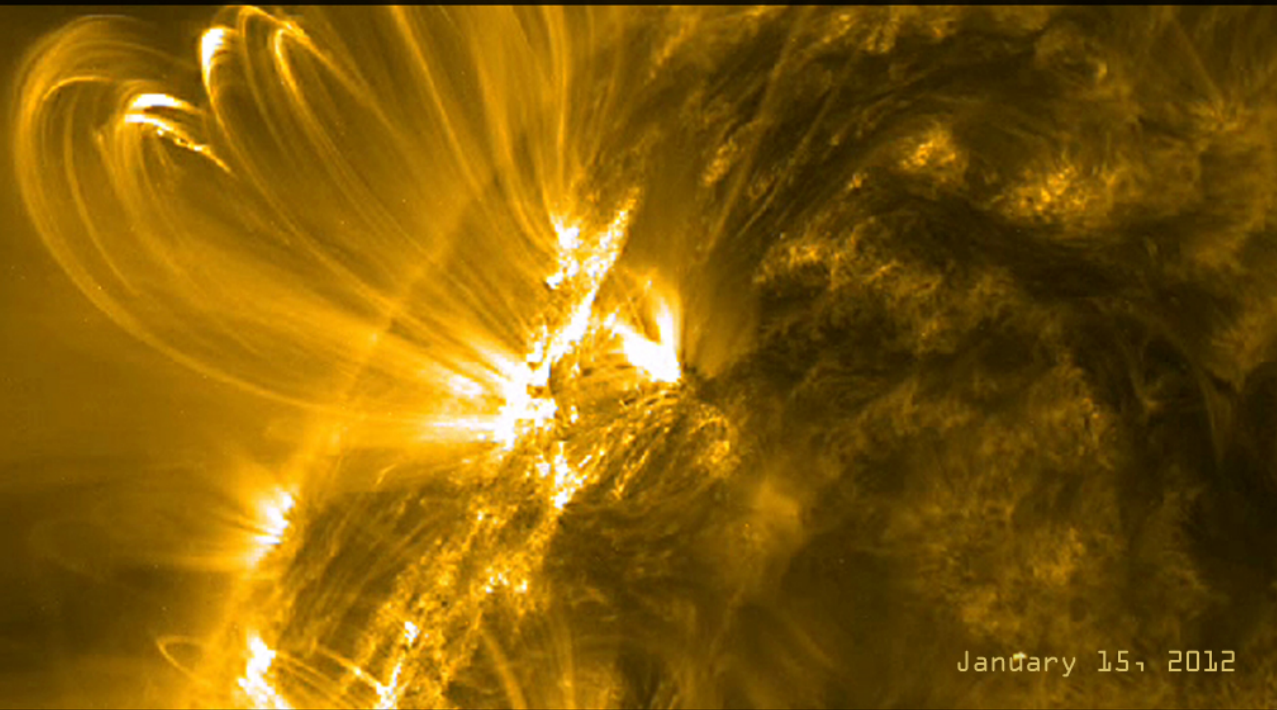


National Aeronautics and Space Administration



January 15, 2012

