Science Mission Directorate

Heliophysics: A Synopsis

to the CCMC Biennial Users' Group Meeting

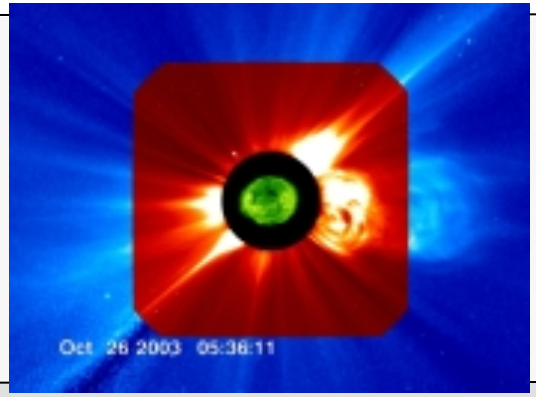
Jeffrey J.E. Hayes

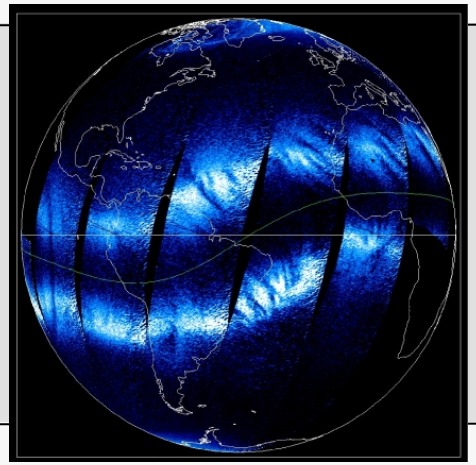
PE for MO & DA

Heliophysics Science Objectives

Open the Frontier to Space Environment Prediction

Understand the fundamental physical processes of the space environment – from the Sun to Earth, to other planets, and beyond to the interstellar medium



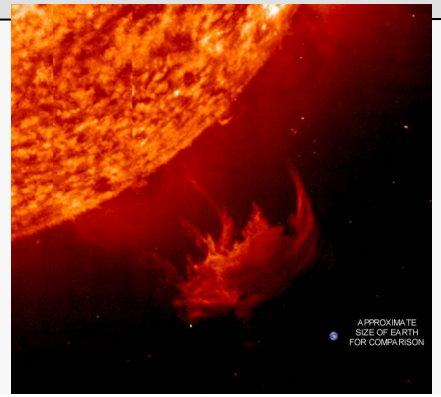


Understand the Nature of Our Home in Space

Understand how human society, technological systems, and the habitability of planets are affected by solar variability and planetary magnetic fields

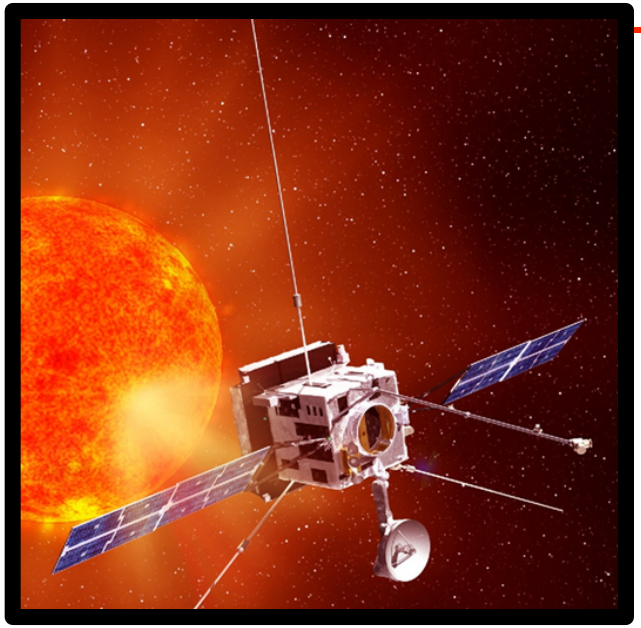
Safeguard Our Outward Journey

Maximize the safety and productivity of human and robotic explorers by developing the capability to predict the extreme and dynamic conditions in space



