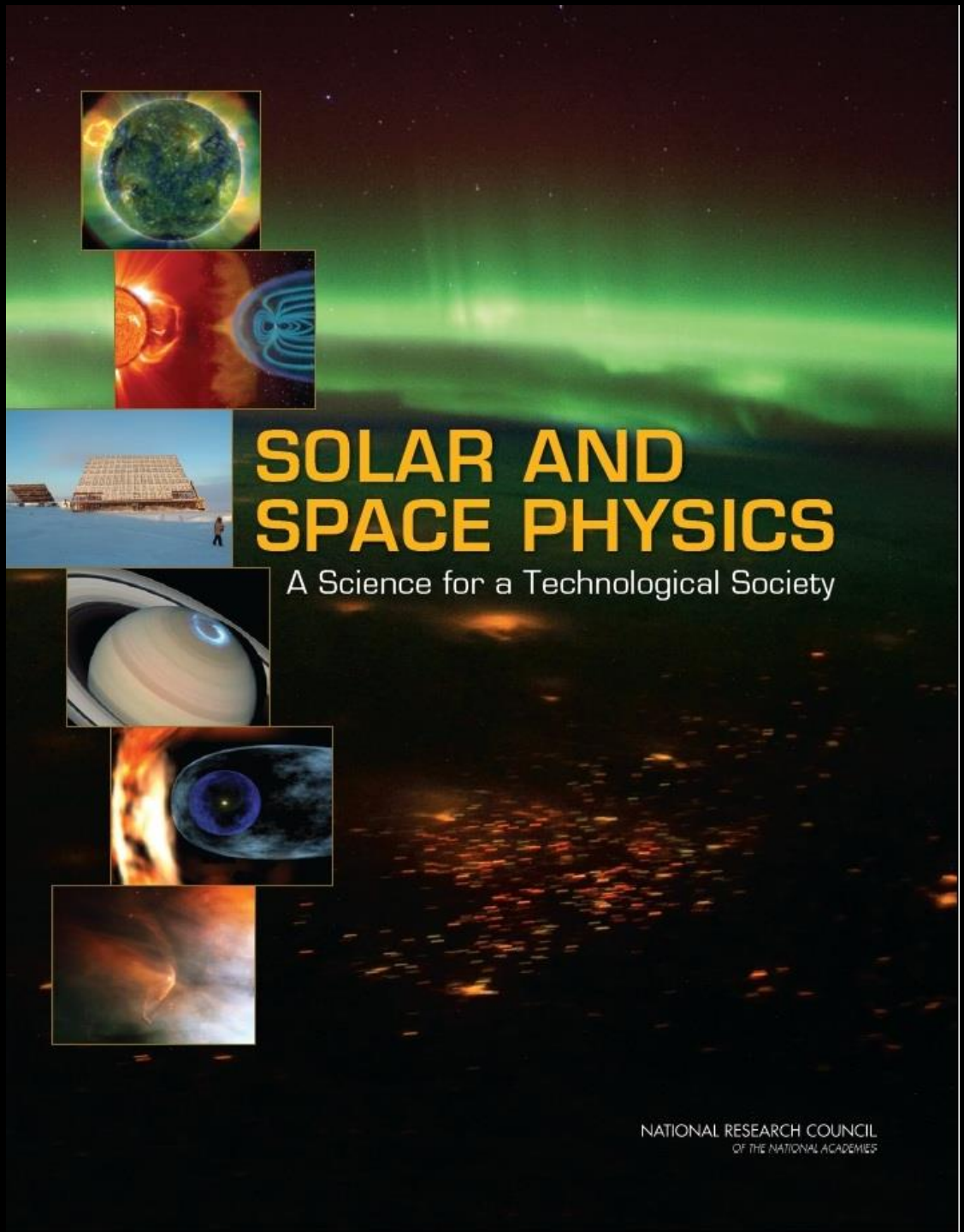


Enabling Effective Space Weather and Climate Capabilities:

The NRC Decadal Survey in Solar & Space Physics

Daniel N. Baker, Chair
NRC Decadal Survey
Steering Committee

LASP-CU/Boulder

Overarching Goals for a Decade of Discovery

- Determine the origins of the Sun's activity and predict the variations of the space environment.
- Determine the dynamics and coupling of Earth's magnetosphere, ionosphere, and atmosphere and their response to solar and terrestrial inputs.
- Determine the interaction of the Sun with the solar system and the interstellar medium.
- Discover and characterize fundamental processes that occur both within the heliosphere and throughout the universe.

Complete the Ongoing Program

- The survey committee's recommended program for NSF and NASA assume continued support in the near-term for the key existing program
  - NASA: complete RBSP, MMS, Solar Probe Plus, Solar Orbiter; also IRIS and Explorer selections.
  - NSF: complete ATST and support core program.

