National Aeronautics and
Space Administration

Science Committee Report

Dr. Bradley M. Peterson
Chair, Science Committee

Science Committee Members

Dr. Brad Peterson, Chair, The Ohio State University and Space Telescope Science Institute

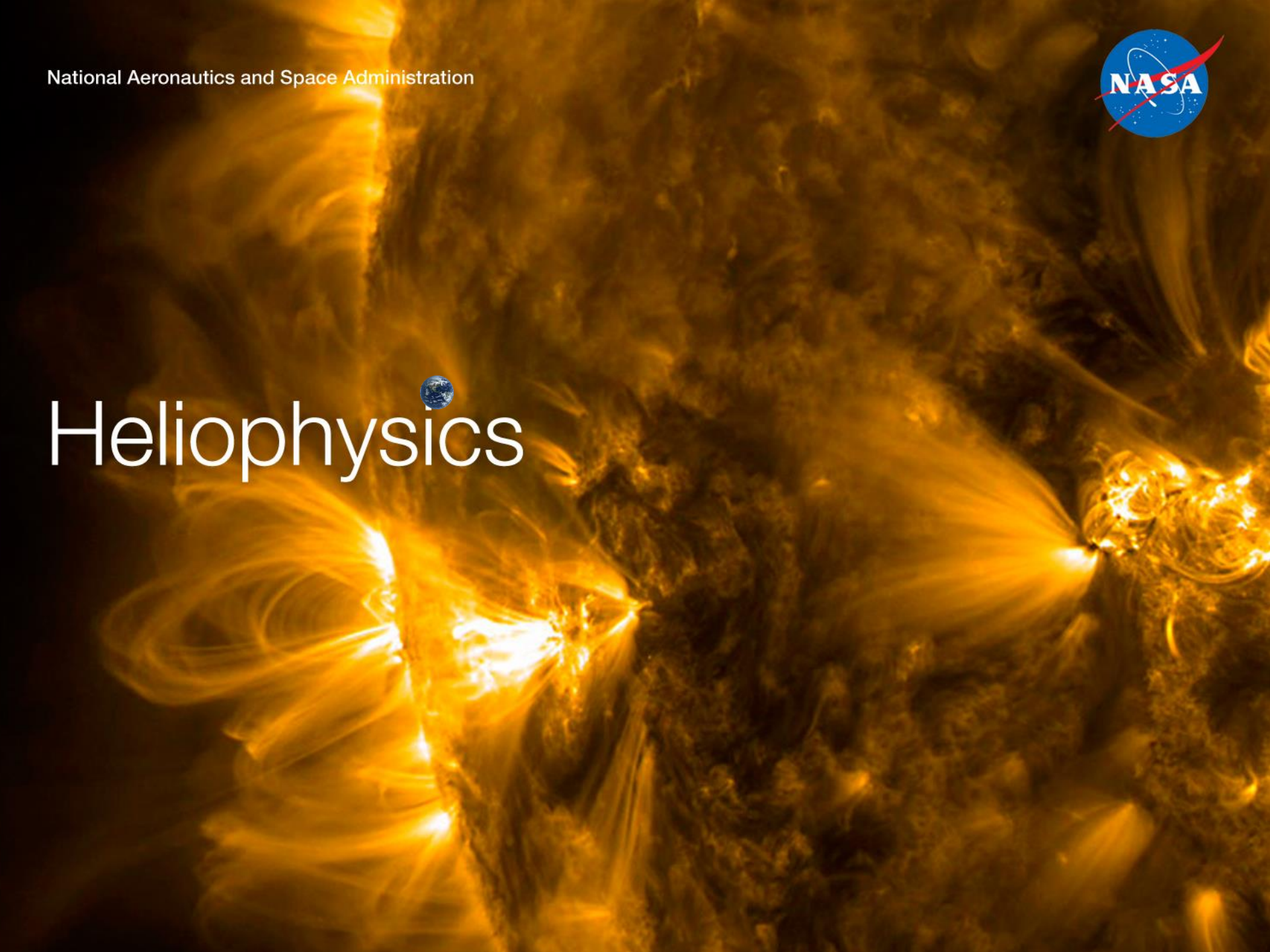
Dr. Scott Gaudi, The Ohio State University, Chair, Astrophysics Advisory Cmte (APAC)
Dr. Jill Dahlburg, Naval Research Laboratory, Chair, Heliophysics Advisory Cmte (HPAC)
Dr. Anne Verbiscer, Chair, Planetary Science Advisory Cmte (PAC)
Dr. J. Marshall Shepherd, Chair, Earth Science Advisory Cmte (ESAC)

Dr. Susan Avery, Woods Hole Oceanographic Institute
Dr. Tamara Jernigan, Lawrence Livermore National Laboratory
Dr. Walter Secada, University of Miami
Dr. Mihir Desai, Southwest Research Institute
Dr. Kathryn Flanagan, Space Telescope Science Institute
Dr. Jeffrey A. Hoffman, Massachusetts Institute of Technology
Dr. Pat Patterson, Space Dynamics Laboratory
Dr. Meenakshi Wadhwa, Arizona State University

Outline

- **Science Results**
- Programmatic Status
- Findings

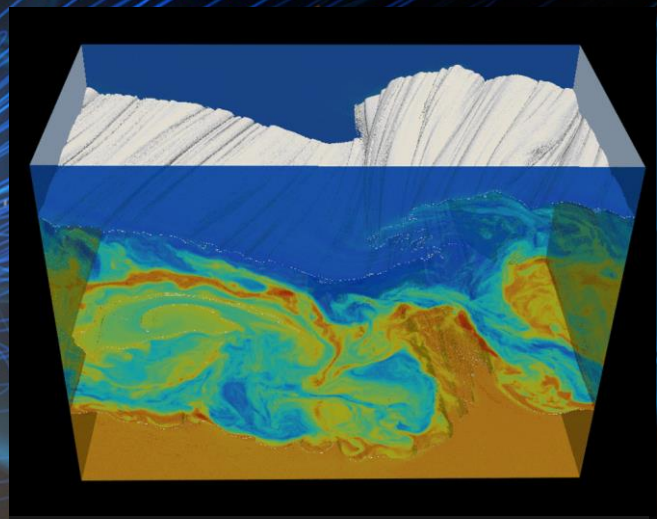
National Aeronautics and Space Administration



Heliophysics

MMS

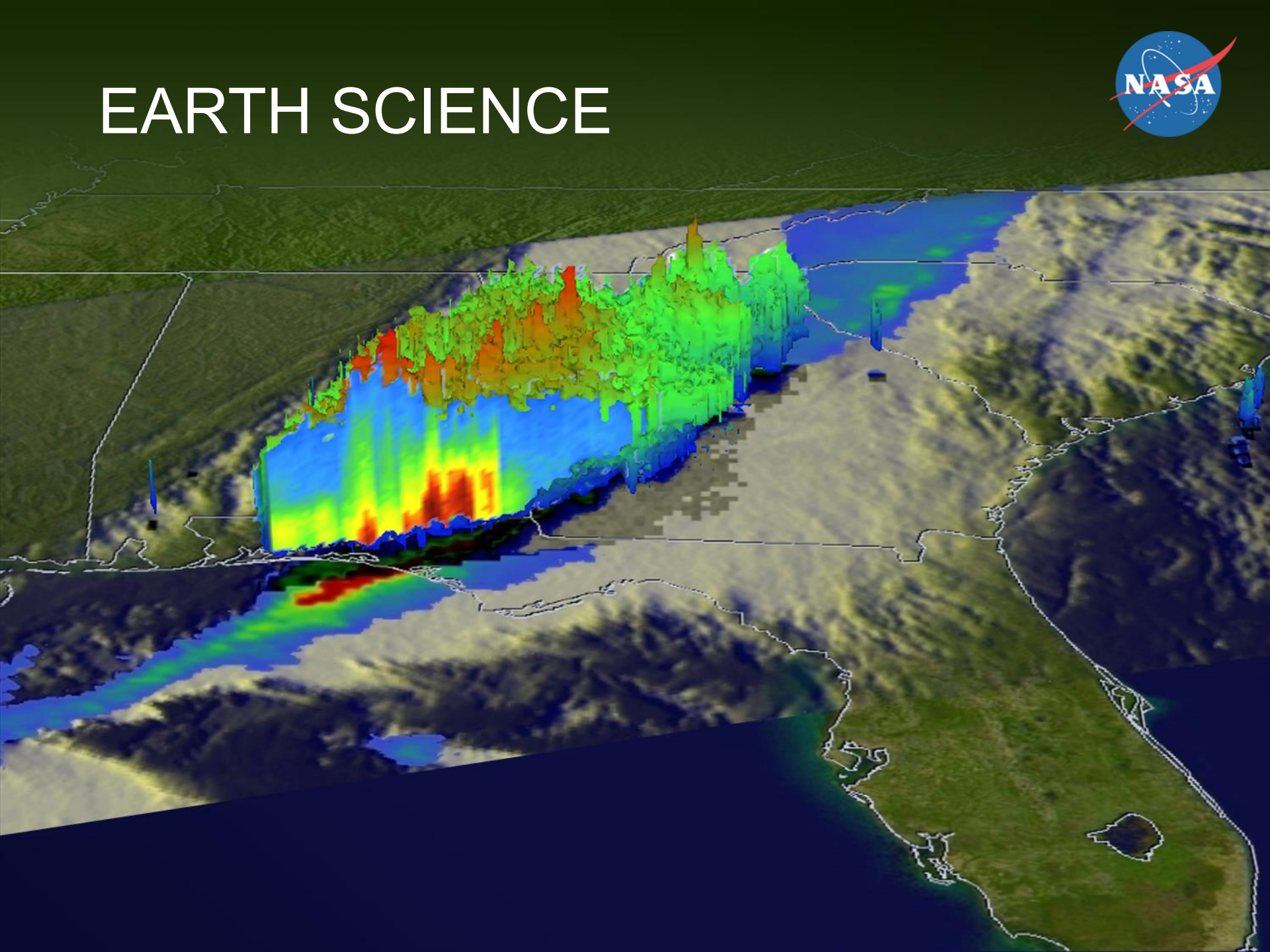
Entering magnetotail reconnection region



