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. Steve Running, University of Montana, Chair, Earth Science Subcte
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)

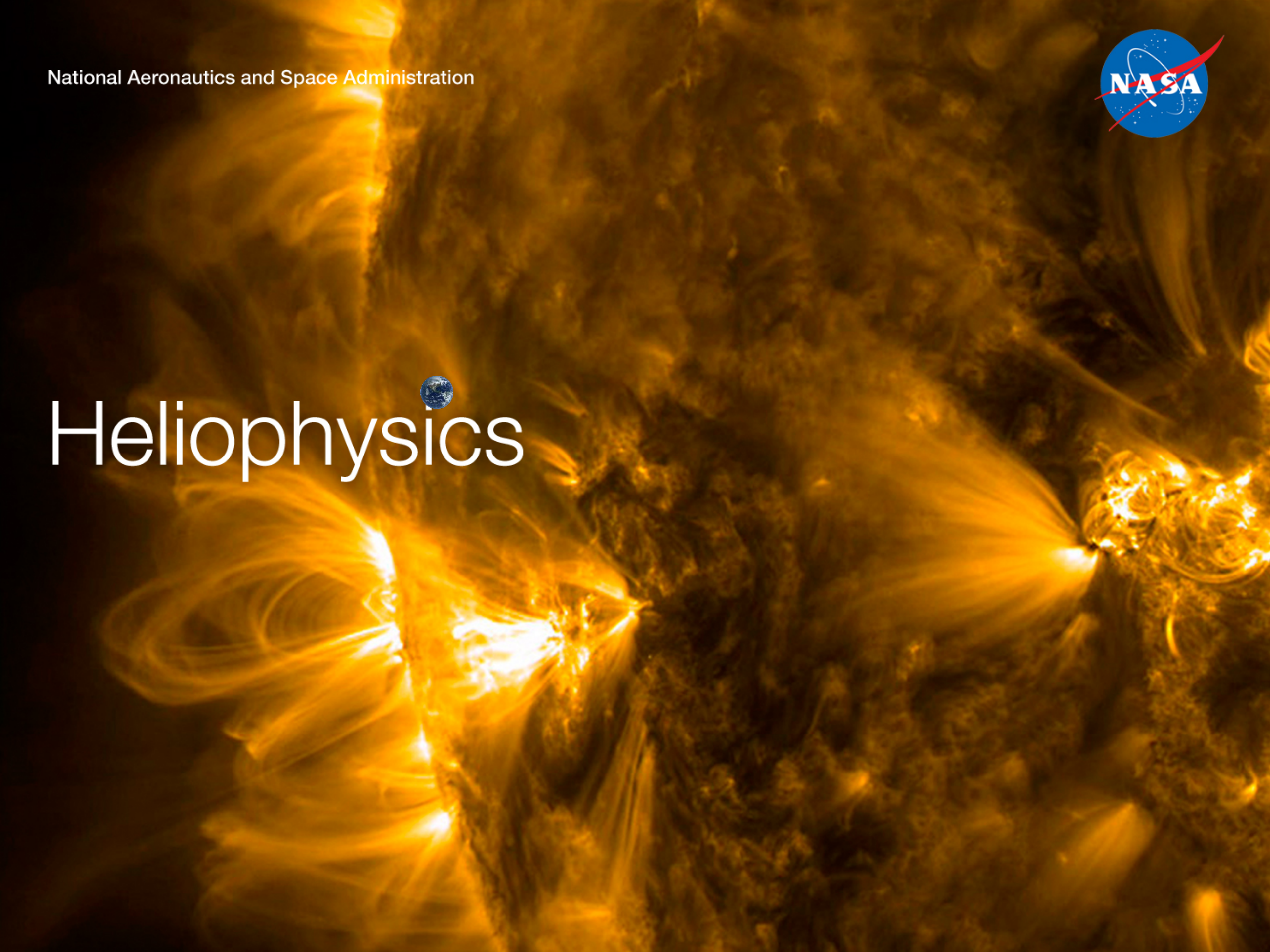
Dr. Doug Duncan, University of Colorado
Dr. Mark Robinson, Arizona State University
Dr. Susan Avery, Woods Hole Oceanographic Institute
Dr. Tamara Jernigan, Lawrence Livermore National Laboratory
Dr. Walter Secada, University of Miami
Dr. Mihir Desai, Southwest Research Institute
Dr. Kathryn Flanagan, Space Telescope Science Institute

Outline

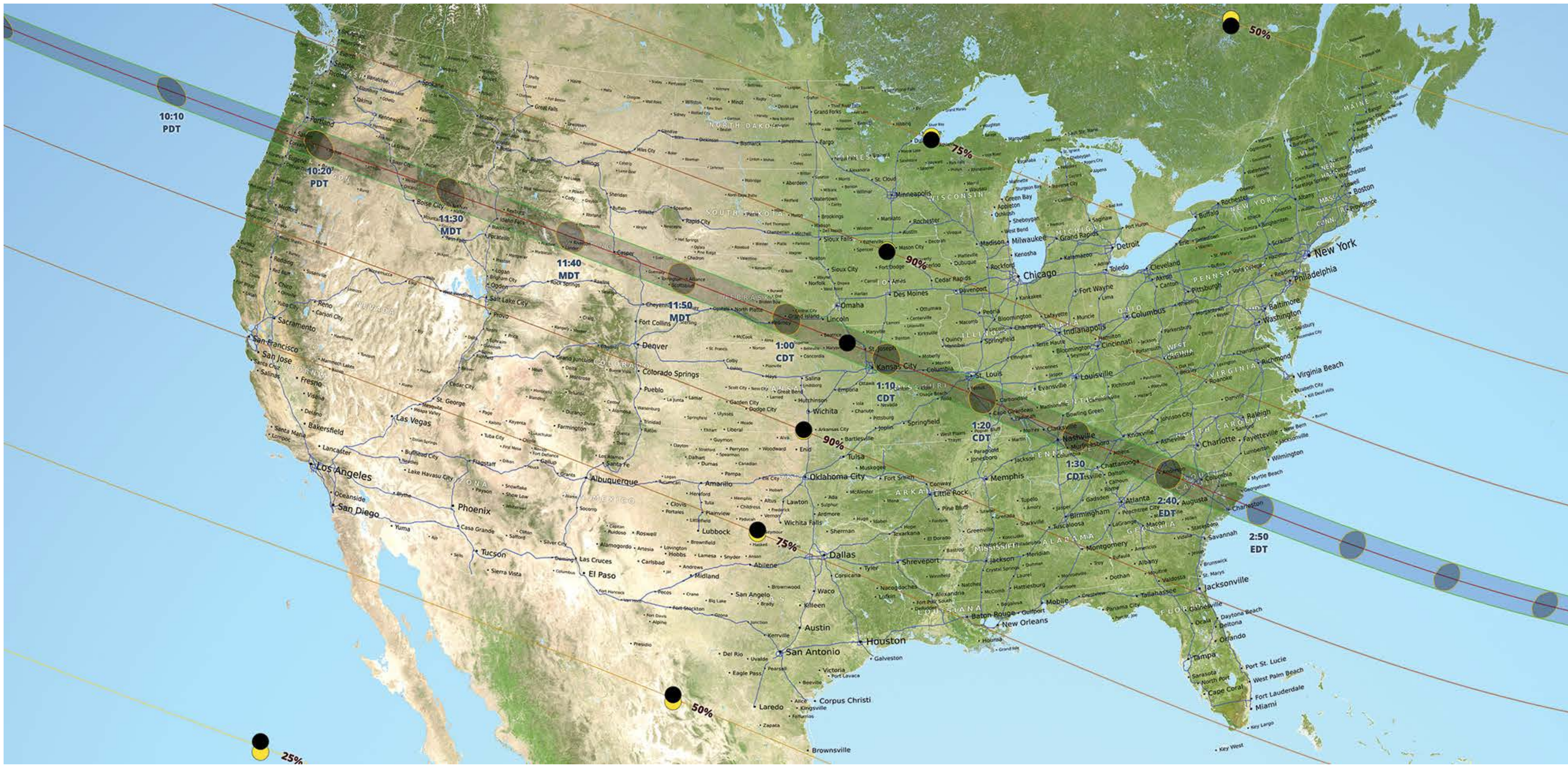
- **Science Results**
- Programmatic Status
- Findings

National Aeronautics and Space Administration

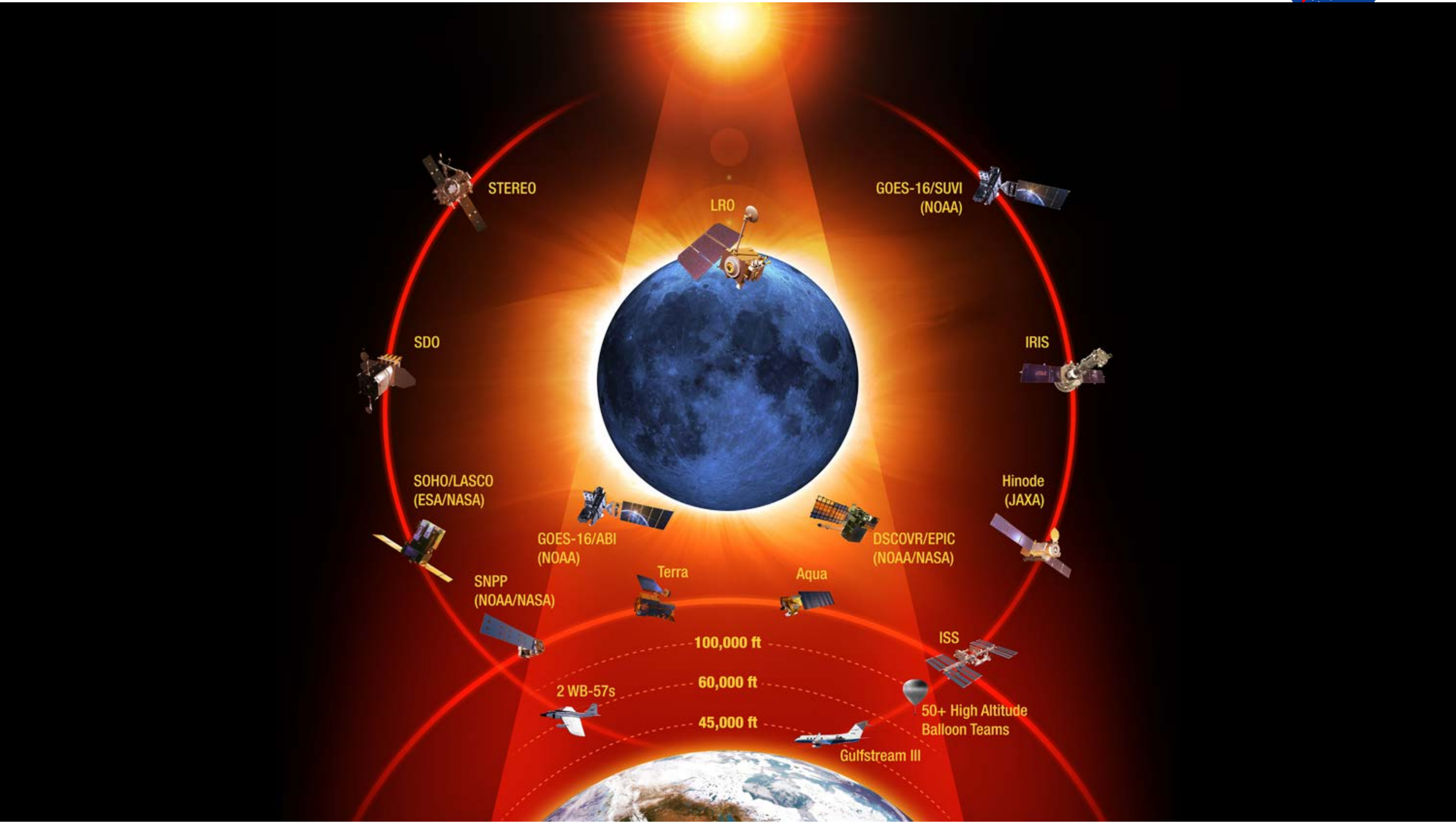
Heliophysics



AUGUST 21, 2017: First total solar eclipse visible in the contiguous United States in 38 years.
First coast-to-coast since 1918.
First just in the USA since 1778.