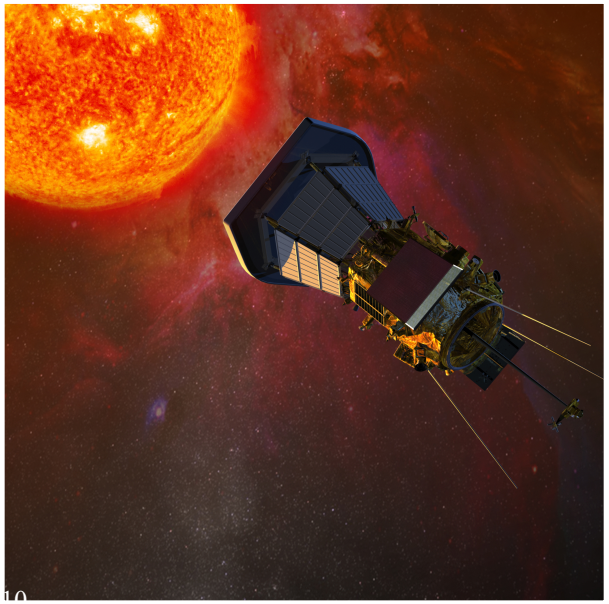
Living With a Star (LWS)

HELIOPHYSICS



Solar Orbiter Collaboration (SOC):
SOC will unravel how solar transients alter the plasma and magnetic field structure of the inner heliosphere and measure the solar polar magnetic fields for the first time using a combination of in-situ and remote sensing instruments.

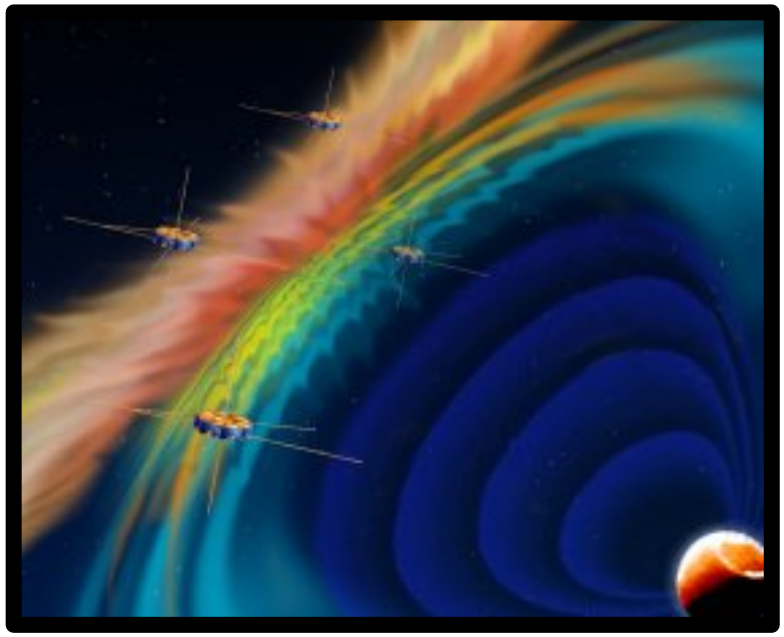
Solar Orbiter will approach the Sun within the orbit of Mercury and using multiple Venus encounters its orbit will be cranked up to above 40 degrees solar latitude giving an unprecedented view of the solar poles to its remote sensing instruments. Launch: No earlier than 2017. On Oct. 8, 2011, ESA selected Solar Orbiter as its first M-class mission.



Solar Probe Plus (SPP):
SPP will approach as close as nine solar radii from the surface of the Sun, repeatedly sampling the near-Sun environment. By directly probing the solar corona, this mission will provide essential knowledge and understanding of coronal heating and of the origin and acceleration of the solar wind, critical questions in heliophysics that have been ranked as top priorities for decades.

By making the first direct, in situ measurements of the region where some of the most hazardous solar energetic particles are energized, SPP will make a fundamental contribution to our ability to characterize and forecast the radiation environment in which future space explorers will work and live. Launch: No earlier than 2018.