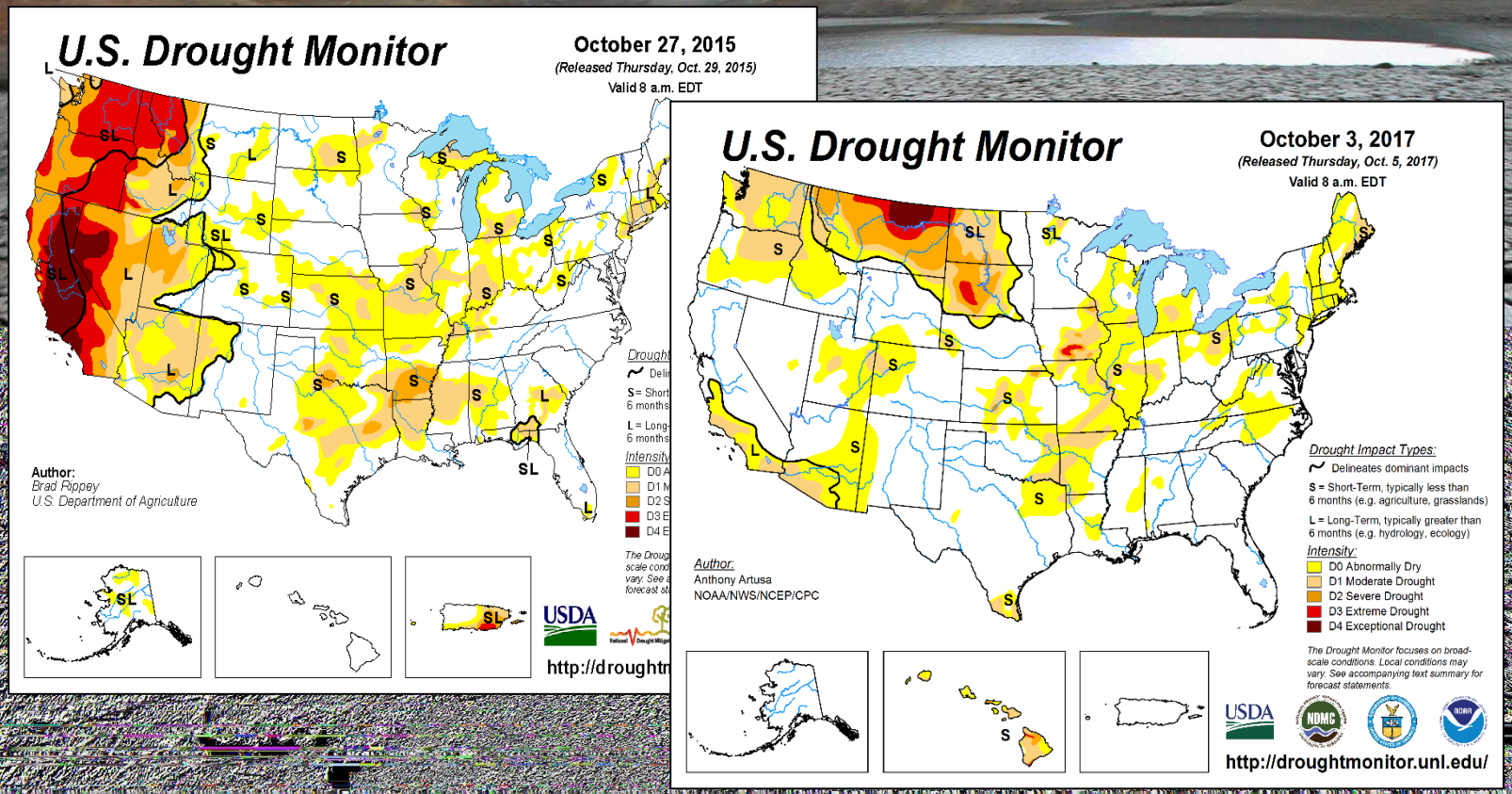
Plasma Space Tornadoes - MMS spotted Kelvin Helmholtz waves at the magnetosphere's boundary, which can allow particles from the solar wind to enter Earth's magnetosphere.

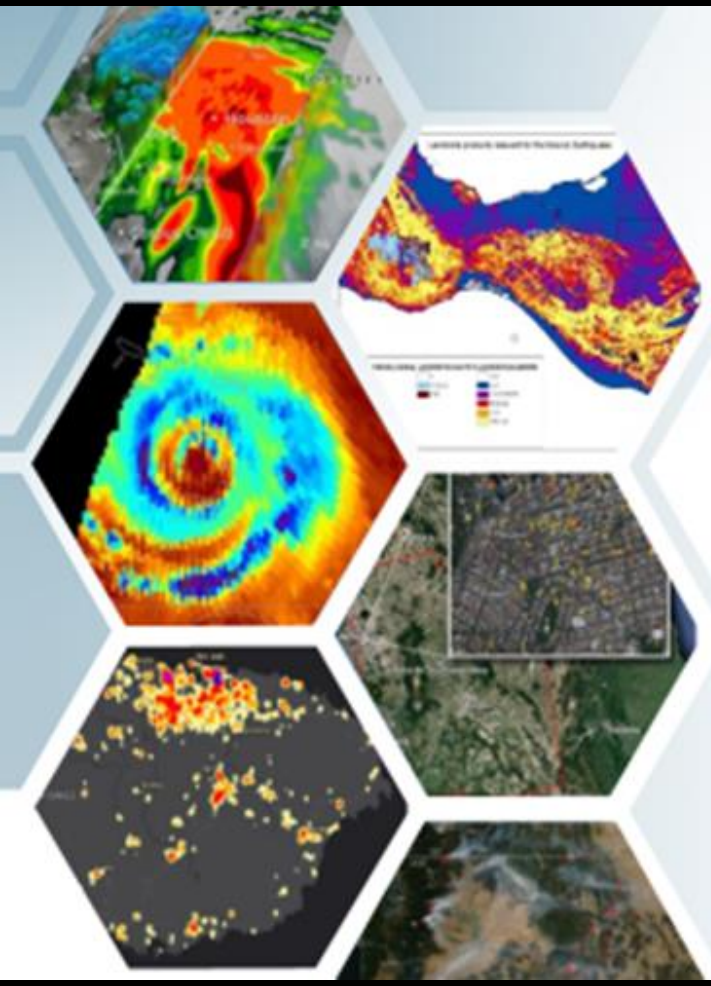
Artist Concept

EARTH SCIENCE



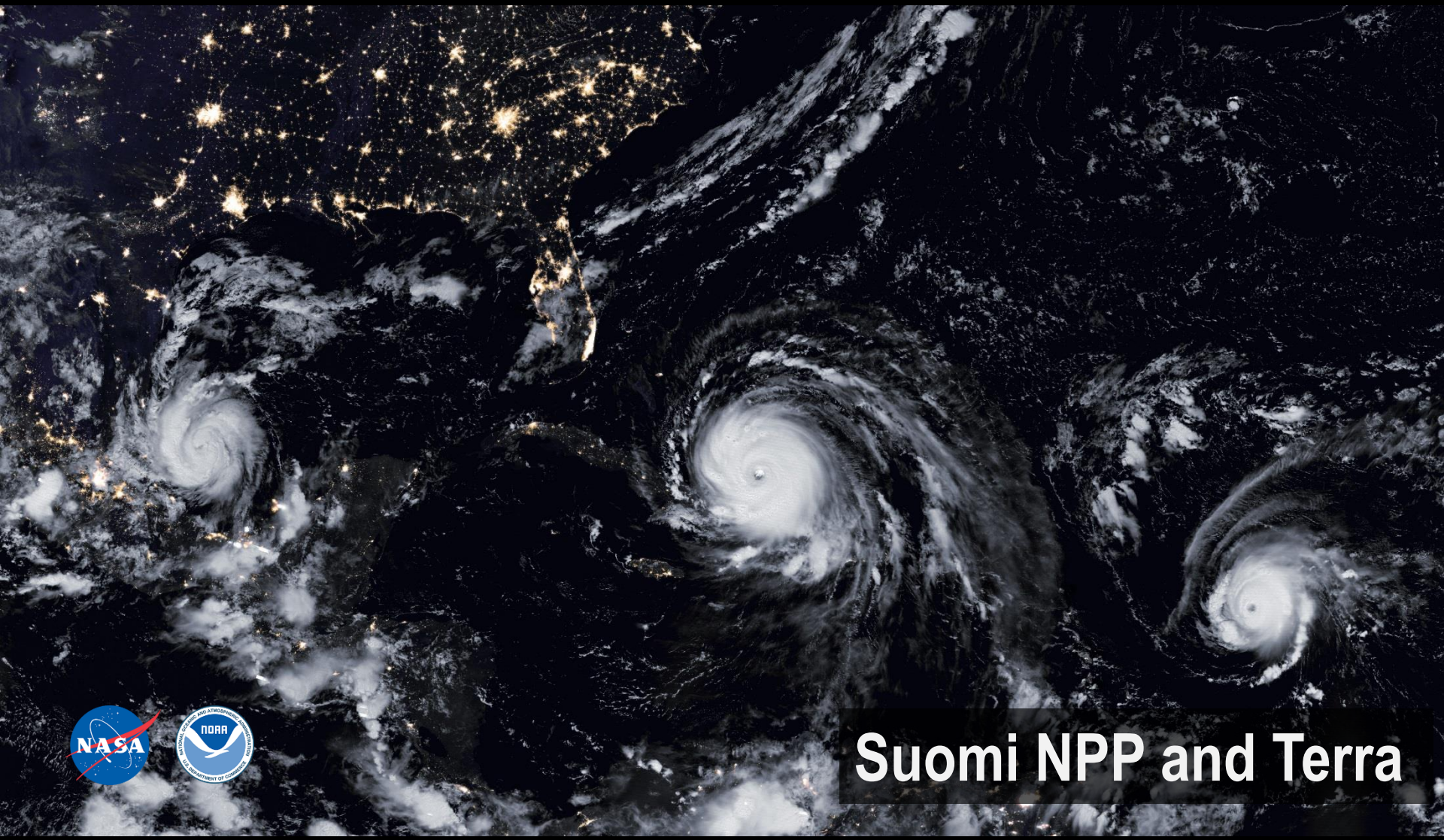
NASA Data Improve Drought Assessments





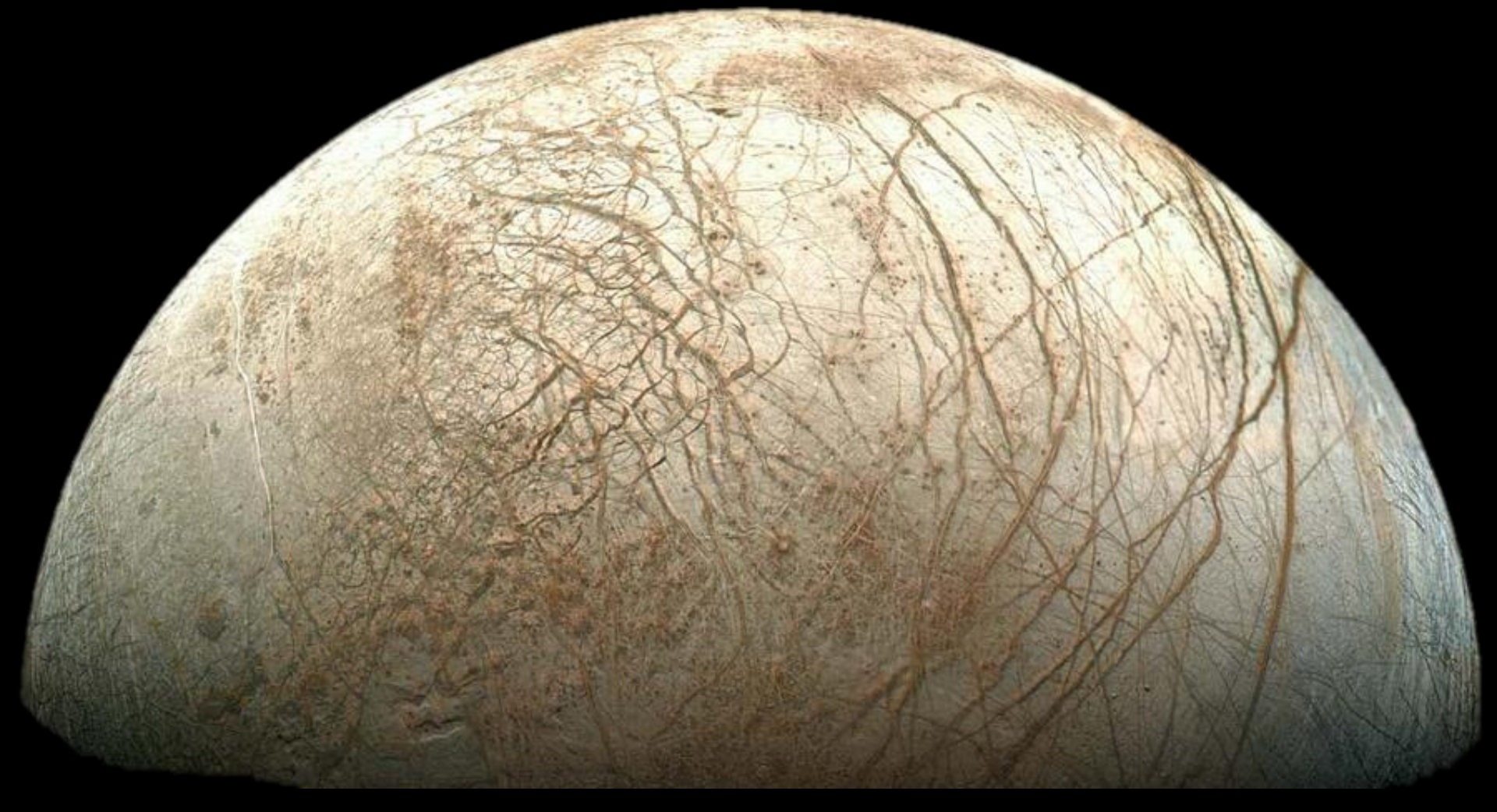
Fall 2017 SMD Disaster Response

- **GPM** - Harvey strikes Texas August 25
- **Landslide Susceptibility Map** - Chiapas (M8.1) Earthquake September 7
- **GPM Microwave** - Irma strikes Florida Keys September 10
- **SAR Damage Proxy Map** - Raboso (M7.1) Earthquake September 19
- **ARIA Damage Proxy Map** - Maria strikes Puerto Rico September 20
- **VIIRS and MODIS** - Western Wildfire Season