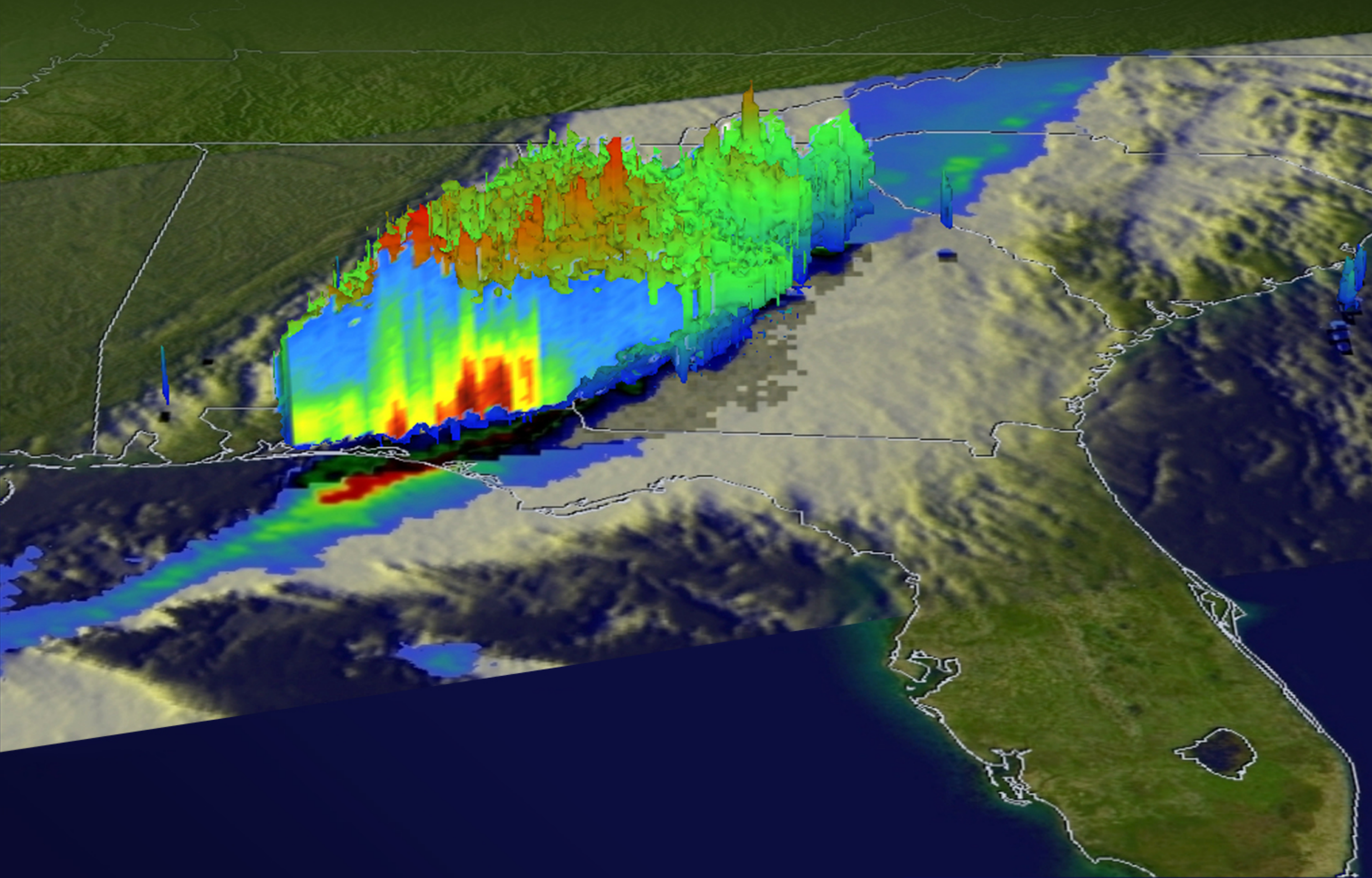


Credit: NASA's Scientific Visualization Studio



STEREO
LRO
GOES-16/SUVI (NOAA)
SDO
IRIS
SOHO/LASCO (ESA/NASA)
Hinode (JAXA)
GOES-16/ABI (NOAA)
DSCOVR/EPIC (NOAA/NASA)
SNPP (NOAA/NASA)
Terra
Aqua
ISS
100,000 ft
60,000 ft
45,000 ft
2 WB-57s
50+ High Altitude Balloon Teams
Gulfstream III

EARTH SCIENCE

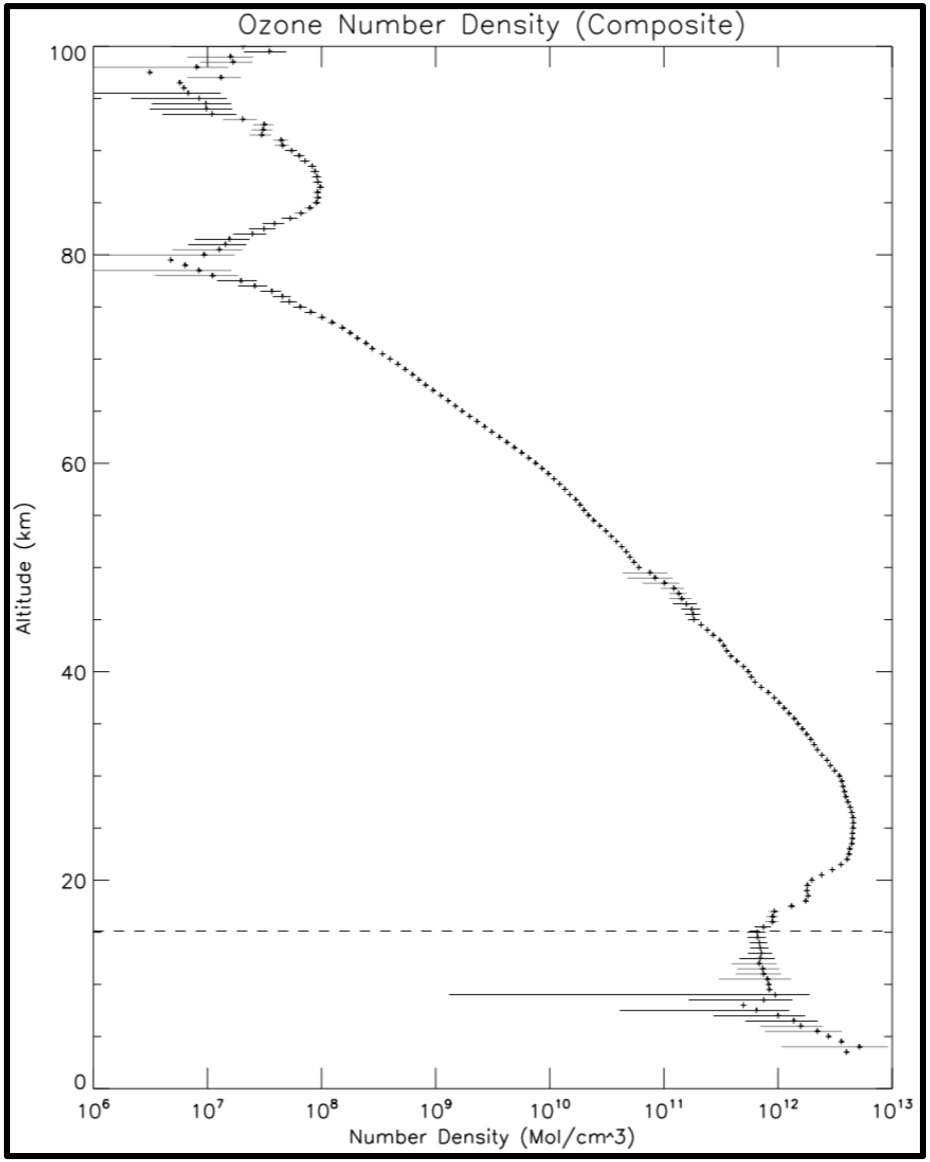


SAGE III on ISS
Ozone (O_3) Profile

SAGE III product development proceeding well

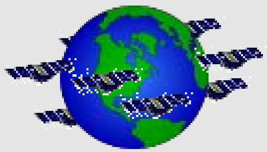
- O_3 profiles span the entire mesosphere, stratosphere and most of the troposphere* with 1km vertical resolution throughout
- O_3 density varies by 6 orders of magnitude over this altitude range
- Uncertainty estimates in individual profiles at the stratospheric peak are typically 0.5%
- Further improvements in overall data quality forthcoming prior to public release (software-settable bands)

(*as clouds permit)



Earth Venture & Trends

Constellations … Hosted … Sat Size … Temporal



CYGNSS

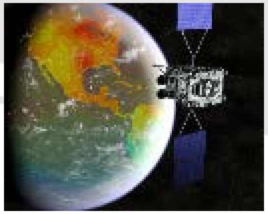
Cyclone Global Navigation Satellite System
8-microsat constellation
Launched 15.Dec.2016

TROPICS

Time-Resolved Obs. of Precipitation structure and storm Intensity with a Constellation of Smallsats
6-12 Cubesats; ~2021

TEMPO

Tropospheric Emissions: Monitoring Pollution
Hosted payload; ~2018
Geostationary platform

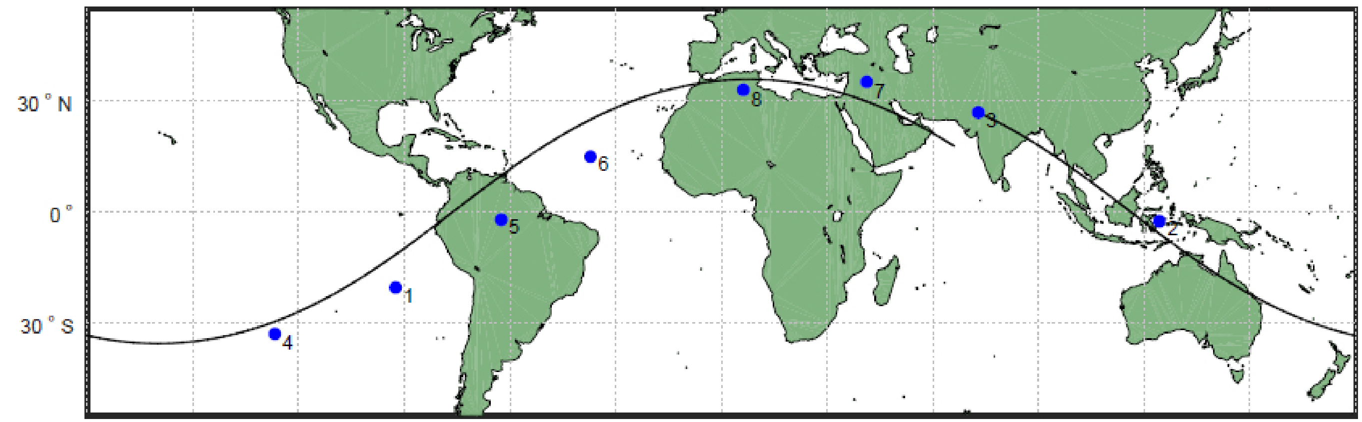


GeoCARB

Geostationary Carbon Observatory
Hosted payload; ~2021
SES Commercial Comm. Satellite

CYGNSS Constellation Spacing (weekly orbit report generated by SOC)

CYGNSS Constellation Status - 2017-07-12 00:00:00 UTC

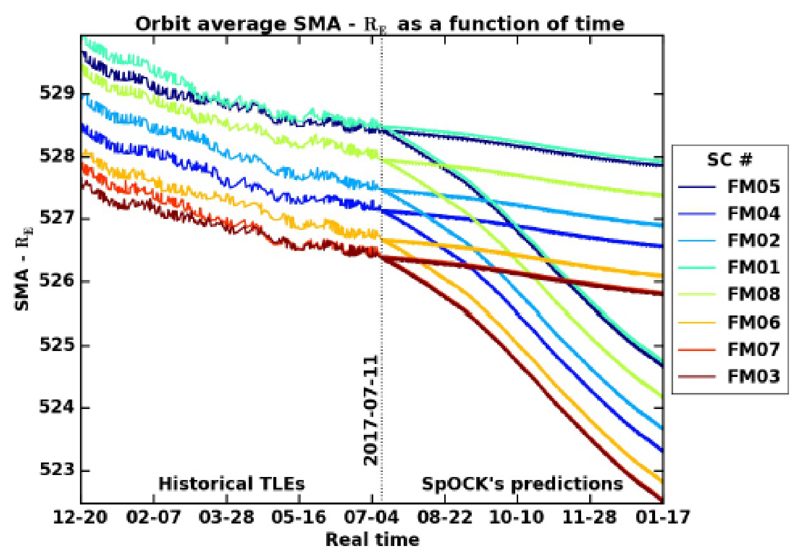


Position and Orbit

Observatory	Lat	Long	Perigee	Apogee
CYGFM01(0xF7)	-21.1	267.7	513.8	535.3
CYGFM02(0xF9)	-2.8	124.6	513.6	533.4
CYGFM03(0x2B)	27.1	73.1	513.7	531.3
CYGFM04(0x2C)	-32.9	233.4	513.6	532.6
CYGFM05(0x2F)	-2.3	297.7	513.9	535.0
CYGFM06(0x36)	15.4	323.1	513.5	531.9
CYGFM07(0x37)	34.5	41.5	513.4	531.4
CYGFM08(0x49)	32.6	6.5	513.8	534.3

Trailing Time, Distance, Phase Angle

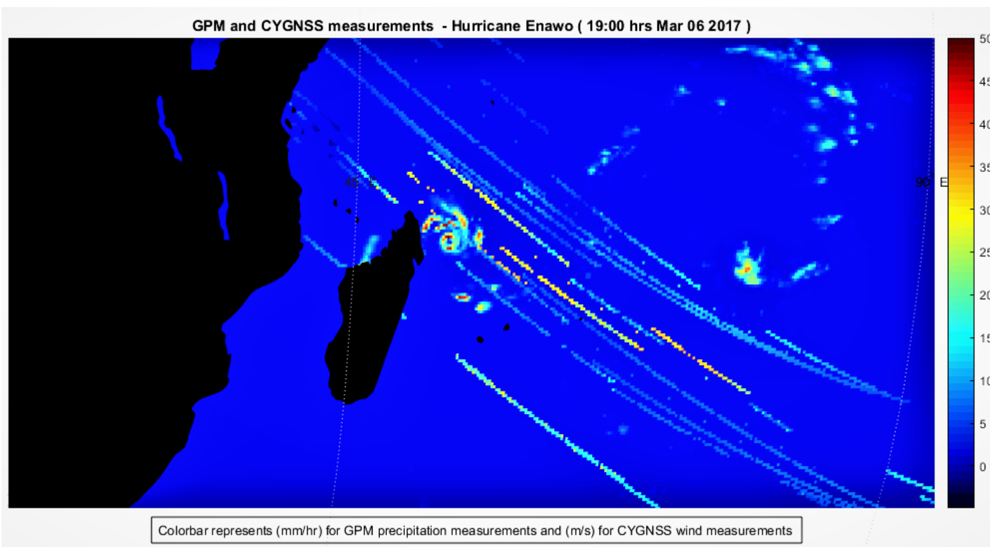
Observatory	Minutes	km	Deg
CYGFM03(0x2B)	0.0	0	0
CYGFM07(0x37)	7.4	3393	32
CYGFM08(0x49)	15.1	6903	67
CYGFM06(0x36)	26.5	12070	110
CYGFM05(0x2F)	34.6	15772	135
CYGFM01(0xF7)	43.8	19955	165
CYGFM04(0x2C)	52.4	23872	200
CYGFM02(0xF9)	79.8	36416	309

