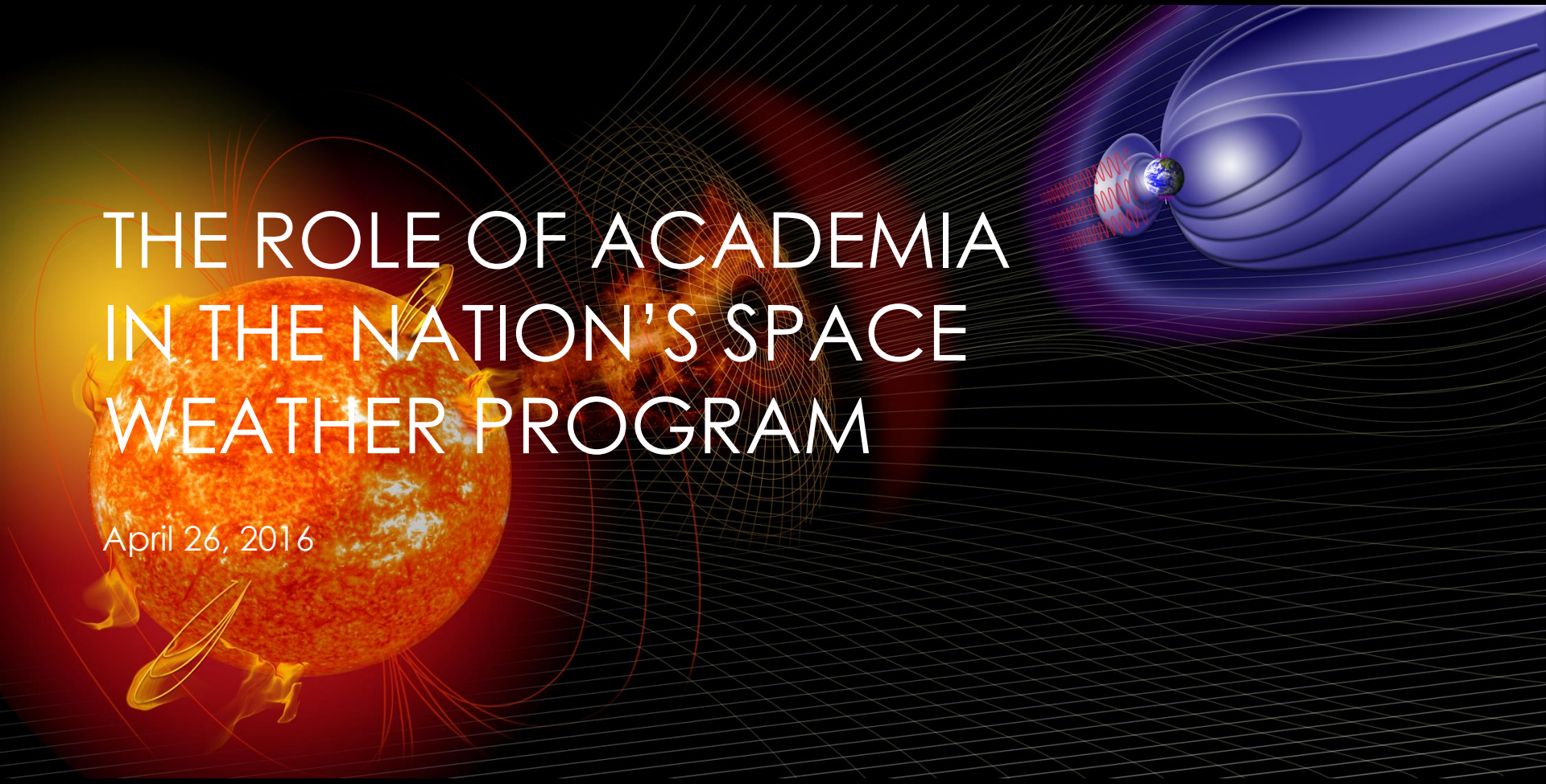


THE ROLE OF ACADEMIA IN THE NATION'S SPACE WEATHER PROGRAM

April 26, 2016

D. N. Baker, A. N. Jaynes, M. Bolton, X. Li, S. R. Elkington, V. Hoxie,
L. Hale, E. Johannson, M. Anfinson, C. Pankratz
Laboratory for Atmospheric and Space Physics—CU Boulder

John F. Kennedy—Special Message to Congress (25 May 1961)

"This decision [to go to the Moon] demands a major national commitment of scientific and technical manpower, materiel and facilities, and the possibility of their diversion from other important activities where they are already thinly spread. It means a degree of dedication, organization and discipline which have not always characterized our research and development efforts. It means we cannot afford undue work stoppages, inflated costs of material or talent, wasteful interagency rivalries, or a high turnover of key personnel."

"…every scientist, every engineer, every serviceman, every technician, contractor, and civil servant [must give] his personal pledge that this nation will move forward… in space."

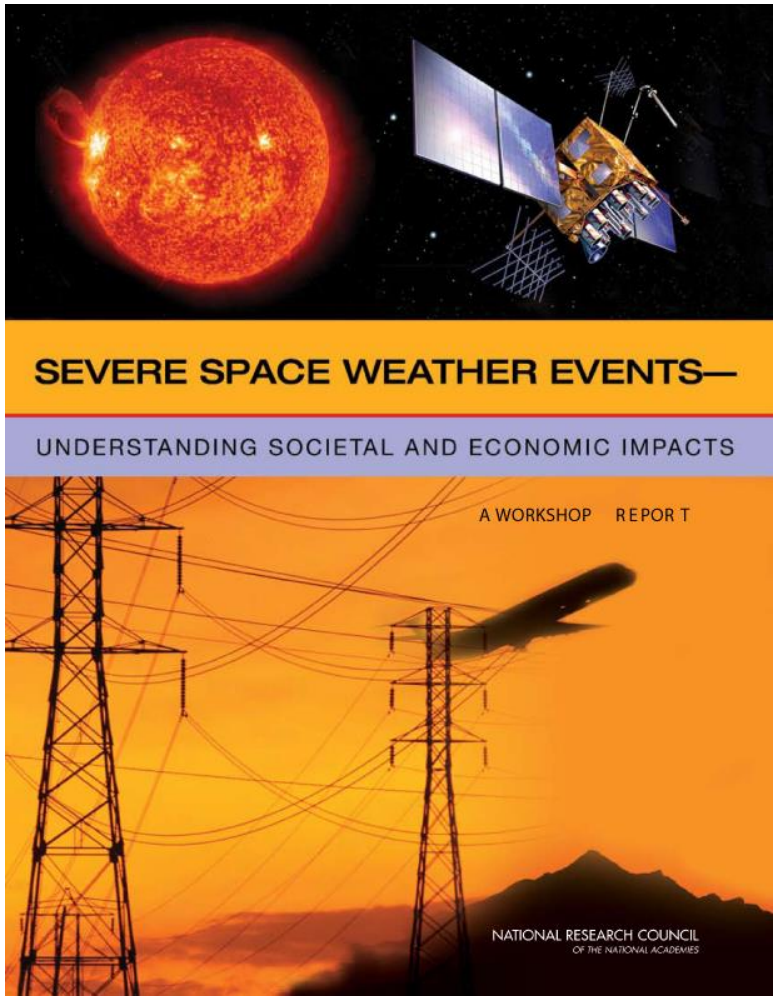
Topics of Discussion

- Policy Aspects
- Colorado Exploration Context
- CU: Grand Challenge and Space Weather
- Required Steps

The Societal and Economic Impacts of Severe Space Weather Events: A Workshop

Workshop details

- May 22-23, 2008 in DC
- Approximately 80 attendees from academia, industry, government, and industry associations
  - Association reps aggregated data and helped avoid concerns about proprietary or competition-sensitive data
- Analyses in specific areas; e.g., GPS, power industry, aviation, military systems, human and robotic exploration beyond low-Earth orbit
- Econometric analysis of value of improved SpaceWx forecasts



[http://www.nap.edu/catalog.php?record_id=12507]

Guido Scarabottolo, NY Times

"Much as America's scientific leadership and policy of open inquiry did wonders for U.S. prestige during the cold war, making most of the [nuclear] detection system data available to the global public would show friends, allies and adversaries alike that the United States is willing to use even its most advanced defense assets for the betterment of humanity.