Suomi NPP and Terra

Planetary Science

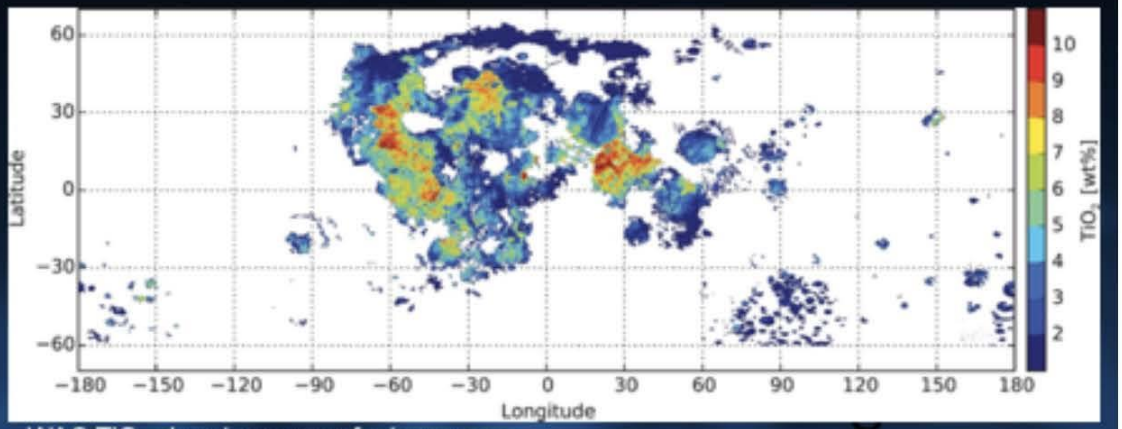


Mapping Minerals On the Moon: TiO_2 Abundances in Volcanic Regions

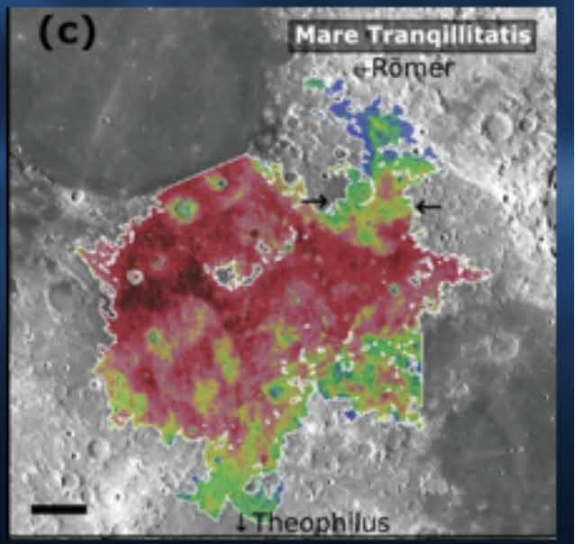
The Lunar Reconnaissance Orbiter Camera - Wide Angle Camera (WAC) has spectral channels sensitive to the abundance of the mineral ilmenite (specifically its main oxide, TiO_2). TiO_2 is found in varying abundances in lunar basalts.

The WAC TiO_2 map (top) illustrates the range of abundances across volcanic units, from a low of ~2 weight % to as much as 12.6 wt%. Apollo and Luna samples have TiO_2 abundances between 0.5 and 10.0 wt%.

This map serves as a key guide to identifying basalt compositions outside of what was sampled by Apollo and Luna, as well as locations for future *in situ* titanium and oxygen extraction.



WAC TiO_2 abundance map for lunar mare (latitude 70°S to 70°N, centered on the nearside). Color corresponds to 1 wt% of TiO_2 values. Values less than ~2 wt% (dark blue) are below the detection limit of the reflectance variations related to ilmenite content.



The highest mare TiO_2 abundances (> 10 wt%) are in the north- western part of Mare Tranquillitatis, while in the southern half there are patchy areas of lower TiO_2 (4-8 wt%), likely due to both true compositional variations of the mare and contamination by ejecta.

Sato, H., et al., (2017), *Icarus*, 296, 216-238, Lunar mare TiO 2 abundances estimated from UV/Vis reflectance

Juno

Unraveling the Secrets of Jupiter

March 8, 2018 Nature: Clusters of cyclones encircling Jupiter's poles; Measurement of Jupiter's asymmetric gravity field; Jupiter's atmospheric jet streams extend thousands of kilometers deep; Pole position for Juno.

National Aeronautics and Space Administration

Astrophysics

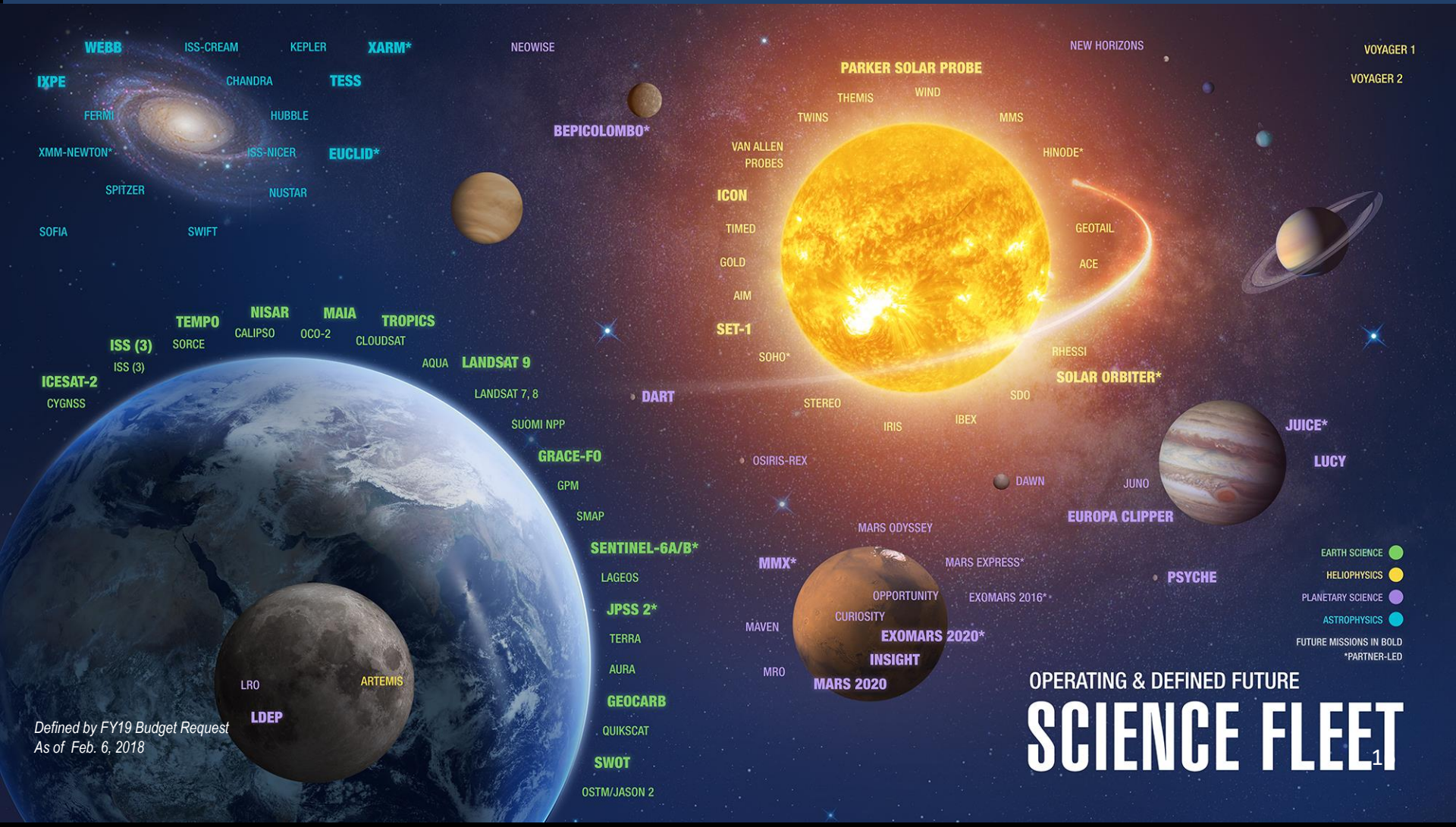
Chandra

Reveals clues to how M51's ultraluminous X-ray source (ULX) shines so brightly

Outline

- Science Results
- **Programmatic Status**
- Findings

NASA Science Overview by SMD Associate Administrator Dr. Thomas Zurbuchen



CY 2018 Launches

- **GOLD -** 1/25/18
- **GOES-S -** 3/1/18
- **TESS -** 4/16/18
- **GRACE FO -** NET 4/29/18
- **InSight -** 5/5/18
- **ECOSTRESS -** 6/9/18
- **SET-1 -** 6/13/18
- **ICON -** 6/18 NET
- **Parker Solar Probe -** 7/31/18
- **IceSat-2 -** 9/12/18
- **MetOp-C -** 10/1/18
- **STROFIO *(BepiColombo)* -** 10/1/18
- **Sounding Rockets -** 23
- **Balloons -** 16

CY 2018 KDP Transitions

- **20 Key Decision Points**
- **6 Critical Design Reviews**
- **4 Program Implementation Reviews**

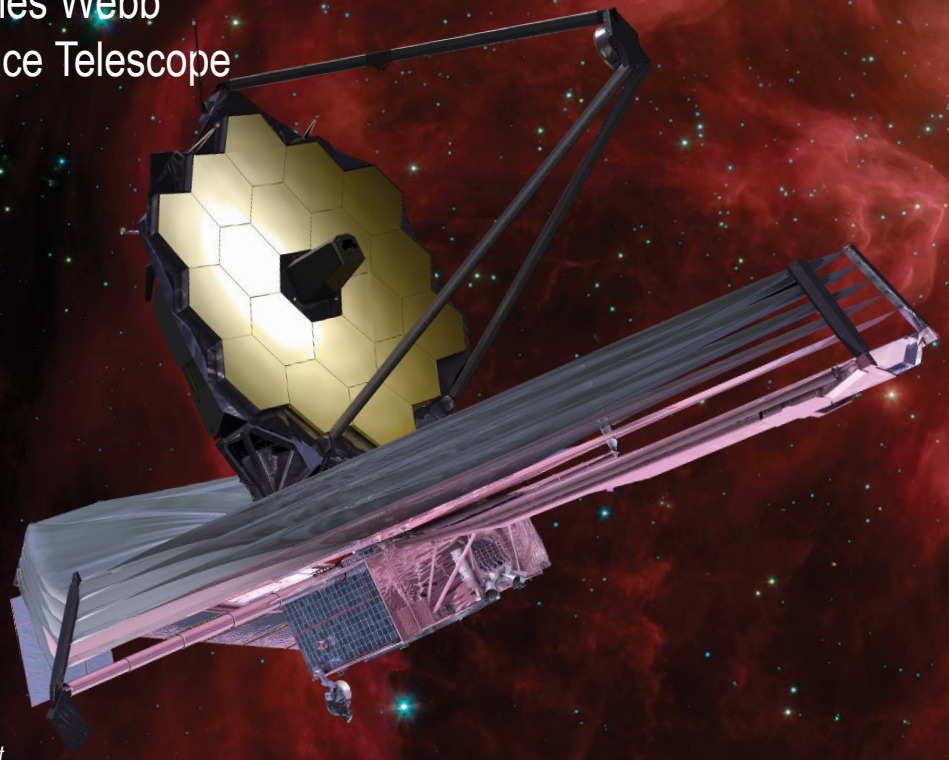
Parker Solar Probe sits inside the thermal vacuum chamber at NASA's Goddard Space Flight Center. On Jan. 27 the spacecraft began space environment testing.

