National Aeronautics and
Space Administration

Science Committee Report

Dr. Bradley M. Peterson
Chair, Science Committee

Science Committee Members

Brad Peterson, Chair, The Ohio State University and Space Telescope Science Institute
Carle Pieters, Vice Chair, Brown University

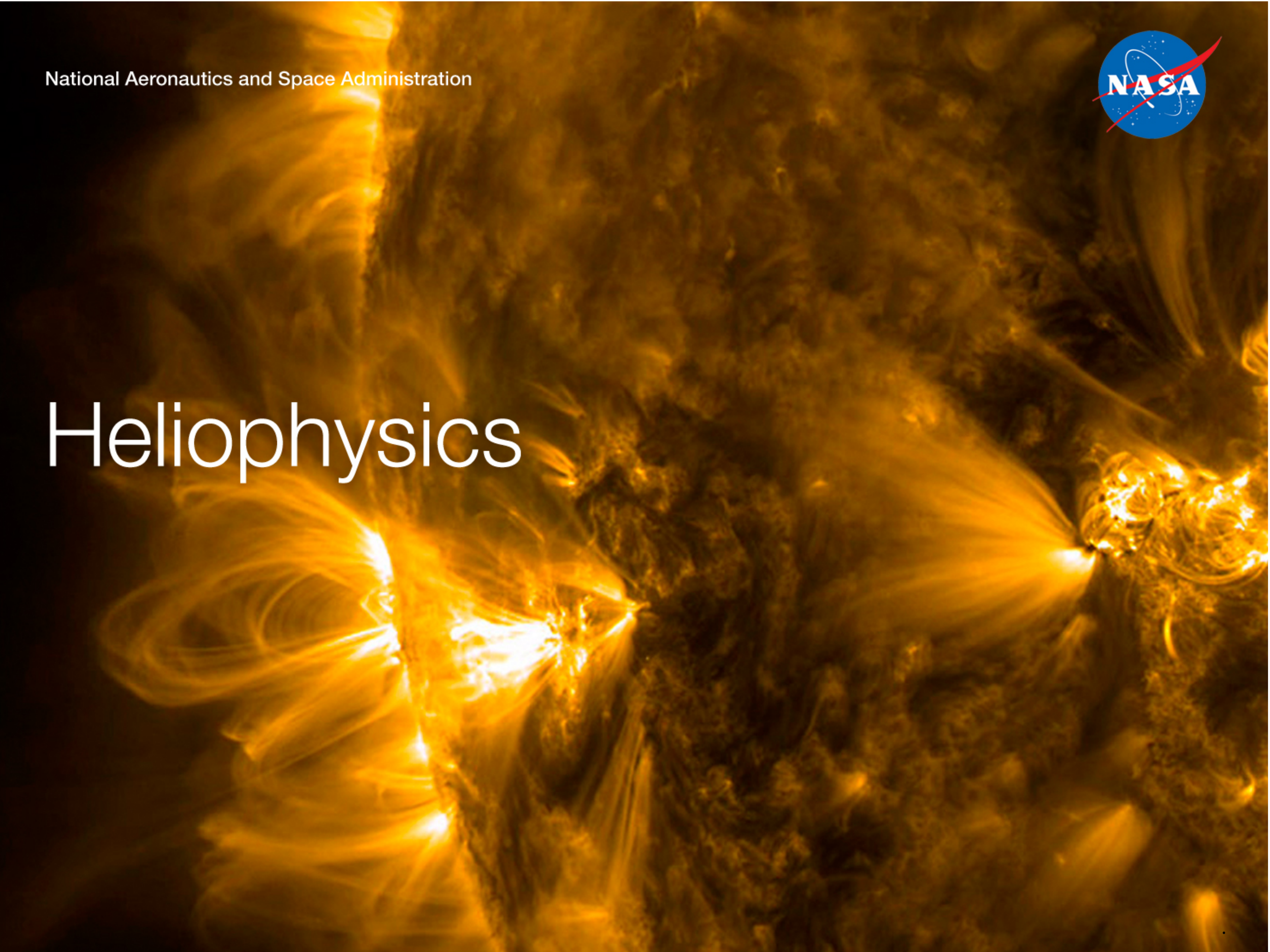
Janet Luhmann, UC Berkeley, Chair of Planetary Science Subcte
Steve Running, University of Montana, Chair of Earth Science Subcte
Scott Gaudi, The Ohio State University, Chair of Astrophysics Subcte
Jill Dahlburg, Naval Research Laboratory, Chair of Heliophysics Subcte
Robert Lindberg, University of Virginia, Chair of Planetary Protection Subcte

Doug Duncan, University of Colorado
Mark Robinson, Arizona State University
James Green, University of Colorado at Boulder
Robert Kirshner, Harvard University
Susan Avery, Woods Hole Oceanographic Institute
Tamara Jernigan, Lawrence Livermore National Laboratory
Walter Secada, University of Miami

David Spergel, Chair of Space Studies Board (*ex officio* member)

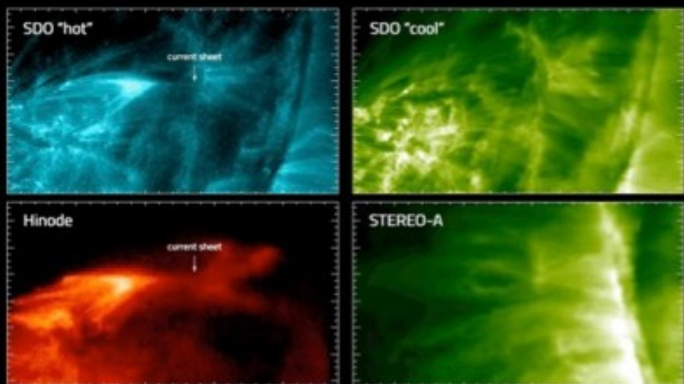
Outline

- **Science Results**
- Programmatic Status
- Observations, Findings, and Recommendations


National Aeronautics and Space Administration
NASA
Heliophysics

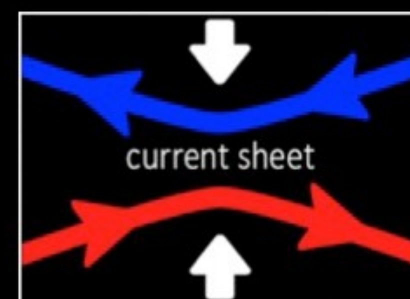
Understanding the Origins of Solar Flares

Chumming, Z., Rui, L., Alexander, D., McAteer, R. (2016). *OBSERVATION OF THE EVOLUTION OF A CURRENT SHEET IN A SOLAR FLARE. Astrophysical Journal Letters, 821(2), doi:10.3847/2041-8205/821/2/L29*



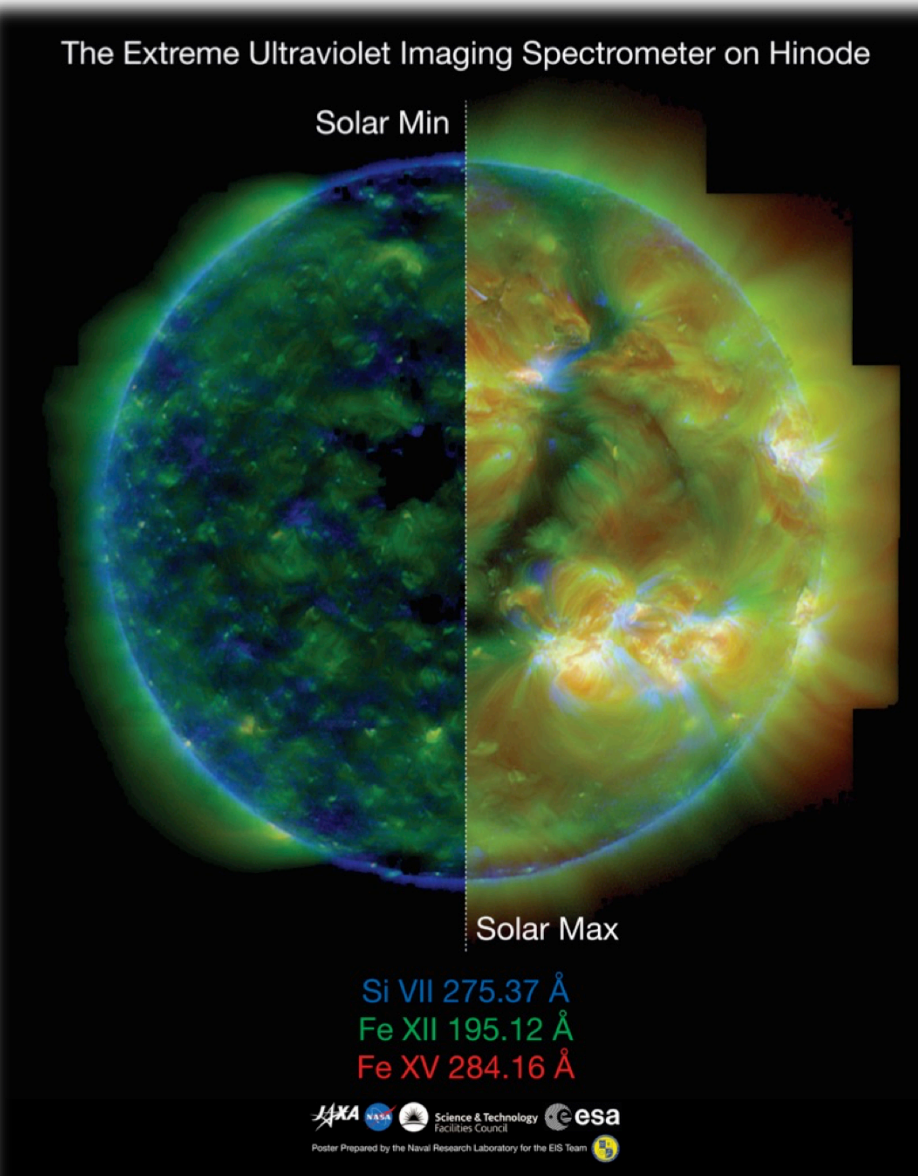
- Solar flares, important drivers of space weather, send intense high energy light and particles into space at or near the speed of light, which means we get very little warning that a flare is going to come our way. Forecasting incoming solar flares is important. These eruptions can impact the ionized part of Earth's atmosphere – the ionosphere – and interfere with our communications and navigation systems, like radio and GPS, and also disrupt satellite electronics aboard our missions. Understanding how solar flares are created will provide useful insight to help us better forecast how solar flares may impact space weather events headed our way. A recent study sheds new light on the creation of solar flares through looking at the role current sheets play in their formation.

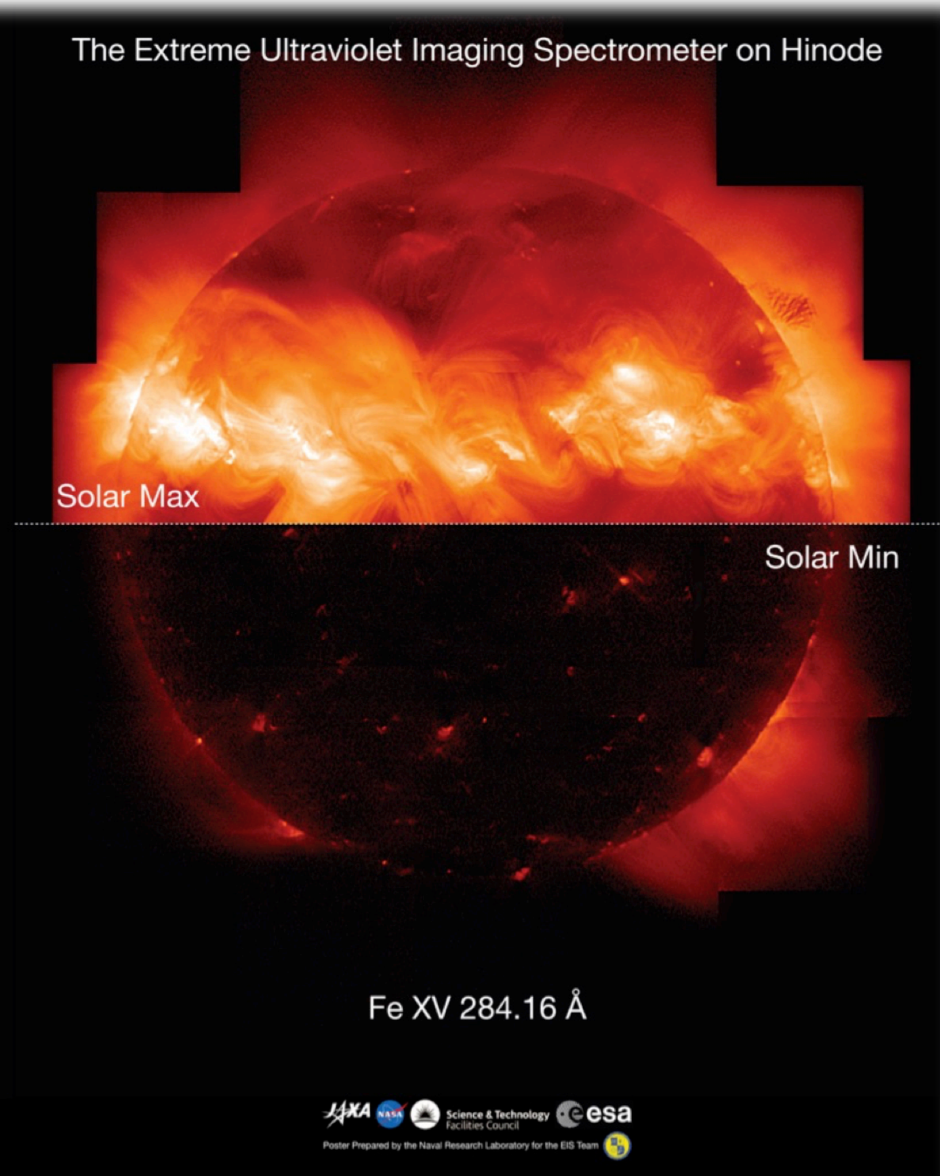
- A current sheet occurs in the space between two oppositely-aligned magnetic fields that are in close proximity. A solar flare occurs when these complicated magnetic fields suddenly and explosively rearrange themselves, converting magnetic energy into light. This energy conversion process is called magnetic reconnection and occurs in many other places throughout the Solar System including close to home, in our very own planet's magnetosphere where NASA's Magnetospheric Multiscale (MMS) mission is now providing key insights.
- During a December 2013 solar flare, NASA 's Heliophysics Solar Dynamic Observatory (SDO), Solar TErrestrial RElations Observatory (STEREO) and the NASA/JAXA Hinode observatory, observed the formation of a current sheet.
- This wasn't the first time a current sheet was observed but what makes this event unique is the breadth of measurements – such as speed, temperature, density and size -- that were obtained. Even when scientists think they have spotted something that might be a current sheet in solar data, they can't be certain without ticking off a long list of attributes. Using the combined observations from multiple spacecraft in the Heliophysics System Observatory, scientists were able to confirm that the measured properties over the course of the December 2013 event were, indeed, consistent with those of a current sheet.