1.Implement the DRIVE Initiative

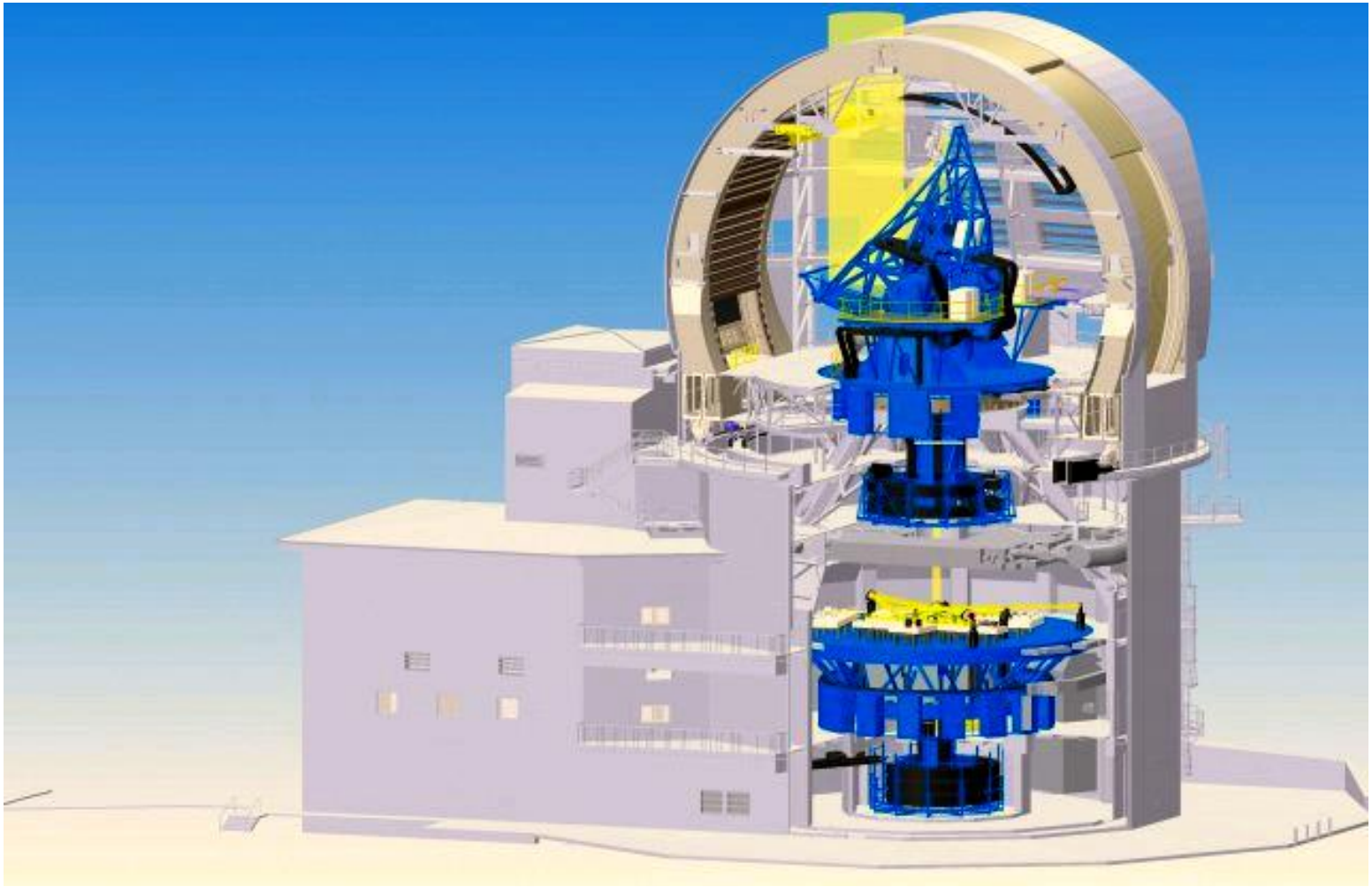
- **Will enable NASA, NSF and other agencies to more effectively exploit their scientific assets:**

Diversify observing platforms with microsatellites and mid-scale ground-based assets
Realize scientific potential by sufficiently funding operations and data analysis
Integrate observing platforms and strengthen ties between agency disciplines
Venture forward with science centers and instrument and technology development
Educate, empower, and inspire the next generation of space researchers

DRIVE for NSF

- **Diversity**:
  - **Recommendation: NSF's CubeSat program should be augmented to enable at least two new starts per year.** Detailed metrics should be maintained, documenting the accomplishments of the programs in terms of training, research, technology development, and contributions to space weather forecasting.
  - Create a mid-scale ($4-90M) line for ground-based projects.
- **Realize**: Provide sufficient funding for efficient and scientifically productive operation of Advanced Technology Solar Telescope.
- **Integrate**:
  - **Recommendation: NASA should join with NSF and DOE in a multi-agency program on laboratory plasma astrophysics and spectroscopy.**
  - **Recommendation: NSF should ensure that funding is available for basic research in subjects that fall between sections, divisions, and directorates, such as planetary magnetospheres and ionospheres, the Sun as a star, and the outer heliosphere.**

