

National Aeronautics and  
Space Administration

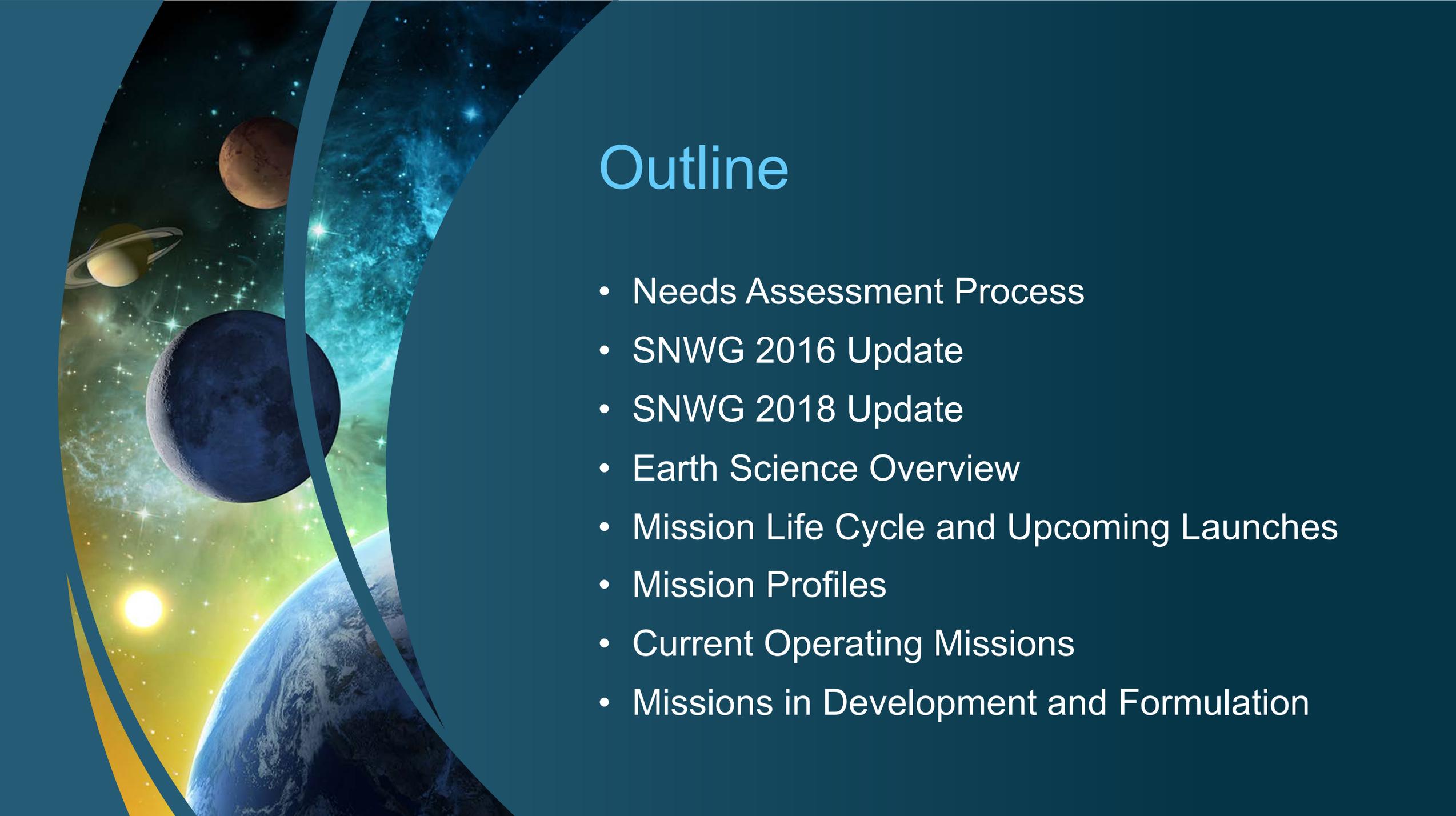


# EXPLORE EARTH

**Satellite Needs Working Group:  
NASA Role in the Process & Current and  
Planned NASA Earth Science Flight Missions**

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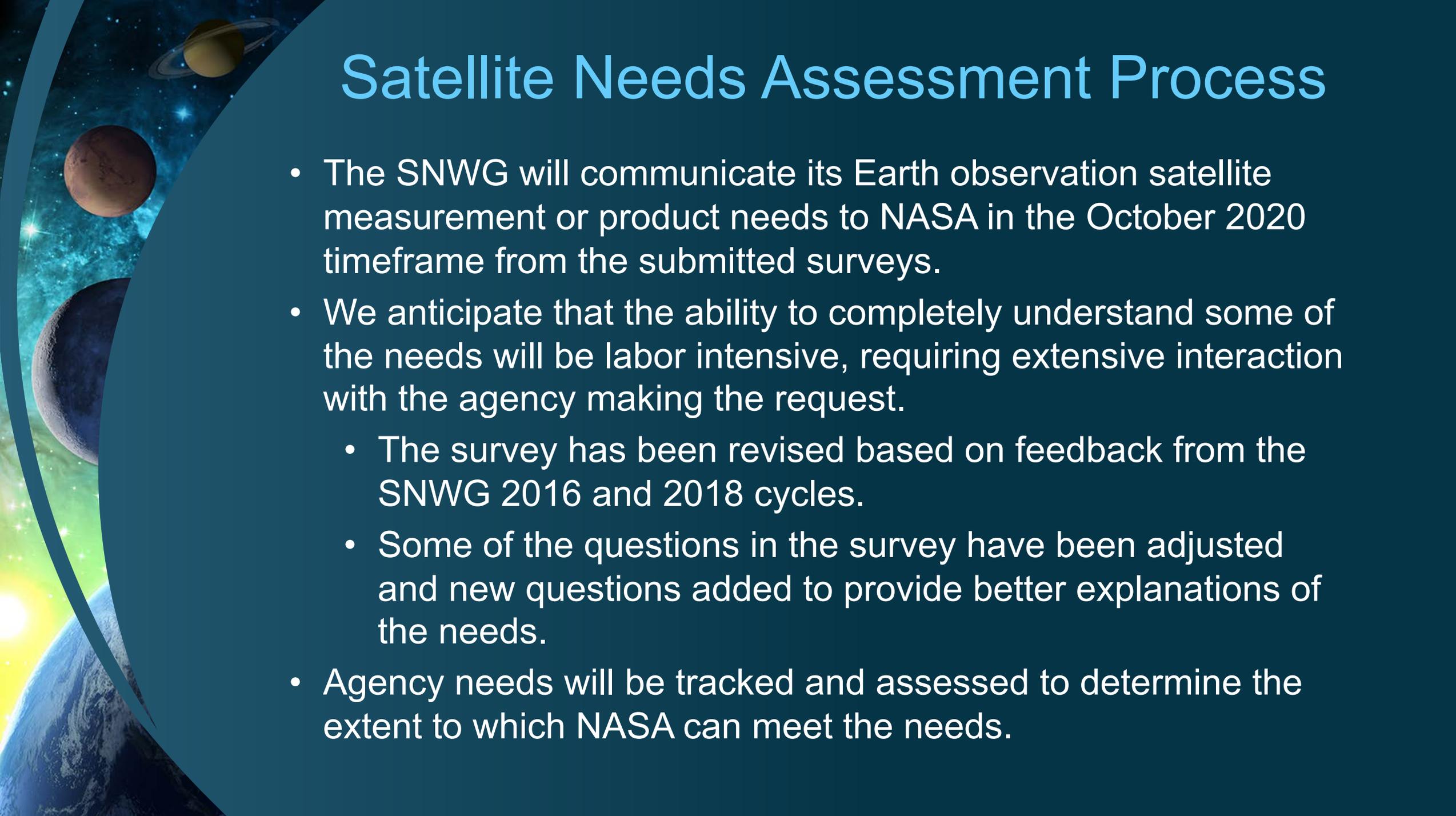
The background of the slide is a vibrant space scene. It features a large, dark blue planet in the foreground, with a bright yellow sun or star in the lower left. Other celestial bodies, including a ringed planet and a reddish planet, are visible in the distance. The background is filled with stars and a blue nebula. The slide is framed by a dark blue circular shape on the right side.