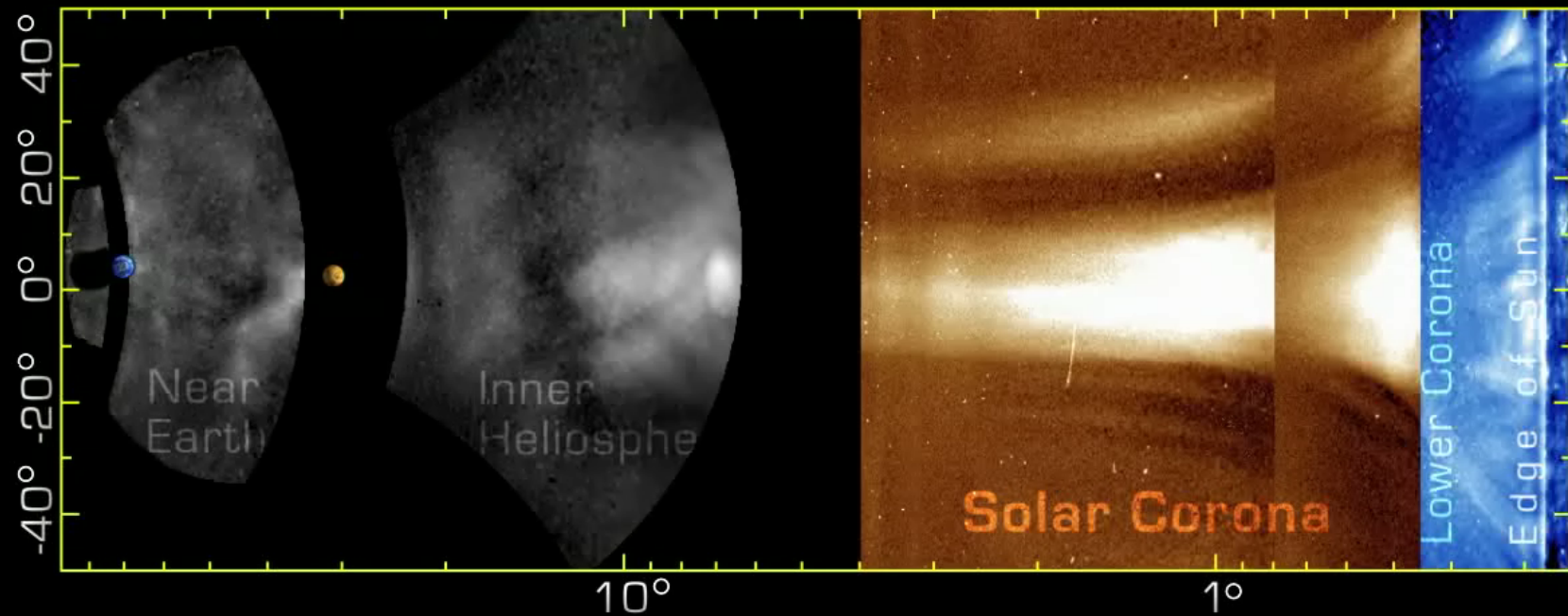
# **NASA Heliophysics: The Science of Space Weather**