Cunent sheets are f0<medin the space between two oppositely-alJgned magnetic fields that arein close proximity.Oppositely-al gned fiekls can explosively reaign to a new oonfiguration ina ptocess called magnetic reoonnection.Because current sheets are so closely tied to magnetic reoonnection,observations of a currenl sheet during the 2013 flare bolster theidea that solar flares can result from magnetic recoonection. Credits:ESA (European Space Agency)

The image above is s still capture of an animation from Zhu, et al. found at: http://www.nasa.gov/feature/goddard/2016/seeing-double-nasa-missions-measure-solar-flare-from-2-spots-in-space

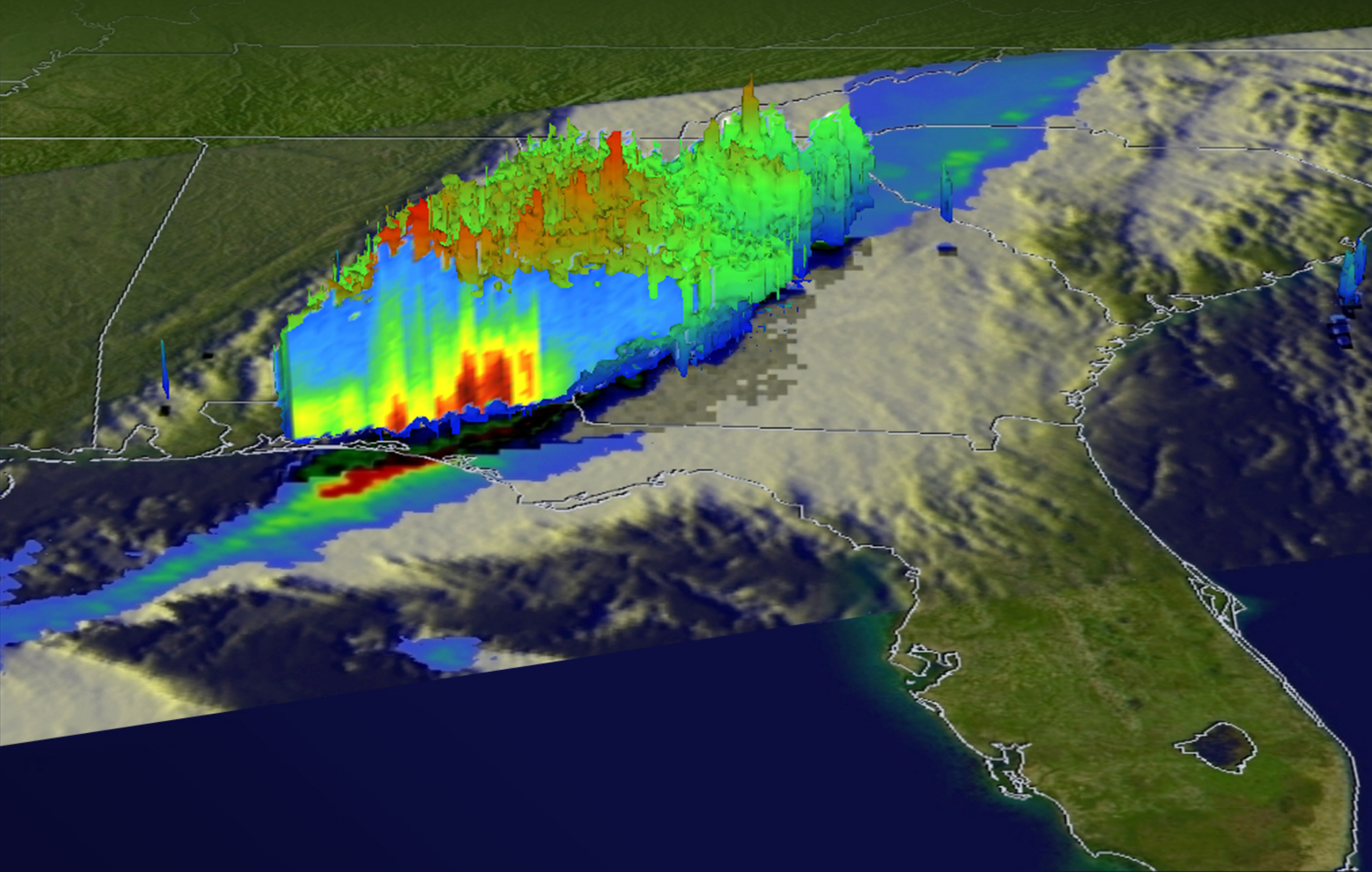




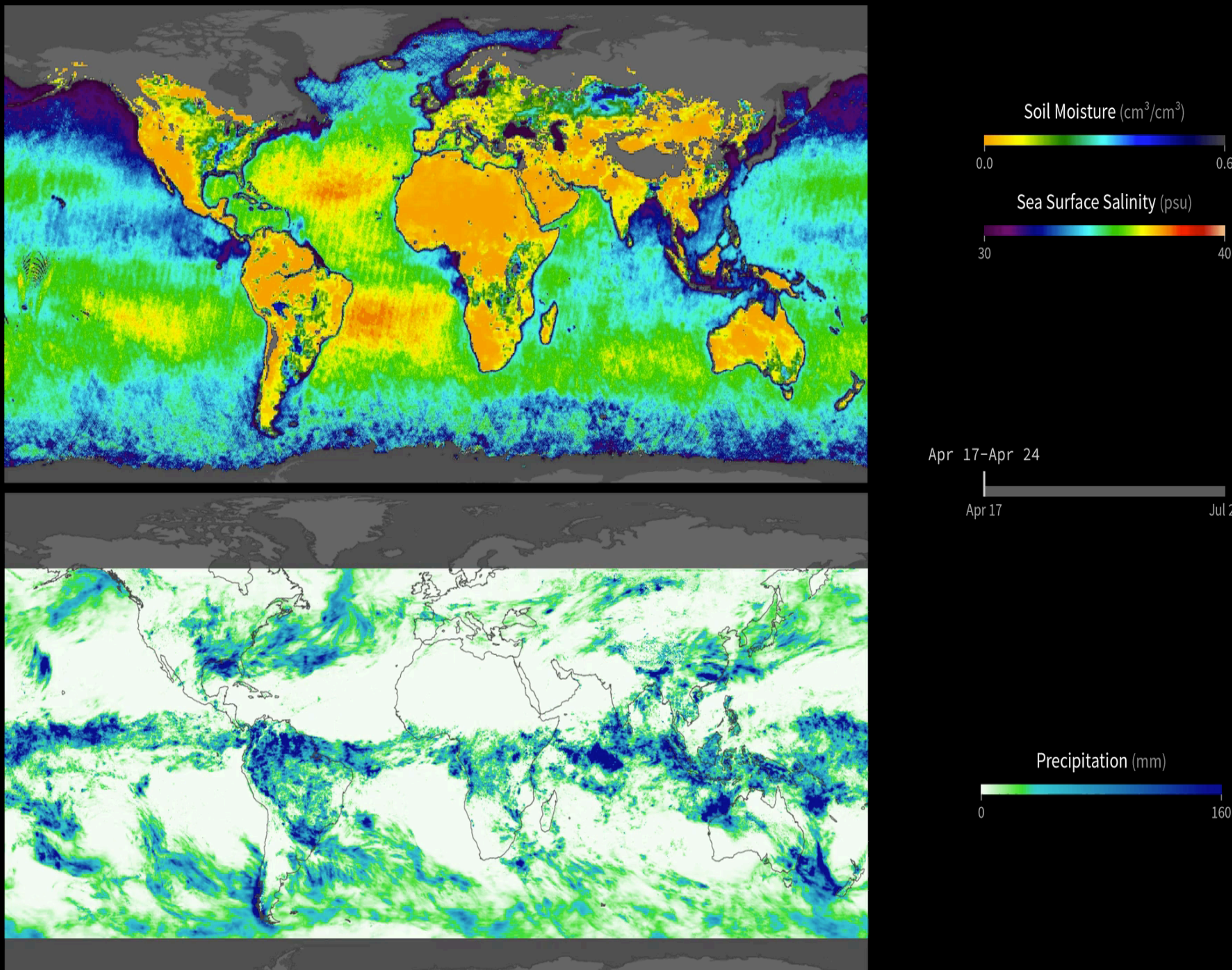
LEFT: EIS images of the Sun seen at different temperatures at times of solar minimum and solar maximum. The temperatures shown are: Si VII – 0.63 MK, Fe XII – 1.6 MK, Fe XV – 2 MK. Note the active regions in the solar maximum image and their high temperatures. The solar minimum image is dominated by blue color, the lowest temperature illustrated.

RIGHT: Similar to the left hand image but only high temperature emission at 2 MK is illustrated. Note that at solar minimum plasma at temperatures of 2 MK virtually vanishes except at very small areas in active regions.

EARTH SCIENCE



Soil Moisture and Ocean Salinity (SMAP); Precipitation (GPM)



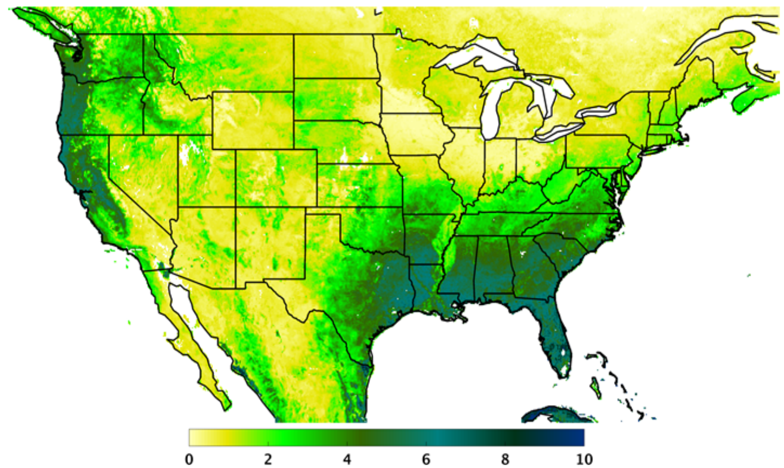
ENSO Influence on 2016 USA Spring Vegetation Growth

Spring 2016 vegetation growth patterns and anomalies from SMAP mission Level 4 Carbon (L4_C) product

- L4_C provides global daily estimates of ecosystem productivity and environmental controls, integrating MODIS vegetation and SMAP-derived surface-to-root-zone soil moisture