American taxpayers support a truly remarkable monitoring system whose information could significantly improve our health, security and well-being. We should use this hidden treasure to make the world a better and safer place."

Opinion Guest Column, *New York Times*

The Earth's Secrets, Hidden in the Skies

By DANIEL N. BAKER

Published: May 27, 2010

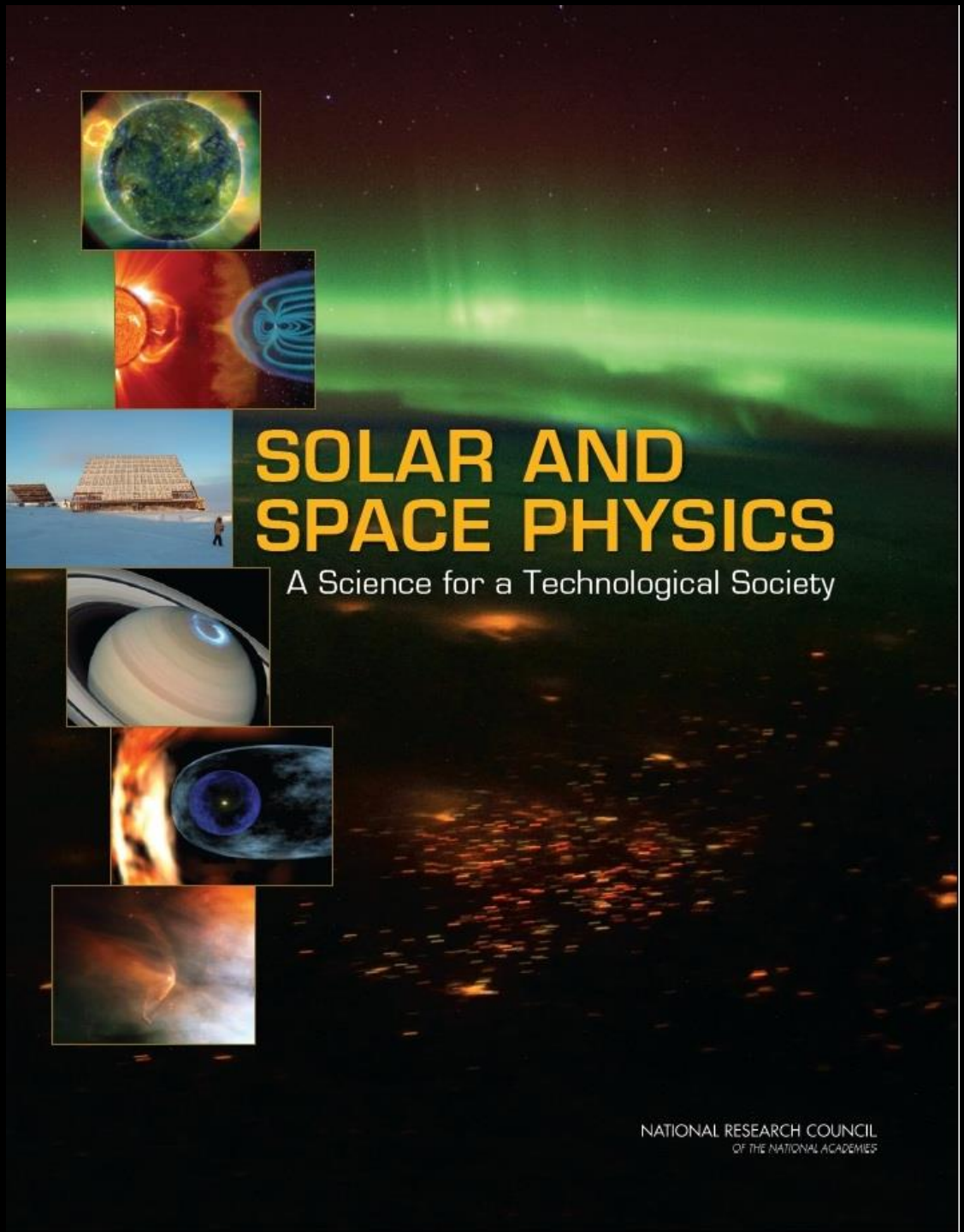
Jacob Macgraw

Op-Ed Contributors

How's the Weather

By MADHULIKA GUHATHAKURTA and DANIEL N. BAKER
Published New York Times: June 16, 2011

LATELY, the Sun has been behaving a bit strangely. In 2008 and 2009, it showed the least surface activity in nearly a century. Solar flare activity stopped cold and weeks and months went by without any sunspots, or areas of intense magnetism. Quiet spells are normal for the Sun, but researchers alive today had never seen anything like that two-year hibernation…



Enabling Effective Space Weather and Climate Capabilities:

The 2013-2022 NRC Decadal Survey

Decadal Survey Purpose and OSTP* Recommended Approach

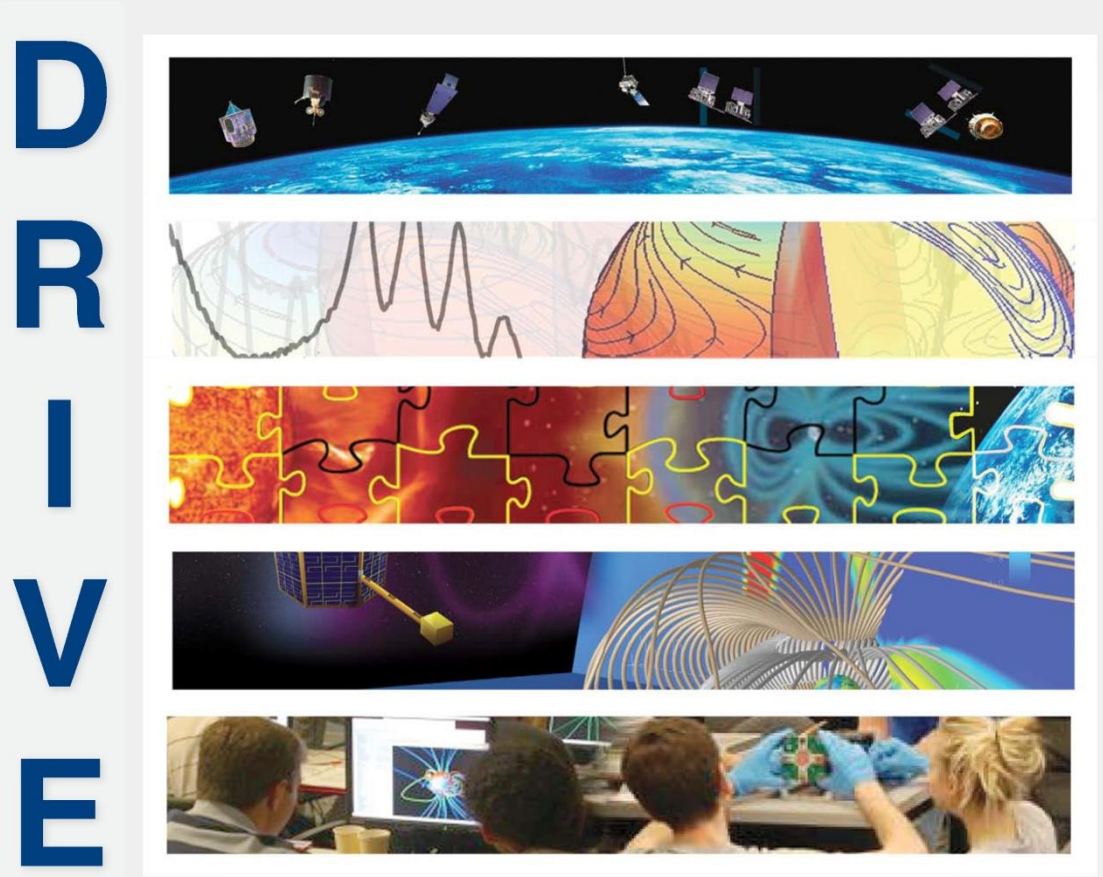
Decadal Survey benefits:

- Community-based documents offering consensus of science opportunities to retain US scientific leadership
- Provides well-respected source for priorities & scientific motivations to agencies, OMB, OSTP, & Congress

Most useful approach:

- Frame discussion identifying key science questions
  - **Focus on what to do, not what to build**
  - **Discuss science breadth & depth (e.g., impact on understanding fundamentals, related fields & interdisciplinary research)**

*From "The Role of NRC Decadal Surveys in Prioritizing Federal Funding for Science & Technology," Jon Morse, Office of Science & Technology Policy (OSTP), NRC Workshop on Decadal Surveys, November 14-16, 2006



Diversify observing platforms with microsatellites and mid-scale ground-based assets

Realize scientific potential by sufficiently funding operations and data analysis

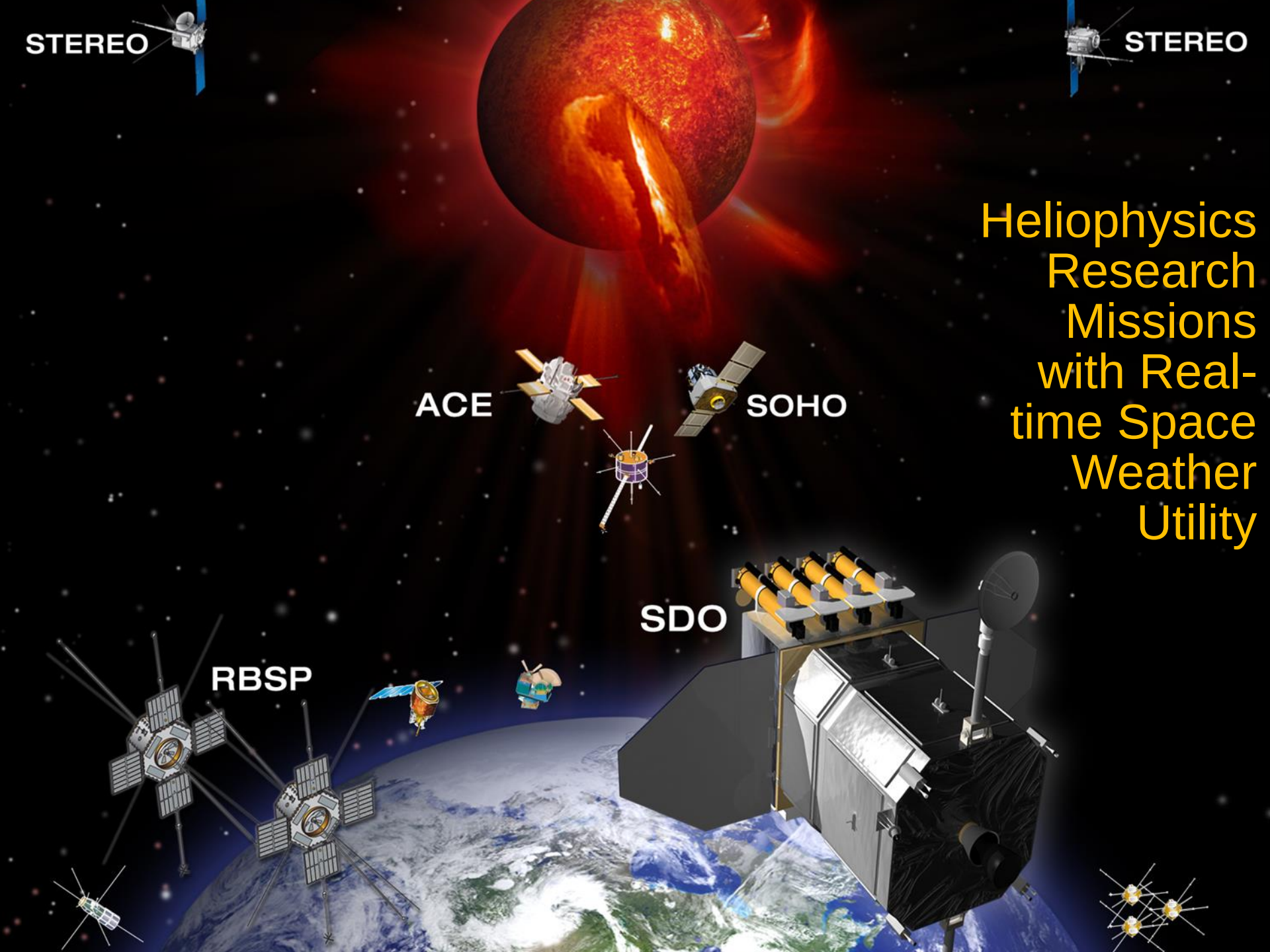
Integrate observing platforms and strengthen ties between agency disciplines

Venture forward with science centers and instrument and technology development

Educate, empower, and inspire the next generation of space researchers

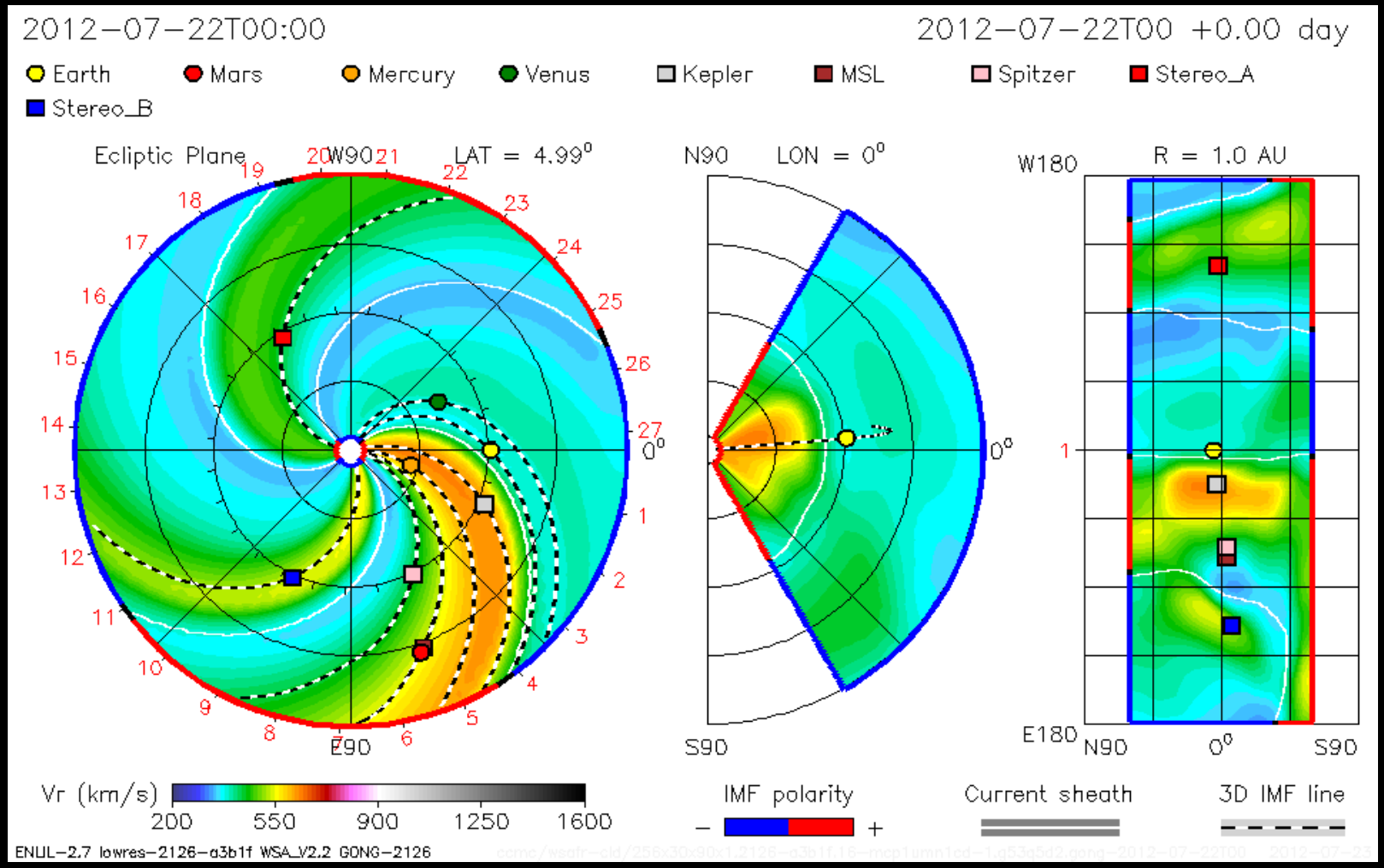
The Decadal: Space Weather

- 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

WSA-ENLIL Model: Solar Wind Speed



Space Weather Recommendations (prioritized)