NSF's Advanced Technology Solar Telescope

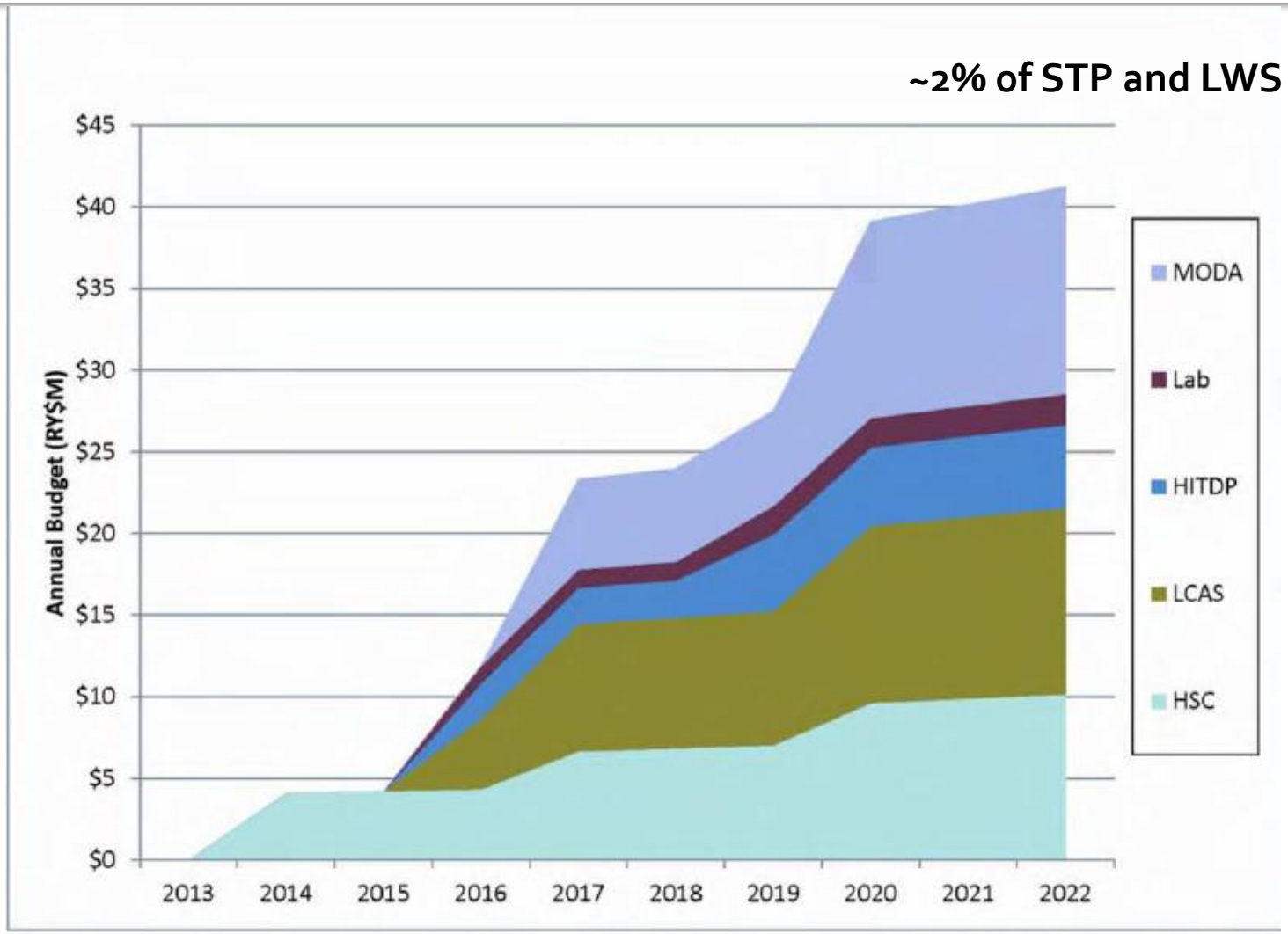


DRIVE for NSF, Cont'd

- **Venture**: Multi-agency development of critical mass science centers.
  - **Recommendation: NASA and NSF together should create heliophysics science centers (HSCs) to tackle the key science problems of solar and space physics that require multidisciplinary teams of theorists, observers, modelers, and computer scientists.**
- **Educate**: Promote faculty and curriculum development and visibility of solar and space physics.
  - **Recommendation: NSF Faculty Development in Space Sciences (FDSS) program should be continued and be considered open to applications from 4-year as well as PhD-granting institutions as a means to broaden and diversify the field.**

Implementation of DRIVE at NASA

~2% of STP and LWS missions - GI



MO&DA Augmentation

Lab Experiments

Tech and Instrument

LCAS Microsats

Heliophysics Science Centers

2. Accelerate and Expand the Heliophysics Explorer Program

- The recommended augmentation of the Explorer line ($70 million/year) allows for missions in a restored MIDEX line to be deployed in alternation with SMEX missions at a 2-3 year cadence; also allows regular selection of MOOs.

3. Restructure Solar-Terrestrial Probes as a Moderate-scale PI-led Line

- NASA's Solar Terrestrial Probes program to be restructured as a moderate-sized, competed, principal investigator-led (PI-led) mission line that is cost-capped at $520 million per mission in fiscal year 2012 dollars including full lifecycle costs.