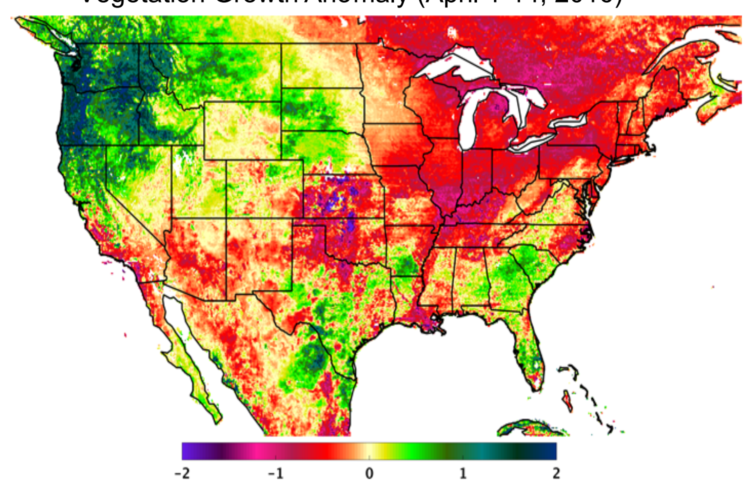
- Top: L4_C observed mean daily growth pattern, Apr 1-14, 2016
- Lower: Spring growth departure from normal conditions indicated from long-term (2001-2013) L4_C simulations
- The recent El Niño contributed to unusual spring vegetation growth variations, including:
  - Higher-than-normal productivity across the Northwest due to early spring onset and adequate moisture
  - Enhanced productivity in Central Valley CA, but continued growth suppression across Southwest from persistent drought
  - Higher-than-normal productivity across southeast from record rainfall
  - Less-than-normal growth in lower Mississippi Valley from widespread flooding
  - Late spring and less-than-normal growth across the Midwest and Northeast
- **SMAP provides new understanding of soil moisture related impacts to productivity**

Mean Daily Vegetation Growth (April 1-14, 2016)



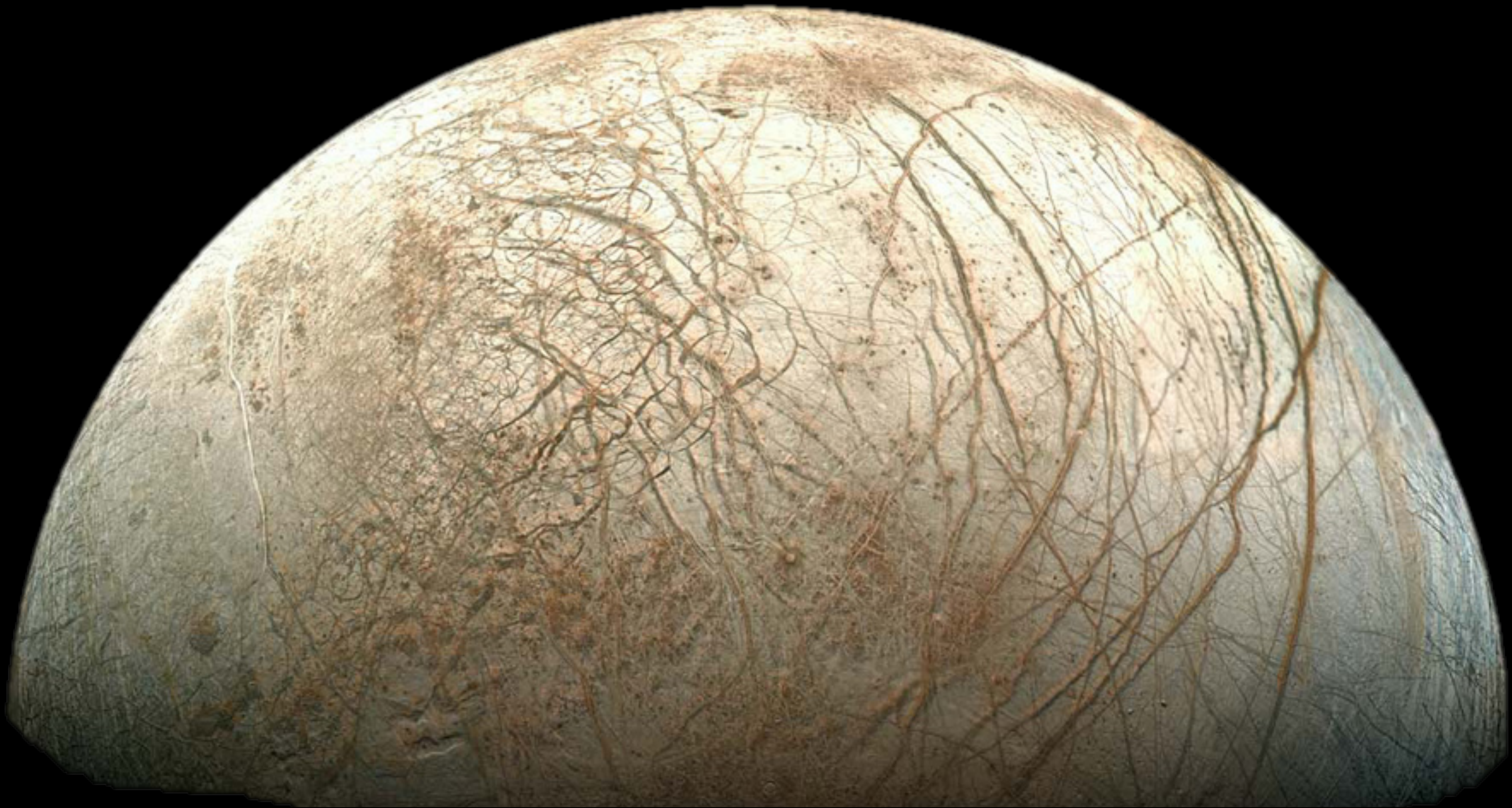
[Estimated Mean Daily Vegetation Gross Primary Production g C m^{-2} d^{-1}]

Vegetation Growth Anomaly (April 1-14, 2016)



[Estimated Mean Daily Vegetation Gross Primary Production g C m^{-2} d^{-1}]

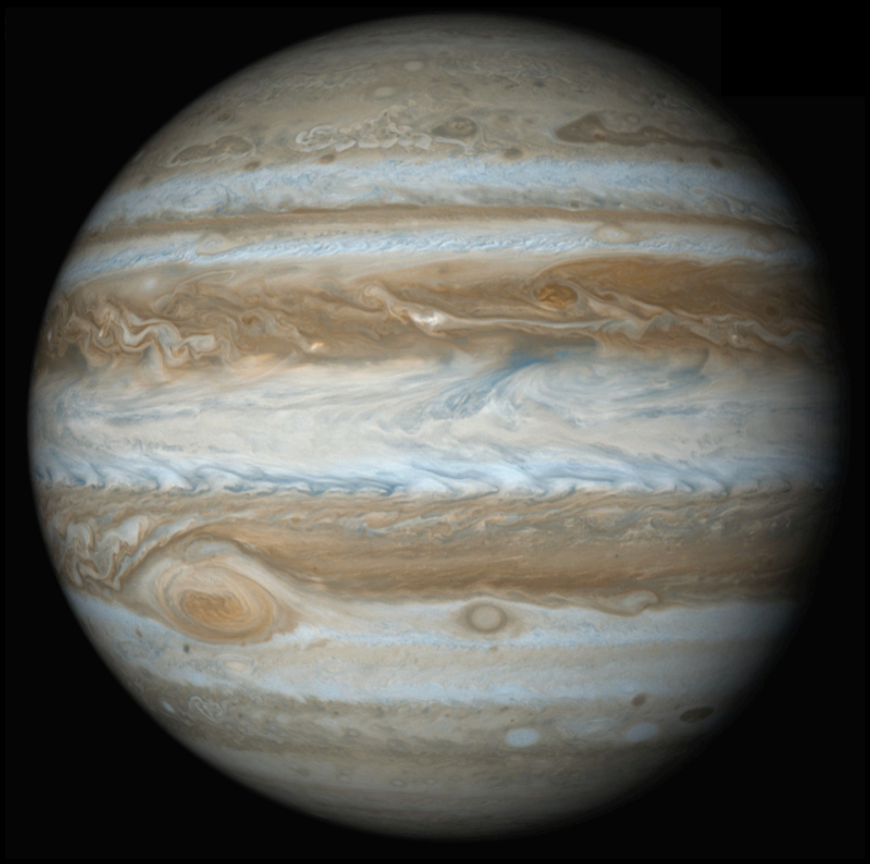
Planetary Science

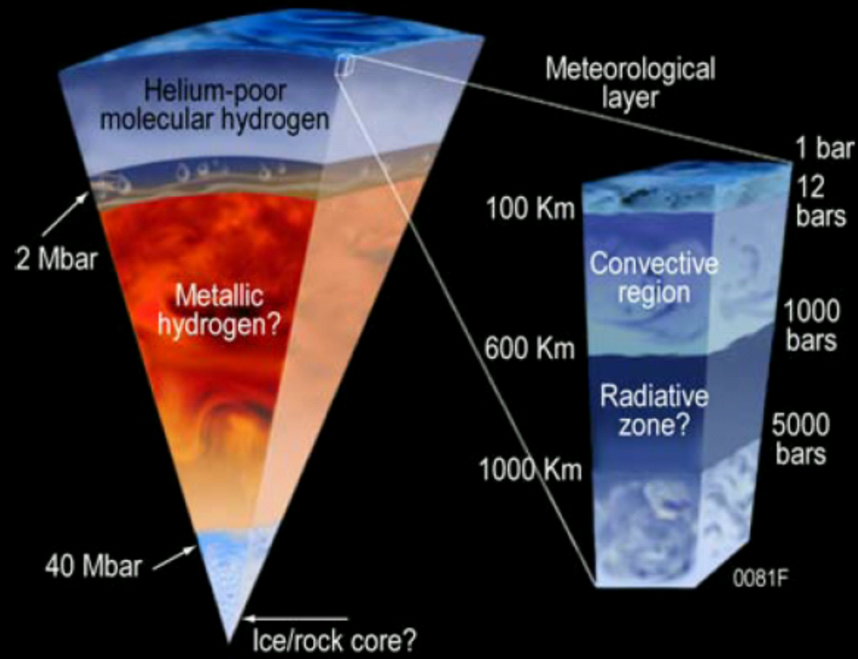


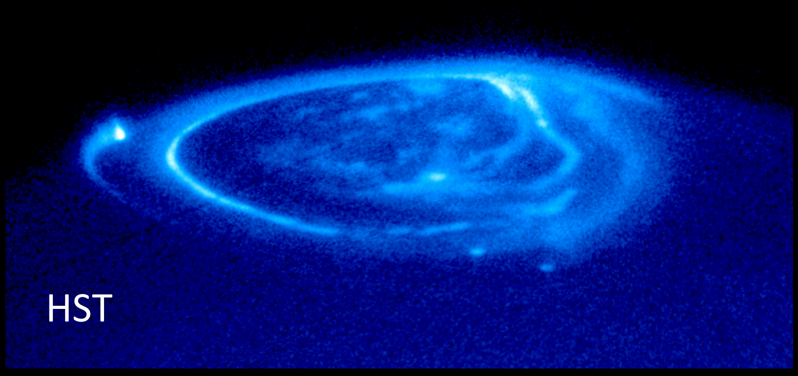
Juno: Mission to the Planet Jupiter

Science Objectives:

- Origin
- Interior Structure
- Atmosphere Composition & Dynamics
- Polar Magnetosphere