1. Re-charter the National Space Weather Program
2. Multi-agency Partnership for Solar/Solar Wind Observations
    1. L1 Solar Wind (DSCOVR, IMAP)
    2. Coronagraph and Magnetograph
    3. Evaluate New Observations and Platforms
    4. Establish a SWx Program for Effective Research to Operations Transition at NOAA
    5. Establish Distinct Programs for Space Physics Research and Space Weather Forecasting and Specification

National Space Weather Action Plan

A National Space Weather Action Plan (NSWAP) establishes a process to implement the National Space Weather Strategy

The NSWAP establishes specific activities with:

- implementation timelines
- detailed actions
- specific agency assignments

Boulder Space-Related Research and Education

NIST

National Institute of Standards and Technology

University of Colorado at Boulder

Major Academic Departments

- Department of Astrophysical and Planetary Sciences
- Department of Atmospheric and Oceanic Sciences
- Department of Aerospace Engineering Sciences
- Department of Physics
- Department of Geological Sciences

Major Research Institutes

- Joint Institute for Laboratory Astrophysics
- Laboratory for Atmospheric and Space Physics
- Cooperative Institute for Research in Environmental Science

~700 faculty/staff in 27 units at CU Boulder are involved in space science and technology research with a value of ~$200 M / Year

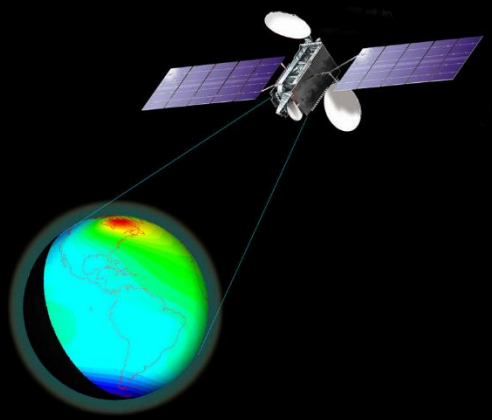
NOAA

National Oceanic and Atmospheric Administration

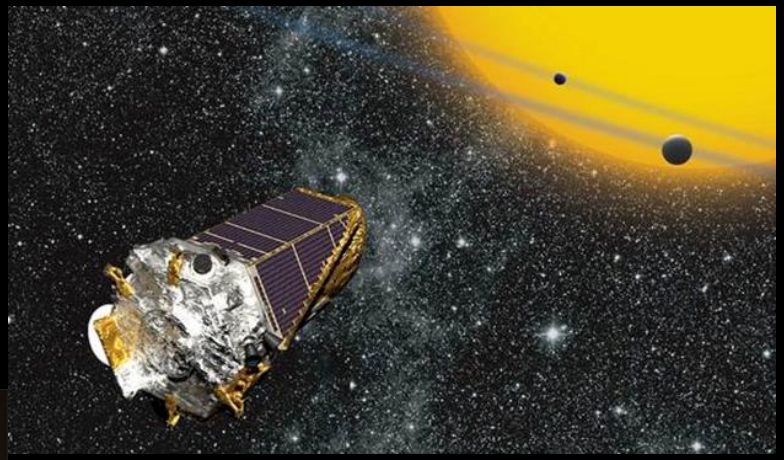
NCAR — **National Center for Atmospheric Research**

NASA — **National Aeronautics and Space Administration**

Some Ongoing LASP Space Activity

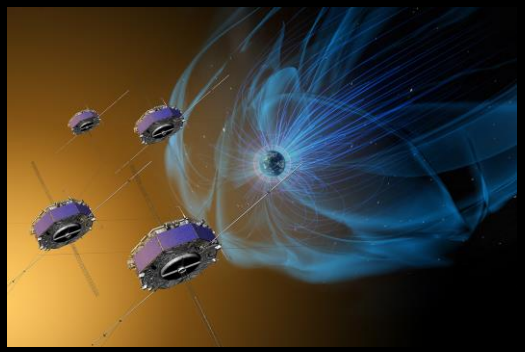


Global-scale Observations of the Limb and Disk (GOLD)
Confirmed to proceed into Fabrication – March 2015



Kepler - 2 year
Extension May 2014

Magnetospheric Multiscale (MMS)
Launch – March 12, 2015



MMS Science Operations
Center at LASP

Miniature X-ray Solar Spectrometer
(MinXSS) ready for ISS launch 2016

Grand Challenge: New Space – New Earth

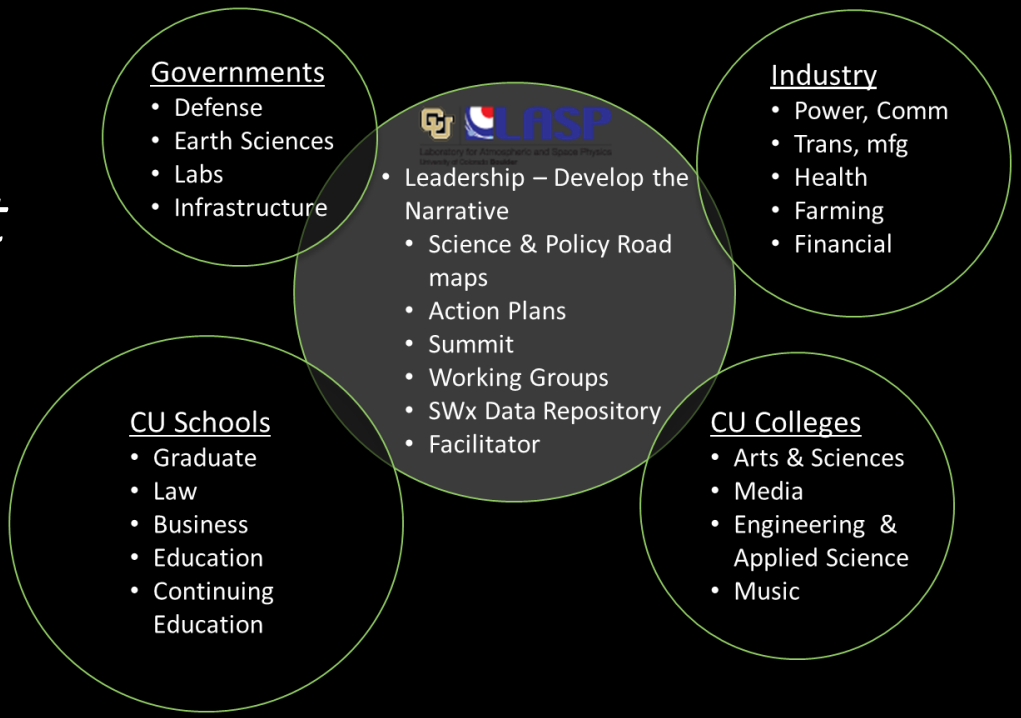
Advancing the connection between space and our lives

University of Colorado Space Weather Initiative

- *Leverages CU/LASP history of space exploration (since 1948) and CIRES (since 1967)*
- *Capability available and utilizes core strengths*
  - **Capitalizes on existing expertise in science, engineering, mission operations, and scientific data analysis**
- *Ideal opportunity to combine academia, government and industry abilities*

Vision for Partnership

- **Explore opportunities and develop roadmap**
- **Engage in National Strategic Goals**
- **Host Near-Term Summit**
  - *Academia*
  - *Government*
  - *Industry*