Solar Terrestrial Probes (STP)



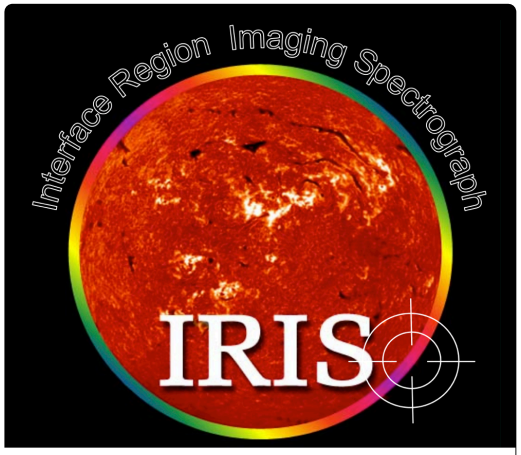
Magnetospheric Multiscale (MMS):
The MMS mission will use Earth's magnetosphere as a laboratory to study the microphysics of magnetic reconnection, a fundamental plasma-physical process that converts magnetic energy into heat and the kinetic energy of charged particles.

These processes — magnetic reconnection, particle acceleration, and turbulence — occur in all astrophysical plasma systems but can be studied in situ only in our solar system and most efficiently in Earth's magnetosphere, where they control the dynamics of the geospace environment and play an important role in space weather. Launch: No later than March 2015.

Fit check of MMS FPI sensors on Spacecraft Deck #1

Solar Terrestrial Probe #5:
STP #5 will be defined by the 2012 Decadal Survey. Mission planning activities will start upon receipt of the Decadal Survey.

Explorers Program



Interface Region Imaging Spectrograph (IRIS):
Understanding the interface between the photosphere and corona is a fundamental challenge in solar and heliospheric science. The IRIS mission opens a window into this crucial region by tracing the flow of energy and plasma through the chromosphere and transition region into the corona and solar wind using spectrometry and imaging. IRIS will contribute to our fundamental understanding of the solar energy transport, will increase our ability to forecast space weather, and will provide an archetype for all stellar atmospheres.
Launch: No later than June 2013.

11 **IRIS Final Frame Inspection**

U.S. Participating Investigator (USPI):
The 2010 Explorer Program AO solicited proposals for U.S. Participants on missions being built and flown by an agency other than NASA. Three of these proposals were selected for funding:

- **J. Forbes**: USPI-GOCE: U. of Colorado: Middle Thermosphere Variability due to Sources From Above and Below

- **J.D. Moses**: Naval Research Laboratory: US Participation in the Solar Orbiter Multi Element Telescope for Imaging and Spectroscopy (METIS)

- W. Peterson: U. of Colorado: Investigations of the mid-latitude thermospheric response to variations in solar irradiance and geomagnetic activity using photoelectron and other observations from the Canadian ePOP Mission

Heliophysics Research Program

Low Cost Access to Space:

Both the Geospace and Solar and Heliospheric programs include Low Cost Access to Space (LCAS) components. LCAS investigations are distinguished from other Research Program efforts in that the achievement of their objectives requires access to space. LCAS investigations may be science investigations in and of themselves or proof-of-concept experiments for techniques/detectors that enable new Heliophysics science. The program offers a variety of methods for providing access to space, including use of sounding rockets, research balloons, the International Space Station, and/or CubeSats. Most of the investigations in the current program take advantage of special attributes of sounding rockets, such as being able to obtain in situ measurements in regions inaccessible to spacecraft or providing key calibration underflights for our orbital fleet of spacecraft.

