# SPACE SCIENCE WEEK

The National Academies of SCIENCES ENGINEERING MEDICINE

**SPRING 2019 MEETING OF THE DISCIPLINE COMMITTEES OF THE SPACE STUDIES BOARD**
**PLANARY AGENDA**

**Tuesday March 26, 2019**

**JOINT PLENARY SESSION**
**Kavli Auditorium – NAS Building – 2101 Constitution Ave NW – Washington D.C**

**Opening Session:**
**NASA Science Program Update**

| | | |
|---|---|---|
| **1:00 PM** | **Welcome** | **Colleen Hartman, SSB/ASEB Director** * |
| **1:05 PM** | **NASA Science Mission Directorate:**<br>**FY 2020 Budget, Lunar Program, Science at the Gateway, and D&I**<br>*Presentation 25 min, Q&A 30 min* | **Thomas Zurbuchen, NASA-SMD** |

**Focus Session:**
**Areas of International Cooperation in the Program of Record and Near- to Long-term Challenges**

| | | |
|---|---|---|
| **2:00 PM** | **International Panel A**<br>*90 min (15 minute talk per person; Q&A 30 min)* | **Steve Running, Moderator** * |
| | • European Space Agency – Space Science (ESA-SCI) | **Fabio Favata, ESA-SCI** |
| | • Chinese Academy of Sciences – National Space Science Center (CAS-NSSC) | **Xiaolong Dong, CAS-NSSC** |
| | • JAXA Institute of Space and Astronautical Science (JAXA/ISAS) | **Masaki Fujimoto, JAXA/ISAS** |
| | • Committee on Space Research (COSPAR) | **Len Fisk, COSPAR President** |
| **3:30 PM** | *Break*<br>*Refreshments available in the West Court* | |
| **4:00 PM** | **International Panel B**<br>*90 min (15 minute talk per person; Q&A 30 min)* | **Alvaro Giménez, Moderator** * |
| | • European Space Agency – Human and Robotic Exploration | **David Parker, ESA-HRE** |
| | • Canadian Space Agency – Space Exploration Development (CSA-SED) | **Erick Dupuis, CSA-SED** |
| | • NOAA National Environmental Satellite, Data, and Information Service (NESDIS) | **Steve Volz, NOAA** |
| | • NASA Science Mission Directorate (SMD) | **Thomas Zurbuchen, NASA-SMD** |
| **5:30 PM** | **Closing Comments** | **John Grunsfeld, Astrophysicist/Astronaut** * |

* No slides were presented by the speaker.

National Aeronautics and Space Administration

# EXPLORE SCIENCE

**SPACE STUDIES BOARD**


**Thomas H. Zurbuchen, Ph.D.**

Associate Administrator
Science Mission Directorate
@Dr_ThomasZ


March 26, 2019

# NASA Science Overview

SMD FY20 Budget Strategy & Highlights

Diversity and Inclusion Activities

Commercial Partnership Strategy

# NASA Science Overview

SMD FY20 Budget Strategy & Highlights

Diversity and Inclusion Activities

Commercial Partnership Strategy

# FY20 Budget Strategy

Advance National Science and Exploration Goals

Maintain a Balanced and Integrated Science Program

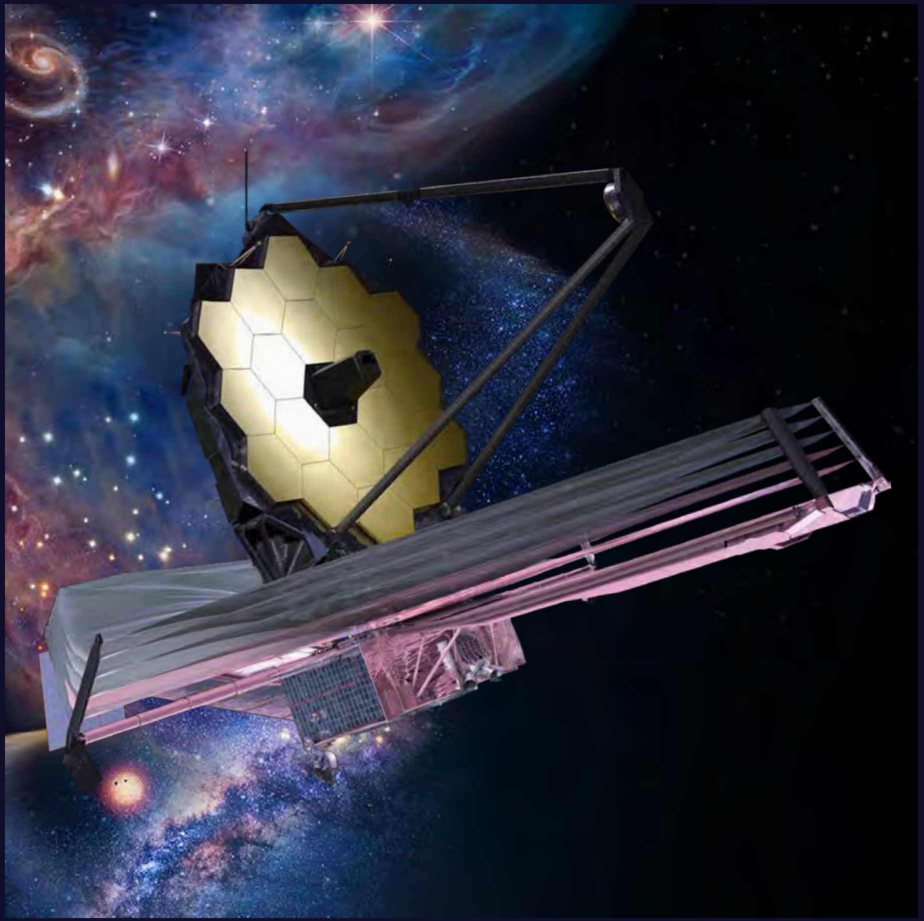
Execute Innovative Partnerships

Inspire Future Leaders

FY20 Budget Highlights

# Advance National Science and Exploration Goals

- Execute Lunar Discovery and Exploration Program to leverage commercial partnerships and innovative approaches to achieve human and science exploration goals
- Enable Mars Sample Return mission, a Decadal Survey priority, leveraging international and commercial partnerships
- Prepare for launch of James Webb Space Telescope, world’s premier space telescope



FY20 Budget Highlights

# Maintain a Balanced and Integrated Science Program

- Execute program informed by Decadal Surveys
- Continue leveraging innovation and commercial partnerships, including SmallSats/CubeSats, rideshares and hosted payloads; invest in innovative early-stage research and technology to promote economic growth
- Protect Astrophysics portfolio by prioritizing funding for competed astrophysics missions and research; fully fund Webb for launch in 2021; no funding for WFIRST
- Support for Europa Clipper mission; no funding for Europa Lander
- Execute a robust and innovative Earth Science portfolio; no funding for PACE or CLARREO-PF

FY20 Budget Highlights

# Execute Innovative Partnerships

- Pursue science on potential future commercial lunar and Mars missions
- Finalize multiple pilot contracts to purchase Earth observation products from existing private sector SmallSat constellations; for evaluation by NASA researchers
- Leverage data and expertise through interagency partnerships to achieve missions; provide data and products to support operational agencies
- Remain the preferred partner across the globe in all levels of experience, ~400 agreements, comprising nearly 60% of NASA international agreements
- Enable science learners across the U.S. through over 200 community-based organizations

# Inspiring Future Leaders

- Achieve excellence by relying on diverse teams, both within and external to NASA, to most effectively perform SMD’s work
- Attract and retain talent by promoting a culture that actively encourages diversity and inclusion and removes barriers to participation
- Encourage development of future leaders, including the next generation of mission principal investigators, through targeted outreach and hands-on opportunities
- Support early-career scientists to build careers working with NASA
- Engage the general public in NASA Science, including opportunities for citizen scientists

FY20 Budget
# Program Highlights

## Planetary Science

- Lunar Discovery and Exploration program continues to grow commercial partnerships and innovative approaches to achieving science, technology demonstration and human exploration objectives
- Enables Mars Sample Return launch as early as 2026
- Accelerates launch readiness date for Europa Clipper to 2023

## Astrophysics

- Accommodates Webb re-plan for 2021 launch
- Maintains regular cadence of Astrophysics Explorers and Missions of Opportunity
- Given its significant cost and competing priorities within NASA, provides no funding for WFIRST

## Heliophysics

- Space Weather increase strengthens 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
- Enables healthy research and applied science programs, and SmallSat/CubeSat investments

# Science Budget Request Summary ($M)

| | Actual | Enacted | Request | Out-years | | | |
|---|---|---|---|---|---|---|---|
| | FY 18 | FY 19 | FY 20 | FY 21 | FY 22 | FY 23 | FY 24 |
| **Science** | 6,211.5 | 6,905.7 | 6,303.7 | 6,319.0 | 6,319.0 | 5,919.5 | 5,919.0 |
| **Earth Science** | 1,921.0 | 1,931.0 | 1,779.8 | 1,785.6 | 1,779.7 | 1,666.5 | 1,674.6 |
| Earth Science Research | 461.6 | | 447.9 | 466.9 | 484.1 | 508.1 | 532.4 |
| Earth Systematic Missions | 899.4 | | 719.2 | 701.5 | 664.1 | 501.5 | 481.3 |
| Earth System Science Pathfinder | 242.0 | | 275.4 | 255.1 | 253.0 | 265.2 | 248.3 |
| Earth Science Data Systems | 204.4 | | 214.4 | 229.0 | 239.3 | 250.1 | 267.7 |
| Earth Science Technology | 60.4 | | 69.6 | 79.2 | 82.8 | 84.6 | 86.4 |
| Applied Sciences | 53.2 | | 53.3 | 53.9 | 56.3 | 57.0 | 58.5 |
| **Planetary Science** | 2,217.9 | 2,758.5 | 2,622.1 | 2,577.3 | 2,629.4 | 2,475.4 | 2,454.9 |
| Planetary Science Research | 279.5 | | 266.2 | 272.6 | 268.6 | 270.2 | 301.9 |
| Planetary Defense | 76.0 | 160.0 | 150.0 | 150.0 | 150.0 | 119.5 | 150.0 |
| Lunar Discovery and Exploration | 22.0 | 218.0 | 210.0 | 327.0 | 417.0 | 494.0 | 512.0 |
| Discovery | 258.3 | 381.2 | 502.7 | 393.4 | 364.4 | 371.6 | 371.6 |
| New Frontiers | 88.1 | 130.2 | 190.4 | 261.2 | 341.9 | 387.3 | 291.7 |
| Mars Exploration | 678.0 | 650.0 | 546.5 | 472.2 | 481.7 | 506.1 | 590.1 |
| Outer Planets and Ocean Worlds | 676.2 | 760.9 | 608.4 | 549.6 | 463.7 | 224.2 | 68.8 |
| Technology | 139.8 | 210.2 | 147.9 | 151.3 | 142.1 | 102.5 | 168.8 |
| **Astrophysics** | 850.4 | 1,191.6 | 844.8 | 902.4 | 965.2 | 913.5 | 907.7 |
| Astrophysics Research | 203.1 | | 250.7 | 309.3 | 302.5 | 299.1 | 298.8 |
| Cosmic Origins | 211.2 | | 185.3 | 173.9 | 181.7 | 121.7 | 121.7 |
| Physics of the Cosmos | 118.0 | | 148.4 | 128.5 | 123.3 | 117.8 | 117.4 |
| Exoplanet Exploration | 200.8 | | 46.4 | 44.3 | 45.6 | 46.1 | 48.5 |
| Astrophysics Explorer | 117.4 | | 214.1 | 246.4 | 312.0 | 328.8 | 321.4 |
| **James Webb Space Telescope** | 533.7 | 304.6 | 352.6 | 415.1 | 175.4 | 172.0 | 172.0 |
| **Heliophysics** | 688.5 | 720.0 | 704.5 | 638.6 | 769.3 | 692.0 | 709.8 |
| Heliophysics Research | 206.3 | | 237.0 | 223.6 | 214.7 | 219.3 | 222.0 |
| Living with a Star | 376.1 | | 107.6 | 83.6 | 108.7 | 121.9 | 118.3 |
| Solar Terrestrial Probes | 45.2 | | 177.9 | 220.4 | 210.9 | 192.7 | 152.0 |
| Heliophysics Explorer Program | 60.9 | | 182.0 | 111.1 | 235.0 | 158.1 | 217.5 |

# KEY SCIENCE THEMES

Protect & Improve Life on Earth

Search for Life Elsewhere

Discover Secrets of the Universe

# InSight

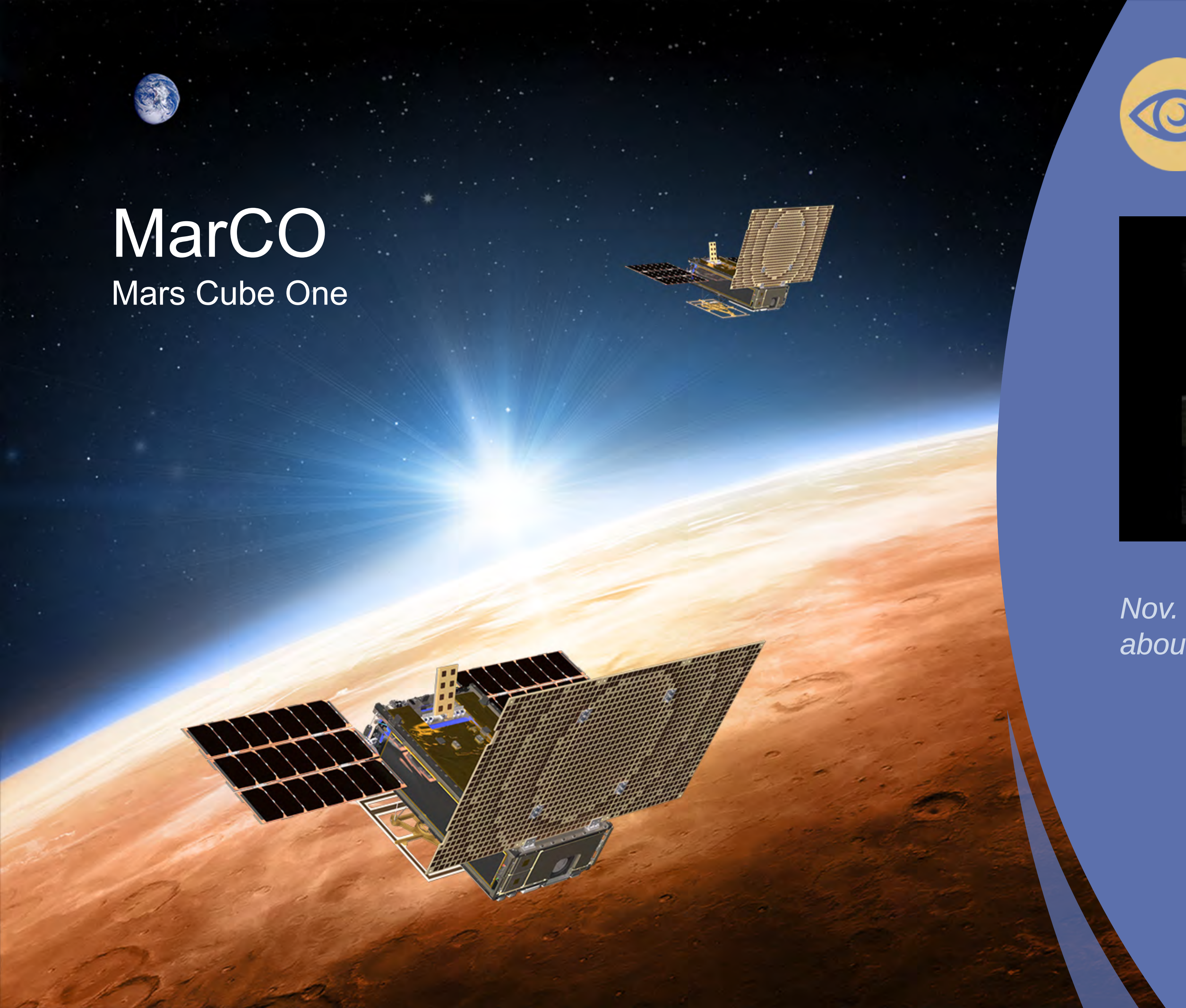
Taking the ‘Vital Signs’ of Mars

**SCIENCE HIGHLIGHT**

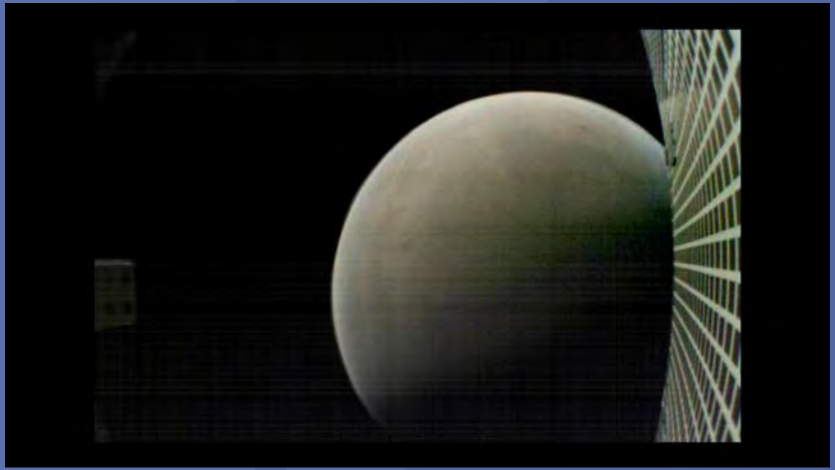
*Dec. 19, 2018 – InSight seismometer on Martian surface – first time a spacecraft robotically placed a seismometer onto surface of another planet*

# MarCO

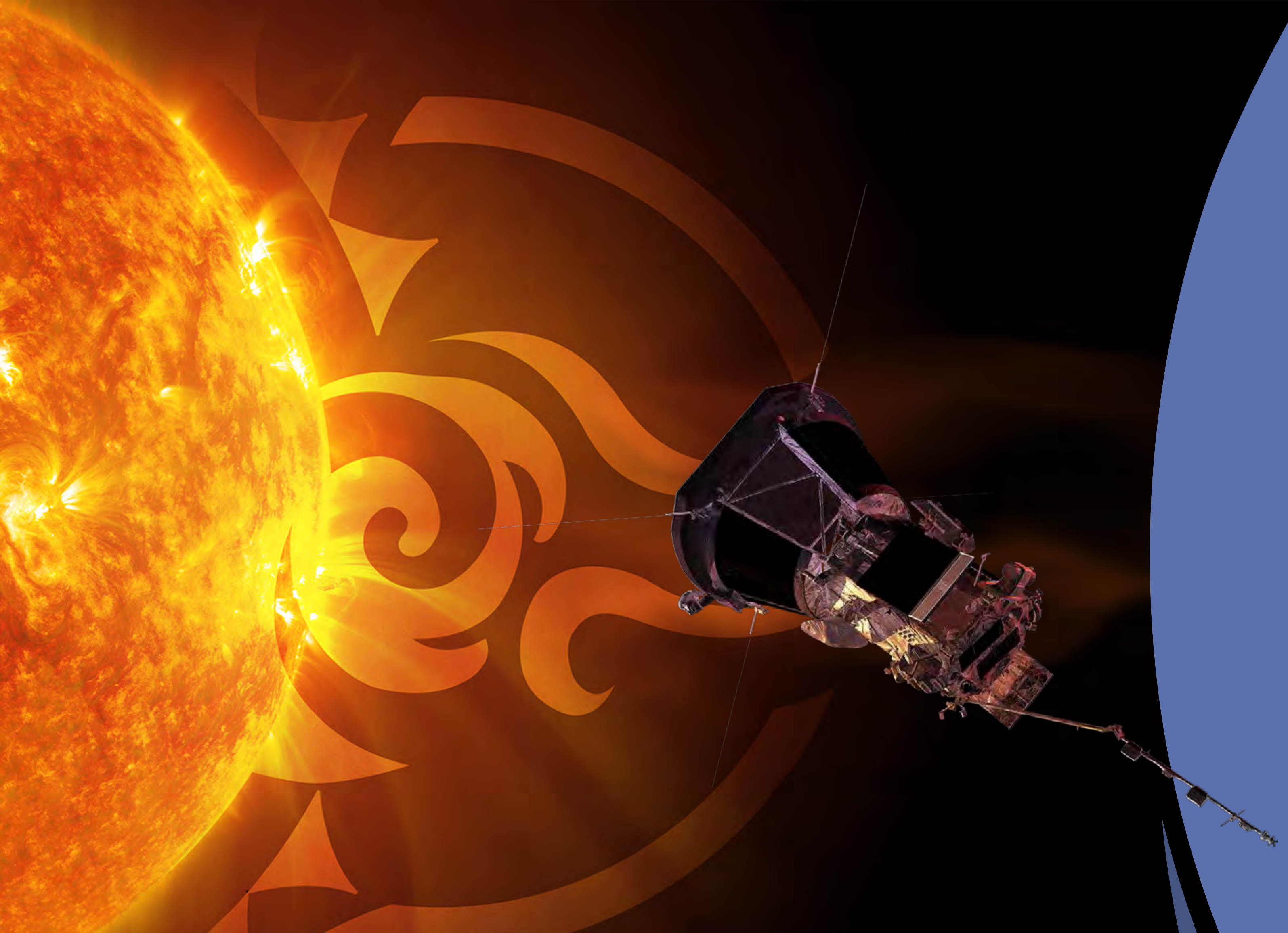
Mars Cube One



## SCIENCE HIGHLIGHT



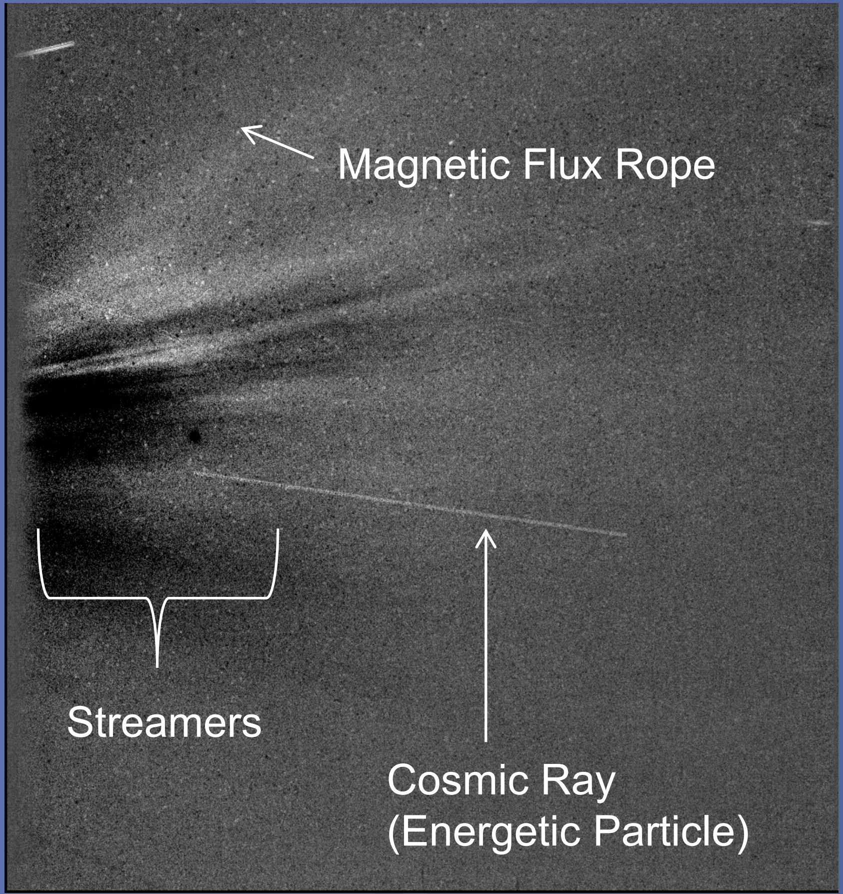
*Nov. 26, 2018 - MarCO image of Mars from about 4,700 miles away during its flyby*



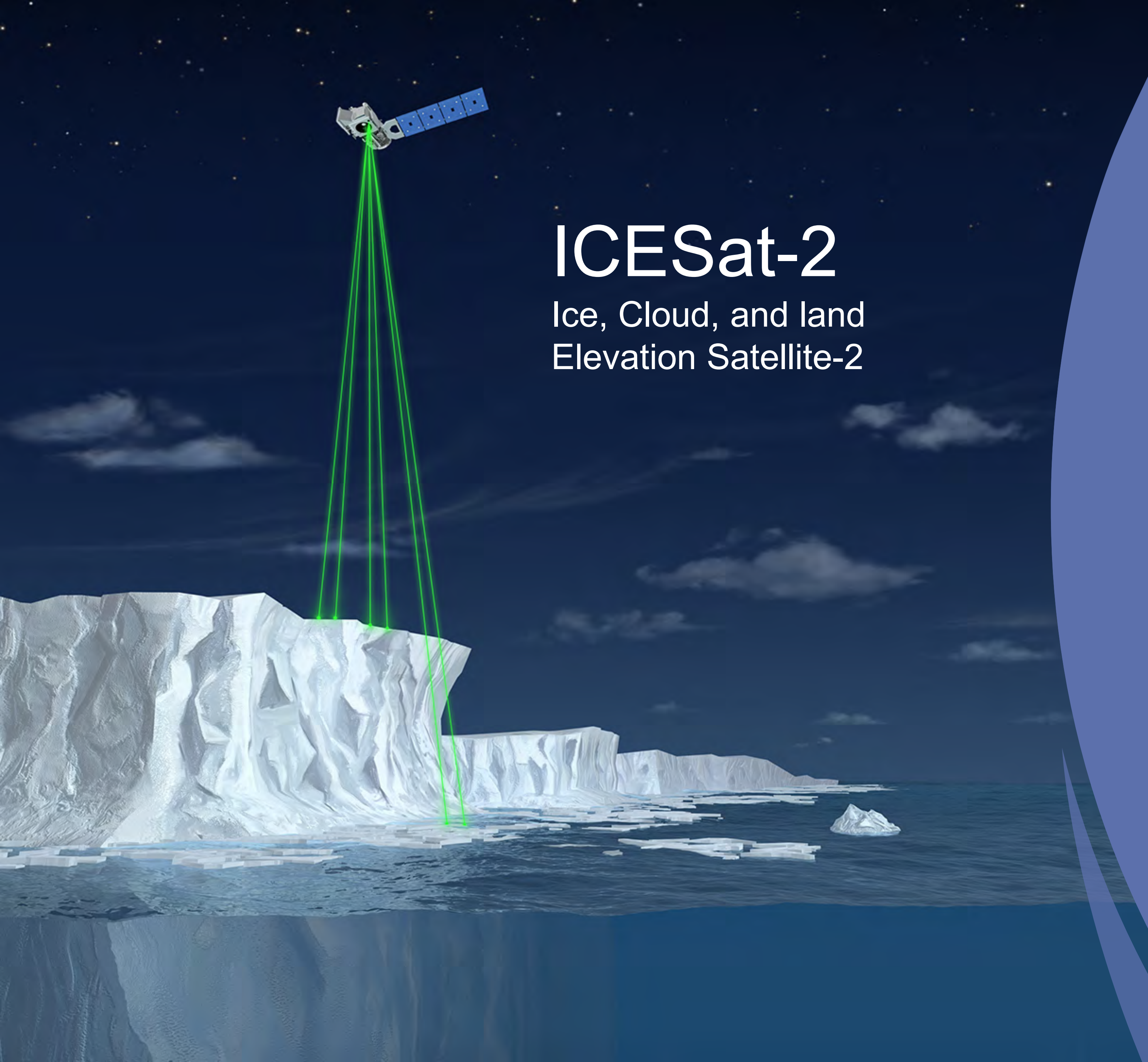
# Parker Solar Probe

A Mission to Touch the Sun

## SCIENCE HIGHLIGHT



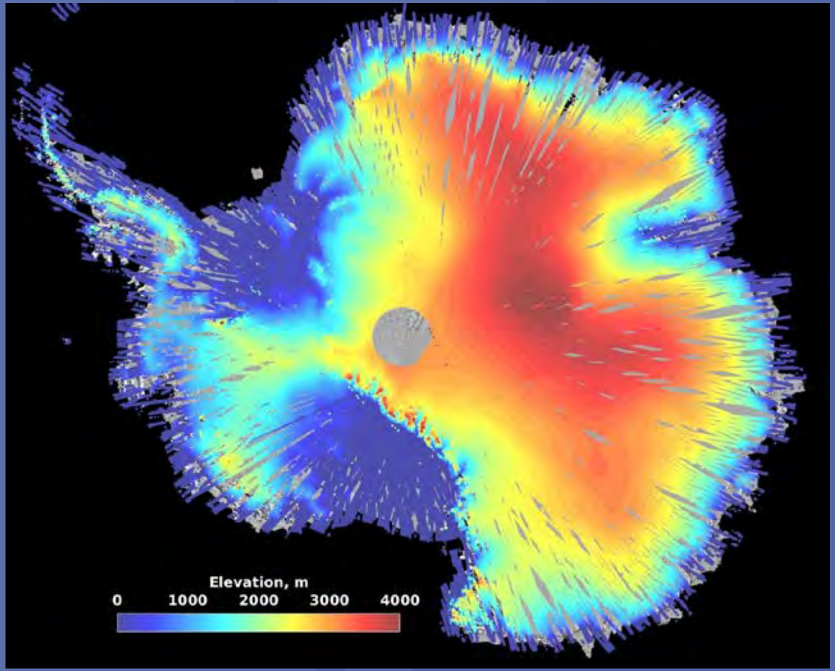

*Nov. 6, 2018, 18:16 UT – Data from WISPR instrument on Parker Solar Probe during first perihelion*



# ICESat-2

Ice, Cloud, and land
Elevation Satellite-2

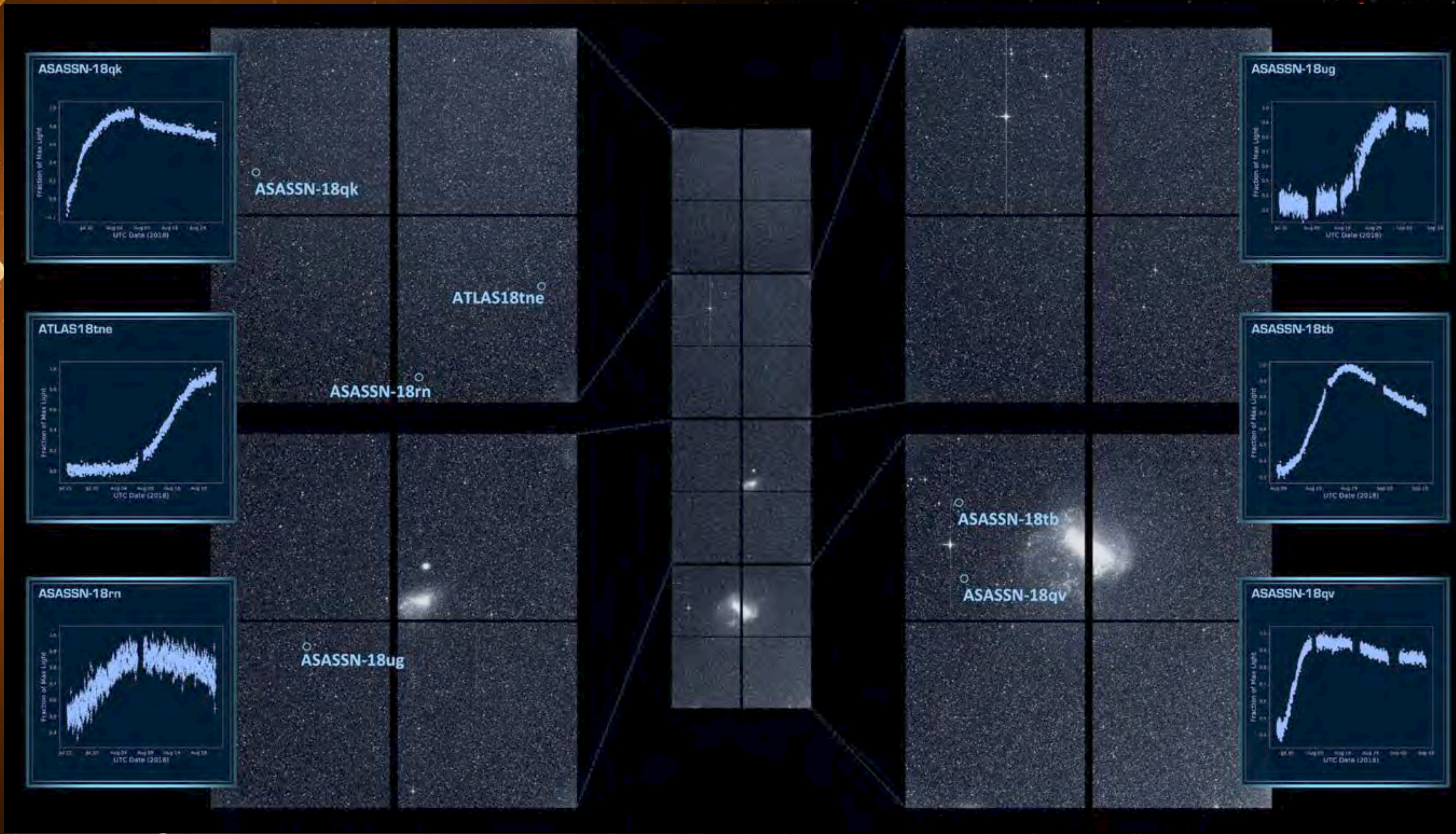
**SCIENCE HIGHLIGHT**



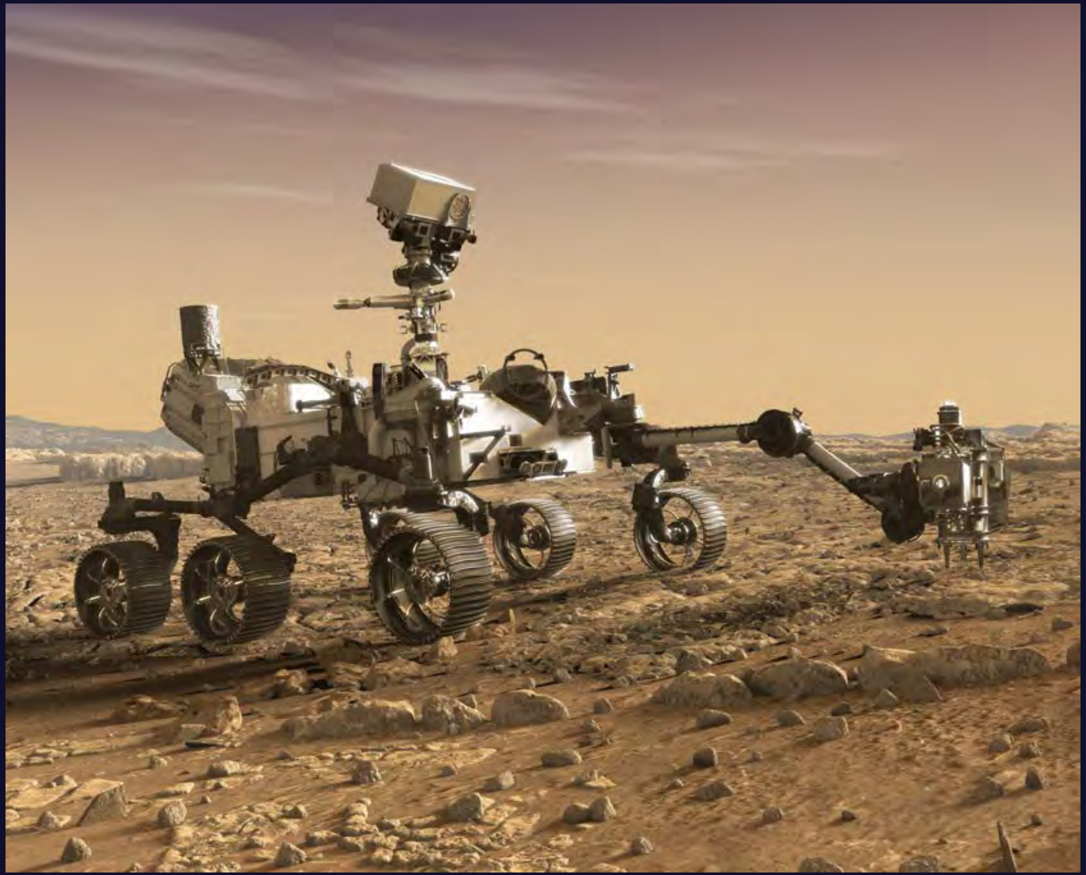

*Dec. 2018 - First three weeks of observations over Antarctica*

# TESS

Transitioning Exoplanet Survey Satellite




*Early analysis of TESS data from Sectors 1-7 has yielded at least a dozen new confirmed exoplanets, including 4 multi-planetary systems, and over 400 exoplanet candidates*

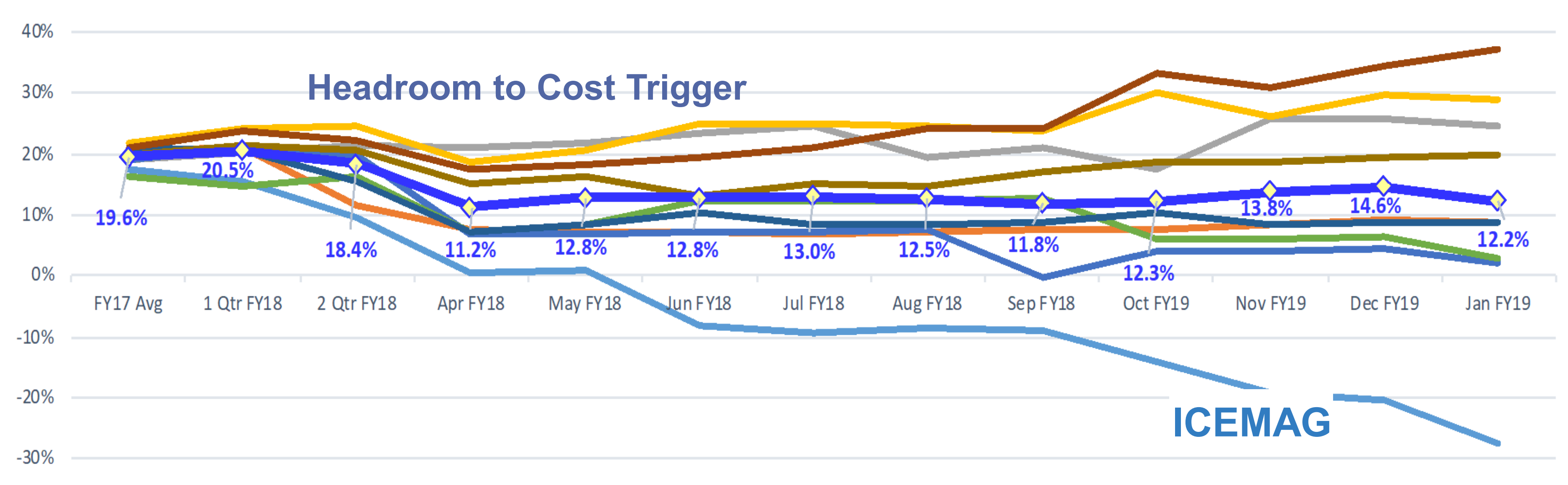


# Mars 2020 on Track for 2020 Launch

- RIMFAX, MOXIE, MEDA delivered to ATLO
- SHERLOC concluded risk review
  - Flight unit to be delivered end of June
  - Flight laser power supply replaces engineering model by end of 2019
- All other systems and instruments to be delivered over next several months

# Europa Clipper Update

As a result of continued, significant cost growth and remaining high cost risk, the ICEMAG investigation on the Europa Clipper mission is terminated




NASA will pursue a flux-gate only magnetometer provided by UCLA. We will appoint a science team leader, and integrated product manager, and retain all ICEMAG Co-Investigators.