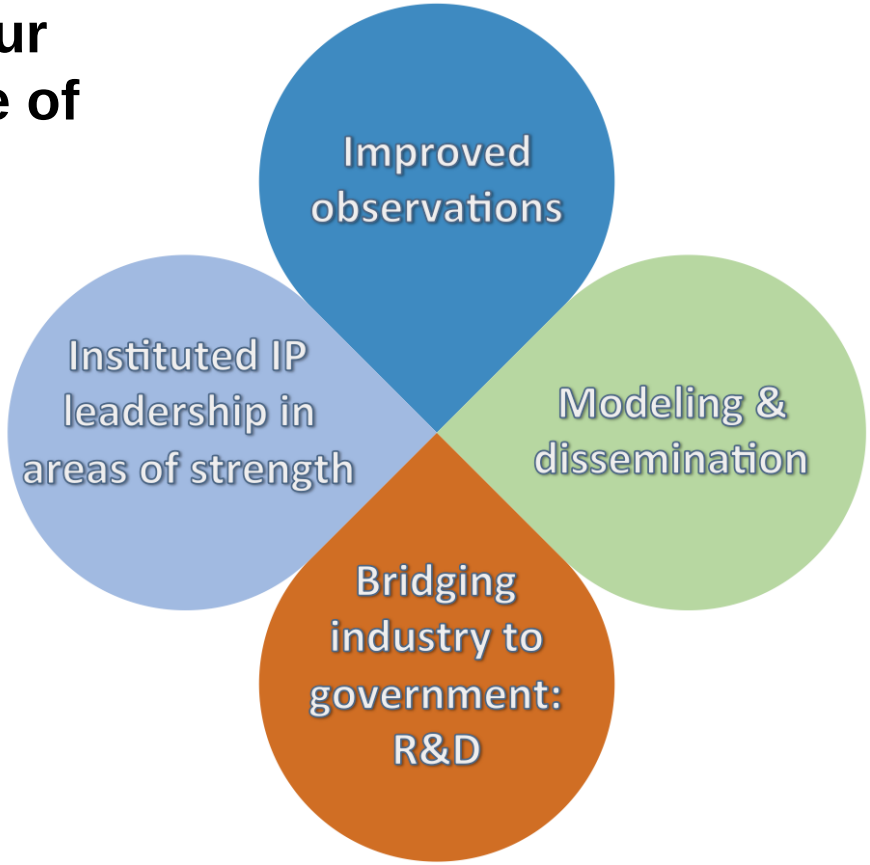


LASP Addressing Space Weather Impacts

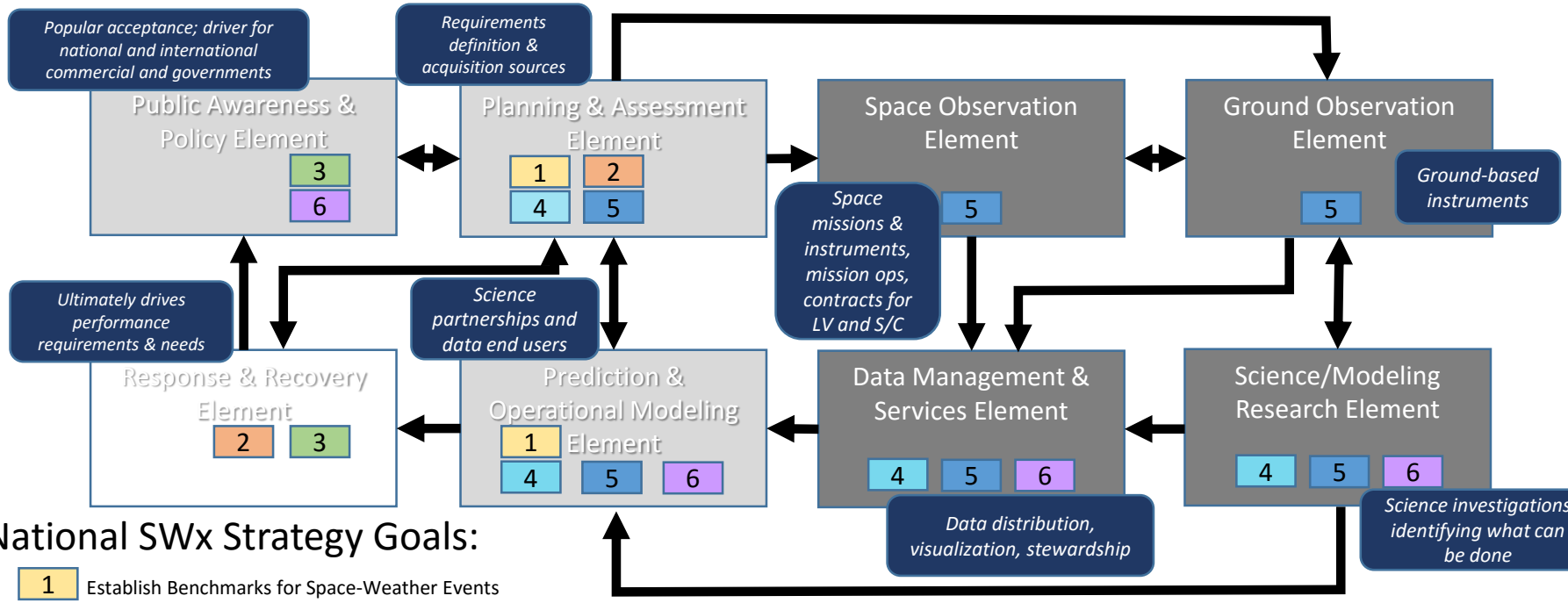
The effects of space weather on our technological infrastructure is one of the main existential issues facing society today.

LASP endeavors to convert ideas into reality by:

- Actively addressing the National Space Weather Strategy (Oct 2015)
- Implementing respective strategic goals
- Assessing existing capability; enhancing strengths to fill gaps
- Engaging community, partners, colleagues, and industry to de-convolve the complexity of space weather



National SWx Strategy: Implications within LASP



National SWx Strategy Goals:

1. Establish Benchmarks for Space-Weather Events
2. Enhance Response and Recovery Capabilities
3. Improve Protection and Mitigation Efforts
4. Improve Assessment, Modeling, and Prediction of Impacts on Critical Infrastructure
5. Improve Space-Weather Services through Advancing Understanding and Forecasting
6. Increase International Cooperation

LASP Engagement Level:

- Awareness
- Influence, Engagement, Collaboration
- Development

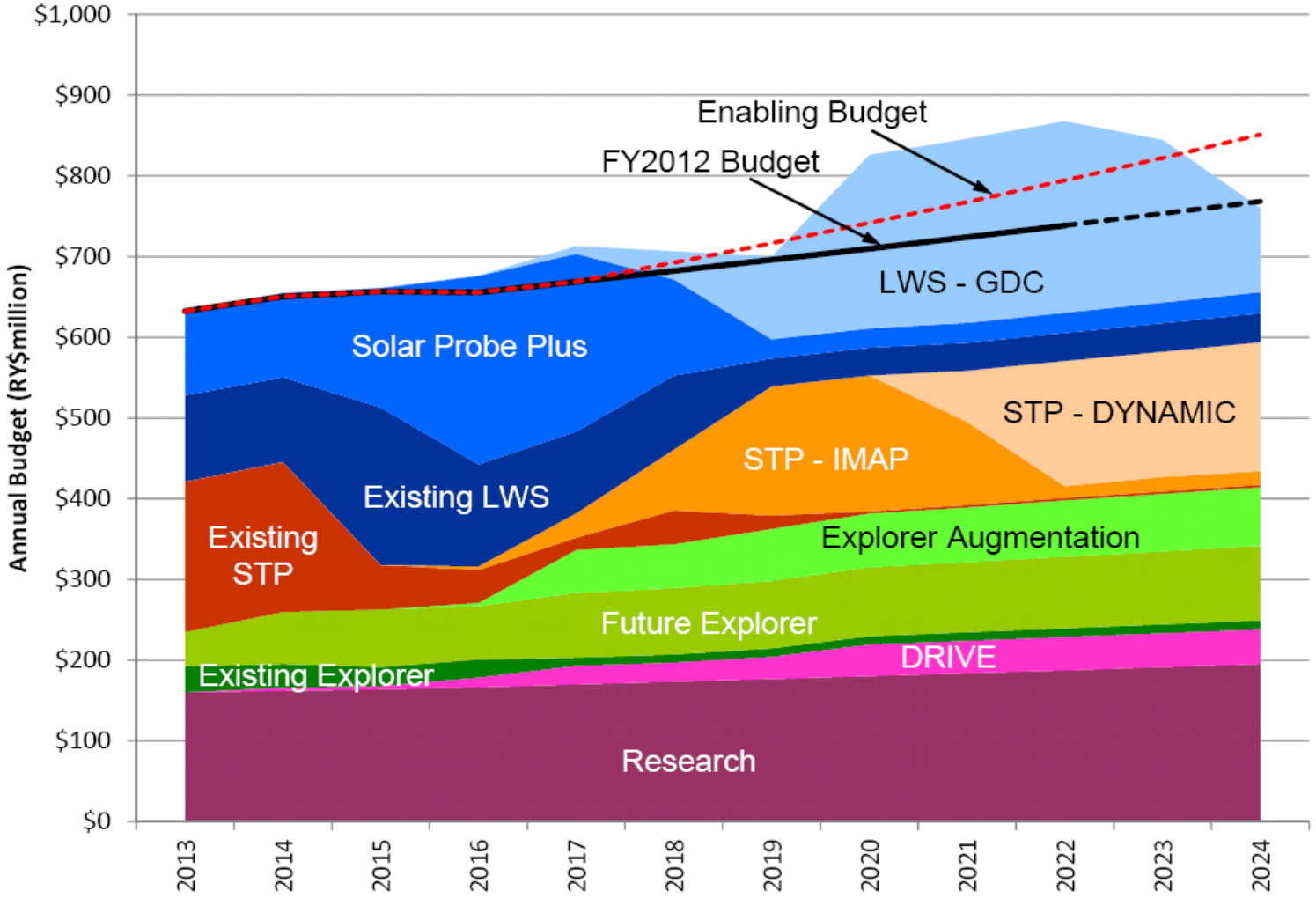
Note: "Elements" are internally defined architectural groupings

