Understand the Sun and its interactions with the Earth, the Solar System, and the Galaxy.

Solve the Fundamental Mysteries of Heliophysics

Understand the Nature of our Home in Space

Build the Knowledge to Forecast Space Weather Throughout the Heliosphere
Heliophysics has 18 operating missions (on 29 spacecraft): Voyager, Geotail, Wind, SOHO, ACE, Cluster, TIMED, RHESSI, TWINS, Hinode, STEREO, THEMIS/ARTEMIS, AIM, CINDI, IBEX, SDO, Van Allen Probes, IRIS (Missions in red contribute to operational Space Weather.)

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

$5.5B total investment in Heliophysics space assets (excluding launch costs)

$68M annual operating budget
Particle injections from the plasma sheet to the inner magnetosphere: Coordinated studies with THEMIS, Van Allen Probes, and geosynchronous satellites (Gkioulidou / Malaspina)

Outer magnetosphere: THEMIS D: ~10 R_E
- First observed dispersionless injection ~22:57 UT both in ions and electrons up to ~800 keV
- Clear dipolarization of the magnetic field

Inner magnetosphere: Van Allen Probe B: L ~ 6
- Observed dispersed in energy injection
- at ~ 23:04 UT for protons (dusk-ward drift) up to ~500 keV
- at ~ 23:28 UT for electrons which have drifted around the earth up to ~200 keV (dawn-ward drift)

Geosynchronous: GOES 13 L = 6.6
- Observed almost simultaneously with VAP B the dispersed proton injection up ~300 keV
- No magnetic field dipolarization signature

Orbits for additional collaborations

May 2013
Jun 2013
Jul 2013
Aug 2013
Sep 2013
Oct 2013
Earth’s Rotation Unexpectedly Causes “Zebra Stripes” in the Inner Electron Radiation Belt

The Van Allen Probes RBSPICE instrument has discovered stripe-like patterns, termed “Zebra Stripes” in the inner portions of Earth’s electron radiation belt.

Earth’s rotation causes a very weak electric field whose effect builds up strongly over time due to quasi-resonance with drifting electrons.

The stripe pattern is caused by a stretching and folding of electron clouds, much like taffy is stretched and folded in a candy machine.

Ukhorskiy et al., In Press at Nature, 2014
X-1 Flare with SDO, HINODE, IRIS, and more!

29 March 2014  17:50 UT
Science data available on the web
IRIS Observations on AIA Image

You have to see the movie!
Heliophysics Program 2014-2018
NASA’s New CubeSat Program

- Heliophysics is administering SMD’s new CubeSat budget, $5M/yr in FY14

- Management approach approved at SMD level on 20 February
  - HQ-based administration, “thin” program office supported part-time
  - Modest contribution to support KSC CubeSat Launch Initiative for accommodations
  - CubeSat proposals will be solicited via ROSES and selected by each SMD Division
  - Science CubeSat Integration Panel established

- Science CubeSat Integration Panel responsibilities:
  - Establish policy, incorporate lessons learned, and conduct outreach
  - Integrate management and implementation as needed
  - Recommend awards following review by Divisions

- CubeSat proposals already reviewed are being considered for 2014 awards

NASA CubeSat proposals will be solicited and selected on the basis of science merit and technology value.
**Two New Explorers for Heliophysics**

Selected in 2013 for Flight Development, Launch in 2017

---

**ICON**  
*Ionospheric Connection Explorer*

- How neutral atmosphere affects the ionosphere  
- How solar wind and magnetosphere affect the ionosphere

ICON is a single s/c traveling eastward and continuously imaging the thermosphere and ionosphere.

Orbit: 550 km at 24° inclination  
PI: **Thomas Immel** / UC Berkeley

- Successful SRR in January 2014  
- PDR in July 2014  
- Confirmation Review, August 2014

---

**GOLD**  
*Global Scale Observations of the Limb and Disk*

... how the ionosphere and thermosphere respond to geomagnetic storms, solar radiation, and upward propagating atmospheric tides

Two identical scanning imaging spectrographs on a geosynchronous commercial communication satellite.  
PI: **Richard Eastes** / U. Cent. FL

- Successful SRR in January 2014  
- PDR in September 2014  
- Confirmation Review in Oct 2014
Solar Orbiter was selected as the first medium-class mission of ESA's Cosmic Vision 2015-2025 Programme