# Wide-Field Infrared Survey Telescope

- Work continues under new Project Manager and Deputy Project Manager and enacted FY19 appropriation which includes $312M for WFIRST.
- WFIRST is at $3.2 B without agency reserves, per Academy and Congressional guidance.
- Key Progress/Milestones
  - Primary mirror polishing continues; shows slightly better than expected figure for this stage
  - Four element Preliminary Design Reviews by September, leading to combined Spacecraft and Mission PDR planned in October 2019
- FY20 budget request provides no funding for WFIRST; instead, focuses on completing Webb

# Planetary Science Budget Features

**What's Changed**

- Enables a Mars Sample Return launch as early as 2026
- Accelerates launch readiness date for Europa Clipper to 2023; proposes Clipper launch on a commercial vehicle, which saves over $700 million
    - No funding included for Europa Lander beyond FY19
- Restructures Technology Program to align investments with flight programs
- Establishes 5-year cadence for New Frontiers while maintaining 2-to-3-year cadence for Discovery – with first New Frontiers mission selection since 2011
- Provides for SmallSat future opportunities within the Discovery Program

**What's the Same**

- Supports development of Mars 2020, DART, Psyche and Lucy as well as instruments on ExoMars 2020, JUICE and MMX
- Funds all prime operating and extended missions through FY20, with Senior Review in 2019
- Maintains Nation's radioisotope power system capability and stable planetary R&A program

# Astrophysics Budget Features

**What's Changed**

- Webb budget increased consistent with 2018 re-plan, Webb proceeding toward launch in March 2021
- Probe program deferred to fund Webb replan
- SPHEREx begun within Explorers program as next Astrophysics MIDEX
- SOFIA mission extended beyond 5-year prime mission, extended mission starts in FY20 with details pending 2019 independent reviews
- Provides no funding for WFIRST space telescope; instead, focuses on completing Webb

**What's the Same**

- Spitzer ends operations January 2020 per 2016 Senior Review
- Phase A studies of Small Explorers (SMEX) and Missions of Opportunity from 2019 AO
- IXPE, GUSTO, XRISM, and Euclid development remains on track and within budget
- Hubble, Chandra, and six smaller operating missions continue pending 2019 Senior Review
- CubeSat initiative and four balloon campaigns within healthy research program

# Heliophysics Budget Features

## What's Changed

- Space Weather increase will strengthen interagency collaboration on Research-to-Operations/Operations-to-Research, a priority of National Space Weather Strategy and Action Plan
- Increased investments in CubeSats and technology development
- Solar Orbiter launch now scheduled for February 2020
- ICON delayed from October 2018 to 2019 to address launch vehicle issue
- Imminent release of MIDEX announcement

## What's the Same

- GOLD launched as planned in January 2018
- Parker Solar Probe launched as planned August 2018
- Solicited science and technology demonstration missions of opportunity for rideshare with IMAP and other missions of opportunity
- Accommodation of NOAA SWFO mission launching with IMAP
- Operating missions funded consistent with Senior Review recommendations
- IMAP selected as planned next Solar Terrestrial Probes mission (LRD October 2024)
- AWE selected as planned to fly on ISS as next SMEX Mission of Opportunity (LRD February 2022)

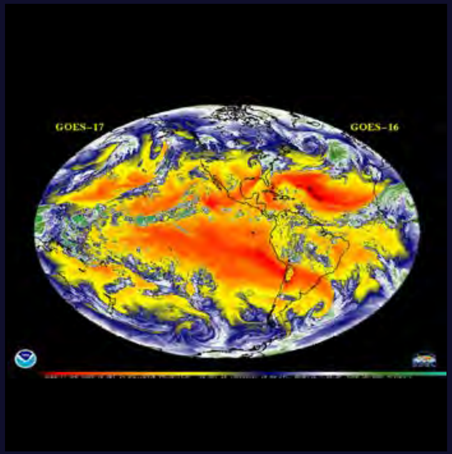
# Earth Science Budget Features

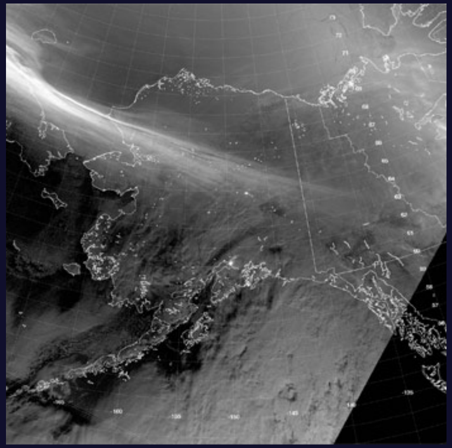
## What’s Changed

- New Decadal Incubation project within ESTO
- Initiated Earth Venture Continuity strand within Venture Class
- Four new DO studies within Decadal Survey
- DSCOVR (operations) and OCO-3 (for FY19 launch) funded through budget window
- TROPICS instrument confirmed as build-to-storage
- Selection of EMIT and PREFIRE instruments within Venture Class

## What’s the Same

- Supports recently launched missions GRACE-FO, ICESat-2, GEDI; ESD now operating 20 on-orbit missions
- SWOT, NISAR, Sentinel-6, Landsat 9, TEMPO, GeoCarb, and MAIA remain on schedule for launch in budget window
- Maintains regular cadence of Venture Class missions and instruments solicitations
- Healthy research and applied science programs, SmallSat/CubeSat investments, and commercial data buy activities
- Like FY19 Presidential Budget Request, provides no funding for PACE and CLARREO-PF



# Joint Agency Satellite Division Overview

## 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 and Implementing missions
  - Developing technologies
  - Identifying ride shares and hosting opportunities
- Continuing projects: GOES-T, GOES-U, GOES-R Ground System, JPSS-2, JPSS-3, JPSS-4, JPSS Ground System, Space Weather Follow On
- Note: Budget information and justification provided in NOAA budget documentation

# Citizen Science Initiative

- New Citizen Science Initiative ($1M / year starting FY20) will award agreements to develop and share best practices within SMD and beyond
- Supports already existing programs in all divisions through cross-divisional training, templates and continuous improvement processes
- Initiative ensures open source platforms, common protocols, transparency of data and reporting, and strong linkages are made to NASA science
- Leverage successes, including projects that have published results by citizens: Stardust, Backyard Worlds/Planet 9 and ArcticSigns
- Approach consistent with 2017 American Innovation and Competitiveness Act, and adds the rigor of professional science

# NASA Science Overview

SMD FY20 Budget Strategy & Highlights

Diversity and Inclusion Activities

Commercial Partnership Strategy


# Program Investigator Workshop

- Held November 27-28, 2018 in Washington, DC
- Nearly 100 participants from NASA, academia, research organizations, and industry in attendance
- Workshop designed to explore various aspects of mission PI role and barriers

# Key Takeaways

- Great interest in being part of mission team, but ways to do so not always well understood
- NASA needs to create better transparency of requirements and expectations of PI vs. mission leadership team
- NASA should create opportunities for new and emerging leaders to be part of mission teams and must incentivize this diversification
- NASA can help foster new partnerships between “gateway institutions” and smaller institutions
- To be successful, science community needs to move away from a “who you know” culture and create a climate free from harassment

# Post-Workshop Activities

**Completed Actions:**

- Conduct pre-reviews of review panels to ensure diversity and reduce conflicts of interest
- Add PI resources webpage to science.nasa.gov
- Add conference code of conduct requirement to ROSES 2019
- Restart proposal writing workshops at major science conferences

**Actions In Work:**

- Include career development positions (i.e. deputies) and associated evaluation criteria as part of future AOs
- Update NASA grant terms and conditions to require notification when grantees are under academic suspension
- Require anti-harassment and bystander training for mission teams
- Develop “PI 101” training for prospective PIs

**Future Work:**

- Assess communications channels by which prospective PIs learn about opportunities
- Assess interest in holding proposal writing workshops at affinity group conferences
- Evaluate potential partnerships between “gateway institutions” and smaller institutions
- Develop a PI Incubator Program

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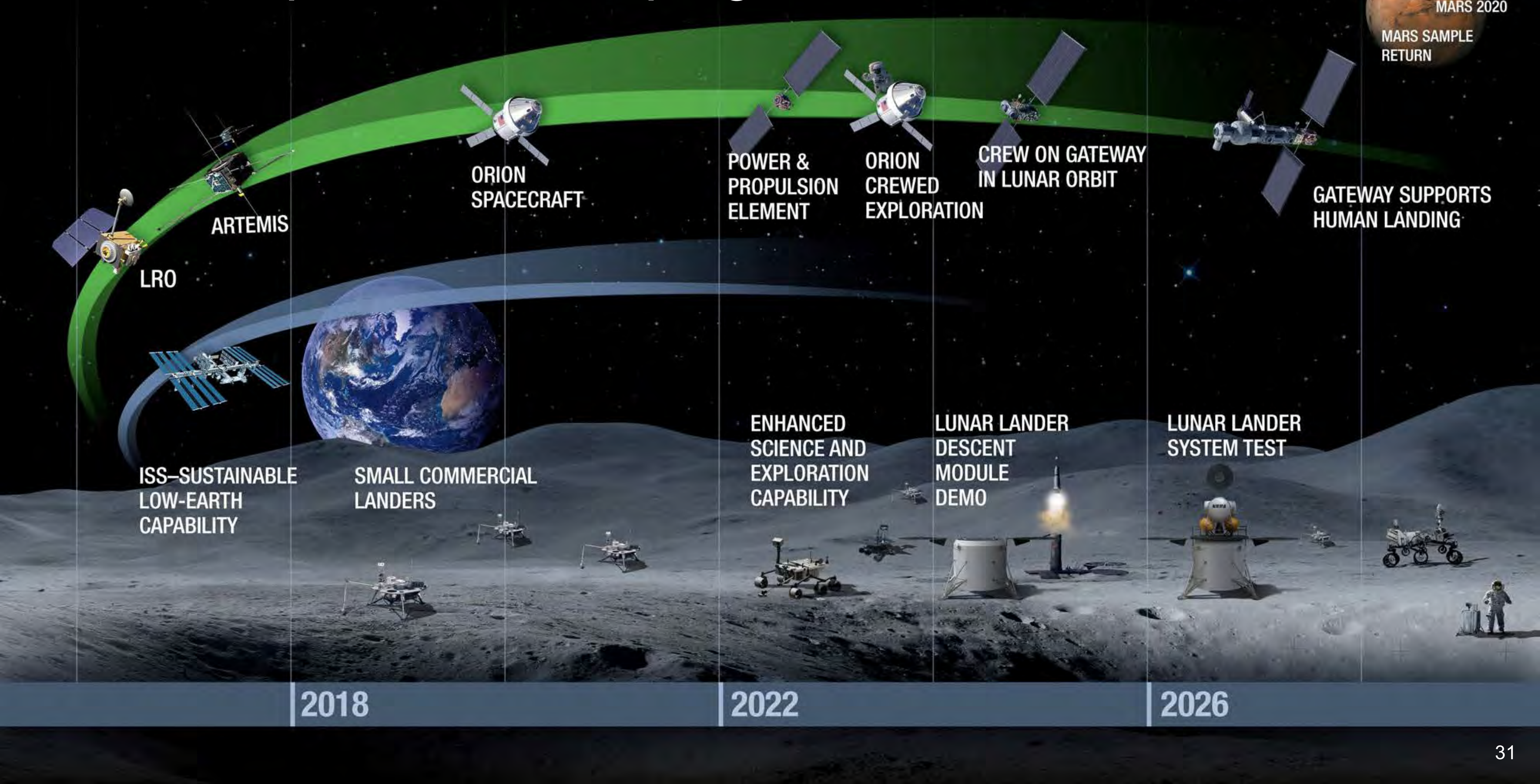
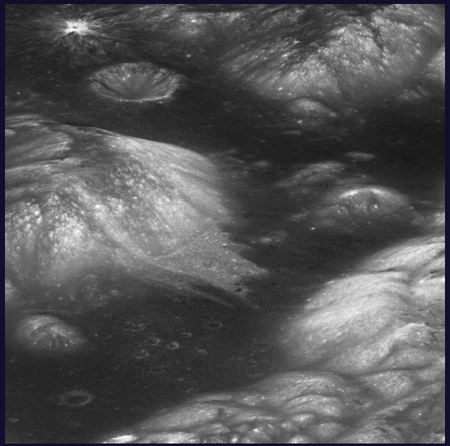
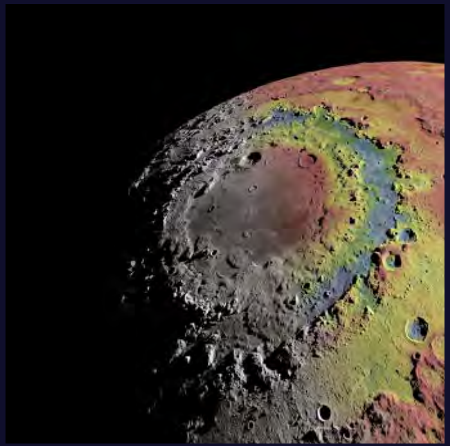
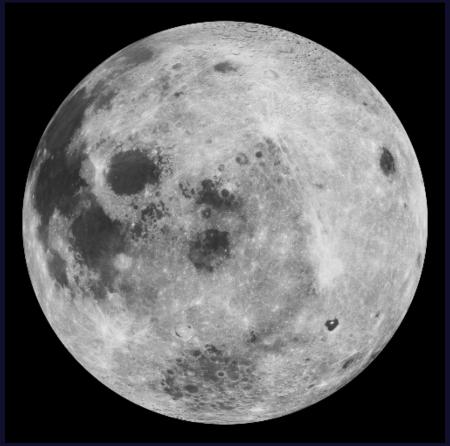
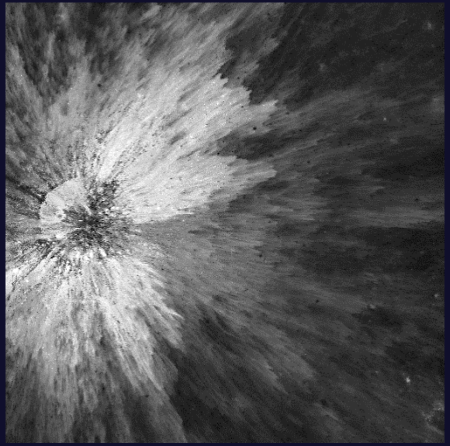
# Lunar Exploration Campaign



# Lunar Academies Reports

- Received two reports from Committee on Astrobiology and Planetary Science
    - Review of the Planetary Science Aspects of NASA SMD's Lunar Science and Exploration Initiative
    - Review of the Commercial Aspects of NASA SMD's Lunar Science and Exploration Initiative
- Working to develop a strategy for path forward in response to recommendations

# Commercial Lunar Payload Services


*Winning CLPS companies:*

- *Astrobotic*
- *Deep Space Systems*
- *Draper*
- *Firefly Aerospace*
- *Intuitive Machines*
- *Lockheed Martin Space*
- *Masten Space Systems*
- *Moon Express*
- *Orbit Beyond*

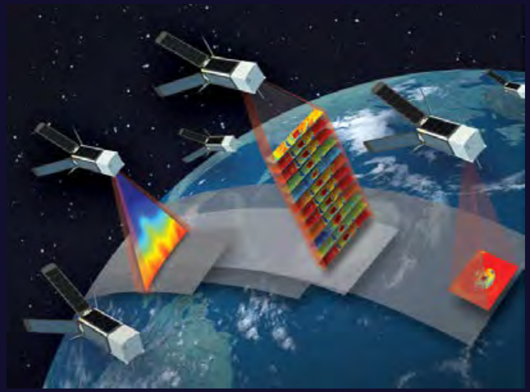
- Nine U.S. companies selected through CLPS Nov. 2018, developing landers to deliver NASA payloads to Moon surface; pre-authorized to compete on individual delivery orders
- Competition open to U.S. commercial providers of space transportation services, consistent with National Space Transportation Policy and Commercial Space Act
- Multi-vendor catalog, 10-year IDIQ contract, managed through task order competition for specific payload deliveries
- On ramps to the CLPS contracts will be used to provide additional capabilities as made available
- Structured for NASA as one of many customers of commercial service
- Building on NASA's model in low-Earth orbit, expands partnerships with industry and other nations to explore Moon and advance missions to farther destinations such as Mars, with America leading the way

# Lunar Payload Selections

- Thirteen science and technology demonstration payloads selected to fly to the Moon as early as end of 2019, depending on the availability of commercial landers
- Selected payloads, along with Lunar Surface Instrument and Technology Payloads, will begin to build pipeline of scientific investigations and technology development payloads using U.S. commercial landing delivery services
- Instruments include:
  - Linear Energy Transfer Spectrometer
  - Near-Infrared Volatile Spectrometer System
  - Advanced Neutron Measurements at the Lunar Surface
  - Ion-Trap Mass Spectrometer for Lunar Surface Volatiles
  - Quadrupole Mass Spectrometer
  - Low-frequency Radio Observations from the Near Side Lunar Surface
  - Stereo Cameras for Lunar Plume-Surface Studies
  - Surface and Exosphere Alterations by Landers
  - Navigation Doppler Lidar for Precise Velocity and Range Sensing
- Two technology demonstrations selected to fly:
  - Solar Cell Demonstration Platform for Enabling Long-Term Lunar Surface Power
  - Lunar Node 1 Navigation Demonstrator
- Future calls for payloads planned to be released each year for additional opportunities

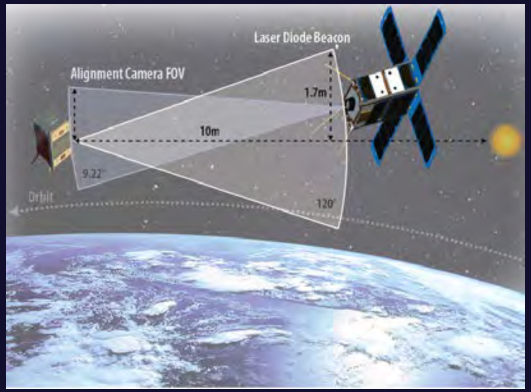
# SmallSat Opportunities

**Three InVEST-17 Awards Announced July 20, 2018**



Earth Venture Missions (EVM/EVI) and In-Space Validation of Earth Science Technologies (InVEST)

**First Major Investment in Astro SmallSat Missions**




Astrophysics Small Explorer (SMEX) and Astrophysics Science SmallSat Studies

**Investing up to $65M for ESPA-class Payloads**

Heliophysics Technology Demonstration Mission of Opportunity

**Investing up to $55M in Deep Space SmallSat Missions**

Small Innovative Missions for Planetary Exploration (SIMPLEx)

*SmallSat/CubeSat commercial engagement opportunities are essential to NASA Science's balanced portfolio, achieving distinct science objectives*

# ROSES Solicitations

- Many ROSES solicitations are specifically and exclusively for SmallSats (see table below), with other ROSES program elements (Heliophysics Technology and Instrument Development for Science) that allow CubeSats and SmallSats
- In total, 30 solicitations fully funded, ***with 20 from outside vendors***, between 2015 and 2018
- Selections for the SIMPLEx SALMON-3 AO are expected next month

| Title | Due date | Selections |
|---|---|---|
| Small Innovative Missions for Planetary Exploration (SALMON-3 AO) | 7/24/2018 | Spring 2019 |
| Astrophysics Science SmallSat Studies (ROSES-18) | 7/13/2018 | 08/29/2018 |
| Planetary Science Deep Space SmallSat Studies (ROSES-16) | 11/18/2016 | 3/27/2017 |
| Small, Innovative Missions for Planetary Exploration (ROSES-14) | 04/10/2015 | 08/08/2015 |

# CubeSat Launch Initiative Broadens Access to Space

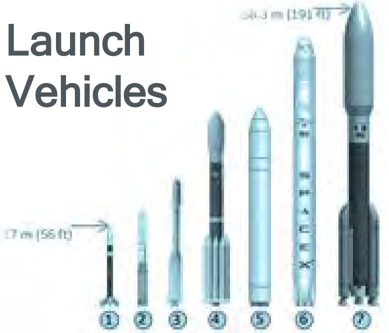
**CSLI:**

- **PROMOTES** innovative public-private technology partnerships
- **FACILITATES** low-cost technology development
- **STRENGTHENS** NASA and the Nation's future workforce

## Launch Providers

| | NASA A | B | C | D | E | VENTURE CLASS F | TOTAL BY STATUS |
|---|---|---|---|---|---|---|---|
| MANIFESTED | 4 | 0 | 2 | 2 | 9 | 21 | 38 |
| LAUNCHED | 15 | 13 | 13 | 1 | 24 | 0 | 66 |
| TOTAL BY PROVIDER | 19 | 13 | 15 | 3 | 33 | 21 | 104 |

## Launch Vehicles



1. SUPER STRYPI
2. MINOTAUR I
3. TAURUS XL
4. DELTA II
5. ANTARES
6. FALCON 9
7. ATLAS V

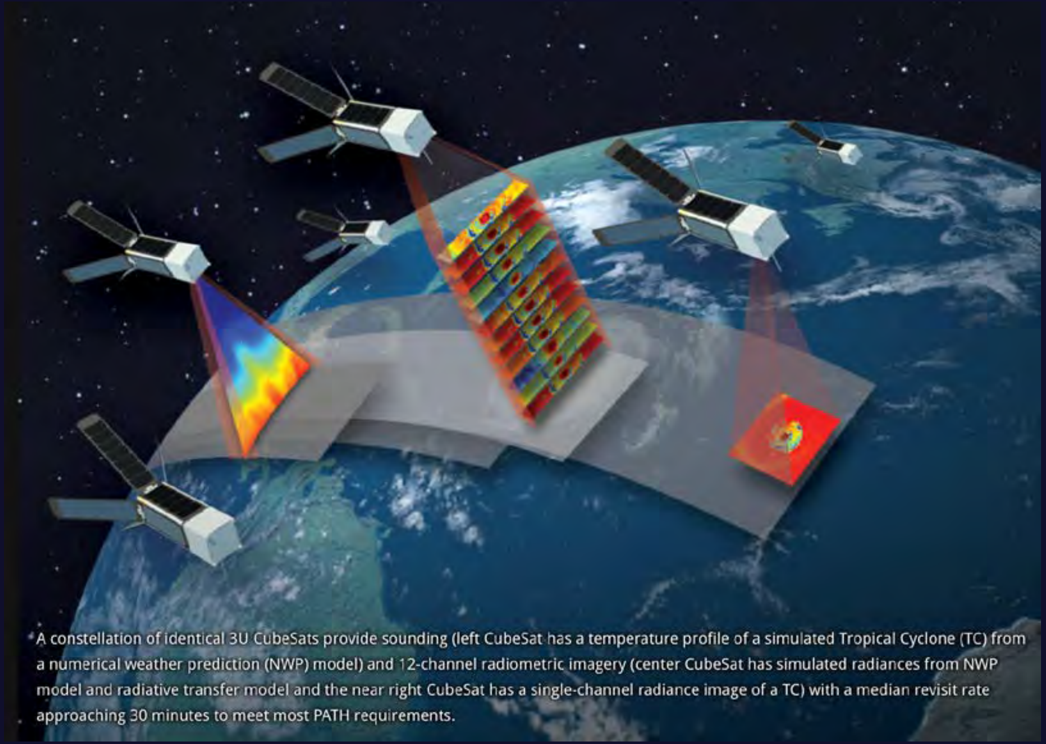
**93** UNIQUE ORGANIZATIONS

**74** UNIVERSITIES

**176** CUBESAT MISSIONS **SELECTED**

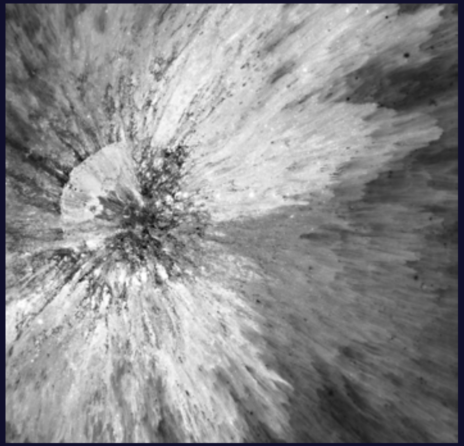
March 2019

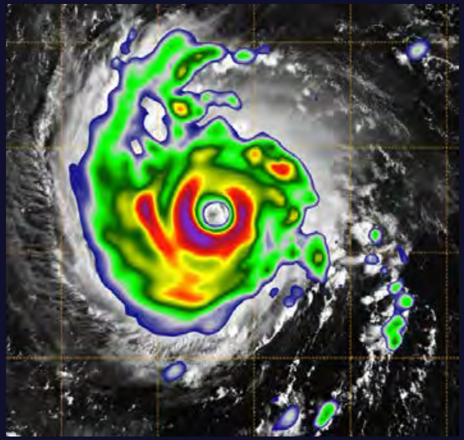
# Rideshare Enables Small Mission Science

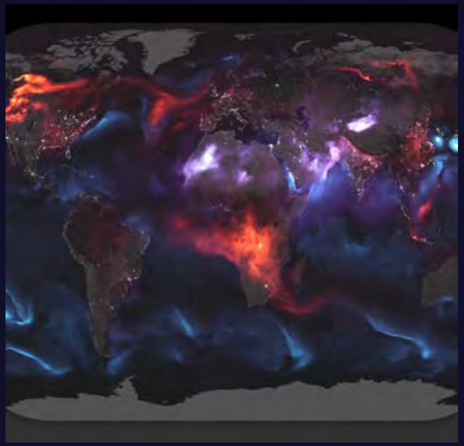


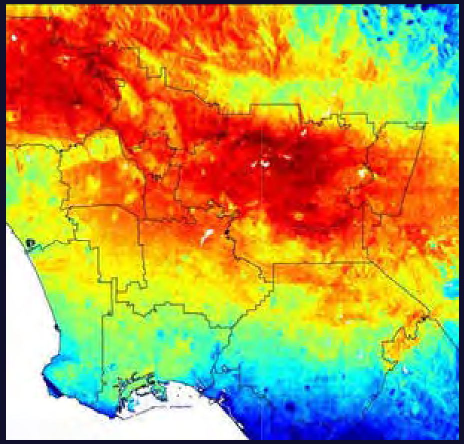
A constellation of identical 3U CubeSats provide sounding (left CubeSat has a temperature profile of a simulated Tropical Cyclone (TC) from a numerical weather prediction (NWP) model) and 12-channel radiometric imagery (center CubeSat has simulated radiances from NWP model and radiative transfer model and the near right CubeSat has a single-channel radiance image of a TC) with a median revisit rate approaching 30 minutes to meet most PATH requirements.

- Enables diverse constellation system science and access to beyond LEO science, possibly through direct-inject approaches
- Provides means to define and answer new science questions via sustained continuity measurements with spacecraft refreshed and improved, on a regular basis, with new technology
- Significant international growth and activity is underway









# Commercial Opportunities in Low Earth Orbit

- Enabling New Science
- Providing platform for Technology Demonstration
- Providing Satellite Broadband and for communication services
- Remote Sensing
- Providing Military Intelligence
- Providing transportation to LEO

# NASA Awards Venture Class Launch Services Contracts

5.5 million

6.9 million

4.7 million

- Three companies selected to provide new commercial launch capabilities for SmallSats/CubeSats
  - Firefly Space Systems Inc.
  - Rocket Lab USA Inc.
  - Virgin Galactic LLC
- Increases frequency NASA can utilize SmallSats/CubeSats for scientific research
- Opens doors for commercial launch services dedicated to transporting smaller payloads

# Engaging the Community for Mission Success

- Small Spacecraft Coordination Group to advise on agency strategy & policy
- Engaging commercial NewSpace industry to partner on science and technology
- Utilize Small Spacecraft Systems Virtual Institute (S3VI) to support community
- https://www.nasa.gov/smallsat-institute


EXPLORE
with us

# The ESA Science Programme

## The challenges of international cooperation

Fabio Favata

# ESA: One agency, 22 countries (or, an agency with cooperation as part of its DNA)

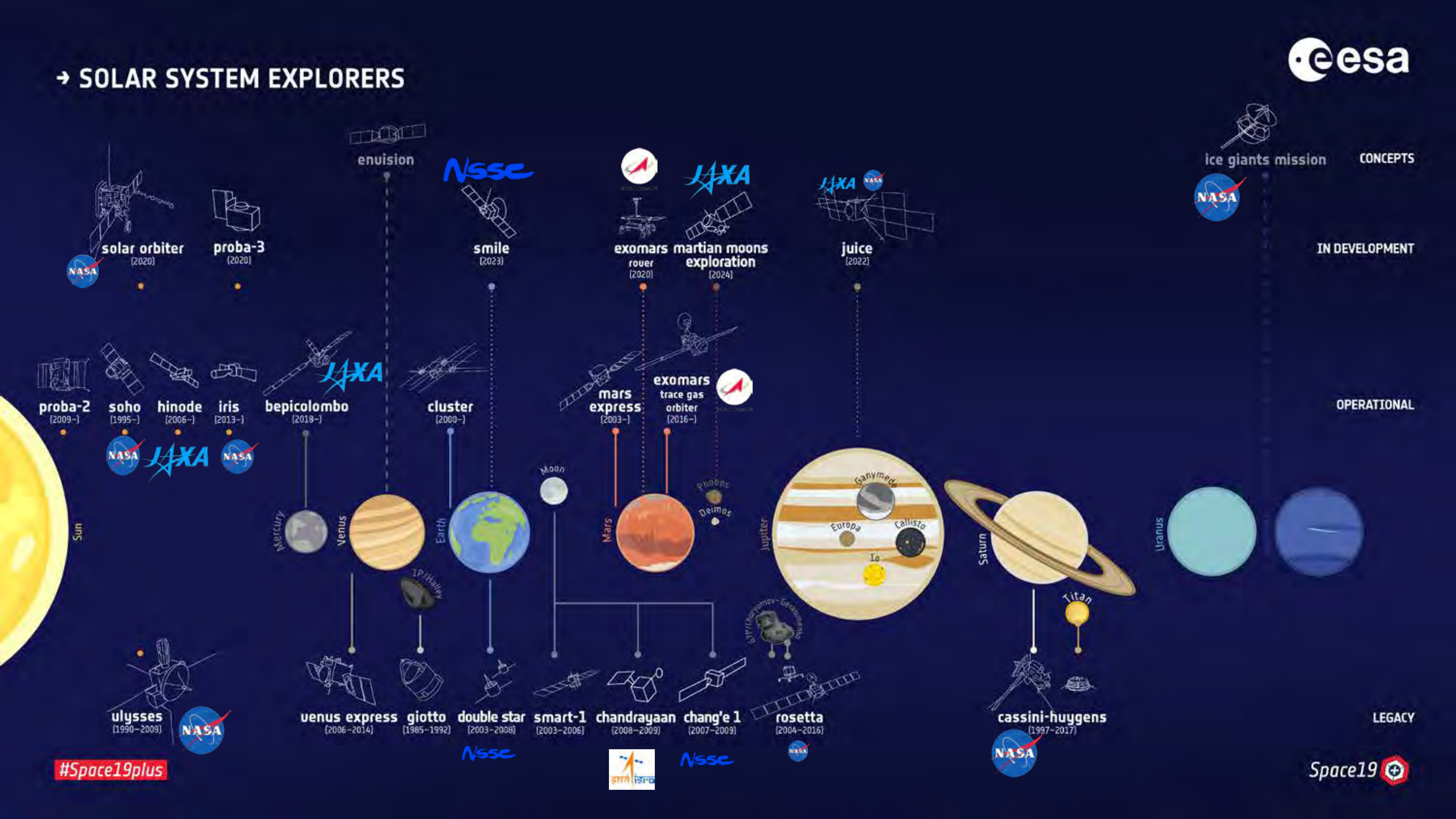
- 22 member states in Europe
- Cooperation Agreement Canada-ESA
- Slovenia associated member state

# One agency, 22 countries (or, an agency with cooperation as part of its DNA)

- Today, only player in the space science field to cooperate with all major players worldwide
  - USA (NASA)
  - Russia (Roscosmos)
  - Japan (JAXA)
  - China (CSA)
  - India (ISRO)

# One agency, 22 countries (or, an agency with cooperation as part of its DNA)

- … and, working toward cooperation with new partners
    - Israel (ISA)
    - South Africa (SANSA)
    - … and more



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(2020)
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isro
chang'e 1
(2007–2009)
NSSC
rosetta
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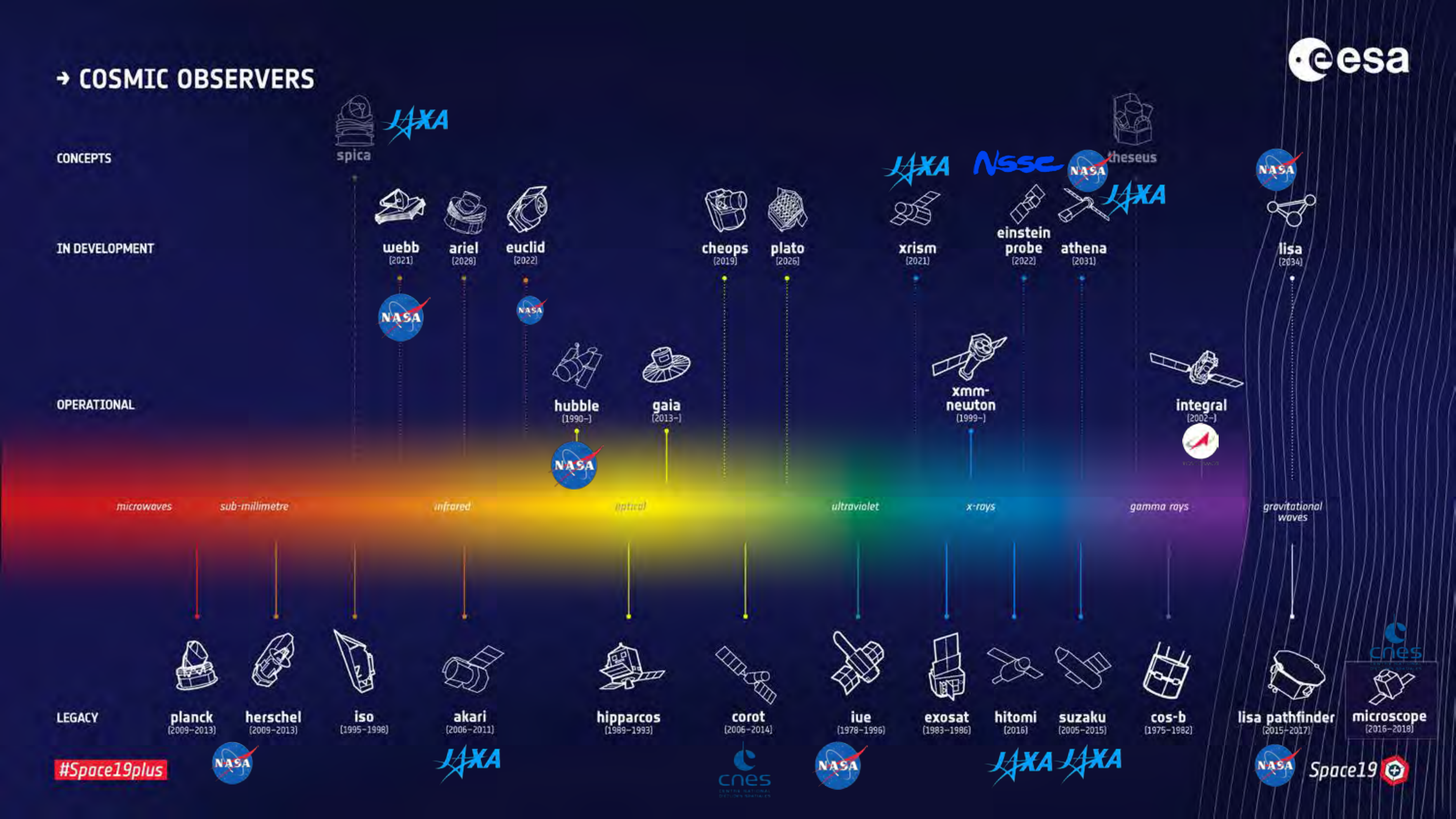
NASA
cassini-huygens
(1997–2017)
NASA
#Space19plus
Space19