Jeffrey Newmark  
Heliophysics  
NASA Headquarters

# SMD Motivation

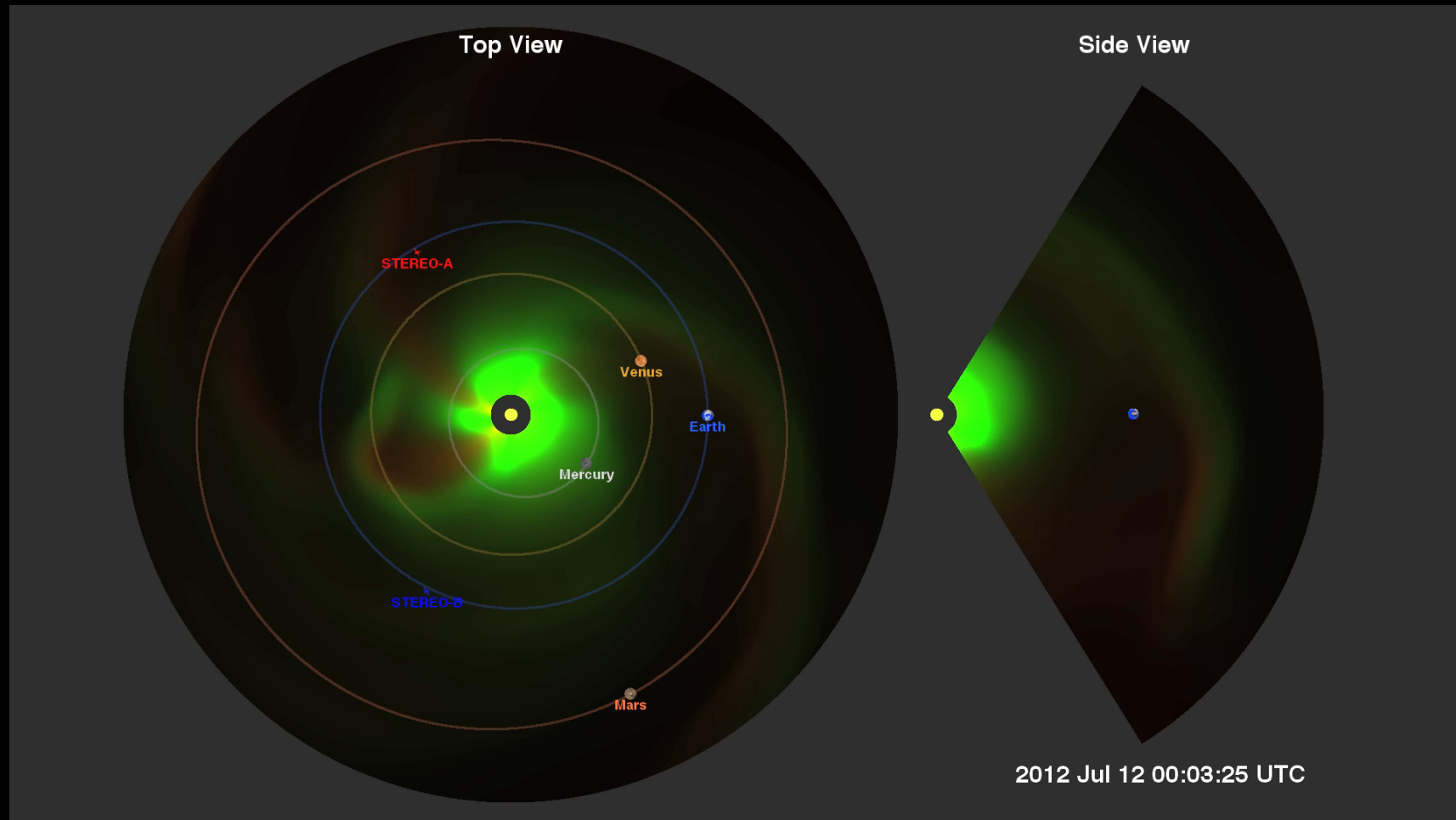
- Fundamental Understanding
  - Heliophysics provides the underlying science required to enable space weather forecasting
- Heliophysics role in Space Weather
  - Roughly one third of Heliophysics addresses Space Weather science
    - Living With a Star Program (SDO, Van Allen (RBSP) and TR&T)
    - STEREO (STP Program), SOHO, ACE
    - CCMC
  - Heliophysics formulates and implements a national research program for understanding the Sun and its interactions with the Earth and the Solar System.
  - Currently, data from Heliophysics science missions are vital to the nation's Space Weather infrastructure

# STEREO Tracks a CME through Interplanetary Space



STEREO-A:12/11/08 12:40:00 AM

# Modeling Storms throughout the Heliosphere



# NASA Heliophysics

Strategic Objective: Understand the sun and its interactions with Earth and the solar system, including space weather

## Explorers



Smaller, Competed  
Flight Program

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 and planetary space environments, and the outer reaches of our solar system.

## Research



Research tasks utilizing  
suborbital and existing assets

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.