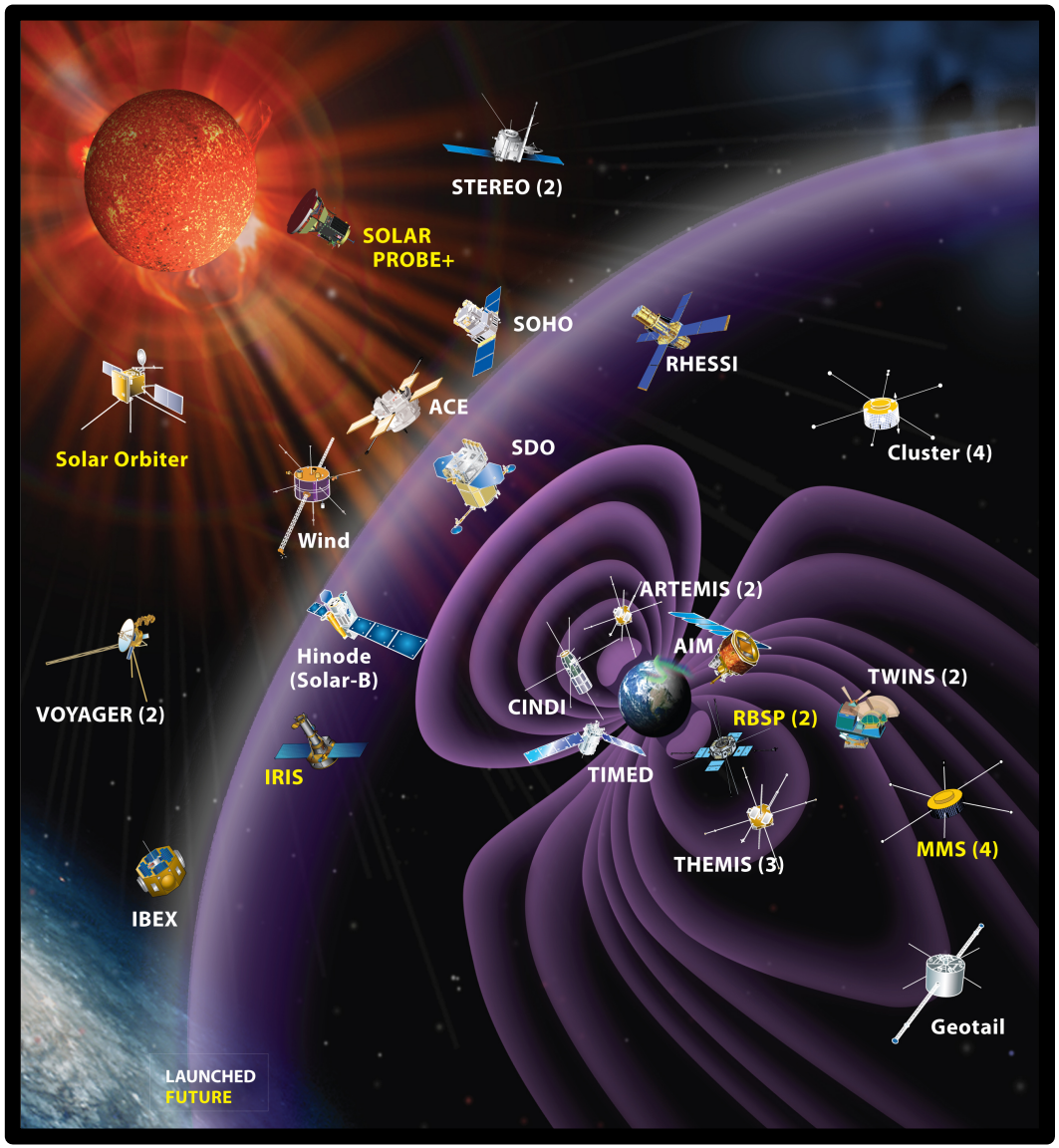
These programs fulfill three critical elements: executing intrinsically meritorious science investigations; advancing the technology readiness levels of future space flight detectors and supporting technologies; and preparing future leaders of NASA space flight missions such as junior researchers, students, and engineers.

Sounding Rocket Program completed 12 NASA suborbital launches, supporting 5 science investigations, 1 technology demonstration, 2 test flights, and 3 educational projects.

Special Program: *Causes and Consequences of the Recent Solar Minimum*

- Fourteen three-year investigations funded
- Special session at Fall 2010 AGU
- Workshop – Boulder. May 2011 - http://heliophysics.nasa.gov/SolarMinimum24/SolarMinimum24.html
- Chapman Conference in planning for November 2012

Heliophysics System Observatory



The observatory utilizes the entire fleet of solar, heliospheric, geospace, and planetary spacecraft as a distributed observatory to discover the larger scale and/or coupled processes at work throughout the complex system that makes up our space environment.

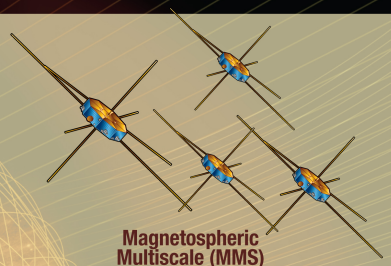
HSO consists of 17 operating missions: Voyager, Geotail, Wind, SOHO, ACE, Cluster, TIMED, RHESSI, TWINS, Hinode, STEREO, THEMIS, AIM, CINDI, IBEX, SDO, ARTEMIS

Heliophysics Data Environment Enhancement awards (VxO) ~ $2M

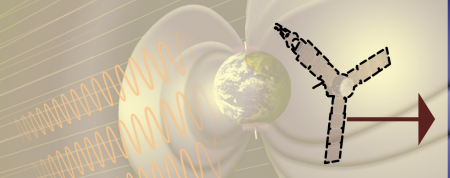
Next Senior Review scheduled for April 2013.