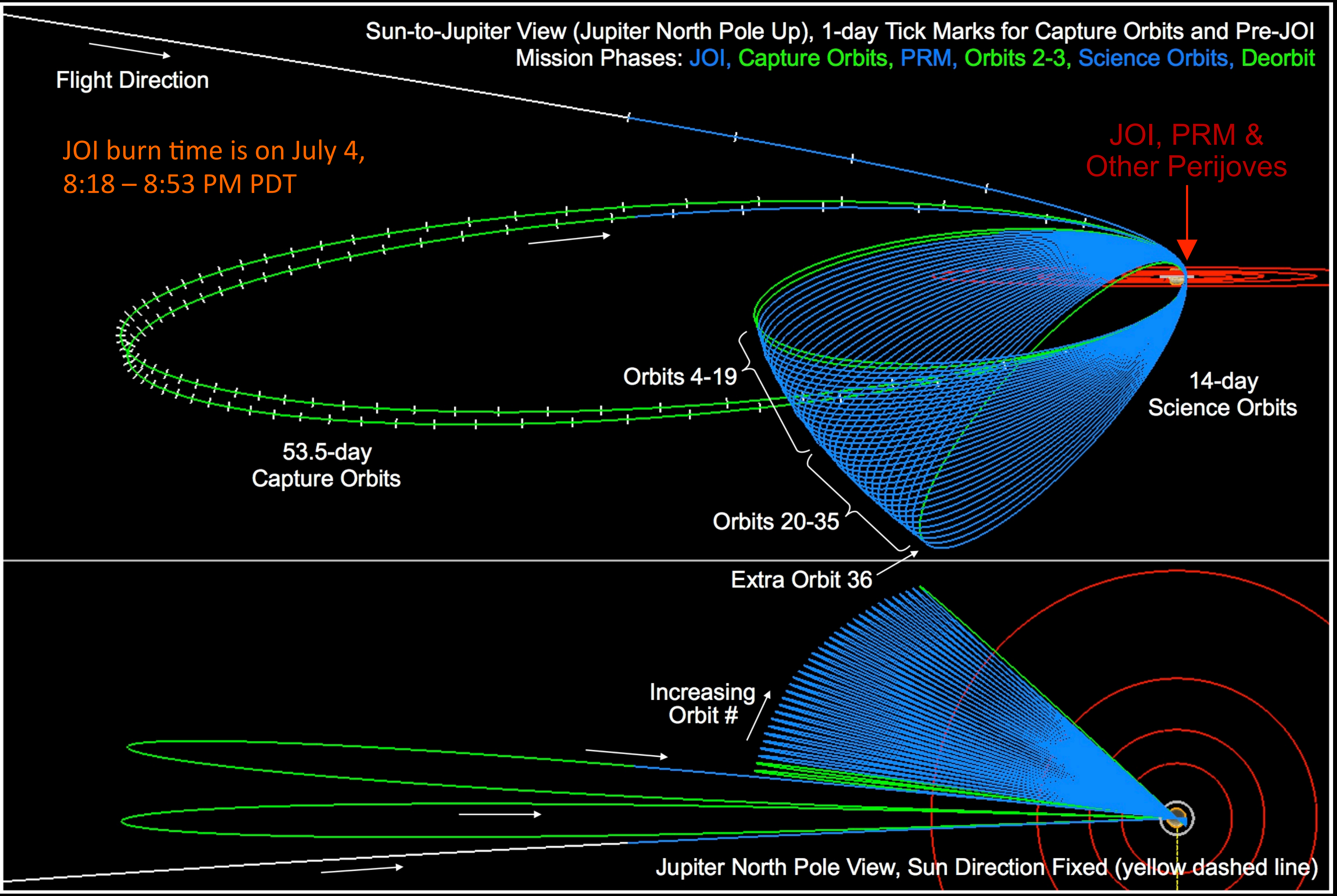






Orbital Trajectory

JOI burn time is on July 4,
8:18 – 8:53 PM PDT



Approach Image From JunoCam

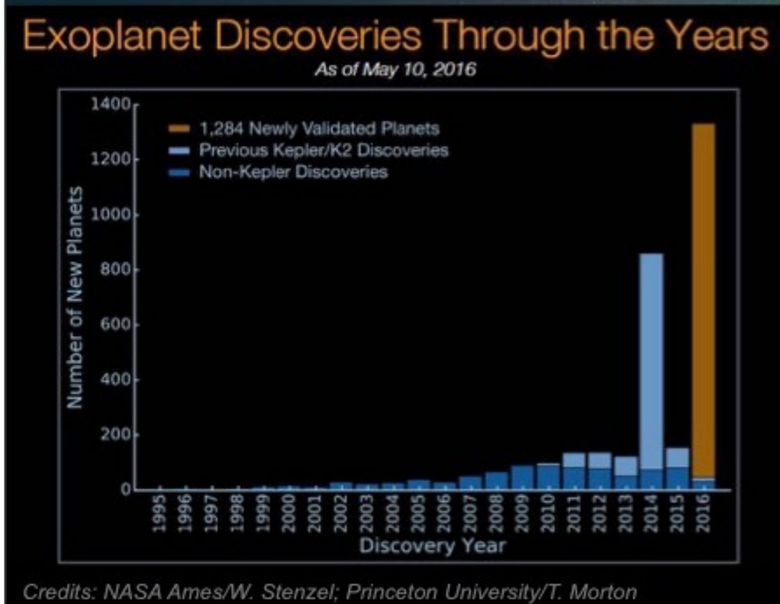
June 21, 2016, at a distance of 10.9 million km

National Aeronautics and Space Administration

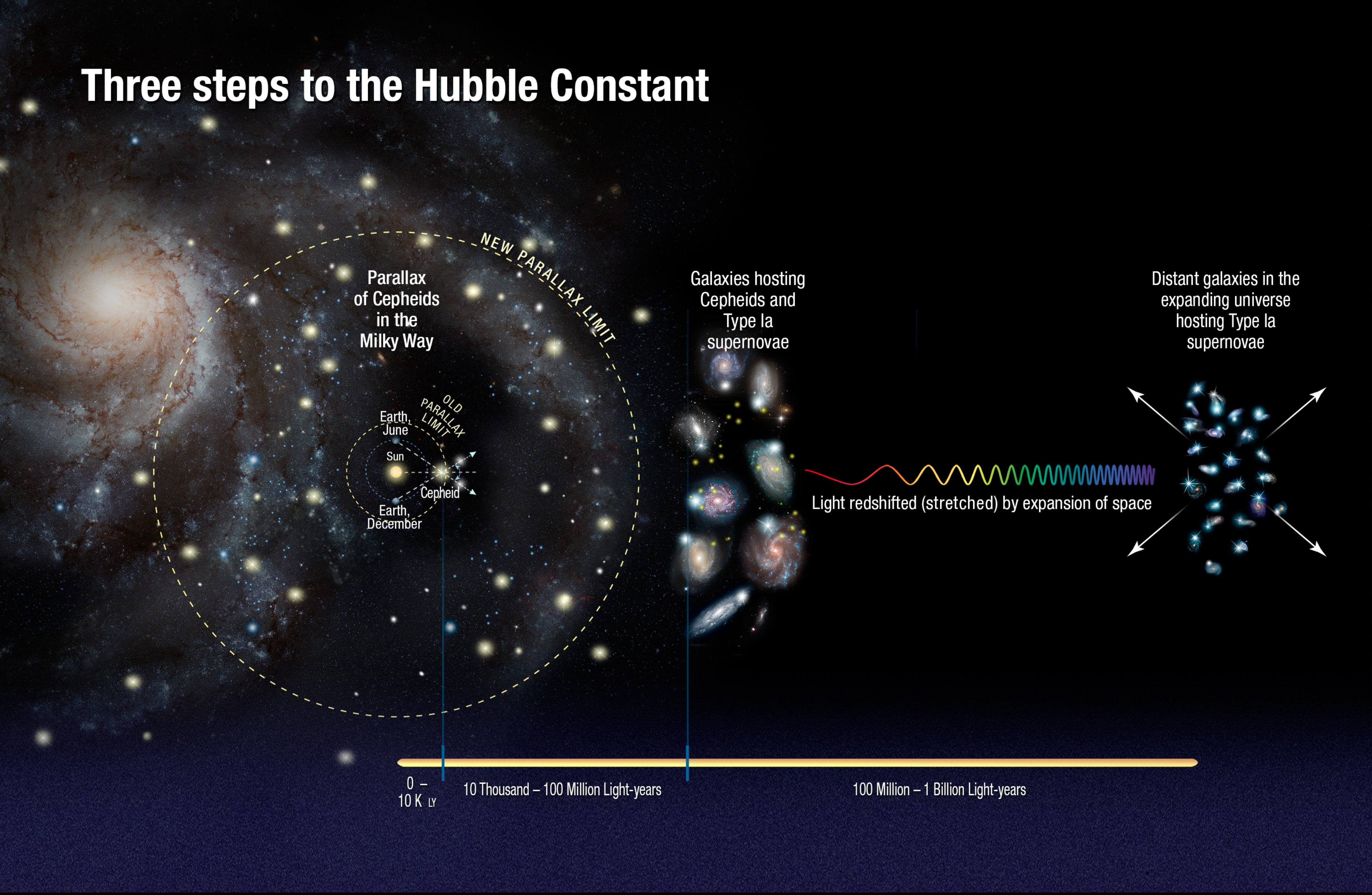
Astrophysics

Kepler Mission Announces Largest Collection of Planets Ever Discovered

Published in the May 10, 2016 edition of The Astrophysical Journal.



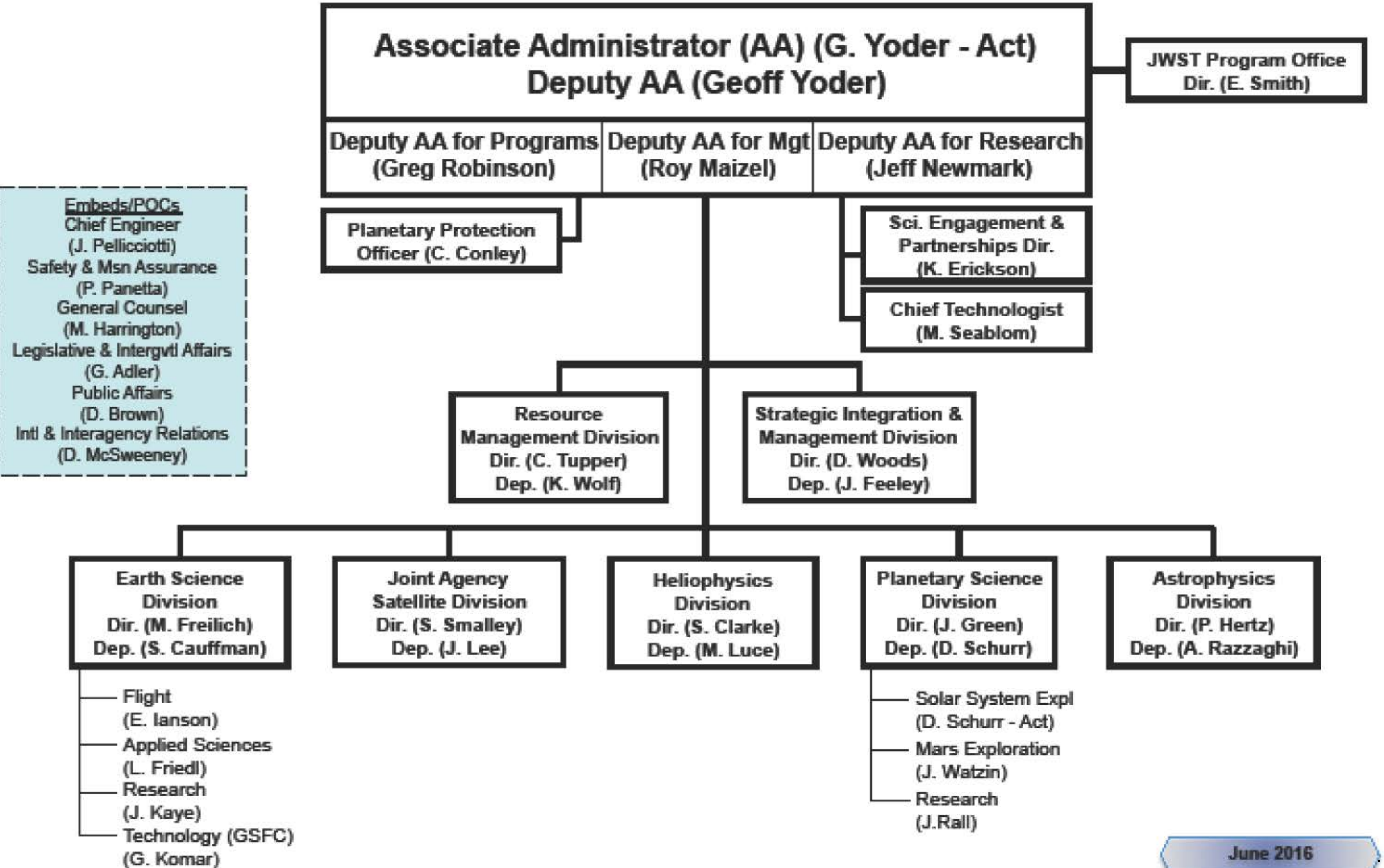
- NASA's Kepler mission has verified 1,284 new planets - the single largest finding of planets to date which more than doubles the number of confirmed planets from Kepler.
- Analysis was performed on the Kepler space telescope's July 2015 planet candidate catalog, which identified 4,302 potential planets. For 1,284 of the candidates. the probability of being a planet is greater than 99 percent - the minimum required to earn the status of "planet."
- An additional 1,327 candidates are more likely than not to be actual planets, but they do not meet the 99 percent threshold and will require additional study. The remaining 707 are more likely to be some other astrophysical phenomena. This analysis also validated 984 candidates previously verified by other techniques .
- Kepler captures the discrete signals of distant planets - decreases in brightness that occur when planets pass in front of. or transit, their stars. Since the discovery of the first planets outside our solar system more than two decades ago, researchers have resorted to a laborious,one-by-one process of verifying suspected planets.
- This latest announcement. however, is based on a statistical analysis method that can be applied to many planet candidates simultaneously. Scientists employed a technique to assign each Kepler candidate a planet-hood probability percentage - the first such automated computation on this scale,as previous statistical techniques focused only on sub-groups within the greater list of planet candidates identified by Kepler.
- In the newly-validated batch of planets. nearly 550 could be rocky planets like Earth, based on their size. Nine of these orbit in their sun's habitable zone, which is the distance from a star where orbiting planets can have surface temperatures that allow liquid water to pool. With the addition of these nine, 21 exoplanets now are known to be members of this exclusive group.
- Of the nearly 5,000 total planet candidates found to date, more than 3,200 now have been verified, and 2,325 of these were discovered by Kepler. Launched in March 2009, Kepler is the first NASA mission to find potentially habitable Earth-size planets. For four years, Kepler monitored 150,000 stars in a single patch of sky, measuring the tiny, telltale dip in the brightness of a star that can be produced by a transiting planet.