Summary of Survey

The 2013-2022 Decadal Survey:

- Fit the 2012 fiscal boundary;
- Focused both on research and its **societal impact**;
- Endeavored to empower the community to innovate, take advantage of the unique constellation of missions and data available now and to **study the coupled domains of heliophysics *as a system*;**
- Strove to build on the community's strength and to facilitate development of cost-effective PI-class missions; and
- Recommended exciting missions of historical significance that held tremendous promise for new discoveries that could also **serve powerfully the needs of Space Weather**.

Decadal Plan for NASA's Heliophysics Division



Congressional Response and Actions

For Immediate Release
April 20th, 2016
Contact: Gardner Press Office, 202-224-5941

Gardner, Peters, Booker Introduce Bipartisan Legislation to Improve Efforts to Predict, Respond To Space Weather Events

WASHINGTON, DC - U.S. Senators Cory Gardner (R-CO), Gary Peters (D-MI), and Cory Booker (D-NJ) introduced the Space Weather Research and Forecasting Act, bipartisan legislation to improve efforts to predict and mitigate the effects of space weather events, which can have significant economic and security implications, on Earth and in space. The legislation will strengthen space weather research and response by delineating clear roles and responsibilities to the agencies that study and predict space weather events, including the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), and the Department of Defense (DOD).

Space weather events are caused by constantly changing conditions in the Sun's magnetic fields and have the potential to disrupt the electric power grid, communications networks, GPS, satellites and aircraft operations leading to serious economic and safety consequences. These events can impact infrastructure and businesses, including causing outages at electric utilities, disrupting GPS and communication networks, and forcing airlines to reroute air traffic, resulting in multi-million dollar economic damages. Estimates for damages from a worst-case scenario space weather event could be up to $2 trillion and impact as many as 40 million people.

"Because space weather may have severe implications for our economic and national security as well as the potential to interrupt the delivery of essential services, it's important that we prioritize the research and development necessary to reduce the risk and allow our nation to react and recover from these events," said Gardner.

Points of Discussion

1. Through hard work of many, we have established a "toe hold".
2. We must redouble our efforts to build on this modest, hard-won success.
3. We must assure continuity of purpose through the upcoming election and administration change.
4. We **must** maintain community cohesiveness and commonality of purpose.
5. Academia has a key role to play in this!

Thank you. Questions?

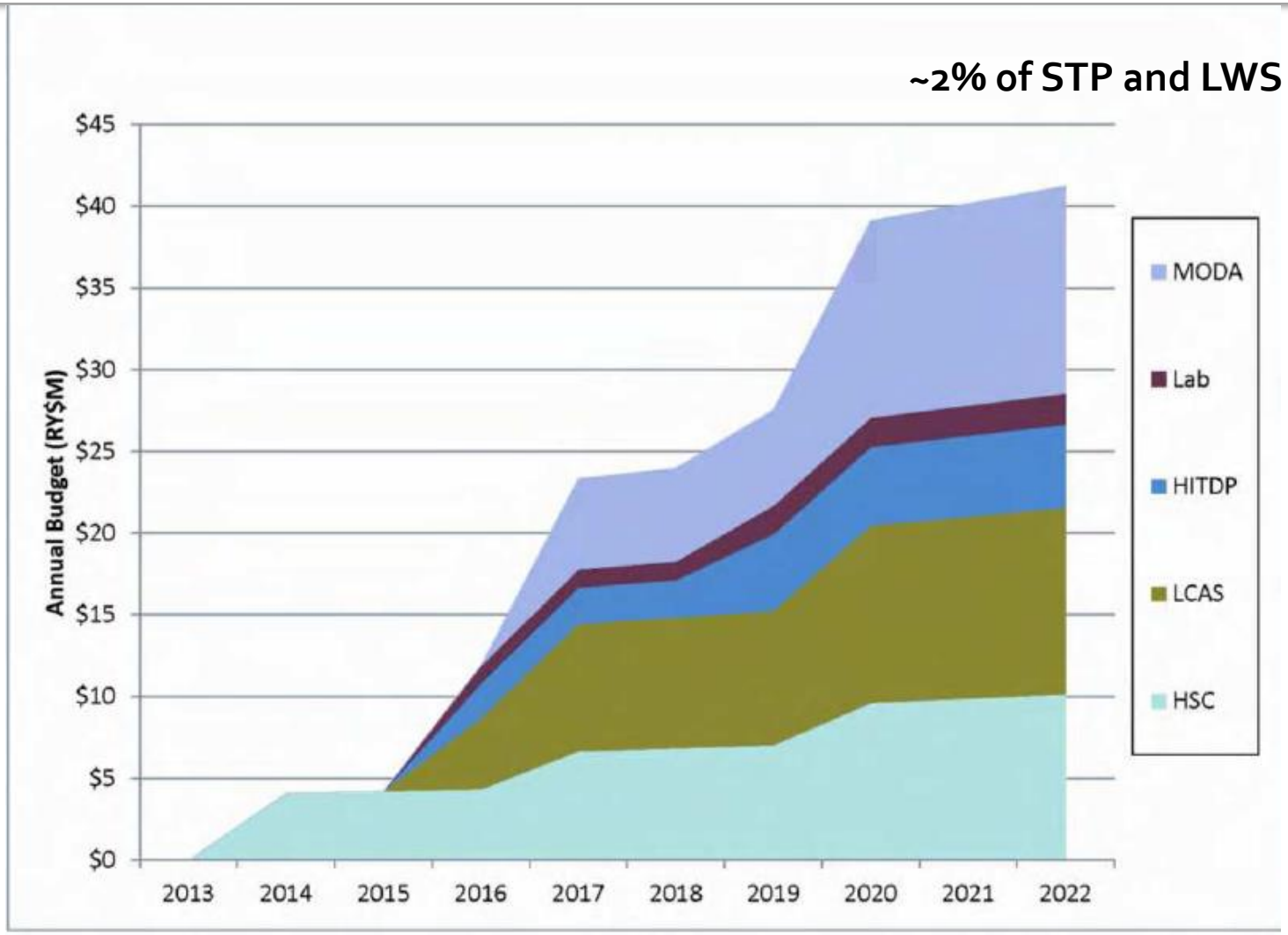
Overarching Goals for a Decade of Discovery

- 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 responses 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.

Summary for NASA (in order of priority)

1. Complete implementation of missions that were currently selected
2. Initiate the DRIVE program
3. Execute a robust Explorer program
4. Launch strategic missions in the reinvigorated STP line and in the LWS line to accomplish the committee's highest-priority science objectives. This includes first the notional IMAP investigation and then DYNAMIC and MEDICI in the STP program and GDC as the next larger-class LWS mission.