# Outline

- Needs Assessment Process
- SNWG 2016 Update
- SNWG 2018 Update
- Earth Science Overview
- Mission Life Cycle and Upcoming Launches
- Mission Profiles
- Current Operating Missions
- Missions in Development and Formulation

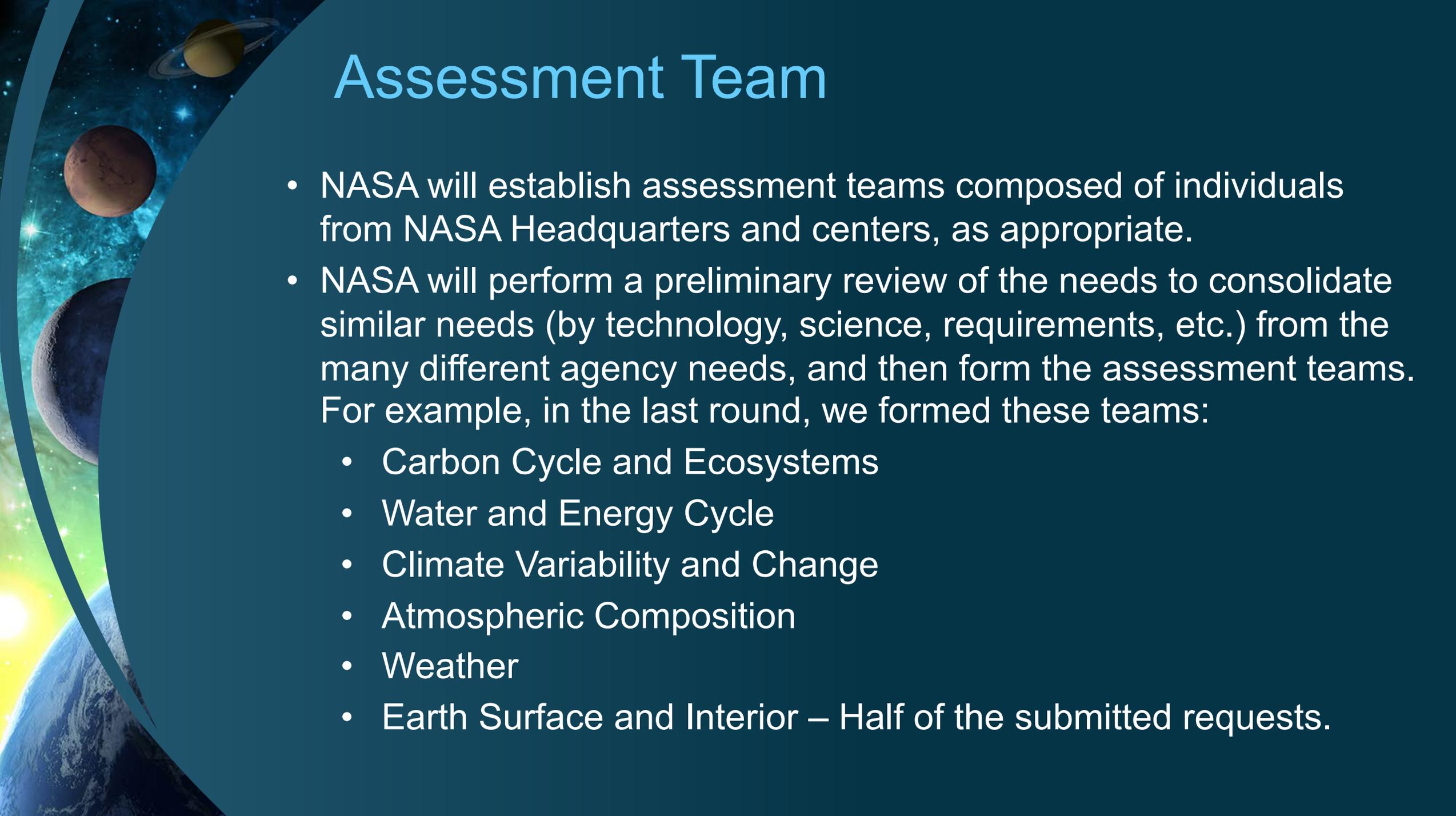
The background of the slide is a cosmic scene. The top half features a dark blue and black space with a prominent blue nebula on the right side, emitting a bright light. The bottom half is dominated by a large, glowing orange and yellow nebula on the left, transitioning into a greenish-blue nebula on the right. Numerous stars of various colors and sizes are scattered throughout the scene, some appearing as bright points of light with diffraction spikes.

# Needs Assessment Process

The background of the slide is a dark blue space-themed image. It features a curved, semi-circular border on the left side. Inside this border, there are several celestial bodies: a yellow planet with rings (Saturn) at the top, a reddish planet (Mars) in the middle, and a grey, cratered planet (the Moon) below it. The background is filled with stars and a bright yellow sun or star in the bottom left corner. The main text is in a light blue color, and the bullet points are in white.