Three steps to the Hubble Constant
NEW PARALLAX LIMIT
Parallax of Cepheids in the Milky Way
OLD PARALLAX LIMIT
Earth, June
Sun
Cepheid
Earth, December
Galaxies hosting Cepheids and Type Ia supernovae
Distant galaxies in the expanding universe hosting Type Ia supernovae
Light redshifted (stretched) by expansion of space
0 – 10 K LY
10 Thousand – 100 Million Light-years
100 Million – 1 Billion Light-years

Outline

- Science Results
- **Programmatic Status**
  - Science Mission Directorate
  - Heliophysics
  - Earth Science
  - Planetary Science
  - Astrophysics
  - Joint Agency Satellite Division
  - Other Reports
- Observations, Findings, and Recommendations

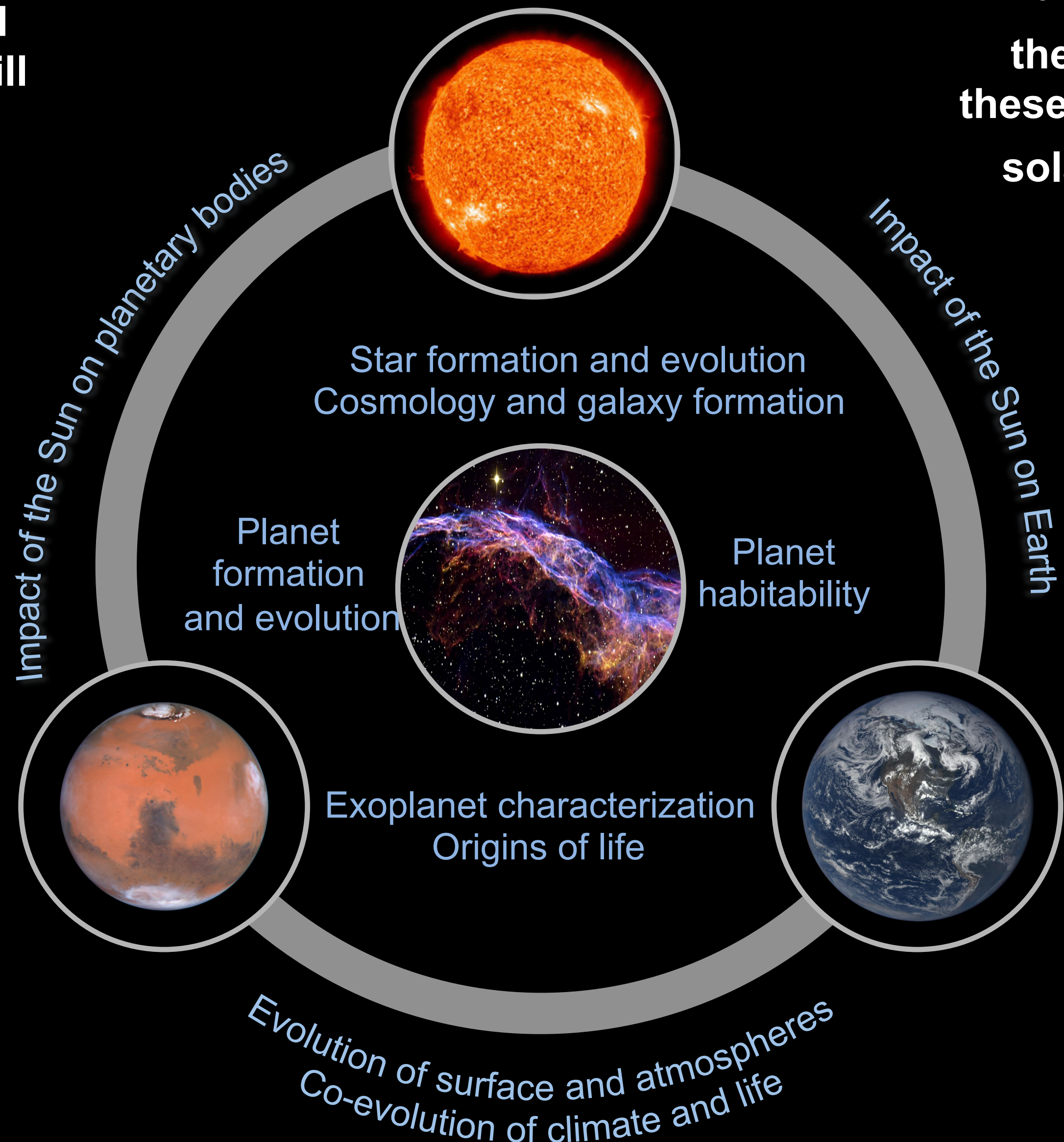
SMD Organization



NASA Science Is Interconnected

How did the universe begin and evolve, and what will be its destiny?

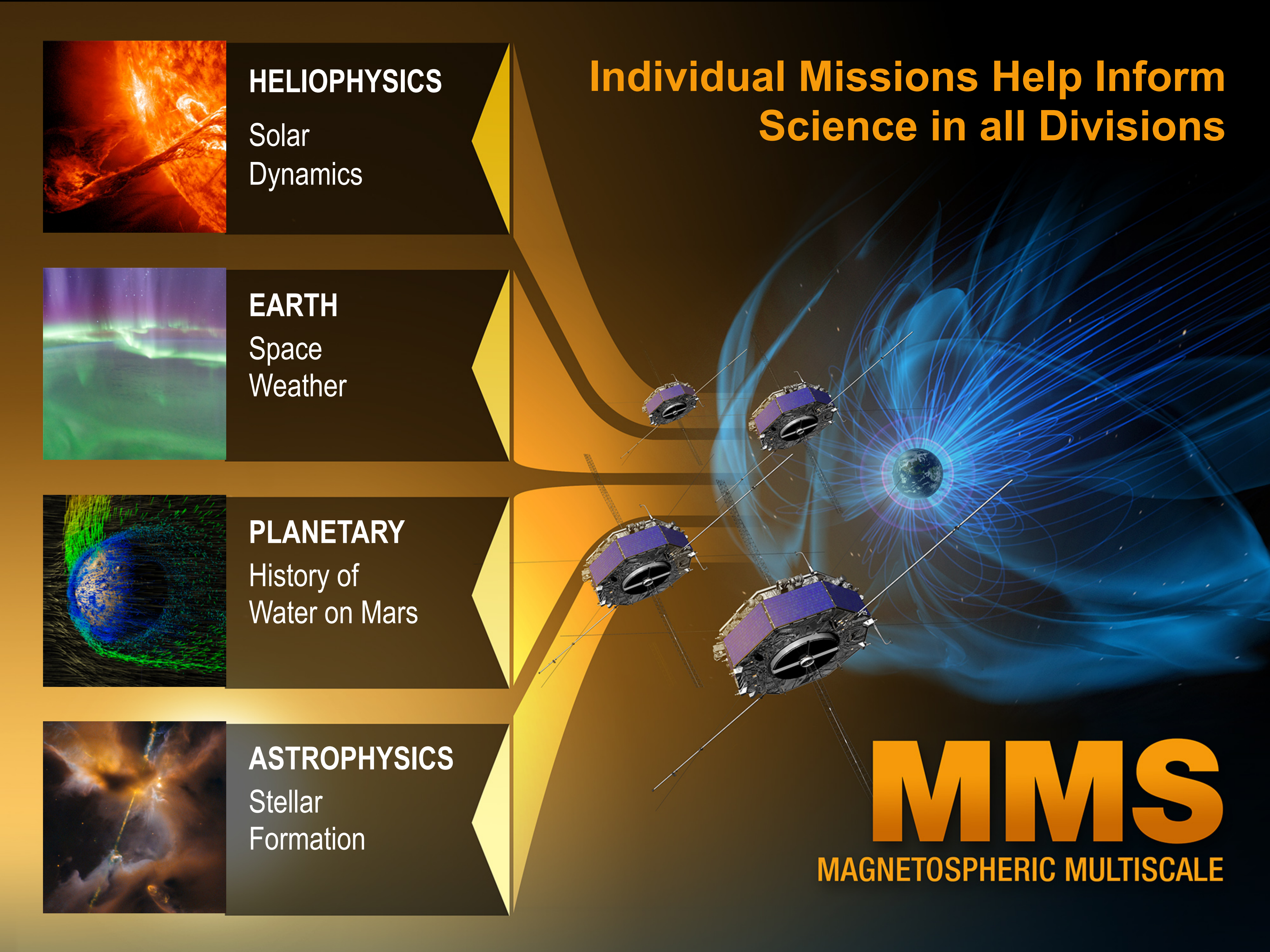
What drives variations in the Sun, and how do these changes impact the solar system and drive space weather?



How did our solar system originate and change over time?

How and why are Earth's climate and environment changing?

How did life originate, and are we alone?


Individual Missions Help Inform Science in all Divisions
HELIOPHYSICS
Solar Dynamics
EARTH
Space Weather
PLANETARY
History of Water on Mars
ASTROPHYSICS
Stellar Formation
MMS
MAGNETOSPHERIC MULTISCALE

Individual Missions Benefit from the Wide Range of NASA Missions
HELIOPHYSICS
Strong Magnetic Fields and Auroras
EARTH
Cloud Circulation Formulation and Dynamics
PLANETARY
Water in the Jupiter Formation Region
ASTROPHYSICS
Gas Giant Exoplanet Formation
Juno
Mission to Jupiter

A Balanced Approach to Achieving SMD Science

SCIENCE MISSION DIRECTORATE

By the Numbers

Spacecraft
102 missions*
85 spacecraft

CubeSats
12 science missions*
11 technology demonstrations

Sounding Rocket Payloads
13 scheduled for FY16

Balloon Payloads
9 scheduled for FY16

Earth-Based Investigations
25 major airborne missions
8 global networks

Technology Development
~$400M invested annually

Research
10,000^{+} U.S. scientists funded
3,000^{+} competitively selected awards
~$600M awarded annually

*114 space-based missions

July 22, 2016

SCIENCE MISSION DIRECTORATE
A balanced Portfolio

114 Space-Based Science Missions

Formulation (10)

WFIRST

HOSTED (Maia)
JPSS-2 *(RBI, OMPS-L)*
NISAR (L-Band SAR)
PACE
TROPICS (12)

AIDA-DART
Europa
JUICE
(JEPI, RIME, UVS)
Mars 2020

Implementation (41)

CeRES
CUPID
CuSP
DSX (SET-1)
ELFIN
HOSTED (GOLD)
ICON
SOC (SoloHI, HIS)
Solar Probe Plus
SORTIE
TBEx (2)

Euclid (SCS)
HaloSat
ISS (CREAM)
ISS (NICER)
TESS
Webb

CYGNSS (8)
GRACE-FO (2)
HOSTED (TEMPO)
ICESat-2
ISS (ECOSTRESS)
ISS (GEDI)
ISS (LIS)
ISS (OCO-3)
ISS (SAGE-III)
ISS (TSIS-1)
SWOT (KaRIn, AMR)

BepiColombo
(Strofio)
ExoMars 2020 (MOMA)
InSight (MarCo (2))
LunaH-Map
OSIRIS-Rex
Q-PACE

GOES-R, -S, -T, -U
JPSS-1
MetOp-C
(AMSU, AVHRR, SEM)

Primary Ops (17)

MinXSS
MMS (4)

LISA Pathfinder (DRS)
SOFIA

DSCOVR
(NISTAR, EPIC)
GPM
ISS (CATS)
ISS (RapidScat)
Jason-3 *(AMR, GPSP)*
Landsat-8
OCO-2
SMAP

Dawn
ExoMars 2016 (Electra)
Juno
New Horizons
Rosetta
(ALICE, MIRO, IES)

Extended Ops (46)

ACE
AIM
Geotail (EPIC, CPI)
Hinode
(XRT, EIS, SOT/FPP)
IBEX
IRIS
RHESSI
SDO
SOHO (LASCO)
STEREO (2)
THEMIS-Artemis (5)
TIMED
TWINS A&B (2)
Van Allen Probes (2)
Voyager (2)
Wind