PARKER SOLAR PROBE

A Mission to Touch the Sun

Webb

James Webb
Space Telescope



Artist Concept

March 12, Webb prepares for additional testing at Northrop Grumman in Redondo Beach, California, signaling the next step in the observatory's integration and testing.

FY 2019 Budget

Program Highlights

Planetary Science

- New Lunar Discovery and Exploration program supports commercial partnerships and innovative approaches to achieving human & science exploration goals
- New Planetary Defense program includes DART development
- Europa Clipper launch as early as FY25
- Plan a potential Mars Sample Return mission

Astrophysics

- ~~Webb remains on track for 2019 launch~~
- Given its significant cost within a proposed lower budget for Astrophysics and competing priorities within NASA, WFIRST terminated with remaining WFIRST funding redirected towards competed astrophysics missions and research

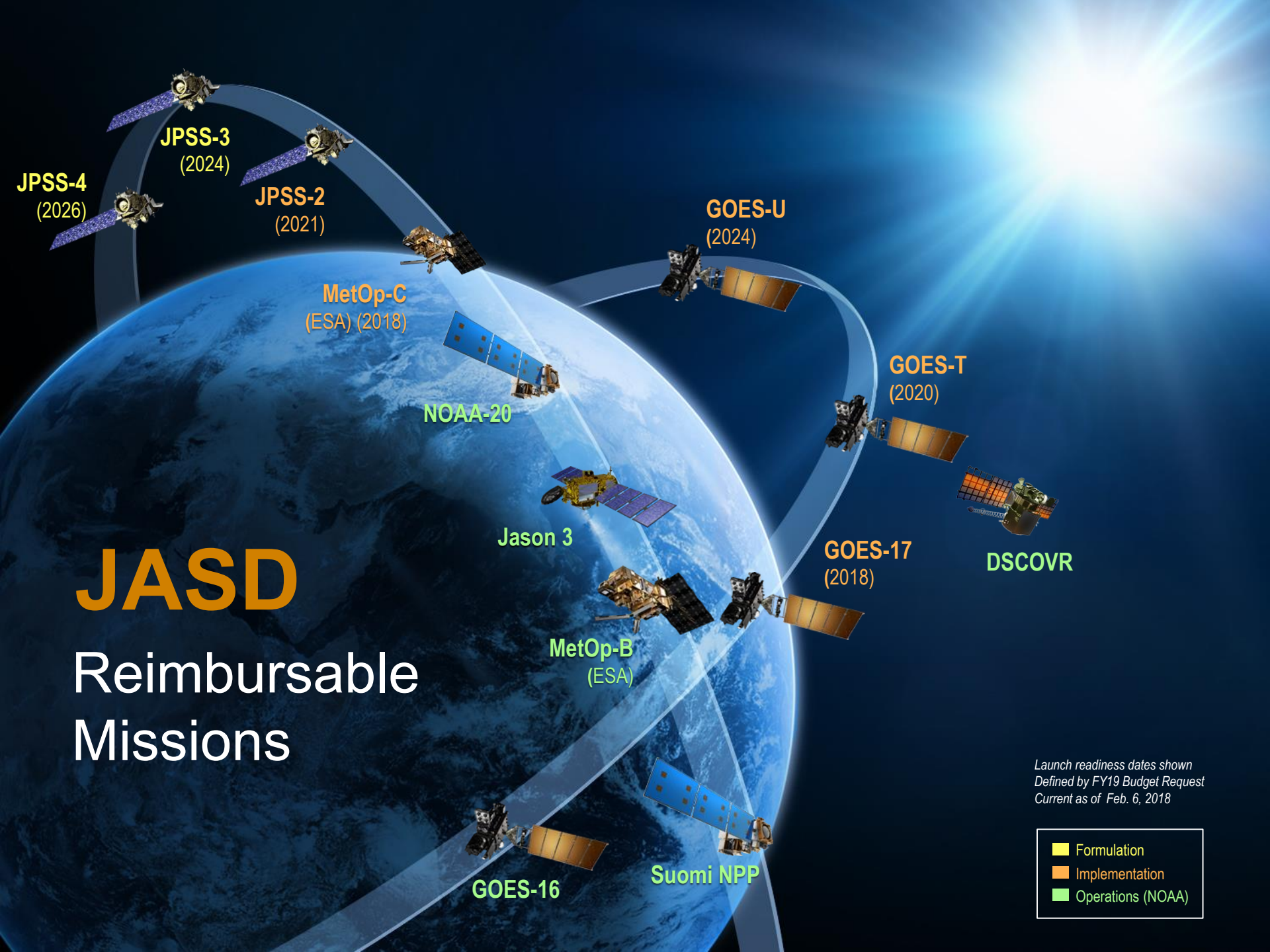
Heliophysics

- Space Weather increase will strengthen cross-agency collaboration on Research-to-Operations/Operations-to-Research
- Provides for a balanced Heliophysics portfolio, including enhanced emphasis on small missions, technology development and expanded opportunities for R&A

Earth Science

- Continues focused, balanced Earth science portfolio
- Maintains regular cadence of Venture Class missions and instruments solicitations
- Healthy research and applied science programs, and SmallSat/CubeSat investments

Science budget ~2% above the FY17 appropriated level


JPSS-4
(2026)
JPSS-3
(2024)
JPSS-2
(2021)
MetOp-C
(ESA) (2018)
NOAA-20
GOES-U
(2024)
GOES-T
(2020)
DSCOVR
Jason 3
GOES-17
(2018)
MetOp-B
(ESA)
GOES-16
Suomi NPP
JASD
Reimbursable
Missions
Launch readiness dates shown
Defined by FY19 Budget Request
Current as of Feb. 6, 2018
Formulation
Implementation
Operations (NOAA)

Joint Agency Satellite Division (JASD) Division Update

Strategic Objective

- Ensure excellence in the nation's operational weather satellites by applying NASA's expertise in systems engineering and program and project management to satellite and ground system development

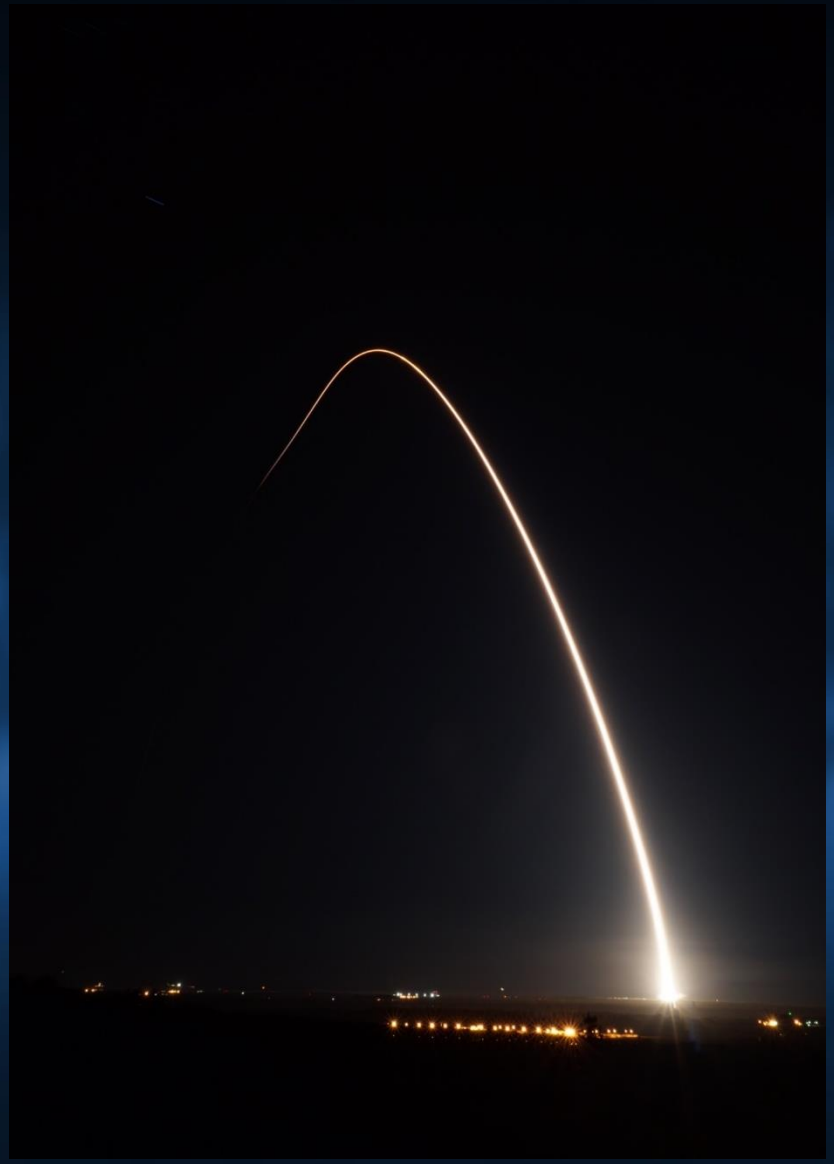
Major Activities

- Advance collaboration opportunities with NOAA and partner organizations
  - Strategic planning
  - Performing studies
  - Formulating missions
  - Developing technologies
  - Identifying ride shares and hosting opportunities
- Continuing projects: GOES-S, GOES-T, GOES-U, NOAA-20, JPSS-2, JPSS-3, JPSS-4, JPSS Ground System, MetOp-C, and Space Weather Follow-On

Note: Budget information and justification provided in NOAA budget documentation

JPSS-1

Launched Successfully on November 18, 2017



NOAA 20 (JPSS-1) VIIRS First Light Image
December 13, 2017

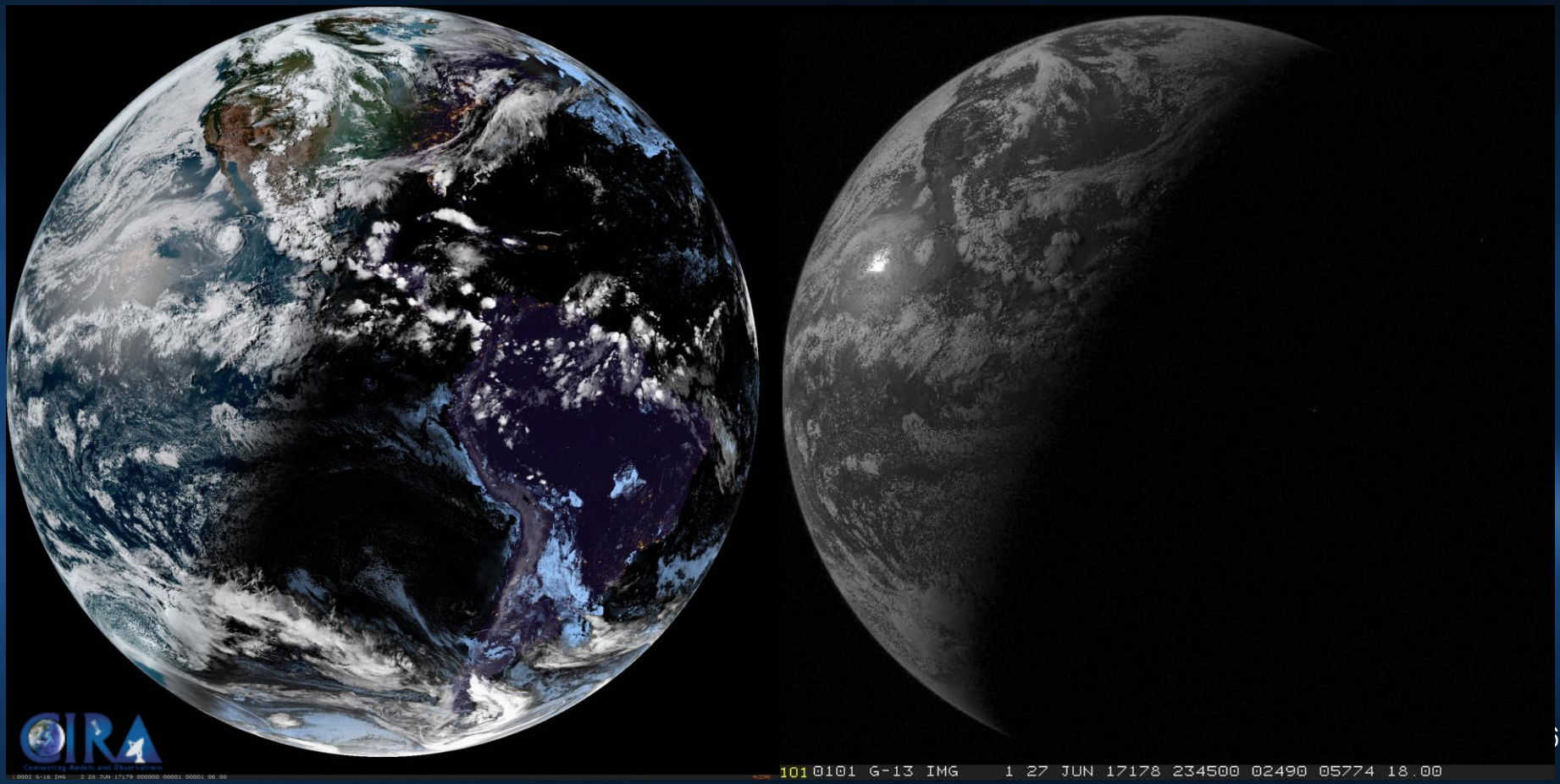
NOAA-20 VIIRS First Light Image Captures One of the Largest Wildfires in California History
(Image generated by the NOAA Visualization Lab and NESDIS/STAR)