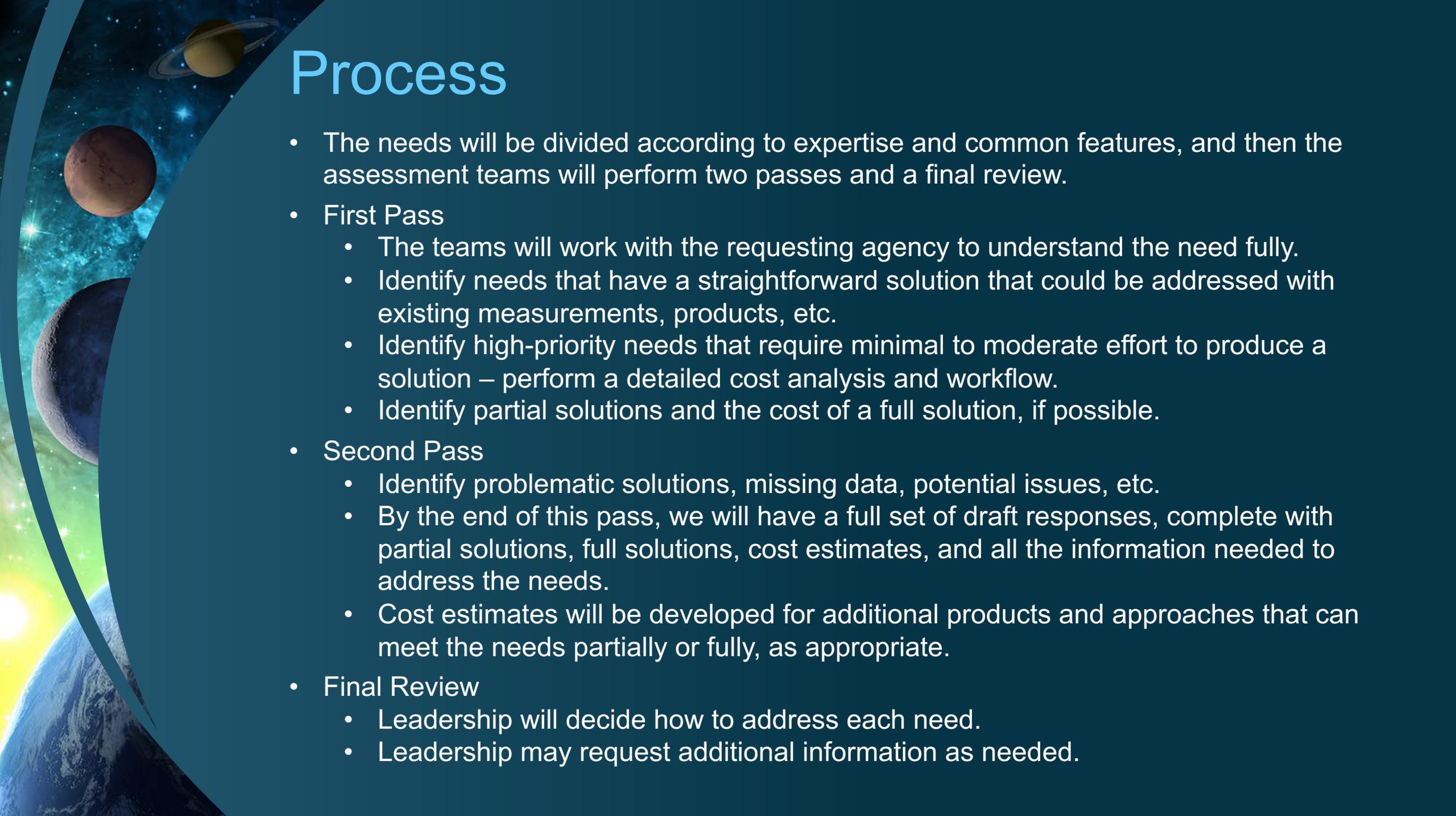
# Satellite Needs Assessment Process

- The SNWG will communicate its Earth observation satellite measurement or product needs to NASA in the October 2020 timeframe from the submitted surveys.
- We anticipate that the ability to completely understand some of the needs will be labor intensive, requiring extensive interaction with the agency making the request.
  - The survey has been revised based on feedback from the SNWG 2016 and 2018 cycles.
  - Some of the questions in the survey have been adjusted and new questions added to provide better explanations of the needs.
- Agency needs will be tracked and assessed to determine the extent to which NASA can meet the needs.

The background of the slide is a dark blue space scene. On the left side, there is a vertical strip showing a yellow sun at the bottom, the blue and white horizon of Earth, and several other celestial bodies: a grey moon, a reddish planet (Mars), and a yellow planet with rings (Saturn). The rest of the background is a deep blue with scattered white stars and a faint nebula.

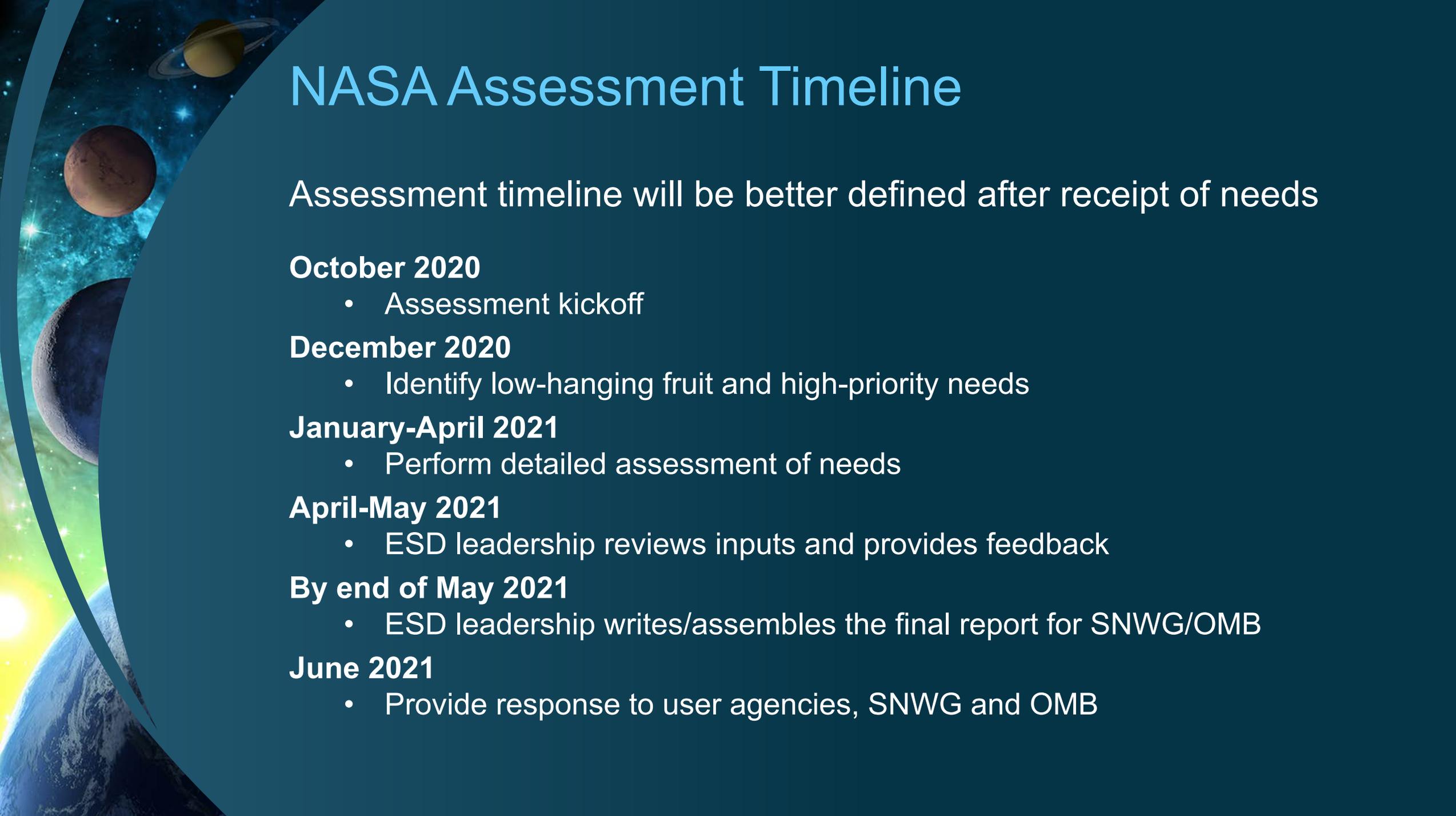
# Assessment Team

- NASA will establish assessment teams composed of individuals from NASA Headquarters and centers, as appropriate.
- NASA will perform a preliminary review of the needs to consolidate similar needs (by technology, science, requirements, etc.) from the many different agency needs, and then form the assessment teams. For example, in the last round, we formed these teams:
  - Carbon Cycle and Ecosystems
  - Water and Energy Cycle
  - Climate Variability and Change
  - Atmospheric Composition
  - Weather
  - Earth Surface and Interior – Half of the submitted requests.

The background of the slide is a vibrant space scene. It features a bright yellow sun in the bottom left corner, partially obscured by the blue and white horizon of Earth. Several planets are visible: a reddish planet (Mars) in the upper left, a greyish planet (Moon) in the middle left, and a yellow planet with rings (Saturn) in the top left. The background is filled with a blue and green nebula and numerous white stars.

# Process

- The needs will be divided according to expertise and common features, and then the assessment teams will perform two passes and a final review.
- First Pass
  - The teams will work with the requesting agency to understand the need fully.
  - Identify needs that have a straightforward solution that could be addressed with existing measurements, products, etc.
  - Identify high-priority needs that require minimal to moderate effort to produce a solution – perform a detailed cost analysis and workflow.
  - Identify partial solutions and the cost of a full solution, if possible.
- Second Pass
  - Identify problematic solutions, missing data, potential issues, etc.
  - By the end of this pass, we will have a full set of draft responses, complete with partial solutions, full solutions, cost estimates, and all the information needed to address the needs.
  - Cost estimates will be developed for additional products and approaches that can meet the needs partially or fully, as appropriate.
- Final Review
  - Leadership will decide how to address each need.
  - Leadership may request additional information as needed.