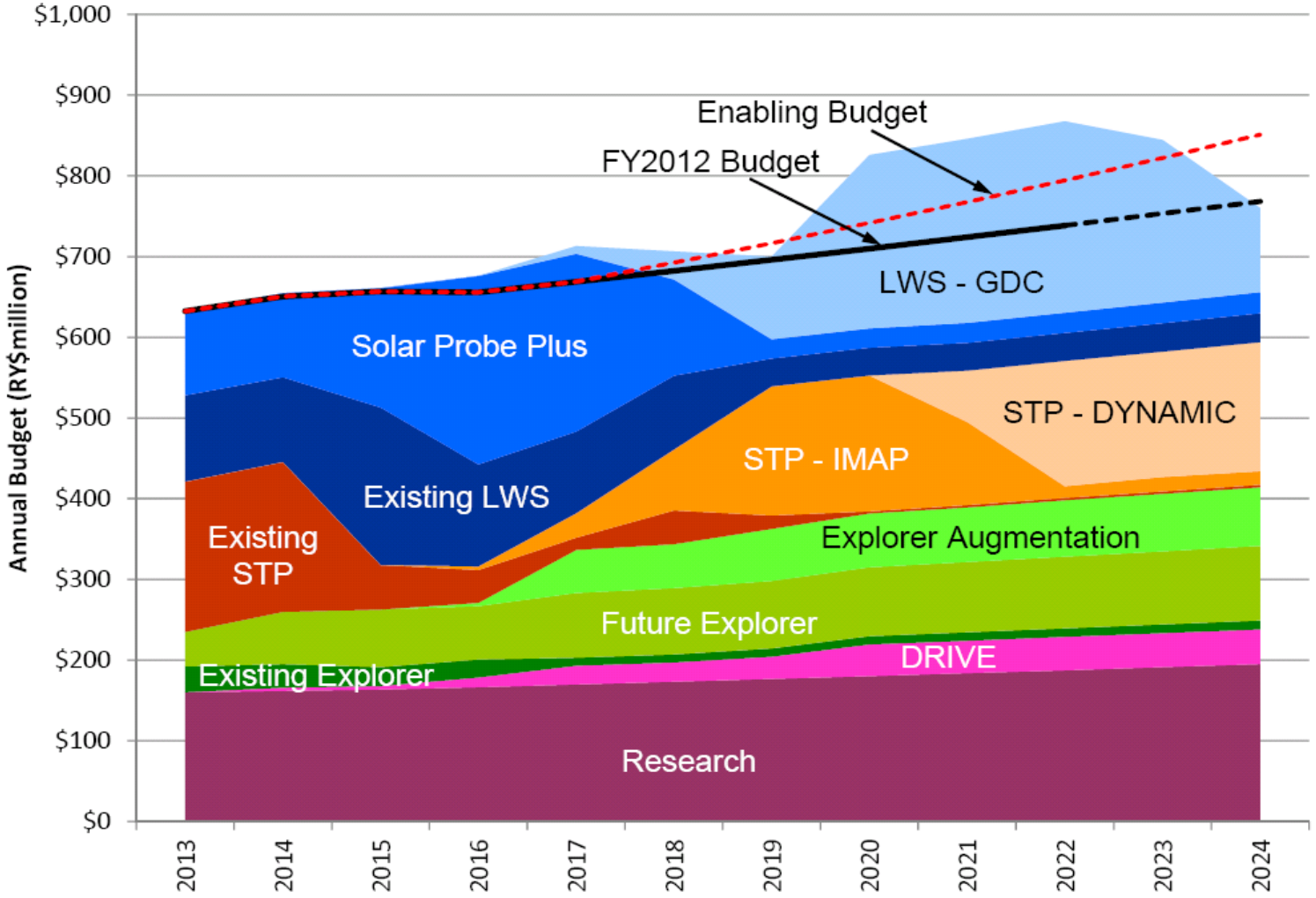
STP Prioritized Science Targets

1. Understand the outer heliosphere and its interaction with the interstellar medium; measure solar wind inputs to the terrestrial system.
   - *Reference mission:* ***IMAP*** *(to be launched* in time to overlap with Voyager)
2. Provide a comprehensive understanding of the variability in space weather driven by lower atmosphere weather on Earth.
   - *Reference mission:* ***DYNAMIC***