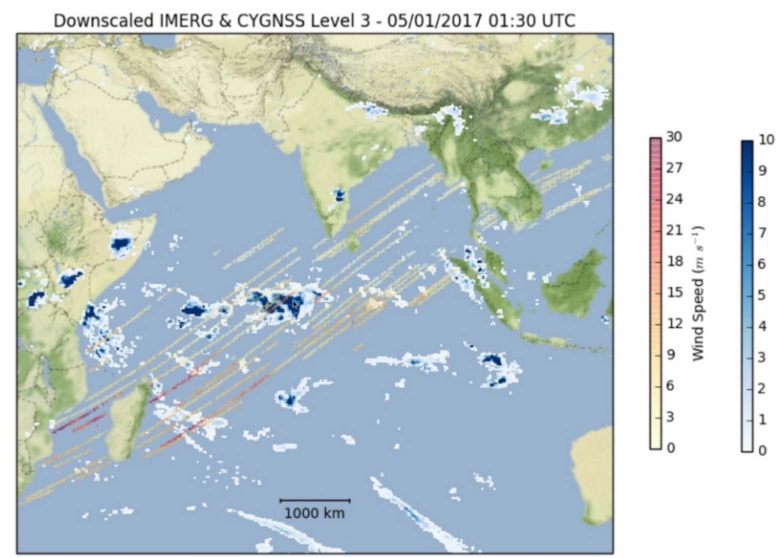


Historical and predicted orbit semi-major axis decay
Upper traces: nominal attitude
Lower traces: high drag attitude

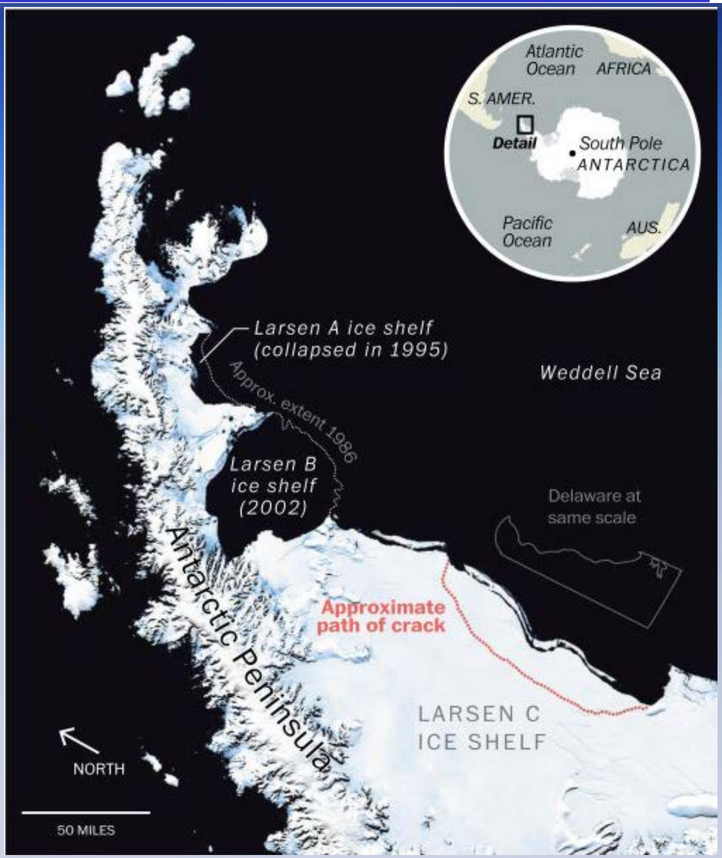
Wind imaging of a tropical cyclone and storm system

- CYGNSS wind speeds overlaid with GPM IMERG rain rates
- (left) Tropical Cyclone Enawo, 2017-03-06 at 19:00 UTC
- (right) Tropical convective storm system on 2017-05-01 at 01:30 UTC





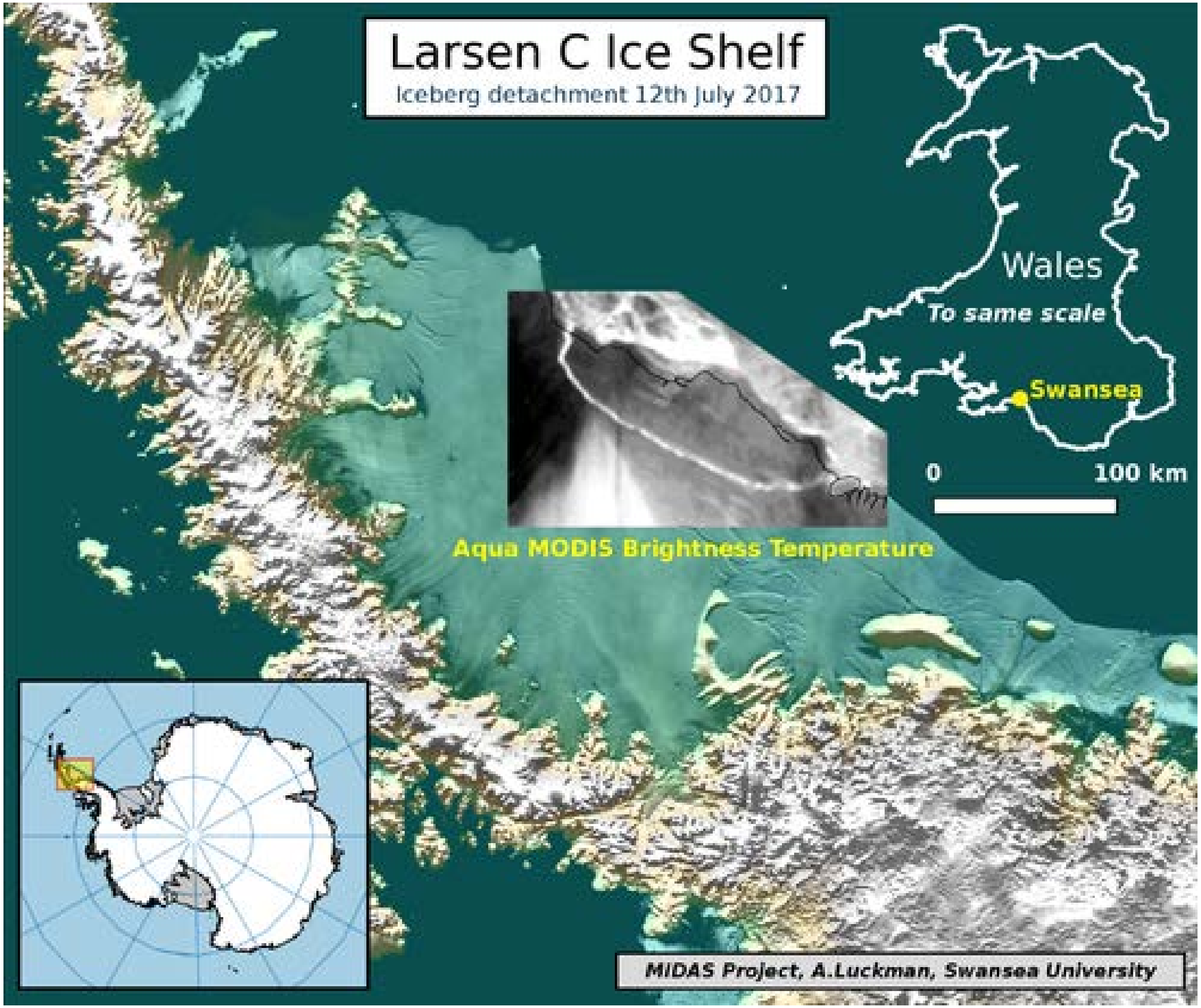
Larsen C Ice Shelf Calves Major Iceberg July 11, 2017



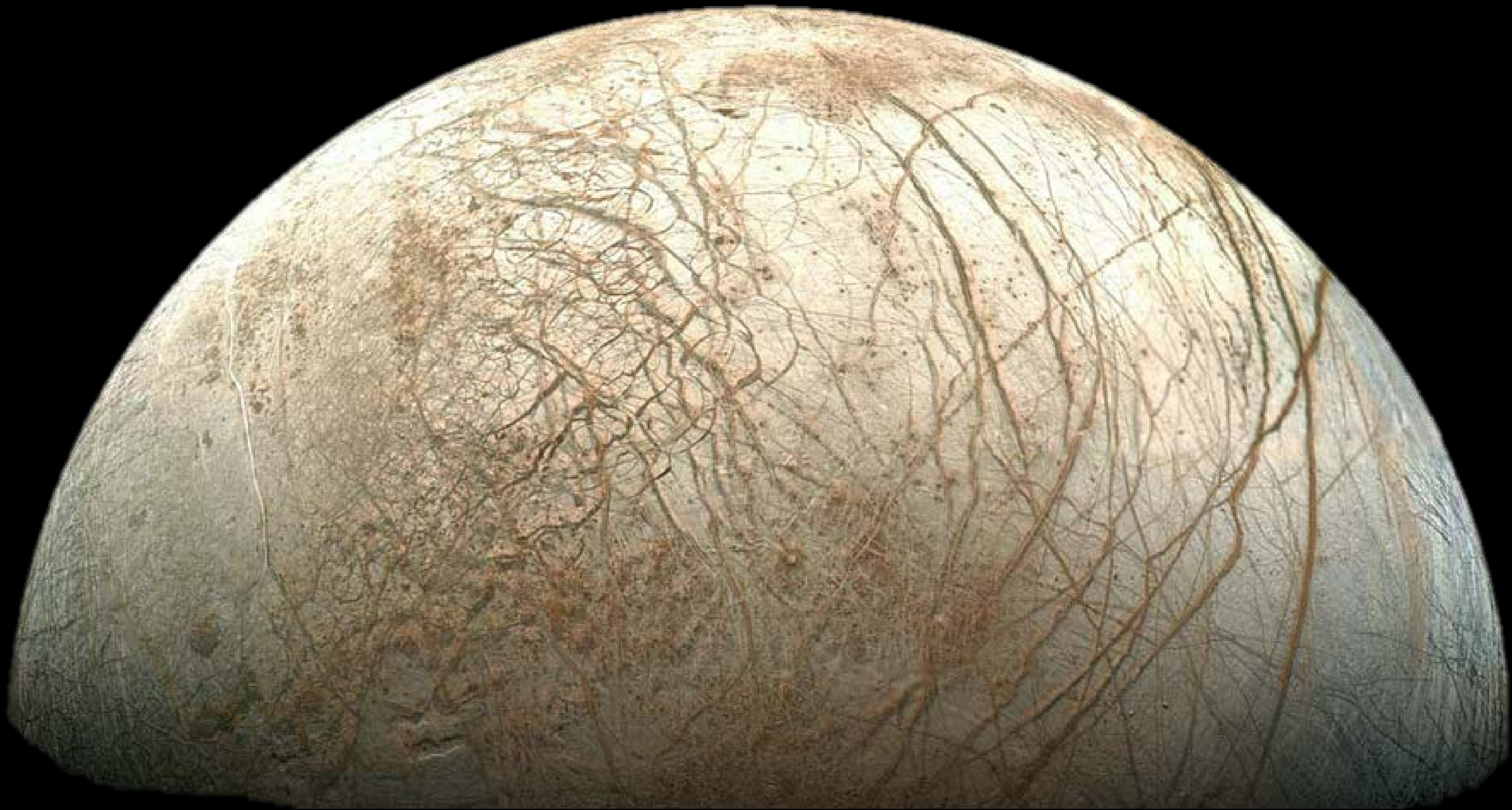
Map: NASA, ESA Sentinel, MIDAS Project. T Meko and D Lu/Wash Post

Photo of Larsen C rift in Antarctica, 10 Nov. 2016, courtesy of J Sonntag, NASA Operation IceBridge