# NASA Assessment Timeline

Assessment timeline will be better defined after receipt of needs

## **October 2020**

- Assessment kickoff

## **December 2020**

- Identify low-hanging fruit and high-priority needs

## **January-April 2021**

- Perform detailed assessment of needs

## **April-May 2021**

- ESD leadership reviews inputs and provides feedback

## **By end of May 2021**

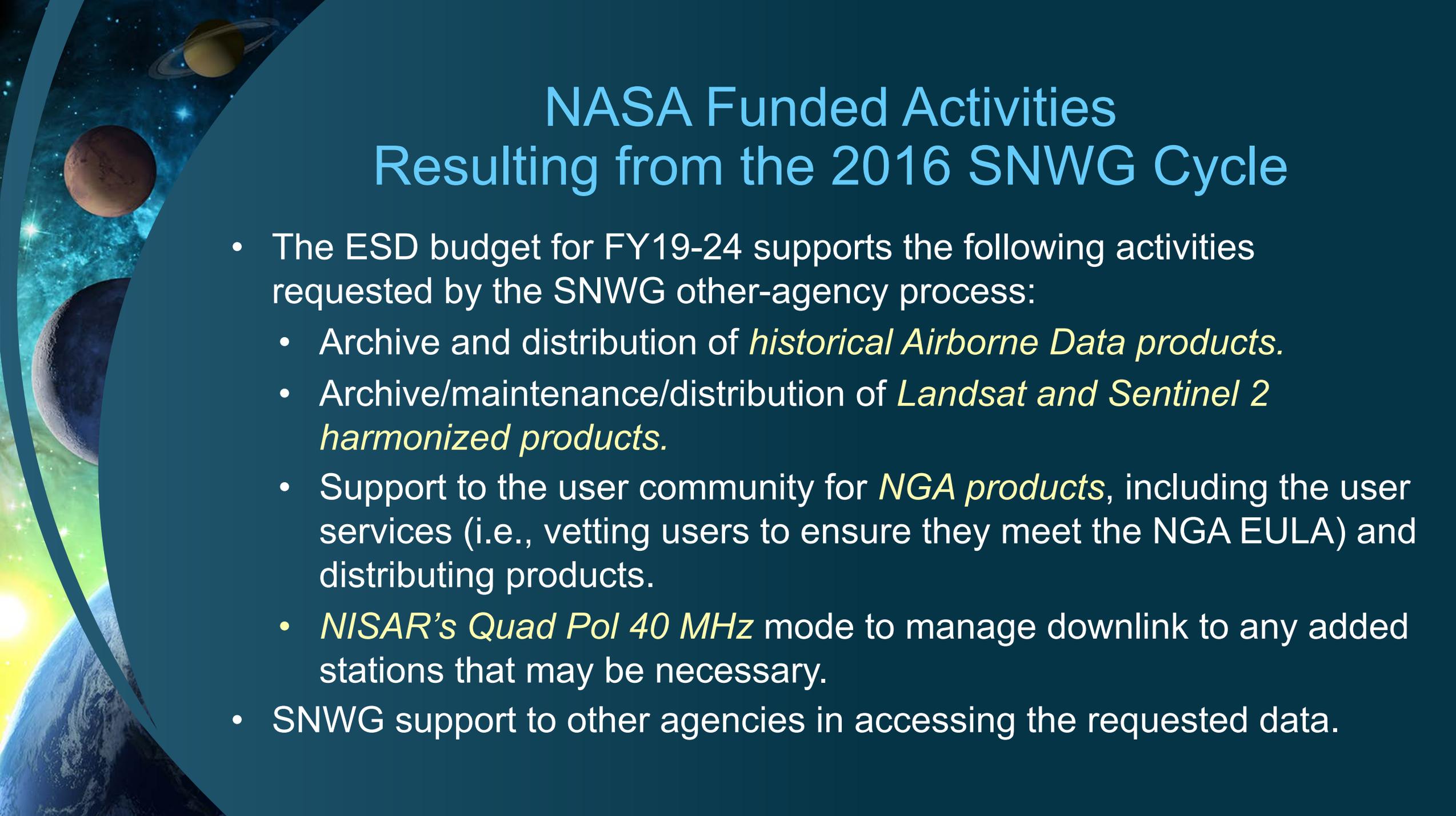
- ESD leadership writes/assembles the final report for SNWG/OMB

## **June 2021**

- Provide response to user agencies, SNWG and OMB

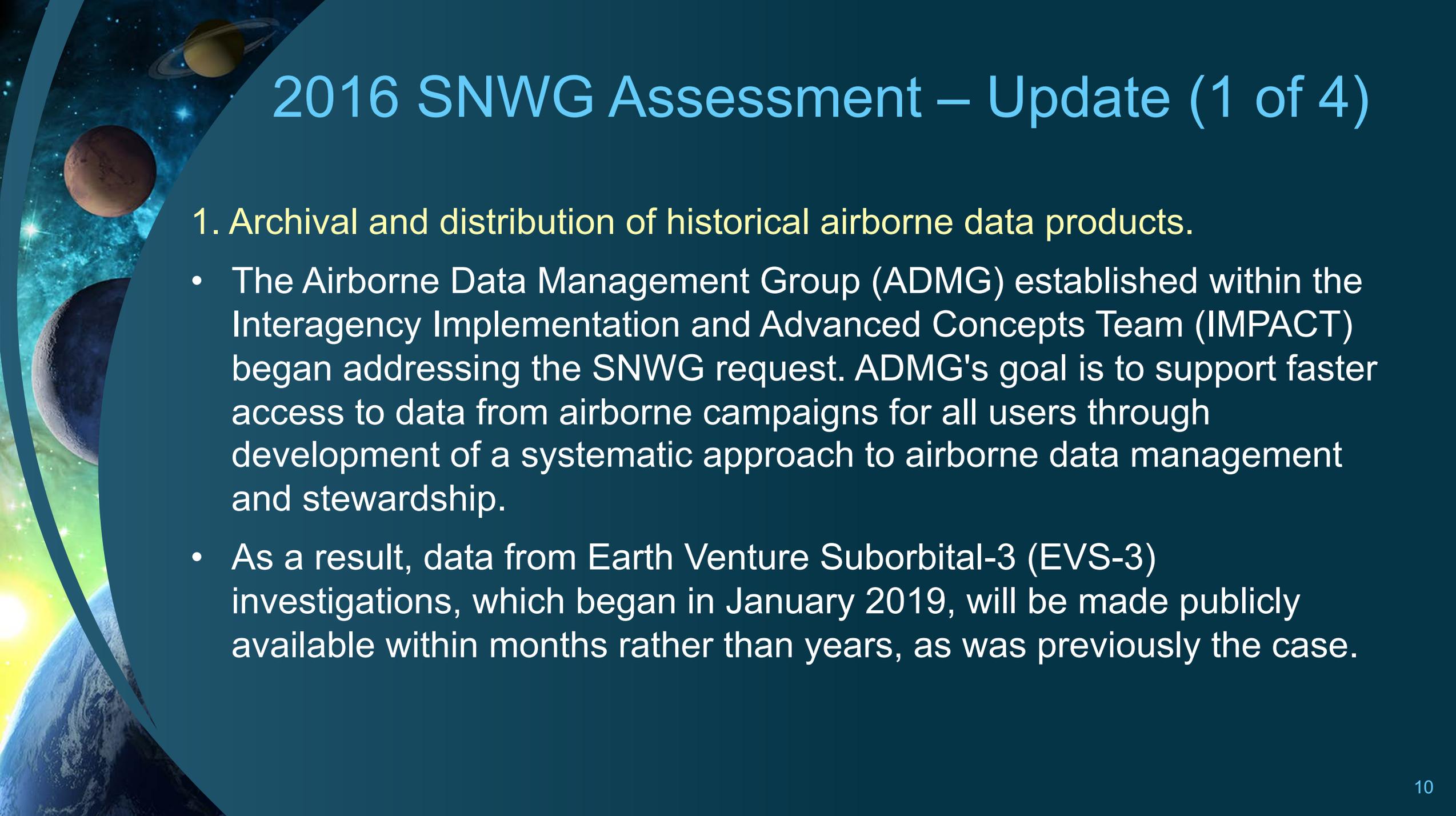
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# Update for 2016 SNWG Activities

The background of the slide features a vibrant space scene. On the left, a large, curved blue shape frames the text. The background is a deep blue with a bright yellow sun or star in the lower-left corner. Several celestial bodies are visible: a ringed planet (Saturn) in the upper left, a reddish planet (Mars) in the middle left, and a dark, cratered moon or planet in the lower left. The overall aesthetic is futuristic and scientific.