GOES-S Launch

Full Disk Imagery Increased From 8X to 96X per Day

GOES-R & S every 15 minutes

GOES-13 every 3 hours



SMD Strategic Data Management Working Group

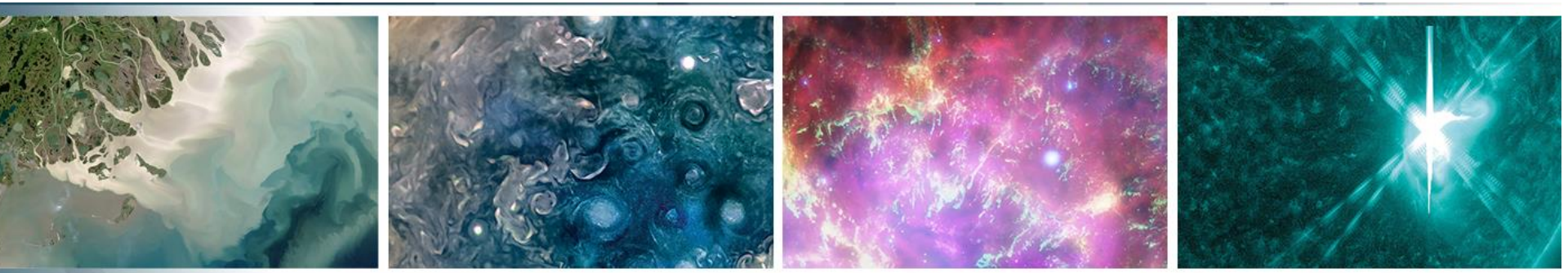
Overview of Task

Enable greater scientific discovery by leveraging advances in information technology for SMD science data archives

- Strategic data management across SMD identified as a priority for assessment and action
- Information system technologies – processing, storage, and artificial intelligence – are growing and impact how we store, manage, and analyze data for science
- NAC SC's Big Data Task Force recently observed that about half of new science comes from the science data archives

Goals

- Develop a 5-year strategy with three overall goals
  - Leverage best practices to improve discovery and access for all SMD data for immediate benefit to science data users and to improve the overall user experience
  - Identify large-scale and cross-disciplinary science users and use cases to inform future science data system capabilities
  - Develop set of recommendations to modernize science data systems and promote development of new technology and analysis techniques for science community accesses to SMD science archives and high-end computing resources for scientific discovery



Big Data Task Force (BDTF) Products

- SC held two working sessions to go through members' review of each individual BDTF final finding and recommendation.
- Final SC big data advice will be delivered at the NAC's July meeting.

Findings (7)

Finding 1: Educating Early Career Scientists in Data Science Approaches to NASA's Science Analysis Problems through NASA's Frontier Development Lab

Finding 2: SMD Data Archive Programs and Projects Performing Well and are Properly Taking Steps to Modernize (also see source doc 1: Are SMD's Science Data Archives Ready to Meet Future Challenges)

Finding 3: The Fraction of Science Papers that Rely on Archive Data Increasing in All Divisions (also see source doc 1: Are SMD's Science Data Archives Ready to Meet Future Challenges)

Finding 4: Volume, Variety and Velocity of NASA Science Data is Taxing Established Methods and Technologies (also see source doc 2: Data Science: Statistical and Computational Methodology for NASA's Big Data in Science White Paper)

Finding 5: Strides in Methodology Often Not Incorporated into NASA Satellite Data or Science Analysis Programs (also see source doc 2: Data Science: Statistical and Computational Methodology for NASA's Big Data in Science White Paper)

Finding 6: Modeling Workflows Largely Ad Hoc and Little Changed from When Conceived (also see source doc 3: Modeling Workflows White Paper)

Finding 7: Mismatch Between Preparation of Scientists and Requirements for IT Mastery (also see source doc 3: Modeling Workflows White Paper)

Recommendations (11)

Rec 1: SMD Should Manage its Data Archives at Same Rank as the Flight Missions in its Portfolio (also see source doc 1: Are SMD's Science Data Archives Ready to Meet Future Challenges)

Rec 2: Incorporate Data Science and Computing Advisory Positions in the SMD Advisory Committees

Rec 3: Establishing a Data Science and Computing Division in SMD

Rec 4: Necessary Changes in Training, Proposal and Mission Reviews, and Implementation of the Critical Capabilities that Data Science Algorithms Provide (also see source doc 2: Data Science: Statistical and Computational Methodology for NASA's Big Data in Science White Paper)

Rec 5: Making NASA's Archived Science Data More Usable and Accessible (also see source doc 4: Making NASA's Archived Science Data More Usable White Paper)

Rec 6: NASA Should Make Prioritized Investments in Computing and Analysis Hardware, Workflow Software and Education and Training to Accelerate Modeling Workflows (also see source doc 3: Modeling Workflows White Paper)

Rec 7: Implementing Server-side Analytics Architectures (also see source doc 5: Server-Side Analytics White Paper)

Rec 8: NASA Participation in DOE's Exascale Computer Program

Rec 9: Joining the Nation's Science Data Superhighway (also see source doc 6: Joining the Science Data Highway)

Rec 10: Joint Program with NSF's Big Data Innovation Regional Hubs and Spokes

Rec 11: SMD Data Science Applications Program Position and Directed Funding

Research and Analysis (R&A) Charge

- SC held three drafting sessions to prepare a draft response to the SMD AA's R&A Charge.
- Final SC R&A charge advice will be delivered at the NAC's July meeting.

Question 1

1. Does the SMD R&A program have processes in place to effectively solicit, review and select high-impact/high-risk projects?
   a) What is your committee's working definition of a high-impact project? A high-risk project?
   b) Are there aspects of the solicitation, review and selection process that could be added, removed or modified that would allow SMD to more effectively elicit and support high-risk/high-impact projects or, is the current practice of soliciting by topic and evaluation for merit followed by flagging high-impact/high-risk projects for the selection official adequate?
   c) If it were to be recommended that solicitations or evaluation methods be modified for high-impact/high-risk projects, how should these be designed?
   d) Acknowledging the value of incremental progress on achieving strategic objectives, and thus recognizing that much of the research that SMD supports will be of moderate impact, how should SMD determine the correct balance between moderate impact research and high-impact/high-risk research?

Question 2

2. Does the SMD R&A program have effective processes in place to solicit, review and select focused, interdisciplinary, and interdivisional projects?
   a) How should SMD determine the right balance between division-specific and interdivisional research?
   b) Once determined, does SMD have effective processes in place to achieve this balance?
   c) How should each of SMD's divisions determine the right balance between discipline-focused and interdisciplinary research?
   d) Once determined, do SMD's divisions have effective processes in place to achieve this balance?
   e) Is SMD missing out on important interdisciplinary and/or interdivisional work because of the way in which we solicit, review, and select projects? If so, what specific research foci are missing?
   f) Are there aspects of the solicitation, review and selection process that could be added, removed, or modified that would allow SMD to more effectively elicit and support interdisciplinary and or interdivisional projects?
   g) If it is recommended that solicitations or evaluation methods be modified for interdisciplinary and/or interdivisional projects, how should these be designed?
   h) What role, if any, should collaborative research structures such as NIH-style "Program-Project" grants, virtual institutes (the NASA Astrobiology Institute (NAI) and Solar System Exploration Research Virtual Institute (SSERVI)) and research coordination networks (the Nexus of Exoplanetary System Science (NExSS)) play?

Deputy Associate Administrator for Research Update on Efforts Underway

Internal Scientist Funding Model

Draft ISFM Success Criteria - Office of Chief Scientist (OCS)

	Criteria	Goal
1	More research work is directed to the centers rather than competed.	Reduce CS FTE in competed R&A by 25%
2	Fewer R&A proposals are submitted, scientists can focus more time on research activities geared toward NASA goals.	Reduce proposals and time spent writing proposals
3	HQ and science capability leads are involved in strategic hiring decisions	Hiring areas are approved by HQ
4	Positive feedback (via survey) of HQ program managers and center managers, and scientists.	Improve satisfaction
5	Scientists are able to participate in more review panels without conflict-of-interest issues.	Improve participation
6	NASA scientists continue to publish research in the peer-reviewed literature	Maintain quality
7	External review panels continue to rate the quality of NASA science as high, initially on a three-year review cycle.	Maintain quality
8	The balance of research funding support to the external community is maintained.	Maintain balance of external/internal funding

6

Diversity and Inclusion

D&I: Efforts Underway

- Beginning in 2017, all solicitations now include language endorsing diverse teams
- Starting with ROSES-2018, all review panels will be briefed on cognitive biases and shown an OCS-produced short video
- Currently developing processes to ensure diversity and inclusion (in all dimensions) on Standing Review Boards (SRBs), advisory committees, and review panels
  - For example, revamped two Division Advisory Committees to expand membership and increase diversity
  - Including in Statements of Task to future NAS ad hoc committees requesting they be more diverse
- Now developing SMD-wide approaches to increase diversity and inclusiveness of future workforce and scientific community, targeted roll-out 2019
  - Developing partnerships with NASA's Office of Diversity and Equal Opportunity (ODEO) and Office of Small Business Programs (OSBP)
  - Exploring partnering with NSF, non-profits
  - Making NASA's current programs better known

10

Discrimination and Harassment

Discrimination and Harassment Efforts Underway

- Recent NSF policy on discrimination requires grantee institutions to report discrimination claims and investigation results
- Developing statement on what individuals should do when they believe they have been faced with discrimination or harassment
  - Statement will be included in future ROSES releases and Announcements of Opportunity (AOs)
  - Promulgated to the scientific community through a "Dear Colleague" letter from NASA leadership
  - Standardize language to be included in grant award letters and in "NASA Night" presentations
  - Information to be added to the Grants FAQ at https://science.nasa.gov/researchers/sara/faqs