**Mission design:**
- **Launch:** July 2017 (2018 backup)
- Multiple gravity assist manoeuvres (Venus, Earth)
- **Minimum perihelion:** 0.28 AU
- **Out of the ecliptic angle:** 25°
- **Maximum solar latitude:** 35°
- **Total mission duration:** 7 years (plus 3 years of extended phase)

**Approved Life cycle cost:** $435.9M

NASA launch vehicle in procurement

US-funded instruments SoloHI (NRL) and HIS (SwRI) are preparing for 2015 deliveries to support a July 2017 launch.
Overview

Using in-situ measurements made closer to the Sun than by any previous spacecraft, SPP will determine the mechanisms that produce the fast and slow solar winds, coronal heating, and the transport of energetic particles.

Solar Probe Plus will fly to less than 10 solar radii ($R_s$) of the Sun, walking-in from 35 $R_s$ over 24 orbits.

Milestones

- Pre-Phase A: 07/2008 – 11/2009
- Phase A: 12/2009 – 01/2012
- Phase B: 02/2012 – 03/2014
- Phase C/D: 03/2014 – 08/2018
- LRD: August 2018
- Phase E: 09/2018 – 09/2025

Approved Life cycle cost: $1,553.4M
Science Objective: Investigate the physics of magnetic reconnection, using a constellation of 4 satellites to probe the reconnection region.

Partners
- IWF (Austria), LPP (France), ISAS (Japan), KTH (Sweden)
- KSC Launch Services Program for Atlas V

Approved Life cycle cost: $1,081.1M

Overall Status
- All 4 satellites are in system-level test
- 3 of 4 completed thermal vacuum test
- Quality issues on one electronic part (HV801)
  - Several instruments affected, all being worked
- Significant cost, schedule impacts of shutdown
- Launch readiness changed from October to 26 November 2014 due to shutdown last fall
- Launch expected in early March 2015
MMS Status and Launch Schedule

Observatory #4 in final assembly

2 of 4 as stacked for launch
1. **Continue to pursue the documented goal of the CCMC:**
   Develop and execute next generation research models in support of the advancement of space sciences and development of new operational space weather capabilities. [expand to “Develop, support, sustain, and execute” ?]

2. **Exploit and apply expertise in model integration and visualization**
   - Integrated Space Weather Analysis System, 3DView, KAMELEON

3. **Expand model validation activities, with focus on operational needs**
   - Coordinate closely with operational agencies to identify needs, plan for the future
   - Continue to maintain and expand on Space Weather Scoreboard
   - Maintain historical database of space weather observations for model validation
   - Support operational agencies with model testing and validation results
   - Lead research required to establish space weather monitoring requirements

**CCMC has a unique and significant role in leading the research to better define space weather monitoring requirements.**
Issues and Concerns: Research Support

- Community demand for research support is far from satisfied
  - Number of proposals is rising
  - Fraction funded is falling to 1 in 6
  - Several activities and inquiries assessing funding statistics
  - Release of consistent dataset is under way to facilitate discussions

- What are we doing?
  - Expanding the 2-step process
  - “Rebalancing” to increase research fraction of budget per Decadal Survey recommendations
  - Near-term objective: Motivate and justify Decadal Survey recommendation to increase research budget by $10M/year
  - Support the community in explaining the benefits of heliophysics research
<table>
<thead>
<tr>
<th>Heliophysics Budget and Projections</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>President's Budget Request</td>
<td>$647.0</td>
<td>$643.0</td>
<td>$668.9</td>
<td>$647.6</td>
<td>$676.6</td>
<td>$673.3</td>
<td>$675.5</td>
</tr>
<tr>
<td>FY13 Sequester Reduction</td>
<td>($30.6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FY13 Operating Plan Reductions</td>
<td>($13.9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other adjustments</td>
<td>($0.7)</td>
<td>$10.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Heliophysics Budget</td>
<td>$603.2</td>
<td>$653.7</td>
<td>$668.9</td>
<td>$647.6</td>
<td>$676.6</td>
<td>$673.3</td>
<td>$675.5</td>
</tr>
<tr>
<td>Heliophysics Budget Appropriated</td>
<td>$603.2</td>
<td>$654.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less Admin &amp; Directed R&amp;T*</td>
<td>($16.6)</td>
<td>($44.1)</td>
<td>($55.0)</td>
<td>($12.2)</td>
<td>($16.7)</td>
<td>($18.7)</td>
<td>($19.0)</td>
</tr>
<tr>
<td>Net Heliophysics Budget</td>
<td>$589.7</td>
<td>$609.9</td>
<td>$613.9</td>
<td>$635.4</td>
<td>$659.9</td>
<td>$654.6</td>
<td>$656.5</td>
</tr>
<tr>
<td>Heliophysics Expenditures for FY</td>
<td>$589.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*These budgets support SMD activities not specific to Heliophysics. Greyed entries represent notional estimates.
Key Budget Consequences for Heliophysics