3. Determine how the magnetosphere-ionosphere-thermosphere system is coupled and how it responds to solar and magnetospheric forcing.
   - *Reference mission:* ***MEDICI***

Living with a Star

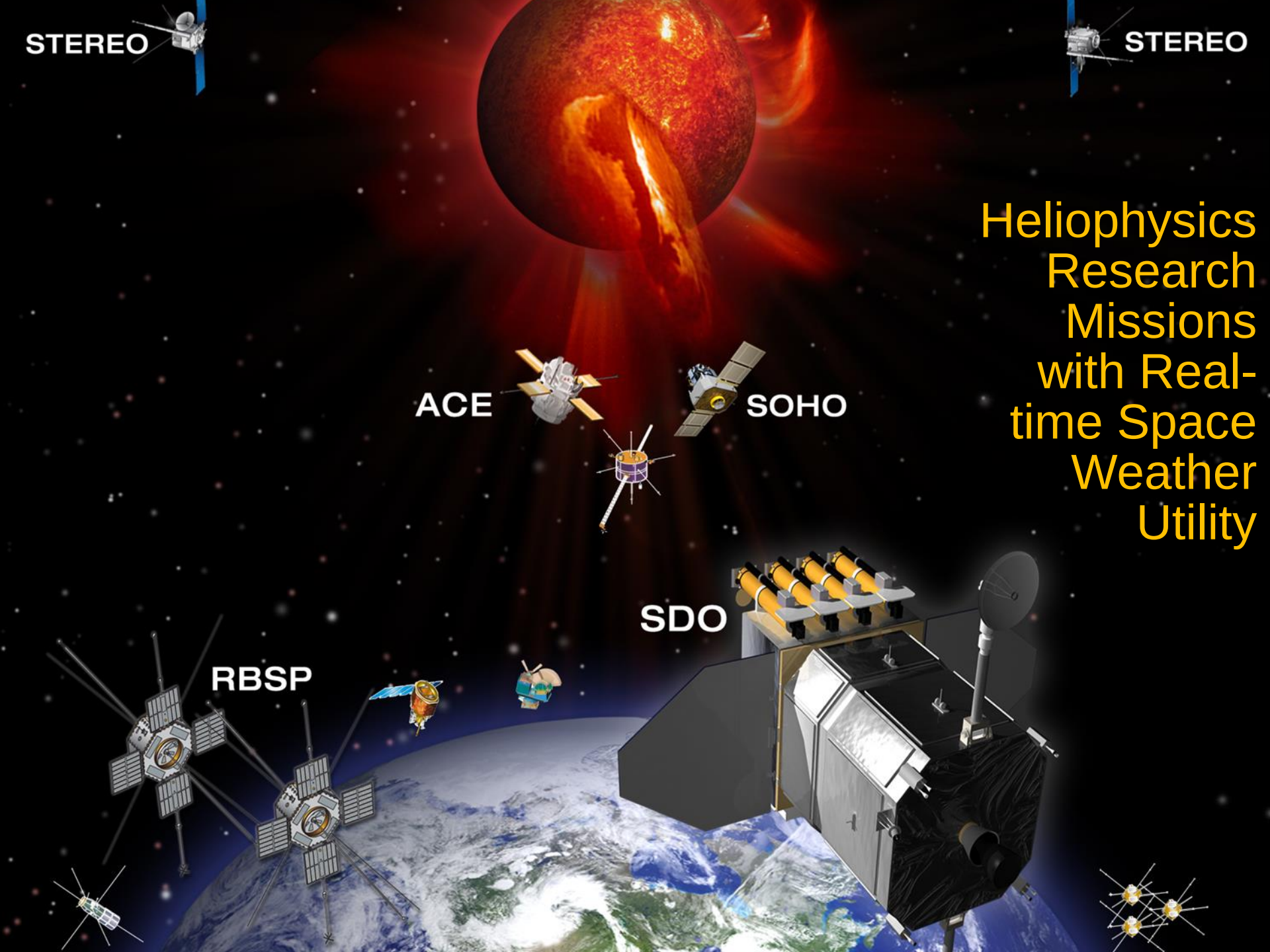
- LWS: Missions, Targeted Research and Technology Programs
- Survey committee does not recommend changes to the organization of LWS missions, which have been highly successful.
  - Large-class mission line.
  - Center-led.