Chandra
Fermi
Hubble
Kepler/K2
NuSTAR
Spitzer
Swift
XMM-Newton

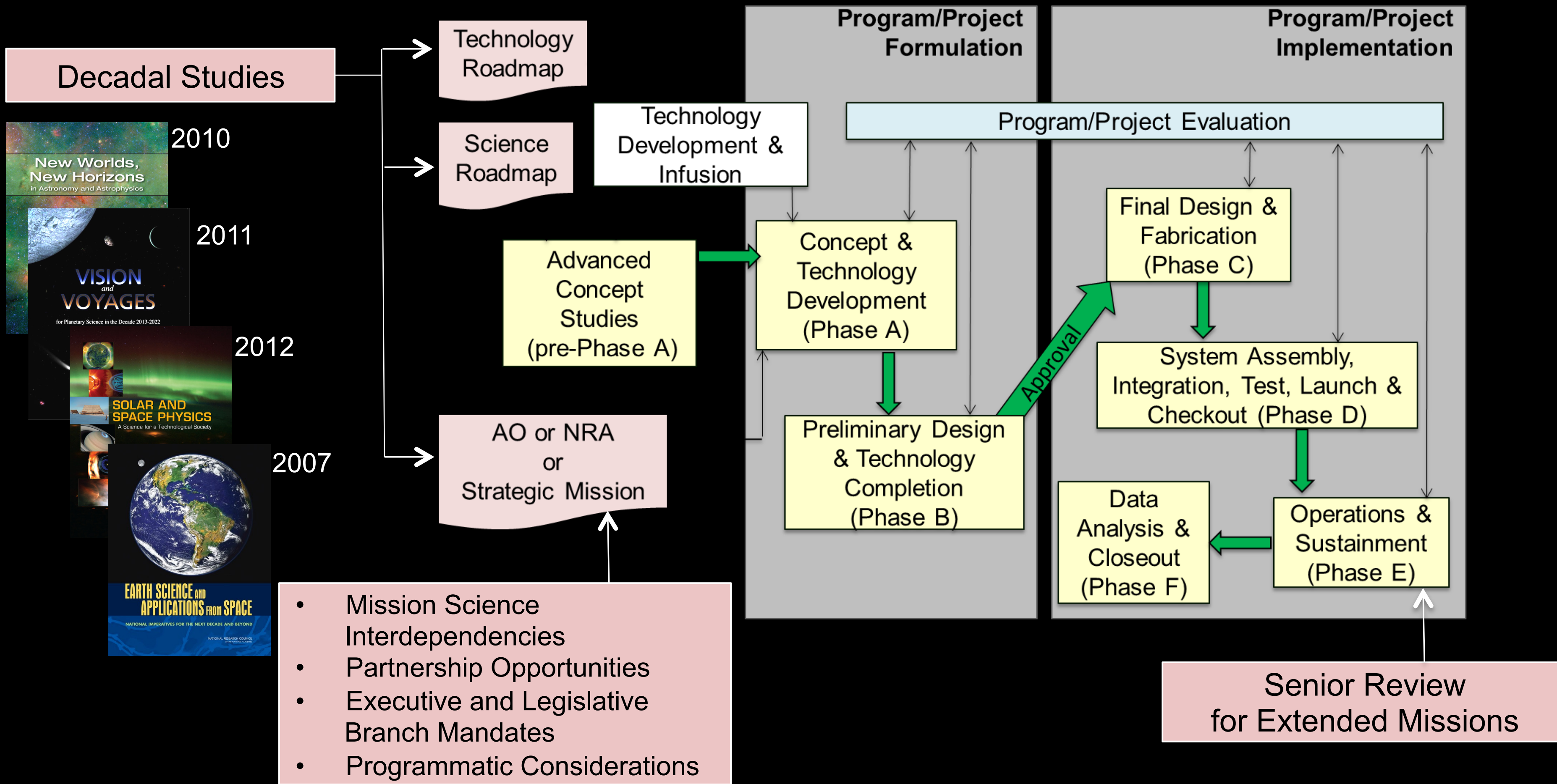
Aqua
Aura
CALIPSO (CALIOP)
CloudSat
EO-1
GRACE (2)
LAGEOS (2)
Landsat-7
OSTM/Jason-2
(AMR, GPSP, LRA)
QuikSCAT
SORCE
Suomi NPP
(OMPS-L Suite)
Terra

Cassini
LRO
Mars Express
(ASPERA-3)
Mars Odyssey
MAVEN
MER Opportunity
MRO
MSL Curiosity
NEOWISE

SMD Spacecraft
Non-SMD Spacecraft (SMD instrument)

HELIOPHYSICS | EARTH SCIENCE | PLANETARY SCIENCE | ASTROPHYSICS | REIMBURSABLES

SMD Missions Start with the Decadals



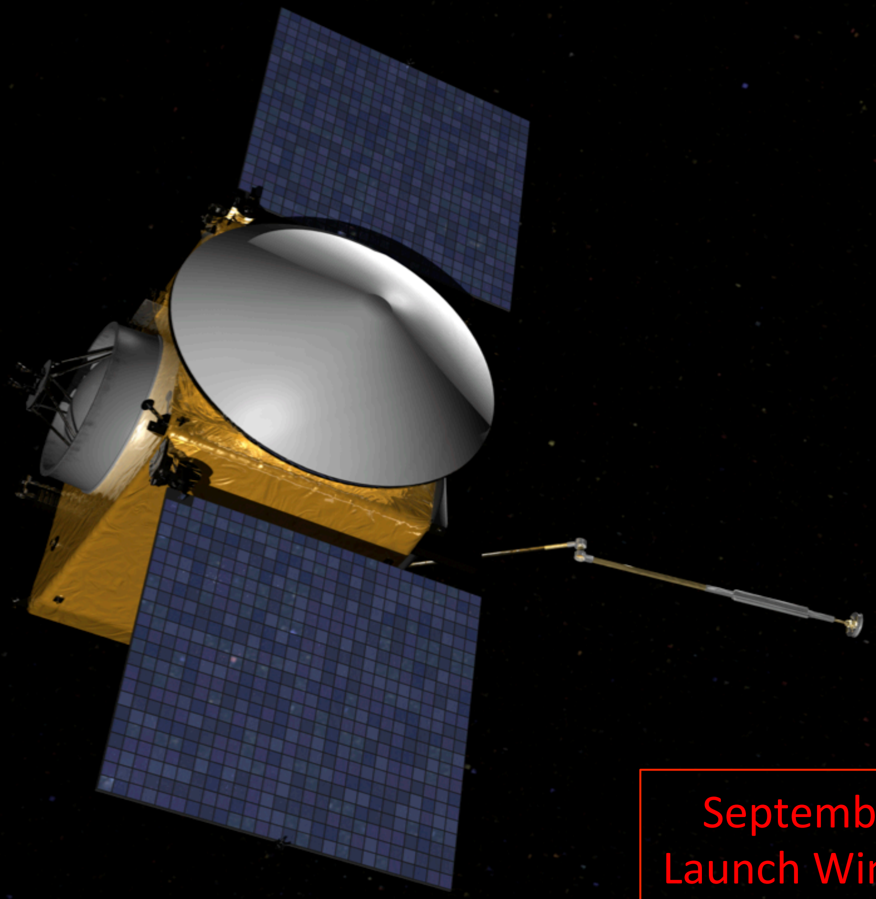
ESAS Decadal Survey 2017

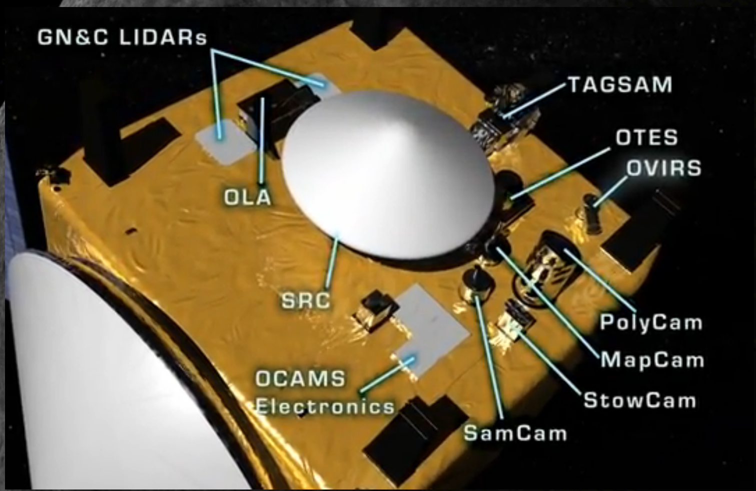
Sponsors:
NASA-Earth Science Division;
NOAA-NESDIS; and
USGS, Climate & Land Use Change

- NRC Approval, May 6, 2015
- NRC Boards covering atmospheric sciences, polar research, ocean science, hydrology, and the solid Earth are collaborating partners with the Space Studies Board
  - Includes membership, execution, staffing, etc.
- RFIs #1, #2 released (RFI#2 inputs were due 30 June 2016)
- Survey Leads Identified: Waleed Abdalati (CU) and ***Bill Gail*** *(Global Weather Corp.)*; steering committee named (see site below)
- www.nas.edu/esas2017
- Final report due ***late CY2017***

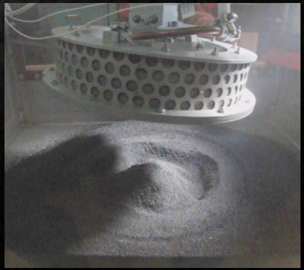
OSIRIS-REx

- Return and analyze a sample of Bennu's surface
- Map the asteroid & document the sample site
- Measure the Yarkovsky effect





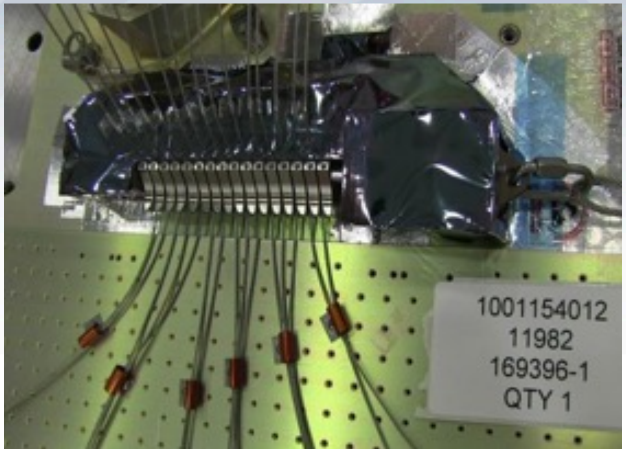
September 8, 2016
Launch Window Opens



OSIRIS-REx Being Un-Boxed

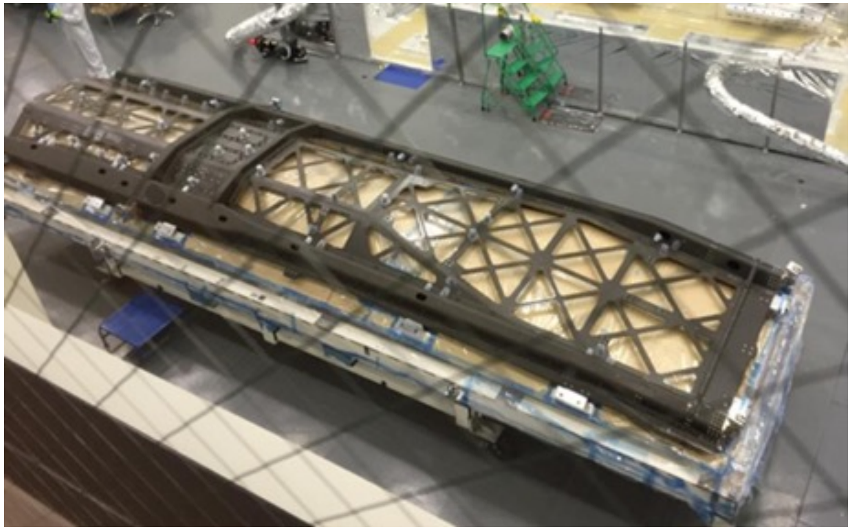
JWST TELESCOPE

JWST SUNSHIELD PROGRESS



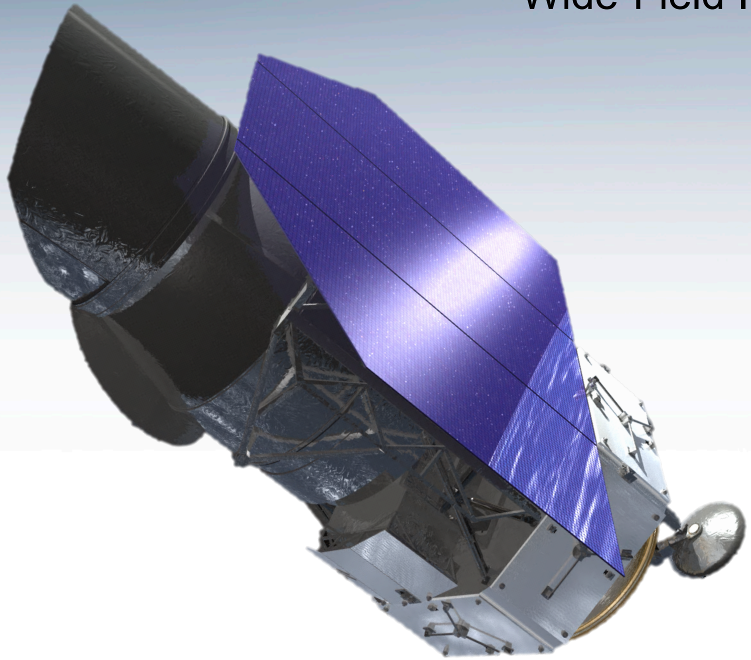
Cable Brake

Flight Core Assembly
Vacuum deployment testing complete
Thermal Balance testing underway



Unitized Pallet Structures
Completed, I&T underway

WFIRST
Wide-Field Infrared Survey Telescope



CURRENT STATUS:

- Completed Mission Concept Review (MCR) held in December 2015
- Formulation Science Investigation Teams selected in December 2015; first meeting held February 2016.
- Ball and Lockheed Martin selected in February 2016 to support Wide-field Instrument Concept Studies
- Passed Key Decision Point A (KDP-A) in Feb 2016
  - Official start of formulation phase
  - Successful KDP-A held February 17, 2016
  - Established management agreement for total mission cost to govern formulation trades
  - Next major milestone is acquisition strategy meeting (ASM) in August 2016
- On track for TRL-6 of new technologies in 2017
- Working toward System Requirements Review (SRR) in June 2017 and KDP-B in October 2017
- FY17 budget request matches FY16 appropriation of $90M. In-guide budget supports launch in mid-2020s.