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x-rays
gamma rays
gravitational waves
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planck
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herschel
(2009–2013)
iso
(1995–1998)
akari
(2006–2011)
hipparcos
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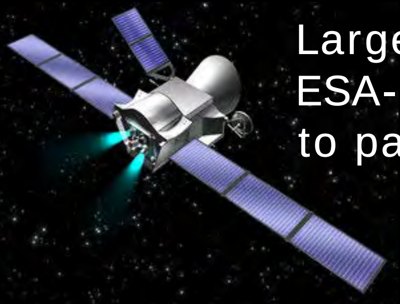
corot
(2006–2014)
iue
(1978–1996)
exosat
(1983–1986)
hitomi
(2016)
suzaku
(2005–2015)
cos-b
(1975–1982)
lisa pathfinder
(2015–2017)
microscope
(2016–2018)
cnes
#Space19plus
NASA
JAXA
cnes
NASA
JAXA
JAXA
NASA
Space19

# ESA Science Programme founding principles

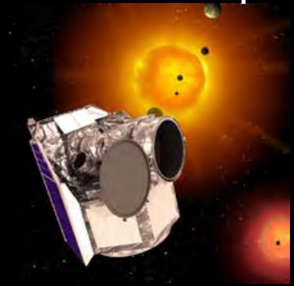
- Long-term planning (stability)
- Bottom-up definition of content (peer review)
- Cooperation
    - Between ESA and Member States
    - With international partners

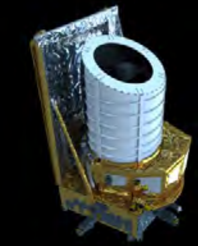
# A stable program structure

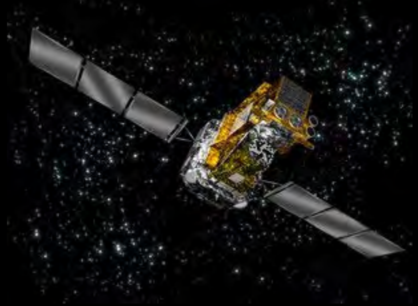


Large missions
ESA-led, open to partners

Small missions
All forms of partnership





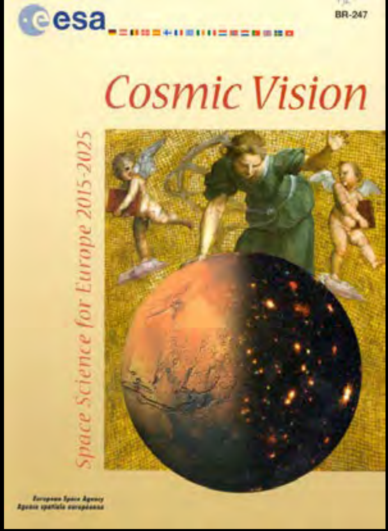


Medium missions
All forms of partnership

Missions of opportunity
Partner-led

# Long-term planning

- Science Programme of ESA based on long-term (2 decades) planning cycles
- Large missions defined long in advance
  - Provide scaffolding to flexible program elements
  - Develop technology
  - Coalesce partnerships



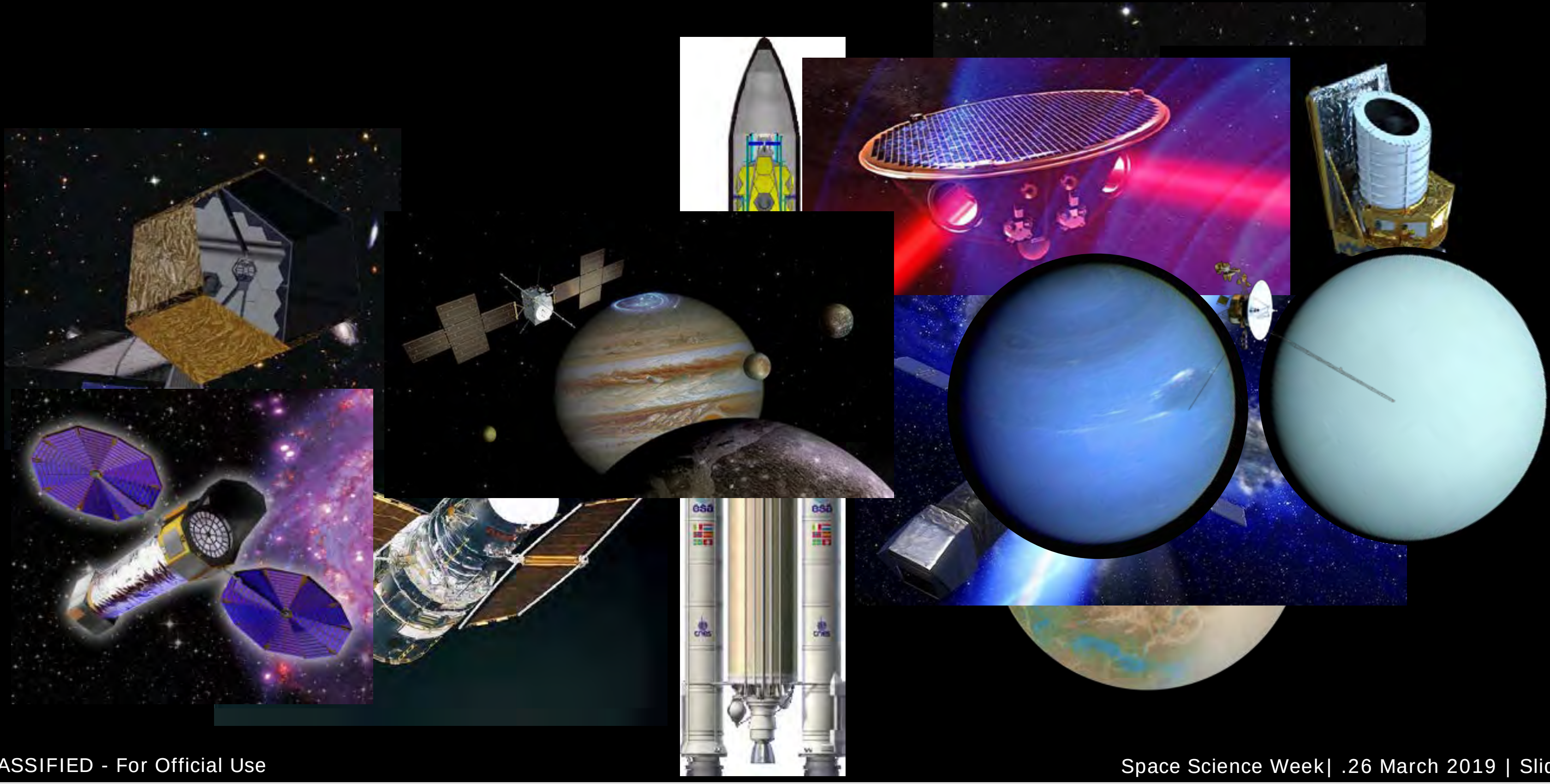
# What fosters cooperation

- Mutual trust
    - Personal relationships
    - Both in the scientific community and in the agencies
    - You recognize your friends when you are down…

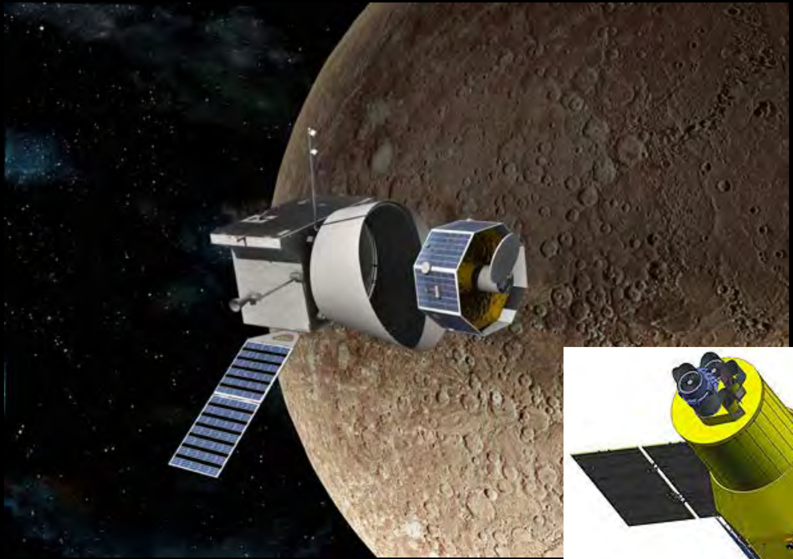
# What fosters cooperation

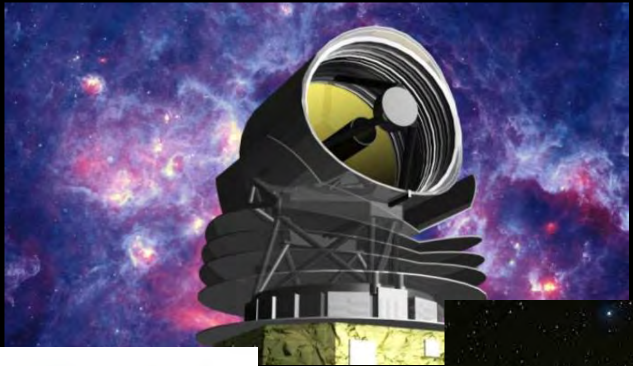
- Program stability
- Common goals and scientific ambitions
- Open data policies

# Success stories: ESA-NASA

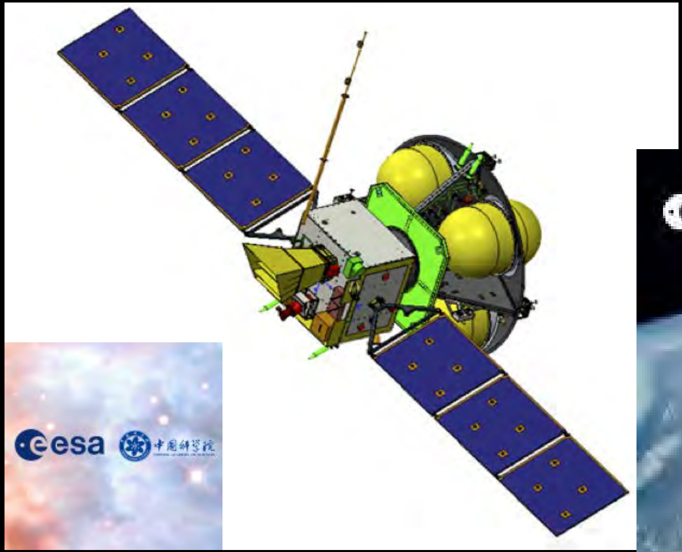


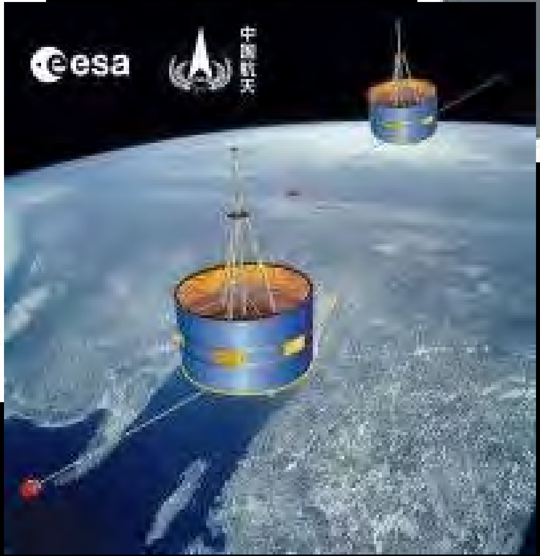
# Success stories: JAXA

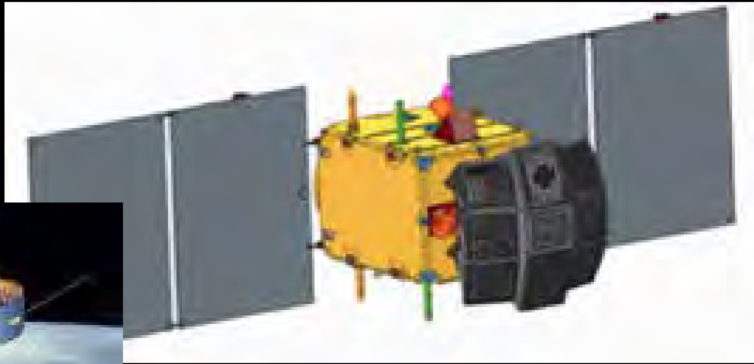




# Success stories: China



# Why we cooperate?

- Building bridges
- Increasing opportunities for scientists
- Belief that we get more than the sum of parts
- Soft power

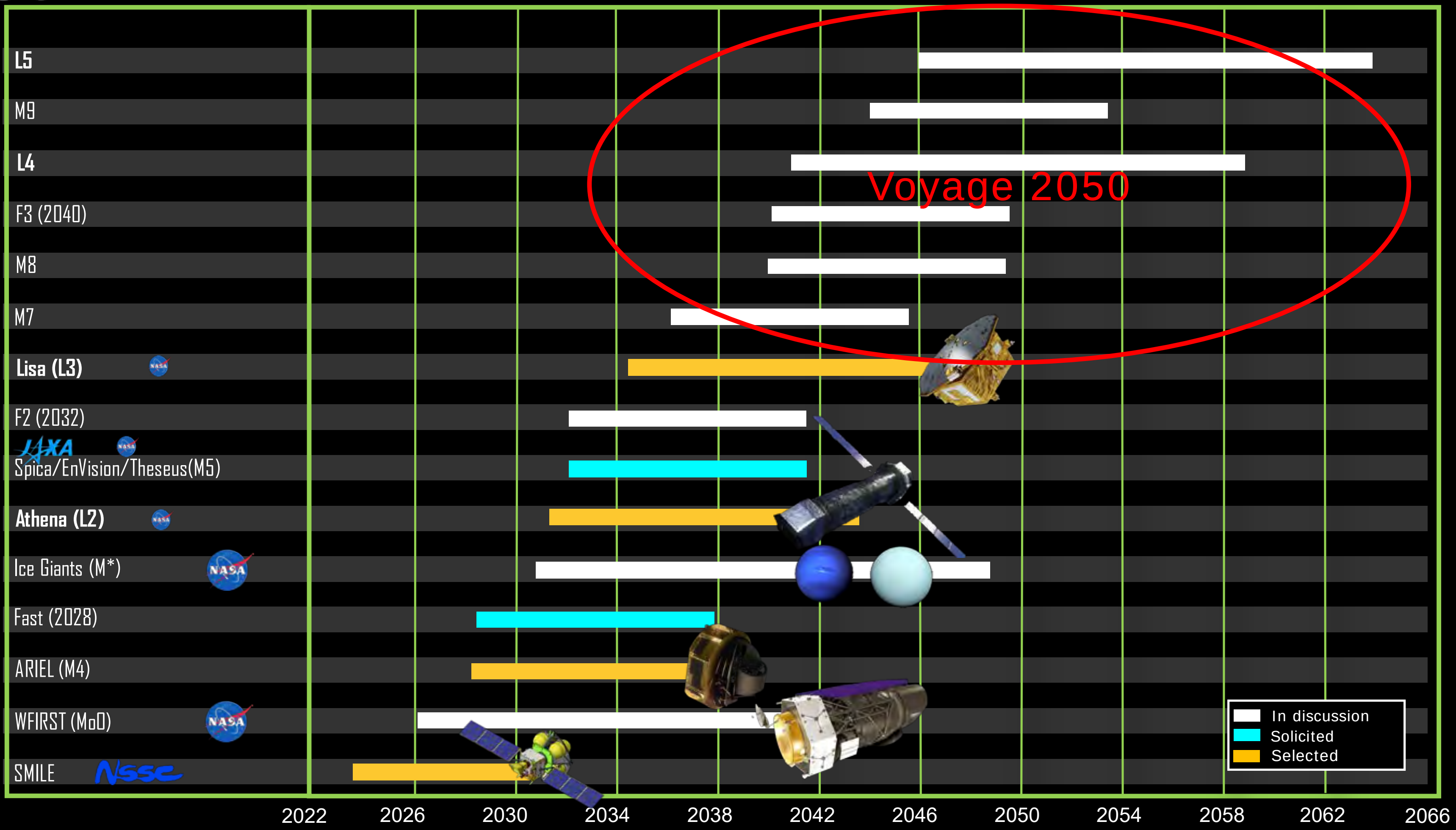
# Challenges (none insurmountable)

- Funding cycles/processes/decisions
- Prima donna syndromes
- Stakeholders not playing their role
- Political chest beating

# New long-term planning starting!

- *Voyage 2050*
- "Call for white papers" open
- Will define Large missions post-LISA and Athena

# Future ESA Space Science Missions




Last update: December 2018


Thank you!

# Progress of Space Science Missions in China

**Xiaolong DONG**

**National Space Science Center**
**Chinese Academy of Sciences**
**(CAS-NSSC)**
**March 26, 2019**

**Space Science Week 2019**
**Washington DC, USA**

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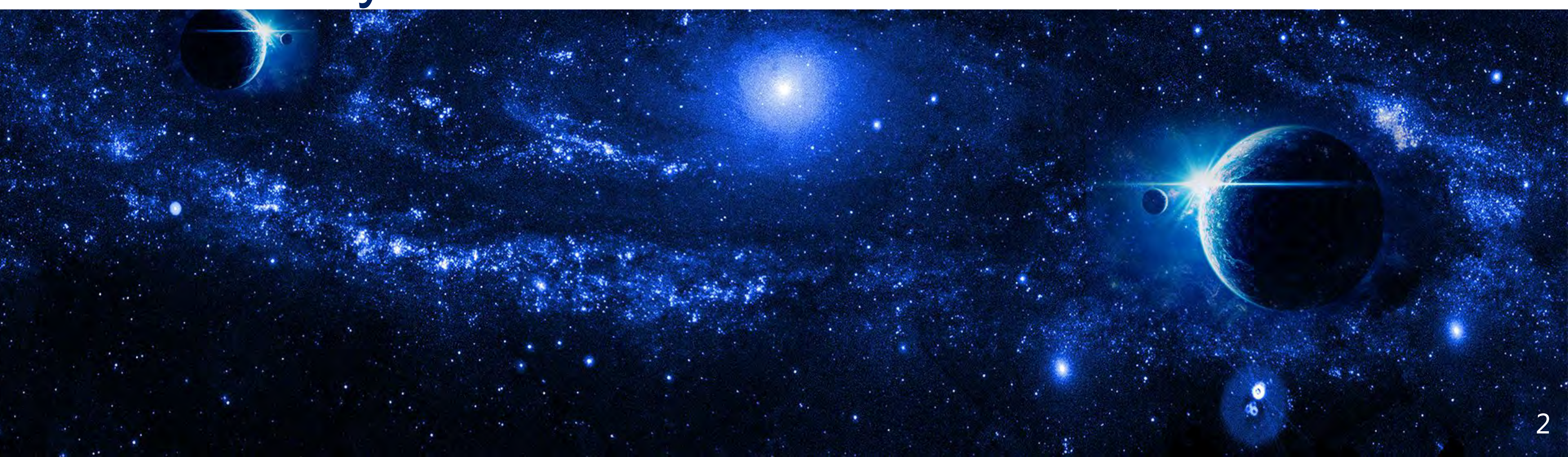

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# Structure of Space Programs in China

| Field | Program (Civil Part) | Agencies in Charge | Role of CAS |
|---|---|---|---|
| Space Applications | National Civil Space Infrastructure<br>• 3 series: Ocean, Meteorology, Land Surface (7 constellations: GEO and LEO)<br>• Specific series: Physical field, atmospheric composition, ocean surveillance | CNSA | Contribution of Payloads |
| | High Resolution Earth Observation System | CNSA | Contribution of payloads;<br>Application system. |
| Lunar and Deep Space Missions | Lunar missions (Chang-E Program) | CNSA | Ground system;<br>VLBI;<br>Scientific research;<br>Payload system. |
| | Martian Missions | | |
| Manned Space Flight Program | | CMSEO | Scientific and application system |
| **Space Science** | **Strategic Priority Program on Space Science** | **CAS** | **Full responsibility** |

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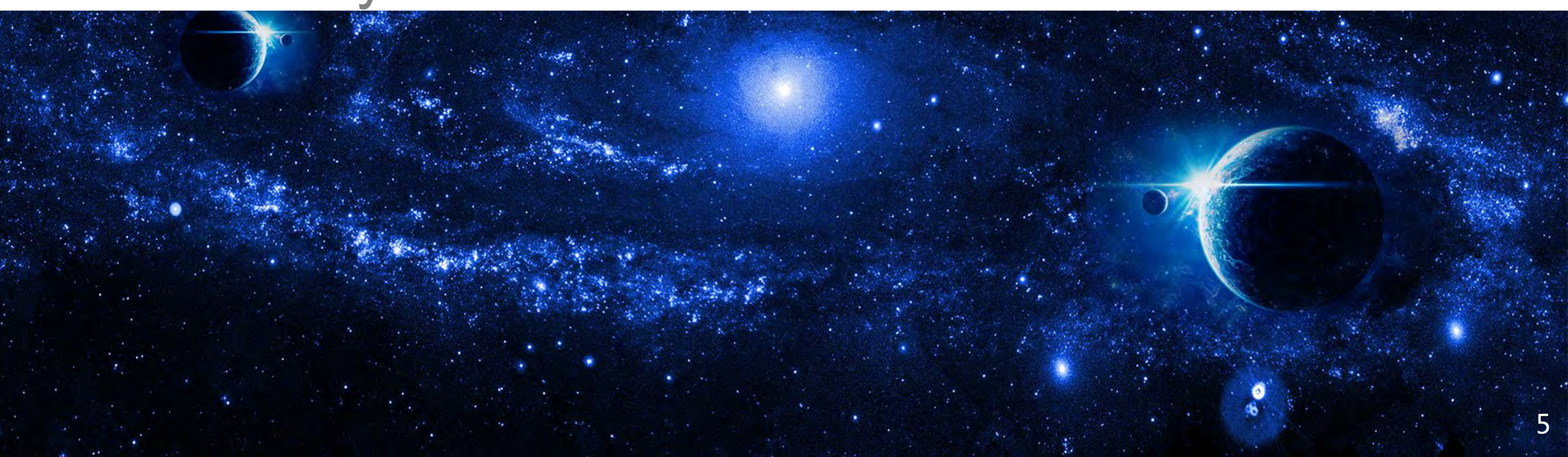

# Strategic Priority Program on Space Science

- **Space science program initiated and proposed by CAS, based on a series strategic planning research during 2006-2010**
  - Make new scientific discoveries
  - Lead the development of space technologies
  - Play a strategic role of space science in the nation's development
- **Approved by Chinese government in March, 2011**
- **Including:**
  - Series space science missions
  - Intensive study of candidate missions
  - Pre-study of future mission concepts and enabling technologies

NSSC

# Themes of Space Science

## Theme 1: How did matter originate, how does it evolve and move?

How did the universe originate and how does it evolve ?

How did life originate and how does it evolve ?

What are the law of matter motion and the law of life activity in space environment?

## Theme 2: What is the relationship between solar system and human being?

What is the nature of solar activity?

What is the origin and evolvement of solar system, and its relationship with the sun?

How does the earth system evolve?

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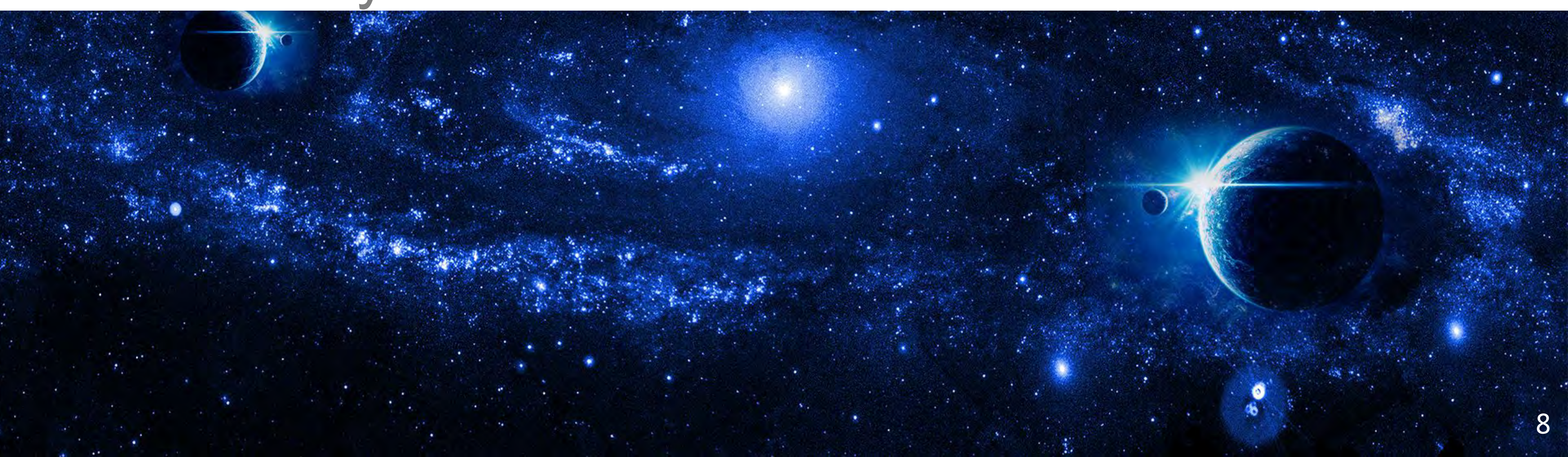


# Two Themes of Space Science

## Theme 1: How did matter originate, how does it evolve and move?

How did the universe originate and how does it evolve ?

How did life originate and how does it evolve ?

What are the law of matter motion and the law of life activity in space environment?

## Theme 2: What is the relationship between solar system and human being?

What is the nature of solar activity?

What is the origin and evolvement of solar system, and its relationship with the sun?

How does the earth system evolve?

# Strategic Priority Program on Space Science ( 2011-2017 )

**Strategic Priority Program on Space Science ( 2011-2017 )**

- Black hole, dark matter
- Test of the laws of quantum mechanics
- Kinetic properties of matter
- Rule of life activity in the space environment

**DArk Matter Particle Explorer (DAMPE)**

**ShiJian-10 (SJ-10)**

**QUantum Experiments at Space Scale (QUESS)**

**Hard X-ray Modulation Telescope (HXMT)**

# 4 Missions Launched and Operated


DAMPE, Dec.17, 2015

SJ-10, Apr. 6, 2016


QUESS, Aug. 16, 2016

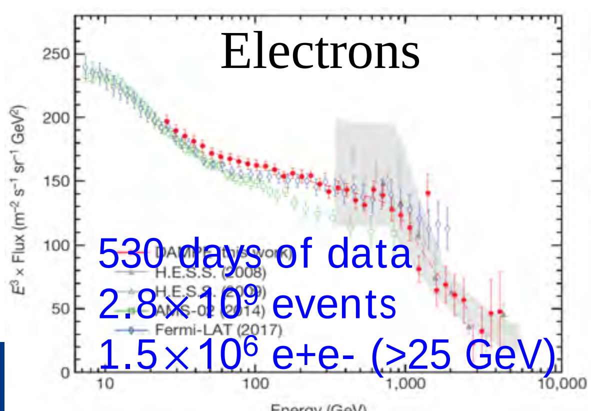

HXMT, Jun. 15, 2017

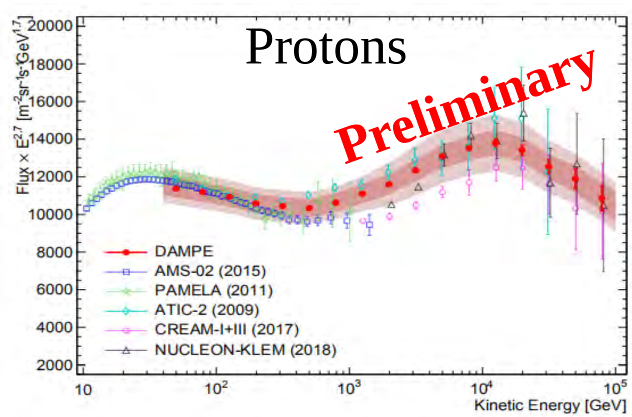
# DAMPE

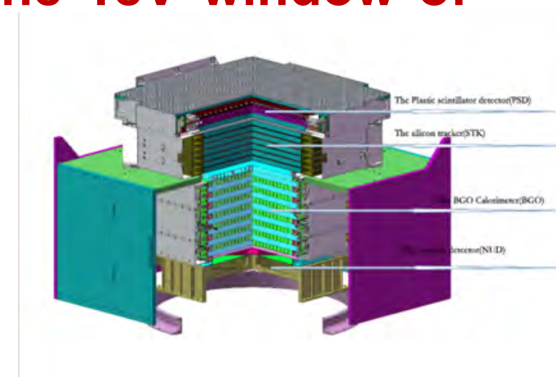
## Scientific objectives

- Indirect detection of dark matter particles
- Origin and propagation of cosmic rays
- High-energy gamma-ray astronomy

- **DAMPE has been in space for more than 3 years, and recorded more than 5.6 billion cosmic rays events (as of Feb. 28, 2019)**
- **Direct detection of a break in the TeV electron spectrum (2017, Nature)**
- **Detection of a spectral break at ~10 TeV in the proton spectrum**
- **DAMPE has been approved to extend its scientific operation for 2 more years to collect more data to scrutinize the TeV window of the Universe**



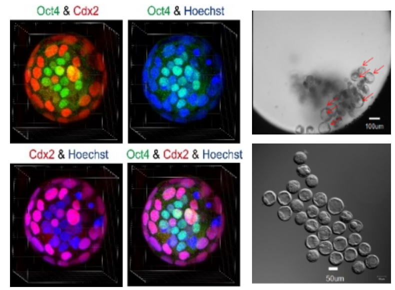



# SJ-10

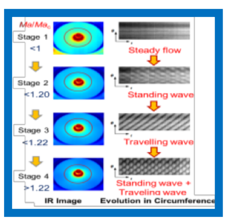
# 15 experiments were conducted for the first time

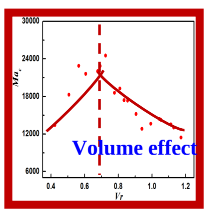
Development of mammalian preimplantation embryo under microgravity

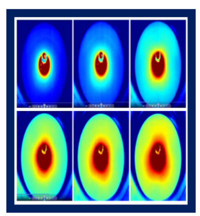



2016.4.6 launching
2016.4.18 return
2016.4.25 extension


Surface wave of thermocapillary convection in An Open Annular Pool



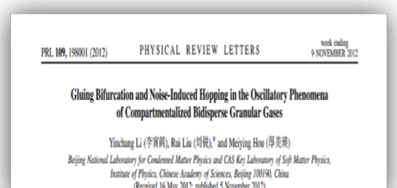



Papers published

JFM: 2.893
POF: 2.279
IJHMT: 3.458
ETFS: 2.830
MST: 1.118

Experimental study on particle motion behavior

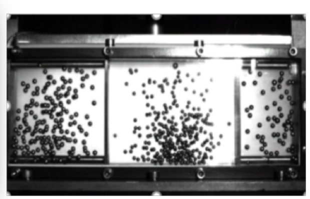

PRL 109, 198001 (2012) PHYSICAL REVIEW LETTERS week ending 9 NOVEMBER 2012

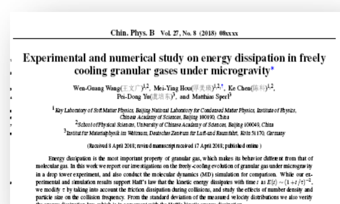
Gluing Bifurcation and Noise-Induced Hopping in the Oscillatory Phenomena of Compartmentalized Bidisperse Granular Gases

Yinchang Li (李寅阊), Rui Liu (刘锐), and Meiying Hou (厚美瑛)

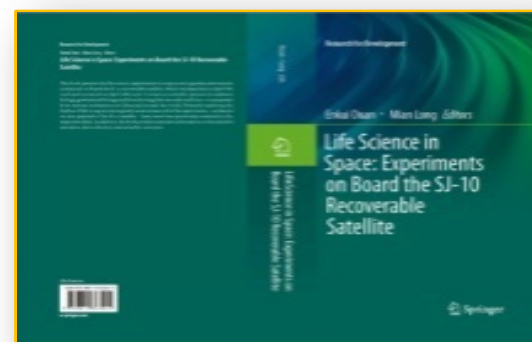
Beijing National Laboratory for Condensed Matter Physics and CAS Key Laboratory of Soft Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China

(Received 16 May 2012; published 5 November 2012)




Chin. Phys. B Vol. 27, No. 8 (2018) 08xxxx

Experimental and numerical study on energy dissipation in freely cooling granular gases under microgravity

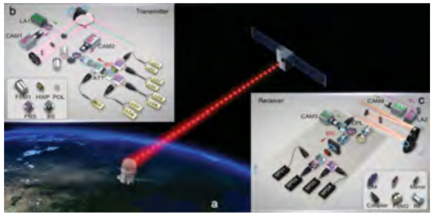


Nssc

QUESS

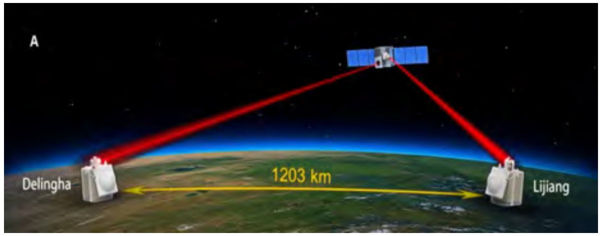
# Operated well in space for 2 yrs+ since Aug 2016

- **Satellite-to-ground quantum key distribution** was accomplished for the first time (Nature,2017)

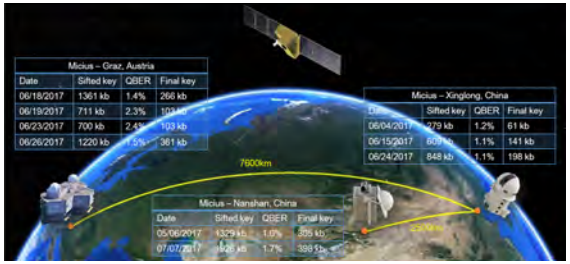


- **Ground-to-satellite quantum teleportation** was accomplished for the first time (Nature,2017)

- **Satellite-ground and ground-satellite entanglement distribution** over 1200 kilometers was accomplished for the first time (Scince,2017)



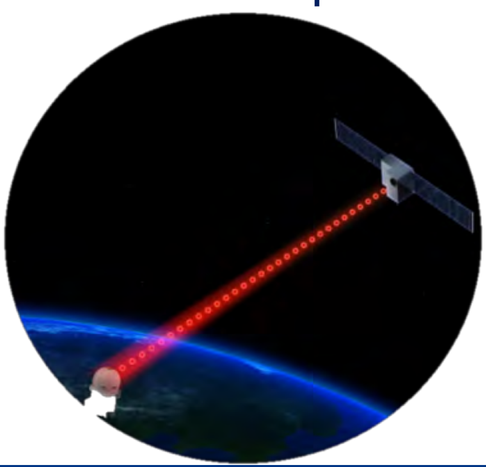

- **Intercontinental quantum key distribution** was accomplished between China and Austria

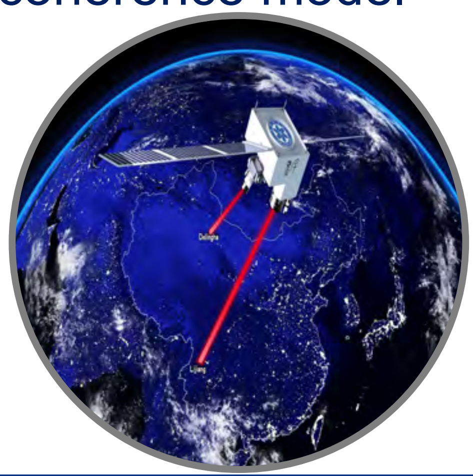


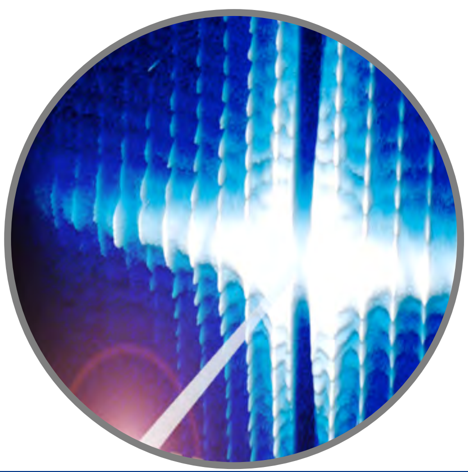
# 2 more year extension of QUESS

## Getting approved to be extended for another 2 yrs:

- Space Quantum Key Distribution and Its Application：Satellite-relayed intercontinental QKD, High speed satellite-to-ground QKD, Miniaturization technique of space QKD ground station
- Quantum experiment based on quantum entanglement distribution: Entanglement-based QKD, Remote state preparation with the distributed entanglement
- Expanded application of space quantum communication：Secure time-frequency transmission, Testing a gravitationally induced quantum decoherence model