12

Workforce Development

Workforce Development Efforts

- In addition to the efforts in diversity and inclusion and discrimination, SMD is developing initiatives to
  - Better prepare NASA and non-NASA early career investigators to be successful researchers and grow into the next generation of mission PI's
    - Formulating training opportunities, such as "PI 101" and "Future Mission PI Incubator", targeted 2020
    - Assess competitiveness of early career PI's in R&A by 4th quarter 2018
    - Reinvigorate the Hands-On Project Experience (HOPE) program, targeted 2019
  - Partner with Centers to develop a more diverse cadre of future project managers
  - Take a more strategic approach to stakeholder interactions
    - A key component of this strategy is outreach to colleges and universities, including minority-serving institutions, and science societies and affinity groups in order to reach a larger population who may not know how to work with NASA

13

Planetary Science Advisory Committee (PAC) Chair Report

- **PAC First Meeting**
  Feb 21-23, 2018

- **PAC identified challenges with the NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES) platform concerning external reviews**

- **SC will be sharing this information with the other SMD division advisory committees as system-wide solutions may be needed**

- Day 1
  - PSD Status Report + Q&A
  - Lunar Discovery and Exploration Program
  - PSD R&A Status, R&A Restructure Review, PSD R&A Response to Review
  - SMD R&A Charge
- Day 2
  - Mars Exploration Program Update
  - Planetary Protection Officer Meet & Greet
  - Joint Workshop on Induced Special Regions (on Mars)
  - Planetary Data System Status and Future Plans
  - The Deep Space Network (DSN)
  - NASA Astrobiology Institute (NAI) and Nexus for Exoplanet System Science (NExSS)
  - Solar System Exploration Research Virtual Institute (SSERVI)
  - Ceres Pre-Decadal Science Definition Team
  - Planetary Defense Coordination Office

NSPIRES External Reviews

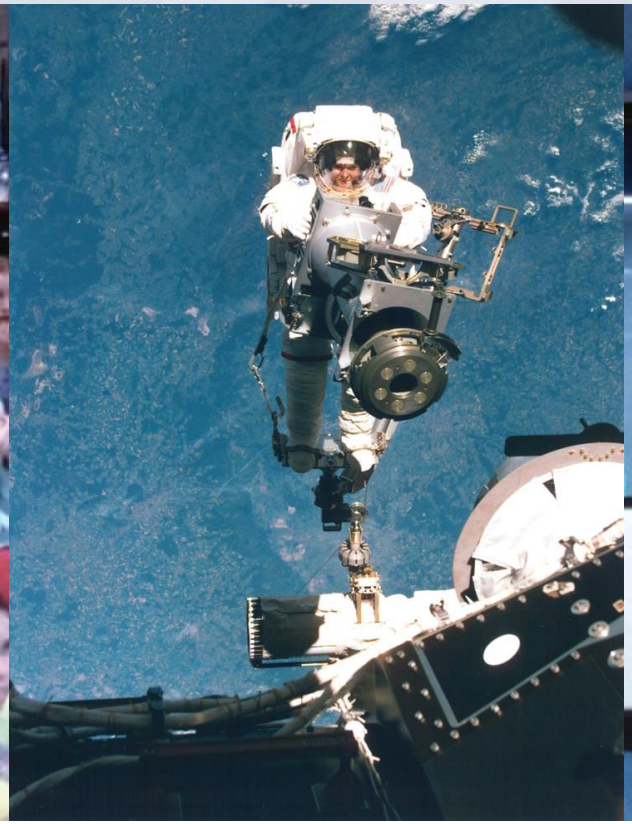
- PAC recommends that delays of not more than 48 hours between the time an external reviewer is identified and they are notified by NRESS that reviews are available to them.
- To ensure that reviewers always have maximum time to complete their assignments, PAC recommends that NSPIRES be modified to provide automated notifications to external reviewers whenever a new review is assigned.
- PAC recommends that NSPIRES be modified such that all panelists who have completed their reviews can see all external reviews as soon as they are completed (this may be accomplished by changing a default setting within NSPIRES).
- PAC recommends that NSPIRES be modified such that group chiefs can always see the status of all reviews for the panel (accept/decline, not logged in, in progress, completed).

Heliophysics Advisory Committee (HPAC) Chair Report

Summary of the NASA Heliophysics Advisory Committee Meeting on 29 Nov - 01 Dec 2017

(1) 2017 Heliophysics Senior Review
(2) NASA Internal Scientist Funding Model
(3) Heliophysics Cubesats
(4) Research & Analysis (R&A) Program Update
(5) HPD Science Centers
(6) High End Computing for Heliophysics
(7) R&A Charge Status
(8) GPRAMA Outcomes

Dr. Tammy Jernigan - SC member presentation
Spaceflight Experience



Connecting from the SC meeting at NASA HQ to 6th graders at Gunston Middle School, Arlington, VA

Outline

- Science Results
- Programmatic Status
- **Findings**

SC Finding:
Joint Agency Satellite Division (JASD)

The NAC Science Committee (SC) finds that:

The spacecraft launched through the Joint Agency Satellite Division (JASD) program already have delivered tremendously valuable data that serves multiple stakeholders and provides broad societal benefits, one of the major goals of NASA. Some of the initial instrumentation on GOES-S is potentially game changing, such as the Geostationary Lightning Mapper (GLM), allowing weather systems to be observed at excellent resolution. These capabilities allow us to move forward and incorporate advances into new model development, as only a minimal amount of interpolation is needed (e.g. ocean observations are being resolved at the needed time and space scales). The SC appreciates NASA's strong partnership with NOAA on these efforts. In this time of extreme weather, these capabilities allow the prediction of a host of weather events, as well as their consequences.

SC Finding: Workforce Diversity

The NAC Science Committee finds that:

NASA is taking proactive steps to make the workforce more inclusive and equitable, and is undertaking efforts to better quantify problems in diversity and inclusion.

Back Up

Remaining I&T Activities

Blue font indicates "first time" activities

Science Payload

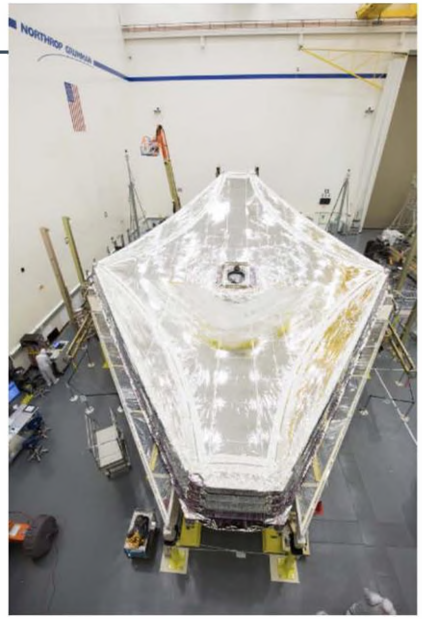
- OTIS Deployments at NGAS (secondary mirror & ISIM radiator)

Observatory Integration

- Pre-environmental Observatory deployments
- Observatory fold & stow
- ***Observatory system (electrical) test***
- Observatory vibration, acoustics tests
- ***Observatory deployment***
- Observatory stow for launch
- Observatory final system test

Spacecraft Element

- ***Acoustics, vibe, and thermal vacuum tests***
- Post-Environmental deployment & stow



Standing Review Board Schedule Review Summary

Summary of SRB Schedule Risk Assessment

- Summary/Historical view of large, complex NASA SMD program and project schedule overruns
- Analysis of historical JWST I&T schedule margin burn rates since 2011
- SRB Delphi analysis
- SRB Assessment of project's grassroots schedule analysis and threats
- JWST Project SRA model and parametric analysis
- Comparison of similarly complex NGAS "Project X" to JWST I&T work to go

- **Based on the above analyses, the SRB assessment results in a probable JWST LRD range of 1/29/20 to 4/30/20 (increasing probability with latter date)**
- **Caveats:**
  - **NGAS schedule performance improves as planned**
  - **No significant hardware anomalies during remaining I&T**

Webb Mission Status - March 23, 2018

Webb Observatory Elements at Northrop Grumman (NGAS) Redondo Beach, CA

Webb Mission Status - March 23, 2018

- Spacecraft Element (SCE) completed, stowed in launch configuration
  - Performance testing complete and ready for environmental testing
  - Sunshield
    - 7 small tears in the sunshield and sunshield covers have been repaired
    - Lessons learned from first deploy/fold & stow were significant
  - Spacecraft
    - Major impact to schedule due to propulsion valve and transducer rework
    - Dual Thruster Modules removed, valves refurbished, DTM's reinstalled, pressure check was good
- Optical Telescope Element (Telescope & Instruments)
  - Full performance and environmental testing complete and OTE delivered for Integration and Test
- Launch Readiness Date (LRD) of March - June 2019 not possible due to lessons learned during SCE Integration & Test (I&T) and propulsion system rework
- Standing Review Board (SRB) has reviewed project schedule and their analysis yields an LRD of ~May 2020 at 70% confidence
- Independent Review Board, chaired by Tom Young; final report ~May 2018
- NASA's final agency decision in June 2018

Webb 18 Month LRD Impact

From October 2018 LRD

- Multiple “critical paths” are tracked during project development
- 15 months of technical issues (**impacts do not add linearly**)
  - Spacecraft critical path dominated by the propulsion system – 13 months
    - 3 Months - Transducer problem
    - Dual Thruster Module rework slip of 9 months (much of this was worked in parallel with Sunshield issues)
    - 1 Month - Recovery from incorrect voltage applied to the catalyst bed heater
  - Sunshield Complications – 7 months
    - 4 months – Deploy/Fold/Stow (2 months to go)
    - 2 months – Tear repairs (1 month to go)
    - 1 month – Snag guard implementation (0.5 months to go)
  - Observatory I&T Replan – 3 months
    - 3 months – OTE lessons learned and applied to SCE & reduction in parallel task activities
- 3 months additional funded schedule reserve

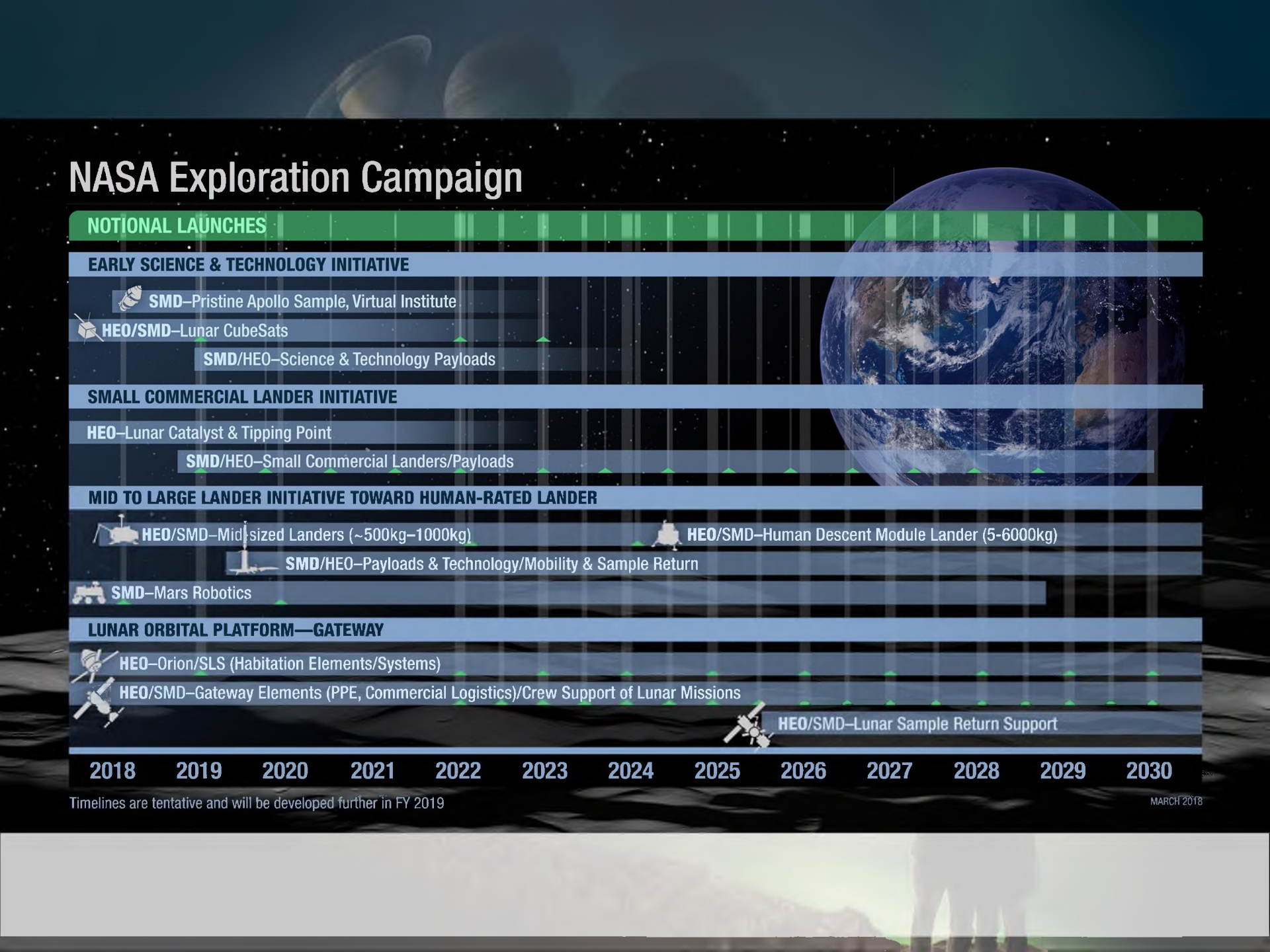
WFIRST

- Given its significant cost within a proposed lower budget for Astrophysics and competing priorities within NASA, WFIRST terminated with remaining WFIRST funding redirected towards competed astrophysics missions and research
- Funds appropriated by Congress in FY18 will allow WFIRST to enter Phase B in April 2018
- If Congress adopts the Administration's request to terminate WFIRST, the funds made available would enable a competed Probe-class mission AO in FY19