Decadal Plan for NASA's Heliophysics Division



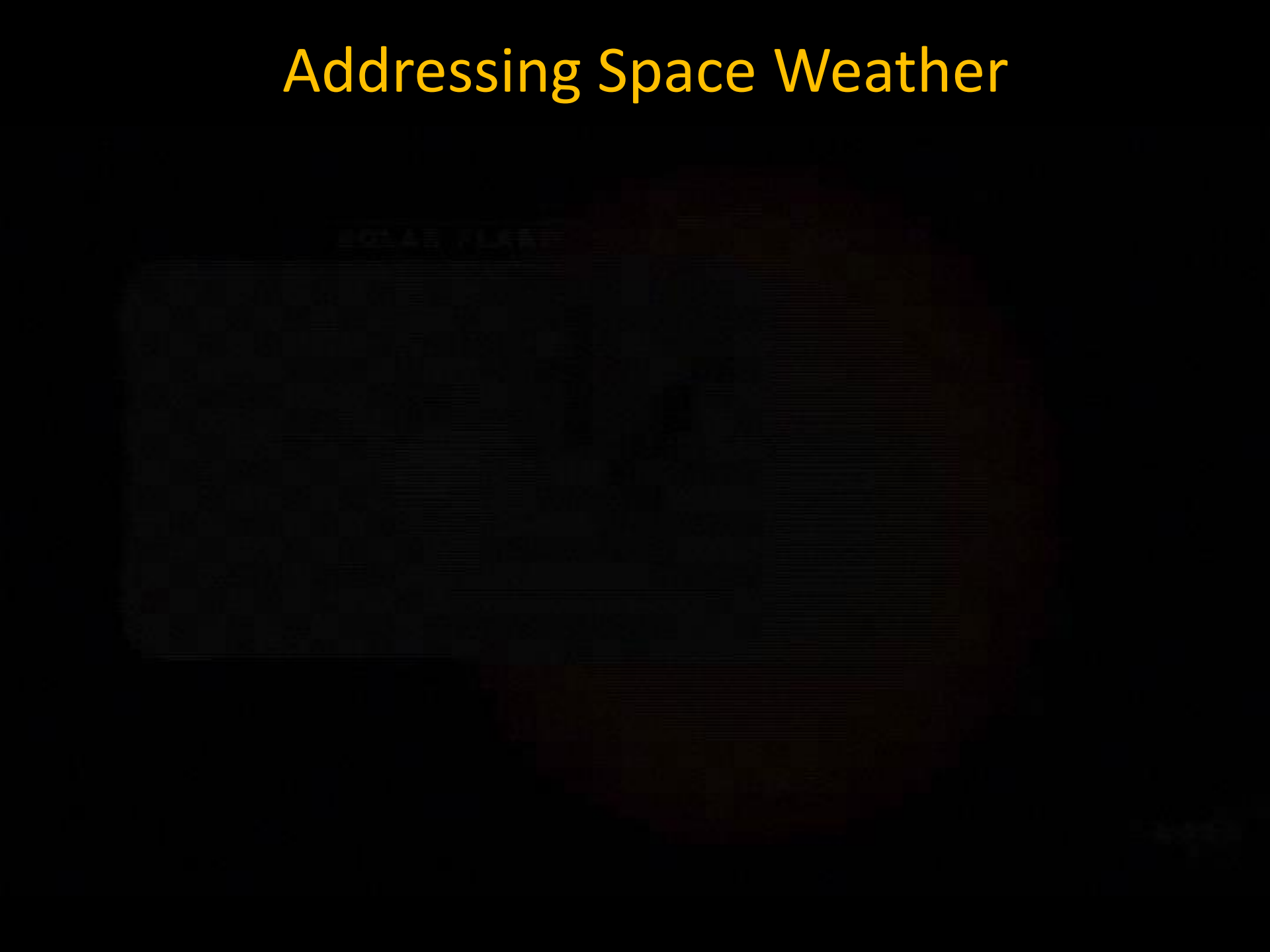
Background: Space Weather

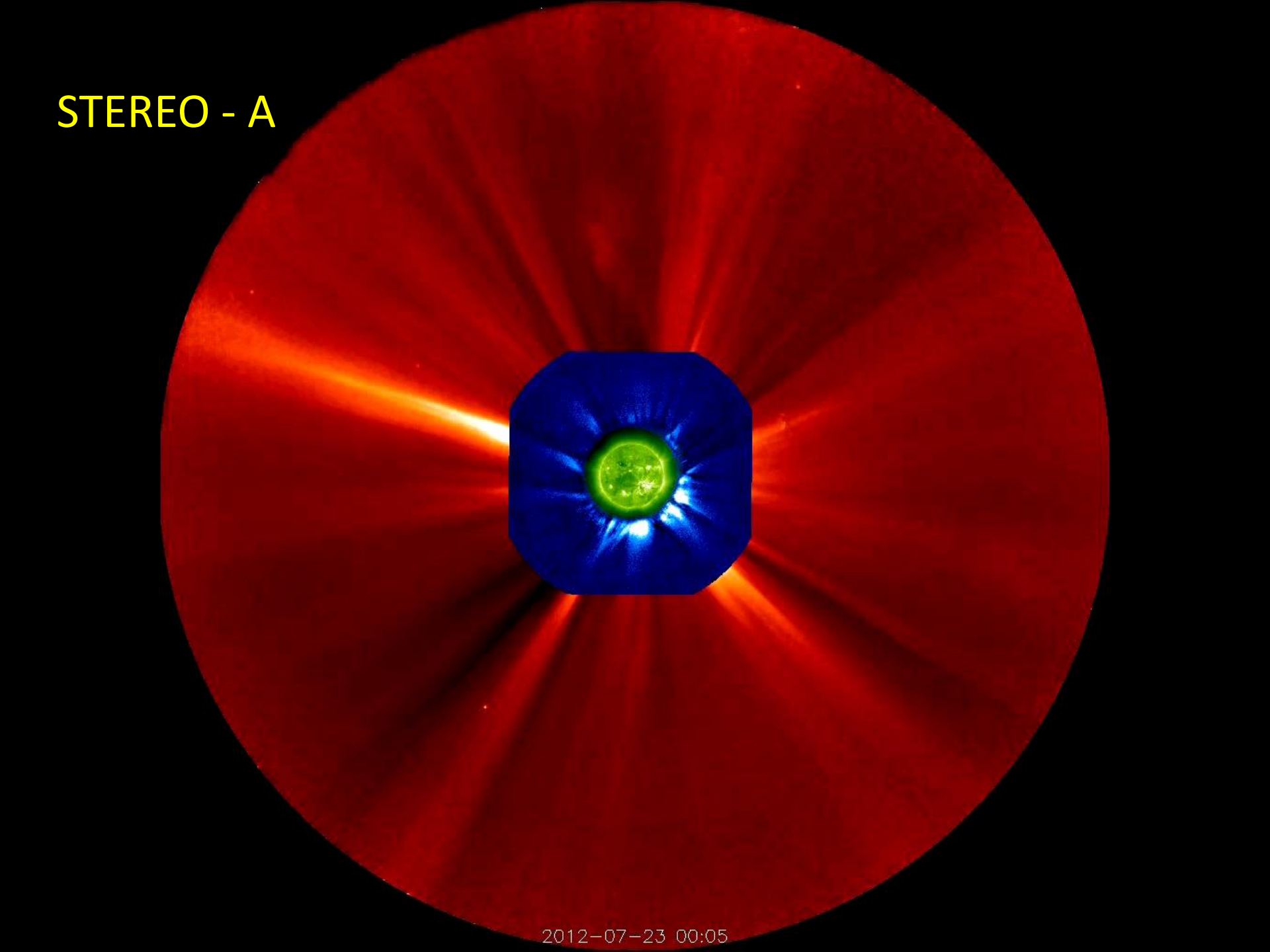
- NASA research satellites, such as ACE, SOHO (with ESA), STEREO, and SDO, designed for scientific studies have provided over the past decade or more critical measurements essential for specifying and forecasting the space environment system, including the outward propagation of eruptive solar events and solar wind conditions upstream from Earth.
- While these observational capabilities have become essential for space environment operations, climatological monitoring, and research, NASA currently has neither the mandate nor the budget to sustain these measurements into the future.
- A growing literature has documented the need to provide a long-term strategy for monitoring in space, and elucidated the large number of space weather effects, the forecasting of which depend critically on the availability of suitable data streams.