Larsen C Ice Shelf Detachment, July 12, 2017

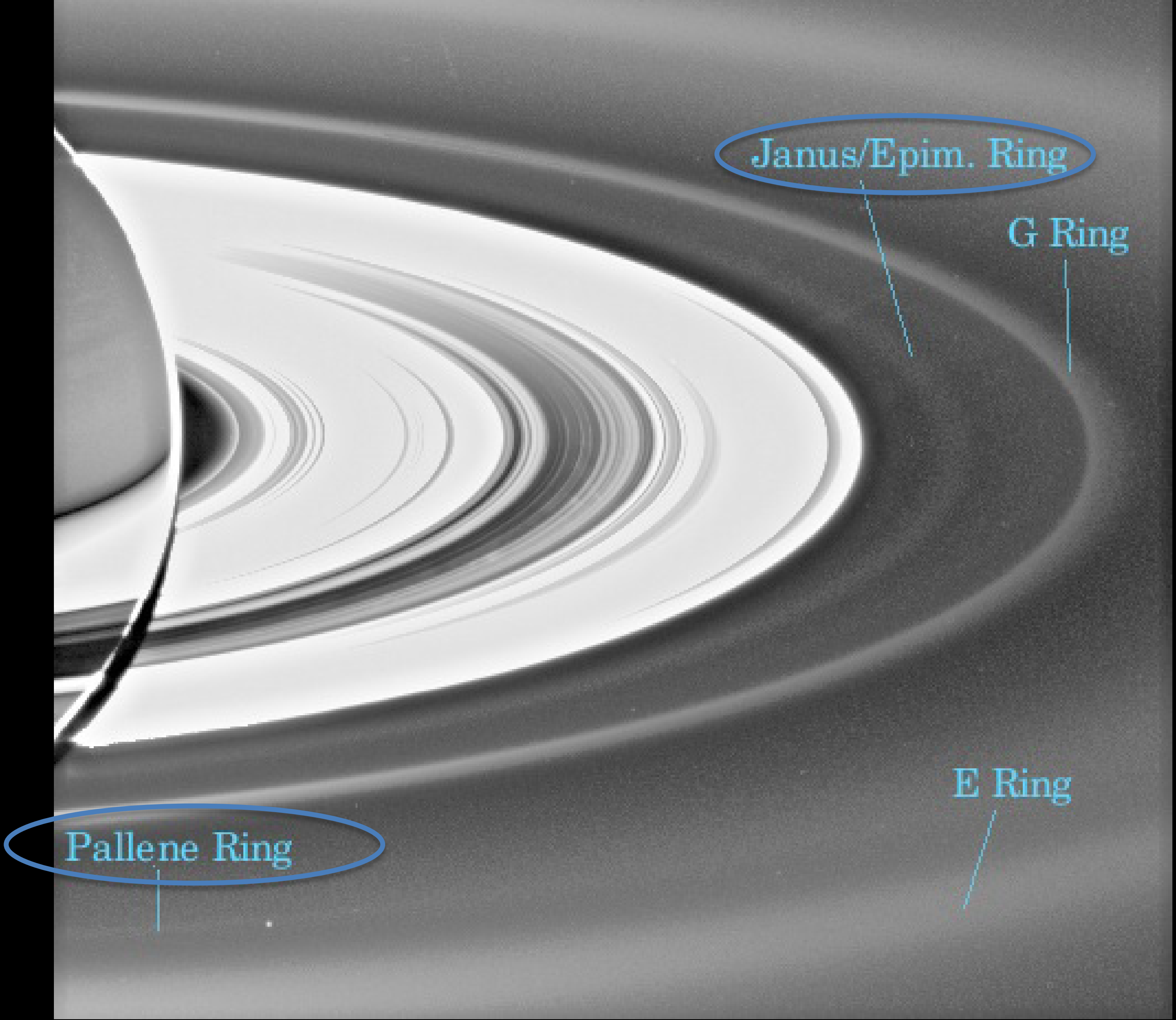


Planetary Science



CASSINI DISCOVERIES, 2004-2017
TITAN
HUYGENS DESCENT
IAPETUS' DICHOTOMY
TITAN SAND DUNES
RAIN ON TITAN
IAPETUS' RIDGE
ENCELADUS
PLUMES OF ENCELADUS
LIQUID ON TITAN
MIMAS THERMAL ANOMALY
RADAR OF ENCELADUS
NORTHERN LAKES
PHOEBE
LAKES ON TITAN
HYDROCARBONS ON HYPERION
SATURN POLAR STORMS, AURORAE
ENCELADUS FOOTPRINT
POLAR HEXAGON, STORM
PROXIMAL ORBITS
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
SATURN STORM
G RING SOURCE
SKR REVERSAL
SATURN ARRIVAL
F RING STRUCTURE
RING CURRENT DYNAMICS
RINGS AT EQUINOX
IMPACT / RIPPLE CONNECTION
NEW RINGS
PROPELLERS
SATURN
FUTURE DISCOVERIES
SEASONAL PLUME VARIATIONS
SATURN EQUATORIAL / POLAR / AURORAL STUDIES
OPEN RING COMPOSITION, DYNAMICS
MAGNETOSPHERE @ SOLAR MAX
SEASONAL CHANGE IN TITAN LAKES
DIONE & RHEA
RING MASS, SATURN INTERIOR

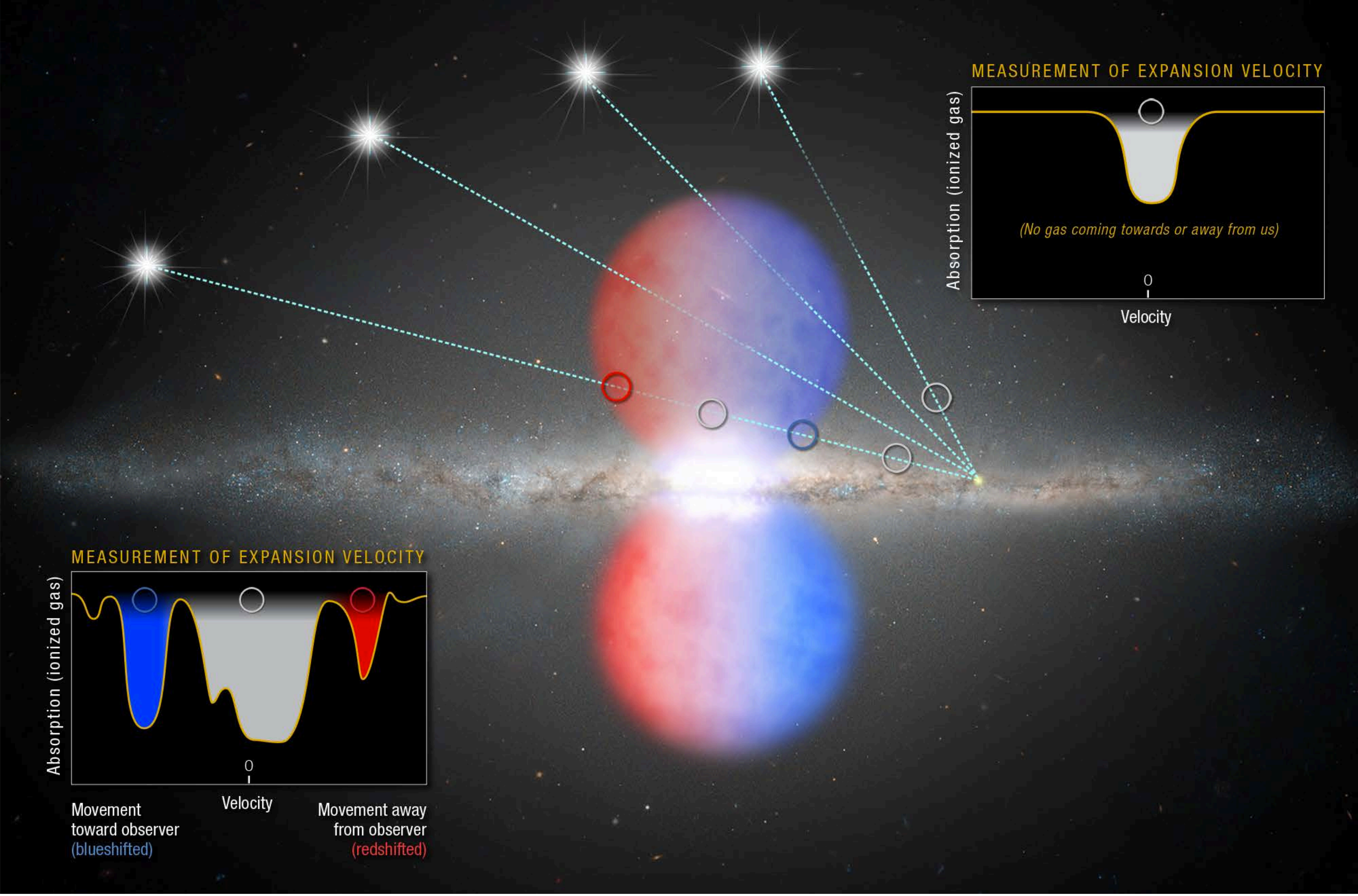
New Rings Discovered



High Resolution Images of the Moons

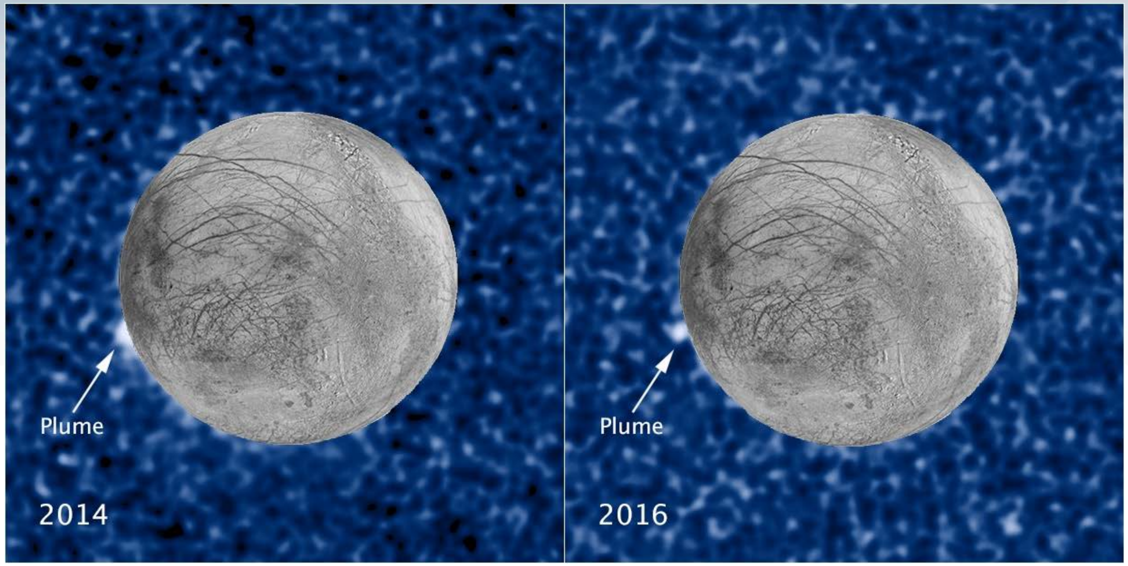

National Aeronautics and Space Administration
NASA
Astrophysics

Hubble Uses Quasar Light to Probe Outflow Bubbles in our Milky Way (Fermi bubbles)

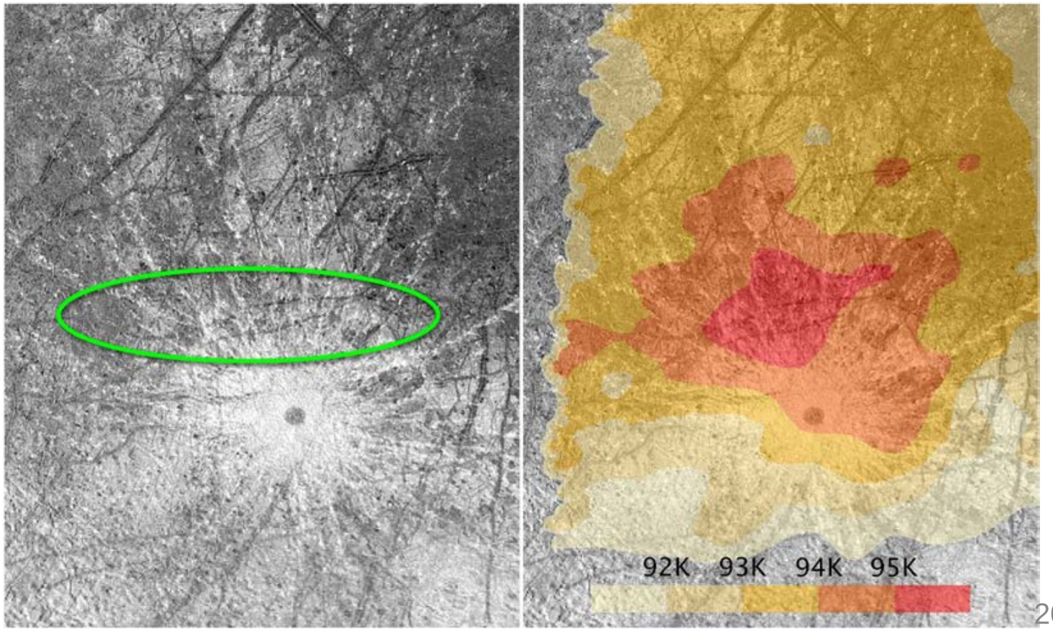


Credits: NASA, ESA, and Z. Levy (STScI)