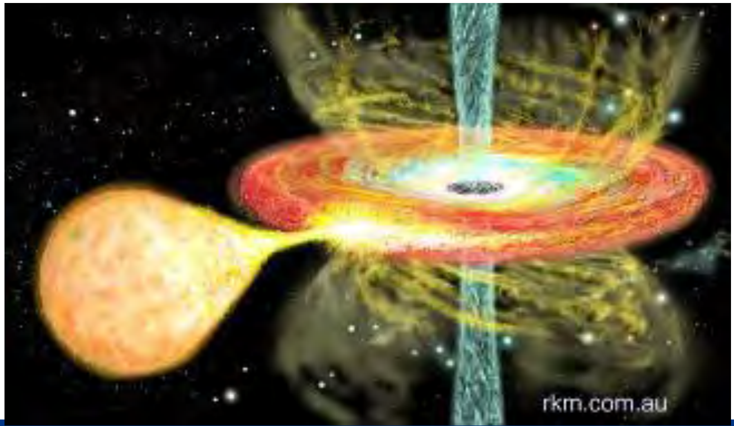


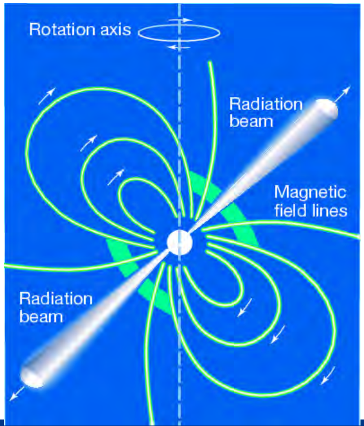
# HXMT

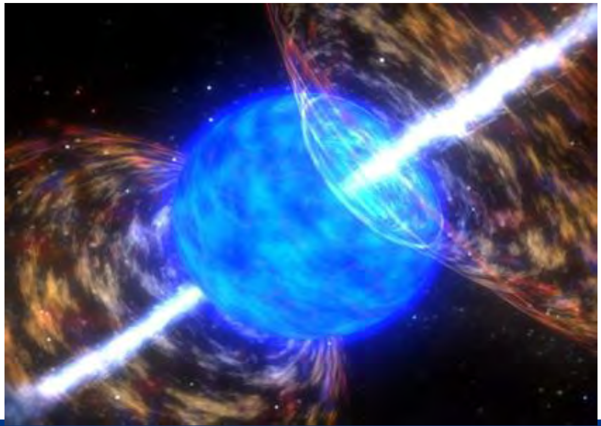
慧眼－HXMT

## The 1st X-ray observatory of China!

- Sciences：BHs, NSs, XRBs, Pulsars, RBs…
- Observation modes
  - Survey observation for new transients
  - Pointed observation of known sources
  - Gamma-ray monitoring (0.2-5 MeV)
- Features:
  - Large effective area
  - High timing resolution
  - Wide energy band (1 keV- 250 keV)

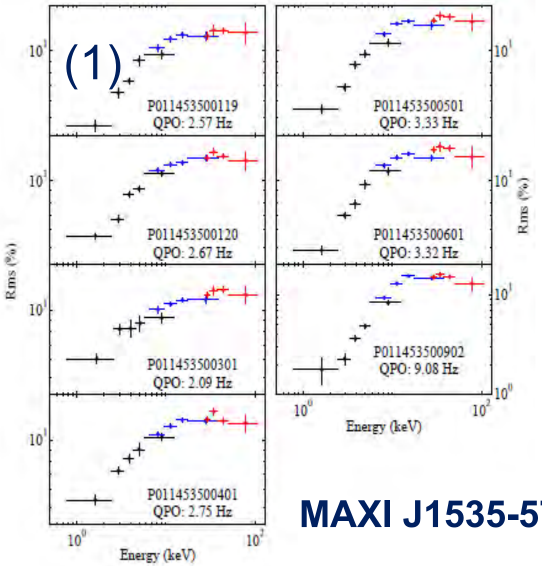


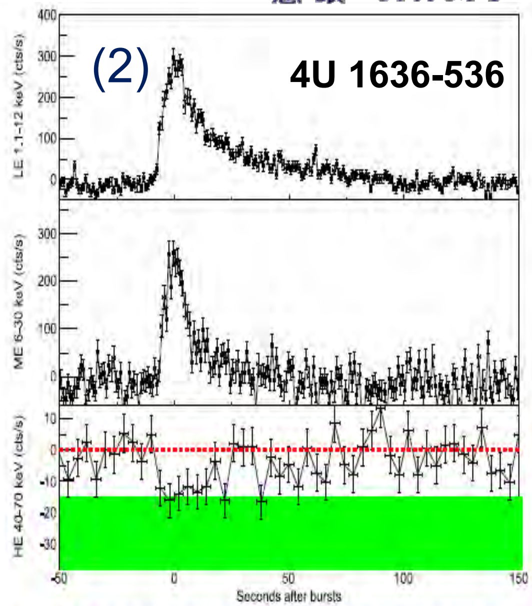



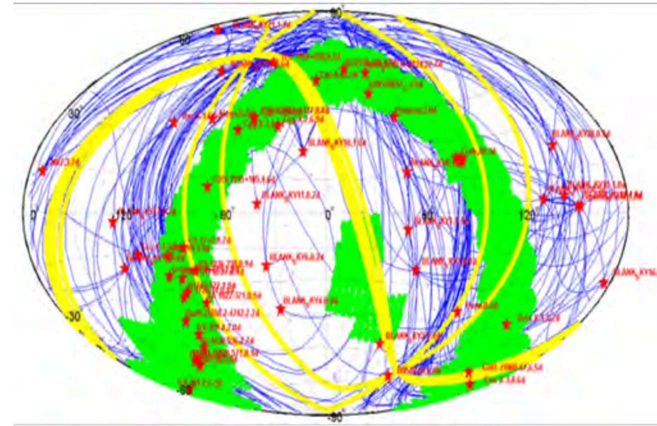
# HXMT

慧眼 – HXMT

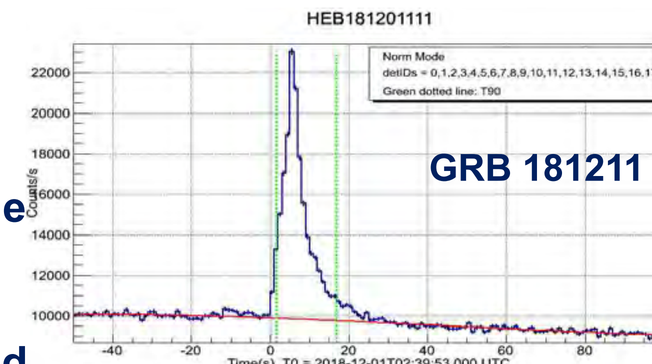



MAXI J1535-571

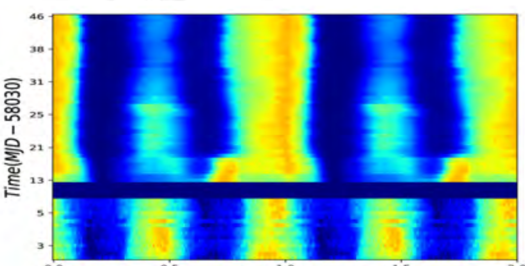


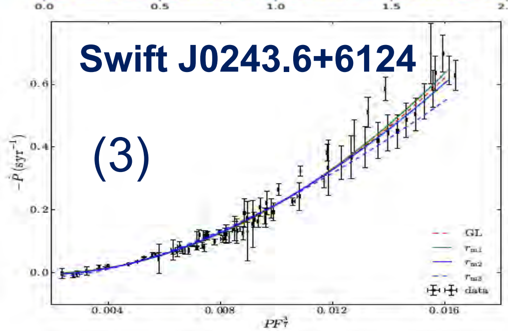



Total observation map of Insight-HXMT: X-ray binaries ~11 Ms, Scan Survey ~5 Ms.




77 gamma-ray bursts detected in 2018; 8 first reported by Insight-HXMT




## X-ray binaries:

(1) MAXI J1535-571: black hole system, QPO observed first time to 100 keV.

(2) 4U 1636-536: neutron star system, corona cooling revealed first time with single short type-I X-ray burst

(3) Swift J0243.6+6124: neutron star spin evolution of the ultra-luminous X-ray source in the Milky Way

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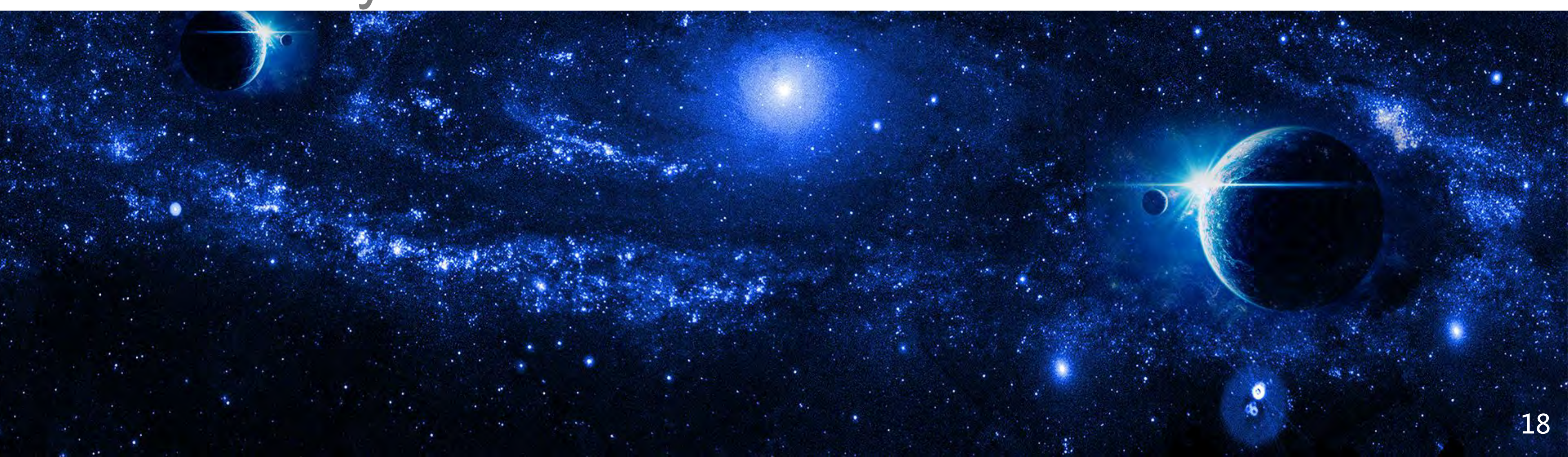


# Two Themes of Space Science

## Theme 1: How did matter originate, how does it evolve and move?

How did the universe originate and how does it evolve ?

How did life originate and how does it evolve ?

What are the law of matter motion and the law of life activity in space environment?

EP
GECAM

## Theme 2: What is the relationship between solar system and human being?

What is the nature of solar activity?

What is the origin and evolvement of solar system, and its relationship with the sun?

How does the earth system evolve?

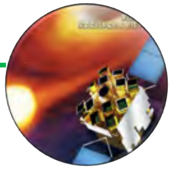
ASO-S

SMILE

# Strategic Priority Program on Space Science (2018-2022)

**Strategic Priority Program on Space Science**
**( 2018-2022 )**

- Time-domain astronomy
- Relationship of solar magnetosphere and eruption
- Interaction of solar wind and magnetosphere
- The electromagnetic counterpart of gravitational waves



**1. Einstein Probe (EP)**

**2. Advanced Space-borne Solar Observatory (ASO-S)**

**3. Solar wind Magnetosphere Ionosphere Link Explorer（SMILE）**

**4. Gravitational wave high-energy Electromagnetic Counterpart All-sky Monitor (GECAM)**

# Strategic Priority Program on Space Science (2018-2022)

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<tr><th>Category</th><th colspan="2">Missions</th></tr>
<tr><td rowspan="4">Space Science Missions in Implementation</td><td colspan="2">Solar wind Magnetosphere Ionosphere Link Explorer (SMILE)</td></tr>
<tr><td colspan="2">Einstein Probe (EP)</td></tr>
<tr><td colspan="2">Advanced Space-borne Solar Observatory (ASO-S)</td></tr>
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<tr><td>Mid-to-high Orbit Quantum Satellite</td></tr>
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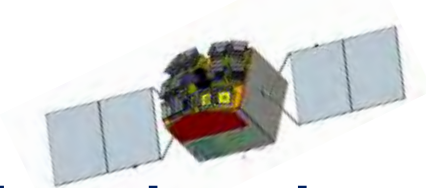


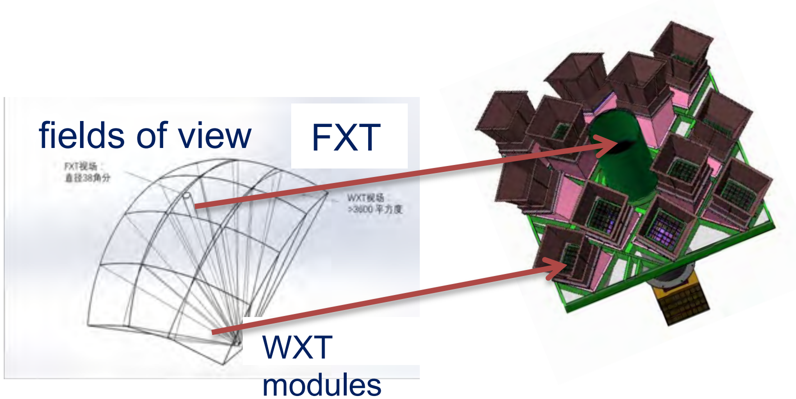
# 1. Einstein Probe (EP)

**EP: A time-domain astronomy mission**

**Scientific Objectives:**

- **discover and study the high-energy transients and variable objects in soft X-ray band**
  - Demography, origin and evolution of black hole population
  - How gravitational waves are produced, and their effects?
  - Life cycle of the first generation of stars, re-ionization
  - How supernovae explode?

- **Payloads**
  - Wide-field X-ray Telescope (WXT)
  - Follow-up X-ray Telescope (FXT)

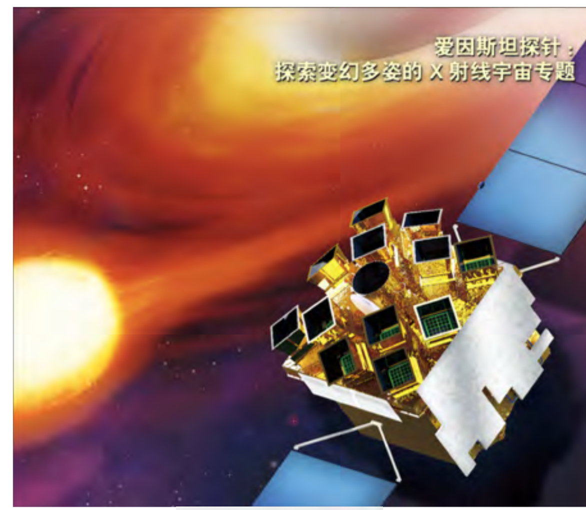


# Mission Profile

- **Specifications:**
  - Orbit: 600 km, 30°
  - Attitude Control: 3-axis stabilized
  - Mass: <1250 kg
  - Lifetime: 3 yrs
  - Rocket: CZ-2C

- **International Cooperation**
  - ESA: Invest >10M Euro in-kind contribution to payload (MoO)
  - MPE (Germany): Hardware contribution
  - French Space Agency: VHF system（TBD）

- Officially approved in Dec. 2017
- Now in Phase B
- Planned launch time: 2022



# EP International Collaborations

FXT: Mirror Assembly and Electron Diverter

WXT: Testing of Optics and Detectors

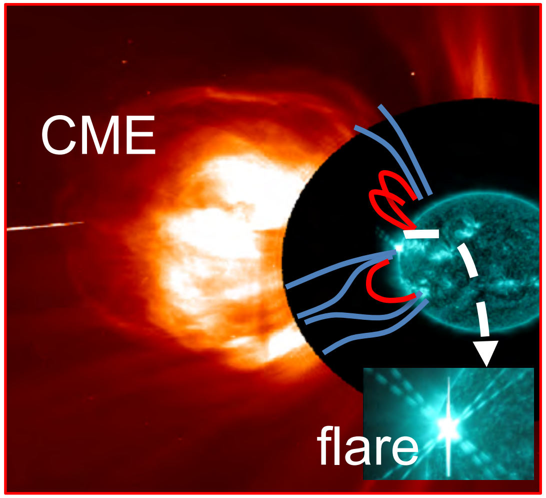
Ground Station Support & Science Exploitation

~5 Detector modules & 1 CAMEX test module for the FXT camera

A detector module comprises a PNCCD sensor and front-end readout ASICs (CAMEX type) mounted on a rigid-flex PCB board

VHF system for “alter” downlink

# 2. Advanced Space-borne Solar Observatory (ASO-S)

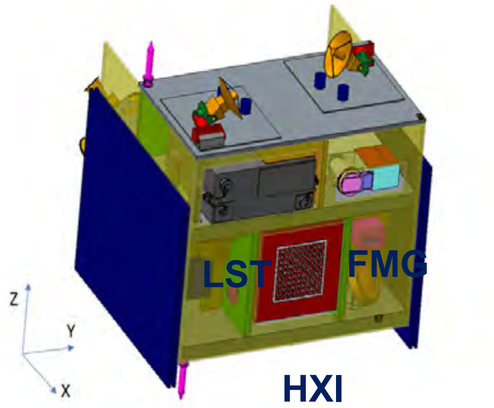



## Scientific Objectives

- Relationship between solar magnetic field and solar flares
- Relationship between solar magnetic field and CMEs
- Relationship between solar flares and CMEs

## Payloads

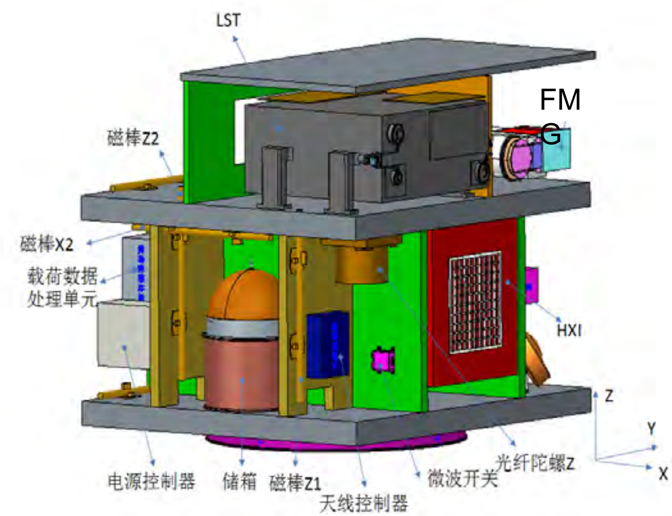
- Full-Disc Vector Magnetograph (FMG): solar magnetic field
- Hard X-ray Imager (HXI): solar flare
- Lyman-alpha Solar Telescope(LST): CME



# Mission profile

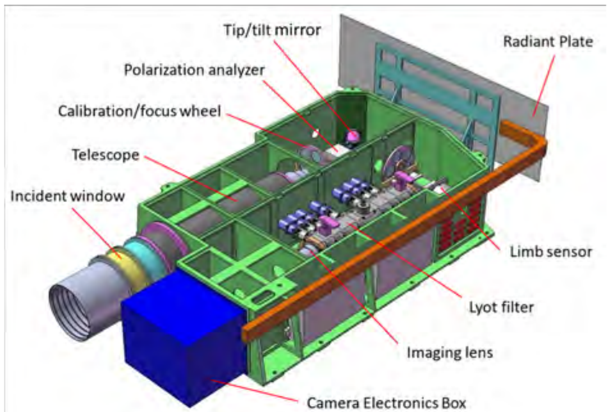
– Orbit: 720 km, sun-synchronous, 98.2°
– Attitude Control: 3-axis stabilized
– Mass: <1000 kg
– Power: < 770 W
– Lifetime: 4 yrs
– Launcher: CZ-2D

– Officially approved in Dec. 2017
– Now in Phase B
– Planned launch time: 2021

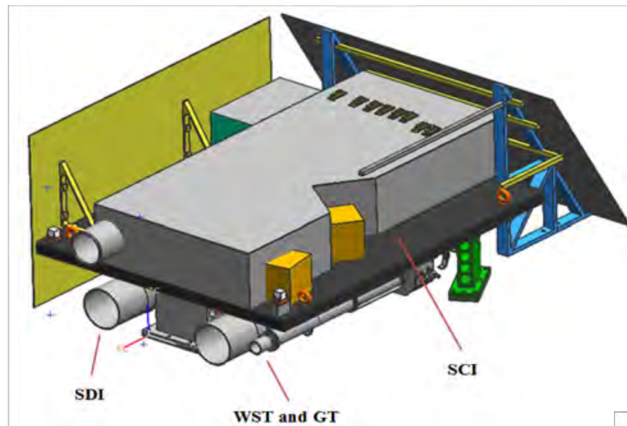



# Progress

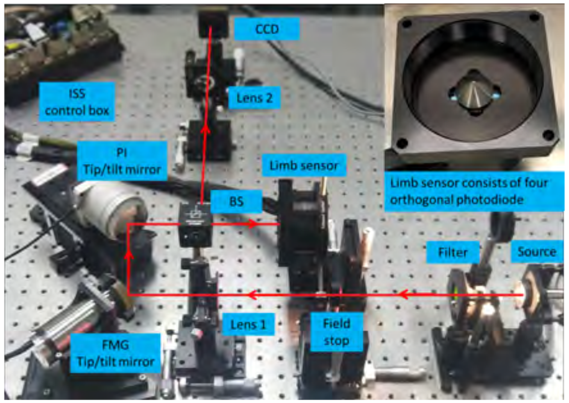
- Payload Prototype completed:

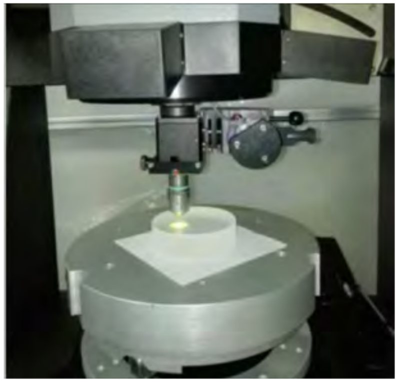


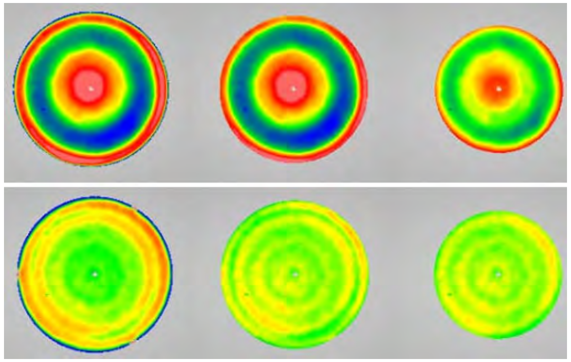

FMG



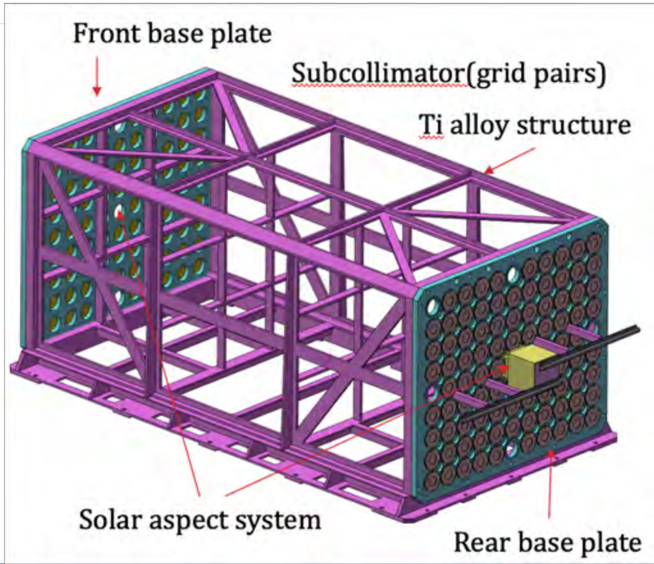

LST





Surface Super-polishing M1 mirror: RMS<0.3nm



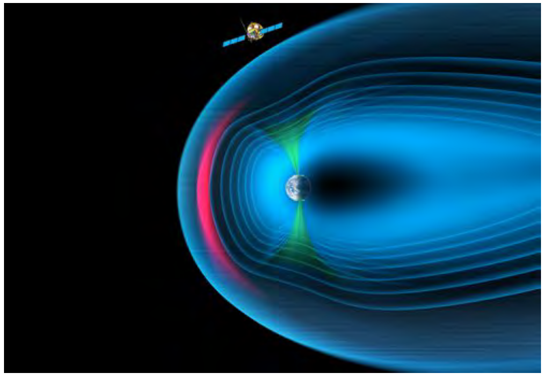
# 3. Solar wind Magnetosphere Ionosphere Link Explorer (SMILE)

## CAS-ESA Joint Mission

- Science Objectives
  - Determine when and where transient and steady magnetopause reconnection dominates
  - Define the substorm cycle, including timing and flux transfer amplitudes
  - Define the development of CME-driven storms, including whether they are sequences of substorms

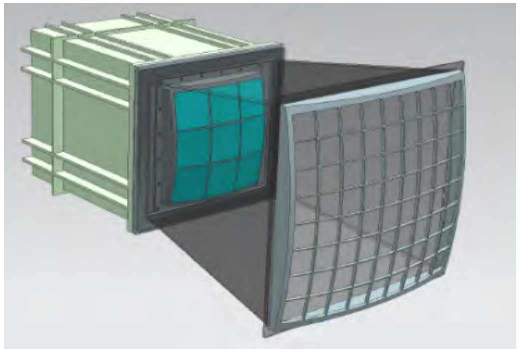
## Scientific Significance

- Imaging of the interaction between solar wind and magnetosphere for the first time

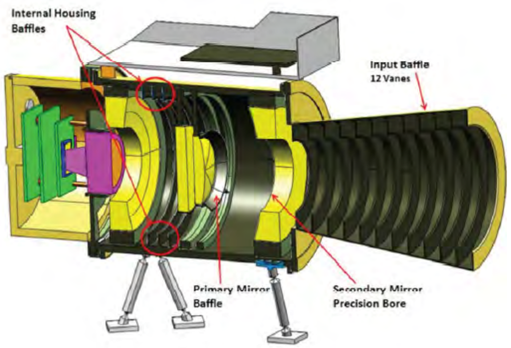


# Payloads

- Soft X-ray Imager (SXI)
- Ultra-Violet Imager (UVI)
- Light Ion Analyzer (LIA)
- MAGnetometer (MAG)



SXI



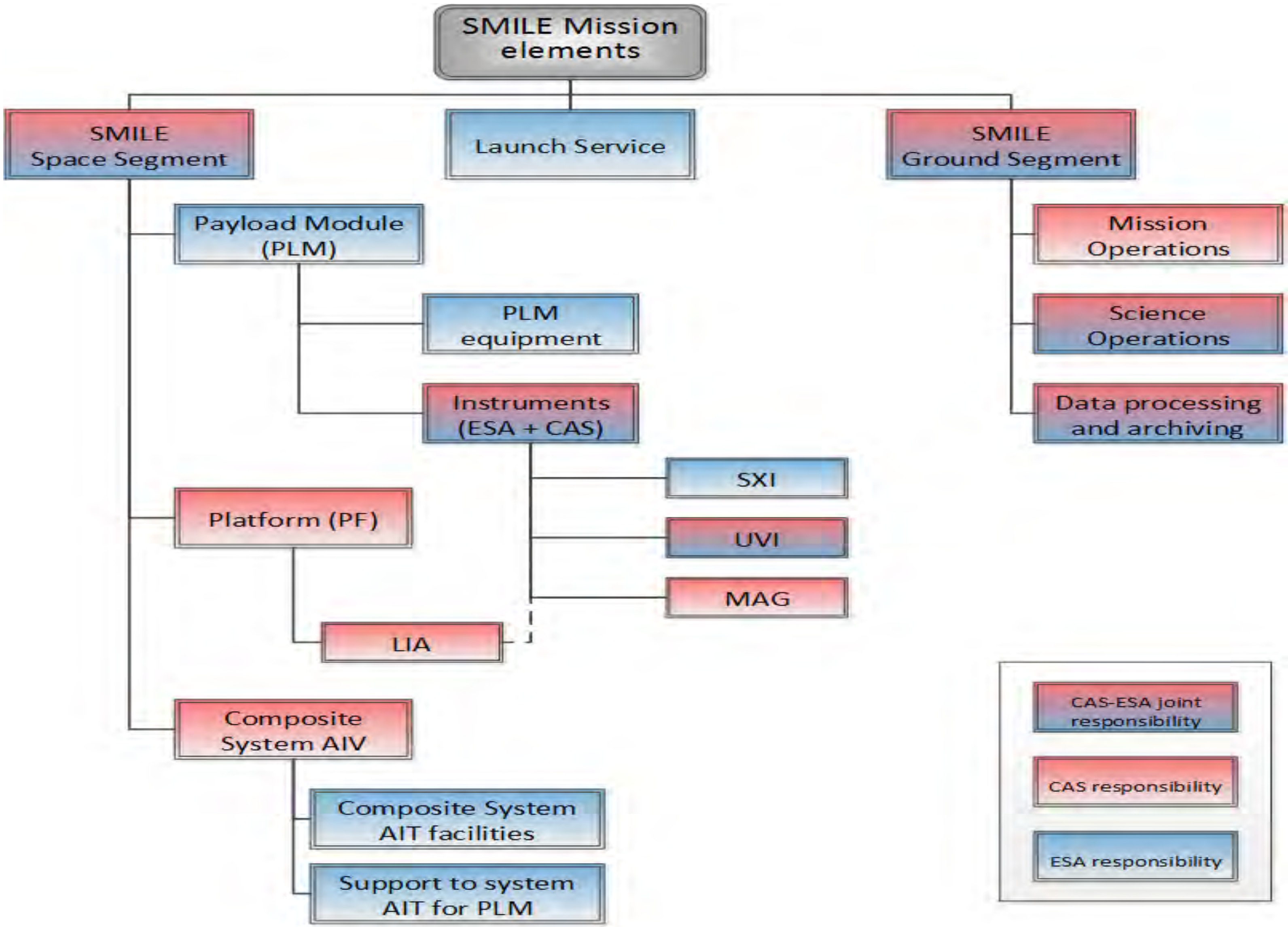

UVI

LIA

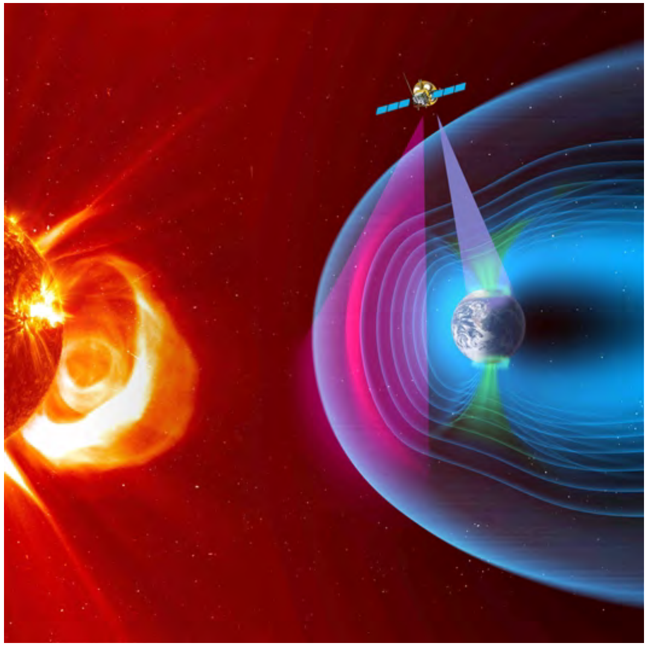
MAG

The payloads and satellite will be provided by scientists and industry from both Europe and China.