Science Budget Request Summary ($M)

	Actual	Enacted	Request	Notional			
	FY 17	FY 18	FY 19	FY 20	FY 21	FY 22	FY 23
Science	5,762.2		5,895.0	5,859.9	5,841.1	5,822.4	5,803.6
Earth Science	1,907.7		1,784.2	1,784.2	1,784.2	1,784.2	1,784.2
Earth Science Research	462.0		451.4	457.4	483.8	507.7	537.8
Earth Systematic Missions	929.7		788.1	729.5	689.1	646.5	595.0
Earth System Science Pathfinder	208.8		235.0	273.7	268.2	274.3	287.7
Earth Science Multi-Mission Operations	204.9		196.9	208.7	225.0	231.6	237.1
Earth Science Technology	62.9		59.7	61.6	64.2	67.8	69.6
Applied Sciences	39.4		53.1	53.3	53.9	56.3	57.0
Planetary Science	1,827.5		2,234.7	2,199.6	2,180.8	2,162.1	2,143.3
Planetary Science Research	230.1		258.0	247.6	247.6	247.6	247.6
Planetary Defense	60.0		150.0	150.0	150.0	150.0	150.0
Lunar Discovery and Exploration	19.0		218.0	218.0	218.0	218.0	218.0
Discovery	194.6		381.2	476.6	375.0	355.6	348.5
New Frontiers	134.0		130.2	163.7	245.0	327.6	388.4
Mars Exploration	647.0		601.5	529.7	371.9	290.8	215.3
Outer Planets and Ocean Worlds	359.5		285.6	213.8	373.3	372.5	375.5
Technology	183.3		210.2	200.2	200.0	200.0	200.0
Astrophysics	1,352.3		1,185.4	1,185.4	1,185.4	1,185.4	1,185.4
Astrophysics Research	190.1		259.2	280.8	321.5	318.4	310.0
Cosmic Origins	779.4		491.4	354.5	311.9	312.7	312.7
Physics of the Cosmos	106.2		136.8	139.1	113.3	108.3	105.0
Exoplanet Exploration	152.6		52.4	44.5	44.6	44.4	44.9
Astrophysics Explorer	124.1		245.6	366.5	394.0	401.6	412.8
Heliophysics	674.7		690.7	690.7	690.7	690.7	690.7
Heliophysics Research	180.8		242.7	234.3	226.7	217.9	220.6
Living with a Star	368.4		247.8	103.4	83.5	93.2	127.8
Solar Terrestrial Probes	38.8		91.0	89.9	177.7	175.6	247.9
Heliophysics Explorer Program	86.7		109.2	263.1	202.9	204.1	94.4

NASA Exploration Campaign

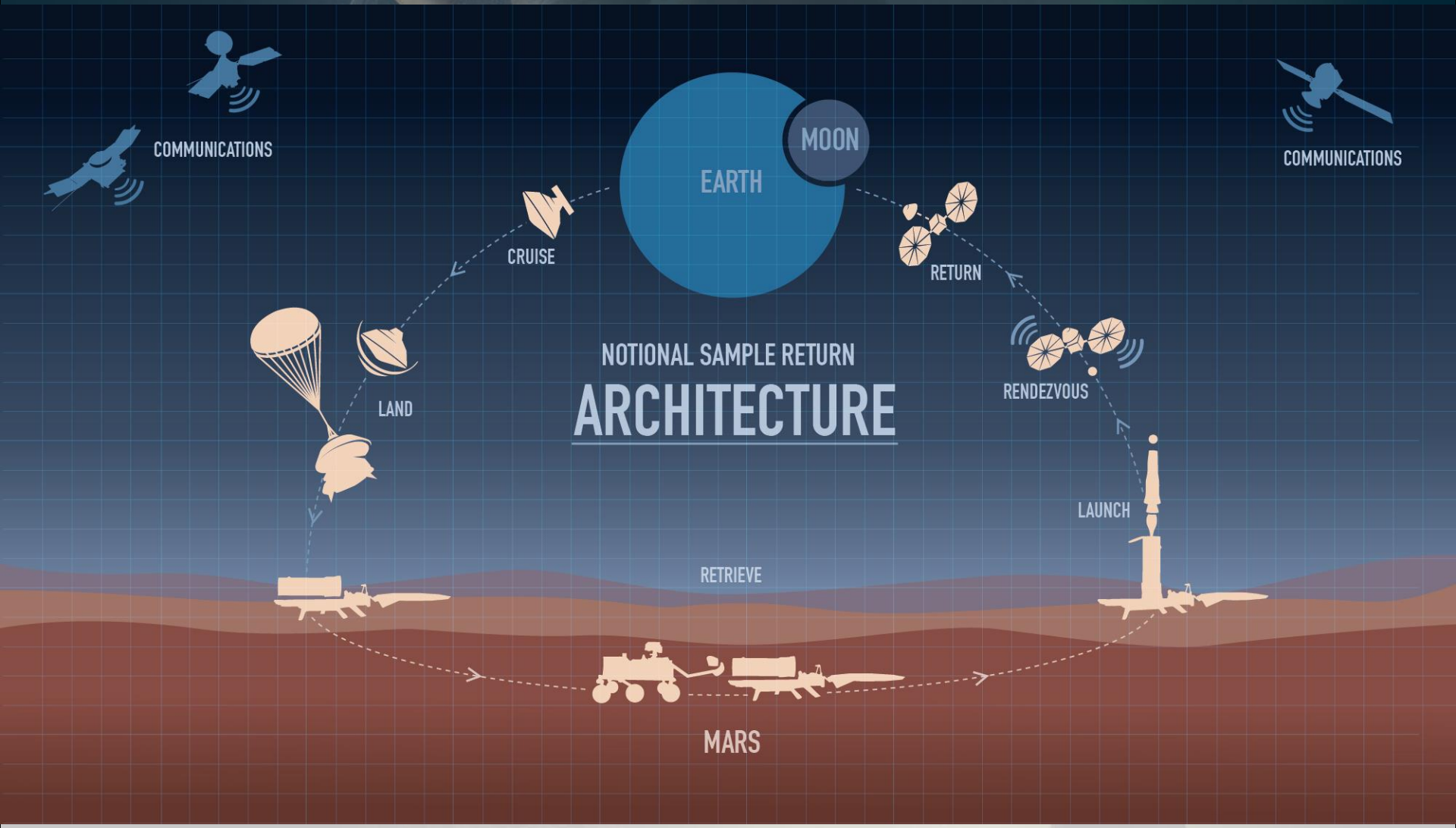


Timelines are tentative and will be developed further in FY 2019

MARCH 2018

Transformative Lunar Science

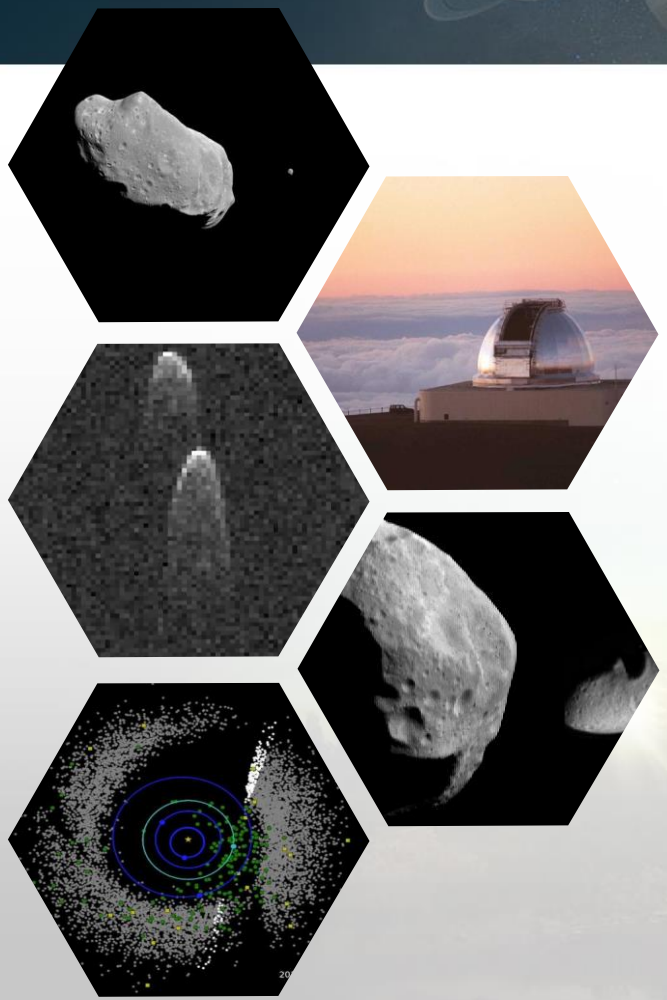
- Based on the decadal survey, a SSERVI white paper identified key areas of lunar science, including
  - Establish period of giant planet migration
  - Provide absolute chronology for Solar System events
  - Use accessible vantage from lunar far side to view universe
  - Understand sources of water, and cycles
  - Characterize lunar interior
  - Evaluate plasma interactions w/ surfaces


COMMUNICATIONS
COMMUNICATIONS
MOON
EARTH
CRUISE
RETURN
LAND
NOTIONAL SAMPLE RETURN
ARCHITECTURE
RENDEZVOUS
LAUNCH
RETRIEVE
MARS

Mars Sample

- Retain flexibility on requirements; cost & risk are part of the essential trade-space
- Focused scope
- Capitalize on experience base
- Limit new development
- Make early technology investments to mature readiness and minimize cost risks
- Leverage partnerships
- Strong programmatic discipline in execution


IAU
Minor Planet Center
ASSESS
[CENTER FOR NEAR EARTH OBJECT STUDIES]
SEARCH, DETECT & TRACK
[GROUND-BASED & SPACE-BASED OBSERVATIONS, IAWN]
PLANETARY DEFENSE
MITIGATE
[DART, FEMA EXERCISES]
CHARACTERIZE
[NEOWISE, GOLDSTONE, ARECIBO, IRTF]
PLAN & COORDINATE
[SMPAG, PIERWG, DAMIEN IWG]



Planetary D

- Planetary Defense budget is three times larger than FY2018
- Supports R&A for ground and space-based observations
- Supports DART, first direct test of deflection technique
- Enables study for low-cost space-based mission
- Supports comprehensive planetary defense through partnerships