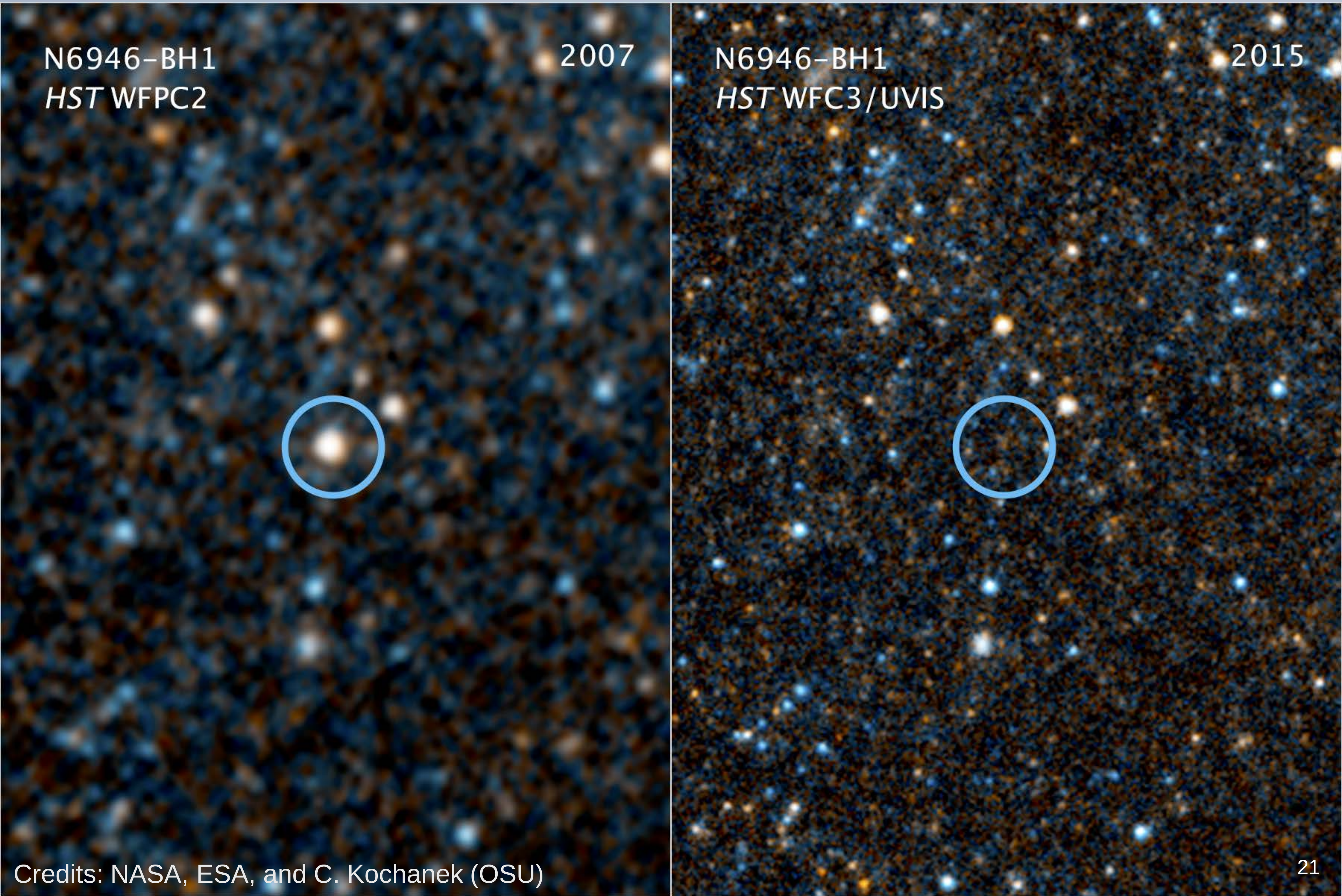
Hubble Observes Recurring Plume from Europa



Credits: NASA/ESA/STScI/USGS



Collapsing Star Gives Birth to a Black Hole



Credits: NASA, ESA, and C. Kochanek (OSU)

Recent Kepler Discovery

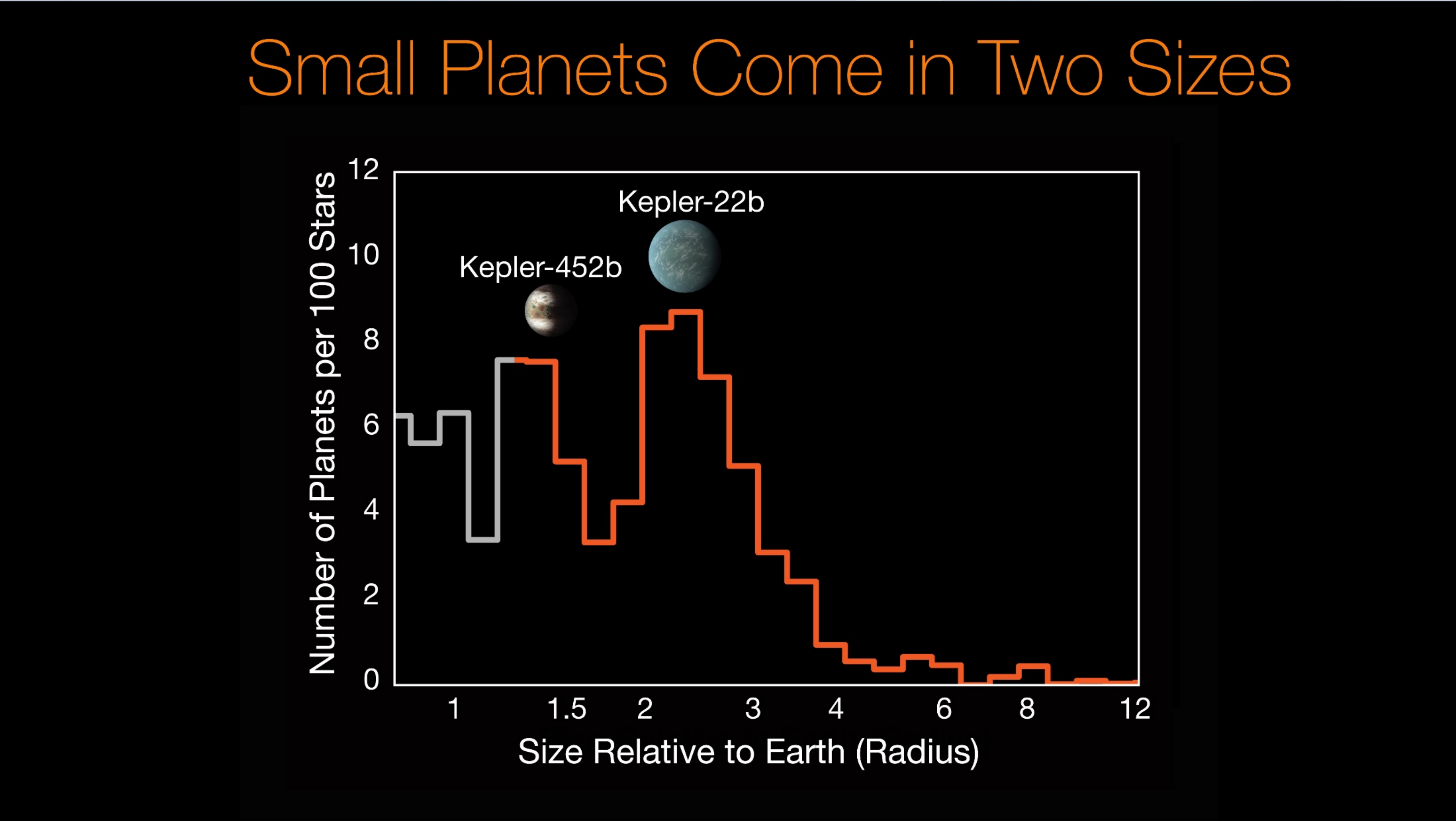
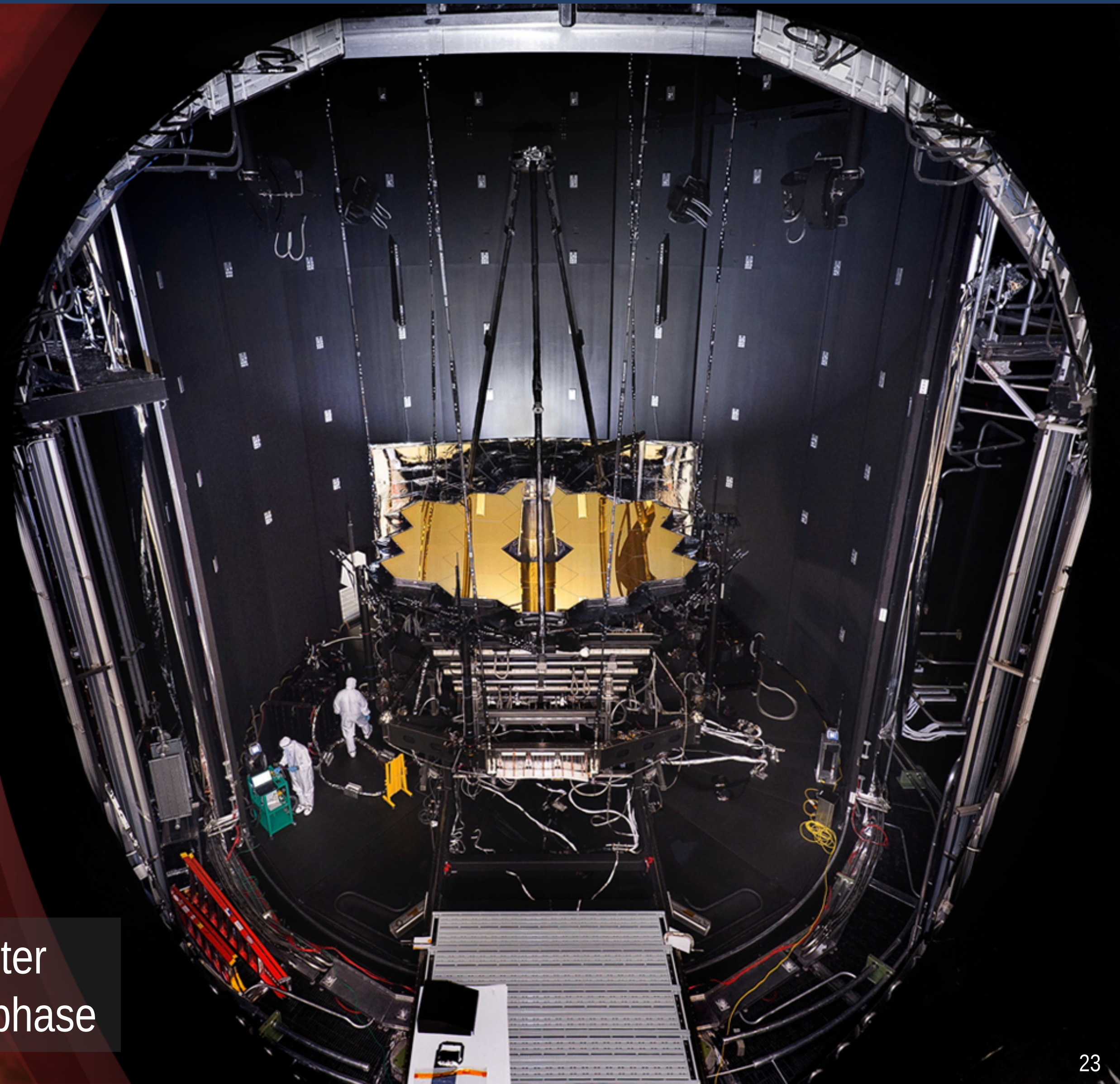


Image credit: NASA/Ames Research Center/Caltech/University of Hawaii/B.J. Fulton

Webb

The James Webb Space Telescope



WEBB at Johnson Space Center for cryogenic-vacuum testing phase

Astrophysics Missions in Development

ISS-NICER 6/3/2017
NASA Mission

Neutron Star Interior Composition Explorer

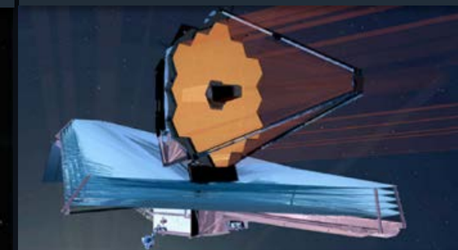
ISS-CREAM 8/2017
NASA Mission

Cosmic Ray Energetics And Mass

TESS 3/2018
NASA Mission

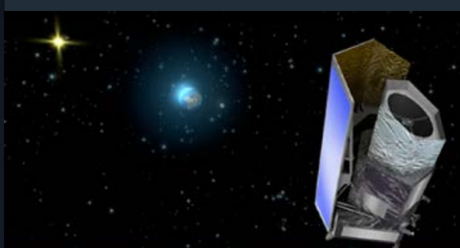
Transiting Exoplanet Survey Satellite

Webb 10/2018
NASA Mission



James Webb Space Telescope

Euclid 2020
ESA-led Mission

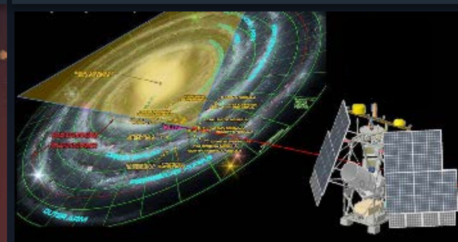


NASA is supplying the NISP Sensor Chip System (SCS)