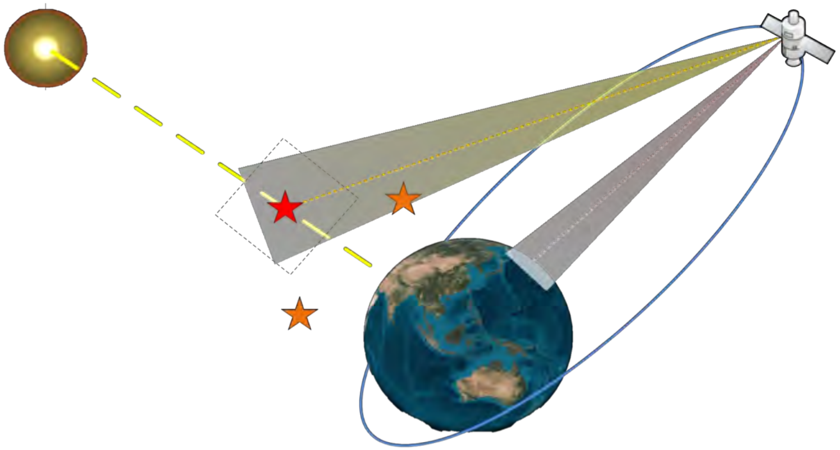
# SMILE International Collaborations



# Mission Profile

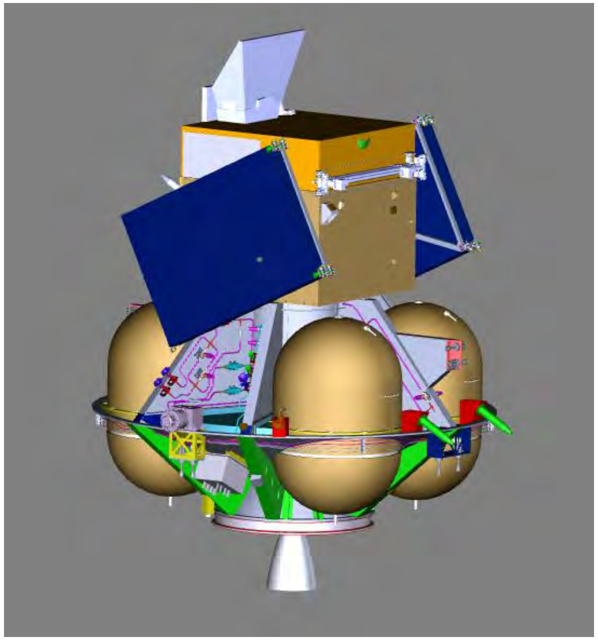


- **Orbit**：5000km@perigee
  19 $R_e$@apogee
- **Mass**: <2200kg
- **Lifetime**：3 years
- **Now in Phase B**
- **Planned Launch time**: 2023



# Progress

SMILE was adopted on March 5, 2019 by ESA

Nssc

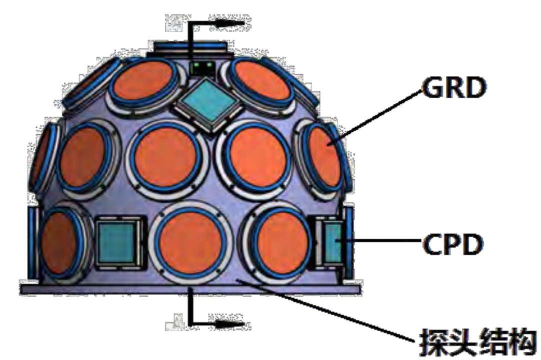
# 4. Gravitational wave high-energy Electromagnetic Counterpart All-sky Monitor (GECAM)

## Sciences: All-time all-sky monitor for GWGRB, GRB...

- Independent confirmation of GW event
- Accurate localization, host galaxy, redshift
- Astrophysical content of the GW source
- GW+EM, Cosmology, fundamental physics

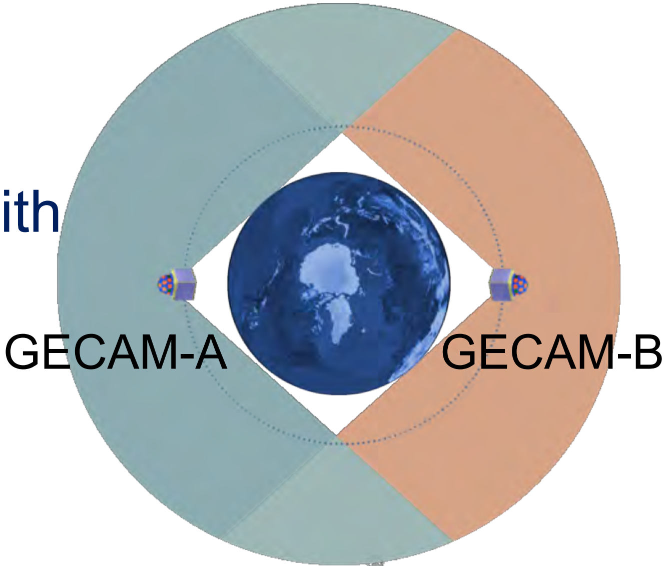

## Payloads: 25 GRD, 8 CPD for each satellite

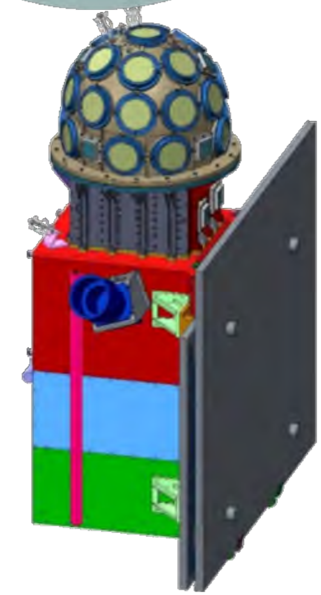
- FOV： 100% all-sky
- Sensitivity：$\sim 2\times 10^{-8}$ erg/cm$^2$/s
- Energy band：6keV~5MeV



# Mission Profile

- **Specifications:**
  - A pair of  satellites in the same orbit with opposite phase
  - Orbit: 600 km, 29°
  - Attitude Control: 3-axis stabilized
  - Mass: 170 kg/satellite
  - Lifetime: 3 yrs
- Planned launch time: 2020
- Joint observation with LIGO & Virgo when they reach the design sensitivity



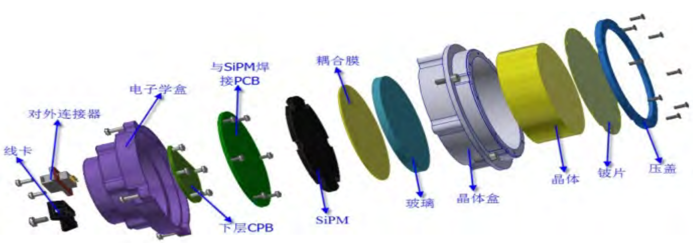



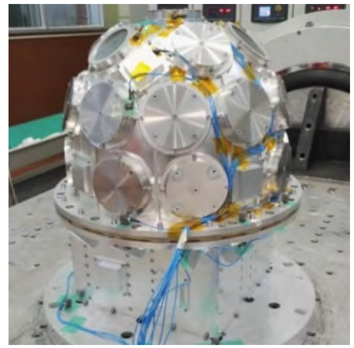
GECAM satellite

# Progress

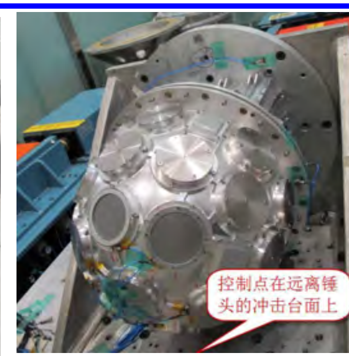
- Completed design phase and turned to Phase C in March 2019

- **Key Technologies:** Sealing and long-term stability of lanthanum bromide ($LaBr_3$) crystal for gamma ray detector (GRD) was verified



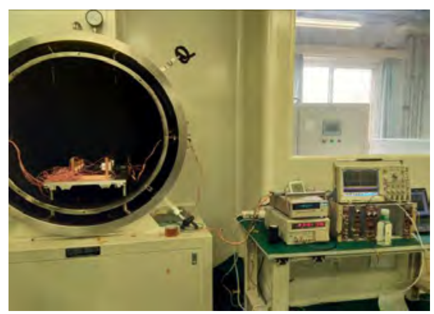



**Random/Sinusoidal**

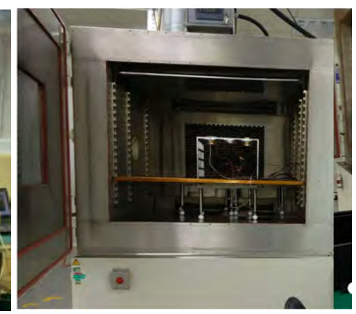



**Impact**

**Noise test**



**Thermal vacuum**

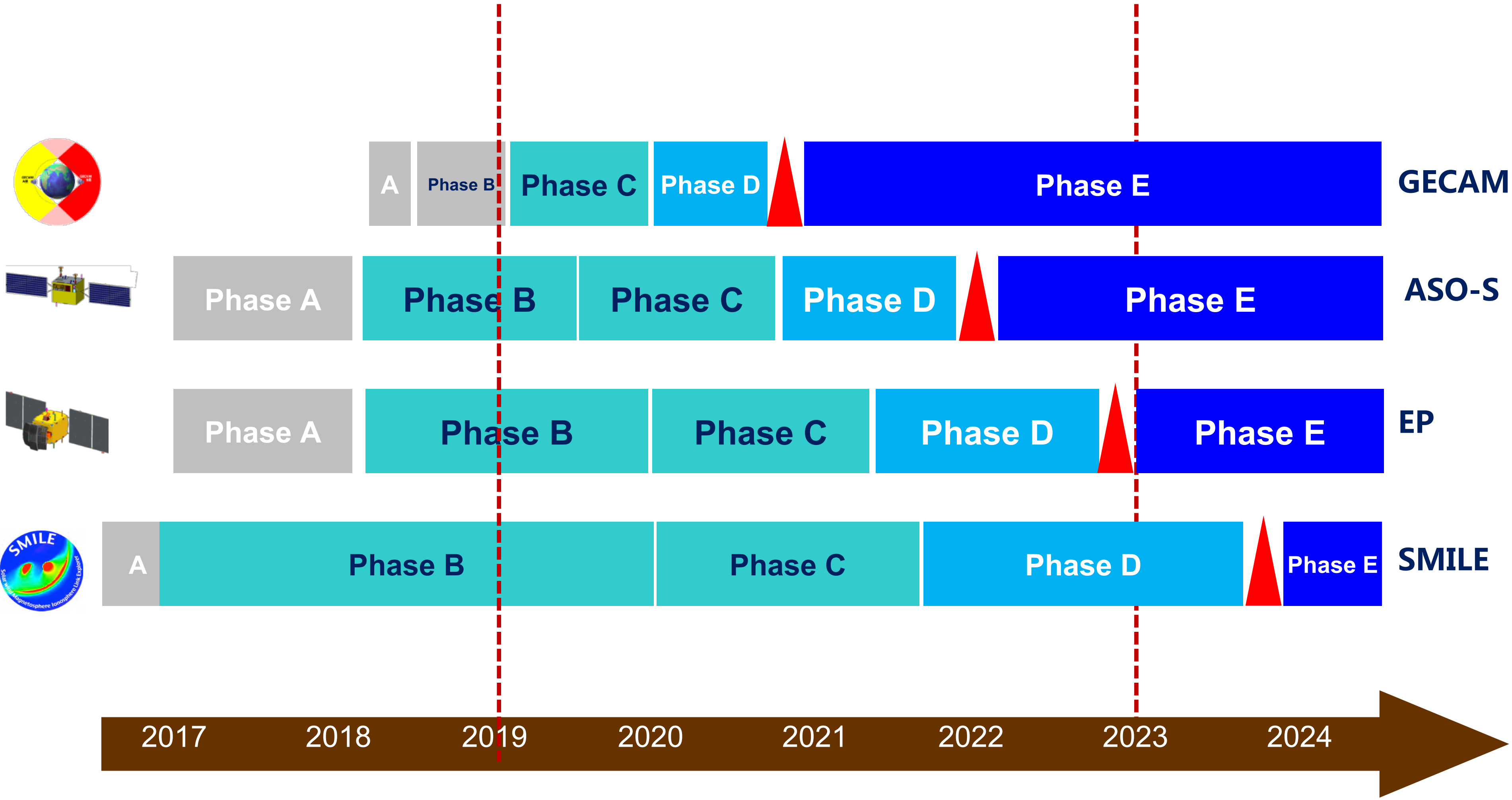


**Thermal cycle**


**Irradiation**

**Key Technologies Test and Verification**

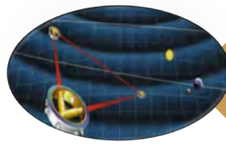
# SPP II Implementation Plan



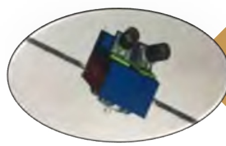
# Strategic Priority Program on Space Science (2018-2022)

**Intensive Study of Candidate Missions (background missions)**

1. enhanced X-ray Timing and Polarimetry mission（eXTP)

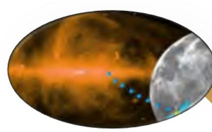


2. Taiji Program



3. MEO-to-GEO Quantum Satellite

4. Small Bodies Sample Return Mission

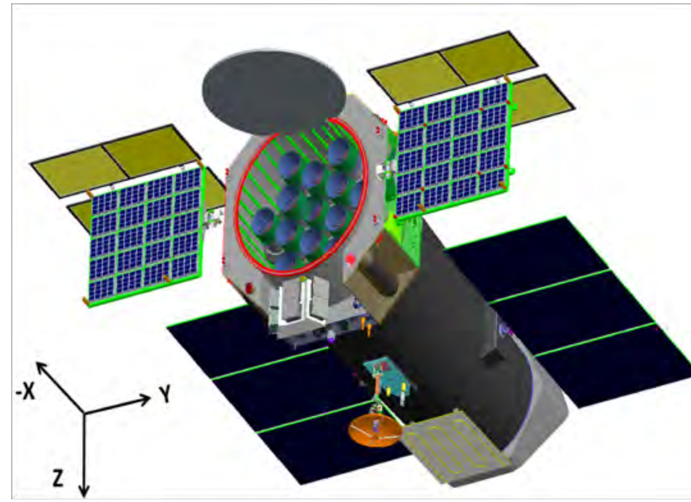


5. Ultra-long Wavelength Astronomical Observation Array

6. Other Candidate Missions (Space weather, Earth Science

# 1. enhanced X-ray Timing and Polarimetry mission (eXTP)

- Science objectives
  - Unprecedented capabilities to study:
    - ✓ 1 singularity (black hole),
    - ✓ 2 stars (neutron star or quark star)
    - ✓ 3 extremes (gravity, density, magnetism)




- ~ 4.5 ton，Low equatorial orbit (550 km)

| Payload | Configu-ration | Optics | Detector |
|---|---|---|---|
| Spectroscopic Focusing Array | 9 Telescopes | Nickel replica | SDD |
| Large Area Detector | 40 Modules | MCP Collimator | SDD |
| Polarimetry Focusing Array | 4 Telescopes | Nickel replica | GPD |
| Wide Field Monitor | 6 Cameras | 1.5 Coded Mask | SDD |

# International Collaboration

- About 20 European countries and 100 international institutions involved in the mission (science community, engineering consortium)
- Now in Phase A+
- Budget of CAS for eXTP development through Phase B was approved

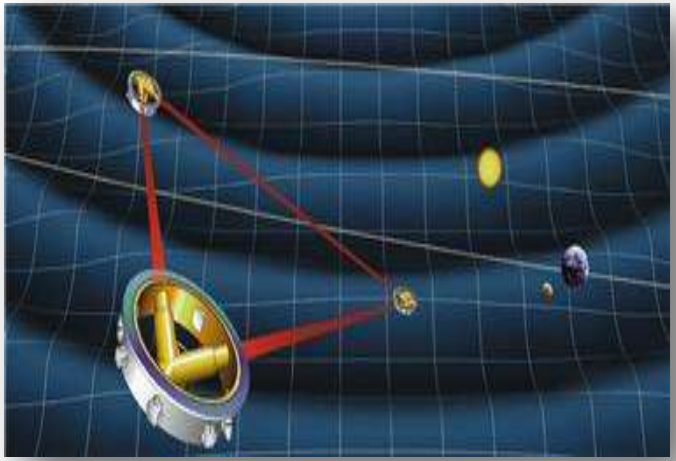
# 2. Taiji Program

## Scientific Objectives

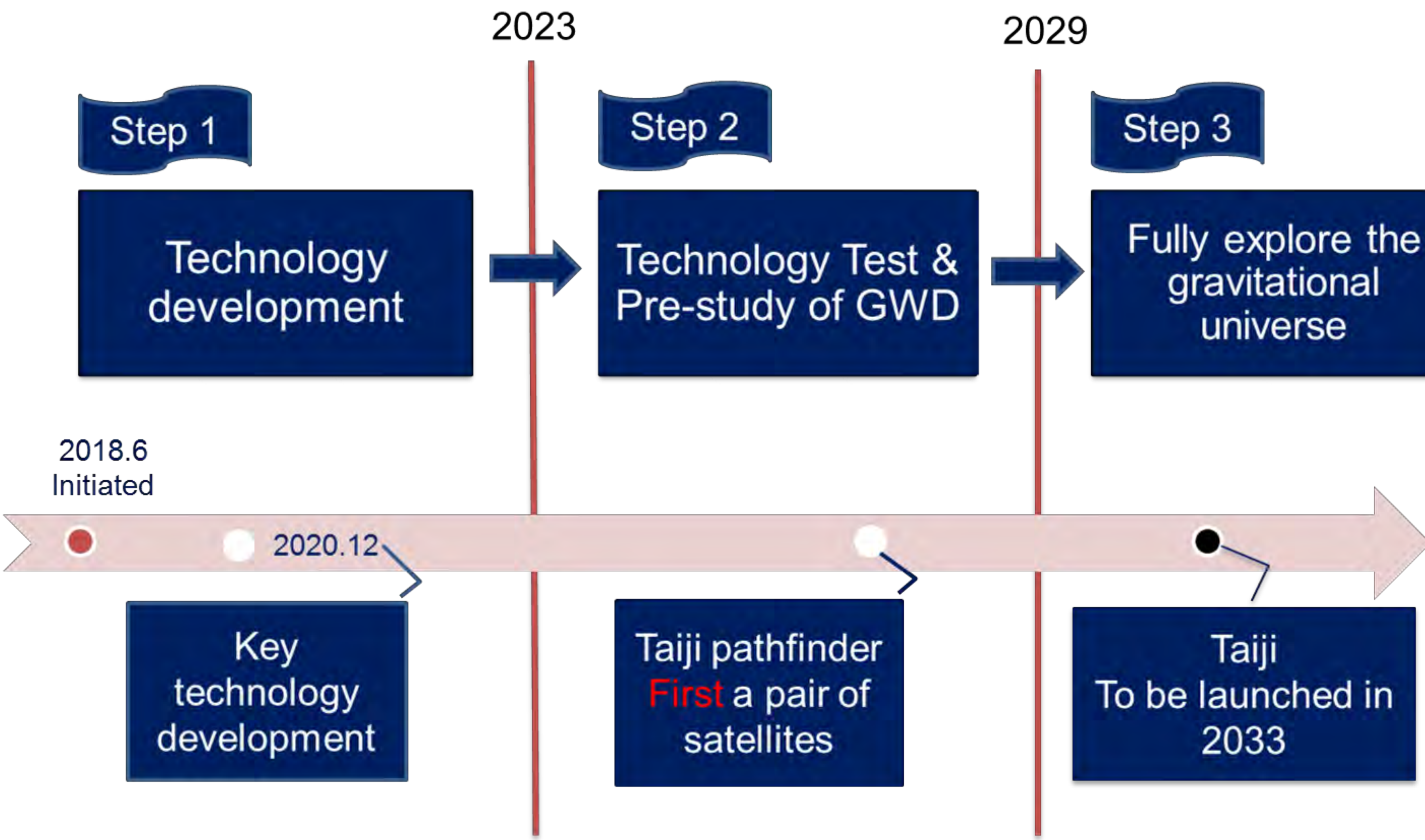
- Observe Gravitational Wave from mergence of binary black holes or great massive celestial bodies in space

## Technologies

- Ultra precise & key techniques
  - Pico-meter measurement within millions of kilometers
  - Sub-femto g drag-free technology
- Ultra complex & key techniques
  - Strong confusion of GW signals
  - Strong couplings of subsystems

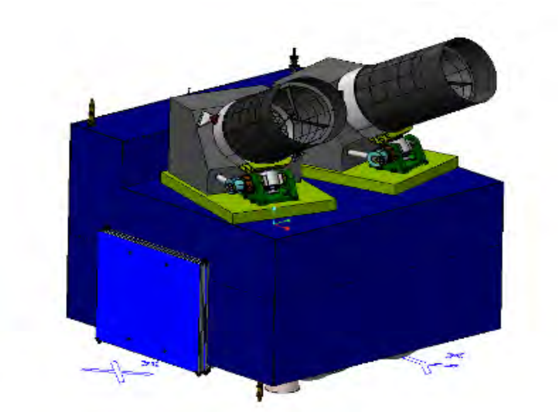


# Roadmap of Taiji Program

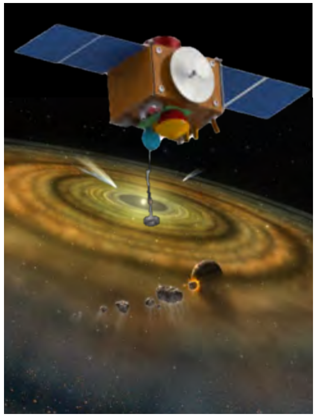


# 3. MEO-to-GEO Quantum Satellite

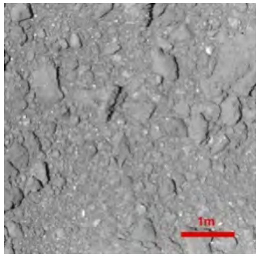
- Scientific Objectives
  - Develop key technologies and MEO-to-GEO quantum satellite, to accomplish ~10000km all-day quantum communication, and build global quantum network
  - Explore new methods of testing the unification of Quantum Mechanics and General Relativity
- Expands space quantum science from LEO to deeper space
- Focus on all-day quantum communications research and fundamental problems



# 4. Advanced Study of Sample Return Mission to Small Bodies

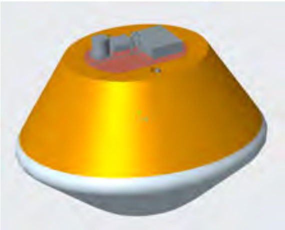


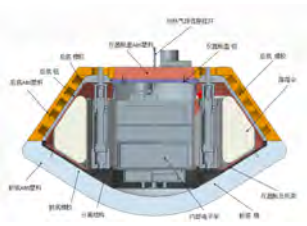
- Science Goal
  - The 1st 10 Ma history of the solar system
- Candidate Targets
  - E-type asteroids (formed closest to the Sun)
- Sampling Way
  - Touch-and-go, Rotating brush/inserting tube
- Sampling technique
  - Multi-site
  - Rough surface

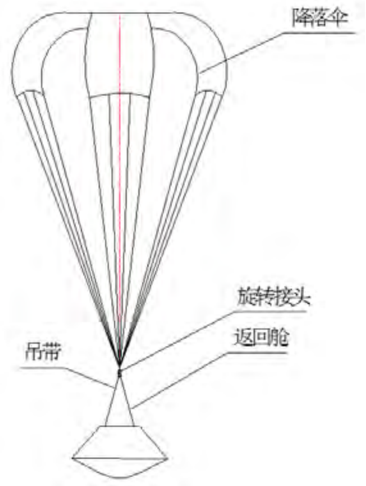



grappler

- Sample capsule
  - Parachute experiments



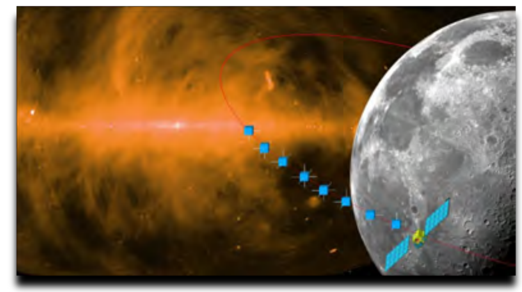




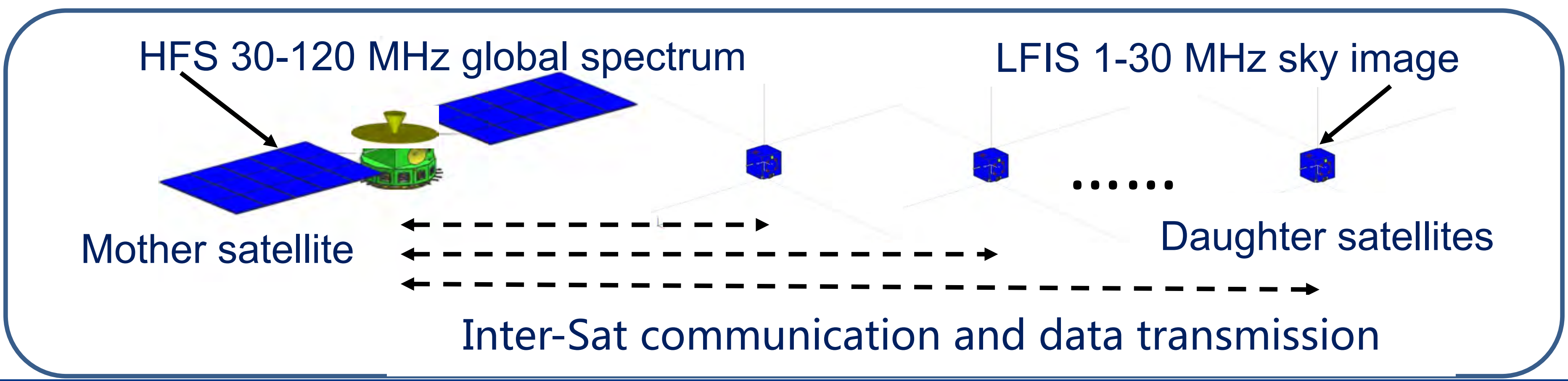

(drop from ~30 km)

# 5. Ultra-long Wavelength Astronomical Observation Array

- Opening up a new window in electromagnetic spectrum for astronomy
- Consists of 1 mother satellite and 5~8 daughter satellites
- In lunar circular orbit of 300 km, forming an interferometer array



- Payloads: Low Frequency Imaging Spectrometer(LFIS)
  High Frequency Spectrometer(HFS)



# Table of Contents

# Summary

- Strategic Priority Program on Space Science getting into Phase II, 4 missions are implementation;
- Major candidate missions under-study
- More international collaborations are encouraged.

# *Thanks for Your Attention!*

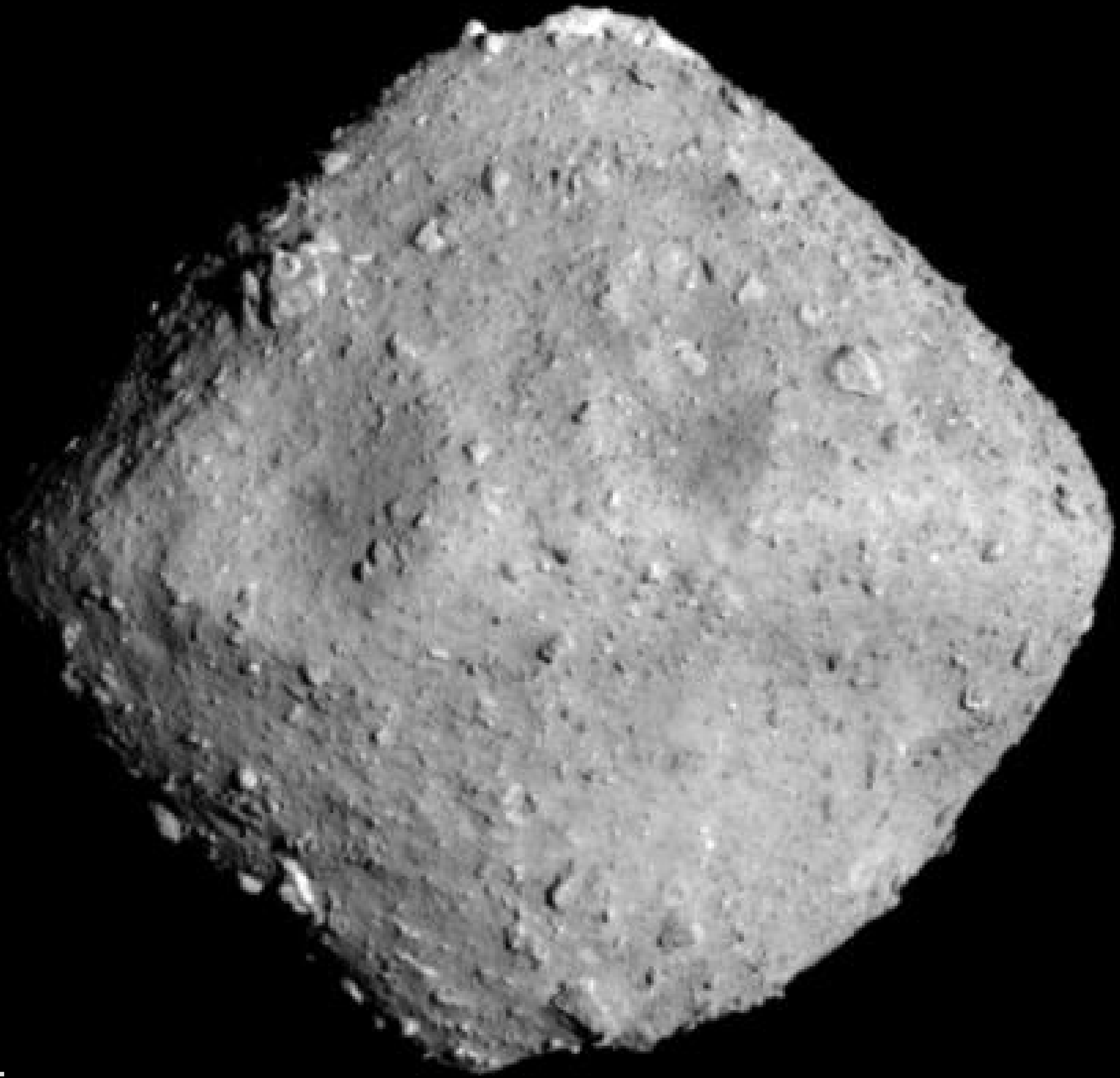
空間科學

# Hayabusa2 and beyond

Deputy Director General, ISAS/JAXA
Masaki Fujimoto

# Arrival at Ryugu

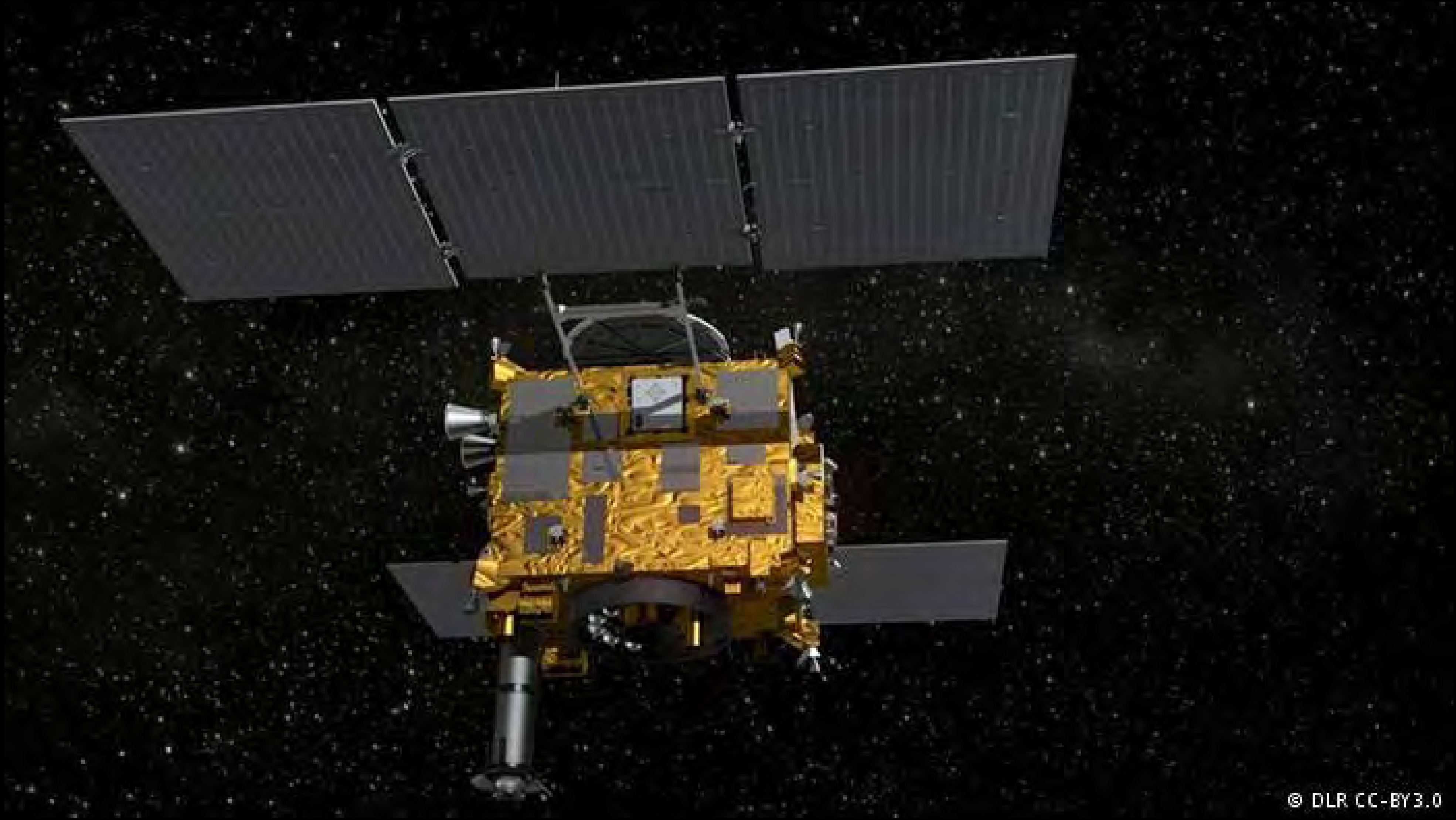
# Ryugu: Guaranteed to blow your mind



20 km distance:
“Home Position”

(JAXA, University of Tokyo and collaborators)

## The tip of the sampler horn needs to touch the surface without any other parts of the spacecraft being damaged by the boulders

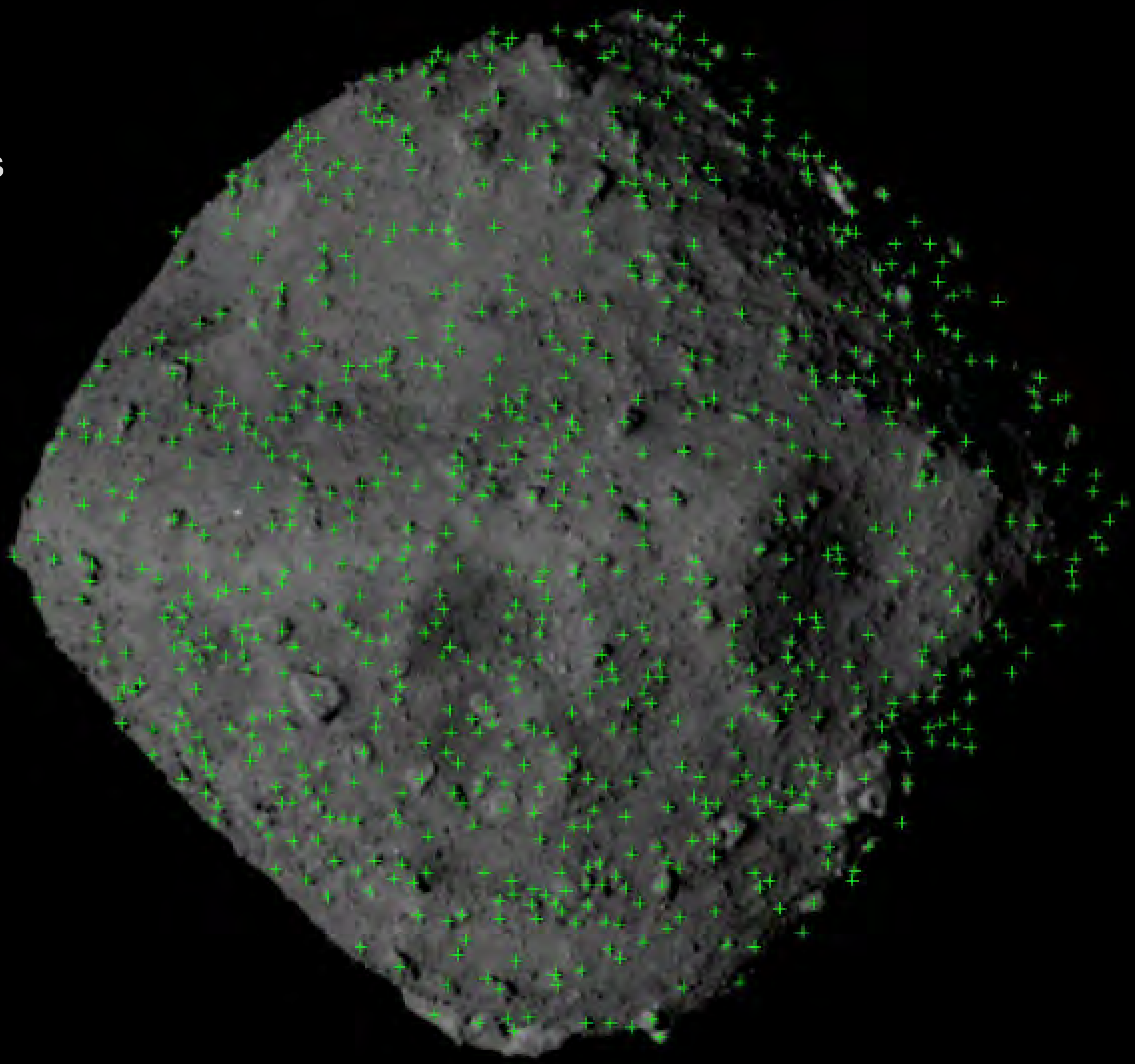


# Where are we going to land?

High boulder coverage

(Green marks identified boulders between 8m to more than 10m)

Largest near south pole ~ 130m across.

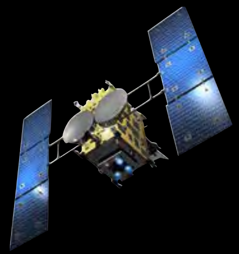


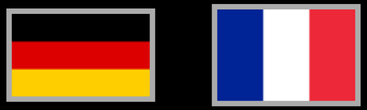
(JAXA, University of Tokyo and collaborators)

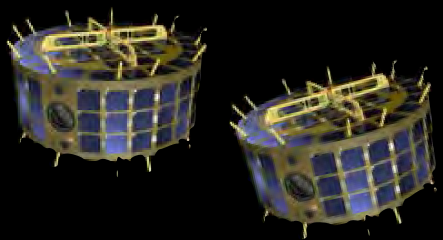
# No time for losers: The team kept moving on.



(JAXA, University of Tokyo and collaborators)







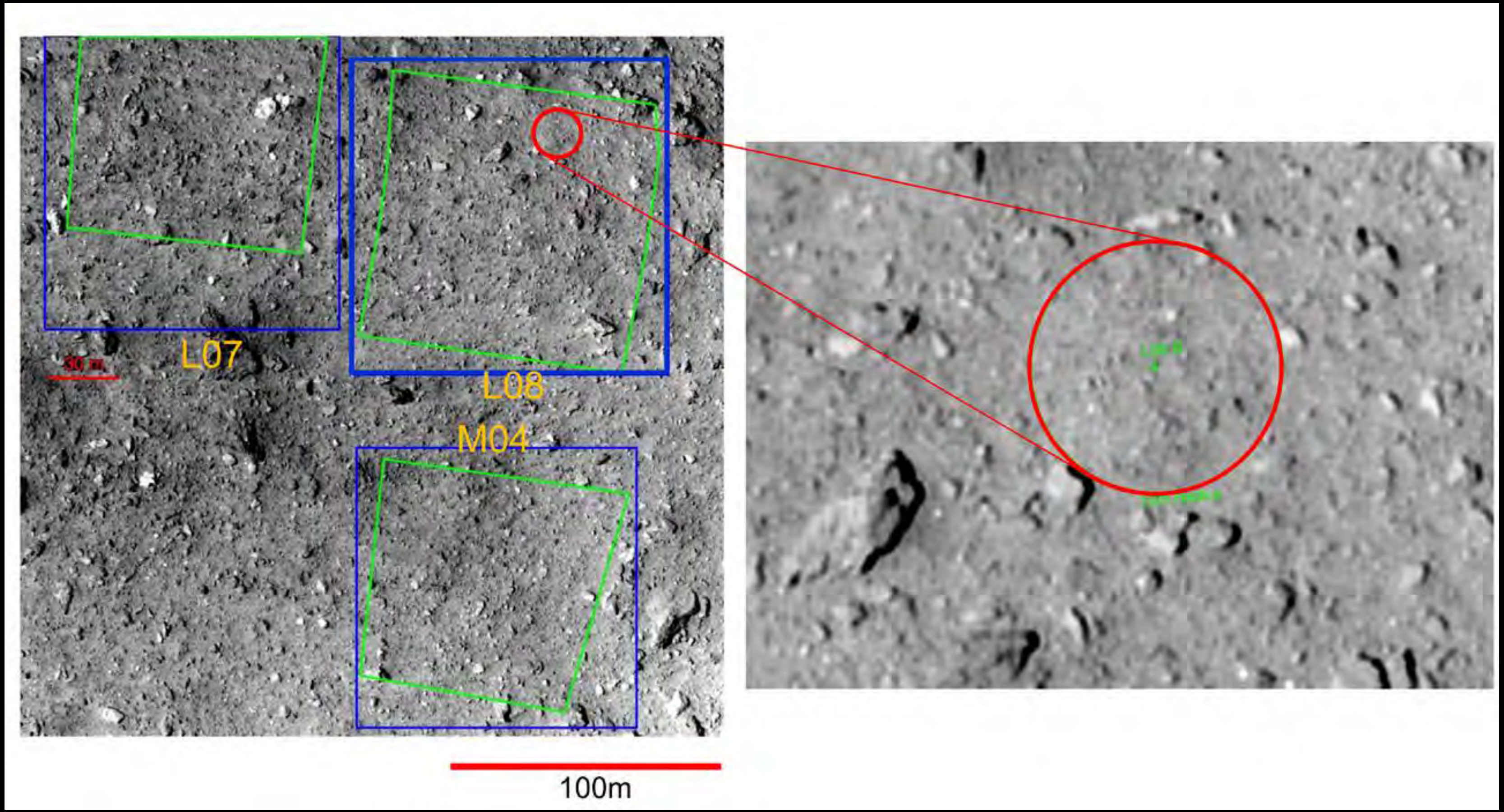
NASA & ESA support for data transmission via Ka band enabled the prompt data analysis necessary for timely landing site selection.

