal mass ejections \(CMEs\) and their interplanetary impacts](#)
- Mannucci; JPL; [IT storm fronts](#)
- Schwadron; [Energetic particle acceleration](#)



National Space Weather Strategy



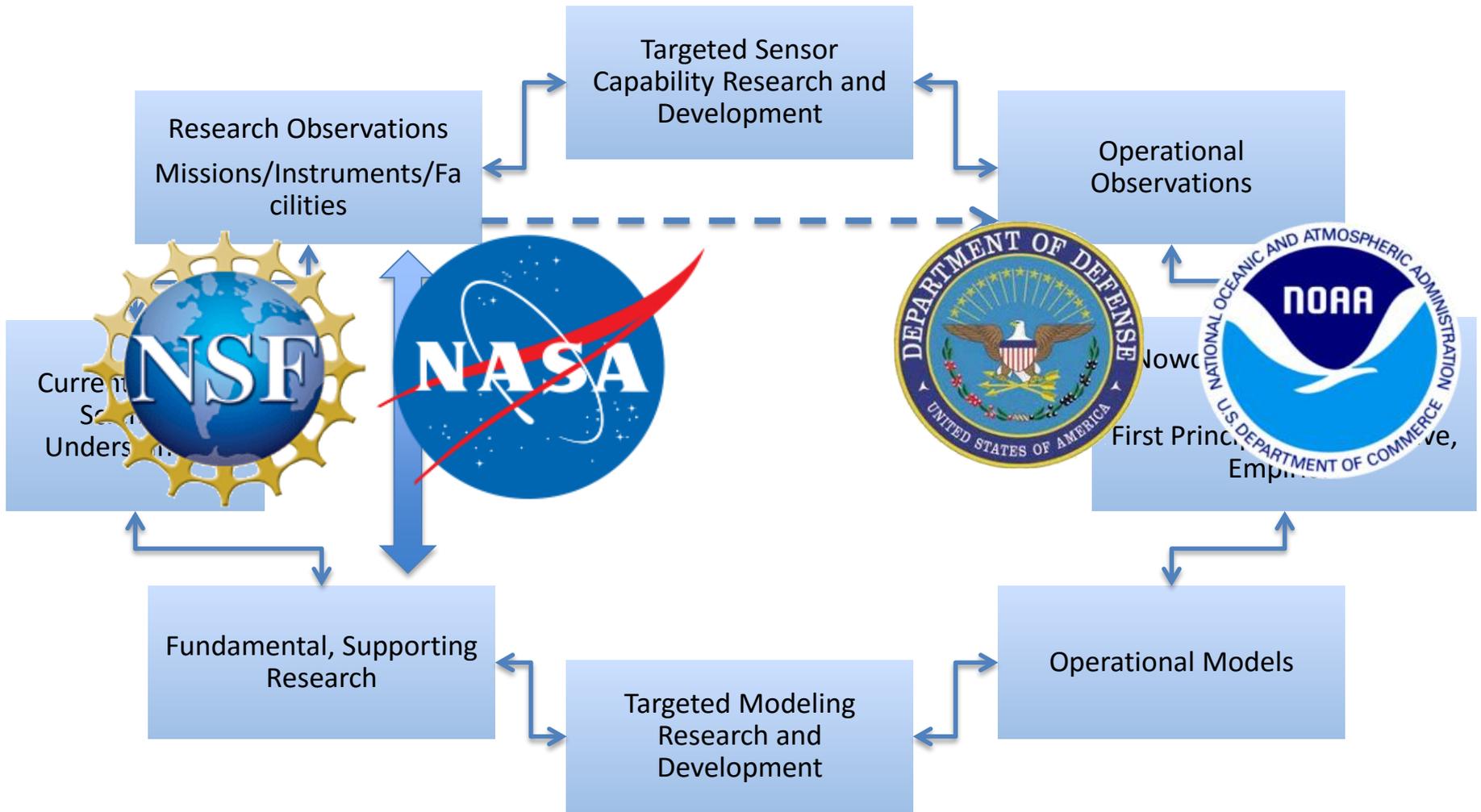
- National Space Weather Strategy and Space Weather Action Plan were officially released on 29 October 2015
- Action Plan details the activities, outcomes and timelines that will be undertaken by Federal departments and agencies for the Nation to make progress toward the strategic goals
- 6 Strategic Goals in the Action Plan
 - ***Establish Benchmarks for Space-Weather Events***
 - ***Enhance Response and Recovery Capabilities***
 - Improve Protection and Mitigation Efforts
 - ***Improve Assessment, Modeling, and Prediction of Impacts on Critical Infrastructure***
 - ***Improve Space-Weather Services through Advancing Understanding and Forecasting***
 - ***Increase International Cooperation***



NASA is providing space weather research expertise to 40 actions in the 6 goals.