IXPE 2020
NASA Mission

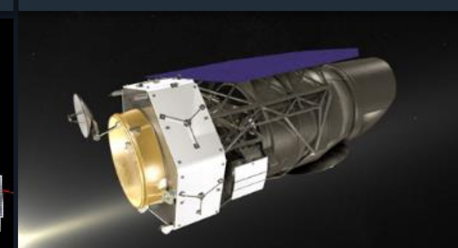
Imaging X-ray Polarimetry Explorer

GUSTO 2021
NASA Mission



Galactic/ Extragalactic ULDB Spectroscopic Terahertz Observatory

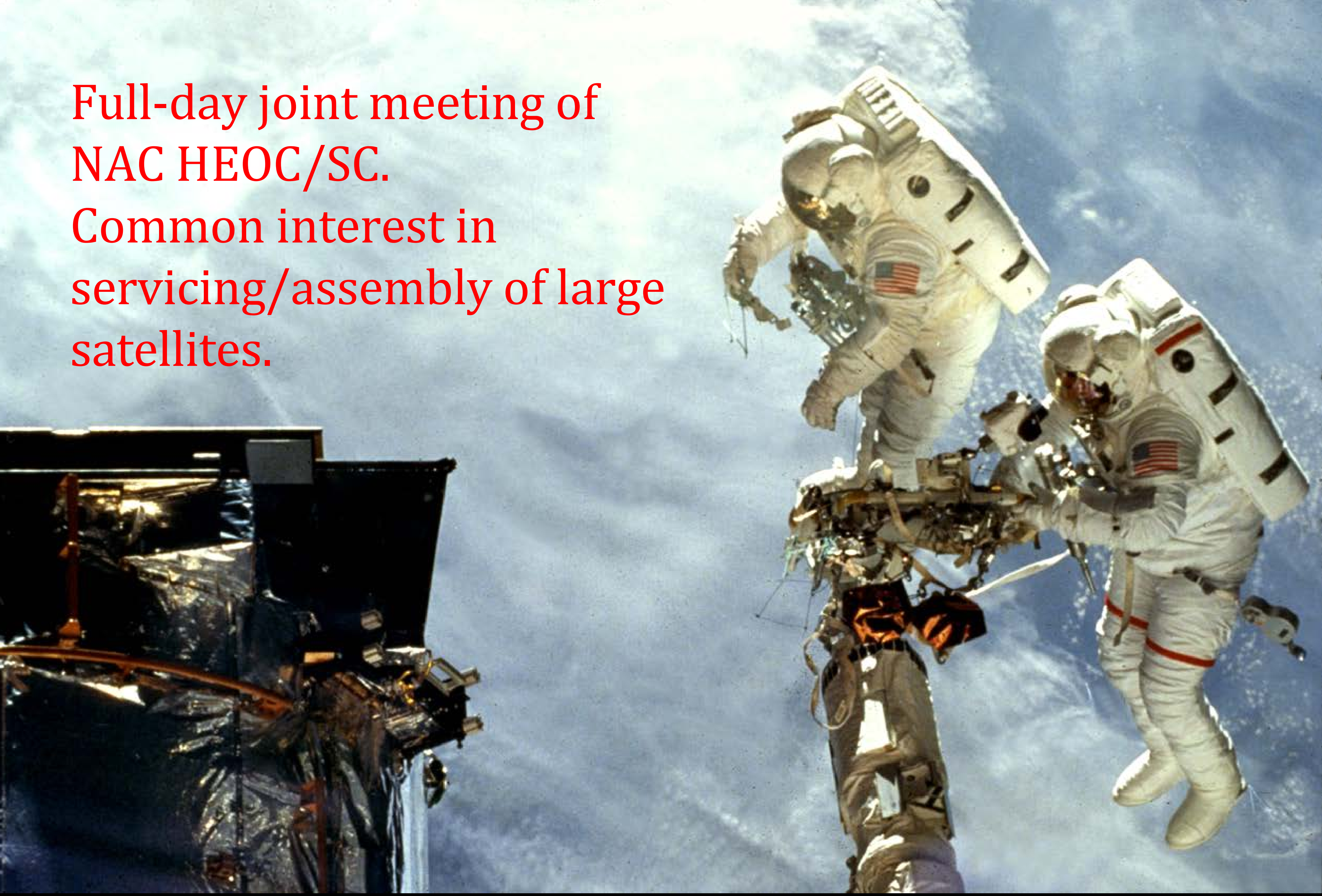
WFIRST Mid 2020s
NASA Mission



Wide-Field Infrared Survey Telescope

Full-day joint meeting of NAC HEOC/SC.

Common interest in servicing/assembly of large satellites.



NEXUS OF SCIENCE & HUMAN EXPLORATION

INTEGRATED PORTFOLIO

SMD has a high impact, integrated and multi-faceted portfolio

COMBINED EFFORT ACROSS TOPICAL AREAS

SMD science discipline areas interrelate to HEOMD with many synergies

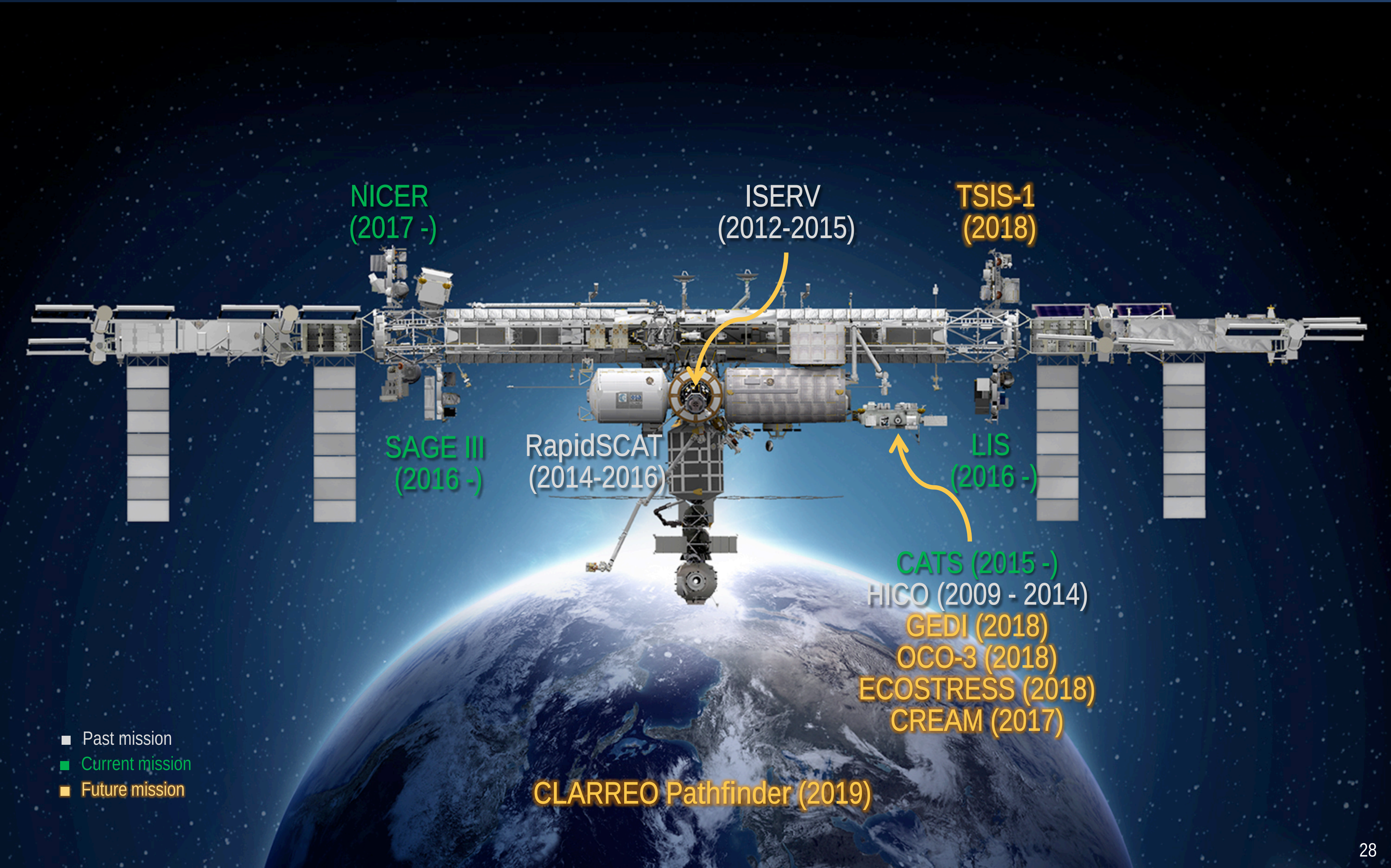
HUMAN ATTENDANT SCIENCE FUTURE OPPORTUNITIES

SMD utilizes ISS and will identify science opportunities within HEOMD's developing architecture, i.e., Gateway infrastructure

COMBINED EFFORT ACROSS TOPICAL AREAS

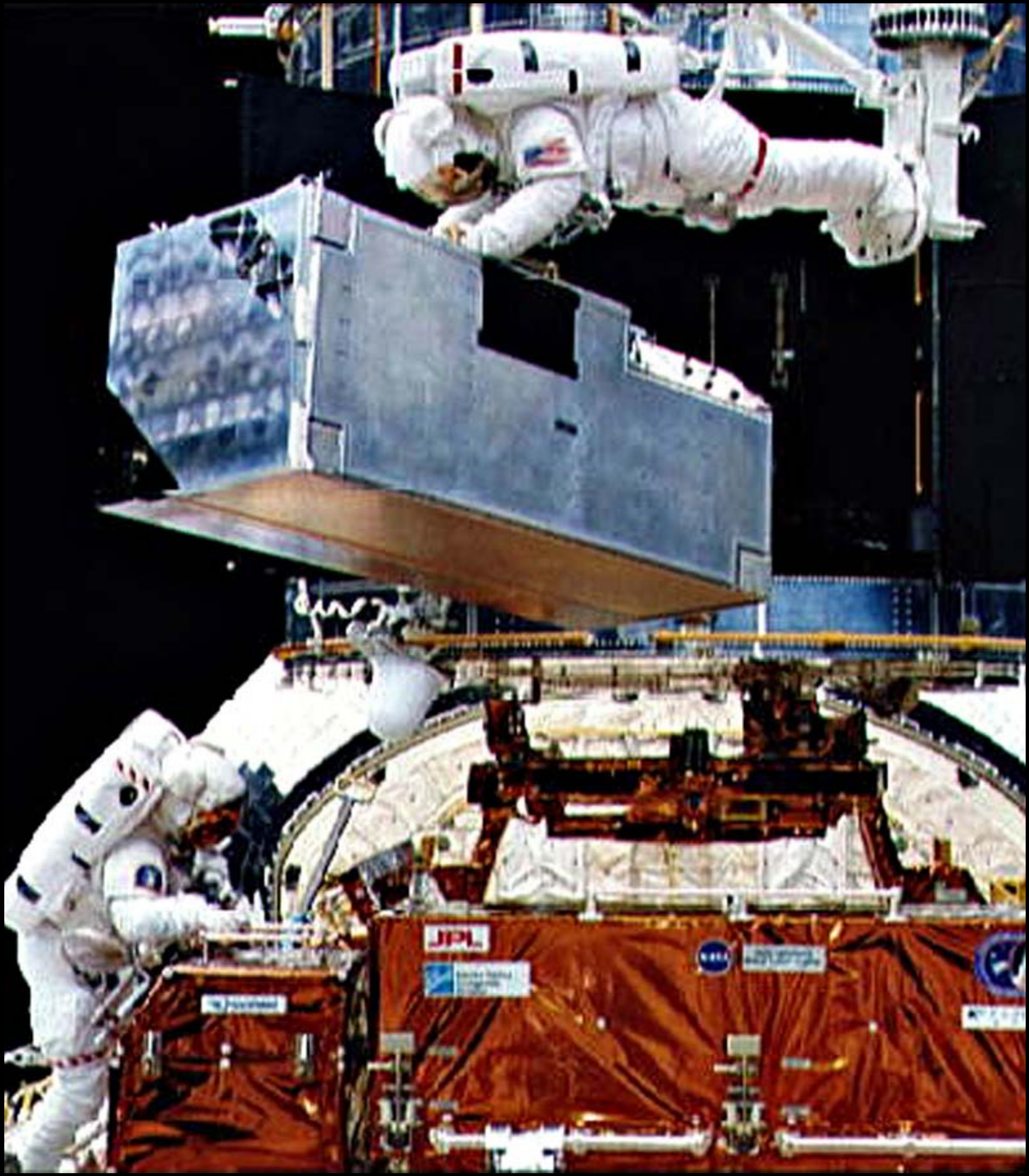
- Lunar Reconnaissance Orbiter
- Mars Exploration Program
  - Mars 2020 Partnership – borne out of current Mars strategy discussions
    - Partnership on HEO/Space Technology Mission Directorate (STMD) instrumentation - Mars EDL Instrumentation (MEDLI-2), Mars Oxygen ISRU Experiment (MOXIE), and Mars Environmental Dynamics Analyzer (MEDA)
  - Working together to study potential future landing sites for crewed missions to Mars
- Studying space weather and the effect of space radiation on astronauts
- Deep Space Optical Communications (DSOC)
- Other areas of collaboration
  - Launch Services
  - Space Communications and Navigation (SCaN)
  - Planetary Protection