Wide-Field Infrared Survey Telescope

Top priority of 2010 Decadal Survey

Science themes: Dark Energy, Exoplanets, Large Area Near Infrared Surveys

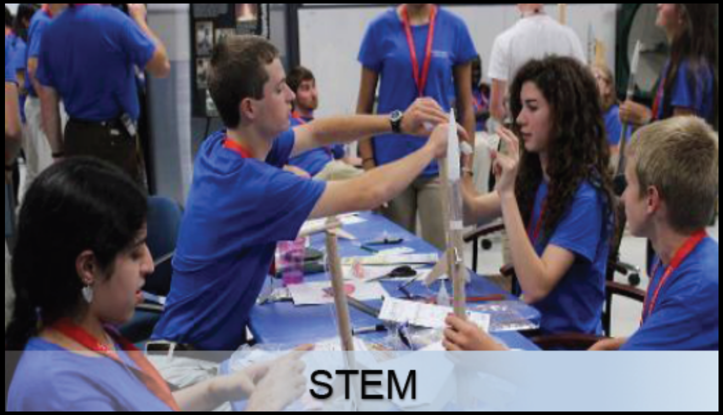
Mission: 2.4m widefield telescope at L2; using existing hardware, images 0.28deg^2 at 0.8-2µm

Instruments (design reference mission): Wide Field Instrument (camera plus IFU), Coronagraph Instrument (imaging/IFS)

Phase: Currently in Formulation (Phase A)

WFIRST has begun Formulation

http://wfirst.gsfc.nasa.gov/



Subcommittee Reports

FACA Chartering

Selected Other Reports

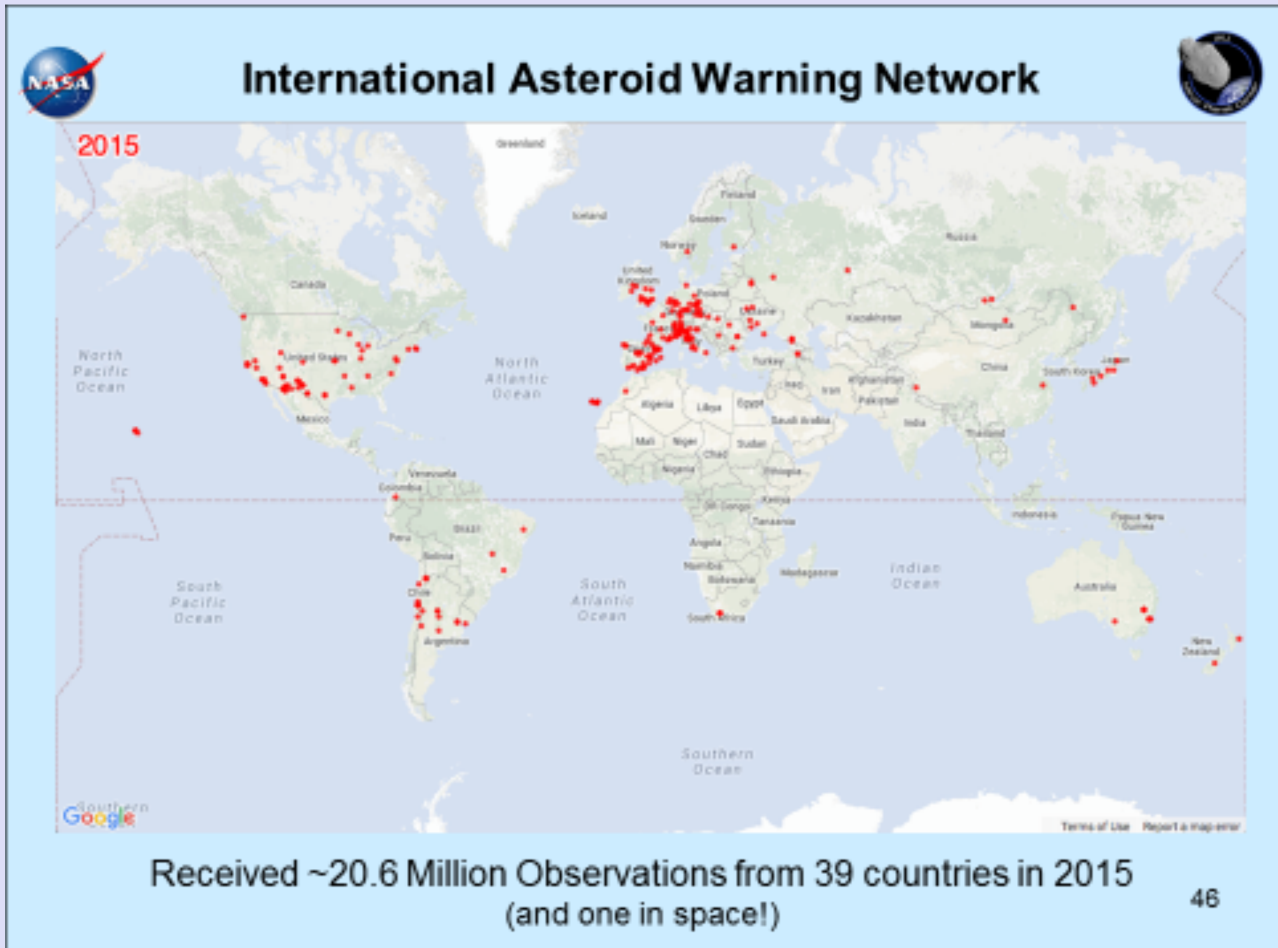
Planetary Defense Coordination Office

This new office was recently established at NASA HQ to coordinate planetary defense related activities across NASA, and coordinate both US interagency and international efforts and projects to address and plan response to the asteroid impact hazard.

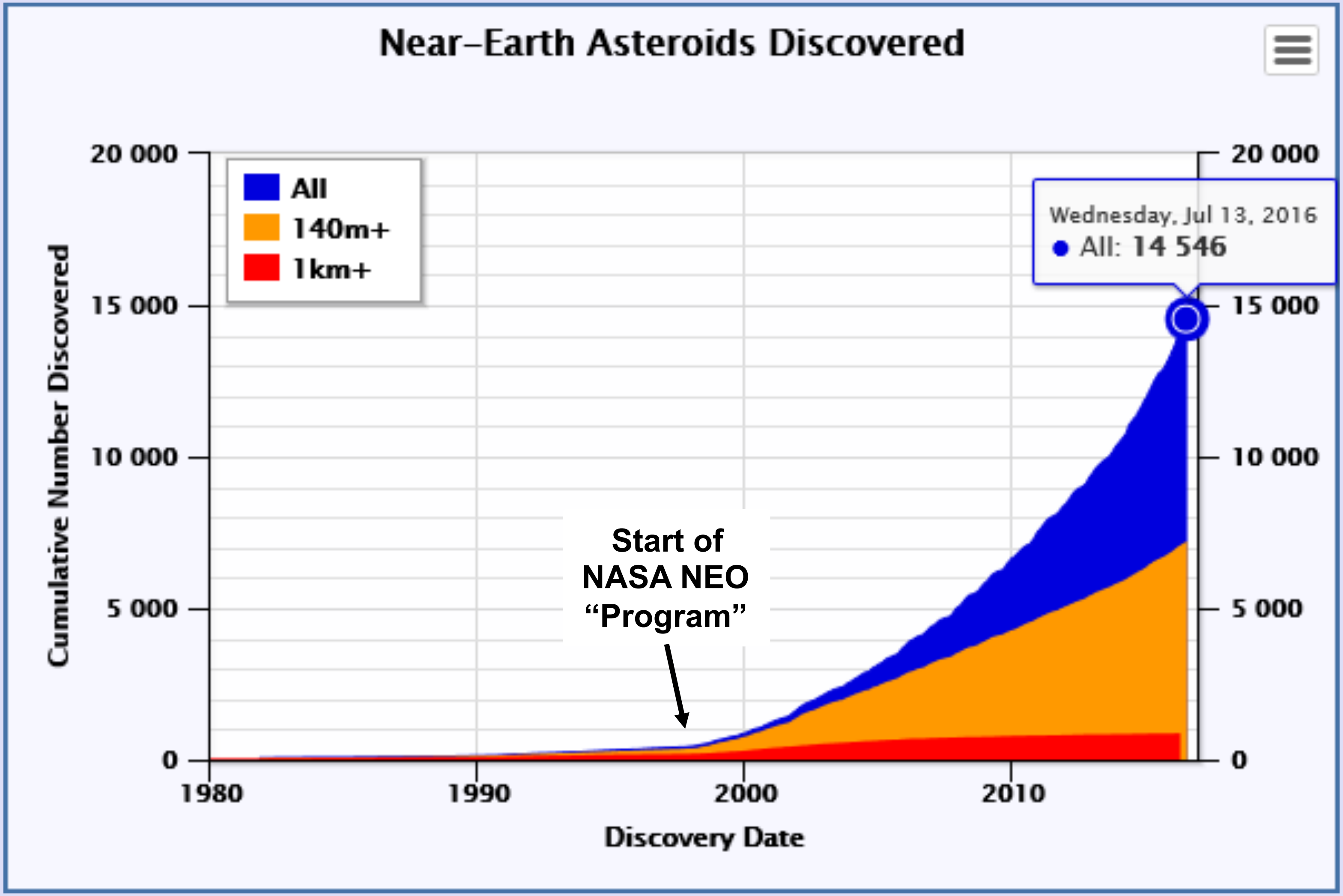
Mission Statement:

Lead national and international efforts to:

- Detect any potential for significant impact of planet Earth by natural objects
- Appraise the range of potential effects by any possible impact
- Develop strategies to mitigate impact effects on human welfare



Known Near Earth Asteroid Population



As of 7/01/2016 14,483

Also 107 comets

1707 Potentially Hazardous Asteroids

Come within 5 million miles of Earth's orbit

872

157 PHAs

Asteroid Threat Assessment Project (ATAP)

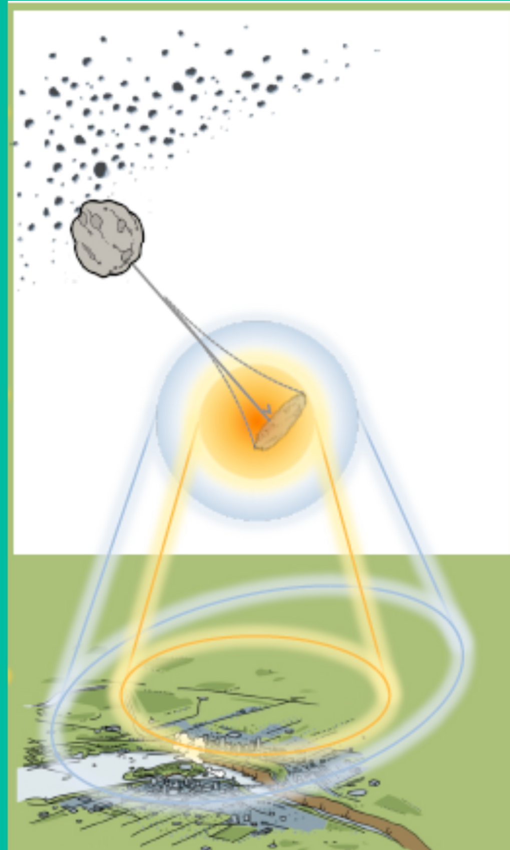
Ames Research Center

Characterization
- Physical Properties
- Orbital Trajectories JPL Web

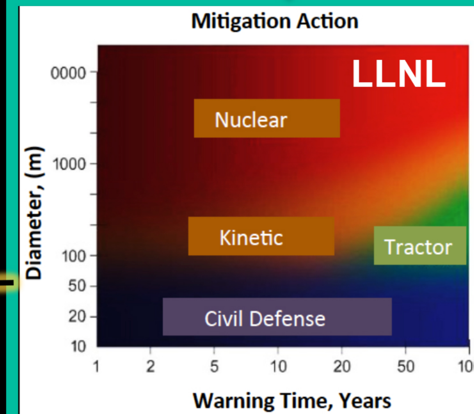
Atmospheric Entry & Airburst Modeling
- Entry Trajectories/Ablation
- Energy Deposition

Surface Impact Effects Modeling
- Ground Damage
- Tsunami Propagation

Physics-Based Impact Risk Modeling
- Quantitative Risk Metrics
- Sensitivity to Uncertainty