## Solar Terrestrial Probes



Strategic Mission  
Flight Program

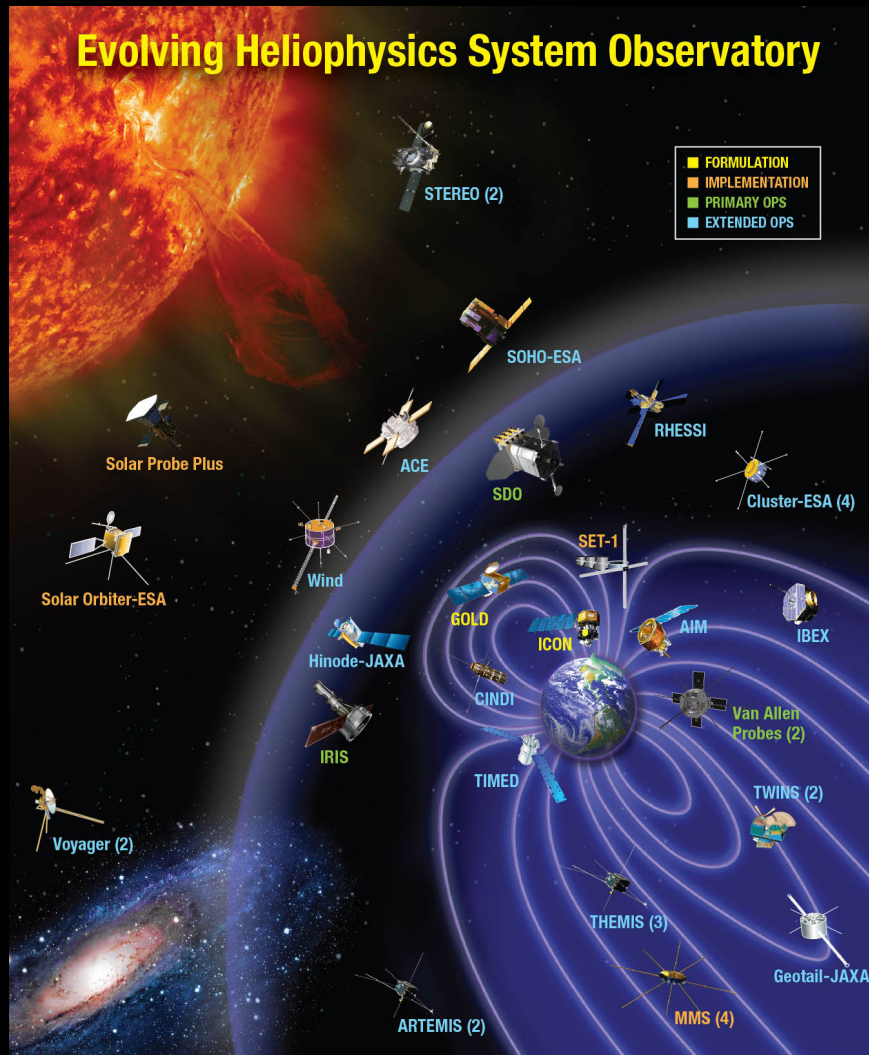
## Living With a Star



Strategic Mission  
Flight Program

# NASA's Heliophysics Research Missions

A FLEET OF SPACECRAFT DESIGNED TO UNDERSTAND THE SUN AND  
IT'S INTERACTIONS WITH EARTH AND THE SOLAR SYSTEM



Heliophysics has 18 operating missions: Voyager, Geotail, Wind, SOHO, ACE, Cluster, TIMED, RHESSI, TWINS, Hinode, STEREO, THEMIS, AIM, CINDI, IBEX, SDO, ARTEMIS,

Van Allen Probes, IRIS

6 missions are in development: SET, MMS, SOC, SPP, ICON and GOLD.

Missions in red have space weather utility.

# Primary Space Weather Satellites

NASA STEREO  
(Ahead)

- NASA Van Allen Probes
  - Radiation belt conditions

- NASA SDO, ESA/NASA SOHO
  - Solar EUV Images
  - Solar Corona (CMEs)

- NOAA GOES
  - Energetic Particles
  - Magnetic Field
  - Solar X-ray Flux
  - Solar X-Ray Images

- NASA ACE
  - Solar wind composition, speed, and direction
  - Magnetic field strength and direction