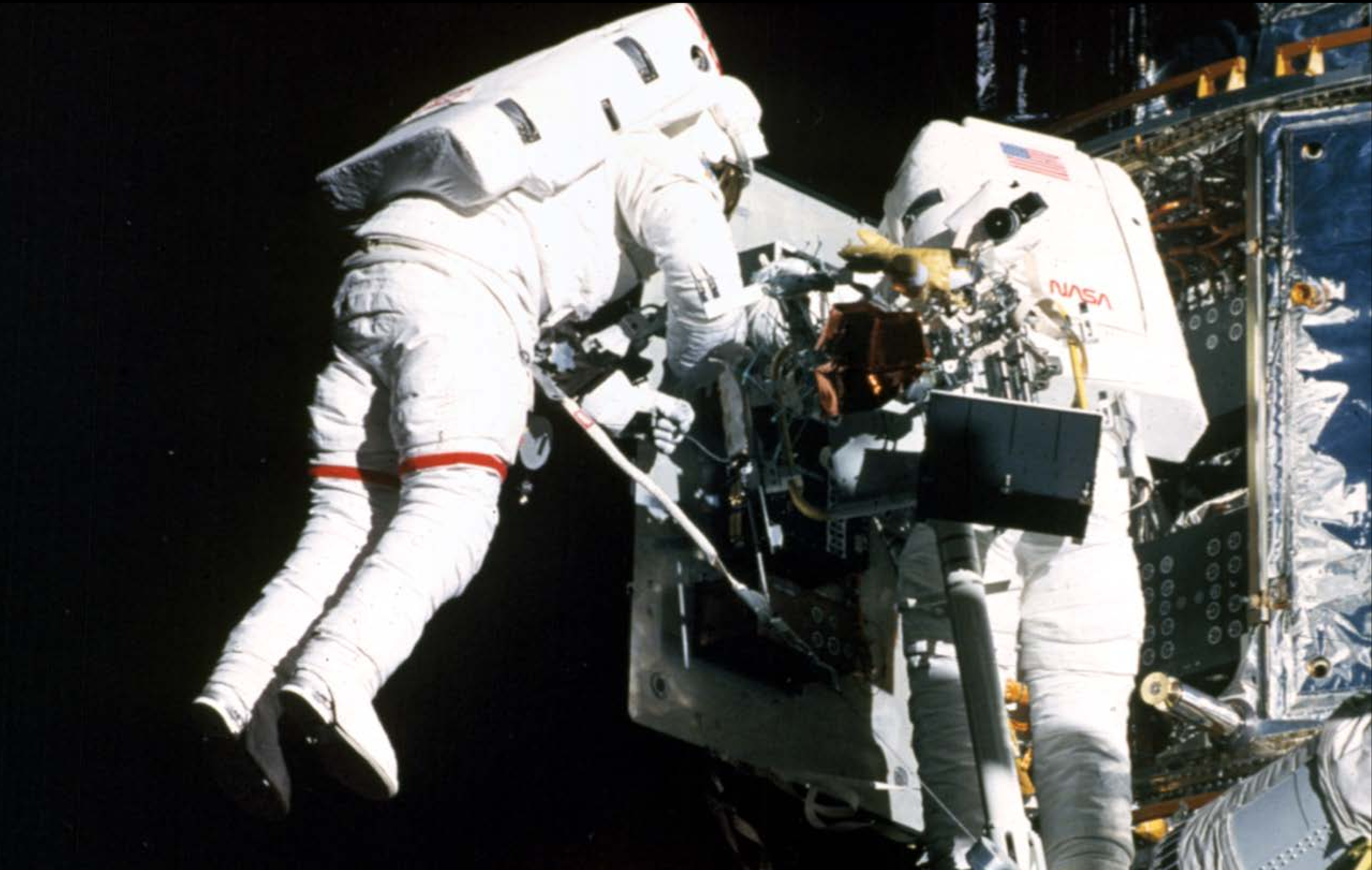
SCIENCE INSTRUMENTS ABOARD ISS



Large Space Telescopes

Two independent presentations on servicing and assembly of large telescopes by Jeff Hoffman (MIT) and Ron Polidan (Future Assembly and Servicing Study Team [FASST]), an area of strong confluence for HEOMD and SMD.




NASA

Fundamental Principles

- The more complex a system is, the more likely it is for something to go wrong
- Design for servicing from the start (mandated by Congress for future large telescopes)
- Allow for new technology
- Make servicing tasks robot-compatible
- Make servicing safe, but be flexible on human rating
- Control and document configuration

Community Technical Interchange Meeting (TIM) on Future Priorities in Astrophysics Enabled by In-Space Servicing and Assembly

NASA GSFC, November 1 – 3, 2017 (FASST activity)

Major developments in space exploration will take place in the coming decade that have the potential to significantly enhance cost-effective science return from major space astrophysics missions:

- Significant reduction in cost of medium-lift launch vehicles
- Continued advances in robotic/telerobotic capabilities: refueling, upgrading, assembly
- Deployment in cis-lunar space of a long-duration human-occupied “Gateway” ops site

First in a series of three-day technical interchange meetings that will bring together ~60 professionals to assess current and near-future capabilities and investments, technology gaps, mission requirements, and opportunities for collaborative work that will take advantage of these developments. Attendees will be SMEs invited from NASA and other government agencies, industry, and academia.

TIM organizing team consists of a representative from each “decadal survey” study, NASA SMD & STMD, the industry “Gateway” studies, DoD, SMEs from NASA Centers, and other experienced industry leaders.

R&A Charge

SCaN 20 Year Plan

Observation of
Kuiper Belt Object
2014 MU69

NASA SMD FY18
BUDGET

Selected Other Reports

FY 2018 PROGRAM HIGHLIGHTS

- Supports formulation of the **Europa Clipper** mission
  - FY 2018 Request is consistent with 2022 **Clipper** launch
- Includes an SMD-wide initiative to use CubeSats/SmallSats to advance selected high-priority science objectives in a cost-effective way
- Supports formulation of **WFIRST**
  - Entered Phase A formulation in February 2016
  - FY 2018 and notional outyear budget profile supports launch as early as 2025
  - Independent review of science, cost and schedule completed this summer
- Supports launch of **ICON, GRACE-FO, InSight, ICESat-2, TESS**, and **SPP** in FY 2018, and final preparations of **JWST** for launch in October 2018
- Fully funds all operating missions (except NASA support of **DSCOVR**)
- Supports the Space Weather Action Plan
- Supports all planned activities in the STEM Science Activation project, unchanged by the proposed termination of the Office of Education

SCIENCE BUDGET REQUEST SUMMARY

	Actual	Enacted	Request		Notional		
	FY 16	FY 17	FY 18	FY 19	FY 20	FY 21	FY 22
Science	**5,584.1**	**5,764.9**	**5,711.8**	**5,728.7**	**5,728.7**	**5,728.7**	**5,728.7**
Earth Science	**1,926.6**		**1,754.1**	**1,769.1**	**1,769.1**	**1,769.1**	**1,769.1**
Earth Science Research	477.7		406.7	435.1	441.1	459.7	477.8
Earth Systematic Missions	914.6		778.0	787.1	755.0	708.7	680.4
Earth System Science Pathfinder	233.6		264.5	243.8	256.0	271.5	268.3
Earth Science Multi-Mission Operations	192.4		196.5	194.1	200.7	208.6	218.6
Earth Science Technology	60.7		60.4	59.7	63.6	65.9	67.8
Applied Sciences	47.6		47.9	49.3	52.8	54.7	56.3
Planetary Science	**1,628.0**		**1,929.5**	**1,921.4**	**1,916.4**	**1,911.4**	**1,911.4**
Planetary Science Research	274.0		291.5	295.1	298.4	298.9	304.7
Discovery	189.0		306.1	425.4	488.3	376.8	375.2
New Frontiers	194.0		82.1	121.7	169.4	227.8	307.0
Mars Exploration	513.0		584.7	562.5	530.4	356.9	450.7
Outer Planets and Ocean Worlds	261.0		457.9	318.1	229.3	446.2	267.2
Technology	197.0		207.2	198.6	200.6	204.8	206.6
Astrophysics	**762.4**		**816.7**	**1,045.8**	**1,153.2**	**1,200.6**	**1,200.4**
Astrophysics Research	192.8		204.4	220.5	225.4	261.9	288.1
Cosmic Origins	195.6		191.6	190.0	142.0	157.8	156.4
Physics of the Cosmos	125.3		99.9	109.4	111.1	93.6	93.7
Exoplanet Exploration	141.2		176.0	350.8	473.3	475.8	440.2
Astrophysics Explorer	107.6		144.7	175.1	201.3	211.5	222.1
James Webb Space Telescope	**620.0**	**569.4**	**533.7**	**304.6**	**197.2**	**149.8**	**150.0**
Heliophysics	**647.2**		**677.8**	**687.8**	**692.8**	**697.8**	**697.8**
Heliophysics Research	160.0		200.2	217.2	214.8	219.0	219.5
Living with a Star	337.1		381.0	255.9	123.3	118.9	122.1
Solar Terrestrial Probes	49.5		37.8	97.9	171.5	185.1	191.1
Heliophysics Explorer Program	100.6		58.9	116.8	183.1	174.9	165.1

Research and Analysis (R&A) Charge to the SMD Advisory Committees

Good practice to periodically step back and review processes to gain insight and spot new opportunities. This charge was formulated by SMD (Front Office, Division Directors, R&A Leads & Division Advisory Committee Exec Secs) and the NAC Science Committee (SC).

Two Questions:

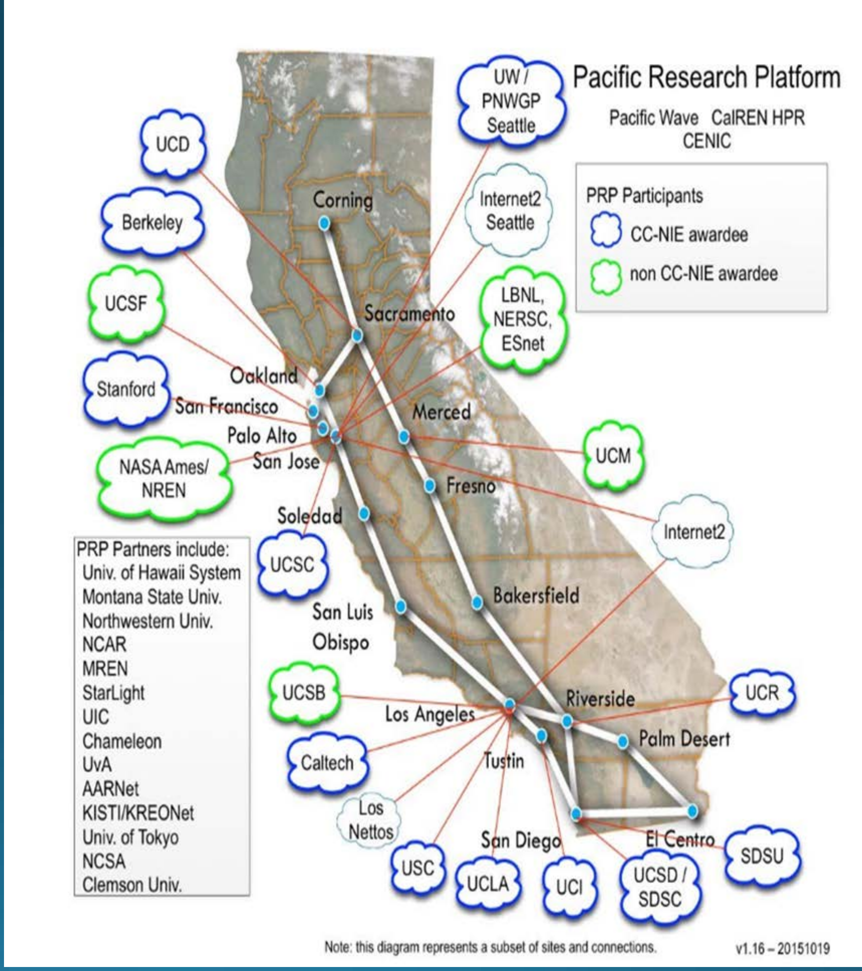
1. Does the SMD R&A program have effective processes in place to solicit, review and select high-impact/high-risk projects?

2. Does the SMD R&A program have effective processes in place to solicit, review and select focused, interdisciplinary, and interdivisional projects?

Big Data Task Force

NAC SC has asked the four SMD division advisory committees to report back on 4 BDTF recommendations:

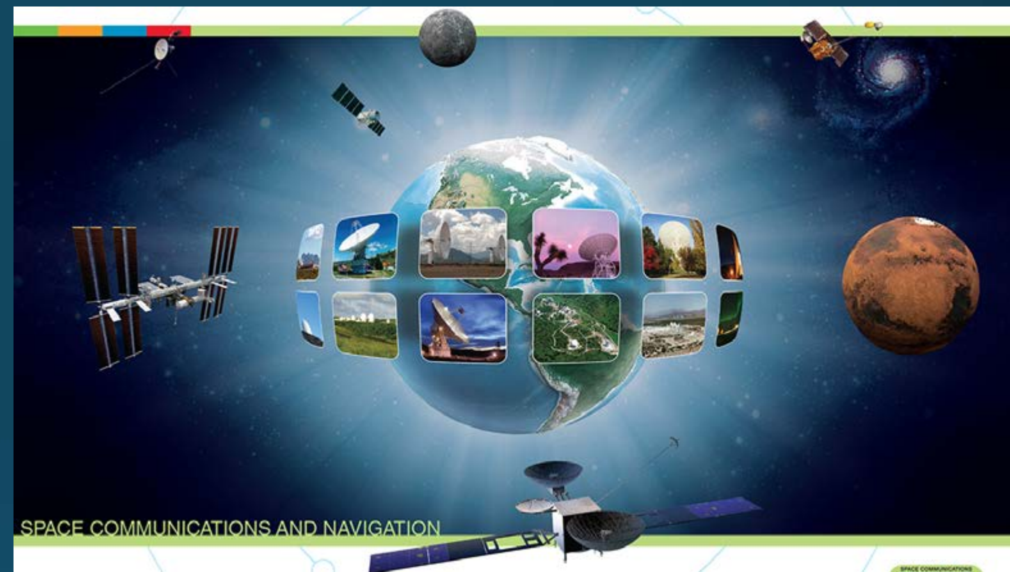
1. NASA Participation in DOE's Exascale Computer Program
2. Joining the National Data Superhighway
3. Joint Program with NSF's Big Data Innovation Regional Hubs and Spokes
4. SMD Data Science Applications Program



Big Data Superhighway

NAC SC Input: Ensuring science is considered in SCaN's 20 Year Strategic Planning

NASA's Space Communications and Navigation (SCaN) was set up in 2006 and consolidated the three communications networks run by NASA: Near Earth Network (NEN), Space Network, and Deep Space Network (DSN)