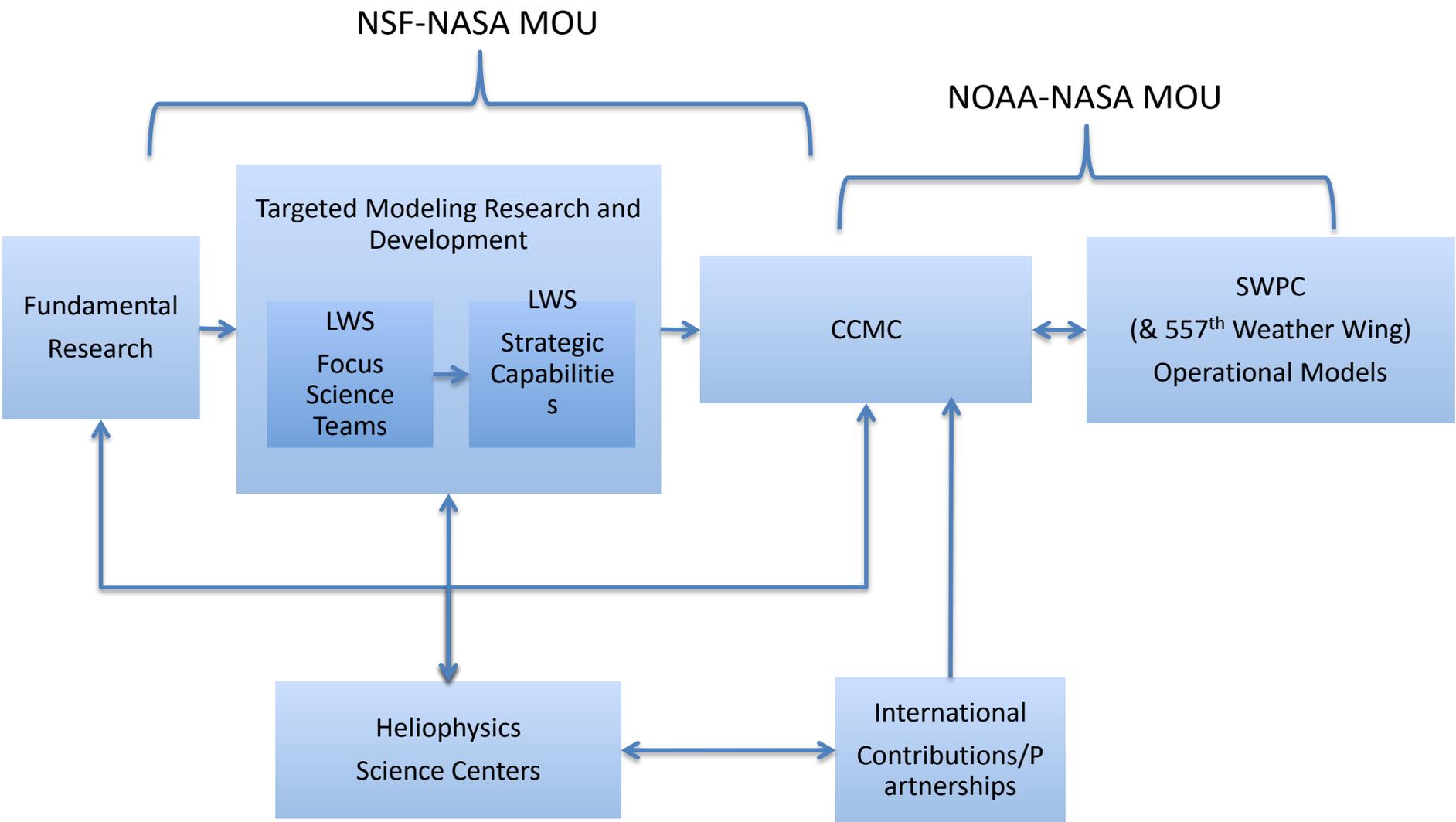
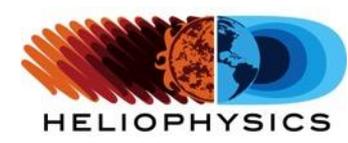


Elements of R2O & O2R System





Future Modeling R2O Concept of Operations



International Space Weather Activities



International Space Weather Initiative (ISWI)

- Program of international cooperation to advance the space weather science by a combination of instrument deployment, analysis and interpretation of space weather data from the deployed instruments in conjunction with space data, and communicate the results to the public and students



International Living With a Star (ILWS)

- Stimulate, strengthen, and coordinate space research to understand the governing processes of the connected Sun-Earth System as an integrated entity



United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS)

- Review the scope of international cooperation in peaceful uses of outer space, to devise programmes in this field to be undertaken under United Nations auspices, to encourage continued research and the dissemination of information on outer space matters, and to study legal problems arising from the exploration of outer space



Coordination Group for Meteorological Satellites (CGMS)

- International forum for the exchange of technical information on geostationary and polar orbiting meteorological satellite systems



COSPAR/ILWS roadmap towards advanced space weather science

- COSPAR and the steering committee of the ILWS program tasked a multi-disciplinary, international team with the development of a roadmap with the goal of demonstrably improving our observational capabilities for, scientific understanding of, and ability to forecast the various aspects of space weather



Long-term interagency, international and public-private collaboration is critical to successful global space weather preparedness.

Thank You!