# NASA Funded Activities Resulting from the 2016 SNWG Cycle

- The ESD budget for FY19-24 supports the following activities requested by the SNWG other-agency process:
  - Archive and distribution of *historical Airborne Data products*.
  - Archive/maintenance/distribution of *Landsat and Sentinel 2 harmonized products*.
  - Support to the user community for *NGA products*, including the user services (i.e., vetting users to ensure they meet the NGA EULA) and distributing products.
  - *NISAR's Quad Pol 40 MHz* mode to manage downlink to any added stations that may be necessary.
- SNWG support to other agencies in accessing the requested data.



# 2016 SNWG Assessment – Update (1 of 4)

## 1. Archival and distribution of historical airborne data products.

- The Airborne Data Management Group (ADMG) established within the Interagency Implementation and Advanced Concepts Team (IMPACT) began addressing the SNWG request. ADMG's goal is to support faster access to data from airborne campaigns for all users through development of a systematic approach to airborne data management and stewardship.
- As a result, data from Earth Venture Suborbital-3 (EVS-3) investigations, which began in January 2019, will be made publicly available within months rather than years, as was previously the case.

# 2016 SNWG Assessment – Update (2 of 4)

## 2. Archival, maintenance, and distribution of Harmonized Landsat-Sentinel-2 (HLS) product development and support for associated research.

- NASA and USGS researchers continue to improve and refine the algorithms that produce the Harmonized Landsat-Sentinel-2 (HLS) data products. A provisional HLS data product over North America is being produced, and is publicly available: <https://hls.gsfc.nasa.gov>
- Anticipate HLS Version 1.5 global production beginning in August 2020. Back processing of the of the 2013-2020 global data beginning this Fall.. <https://lpdaac.usgs.gov/>

# 2016 SNWG Assessment – Update (3 of 4)

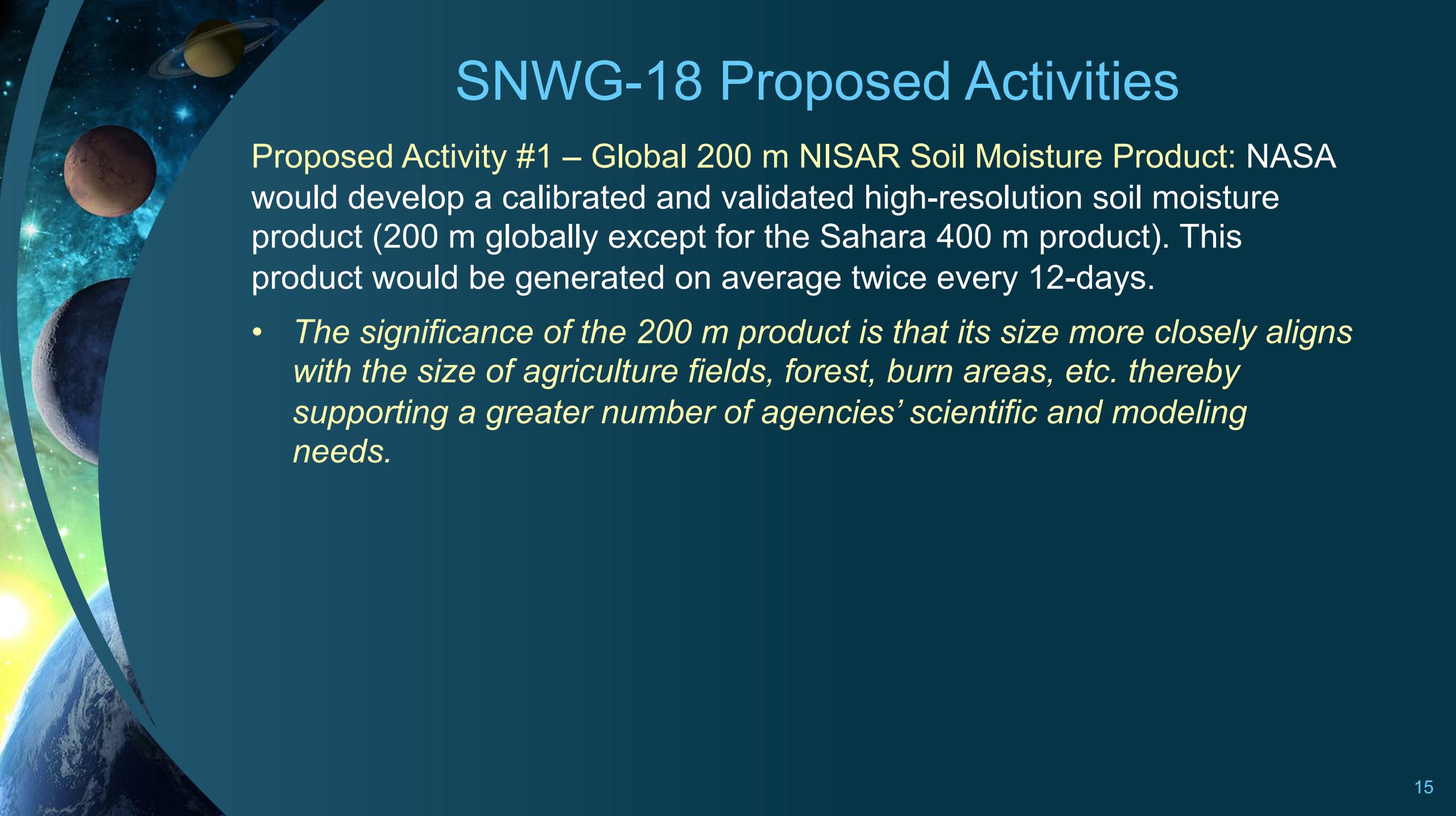
3. Support to the user community for NGA products, including the user services (i.e., vetting users to ensure they meet the NGA EULA) and distributing products.
  - NASA is actively supporting users requesting archived data, as well as new acquisitions provided through NGA's *NextView* license. All users who request these products are vetted to ensure they are legitimate and they understand the license restrictions.
4. NISAR Quad Pol 40 MHz.
  - The SNWG Augmentation for NISAR added 9 Tbits/day of downlink capacity through the addition of a new NISAR downlink station. This enabled the collection of high-resolution (8 m x 6 m) imagery over North America in quasi-quad-pol mode.

# 2016 SNWG Assessment – Update (4 of 4)

5. SNWG support to other agencies in accessing the requested data.
  - The Data Curation for Discovery (DCD) project within IMPACT focuses on design and implements a systematic plan to assist other agencies in incorporating NASA Earth observation data into their workflows.
  - *The DCD team improves the discoverability of NASA Earth science data and other curated Earth observation data in trusted catalogs and platforms.*
  - DCD supports the accurate publication of NASA Earth observations in platforms such as [data.gov](https://data.gov) and [geoplatform.gov](https://geoplatform.gov) and with [schema.org](https://schema.org).
  - Additionally, the DCD team creates a profile of agency needs captured through the federal-civil satellite needs survey conducted by USGEO SNWG.