Impact Risk Assessment Tools



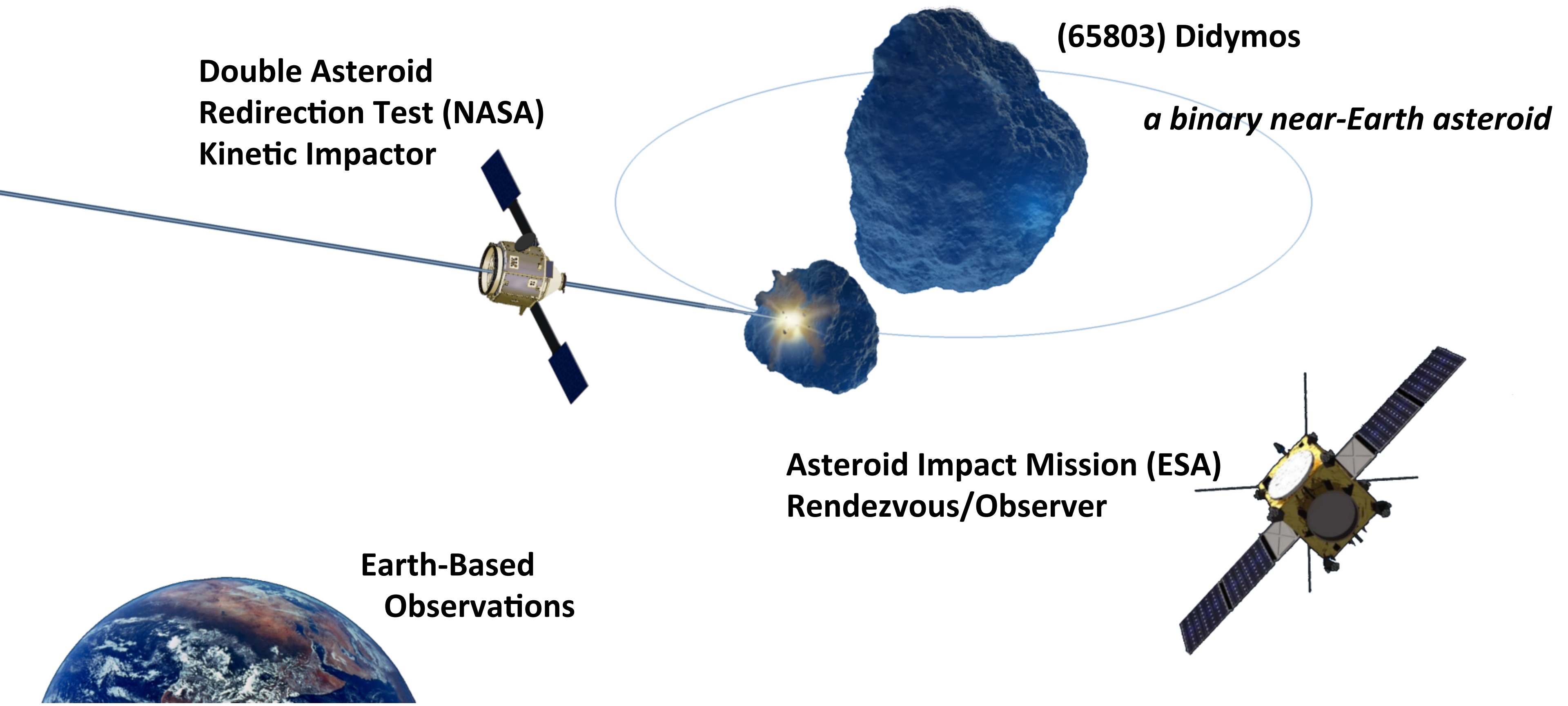
Deliverables
- Mitigation Decision Tools
- Near Real-Time Bolide Reporting System

US Gov. Surveillance System
- Light Curves: New 600 Plus Existing

AIDA Mission Concept

Asteroid Impact Deflection Assessment (AIDA) Mission

- currently in parallel formulation studies with European Space Agency (ESA)



Chartering of Division Committees

- NASA is proposing that the NAC Science Committee's four subcommittees associated with SMD divisions become stand-alone Federal Advisory Committee Act (FACA) committees.
  - Earth Science Subcommittee
  - Planetary Science Subcommittee
  - Astrophysics Subcommittee
  - Heliophysics Subcommittee

- Committees will advise the respective Division Director within SMD
  - Advice to be delivered and acted upon at the right organizational level
  - Many community-based studies (e.g., Senior Reviews, Science and Technology Definition Teams) will now have a chartered Federal advisory committee to report to

- Committees will have
  - Charters (rather than a Terms of Reference)
  - Membership balance plans

- Next steps
  - Approval of charters and membership balance plans by the NASA Administrator
  - Review by the General Services Administration
  - Filing with Congress

Big Data Task Force

BDTF Focus Topics:

1. ***Data discovery*** *– assess across the board the current level of accessibility to the NASA's science data and identify areas of strengths and weaknesses.*
2. ***Improved data/science analysis methodologies*** *- improve methodologies used for current and future missions across all science domains (software, tools, strategies for data science and statistical methods),*
3. ***Modeling workflows*** *- help NASA make more effective use of both internal and external computing resources, with a particular focus on achieving shorter times to solution for modeling-focused research.*
4. ***Server-side analytics*** *-* tailored processing capability appropriate to the type and use of the data served, for results at a much lower volume, easier to transport to and store locally by the user and easier for the user to interoperate with data sets from other remote data stores.

Question from the 1st BDTF meeting at HQ: "Are there adequate planning activities focused on future needs and solutions for SMD's data infrastructure?" After 2+ days with the data and computing managers at GSFC, the answer is an outstanding "Yes". The Goddard projects are not resting on their laurels. They are dynamic, they are engaged with and taking feedback from their user communities, they are trying out new methods and technologies, and they are doing exceptional jobs within their budgets. Will this be sufficient? That's another question!

NASA Education Mission

Advance high-quality STEM Education using NASA's unique capabilities.

Task Force on STEM Education Recommendations

- NASA should form a high level external committee(s) to provide strategic guidance and content expertise on all of NASA 's Education program investment priorities.

- Identify and execute a process to determine a strategic focus for NASA's education discretionary/non-directed dollars. For example, we encourage NASA to consider focusing on particular age bands, geographic areas, segments of the population, or content areas in each solicitation area.

- NASA should more actively support and engage their education grantees and the larger network of NASA educators and researchers to connect to the broader STEM education community.

- Collect and utilize data to inform solicitations and strategic directions for NASA's education programs.

Outline

- Science Results
- Programmatic Status
- **Observations, Findings and Recommendations**

Observation Regarding Investments in the Modernization of Planetary Protection Technology and Processes

The Science Committee welcomes NASA's renewed attention to investments in the modernization of planetary protection technology and processes. The Planetary Protection Subcommittee notes as well that the ESA Planetary Protection community is currently making similar investments including through the COSPAR PPOSS (Planetary Protection of Outer Solar System Bodies). The Subcommittee recognizes a significant opportunity for NASA to closely coordinate these new planetary protection technology and process investments with analogous investments within ESA and sponsored by COSPAR. For example, ESA is already investing in the development of a sample capture and flight containment system for a possible Mars sample return cooperation scenario. The involvement of the planetary science community in this process would allow integrated options to be presented.

Background: Planetary Science Division (PSD) Director Dr. James Green reported to the Subcommittee that PSD has created a Planetary Protection Technology Definition Team to delineate the planetary protection processes and techniques available to meet future planetary protection mission requirements, and catalog materials and components compatible with planetary protection protocols. The team will report out in November, followed by a ROSES call in February 2017 to invest in the necessary technologies.

SC Finding: Astrophysics Data System Modernization

Finding:

The Astrophysics Data System (ADS) is a large bibliographic, web-based system that a provides searchable database of the research literature in astronomy, solar physics, solar-terrestrial interactions, planetary science, earth science and physics. ADS is a funded out of the NASA SMD Astrophysics data archive program that also supports the Science Archive Research Centers. The ADS, freely available to the public, allows a researcher to locate the entire published literature based on queries of author, title, keyword, astronomical target, abstract or full text. Links are provided to references, citations, and on-line data associated with each article. ADS is widely used and is an invaluable resource to the research community. It is not uncommon for a space scientist to use ADS every day. ADS datasets are up-to-date and it develops services at the frontier of digital library services. Other scholarly fields often have weaker and more costly bibliographic systems.

ADS has proposed modernization of its database engine, user and visualization interfaces but implementation may not be feasible at current funding levels.

SC Recommendation: Coordination and Communication between the Planetary Science and Planetary Protection Subcommittees

Recommendation:

The NAC Science Committee recommends that the Planetary Science Subcommittee (PSS) and Planetary Protection Subcommittee (PPS) begin regular communication regarding the technologies and procedures required to ensure the scientific integrity of returned samples. This is particularly important for astrobiologically significant regions for preventing forward and backward planetary contamination. Involvement of the science community, including astromaterials curation, early in the discussion of science return is critical for mission success. Regular updates on the outcomes of such communication should be given to the NAC Science Committee.

Major Reasons for the Recommendation:

One of NASA's science goals is to search for life in the Solar System. This requires exploration of astrobiologically significant regions (e.g., Mars, Europa, etc.) and the return of samples for detailed studies in terrestrial laboratories. Intricately involved in this endeavor is the prevention of forward contamination by Earth-based microbes (resulting in a "false-positive result" in the search for extant life on other planets), and also preventing reverse contamination of Earth by alien life. Scientific value of

SC Recommendation: Coordination and Communication between the Planetary Science and Planetary Protection Subcommittees (cont.)

returned samples can be maximized by attention to the development of new planetary protection methods and technologies so that the cleanest spacecraft possible can be sent to these astrobiologically significant regions, both to conduct in-situ search for extant / extinct life, and return the best samples possible to achieve science goals. Technologies and processes for improved spacecraft cleanliness will improve confidence that we do not contaminate planetary destinations, and that we avoid false negatives when evaluating the safety of returned samples. Continued communication and cooperation between Planetary Protection and Planetary Science is essential so that, for example, the current Planetary Science decadal survey goal of returning samples from Mars can be achieved.

Consequences of No Action on the Recommendation:

The consequences of not consulting the scientific community early in the process could be loss of science content, increased cost, and mission delays.

SC Recommendation: Internal NASA Assessment of Mission Authorization Applications to the DoT/FAA by Non-Governmental Entities for Planetary Protection Purposes

Recommendation:

The Planetary Protection Subcommittee of the NASA Advisory Council recommends that NASA's internal assessment of authorization for missions by non-governmental entities include an assessment by the NASA Planetary Protection Office to determine if the proposed mission meets NASA planetary protection policy and requirements.

Reasons for the Recommendation:

Private industry has announced its intention to land on the Moon and Mars in the near term. These plans raise concerns regarding how planetary protection is going to be handled on non-governmental missions.

Consequences of No Action on the Recommendation:

The Office of Science and Technology Policy (OSTP) was Congressionally directed to recommend "an authorization and supervision approach" for "current and proposed near-term, commercial non-governmental activities conducted in space." NASA was included in the agencies and administrations named to participate in this approach. No action may result in failure to meet treaty obligations. Furthermore, no action may compromise the science of future NASA missions.

SC Recommendation: Additional Civil Servant FTE for Planetary Protection Office

Recommendation:

The Science Committee recommends that NASA assign an additional civil servant FTE to the Office of Planetary Protection to address increased workload.

Reasons for the Recommendation:

In recent years, there has been an increase in the number of missions involving planetary protection considerations and in the complexity of those missions. With the growing participation of commercial entities in space exploration, the workload will only increase in the future. The Planetary Protection Subcommittee (PPS) notes that the ESA PPO has a larger cadre of staff assigned to the office who provide laboratory capabilities and administrative support. Having an additional FTE in the NASA office is necessary to ensure ongoing timely compliance with the Outer Space Treaty.

Consequences of No Action on the Recommendation:

Obligations will not be met in a timely manner, resulting in delays and increased costs.

SC Recommendation: Hitomi

Recommendation:

The Science Committee recommends that NASA proceed with the plan to rebuild the SXS instrument, provided that efforts were made to ensure that risks of another catastrophic failure will be mitigated, that doing so will not affect the other priorities of the decadal surveys, and subject to the conclusions of the mid-decadal report.

Major Reasons for the Recommendation:

On March 26th, Hitomi (née Astro-H) experienced an unrecoverable failure. Before the failure, the successful demonstration of the Soft X-ray Spectrometer (SXS) demonstrated TRL-9 for this technology and retired the technology maturation risk. On June 1 and June 14, JAXA President Okumura announced JAXA's intent to study a rebuild of Hitomi ("ASTRO-H2") and JAXA has asked NASA to consider participating in the mission. NASA has agreed to consider a build-to-print of the instrument demonstrated on Hitomi. JAXA has indicated a desire to begin development of ASTRO-H2, if approved, in FY2017.

SC Recommendation: Hitomi (cont.)

Assuming a build-to-print SXS instrument, and taking into account lessons learned and available flight spare parts, the estimated cost for the U.S. (4.5 year Phase A-D, not including operations and GO program) would be $70-90M (FY2017-FY2021). At this time, it is not known whether any additional funding would be made available to supplement the planned NASA astrophysics budget to undertake a NASA contribution to ASTRO-H2. The approximately $20M per year required for a NASA contribution to ASTRO-H2 is smaller than the challenges to the planned astrophysics program in recent appropriations that have been accommodated with modest acceptable impact.

Consequences of No Action on the Recommendation:

Loss of a unique capability in x-ray observations for the scientific community. Such observations are identified as a priority in the decadal survey.