ESA/NASA SOHO  
L1  
NASA ACE

NOAA GOES

NOAA POES

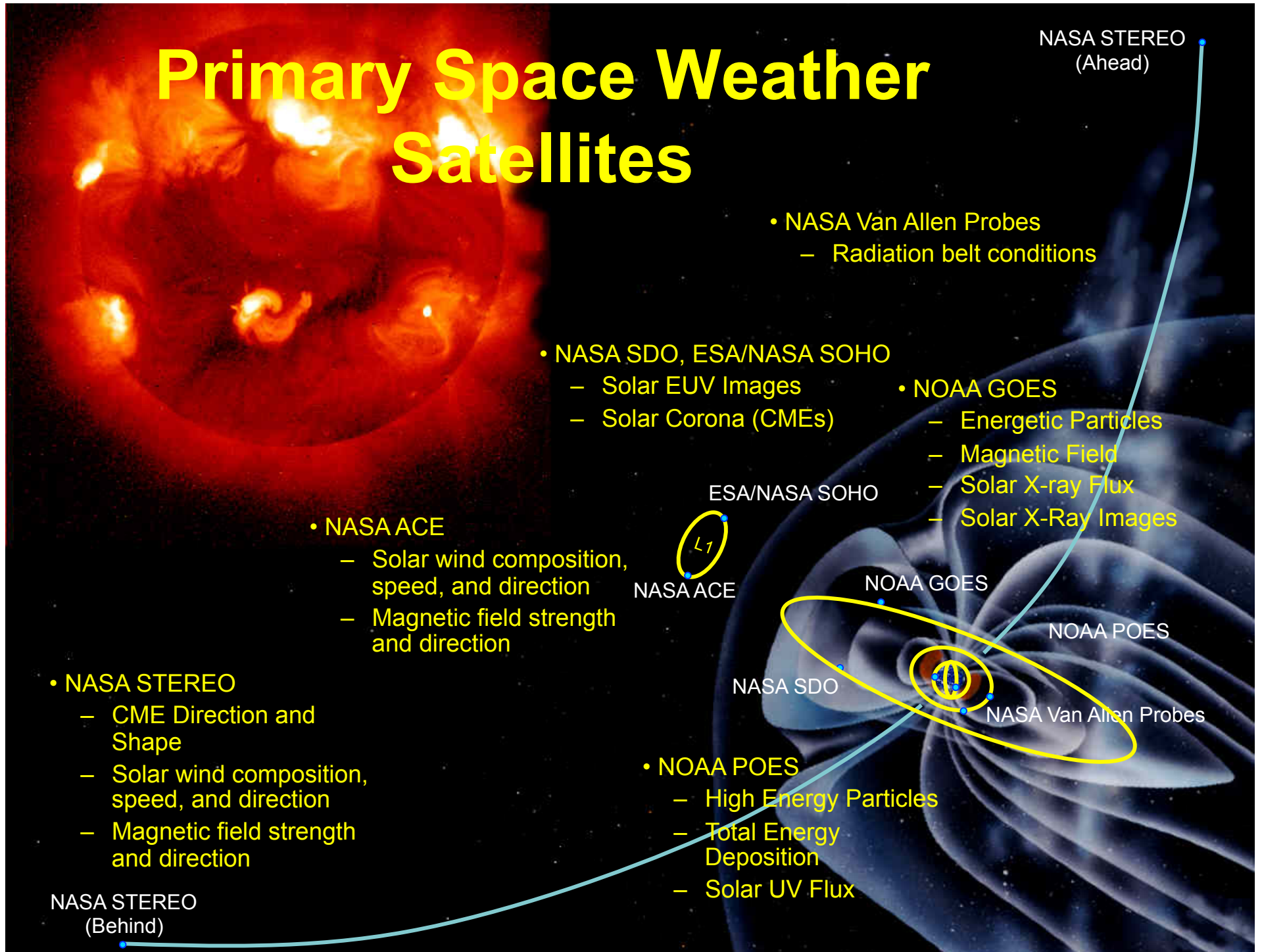
NASA SDO

NASA Van Allen Probes

- NASA STEREO
  - CME Direction and Shape
  - Solar wind composition, speed, and direction
  - Magnetic field strength and direction

- NOAA POES
  - High Energy Particles
  - Total Energy Deposition
  - Solar UV Flux

NASA STEREO  
(Behind)