Heliophysics Program 2012-2018

Solar Terrestrial Probes



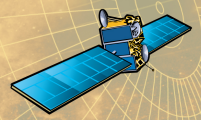
Magnetospheric Multiscale (MMS)
NLT March 2015



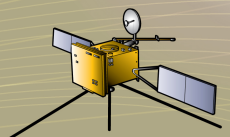
STP #5

Living With a Star

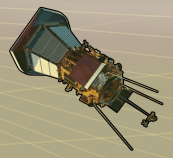
Radiation Belt Storm Probes (RBSP)
September 2012



Space Environment Testbeds (SET)
January 2014

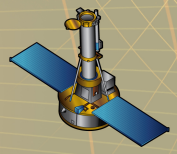


Solar Orbiter Collaboration (with ESA)
NET January 2017



Solar Probe Plus
NET July 2018

Explorers



Interface Region Imaging Spectrograph (IRIS)
NLT June 2013

Future Explorer Mission(s)
2016-2018

Research Flight Program

FOXSI - January 2012
MICA - February 2012
ATLT - March 2012
RAISE - April 2012
EUNIS - April 2012

VERIS - May 2012
RockOn - June 2012
RockSat - June 2012
EVE Underflight 3 - June 2012

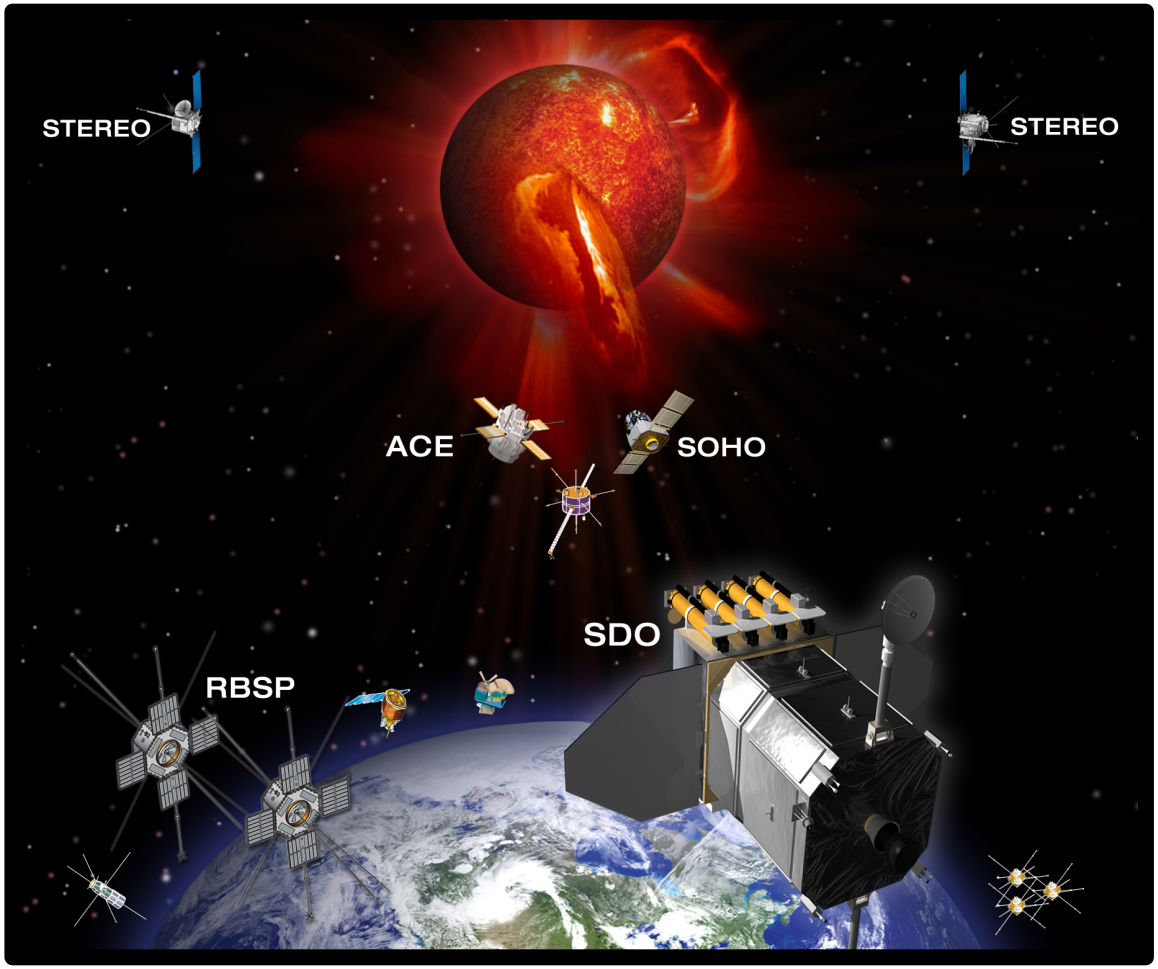
HI-C - June 2012
SUMI - June 2012
DFS - July 2012
EVEX - September 2012