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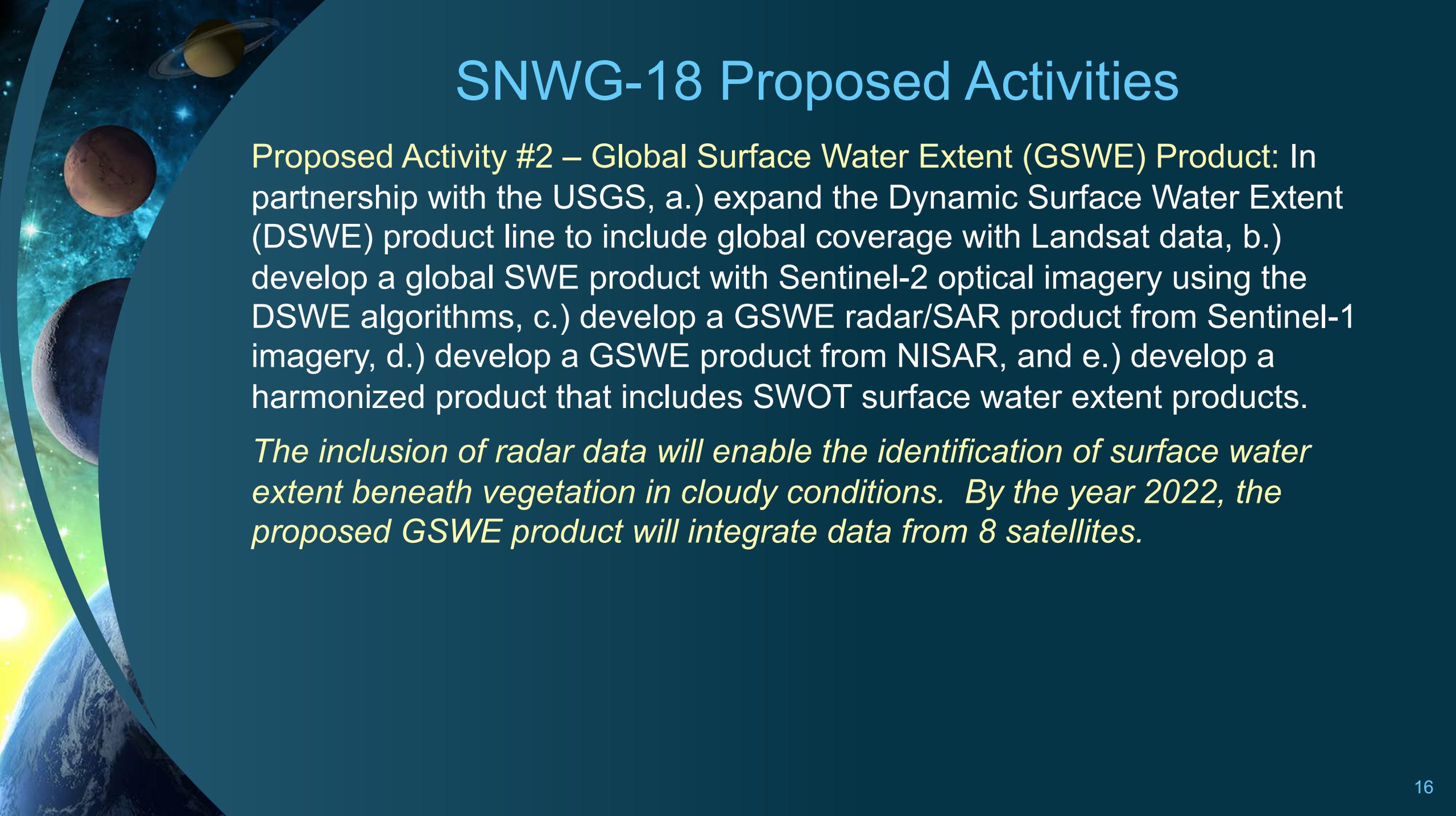
# Update for 2018 SNWG Activities

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# SNWG-18 Proposed Activities

Proposed Activity #1 – Global 200 m NISAR Soil Moisture Product: NASA would develop a calibrated and validated high-resolution soil moisture product (200 m globally except for the Sahara 400 m product). This product would be generated on average twice every 12-days.

- *The significance of the 200 m product is that its size more closely aligns with the size of agriculture fields, forest, burn areas, etc. thereby supporting a greater number of agencies' scientific and modeling needs.*

The background of the slide features a dark blue space theme. On the left side, there is a vertical strip showing a yellow planet with rings (Saturn), a reddish planet (Mars), and a grey planet (Moon) against a starry sky. At the bottom left, the blue and white horizon of Earth is visible. The main content area is a large, semi-transparent dark blue circle.

# SNWG-18 Proposed Activities

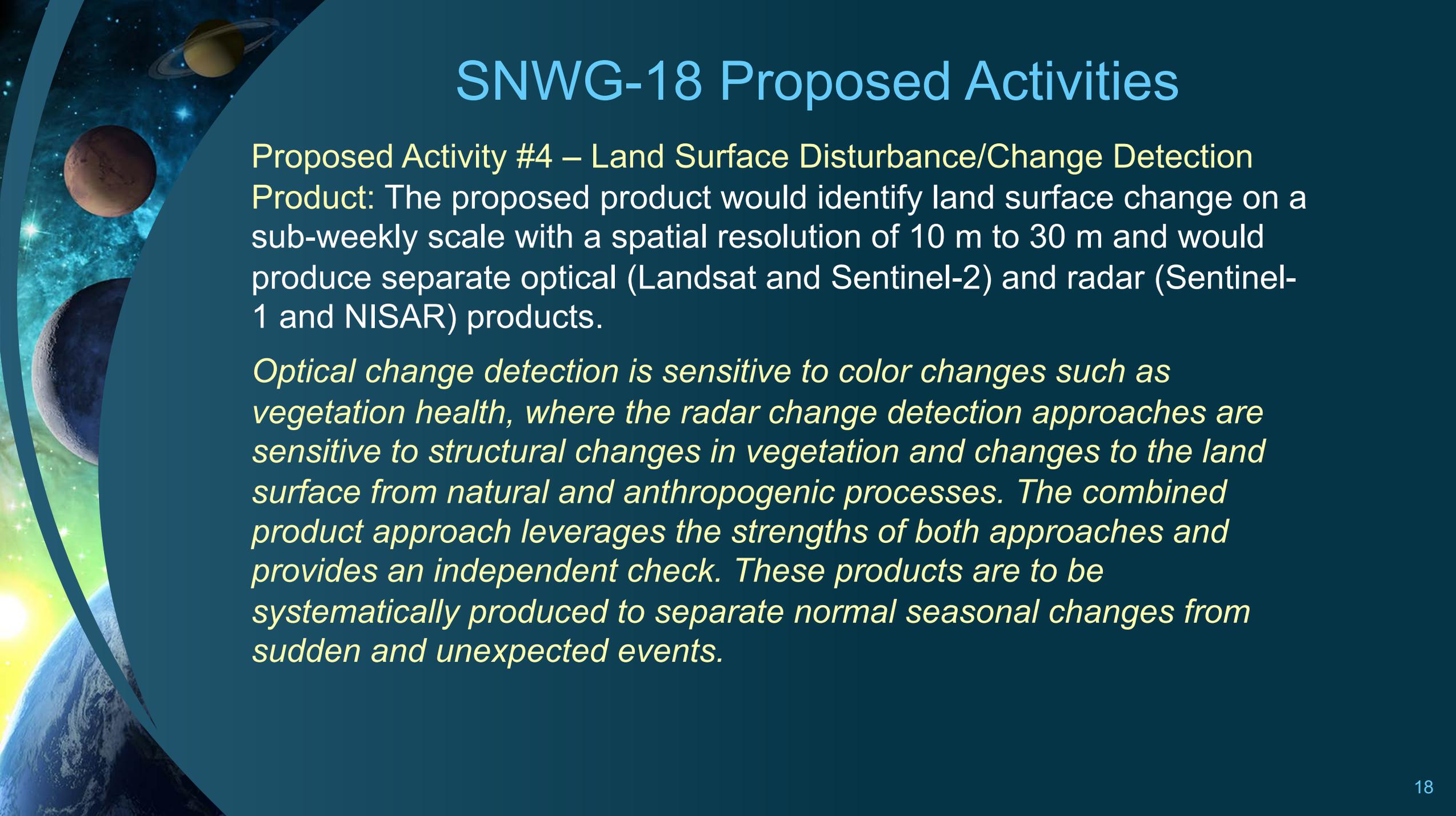
**Proposed Activity #2 – Global Surface Water Extent (GSWE) Product:** In partnership with the USGS, a.) expand the Dynamic Surface Water Extent (DSWE) product line to include global coverage with Landsat data, b.) develop a global SWE product with Sentinel-2 optical imagery using the DSWE algorithms, c.) develop a GSWE radar/SAR product from Sentinel-1 imagery, d.) develop a GSWE product from NISAR, and e.) develop a harmonized product that includes SWOT surface water extent products.