# Current Suite of Space Weather Observing Systems

## SPACE SENSORS

DOD	CIVIL
NASA	Foreign

**STEREO-A&B (NASA)**  
 1AU Solar orbit  
 - Solar imaging  
 - Solar wind & particles



**Orbit Areas**  
 Solar

**SOHO (NASA/ESA)**  
 - Coronal imaging  
 - Solar wind  
 - Solar particles

**ACE (NASA)**  
 - Solar particles  
 - Solar wind  
 - Interplan. mag field

L1

**DSP**  
 - Energetic particles

**Solar Dynamics Observatory (NASA)**  
 - Solar Imagery  
 - Solar magnetic field

**GOES (NOAA)**  
 - Magnetic fields  
 - Solar x-rays  
 - Energetic particles

GEO

**GPS**  
 - Energetic particles

**Classified Sensors**

**Iridium / AMPERE (Commercial/ NSF)**  
 - Magnetometers

LEO

**DMSP**  
 - Energetic particles  
 - Auroral imaging  
 - Electron and Neutral Density profiles

**C/NOFS**

**COSMIC (NOAA / Taiwan)**  
 - Ionospheric

**POES & MetOp (NOAA / Eumetsat)**  
 - Energetic particles

## GROUND-BASED SENSORS

Neutron Monitors

Riometers

Next Generation Ionosonde

GNSS Receivers

Solar Optical Telescopes

Ionospheric radars (NSF)

Radio Solar Telescopes

Scintillation Network Decision Aid

Magnetometer Network (USGS)

From: Report on Space Weather Observing Systems: Current Capabilities and Requirements for the Next Decade  
 OFCM – NSWPC JAG for SEGA



# NASA Roles & Responsibilities

## Unified National Space Weather Capability (UNSWC)

- The NASA mission is to drive advances in science, technology, and exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of the Earth
- Specific to space weather, NASA formulates and implements a national research program for understanding the Sun and its interactions with the Earth and the Solar System.
- NASA develops on a reimbursable basis operational space weather satellites on behalf of NASA's interagency partners; and provides leadership and management of space weather operations related to human space exploration; and is responsible for providing information for the safe and efficient operation of NASA's robotic and human missions.

## Heliophysics Research

- Heliophysics research provides Theory, Data, and Modeling development services to national space weather efforts including Living With a Star Targeted Research and Technology and Strategic Capabilities, and 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.

# **Space Weather: NASA's Role**

**Specific to 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**

# Space Weather: NASA's Role

**NASA** researches and prototypes new mission and instrument capabilities in this area, providing new physics-based algorithms to advance the state of solar, space physics, and space weather modeling.

# Overarching LWS Science Goals

- Energetic particles from giant solar storms and galactic cosmic rays pose major radiation hazards for astronauts. Passengers and crew on polar flights are also endangered by penetrating particle radiation. In support of NASA's Exploration objectives, the TR&T **delivers the understanding and modeling required for useful prediction of SEP variability and GCR modulation at the Earth, Moon, Mars and throughout the solar system.**
- Communication, navigation and other national infrastructures are increasingly dependent on satellites orbiting Earth. With increasing miniaturization these systems are ever more sensitive to the near-Earth space environment. To protect these assets, the TR&T **delivers the understanding and modeling required for effective forecasting/specification of inner magnetospheric radiation and plasma.**
- The upper atmosphere and ionosphere is central to a host of space weather effects, ranging from anomalous satellite drag, GPS position error, radio blackouts, radar clutter and geomagnetically induced currents (GIC). In order to mitigate space weather's impact on life and society the TR&T **delivers understanding and predictive models of upper atmospheric and ionospheric coupling above and below.**
- One of the major challenges facing humanity is global climate change. In order to determine effective mitigation policies, natural and anthropogenic causes must be distinguished; the TR&T **delivers the understanding of how variations in solar radiation, particles and magnetic fields contribute to global and regional climate change.**