# MINERVA-II1

September 23, 2018: immediately before hop of Rover-1B

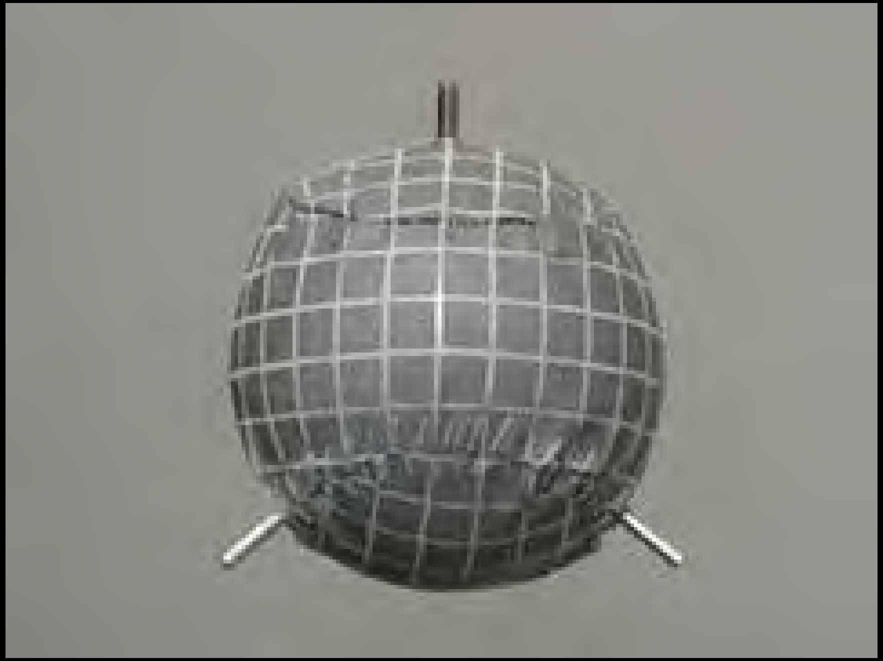
(JAXA)

# Landing site:
# 100m x 100m → 20m diameter circle




NASA & ESA support for data transmission via Ka band enabled the prompt data analysis necessary for timely landing site selection.

The original plan:
- First Touch-Down (TD1) and sampling at the end of Oct 2018
- Three TDs in total
- Pin-point landing utilizing a Target Marker (TM) to be performed at the TD3

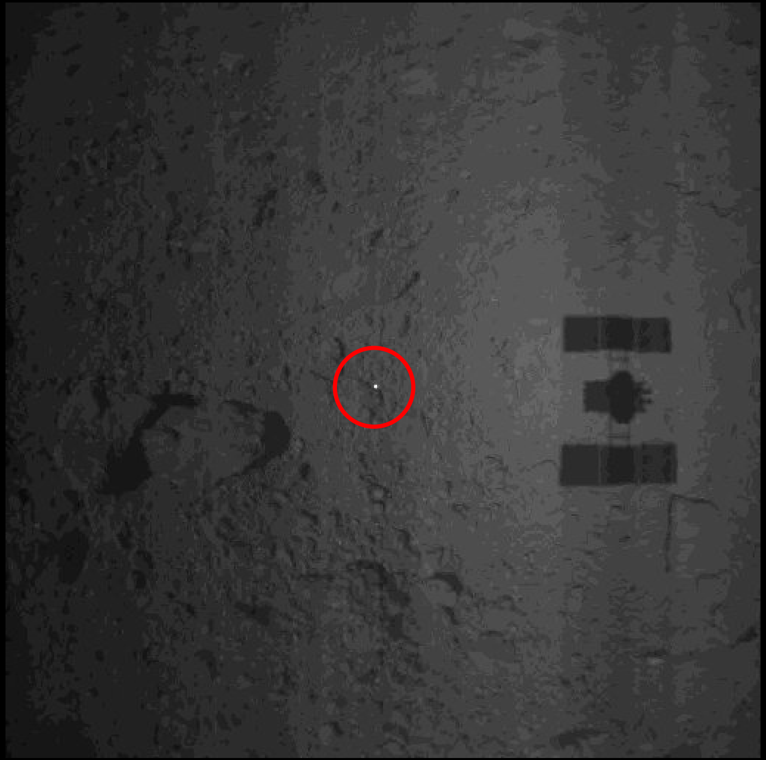


The team naturally changed the plan to
- Postpone TD1 to early 2019
- Introduce pin-point landing technique for TD1

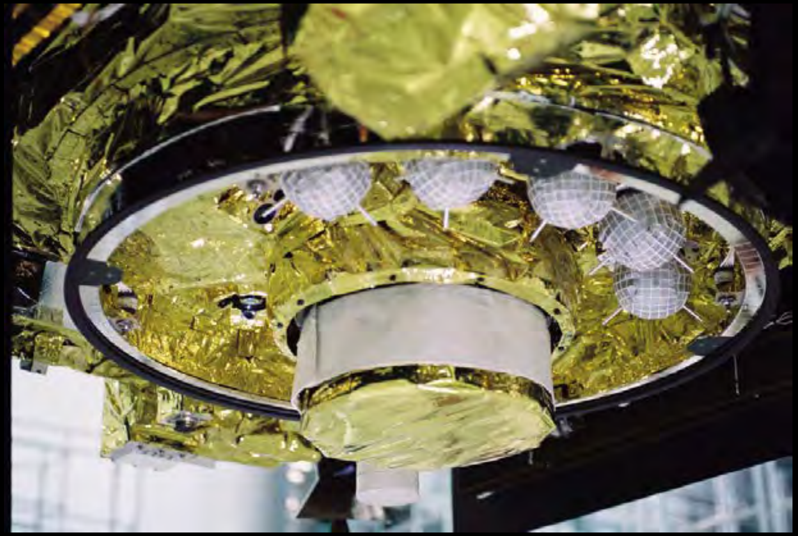
*A pleasant surprise was that none of the media folks complained the delay of TD1.*

# Rehearsal at ended on Oct 26:

- Descent down to 12m altitude
- TM (Target Marker: artificial land mark to be deployed on the surface for precise navigation) deployed successfully from 13m altitude
- TM imaged successfully from the hovering position of 20m altitude
- TM tracking navigation performance confirmed

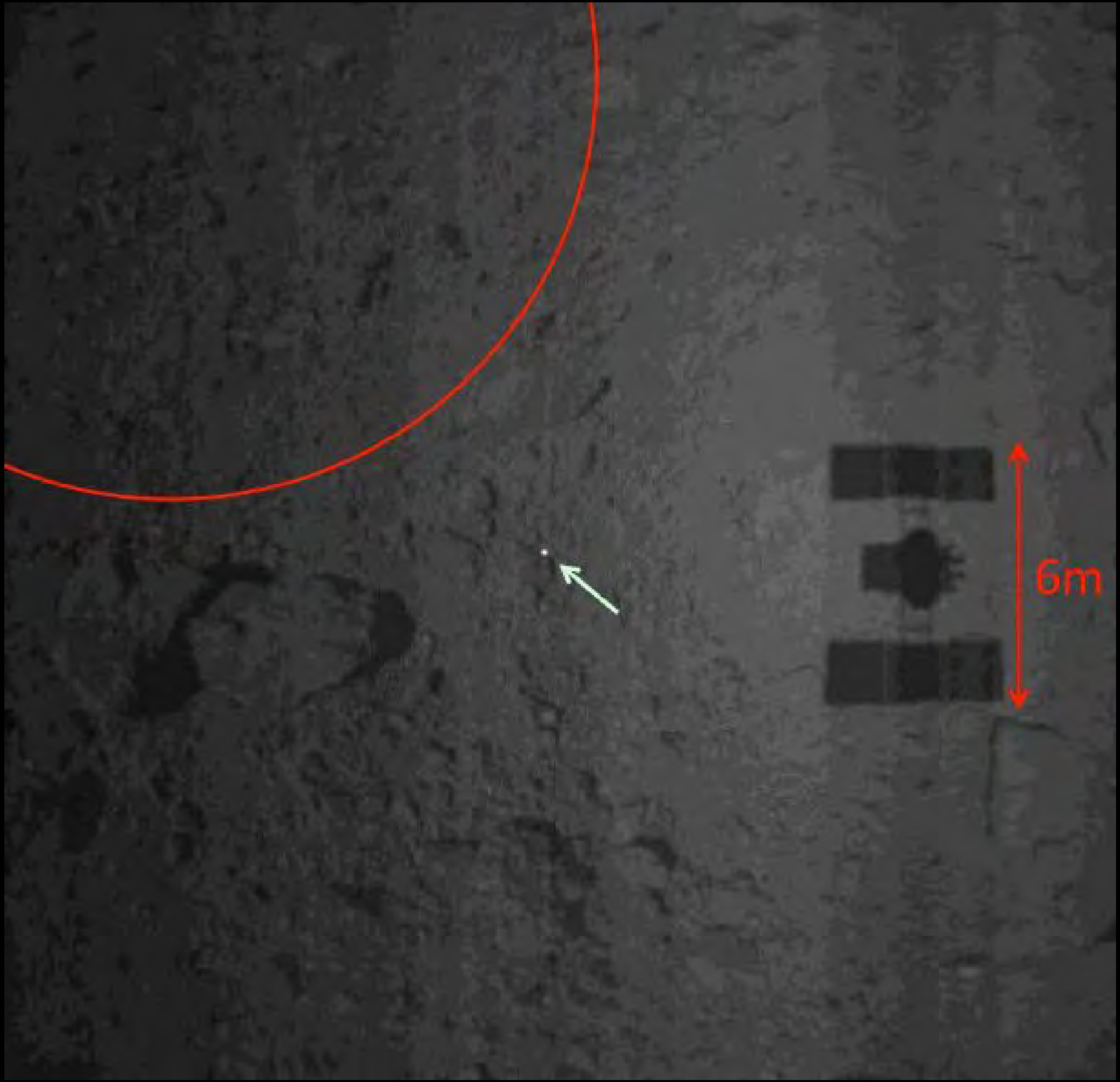


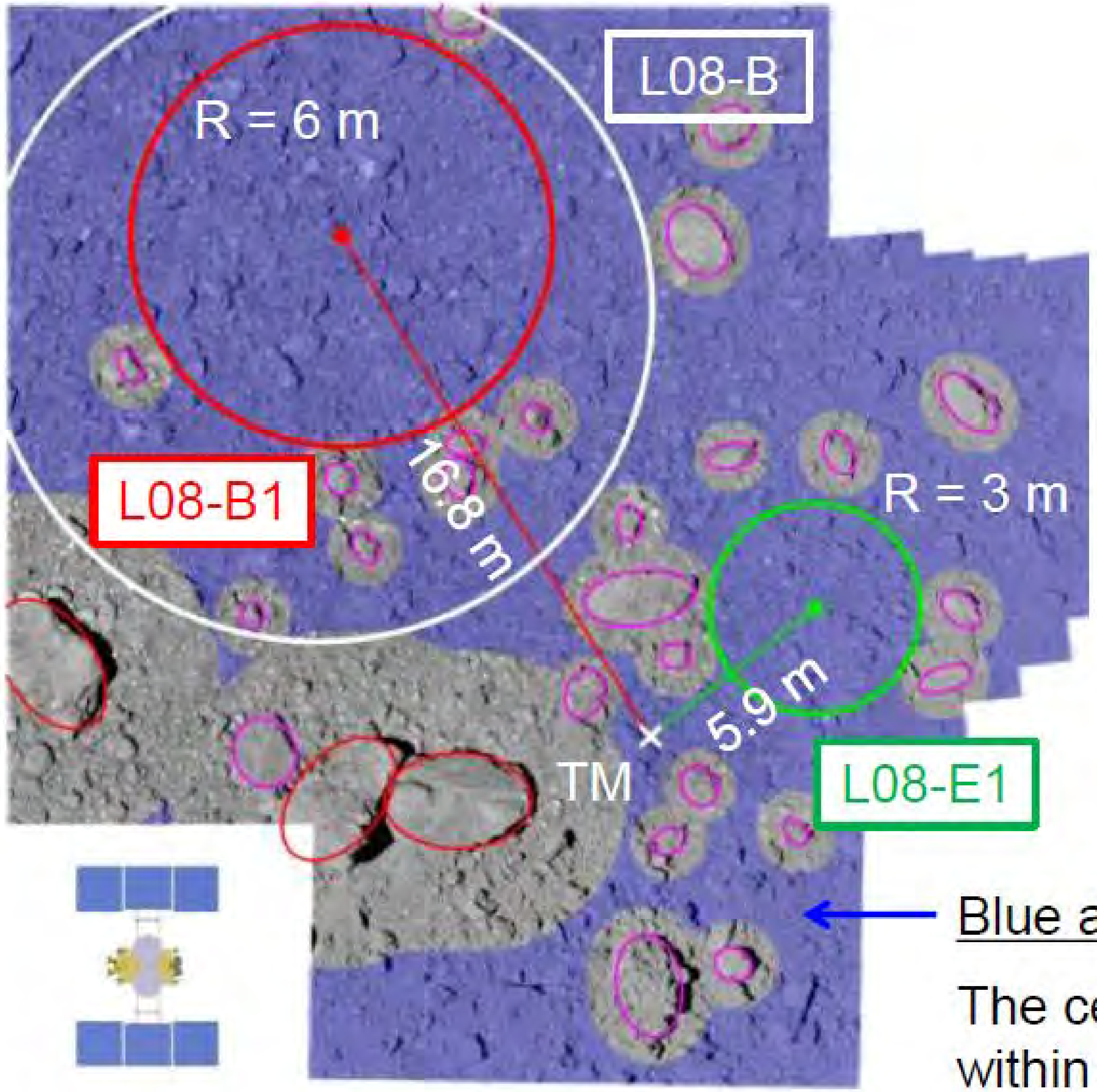
Imaged on Oct 25, 2018, 11:47 JST.
Hayabusa2 altitude 20m.



TM: 10cm-ish ball covered by retroreflective film. Situating bright points at known locations enables precise relative navigation.

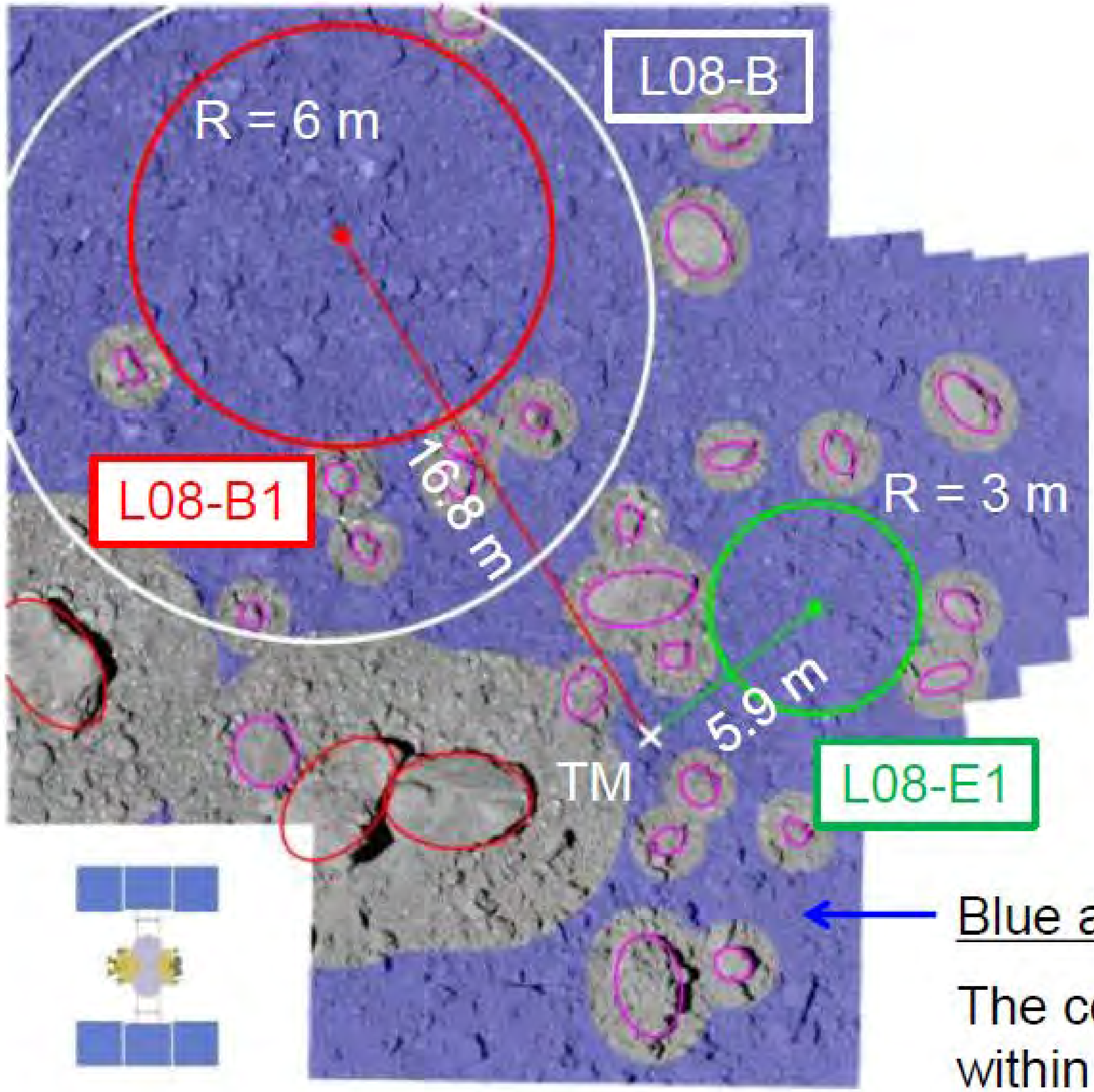
Oops…






Blue area = Safe area

The center of the s/c must be located within this area.




Feasible landing sites:

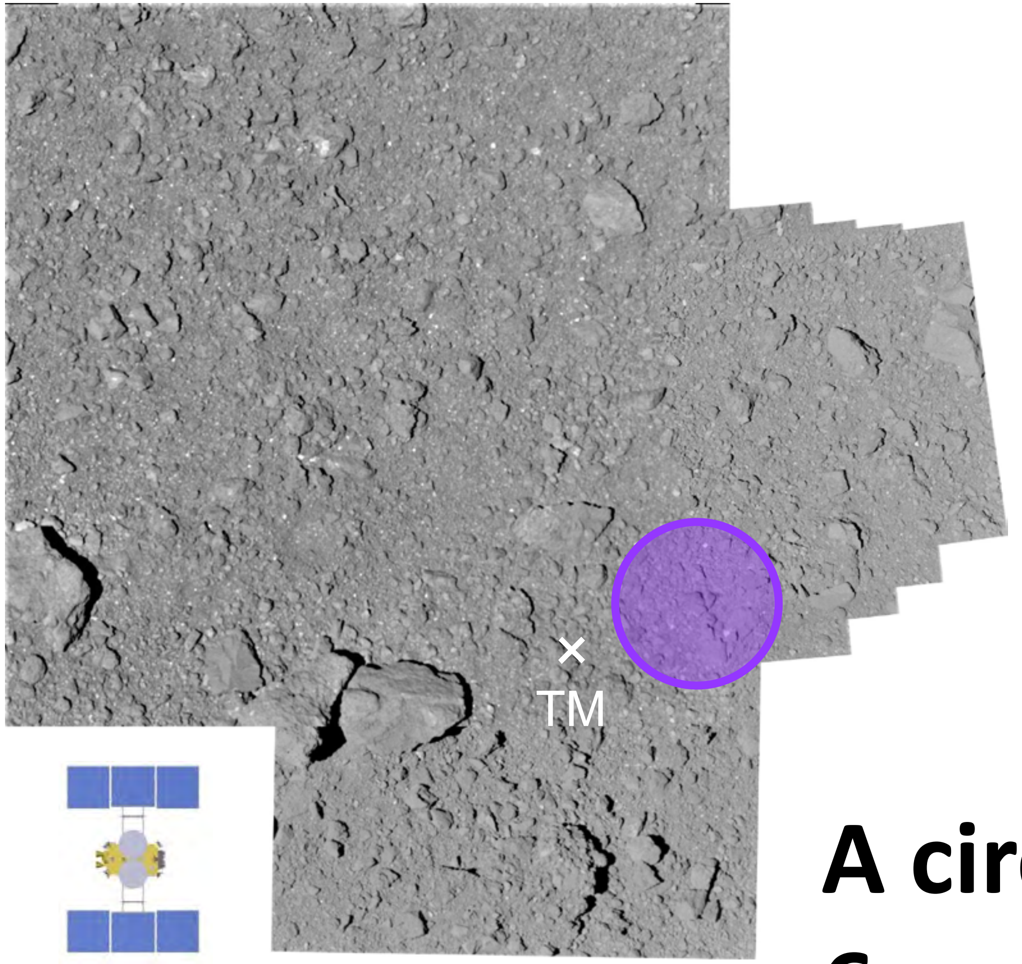
I. L08-E1 ← TD1 target

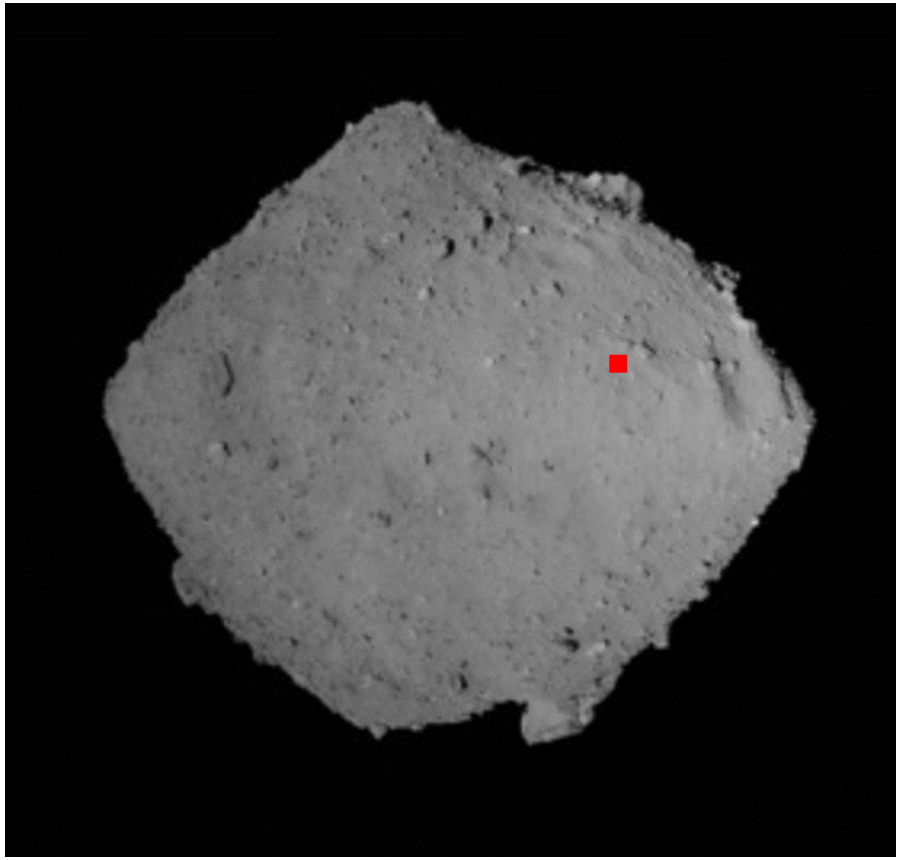
~~II. L08-B1 (with an additional TM)~~

← Blue area = Safe area

The center of the s/c must be located within this area.

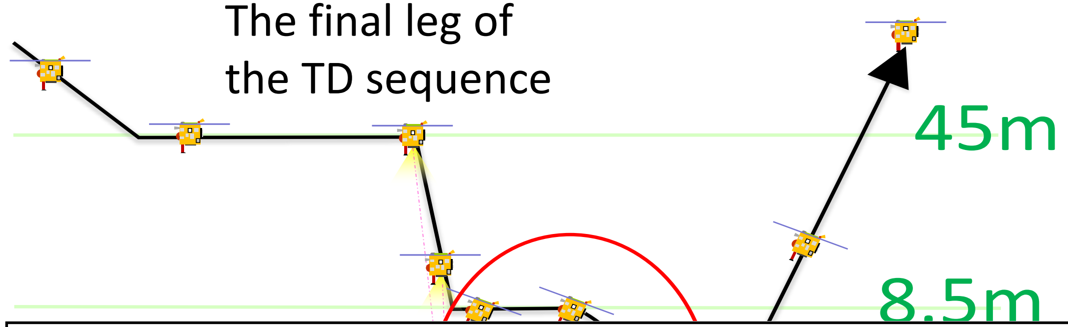
# TM as the lighthouse leading the spacecraft to hit a hole-in-one



**A circle of 6m diameter**

The final leg of the TD sequence

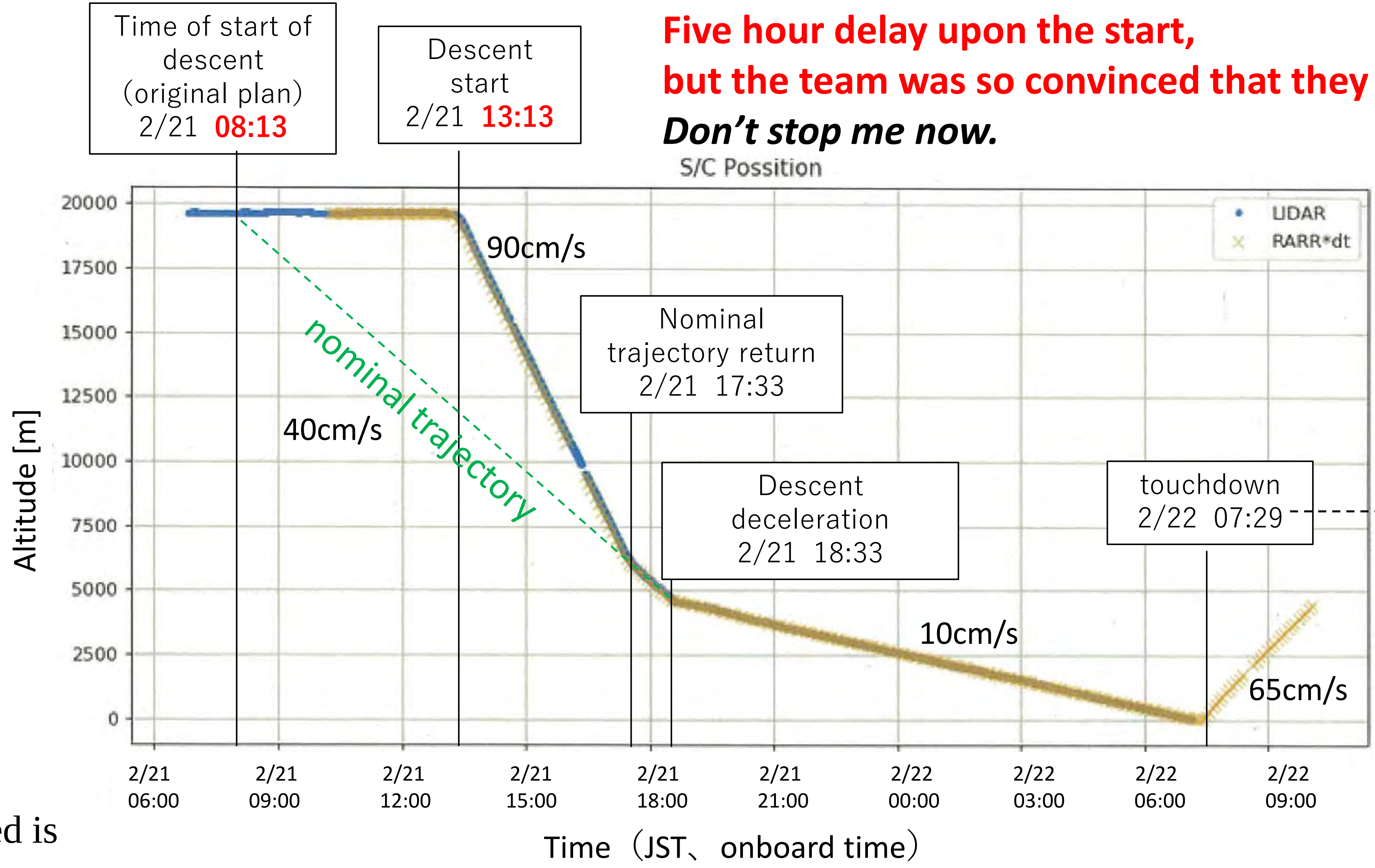


# Redoing the sampling scheme testing

# Everything was ready, then, on that day…

# Everything was ready, then, on that day…

**Five hour delay upon the start,**
**but the team was so convinced that they would make it:**
***Don't stop me now.***



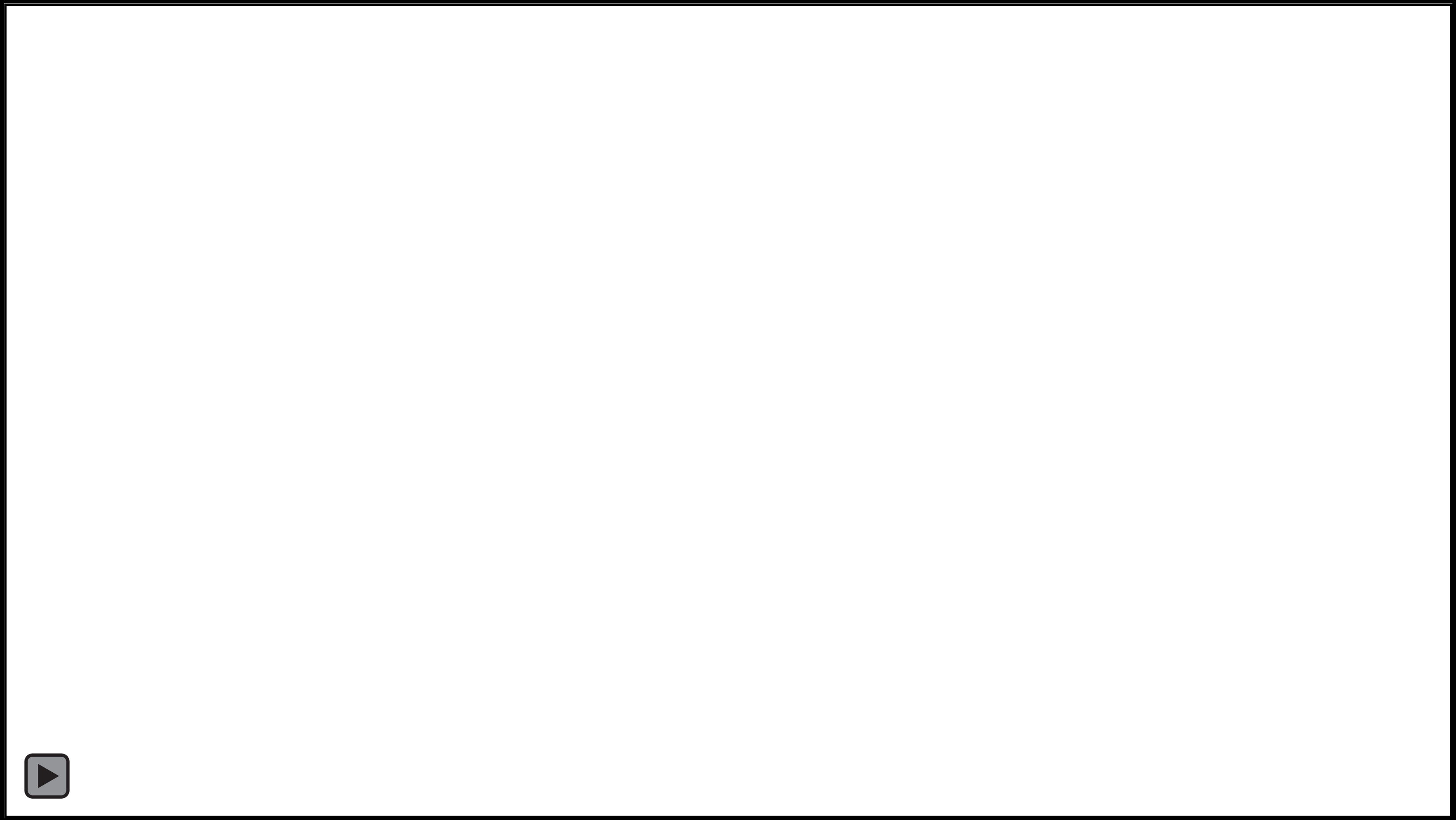

Note） Touchdown detected by change in attitude.

Value of speed is approximate

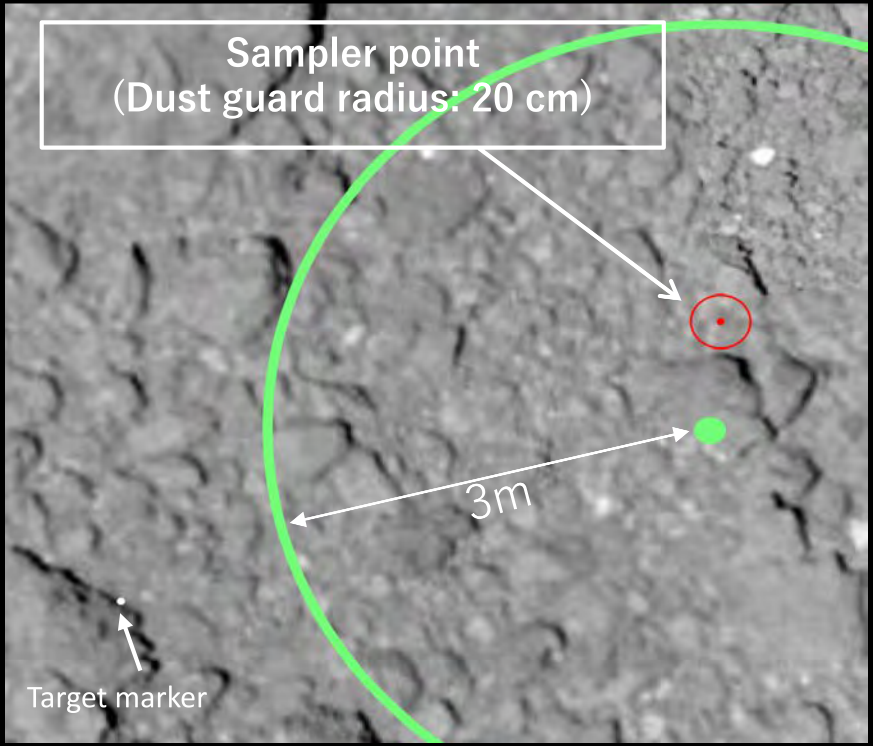
（image credit：JAXA）

# February 22, 2019 0748JST

# What must have been happening inside the sampler horn

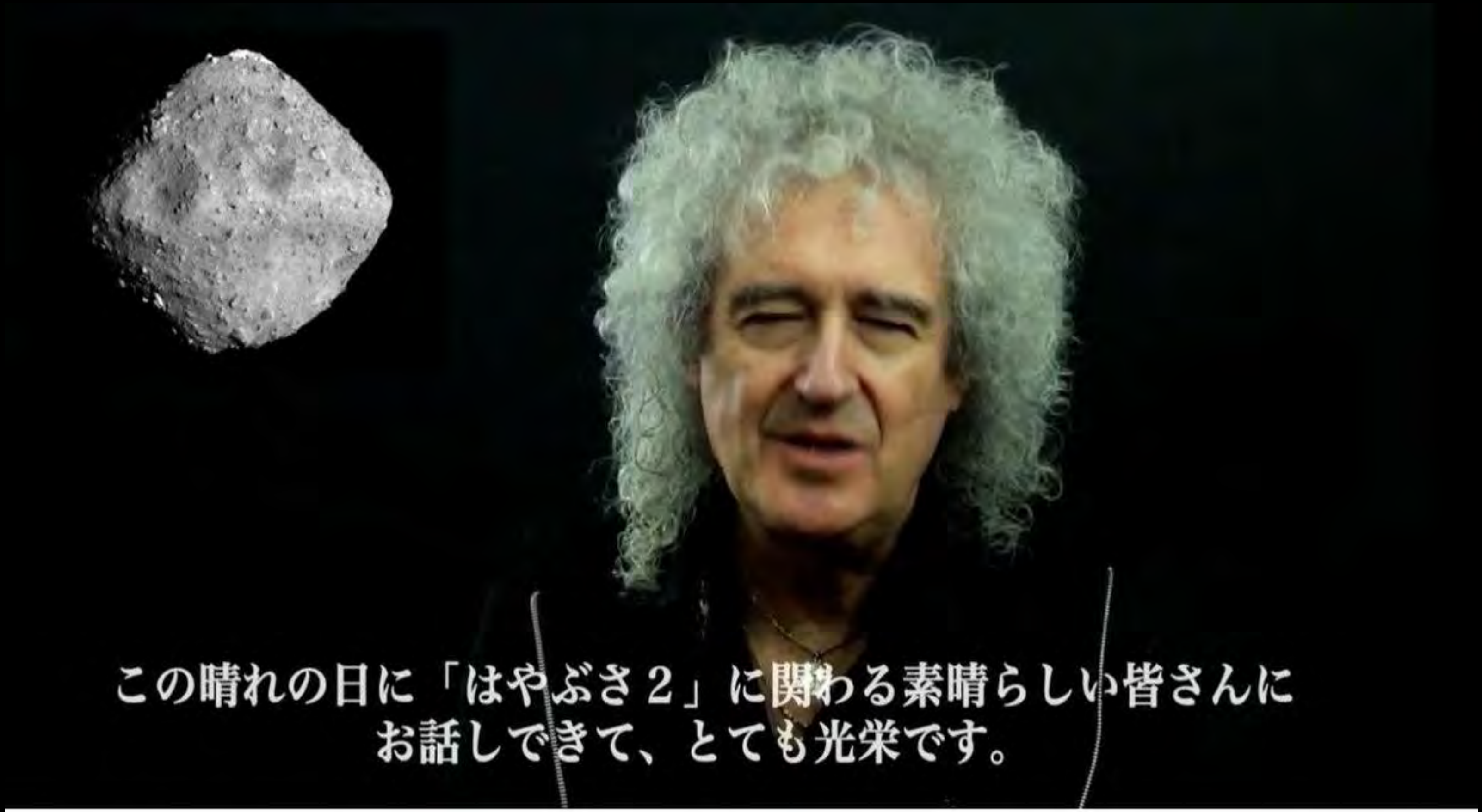


# Images taken during the ascent




**Landing error 1.08m**

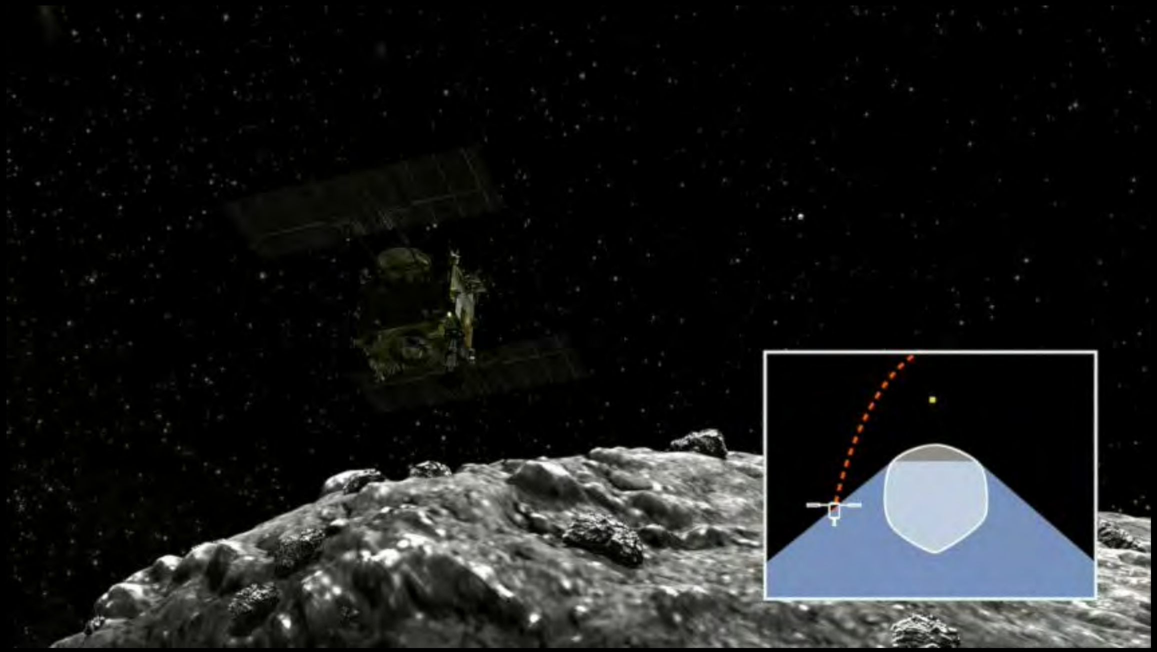
# And we'll keep on fighting 'til the end.