Implementation of DRIVE at NASA



MO&DA Augmentation

Lab Experiments

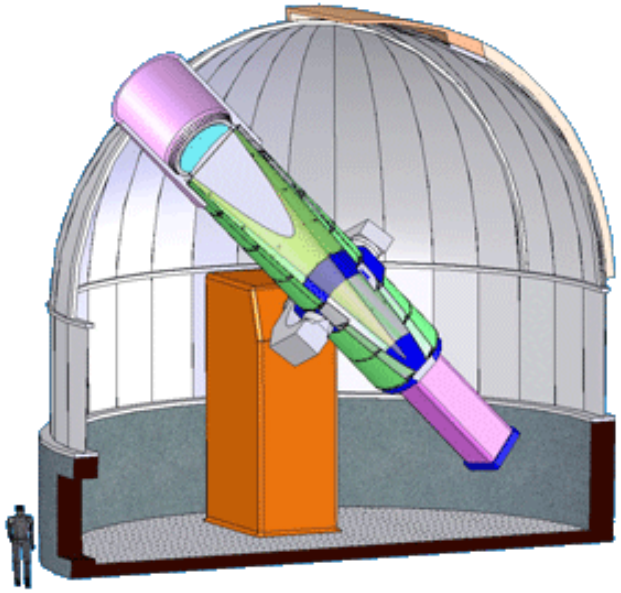
Tech and Instrument

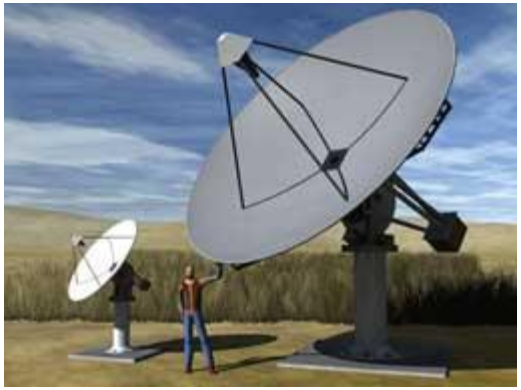
LCAS Microsats

Heliophysics Science Centers

Mid-Scale Line for NSF

- A new funding line for mid-scale projects at the National Science Foundation will facilitate long-recommended ground-based projects, such as COSMO (COronal Solar Magnetism Observatory) and FASR (Frequency-Agile Solar Radio-telescope), by closing the funding gap between large and small programs.





Accelerate and Expand the Heliophysics Explorer Program

- The recommended augmentation of the Explorer line 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.

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 ~$500 million per mission in fiscal year 2012 dollars including full lifecycle costs.

Decision Rules (in recommended order)

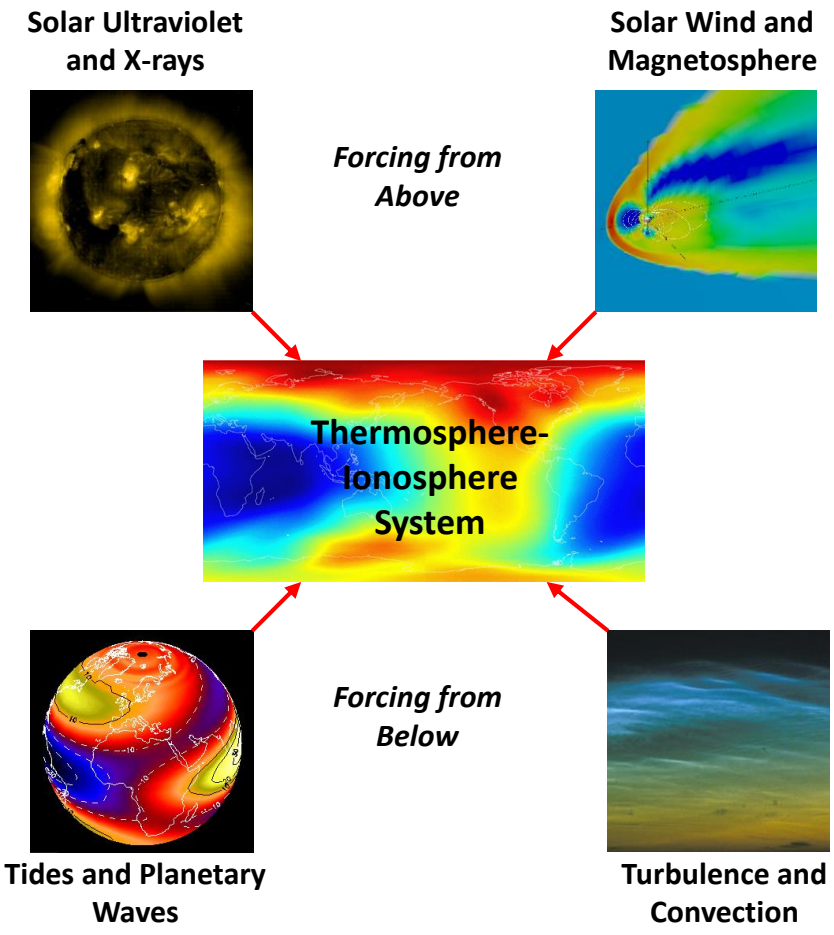
1. Missions in the STP and LWS lines should be reduced in scope or delayed to accomplish higher priorities.

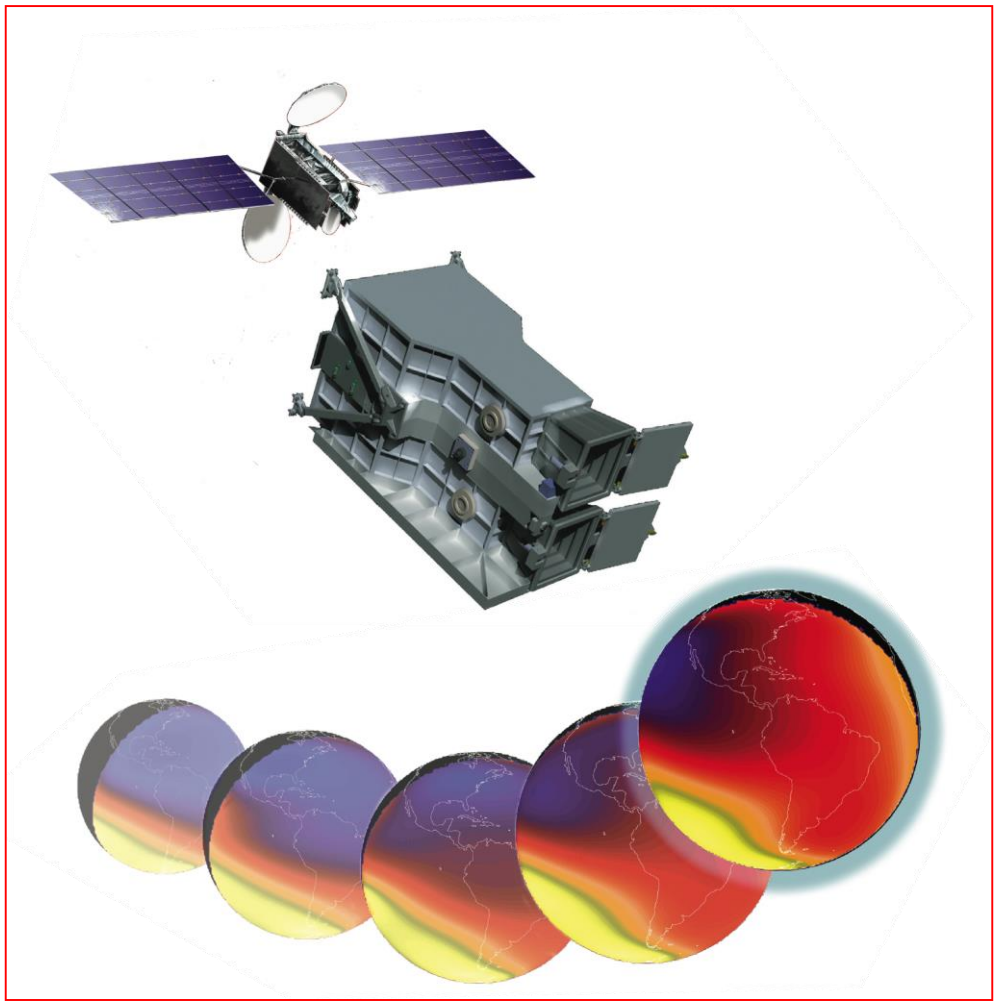
2. If further reductions were needed, the recommended increase in the cadence of Explorer missions should be scaled back, with the current cadence maintained as the minimum.