# 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.

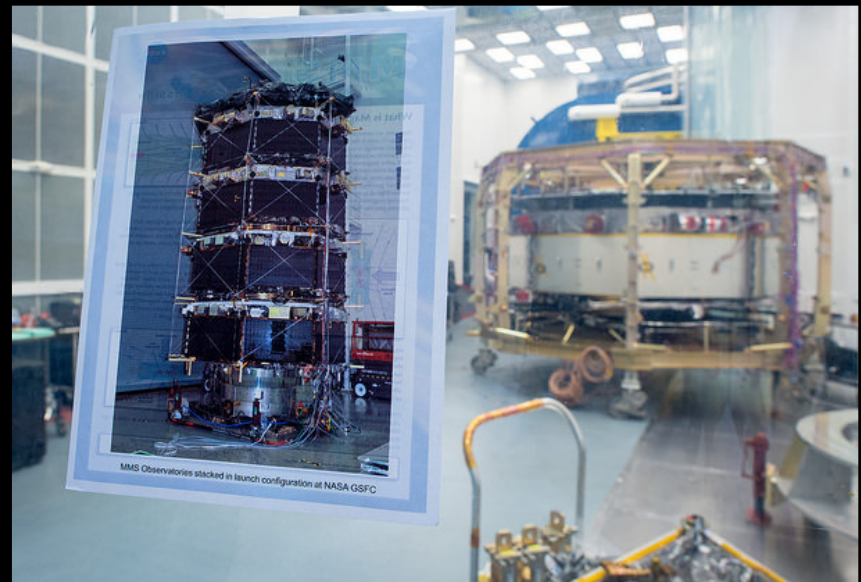
# NASA Administrator Visits MMS Spacecraft at the Naval Research Lab

August 4, 2014



Above: NASA Administrator Charles Bolden with MMS Project Manager Craig Tooley outside the Naval Research Lab cleanroom where Observatory #3 had just completed environmental testing.

*Credit: NASA*



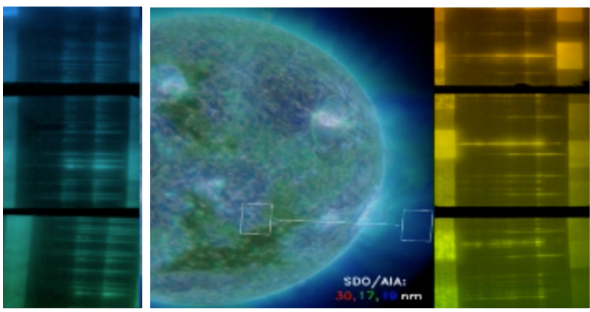
# Significant Progress: SMD CubeSat Initiative

- Grants are in place for the six distinct scientific CubeSat Investigations initiated under the FY-14 CubeSat Initiative.
  - **IceCube**: Spaceflight Validation of an 874-GHz Submillimeter Wave Radiometer for Ice Cloud Remote Sensing
    - Co-funded with ESTO
  - Electron Loss and Fields Investigation (**ELFIN**)
    - Co-funded with National Science Foundation
    - Combined Systems and Science Requirements Review held July 30, 2014
  - A CubeSat Mission to Study Solar Particles over the Earth's Poles (**CuSPP**)
  - Tandem Beacon Experiment (**TBEx**): Toward Identifying How Seeding Affects the Day-to-Day Variability of Equatorial Scintillations
  - Miniature X-ray Solar Spectrometer (**MinXSS**) CubeSat Mission
  - Scintillation Observations and Response of The Ionosphere to Electrodynamics (**SORTIE**)

- Monthly Highlight: **MinXSS** (pronounced “minks”) is in flight integration (photo right)
  - University of Colorado – Boulder
  - Significant pre-award student involvement (3-yr)
  - Flight solar cells arriving early-Sept.
  - CSLI/ELaNa-provided launch planned via ORB-4 to ISS in April 2015
  - NanoRacks deployment from ISS



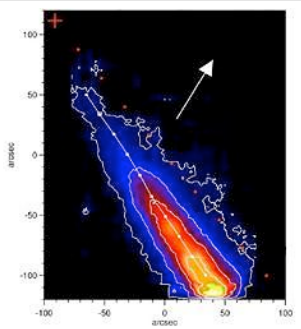
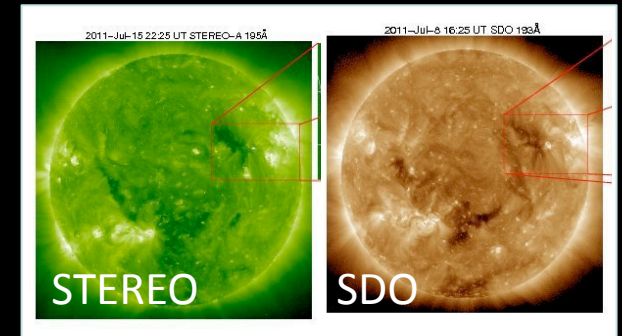
# Recent Heliophysics Science Highlights