Heliophysics Research Missions with Real-time Space Weather Utility

Addressing Space Weather

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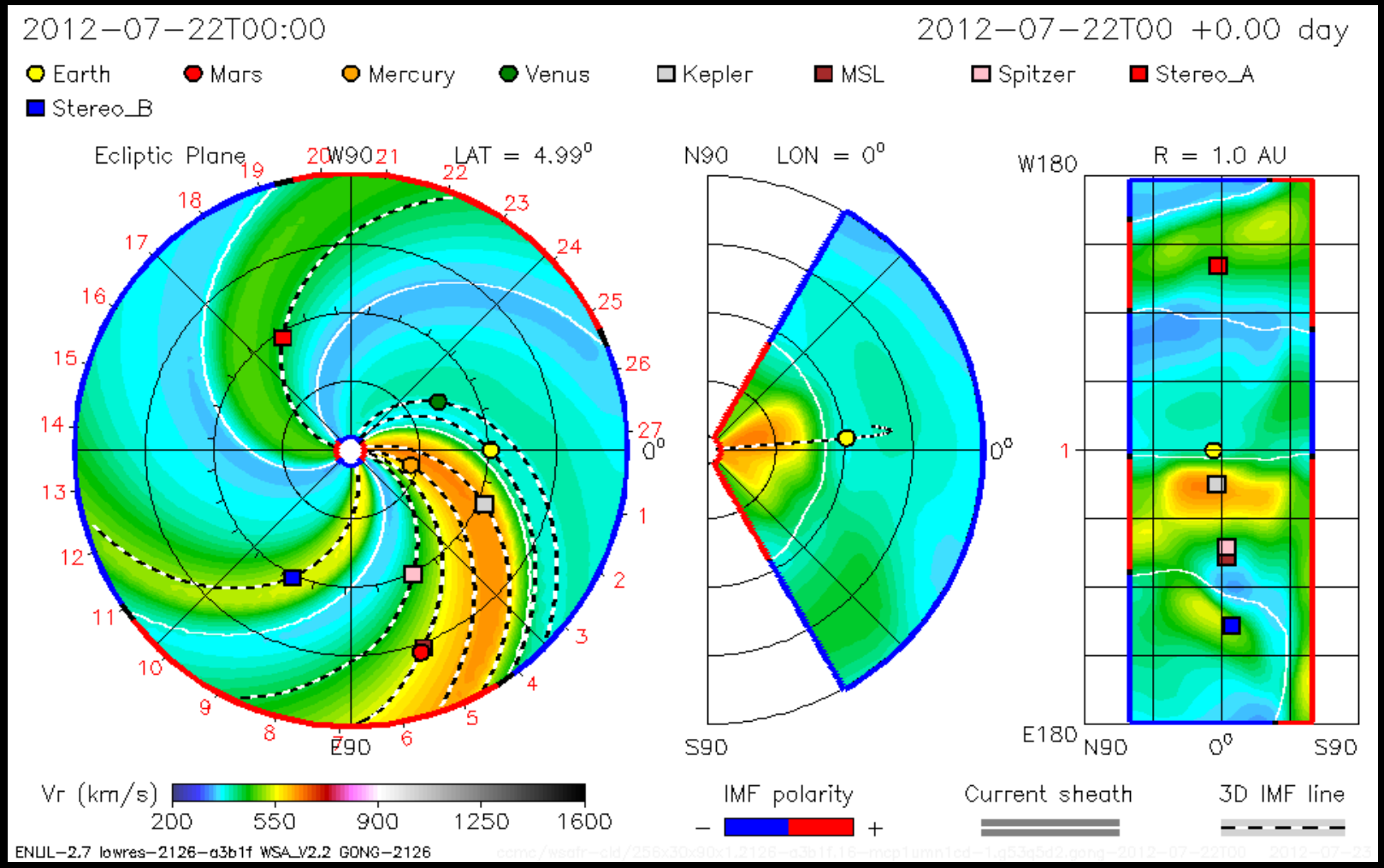
WSA-ENLIL Model: Solar Wind Speed



Papers in preparation: GRL, Space Weather

Overview of Recommendations (prioritized)

- **The National Space Weather Program should be re-chartered under the auspices of the National Science and Technology Council and should include the active participation of the Office of Science and Technology Policy and the Office of Management and Budget. The [re-chartering] plan should build on current agency efforts, leverage the new capabilities and knowledge that will arise from implementation of the programs recommended in this report, and develop additional capabilities, on the ground and in space, that are specifically tailored to space weather monitoring and prediction.**
  - Re-chartering provides an opportunity to review the program and to consider issues pertaining to program oversight and agency roles and responsibilities.
  - A comprehensive plan for space weather and climatology is also needed to fulfill the requirements as presented in the June 2010 U.S. National Space Policy and as envisioned in the 2010 National Space Weather Program Strategic Plan.

Overview of Recommendations, Cont'd.

Multi-agency Partnership for Solar/Solar Wind Observations

- L1 Solar Wind (DSCOVR, IMAP)
- Coronagraph and Magnetograph
- Evaluate New Observations and Platforms
- Establish a SWx Research Program for Effective Research to Operations Transition at NOAA
- Establish Distinct Programs for Space Physics Research and Space Weather Forecasting and Specification

Key Steps From EIS Summit (London, May 2012)