- The Heliophysics budget for FY15 is increased over FY14
  - Net of administrative items: $609.8 in FY14, to $613.9 in FY15
- The budget sustains long-standing HPD programs
  - Research & Analysis, operating mission support is essentially constant
- The budget enables a 2018 launch date for Solar Probe Plus without impacting research and analysis support
- It maintains the July 2018 launch date for Solar Orbiter
- It supports MMS through final integration and test
- It funds both ICON and GOLD for launches in 2017

- We will continue to implement the DRIVE initiative
  - Small satellites: CubeSat budget line item is a good start
  - Next objective: $10M/yr increase for MO&DA
# Decadal Survey Research Recommendations

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Science</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete the current Program</td>
<td>Support the existing program elements that constitute the Heliophysics Systems Observatory (HSO) and complete missions in development (RBSP, IRIS, MMS, SOC, SPP).</td>
<td>Review in case of any significant cost growth</td>
</tr>
<tr>
<td>DRIVE (Diversify, Realize, Integrate, Venture, Educate)</td>
<td>Strengthen observational, theoretical, modeling, and technical advances with additional R&amp;A capabilities: small satellites; MO&amp;DA funding, science centers and grant programs; instrument development</td>
<td>Program rebalance: move up to $40M/yr into Research</td>
</tr>
<tr>
<td>Accelerate and expand Heliophysics Explorer Program</td>
<td>Launch every 2-3 years, alternating SMEX &amp; MIDEX with continuous Missions of Opportunity.</td>
<td>Program rebalance: move $70M/yr into Explorers</td>
</tr>
<tr>
<td>Restructure STP line as a moderate scale, PI-led flight program. Implement three mid-scale missions.</td>
<td>Mission 1: Understand the interaction of the outer heliosphere with the interstellar medium; includes L1 space weather observations Mission 2: Understand how space weather is driven by lower atmosphere weather. Mission 3: Understand how the magnetosphere-ionosphere-thermosphere system is coupled and responds to solar forcing.</td>
<td>$520M per mission in FY12$; launches in 2021, 2025, 2029</td>
</tr>
<tr>
<td>Start another LWS mission by the end of the decade.</td>
<td>Mission 4: Study the ionosphere-thermosphere-mesosphere system in an integrated fashion.</td>
<td>$1B mission, Launch 2024</td>
</tr>
</tbody>
</table>

Notes: 1) Recommendations listed above are top level, each contains a number of sub-elements 2) Recommendations are listed in priority order, pending budget constraints 3) Recommendations are separable by Agency, only NASA Recommendations are listed here
Where is the Heliophysics Division Going?

- NASA’s SMD Heliophysics Division Mission Statement (draft):
  Adopt the 2013 Heliophysics Decadal Survey and the Roadmap as our foundation to foster the next decade of heliophysics research, and to apply its scientific discoveries to provide direct benefits, both to the science of space weather and, through its study of fundamental processes and coupled systems, to NASA and space science overall.

- Approach to implementing Decadal Survey recommendations
  - Heliophysics Roadmap defines our detailed implementation plan for the Decadal Survey, including technology development requirements
  - Perform on our commitments to complete the current program on time and on budget
    - President’s FY15 budget supports Solar Probe Plus launch in 2018
  - Strengthen our Research and Analysis, MO&DA, and Technology Programs
    - Work towards rebalancing research program as recommended by the Decadal Survey
  - Plan for more frequent, lower cost missions: Expand Explorers and Missions of Opportunity
    - CubeSat line started in FY14, next Heliophysics Explorer A/O likely in 2016
  - Commence development of the highest priority Strategic Program (STP, LWS) science targets, consistent with the budget and with Research and Explorer priorities

- Continue to build our understanding of heliophysics (the sun and its interaction with the Earth and the solar system) and the science of space weather
Questions?