Ongoing

GRIPS - September 2012/New Mexico
BARREL #1 - December 2012/Antarctica
BARREL #2 - December 2013

2012 2013 2014 2015 2016 2017 2018

Heliophysics Research Missions with Space Weather Utility



Every day we watch the Sun for signs of flares and coronal mass ejections with SDO, STEREO, ACE, Wind, and other solar sensing satellites. We monitor the effects on Earth's near space environment with AIM, THEMIS, CINDI and other Sun-Earth connection satellites.

Heliophysics research provides Theory, Data, and Modeling development services to national space weather efforts including 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 participates in the National Space Weather Program Council (along with NSF, NOAA, DOD, and 7 other agencies).

FY12 Budget Appropriation

Heliophysics	FY11 589.4	FY12 622.0	FY13 632.4	FY14 650.6	FY15 656.8	FY16 655.8
Heliophysics Research	143.3	156.7	160.2	161.9	163.8	166.6
Living with a Star	222.5	213.2	211.0	209.0	343.0	360.0
Solar Terrestrial Probes	136.1	182.2	186.5	185.8	55.1	40.7
Heliophysics Explorer Program	87.5	69.8	74.7	94.0	94.8	88.4

$'s in Millions

Heliophysics Decadal Survey

The Space Studies Board has organized a broadly-based assessment of the scientific priorities of the U.S. solar and space physics research enterprise for the period 2013-2022.

There is an emphasis on developing a systems approach to the theoretical, ground-based and space based research programs that comprise the flight programs and focused campaigns of NASA, the ground-based and basic research programs of NSF, and the complementary operational programs of other agencies such as NOAA.

The NRC, NSF, NOAA, and NASA are planning roll-out activities to include the entire science community using a multiple Town Hall format with live feed from the main event in Washington, DC.