*The inclusion of radar data will enable the identification of surface water extent beneath vegetation in cloudy conditions. By the year 2022, the proposed GSWE product will integrate data from 8 satellites.*

# SNWG-18 Proposed Activities

**Proposed Activity #3 – Water Quality Product:** The Ocean Biology Processing Group (OBPG) would develop ARD (Application Ready Data) Level 2 and 3 products from OLCI data by undertaking higher-level data processing, archival and distribution of the new products at the Ocean Biology Distributed Active Archive Center (OB.DAAC).

*The activity includes further development of ocean color data processing software, performance of vicarious calibration necessary to minimize bias across harmonized ocean color data products, and integration support for display and processing of OLCI data into the SeaDAS software package.*

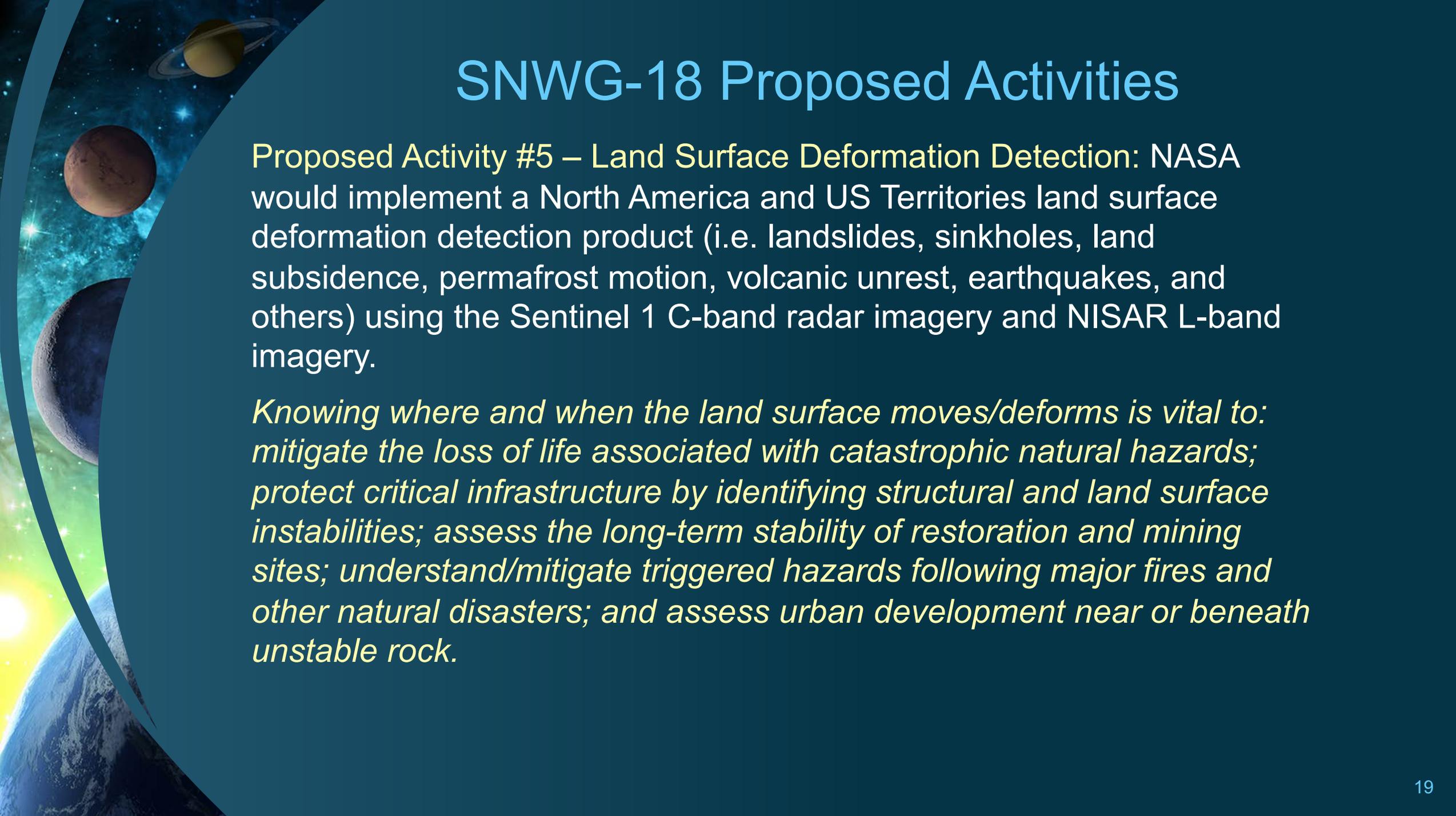
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# SNWG-18 Proposed Activities

## Proposed Activity #4 – Land Surface Disturbance/Change Detection

**Product:** The proposed product would identify land surface change on a sub-weekly scale with a spatial resolution of 10 m to 30 m and would produce separate optical (Landsat and Sentinel-2) and radar (Sentinel-1 and NISAR) products.

*Optical change detection is sensitive to color changes such as vegetation health, where the radar change detection approaches are sensitive to structural changes in vegetation and changes to the land surface from natural and anthropogenic processes. The combined product approach leverages the strengths of both approaches and provides an independent check. These products are to be systematically produced to separate normal seasonal changes from sudden and unexpected events.*

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# SNWG-18 Proposed Activities