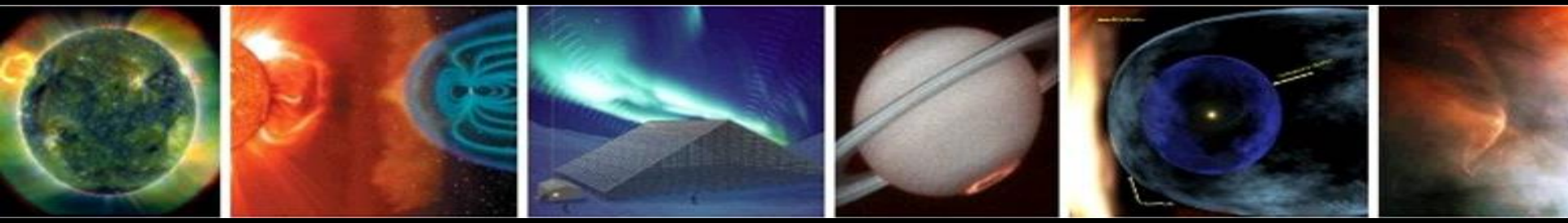
- **Establish severe space weather working group** to identify and define the most reasonable extreme space weather event(s) that might be the basis for operators of the bulk power grid and for system engineers to base threat analysis upon;
- **Identification of the critical infrastructures and facilities** that MUST continue to have power across the nation during extreme space weather events or during EMP attack scenarios (spearheaded by FERC);
- **Detailed modeling of the effects and interconnections of the national power grid** under the influence of severe space weather (Point 1. above) or other threat such as EMP attack (undertaken by companies, system engineers, and operators with the protection of key assets in Point 2. above);
- **Specific and detailed work to identify techniques and engineering solutions that would keep GIC (or EMP) isolated** from key infrastructure (blocking solutions). This would require work by power engineers and transformer experts.

D. N. Baker, **Space Weather** July 2012)

Summary

The 2013-2022 Decadal Survey:

- Fits the current fiscal boundary;
- Focuses on research and its **societal impact**;
- Empowers the community to innovate, take advantage of the unique constellation of missions and data available today, and **study the coupled domains of heliophysics *as a system*;**
- Builds the community's strength and facilitates development of cost-effective PI-class missions; and
- Recommends exciting missions of historical significance that hold tremendous promise for new discoveries that will also **serve powerfully the needs of Space Weather**.

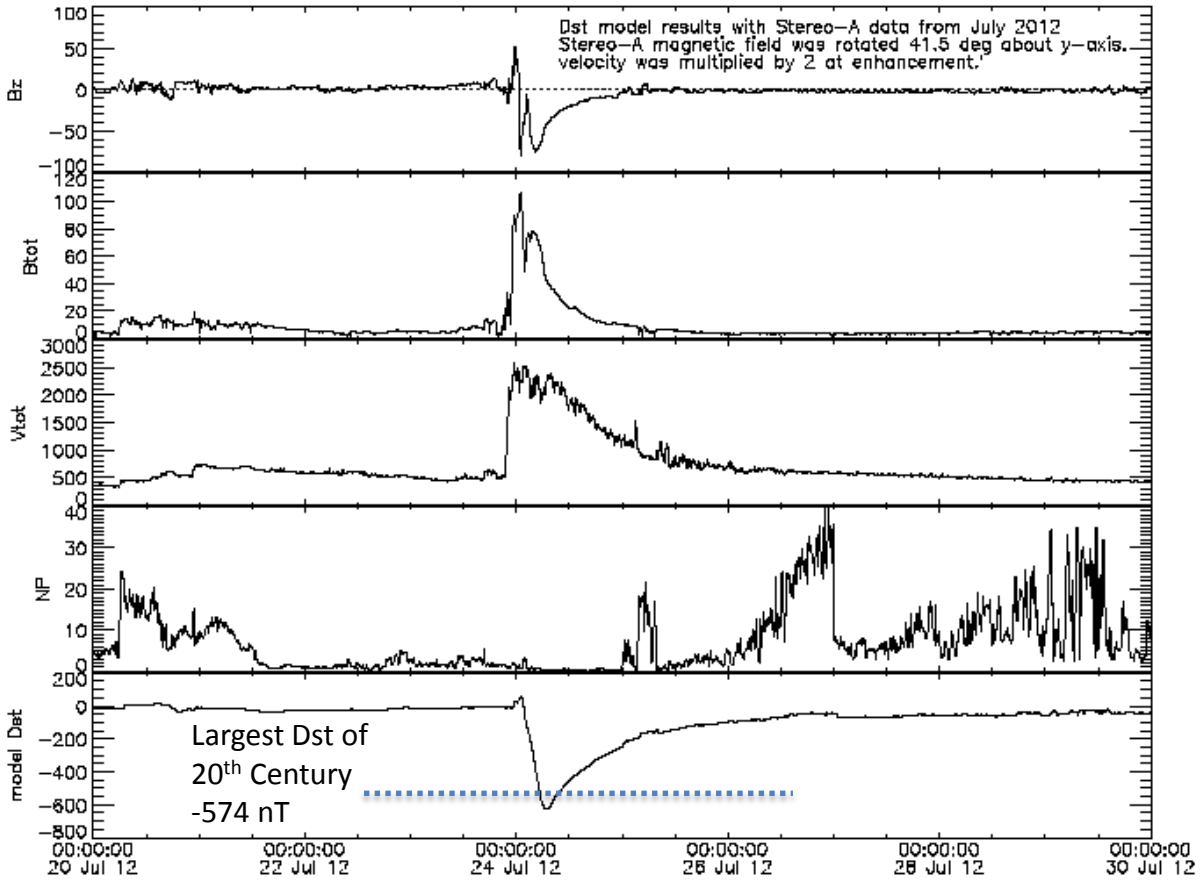


Solar and Space Physics: A Science for a Technological Society

2013-2022: A decade of discovery enabled by new and innovative approaches and tools and by treating heliophysics as a system; focus on societal impact.

http://www.nap.edu/catalog.php?record_id=13060

Solar Wind/IMF Results: July 2012



Courtesy Prof. Xinlin Li