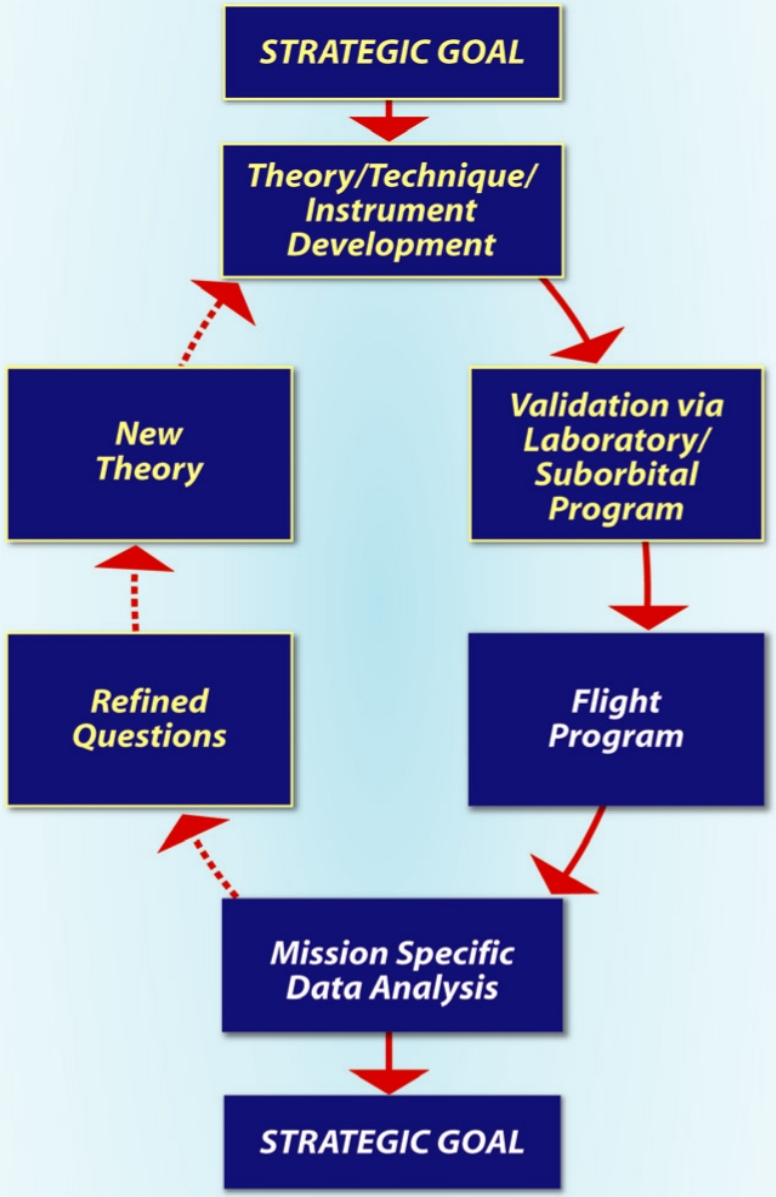
Anticipated Completion Date for the Survey: No later than 31 March 2012.

Strategy of Heliophysics Programs

- **Theory**
- **Models**
- **Data**

SR&T Contributions to Scientific Process

- Strategic Goal
- Requires Development of
  - Theory
  - Data Analysis Techniques
  - Models
  - Instruments
- Which are Tested via the
  - Laboratory and/or
  - Suborbital Program
- Leading to Flight Programs and Analysis of Mission Data
- Which Leads to Either
  - Achievement of the Goal
  - Or a New Cycle Which then Leads to
  - Achievement of the Goal



CCMC role within Heliophysics

The CCMC makes a major contribution in the strategic interplay of theory, modelling and data; it is a continuous feed-back loop.

The insights offered by this interaction make for better-defined and realizable science goals in a constrained budget environment.

Given the nature of the complex, connected regimes which constitute the field, it would be very difficult, if not impossible, to make meaningful headway in understanding the processes which connect the inner Sun to the magnetosphere, without the ability to compare theory, models, and data.

CCMC meets a need that is essential for better understanding the science, and the continued progress in the field.

Models without data are academic exercises, while data without models are just gathering unrelated facts. Both require theory to hold them together.

EOS Cover Story – E/PO

Beth Barbier's brief report on the GSFC Heliophysics Science Division's E/PO program, "Education and Outreach Bring NASA Heliophysics to the Public," was published as a cover article in the Nov. 29, 2011 issue of the AGU's weekly newspaper, *EOS*. She was invited by editor Christina Cohen to write the article.

EOS

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

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IN THIS ISSUE:

Hydrologic Projections for the Western United States

Motivated by a common interest in establishing data access for climate change impacts analysis, the U.S. Department of the Interior's Bureau of Reclamation (referred to hereinafter as Reclamation) has collaborated since 2007 with federal and nonfederal entities to provide monthly gridded precipitation and temperature data from 112 contemporary climate projections (Coupled Model Intercomparison Project Phase 3 (CMIP3)) over the contiguous United States. The grid size resolution of this downscaled data archive (publicly available at http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/) is 1/8° latitude × 1/8° longitude (approximately 12 × 12 kilometers) and covers the period 1950–2099 [*Maurer et al.*, 2007].

Downscaling is necessary to develop hydroclimate data (e.g., precipitation and temperature) from a coarse-resolution climate model grid to a higher-resolution grid, and the CMIP3 archive was downscaled using the statistical method of bias correction.