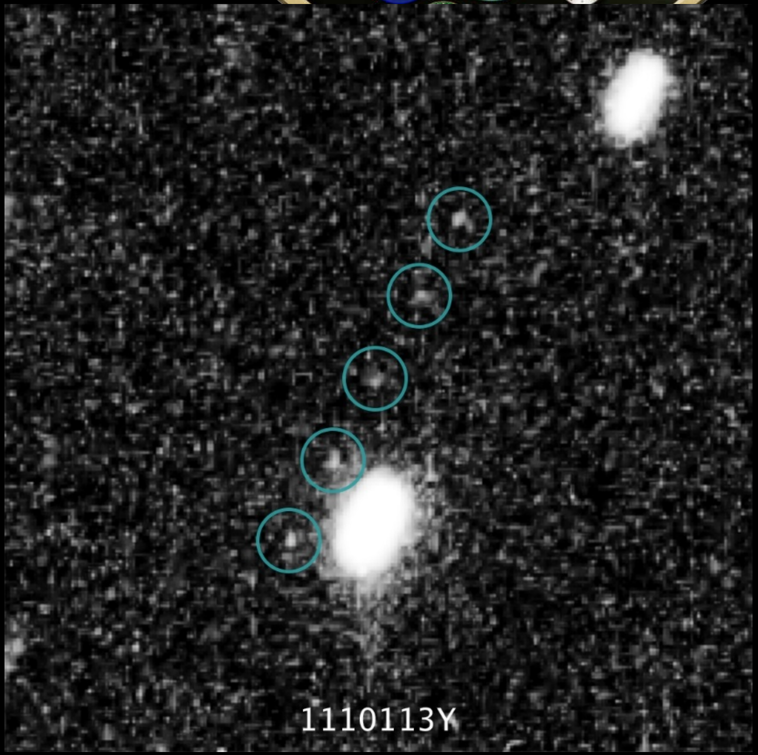


- NASA Transition Authorization Act of 2017 requires that SCaN develop a plan "to meet the Administration's projected space communications and navigation needs for low-Earth orbit and deep space operations in the 20 year period…" SMD would like the NAC SC to provide inputs for the SCaN plan. **Using the current decadal surveys as a starting point, what are the communication and navigation assets needed over the next 2 decades that will enable the exciting science we want to do?**

Planetary Science
Advisory Committee
Science Highlight
Dr. Anne Verbiscer

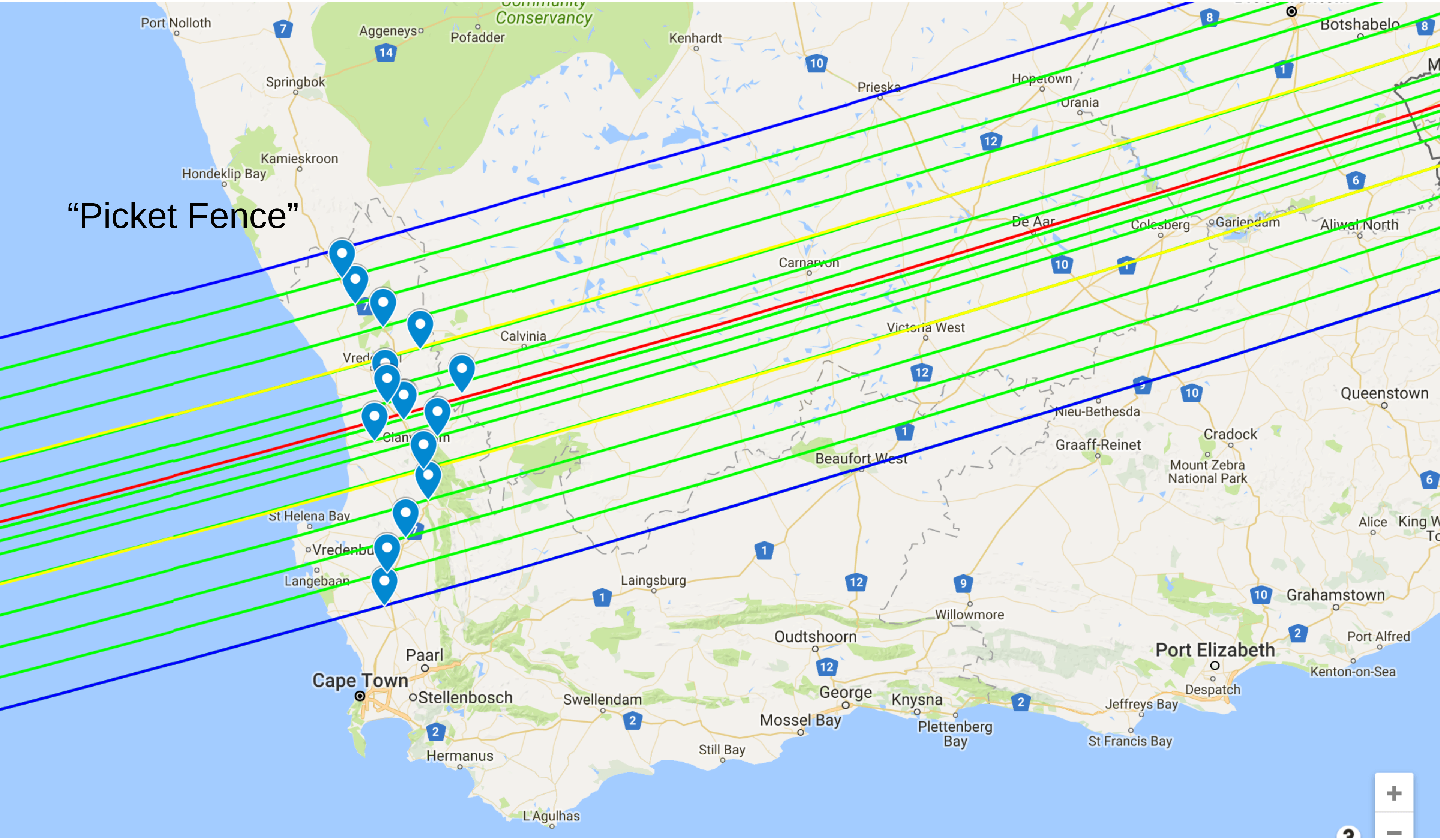
Stellar Occultations by New Horizons Extended Mission Target 2014 MU_{69}

After the spectacular success of the Pluto flyby in July 2015, New Horizons set sail for its next destination: Kuiper Belt Object 2014 MU69 on 1 January 2019

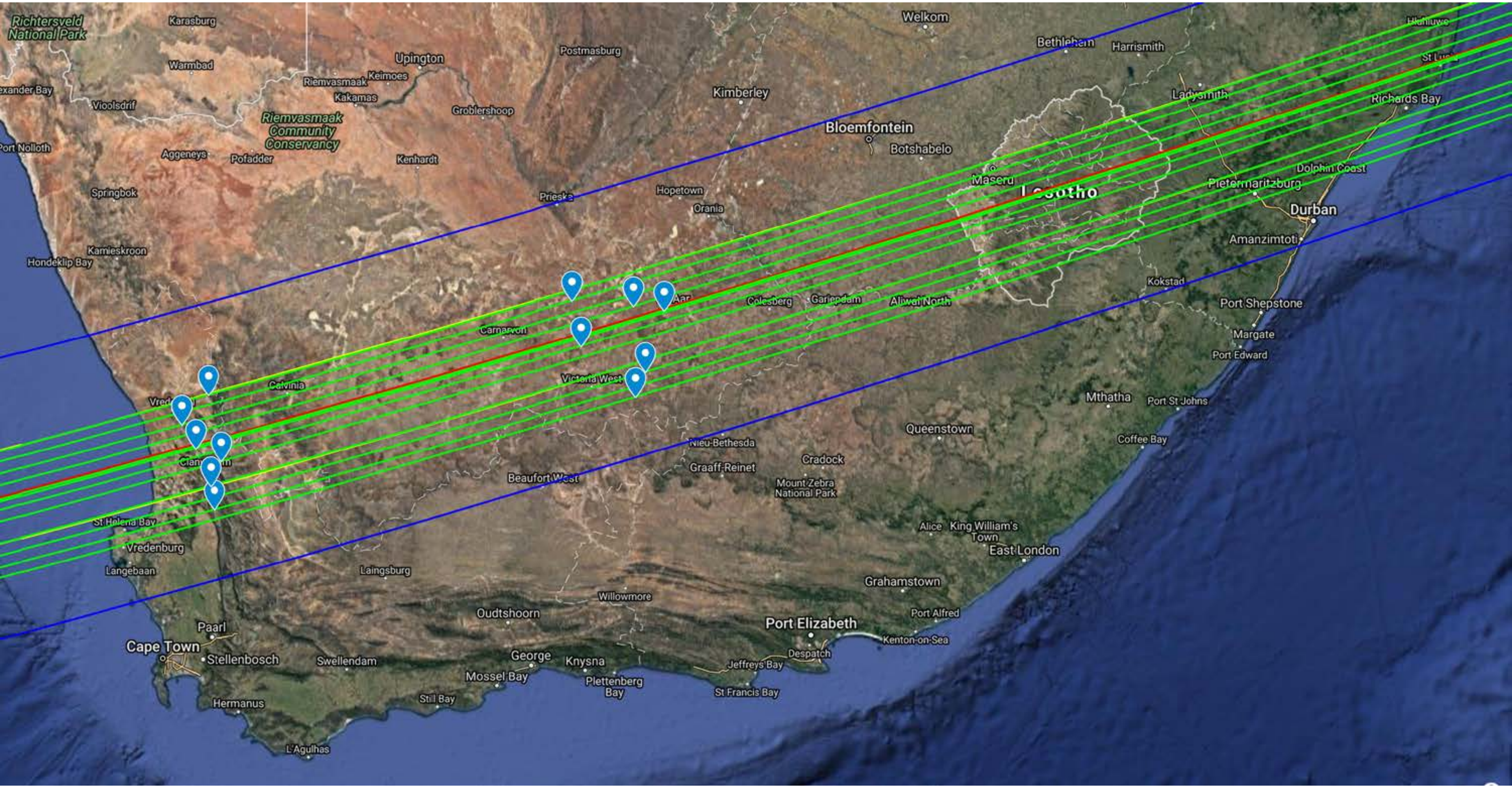


HST Discovery image(s)

3 June South Africa Deployment Plan



3 June South Africa Actual Deployment



Astrophysics Advisory Committee (APAC) April and July, 2017 Meetings Common Themes and Important Topics

- **R&A Funding and Selection Rates (as examples, the ATP theory funding cycle change, the change in the civil servant funding model, and the reduction in the NASA named fellows)**
- **Portfolio balance and the role of flagship missions**
- **NASA support for ground-based research and facilities**
- **Diversity and equal representation issues in general**

Outline

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

SC Finding: Upgrades to High-End Computing

In 2016, the NASA High-End Computing (HEC) facilities grew to support an additional 42% in computing capacity as measured in standard billing units. Additionally, the application support team is proving to be effective at significantly improving the efficiency of codes running on the HEC assets. The HEC management team is proactively attempting to address platform oversubscription concerns via collaborative efforts with NASA mission teams, independent of budget requests for additional platform resources. The Science Committee (SC) and Big Data Task Force (BDTF) enthusiastically endorse these efforts to improve both NASA's HEC capacity and the efficient utilization of the HEC resources.

SC Finding: Esteemed NASA Civil Servant Workforce

The Science Committee (SC) wishes to acknowledge the community's great esteem for its civil servant colleagues. NASA civil servants have worked tirelessly in many roles – as project scientists, mission planners, analysts, archivists, project managers, engineers, and more – to enable the breakthrough science of NASA's missions. The commitment, professionalism, and dedication of NASA's civil servants have earned the respect and gratitude of the science community. The community considers its civil servant colleagues – along with the missions they support – a national treasure.

SC Finding: Earth Observations Socio-Economic Value

(Request Transmission to SMD AA)

The Science Committee (SC) and Earth Science Subcommittee (ESS) support efforts to better assess socio-economic implications of improved Earth observations from space. Related to this topic, SC and ESS support efforts to improve integration between Applied Sciences and Research, and the creation of the consortium to assess socio-economic values of improved Earth observations from space.

Background: The ESS heard a presentation on a framework for formulating the socio-economic value of improved Earth observations from space. The framework was presented using the example of the cost of improved observations of Earth radiation balance relative to the cost of socio-economic impacts. NASA Science Mission Directorate (SMD) Earth Science Division (ESD) Applied Sciences has issued a contract with Resources For the Future to develop a consortium to assess the socio-economic values of Earth observations from space.

HEOC/SC Joint Finding: Cooperation Between HEOMD and SMD

Finding:

It is clear from the presentations and discussions during the joint session of the HEO and Science Committees that the HEOMD and SMD are working well together and have already identified opportunities for cooperation on future activities such as the Deep Space Gateway and servicing and possible future assembly of deep-space telescopes. Both committees believe that this collaboration is beneficial to NASA.

HEOC/SC Joint Finding: Servicing and Assembly of Satellites On-Orbit (Request Transmission to HEOMD AA and SMD AA)

Finding:

Both committees were pleased that the servicing and assembly of large satellites, such as future deep space telescopes or other scientific instruments, is being explored by groups internal to NASA as well as groups representing broader communities that include NASA representation. The HEO and Science Committees believe that these efforts are valuable contributions for planning for the Deep Space Gateway (DSG) which could enable or enhance on-orbit servicing or assembly of future space assets and potentially lower costs for large satellites.

HEOC/SC Joint Finding:
Deep Space Gateway Workshop
(Request Transmission to HEOMD AA and SMD AA)

Finding:

Both committees commend NASA’s efforts to maximize the science benefit of the Deep Space Gateway as specified in the existing Decadal Surveys and other key NASA science planning documents.

HEOC/SC Joint Recommendation: Mitigating Space Radiation Risk

Recommendation:

The committees recommend that NASA accelerate efforts to reduce the radiation risk for future crews by exploring novel concepts for radiation shielding and improving deep space propulsion that would reduce transit time.

Major Reasons for the Recommendation

The Science and HEO Committees met jointly to get an update on the expected radiation exposure for deep space missions.

Current data shows that the deep space transit to Mars would expose the crew to roughly two to three times the radiation dose received on a similar mission aboard ISS, and approximately the same level exposure as ISS while on the surface of Mars. For a two to three year transit to and from Mars as currently envisioned for the deep space transport, an increase in lifetime cancer risk of approximately 10% would be expected for the crew members.

Consequences of No Action on the Recommendation

Greater health risk must be accepted for Mars human exploration missions.