3. If still further reductions were needed, the DRIVE augmentation profile should be delayed, with the current level of support for elements in the NASA research line maintained as the minimum.

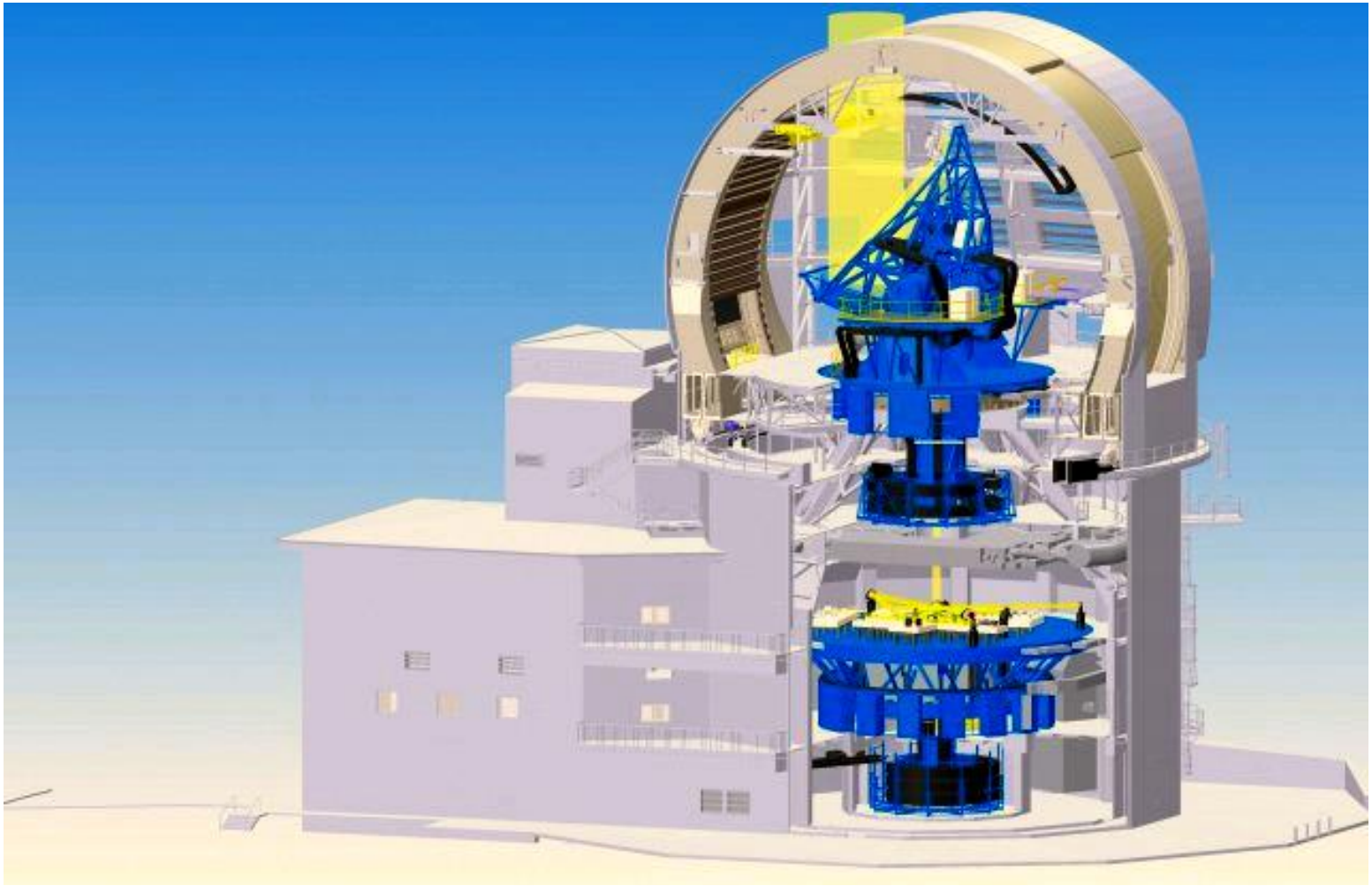
GOLD: Global-scale Observations of the Limb and Disk)

GOAL: Understand the global response of the thermosphere and ionosphere to forcing from the Sun-Earth system





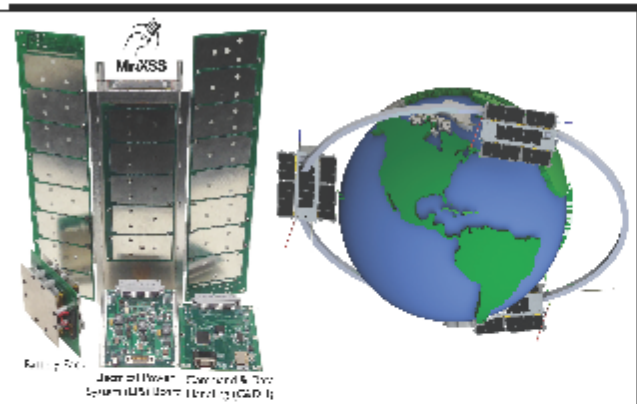
NSF's Daniel K. Inouye Solar Telescope



Solar CubeSat: MinXSS

CubeSat: Miniature X-ray Solar Spectrometer

National Aeronautics and Space Administration (NASA)
and National Science Foundation (NSF)



Mission Description

MinXSS will measure the soft X-ray (SXR) solar spectrum with high spectral resolution (better than 0.15 keV full width half maximum) to better understand the solar irradiance energy distribution of solar flare SXR emission and its impact on Earth's ionosphere, thermosphere, and mesosphere.

Major Milestones

- May 2013: Partially funded by NSF
- Feb 2014: Selectable for NASA H-TIDeS
- Summer 2014: Environmental testing
- Fall 2014: Delivery
- Nov. 2014: First launch opportunity

Spacecraft Specifications

- Spacecraft Developer:
  - University of Colorado, Dept. of Aerospace Engineering Sciences and Laboratory for Atmospheric & Space Physics (PI: Dr. Thomas Woods), involved with over 35 grad and undergrad students
- Mass: 3.35 kg
- Ave. Power: 11.30W generated, 4.76W consumed
- Size: 3U (10 cm x 10 cm x 34 cm)

SWAP: Space Weather Action Plan

- U. S. National Space Weather Strategy and Action Plan (2015) established Strategic Goals to address gaps in preparedness
  - Strategic Goal 1: Establish Benchmarks for Space-Weather Events
    - Gap: Understanding the magnitude and frequency of SWx events
  - Strategic Goal 2: Enhance Response and Recovery Capabilities
    - Gap: Comprehensive guidance for response and recovery
  - Strategic Goal 3: Improve Protection and Mitigation Efforts
    - Gap: Capability to reduce vulnerability and minimize risk
  - Strategic Goal 4: Improve Assessment, Modeling, and Prediction of Impacts on Critical Infrastructure
    - Gap: Understanding of actions required during SWx events
  - Strategic Goal 5: Improve Space-Weather Services through Advancing Understanding and Forecasting
    - Gap: Observation and forecast accuracy, reliability, and timeliness
  - Strategic Goal 6: Increase International Cooperation
    - Gap: Global engagement and coordination

Assessment

The 2013-2022 Decadal Survey:

- Joins Earth Science, Astro, and Planetary decadal surveys in facing challenges to implementation;
- Until now, has been restrained by budget inaction of NASA, OMB, Congress;
- Requires intervention by NASA leadership to restore prospect of key forward motion;
- Needs continued community pressure to assure action on larger goals in the designated decadal interval; and
- Also demands reinvigoration of the National Academy processes in the present budgetary and political climate.

Crucial Steps

It is (in my view) imperative for our community to:

- Stop bickering and infighting;
- Get leadership restored at the agencies;
- Come together as a community and **act** like a community;
- Continue to embrace the Decadal Survey—it is the only recognized **consensus** plan we have;
- Get the DRIVE initiative going full bore ASAP;
- Reinvigorate the Explorer line right away;
- Establish **SDT committees** for **all STP missions and LWS**;
- Act positively regarding **Space Weather** and move forward with Decadal Survey advice (SWORM activity).