Although approximately 1000 unique users to date have downloaded the precipitation and temperature information contained within the archive (commonly referred to as the bias corrected spatially downscaled, or BCSD-CMIP3, archive), these temperature and precipitation projections have not been used to consistently generate hydrologic projections over the United States and at fine enough scale to perform hydrologic impacts analysis and support local adaptation assessments. Without available hydrologic projections, planners typically develop and apply their own site-specific and local hydrology models to fill this information

To address this challenge, Reclamation has collaborated with the University of Washington and the Colorado Basin River Forecast Center (CBRFC) of the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) to generate 1/8° gridded hydrologic projections over the western United States using the variable infiltration capacity (VIC) macroscale hydrology model [*Liang et al.*, 1994]. The VIC model simulates water balance for each area element in a 1/8° spatial grid (coincident with BCSD climate projections' 1/8° spatial grid) and on a daily time step, with an hourly time step for the snow model.

The development of the 1/8° gridded hydrologic projections over the western United States involved using the existing BCSD-CMIP3 climate archive and available calibrated versions of the VIC model covering most of the 17-state Reclamation region (whose boundary is defined by the states of North Dakota, Texas, California, and Washington) including the eight major Reclamation river basins: Colorado, Columbia, Klamath, Missouri, Rio Grande, Sacramento, San Joaquin, and Truckee (Figure 1). The development of these BCSD-CMIP3 hydrologic projections (a total of 112 covering the period 1950–2099), including analysis for the eight major river basins, was documented [*Bureau of Reclamation*, 2011a] in support of Reclamation's first Science and Engineering to Comprehensively Understand and Responsibly Enhance (SECURE) Water Act report to Congress [*Bureau of Reclamation*, 2011b]; both reports are available at http://www.usbr.gov/climate/.

The BCSD-CMIP3 hydrologic projections

Education and Outreach Bring NASA Heliophysics to the Public

Educating and inspiring students, teachers, and the public by communicating advances in heliophysics science is the objective of the education and public outreach (E/PO) specialists at the Heliophysics Science Division (HSD) at NASA Goddard Space Flight Center (GSFC) in Greenbelt, Md. The specialists carry out NASA's E/PO goal to enhance the nation's formal education system and contribute to the broad public understanding of science, math, and technology. HSD E/PO projects exploit community best practices to meet or surpass NASA's requirements, which include attention to quality; leverage through internal and external partnerships; and a focus on customer needs, project sustainability, and audience diversity.

One key to the group's success is the involvement of enthusiastic HSD research scientists who directly interface with E/PO specialists and various audiences, verify scientific content, and/or provide data access or other resources. Scientists also mentor interns from high school to graduate school through NASA and GSFC programs, and several have shared their science with the public via appearances on national media, including the National Geographic and History channels as well as local news.

E/PO Staff

The HSD associate director for science leads efforts to coordinate and advance the most effective methods to reach an array of audiences. The division's eight E/PO specialists bring a wide range of complementary talents, depth of experience, and valuable partmultimedia resources are collected on SED's Web site (Figure 1), which won the Pirelli *Internet*ional Award for the communication of science and technology in 2004. While SED is currently run by only three part-time HSD E/PO specialists, more than 26,000 participants used resources related to the 2010 program in their own outreach programs, and in 2011 roughly 80,000 people followed the program's Twitter feeds. Featuring the "Magnetic Storms" theme that year, the 2010 webcast from the National Science Teachers Association (NSTA) conference connected with 650,000 live viewers and another 3.5 million through the Web site.

Built around NASA space science discoveries and multimedia resources, SpaceMath@NASA is a growing Web collection of more than 400 math problems. The site receives more than 10,000 visits monthly, and workshops coach math and science teachers on enticing and relevant ways to draw in students. Printed guides with new content are also published each year, with the most recent being "Earth Math," "Space Weather Math," and "Electromagnetic Math."

NASA's Space Weather Action Centers (SWACs) allow students to enjoy the "scientific discovery" process. Online through SWACs, they monitor the progress of a solar storm from the Sun to the Earth, following real NASA satellite and observatory data, and then create video space weather reports from the experience. This project trains educators to run SWAC, and more than 3000 now use it in their classrooms. Also, a SWAC scenario where students follow and report on a

Fig. 1. A screen shot of NASA's Sun-Earth Day Web site. The site is the bridge to a wide range of educational and outreach activities in science, math, and technology related to the Sun, the heliosphere, and space weather (see http://sunearthday.nasa.gov).

Screenshots from the EOS online edition at
http://www.agu.org/journals/eo/v092/i048/2011EO48_tabloid.pdf