Queen Guitarist Brian May

And we'll keep on fighting 'til the end.

What’s next?: Another exciting ops next week.



And we'll keep on fighting 'til the end.

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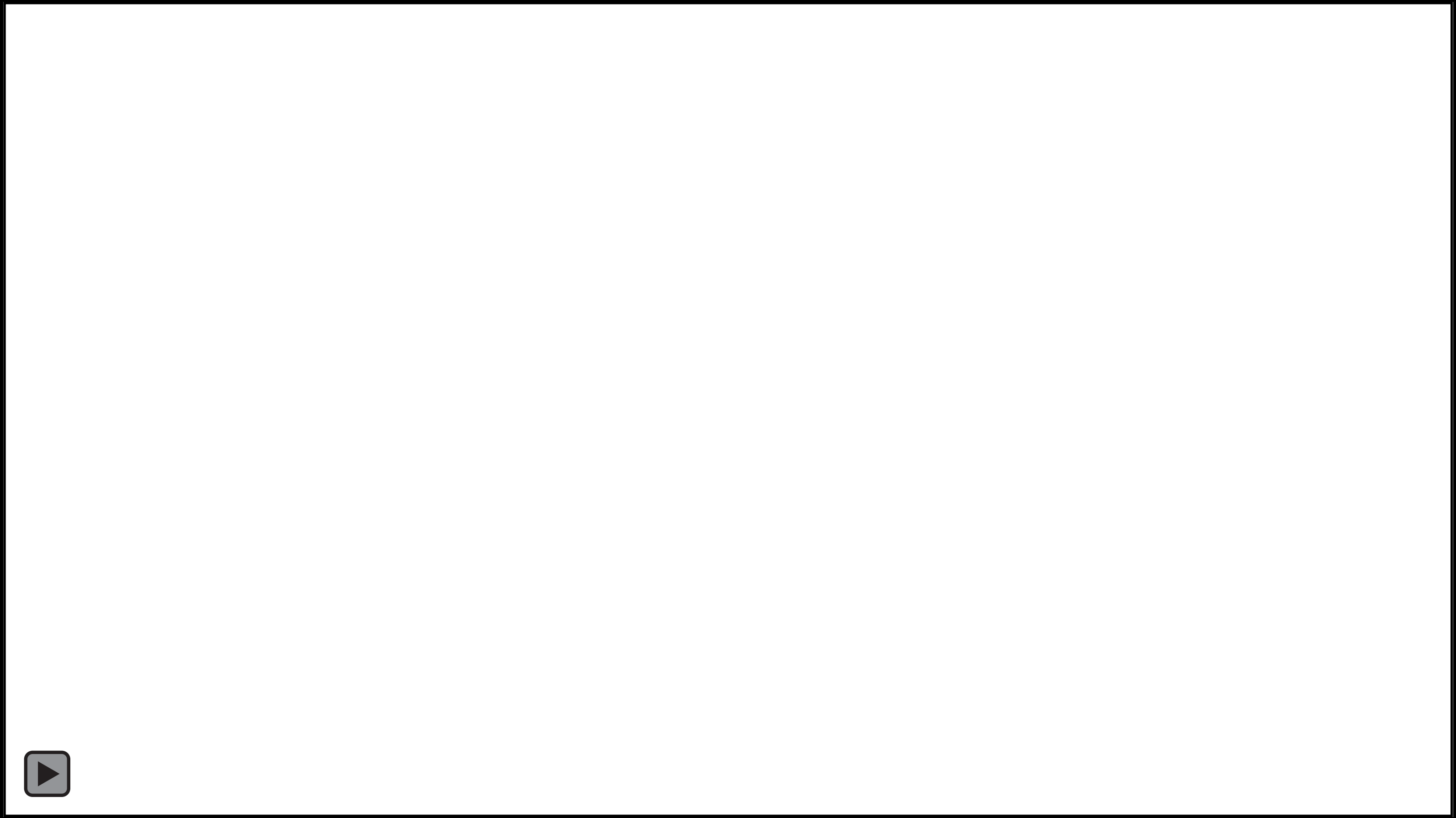

# And we'll keep on fighting 'til the end.

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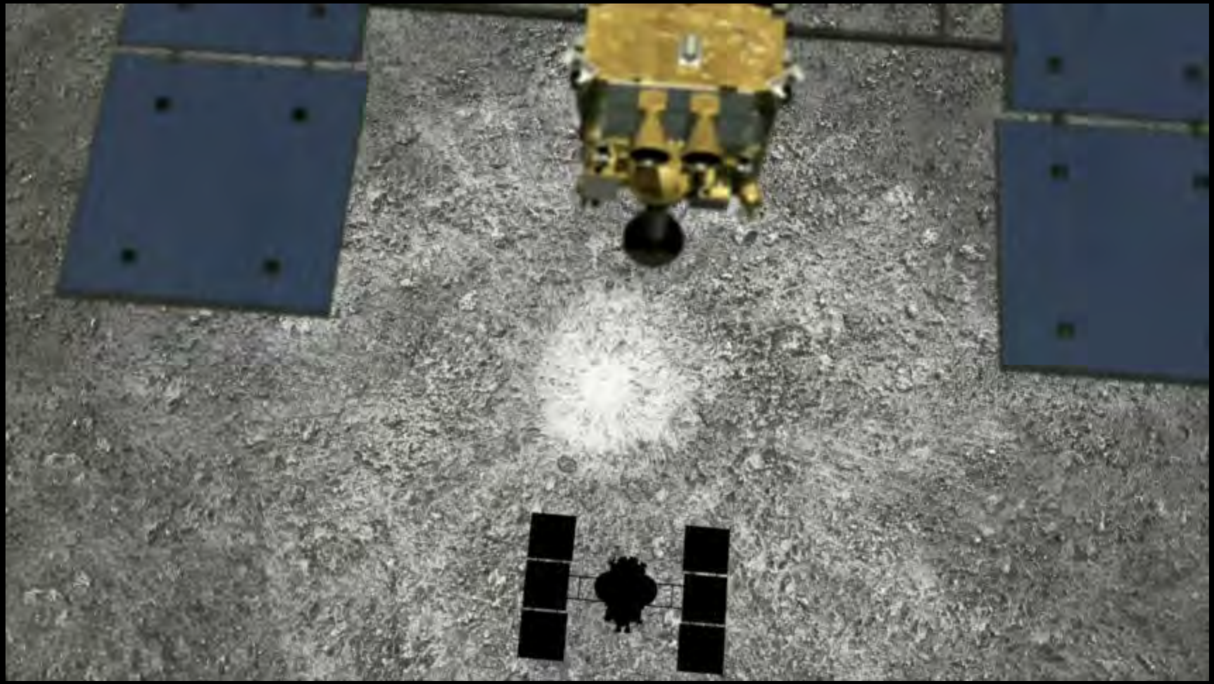
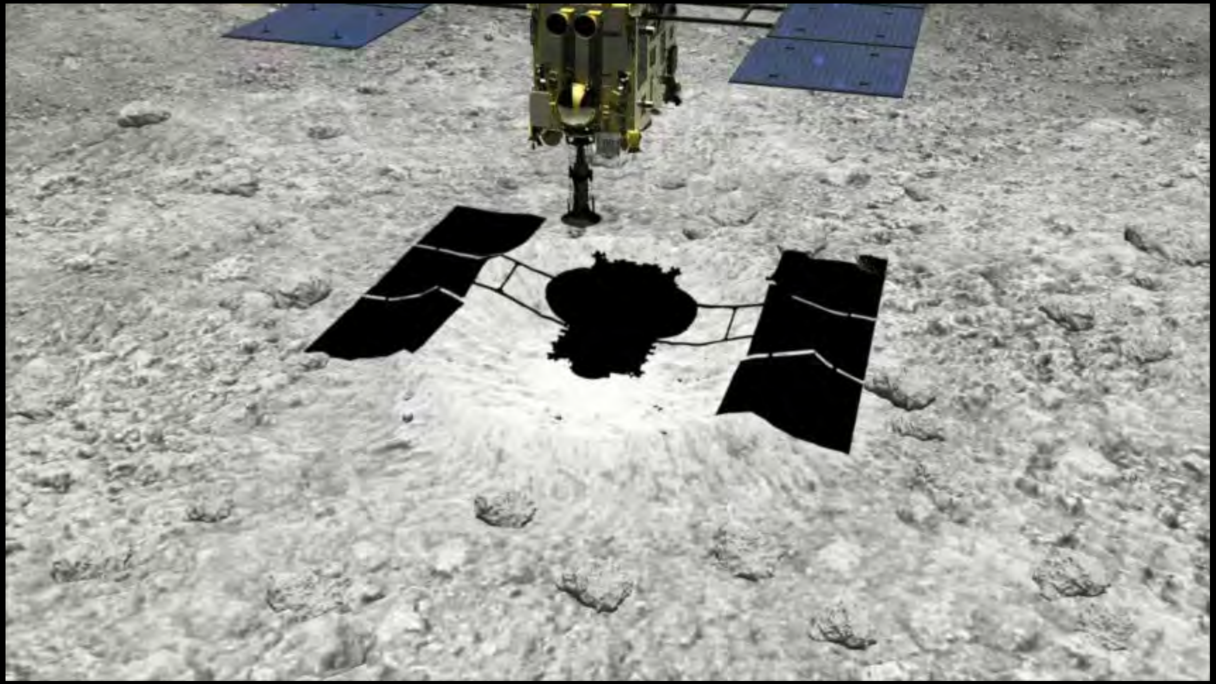
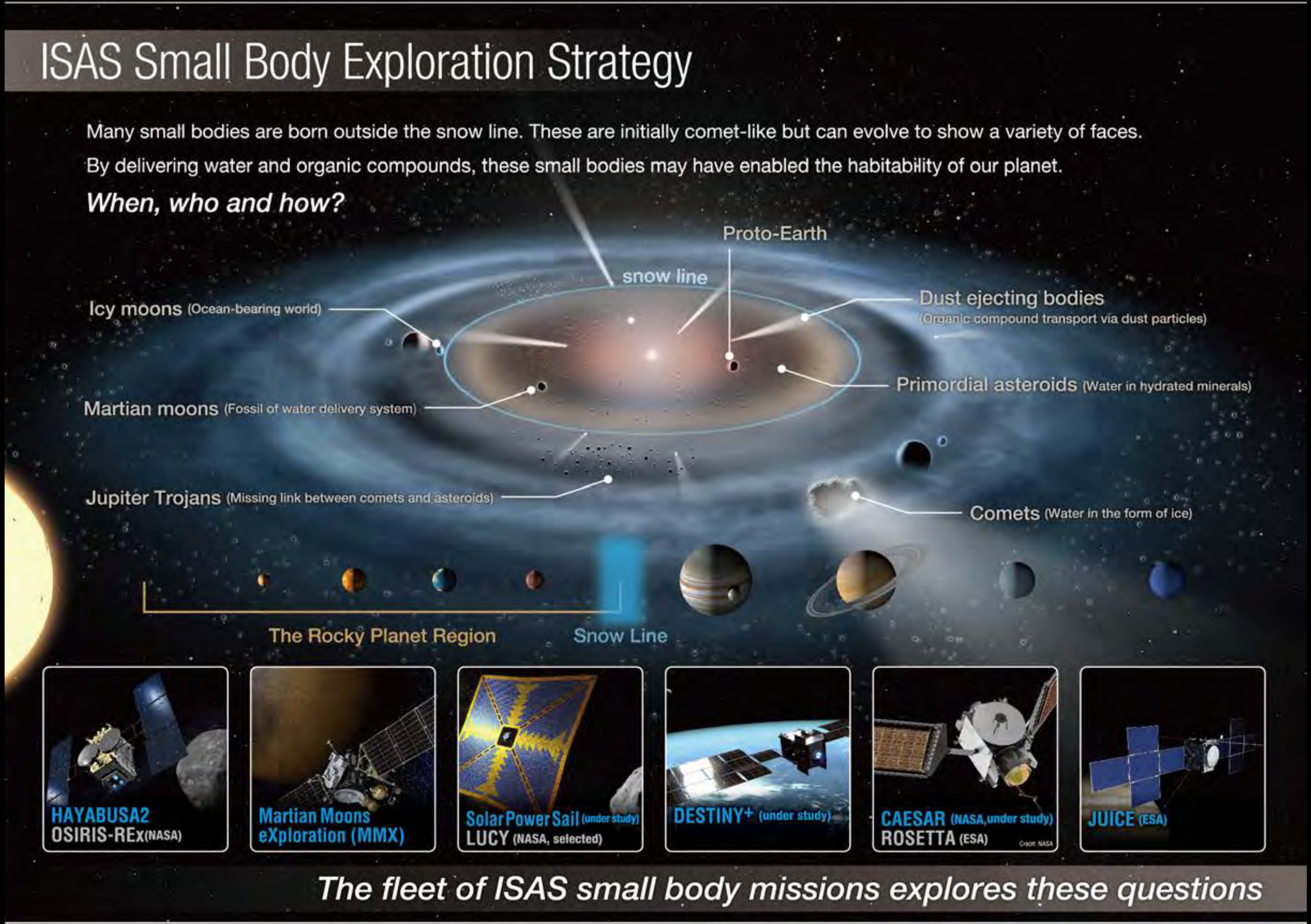




# And we'll keep on fighting 'til the end.
# What's the end?




**Hayabusa2 is an element in our program of exploring systematically those small bodies born outside the snowline which played key roles in making our planet habitable.**

**Hayabusa2 is followed by MMX, a sample return mission to Phobos, launch in 2024.**


If you really love the things that we do,
You’re my best friend.
NASA ESA CNES DLR ASI

# We are ISAS/JAXA

# INTERNATIONAL COOPERATION IN SPACE IN AN ERA OF INCREASED MILITARIZATION

Len Fisk
President of COSPAR



Space Studies Board Space Science Week, 26 March 2019

- COSPAR is the oldest and largest international society devoted to encouraging and facilitating international cooperation in space research. Our Members are the national scientific institutes of 45 nations. For the U.S., the National Academy of Sciences is the Member, and the Academy membership is overseen by the Space Studies Board. Approximately 10,000 scientists from around the world participate in our activities.

# THE COMMITTEE ON SPACE RESEARCH - COSPAR

- International cooperation in space is doing at least as well if not better than international cooperation on the ground. The Americans and the Russians, despite growing tensions, maintain an extraordinarily successful cooperation operating the ISS. The Chinese and the Americans have difficulty cooperating in space, even in space science, but this is an anomaly, due to Congressional legislation. The American space science program has always had as a guiding principle, international cooperation. Indeed, throughout the world, space science missions are pursued through international cooperation.

# THE CURRENT STATE OF INTERNATIONAL COOPERATION IN SPACE

- One of the principles to which COSPAR adheres is that we pursue our mission of encouraging and facilitating international cooperation in space research without regard to geopolitical tensions and impediments. And for the most part we do this without difficulty. Space does not belong to any one nation, and so long as that is an accepted concept, we should be able to insist that geopolitical tensions not interfere with the exploration and utilization of space.
- The question is: will this continue to be the case, and what can we do to encourage the peaceful use of outer space for all?

# INTERNATIONAL COOPERATION WITHOUT REGARD TO GEOPOLITICAL TENSIONS AND IMPEDIMENTS.

- With each passing year, our technological civilization becomes increasingly dependent on satellites in orbit. Whether it is for communications; for direct broadcast; for reliable weather forecasts; for the location services from GPS satellites, or for that matter for the military capabilities of nations. Our satellites in space are essential components of the infrastructure of our civilization.
- The primal threats to our civilization – global climate change caused by anthropogenic emissions, and space weather resulting from our variable sun – can only be understood through the use of satellite observations.

# THE INCREASING DEPENDENCE OF OUR TECHNICAL CIVILIZATION ON SATELLITES.

- If there was ever a major conflict, or even a threat of a conflict between nations that depend for their survival, or for their capability to wage war, on their satellites in orbit, then these satellites would be the first to be attacked. Thus, as more nations have access to and capabilities in space, there is a militarization of space underway, in which it is reasonable to assume that these same nations are developing the capability to defend their space assets or, if need be, to retaliate.

# THE DARK SIDE OF OUR COMPLETE DEPENDENCE ON SATELLITES

- The only real treaty is the UN Outer Space Treaty of 1967, which recognizes and protects the common interest of humankind in exploring and using space for peaceful purposes.
- With regard to the militarization of space, the Outer Space Treaty prohibits the establishment of military bases and fortifications on planetary bodies. It prohibits the placement of nuclear weapons, or other weapons of mass destruction in space. However, it does not prohibit conventional weapons, such as kinetic weapons or lasers that can destroy satellites.
- The space policy of the United States, over several Administrations, appears to be based on the principle that the U.S. is entitled to do whatever it wants in space, particularly if it is judged to be in defense of the nation.

# SPACE IS A LAWLESS FRONTIER

- The best way to avoid conflict and confrontation in space is to have policies and practices in place, which are shared by all spacefaring nations, that will allow and encourage each and every nation that desires, and has the capability, to use and to explore space for peaceful purposes. Then, all nations will have a vested interest in maintaining space as a peaceful domain.
- If we cooperate rather than compete, nations have a shared common interest.
- If we return to the Moon, or inhabit Cis-Lunar space, we should at least do so with coordination and not create a contested domain.
- If we go to Mars, it should be on behalf of all humankind.

# AVOIDING CONFLICT AND CONFRONTATION IN SPACE

- Virtually every nation now has as space agency, some obviously very small. To be a true space agency you need to be able to do something in space, rather than simply having a tracking station, sharing in data, buying communication and remote sensing satellites. In the past that has been difficult, but today with the spread of small satellite technology, virtually every space agency in the world can build a small satellite, or be guided in doing so. And provided that their small satellite can be launched into space, the nation with the developing space agency becomes a spacefaring nation, and is proud to do so.

# SPREADING THE BENEFITS OF THE USE AND EXPLORATION OF SPACE TO ALL NATIONS

- An ideal way to spread small satellite technology throughout the world, and to give developing space programs a proper role in the use and exploration of space, would be to have an international mission that requires a constellation of small satellites, which are to be provided by both developed and developing space programs.
- An example of such a mission would be a constellation of small satellites offered by many nations to improve space weather forecasting through multi-point measurements of the ionosphere.

# AN INTERNATIONAL MISSION THAT WOULD ADD TO THE NATIONS OF THE WORLD THAT HAVE A VESTED INTEREST IN SPACE REMAINING A DOMAIN WITHOUT CONFLICTS.

- We need to recognize, encourage, and enable that space be considered a global commons. A 'commons' in the English language is a piece of land owned by and used by all members of a community, as in a pasture used by all residents of a village. Many nations of the world view space as a global commons, a resource not owned by any one nation but crucial to the future of all humankind. And every nation, which is able and dedicated to the exploration of space, the conduct of science research in and from space, and the use of space, all for peaceful purposes, should be encouraged and enabled to do so.

# WE NEED TO CLAIM SPACE AS A GLOBAL COMMONS, WHERE COOPERATION IS EXCOURAGED, COMPETITION IS DISCOURAGED, AND CONFLICTS ARE FORBIDDEN.

At this time of posting (4/2/19) we do not have consent to publish David Parkers slides onto this website. If you have questions, contact ssb@nas.edu

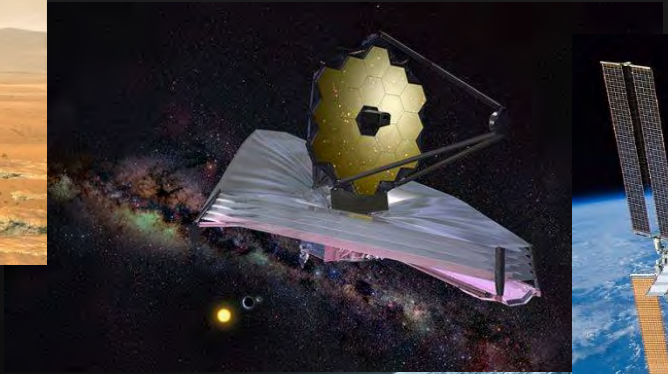
# Benefits and Challenges of International Collaboration

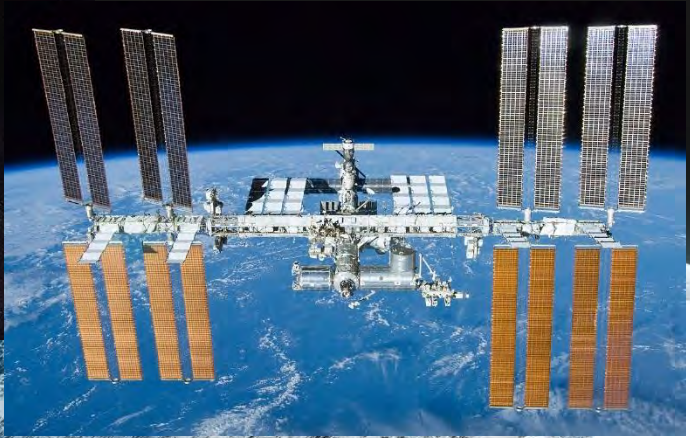
NAS Space Science Week

ERICK DUPUIS

# The Mathematical Argument

| | MSL | | JWST | | ISS |
|---|---|---|---|---|---|
| Overall | 1’s B$ | x10 | 10’s B$ | x10 | 100’s B$ |
| Canada | 10’s M$ | | 100’s M$ | | 1’s B$ |





# Benefits (Must be Win-Win)

- Financial
  - Leverage for Partner
  - Cost Offset for Mission Prime
- Access to/Contribution of Niche Expertise
- Partnerships solidify missions in face of political changes

# Challenges

- Dependency on Partners
  - Cancelations/Non-Confirmations
    - MATMOS on ESA's Trace Gas Orbiter
    - Synthetic Aperture Radar on NASA's NeMO
    - Missed Opportunity: WFIRST
    - Missed Opportunity: Euclid


Image Credit ESA

Image Credit ESA

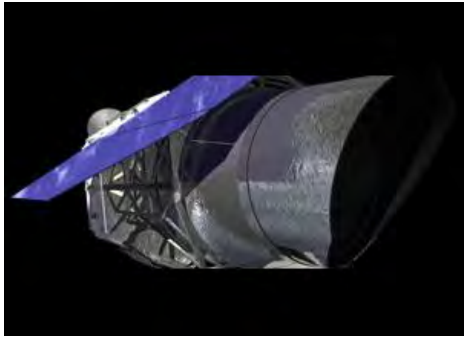


Image Credit NASA

# Challenges

- Schedule Issues
  - Synchronisation of Authorities
    - SAR instrument on NeMO (Mismatch between confirmation points)
    - Laser Altimeter on OSIRIS-Rex (delays between phases)
  - Delays
    - JWST: Impact on Future Missions
    - ASTROSAT: Components exceeded shelf life

Image Credit NASA

Image Credit ISRO

# Challenges

- Cost Risks
  - Impact of Delays
    - JWST: Cost increase due to delays (and vice-versa)
  - Moral Obligation to follow-through on extensions
    - International Space Station
    - Mars Science Laboratory
  - Risk associated with not Being Selected during Competitive Process
    - Discovery, New Frontiers, Explorers, Cosmic Vision

# Challenges

- Information Sharing
  - ITAR
    - MET within 48 hours of being descoped on Phoenix because contractor afraid to share test result glitch info
  - Language Barrier
    - Documents in Japanese on Hitomi and misunderstanding on interpretation of requirements.

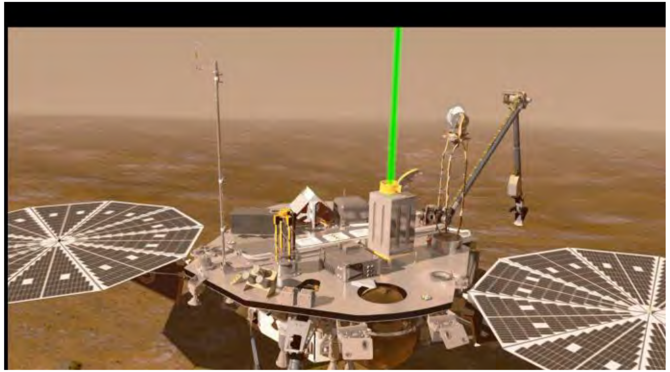


Image Credit JAXA

# New Factors

- Commercial Services for Launch and Delivery to the Moon
  - Impact on international collaboration: unknown
- Micro/Nanomission Opportunities
  - Impact on International Collaboration: unknow
    - (+) More opportunities for piggy-back
    - (-) Cost reduction reduces imperatives for collaboration
    - (-) Smaller size reduces payload accommodation
- Launch Cost reduction
  - Impact on International Collaboration: unknow
    - (+) More opportunities for piggy-back
    - (-) Cost reduction reduces imperatives for collaboration

# The Road Ahead for Canada

- 1.9B$ for Gateway

- $150M/5yrs Lunar Exploration Accelerator Program

- Continuation of On-going Missions

# Conclusion

- **Benefits far outweigh difficulties**

- **What we need for Success:**
  - **Predictability**
  - **Stability** of Decisions
  - Yet **Flexibility** to Accommodate Each Other's Challenges

- Feels like sharing a bed with an elephant (or two)

Canadian Space Agency

Agence spatiale canadienne

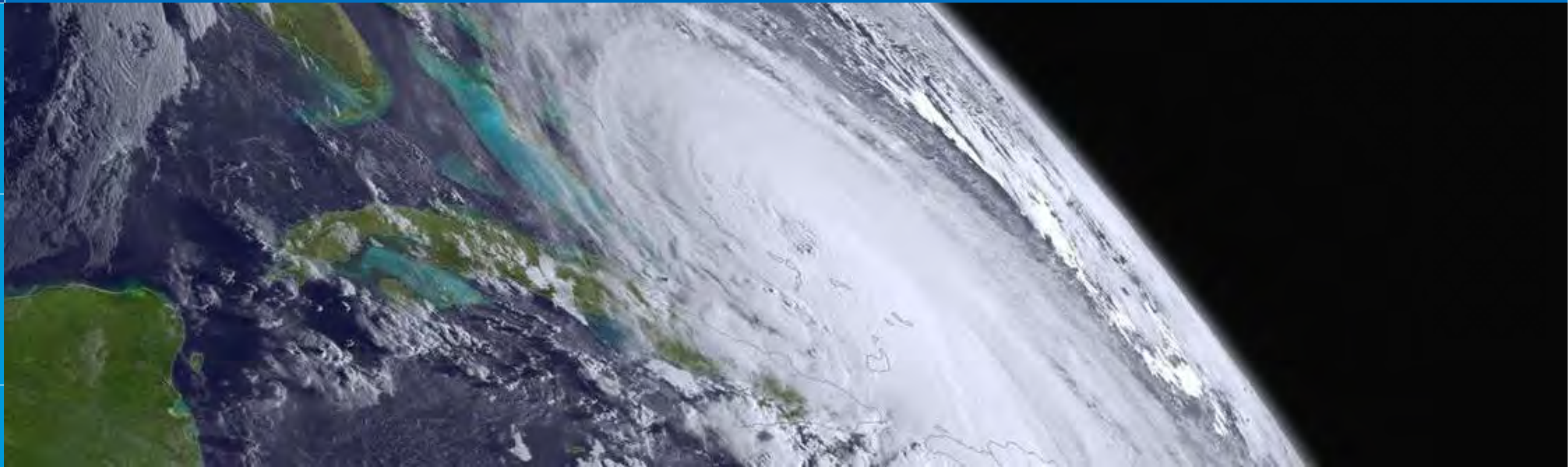
NOAA

Satellite and Information Service

March 26, 2019

# NESDIS International Cooperation

Stephen Volz, Ph.D., Assistant Administrator for Satellites and Information Services, National Oceanic and Atmospheric Administration



# International Partnerships are an Essential Part of NOAA's Observing System

# What are the challenges to producing an integrated observing system?

## Requirements
## Standards

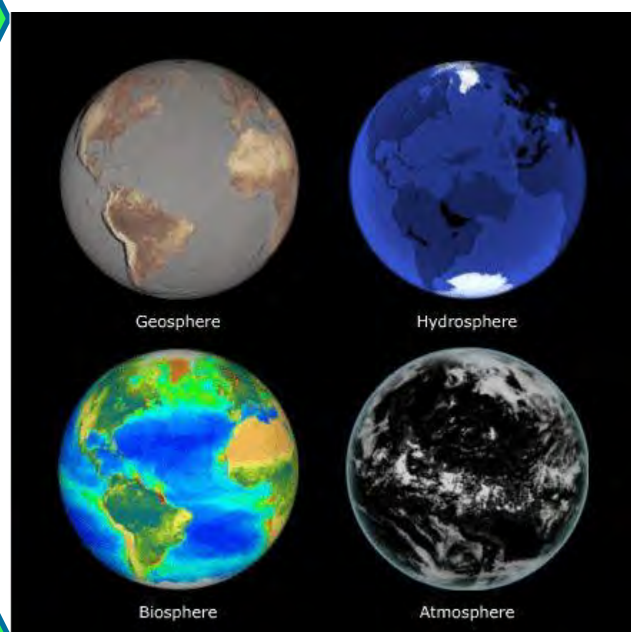
## Calibration and Validation
## Information Security

Observation Requirements

Measure-ments

Data

Resolution




Observation Standards

Interopera bility

Common Models

Secure Ingest

Pipeline Resiliency

Information Security

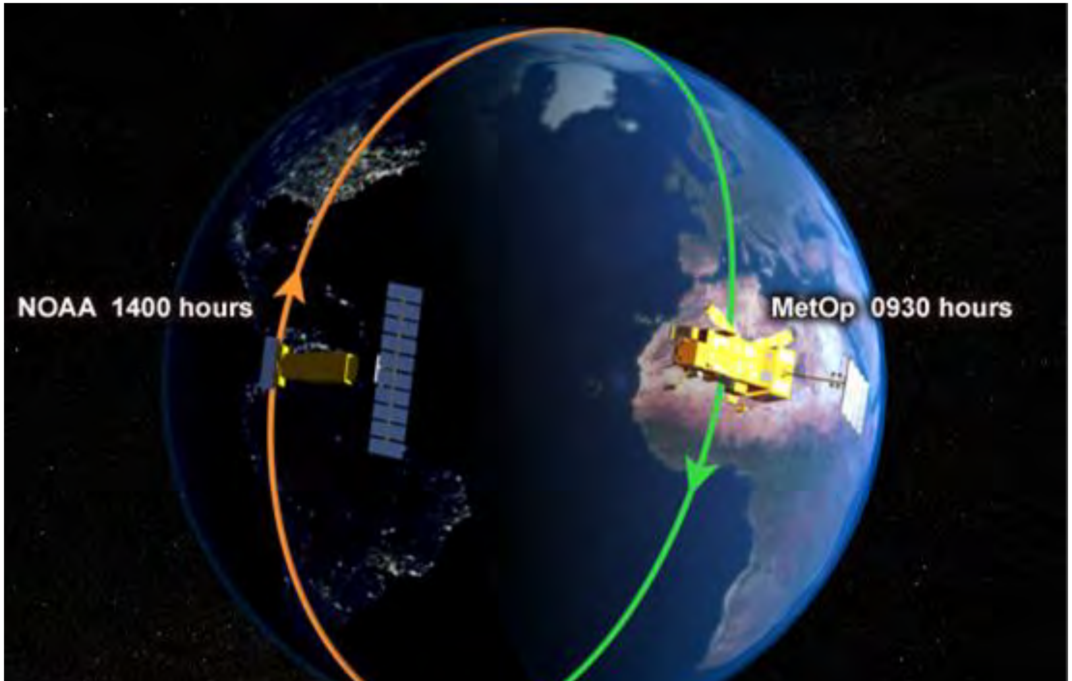
Inter-calibration

Metadata STandards

Calibration & Validation

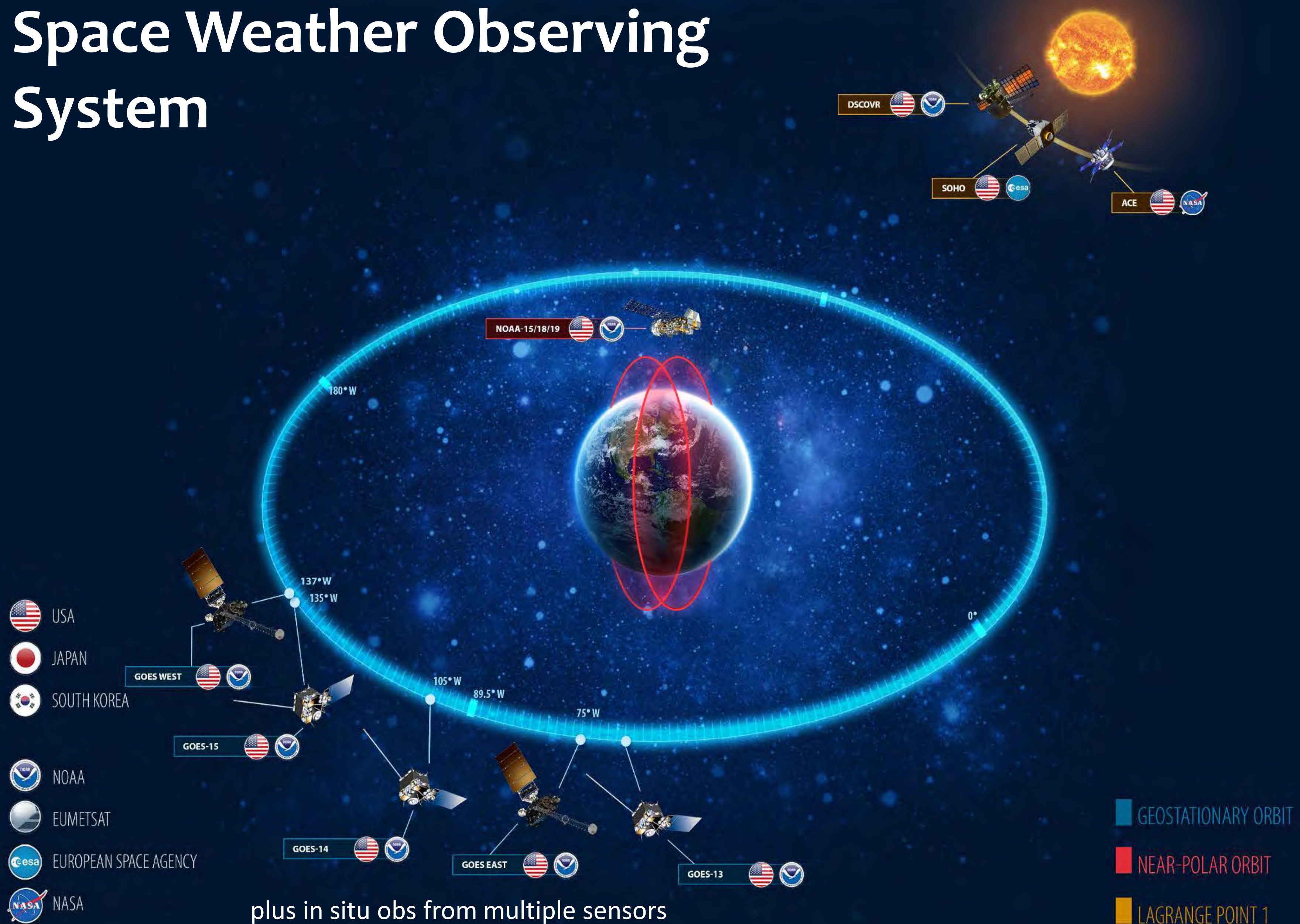
# International Partnership Success: Metop-C

- EUMETSAT launched Metop-C, a new polar-orbiting satellite, on November 6, 2018
- Metop satellites monitor the “mid-morning” orbit, while NOAA’s polar-orbiting satellites, NOAA-20 and Suomi NPP, provide observations in the “mid-afternoon” orbit
- NOAA supplied 4 of the 13 instruments on Metop-C
- NOAA is still receiving data from Metop-A and Metop-B, launched in 2006 and 2012 respectively. These satellites, including Metop-C, are flying POES era instruments.
- **NOAA JPSS and Metop each provide just under 50% of the data that goes into our Numerical Weather Prediction models**



NOAA and EUMETSAT polar-orbiting satellites pass over the same location at different times of the day.