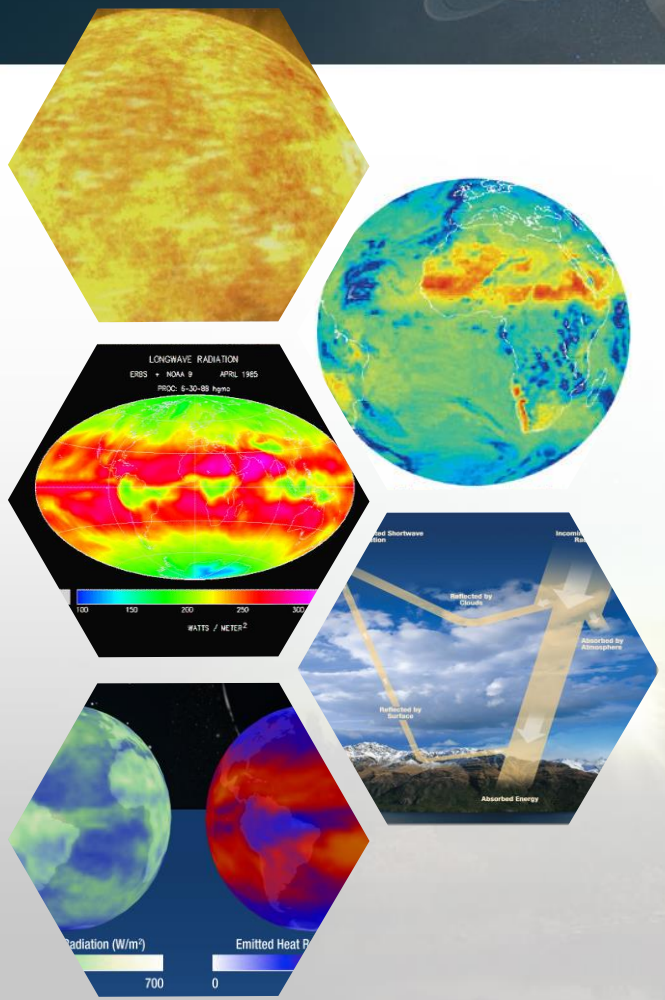
Space Weather

- Strengthens cross-agency collaboration on Research-to-Operations/Operations-to-Research, a priority of National Space Weather Action Plan
- Improve space weather prediction capabilities by leveraging partnerships with other federal agencies, academia, and private sector

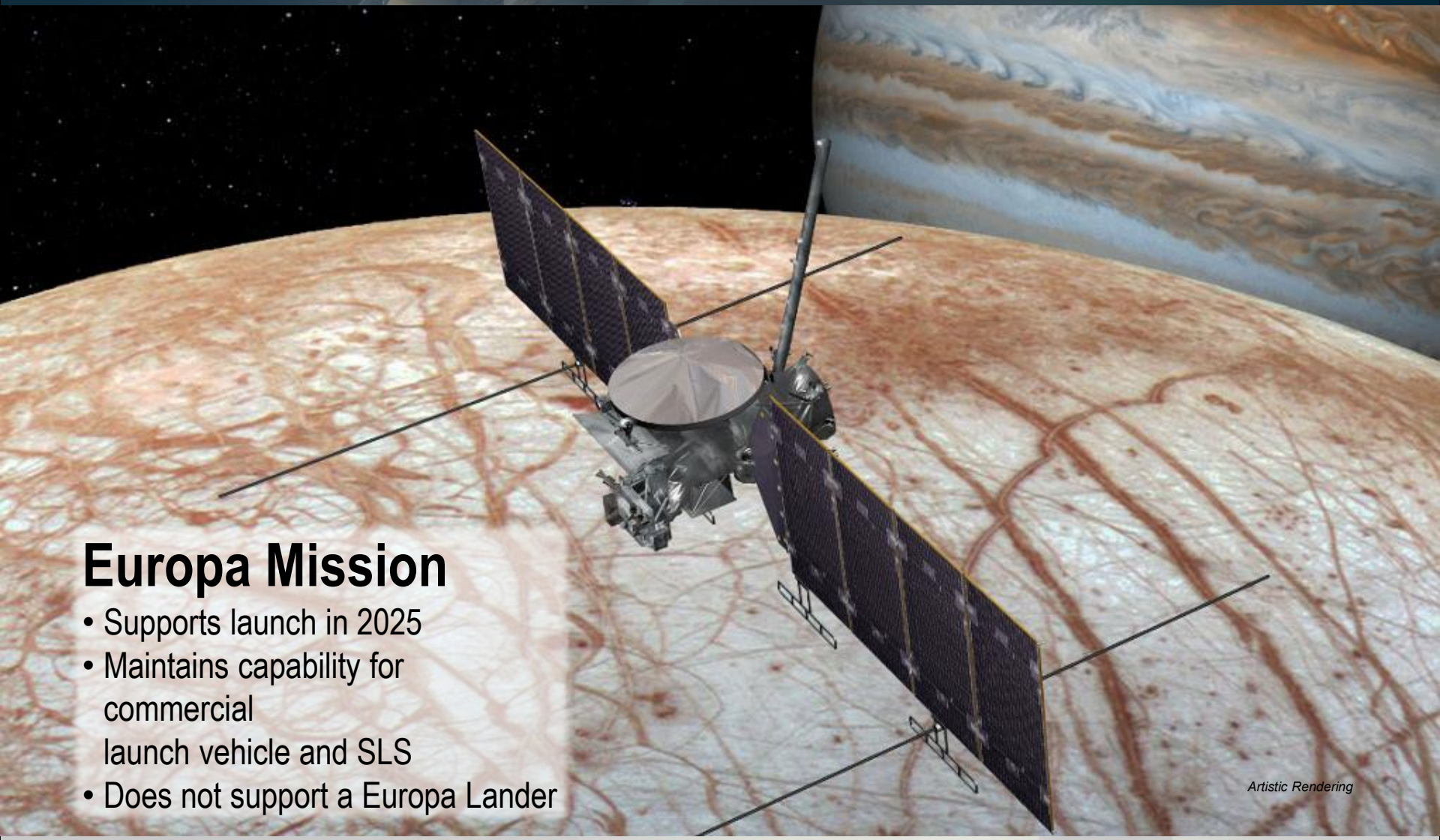
Earth Science

- Continues focused, balanced Earth science portfolio with new systematic mission launches
- Completes Landsat-9 for launch in CY2020 as cornerstone of Sustained Land Imaging System with USGS
- Healthy research and applied science programs, and SmallSat/CubeSat investments
- As in FY18 Presidential Budget Request, assumes termination of PACE, OCO-3, CLARREO Pathfinder, DSCOVR Earth-viewing instruments, and Carbon Monitoring System

Radiation Budget Instrument



- Radiation Budget Instrument (RBI), previously planned for flight on JPSS-2, terminated for technical and programmatic reasons
- Intention to develop a capable, affordable, radiation budget sensor/approach for launch no later than the 2026 time frame – consistent with the expected earliest launch date for JPSS-3
- Initiate a “Venture Class-Continuity” activity, consistent with 2017 Decadal recommendations, to specify, solicit, and develop the new sensor as soon as possible

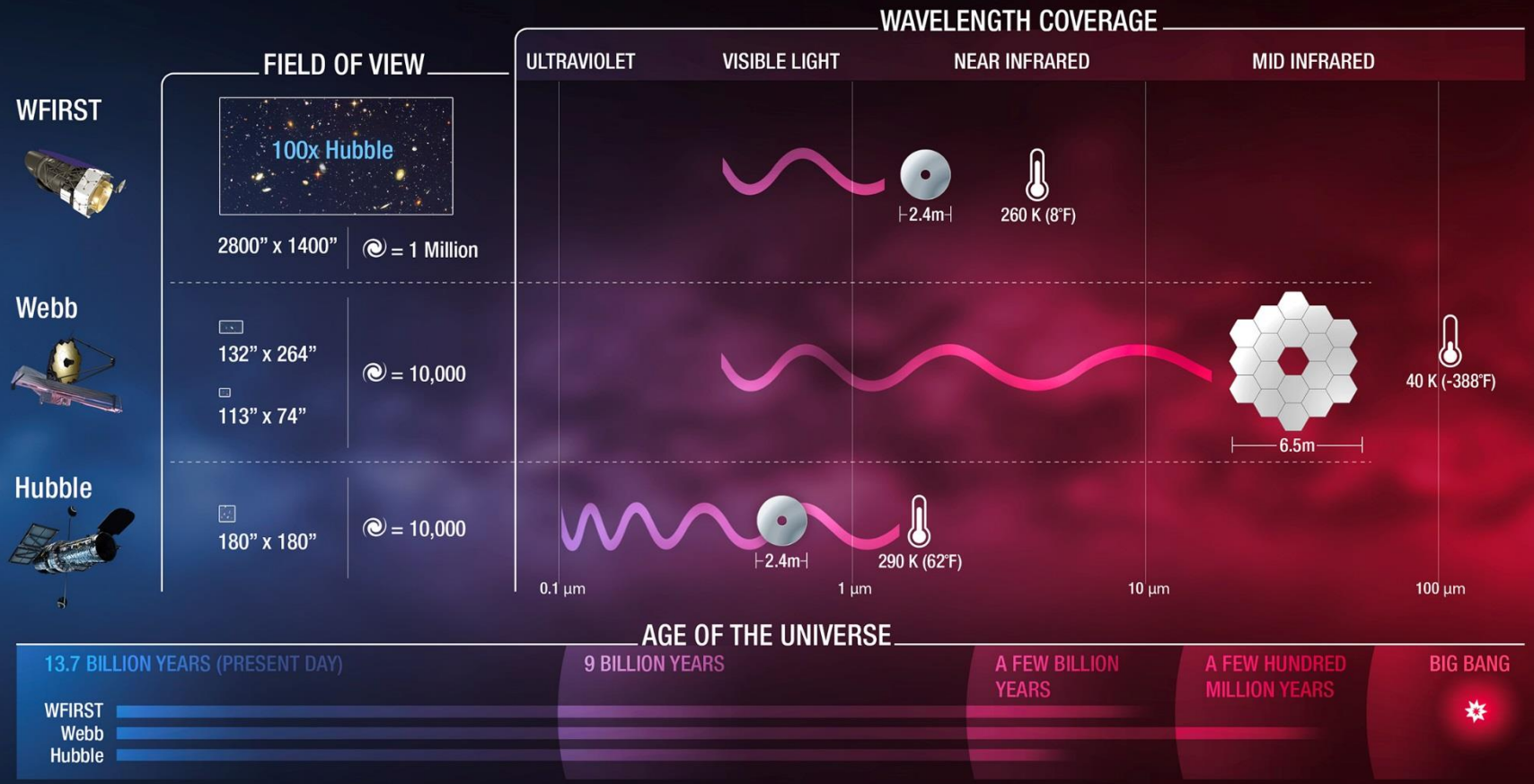


Europa Mission

- Supports launch in 2025
- Maintains capability for commercial launch vehicle and SLS
- Does not support a Europa Lander

Artistic Rendering

Great Observatories



WFIRST

- Given its significant cost within a proposed lower budget for Astrophysics and competing priorities within NASA, WFIRST terminated with remaining WFIRST funding redirected towards competed astrophysics missions and research
- Funds appropriated by Congress in FY18 will allow WFIRST to enter Phase B in April 2018
- If Congress adopts the Administration's request to terminate WFIRST, the funds made available would enable a competed Probe-class mission AO in FY19

Advance National Science and Exploration Goals

- Execute program informed by National Academy of Sciences **Decadal Surveys**
- Support for **Europa Clipper** mission, no funding for Europa lander
- Given its significant cost within a proposed lower budget for Astrophysics and competing priorities within NASA, **WFIRST** terminated with remaining WFIRST funding redirected towards competed astrophysics missions and research
- Continue leveraging innovation and partnerships, including **SmallSats/CubeSats** and commercial efforts
- Invest in innovative early-stage research and technology to promote **economic growth**