**NASA Sounding Rocket Provides Insight Into Coronal Heating:** New observations from EUNIS, the Extreme Ultraviolet Normal Incidence Spectrograph explain what makes the sun's outer atmosphere so much hotter than its surface and are consistent with only one current coronal heating theory: nanoflares – a constant peppering of impulsive bursts of heating, which cannot be individually detected.

## **STEREO and SDO Track How the Sun Releases a Rare Variety of Helium:**

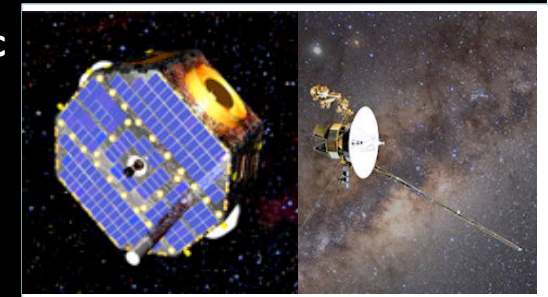
Using observations from STEREO and SDO, researchers tracked the sun's release of the rare helium isotope helium 3. The heavier isotope helium 4 occurs 10,000 times more frequently and the solar wind reflects this ratio. However, for limited periods, regions on the sun can emit greatly increased concentrations of helium 3.



**SOHO Spacecraft Provides New Insight into Comet ISON's Dramatic Final Hours:** New analysis of data from the joint ESA and NASA SOHO spacecraft has revealed that Comet ISON stopped producing dust and gas shortly before it raced past the sun and disintegrated in November 2013. Images show there was a short, violent outburst which released a 11,500 tons of dust, 8.5 hours before perihelion that most likely was the final break-up of the nucleus. To date, SOHO observations have been used by citizen scientists to discover over 2,700 comets.

## **Observations from NASA's IBEX and Voyager Spacecraft Advance Heliospheric Research:**

IBEX complements the Voyagers' "point" measurements by imaging the interactions occurring at the edge of the heliosphere. In 2009, IBEX observed a ribbon of enhanced emissions at the interstellar boundary, in between the two Voyager spacecraft measurements. Despite the extensive data the Voyagers and IBEX have collected, the question of whether Voyager 1 has already left the solar system continues to stir debate.





# Heliophysics Program 2012-2020

Solar Terrestrial Probes



Magnetospheric Multiscale (MMS)  
March 2015



STP #5

Living With a Star



Van Allen Probes  
August 2012



Space Environment Testbeds (SET)  
Mid-2016



Solar Probe Plus  
July 2018



Solar Orbiter Collaboration (with ESA)  
October 2018

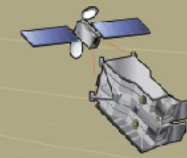
Explorers



Interface Region Imaging Spectrograph (IRIS)  
June 2013

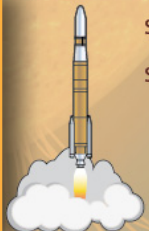


Ionospheric Connection Explorer (ICON)  
June 2017



Global-scale Observations of the Limb and Disk (GOLD)  
September 2017

Research Program



Solar/Heliospheric - September 2014  
Solar/Heliospheric - November 2014



Geospace - November 2014  
Geospace - November 2014  
Solar/Heliospheric - December 2014

HySICS - August 2014 / WFF

UV/Optical Astro - January 2015  
PEREGRINE#1 - January 2015

Geospace - January 2015  
Geospace - January 2015  
Geospace - January 2015

Ongoing

Heliophysics Missions  
Astrophysics Missions  
Planetary Missions

2012

2013

2014

2015

2016

2017

2018