# Space Weather Observing System




plus in situ obs from multiple sensors

# The Future Space Weather System includes both Research & Operational satellites

**NOAA-ESA Enhanced space weather observation system: L1 & L5**

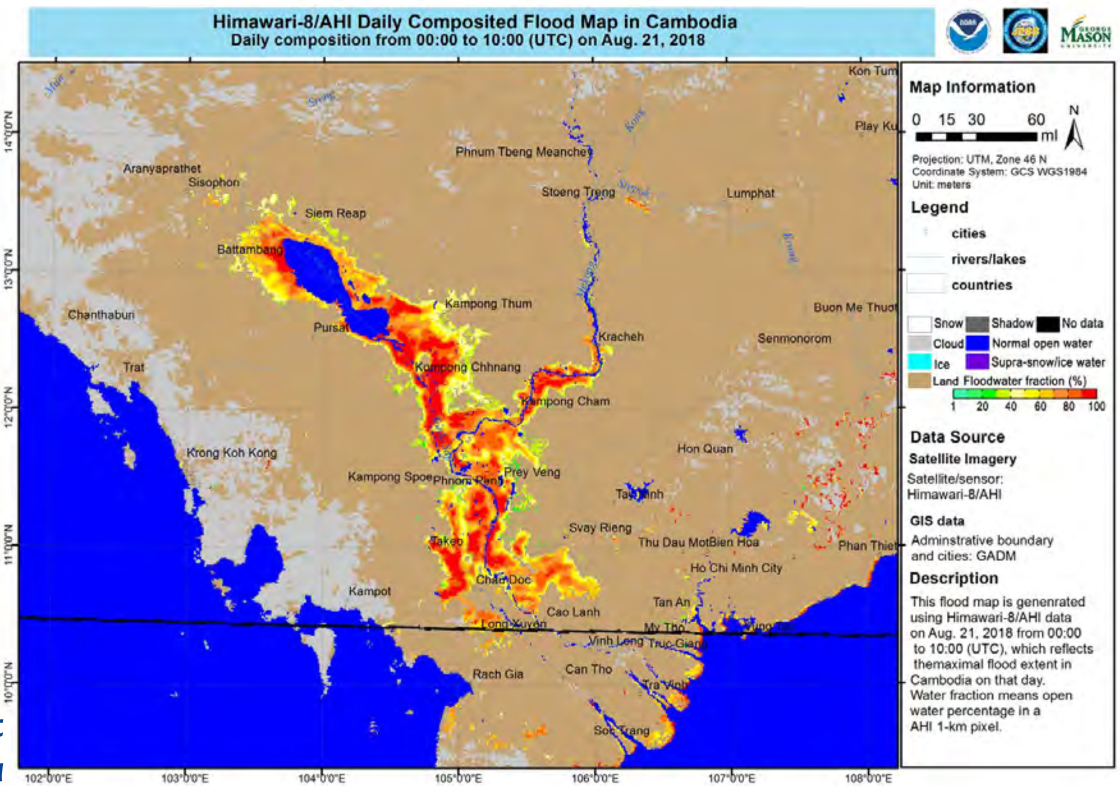
- Possible future areas of cooperation between NOAA & ESA include: Data sharing, instrument collaboration, ground system resources, and scientific exchange

**NOAA-NASA Observations from L1 Partnership on SWFO-L1 Mission**

- NOAA & NASA will partner with NOAA's SWFO-L1 flying as a rideshare with NASA's Interstellar Mapping and Acceleration Probe (IMAP) to L1
- NOAA and NASA will create an integrated program office to ensure the success of the SWFO Program

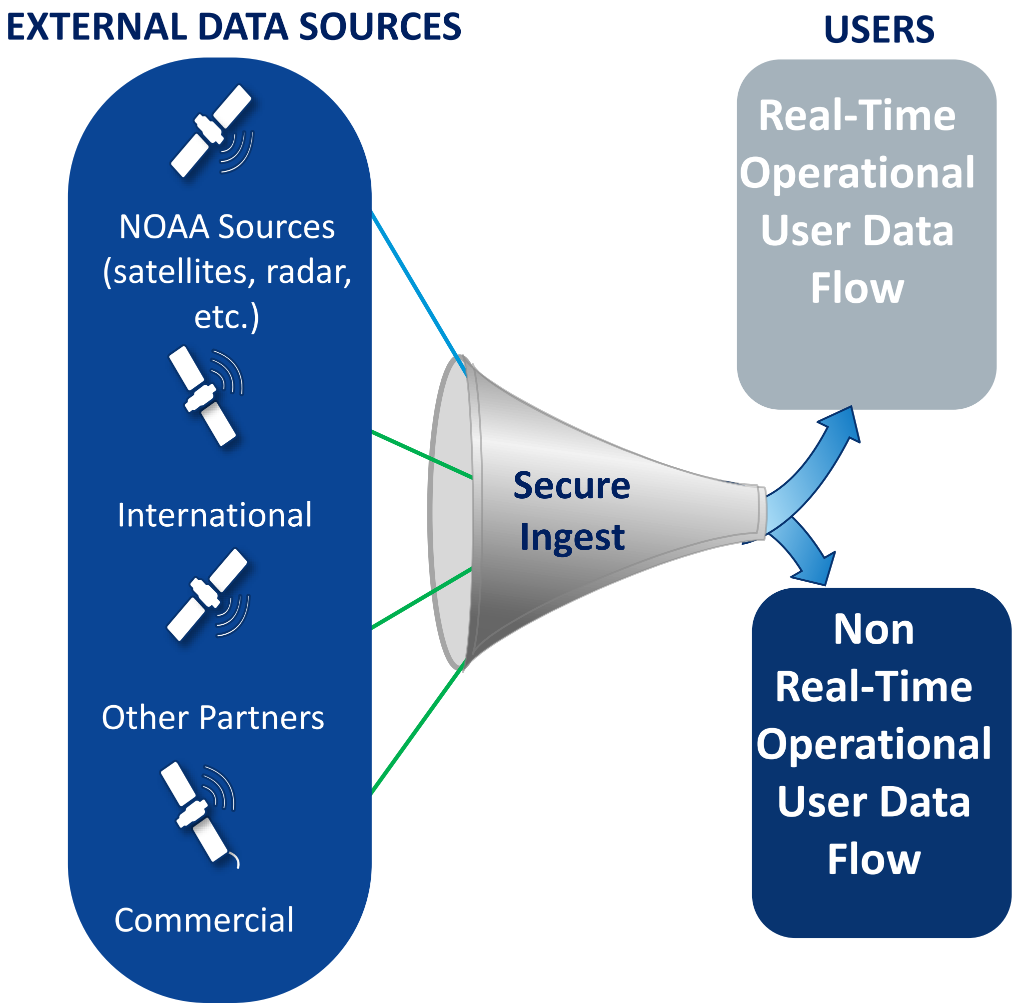
# Partnerships Enhance the value of both systems: LEO/GEO Data Fusion

- New generation of operational polar and geostationary satellites are now providing new capabilities for disaster support, including flood mapping
- Under the CEOS and CGMS initiative, NOAA is partnering with both JMA and CMA to produce consistent GEO/LEO integrated flood maps for our hemispheric regions and provide products in near real time
- Work is already underway within NOAA to merge VIIRS ocean color products from Suomi-NPP and NOAA-20 platforms and create daily gap-filled ocean color products
- Plans are in place to generate ocean color products consistent with those from VIIRS as from OLCI on Sentinel-3




*Flood mapping product in southeast Asia*

# Secure Ingest Gateway Pilot (SIGP)




- NESDIS initiated the SIGP project to establish standard enterprise secure methods for receiving data from NOAA external partners or other sources
- To take advantage of the available quality external data, NOAA must develop new multi-mission enterprise science algorithms
- This will allow NOAA efficiently bring in data from partners and commercial sector in a cost-effective manner

# New Capabilities Possible and Under Consideration

## LEO

- Next generation & additional sounders, including smallsats
- Higher density GNSS-RO
- Interagency weather observations

## GEO

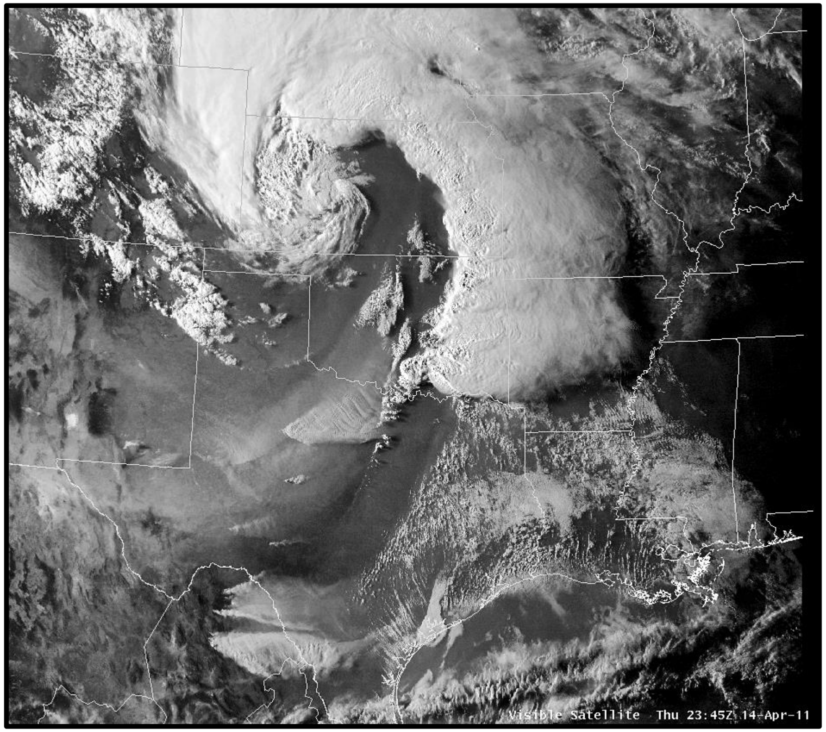
- Diverse quality imaging from three locations (east, west, center)
- Includes mixture of qualities, taskable update rates, and spectrum content (including hyperspectral)
- Higher quality lightning mapper in center

## Space Weather

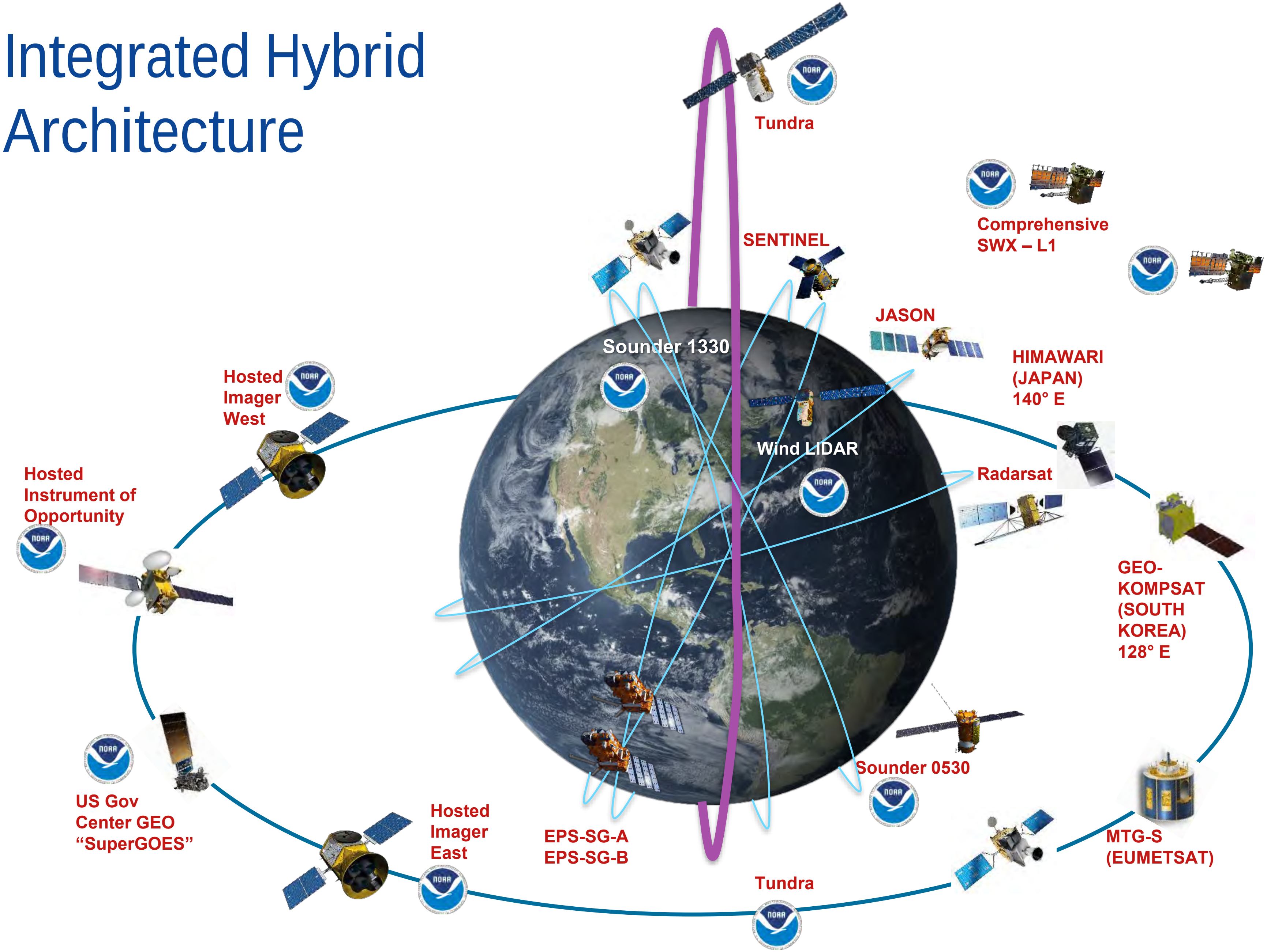
- Operational and improved on-Earth-Sun-Axis solar observation
- Off-axis solar observation and situ space weather

## Tundra and Alternative Orbits

- Extension of real-time imagery collection at high Latitudes
- Extend GEO belt to Alaska and all arctic




# Integrated Hybrid Architecture



# Hot Issues for NESDIS

- Defining and financing the next generation satellite observing system
- Maintaining and growing commercial and international partnerships to deliver a resilient and high-performing observing system
- Reliable secure Ingest of partner data
- Exploiting IT advances in data analytics, and efficient movement to the cloud
- Incorporating AI into weather forecasts and data products
- Develop robust methodology to estimate economic and societal impact assessments for future observing system options

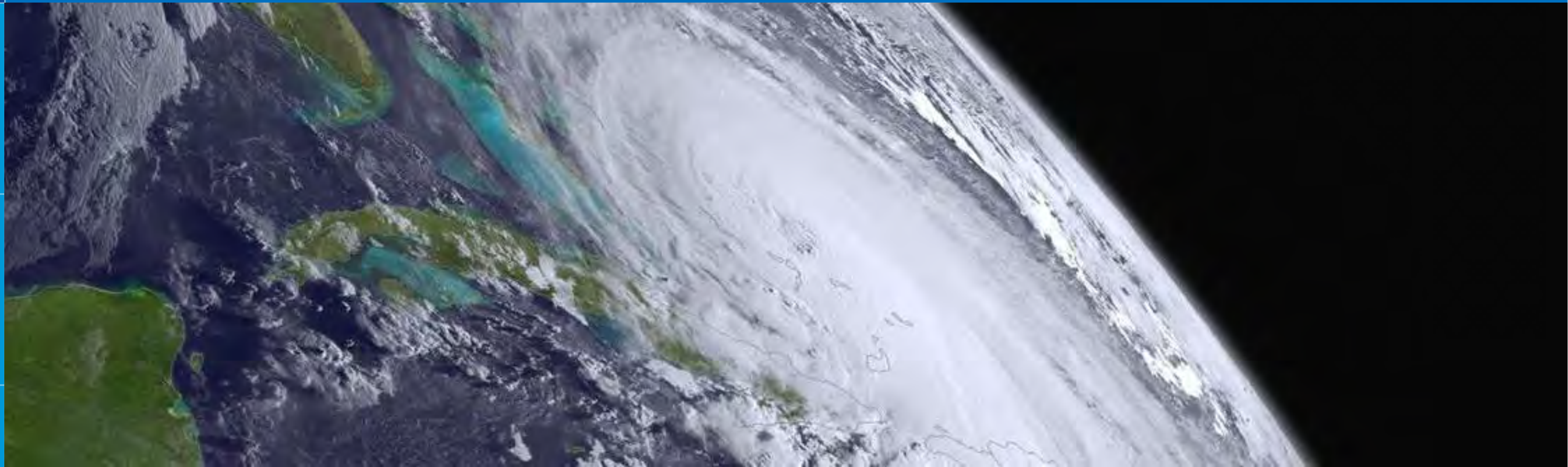
NOAA

Satellite and Information Service

March 26, 2019

# THANK YOU

Stephen Volz, Ph.D., Assistant Administrator for Satellites and Information Services, National Oceanic and Atmospheric Administration



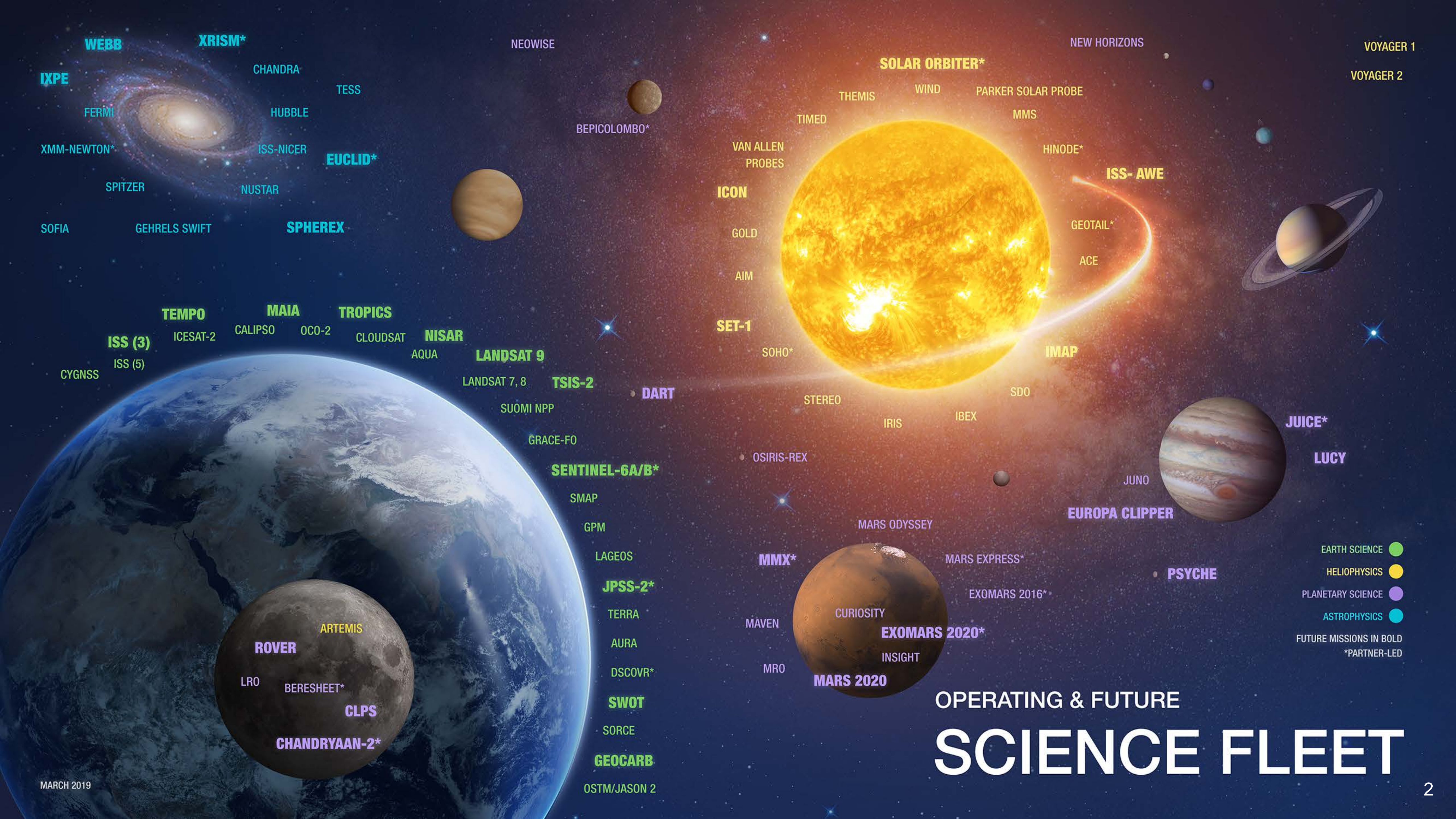
National Aeronautics and
Space Administration

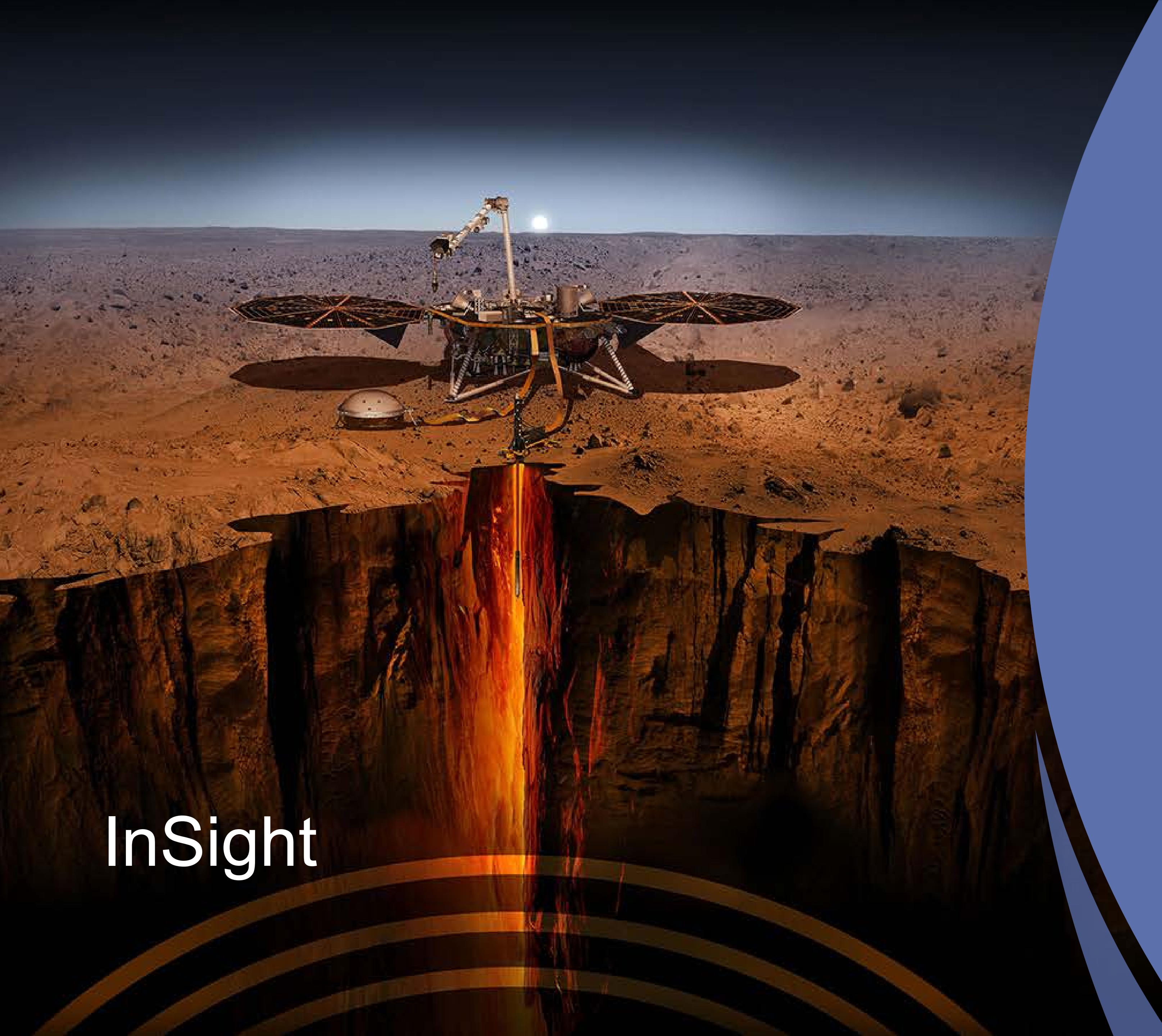
# EXPLORE SCIENCE

**Thomas H. Zurbuchen, Ph.D.**

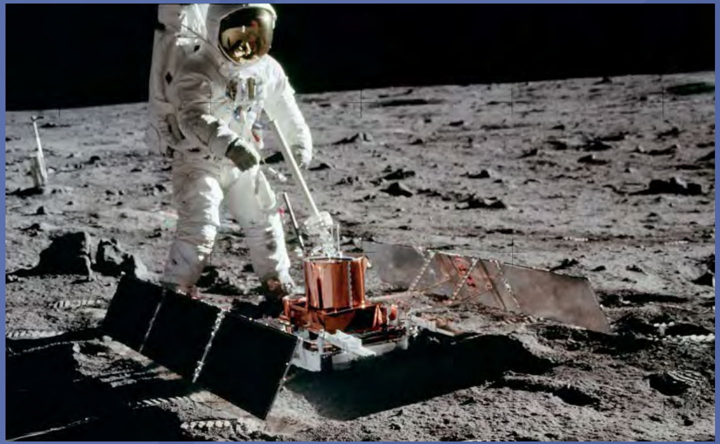
Associate Administrator
Science Mission Directorate
@Dr_ThomasZ

March 26, 2019


OPERATING & FUTURE
SCIENCE FLEET
WEBB
XRISM*
IXPE
CHANDRA
TESS
FERMI
HUBBLE
XMM-NEWTON*
ISS-NICER
EUCLID*
SPITZER
NUSTAR
SOFIA
GEHRELS SWIFT
SPHEREX
NEOWISE
BEPICOLOMBO*
NEW HORIZONS
VOYAGER 1
VOYAGER 2
SOLAR ORBITER*
THEMIS
WIND
PARKER SOLAR PROBE
TIMED
MMS
VAN ALLEN PROBES
HINODE*
ISS- AWE
ICON
GEOTAIL*
GOLD
ACE
AIM
SET-1
SOHO*
IMAP
STEREO
SDO
IRIS
IBEX
TEMPO
MAIA
TROPICS
ISS (3)
ICESAT-2
CALIPSO
OCO-2
CLOUDSAT
NISAR
ISS (5)
AQUA
LANDSAT 9
CYGNSS
LANDSAT 7, 8
TSIS-2
DART
SUOMI NPP
GRACE-FO
SENTINEL-6A/B*
SMAP
GPM
LAGEOS
JPSS-2*
TERRA
AURA
DSCOVR*
SWOT
SORCE
GEOCARB
OSTM/JASON 2
ARTEMIS
ROVER
LRO
BERESHEET*
CLPS
CHANDRYAAN-2*
OSIRIS-REX
JUICE*
LUCY
JUNO
EUROPA CLIPPER
MARS ODYSSEY
MMX*
MARS EXPRESS*
PSYCHE
EXOMARS 2016*
CURIOSITY
MAVEN
EXOMARS 2020*
INSIGHT
MRO
MARS 2020
EARTH SCIENCE
HELIOPHYSICS
PLANETARY SCIENCE
ASTROPHYSICS
FUTURE MISSIONS IN BOLD
*PARTNER-LED
MARCH 2019

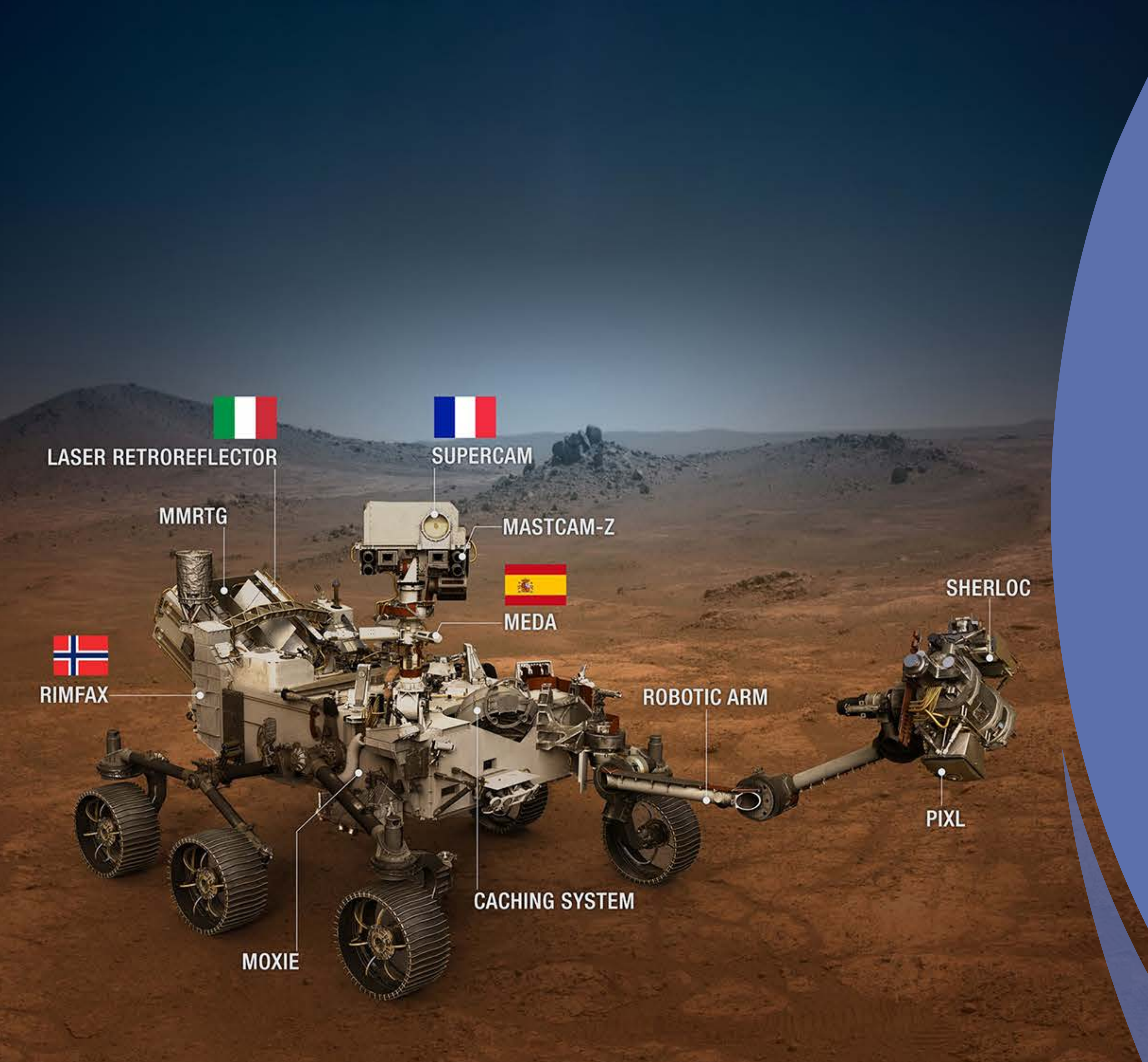


# InSight

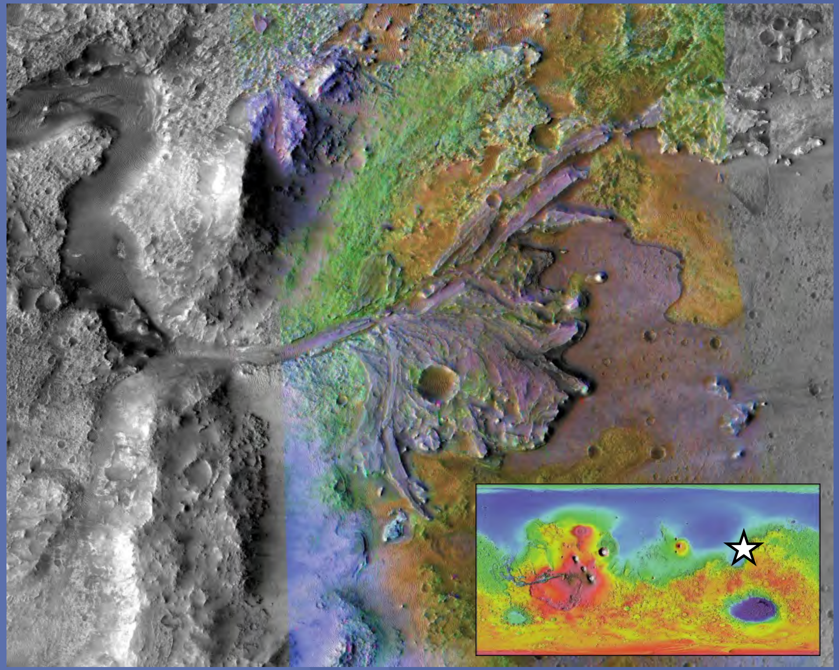


*Jul. 20 1969 – Buzz Aldrin with the Passive Seismic Experiment – first seismometer placed on Moon’s surface*

*Dec. 19, 2018 – InSight seismometer on Martian surface – first time a spacecraft robotically placed a seismometer onto surface of another planet*




# MARS 2020



*Nov. 19 - NASA Announced landing site for Mars 2020 Rover mission as Jezero Crater*

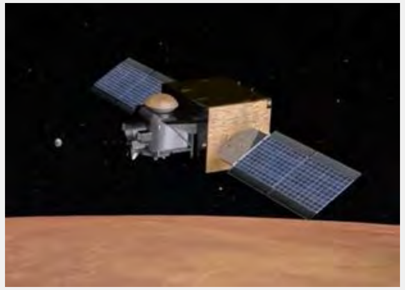

New American
Exploration Partnerships
EXPLORE
MOON to MARS
NASA

# Mars Sample Return (MSR) Concept

## Mars Sample Return Notional Elements

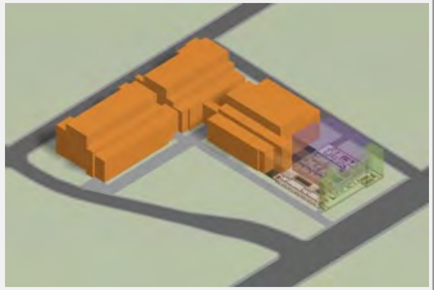
**Sample Caching Rover (Mars 2020)**
- *Sample acquisition and caching*

**Sample Retrieval Lander***
- *Fetch Rover*
- *Orbiting Sample container*
- *Mars Ascent Vehicle*



**Earth Return Orbiter****
- *Capture/Containment Module*
- *Earth Return Module*
- *Comm Relay for MSR*

## Future Work



**Mars Returned Sample Handling**
- *Sample Receiving Facility*
- *Curation*
- *Sample science investigations*

| 2020 | NET 2026 | NET 2026 | 2031 |
|---|---|---|---|
| ***Flight Elements*** | | | ***Ground Element*** |

*NASA-led
**ESA-led per April 2018 Statement of Intent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