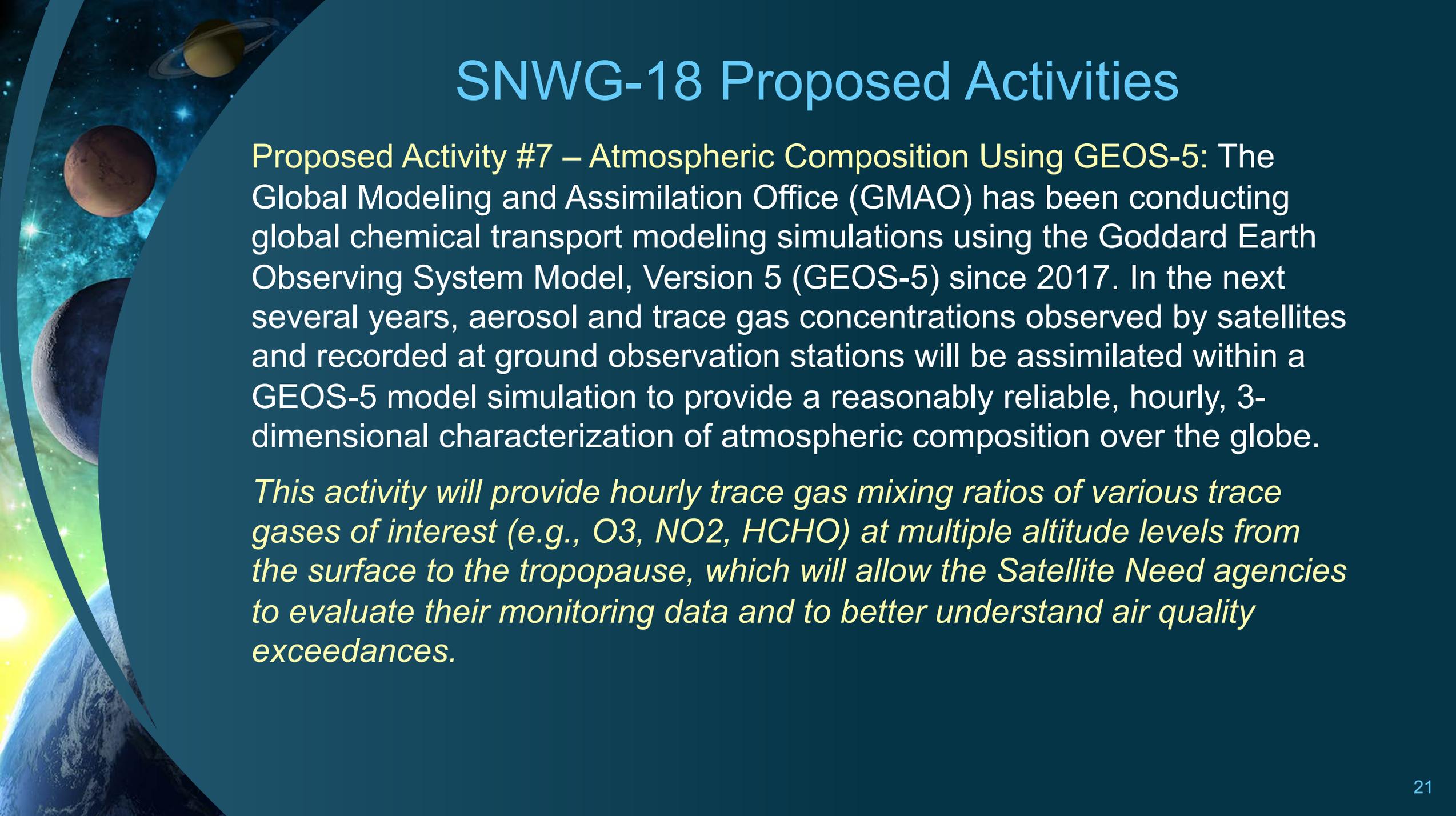
**Proposed Activity #5 – Land Surface Deformation Detection:** NASA would implement a North America and US Territories land surface deformation detection product (i.e. landslides, sinkholes, land subsidence, permafrost motion, volcanic unrest, earthquakes, and others) using the Sentinel 1 C-band radar imagery and NISAR L-band imagery.

*Knowing where and when the land surface moves/deforms is vital to: mitigate the loss of life associated with catastrophic natural hazards; protect critical infrastructure by identifying structural and land surface instabilities; assess the long-term stability of restoration and mining sites; understand/mitigate triggered hazards following major fires and other natural disasters; and assess urban development near or beneath unstable rock.*

# SNWG-18 Proposed Activities

**Proposed Activity #6 – Radiation & Clouds:** NASA would refine the Satellite CLOUD and Radiation Property retrieval System (SatCORPS) composite GEO and LEO satellite cloud and radiation parameters data products from daylight-only to: a.) fully global, b.) increase their horizontal resolution from 5 km to 3 km, c.) increase temporal resolution to hourly, d.) develop new parameterizations for ice and liquid water path in ice over liquid cloud conditions, e.) add these parameters to the current data products, and f.) determine how the incorporation of VIIRS data may improve coverage.

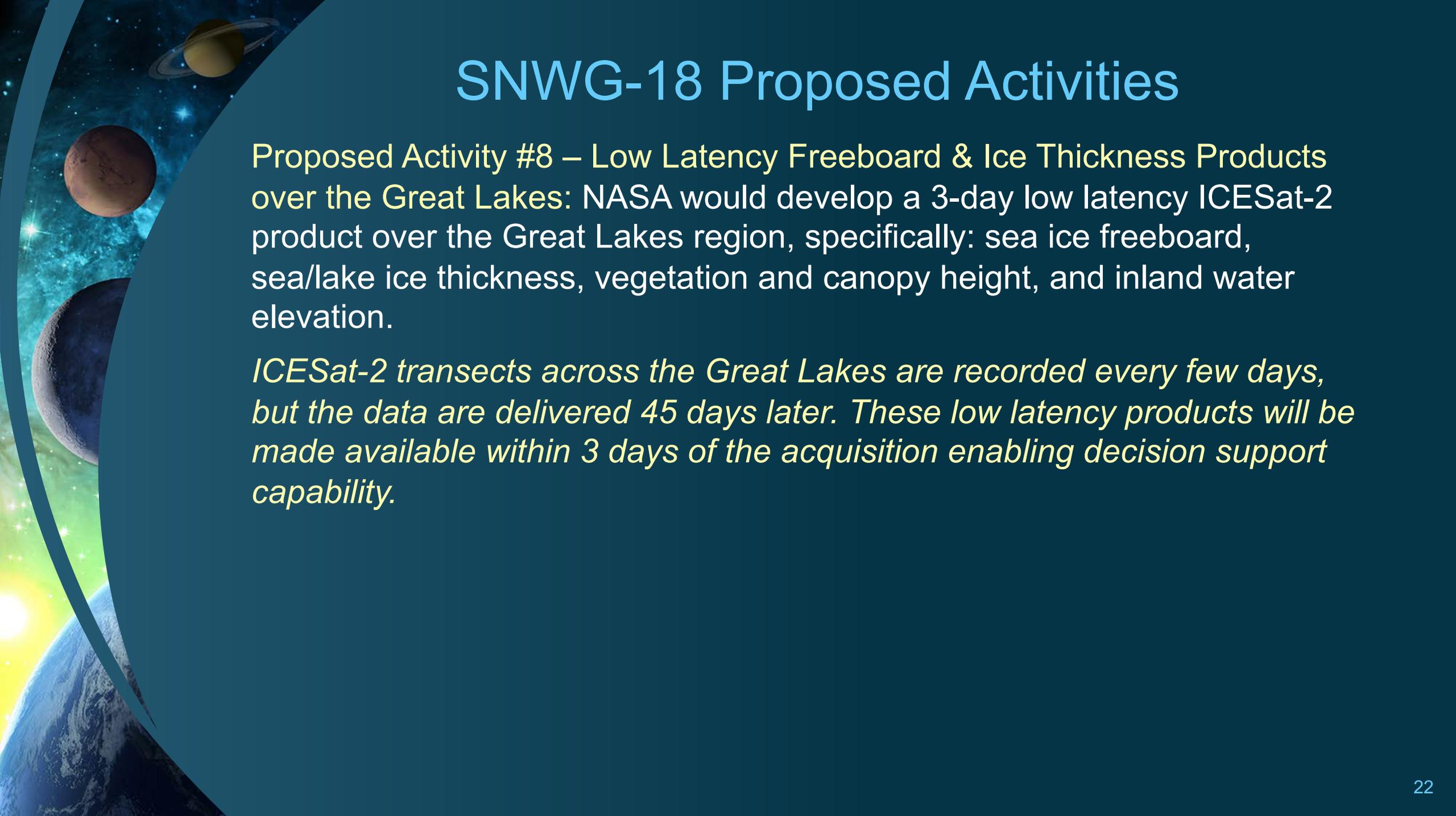
*This activity would improve SatCORPS cloud data products that support a number of atmospheric and climatic agency needs.*

The background of the slide features a vibrant space scene. On the left, a large, curved blue shape frames the text. The background is a deep blue with scattered white stars. Several celestial bodies are visible: a yellow planet with a ring system (resembling Saturn) in the upper left, a reddish-brown planet (resembling Mars) in the middle left, and a dark, cratered planet (resembling the Moon) in the lower left. The bottom left corner shows the blue and white horizon of Earth, with a bright yellow sun partially visible behind it.

# SNWG-18 Proposed Activities

**Proposed Activity #7 – Atmospheric Composition Using GEOS-5:** The Global Modeling and Assimilation Office (GMAO) has been conducting global chemical transport modeling simulations using the Goddard Earth Observing System Model, Version 5 (GEOS-5) since 2017. In the next several years, aerosol and trace gas concentrations observed by satellites and recorded at ground observation stations will be assimilated within a GEOS-5 model simulation to provide a reasonably reliable, hourly, 3-dimensional characterization of atmospheric composition over the globe.

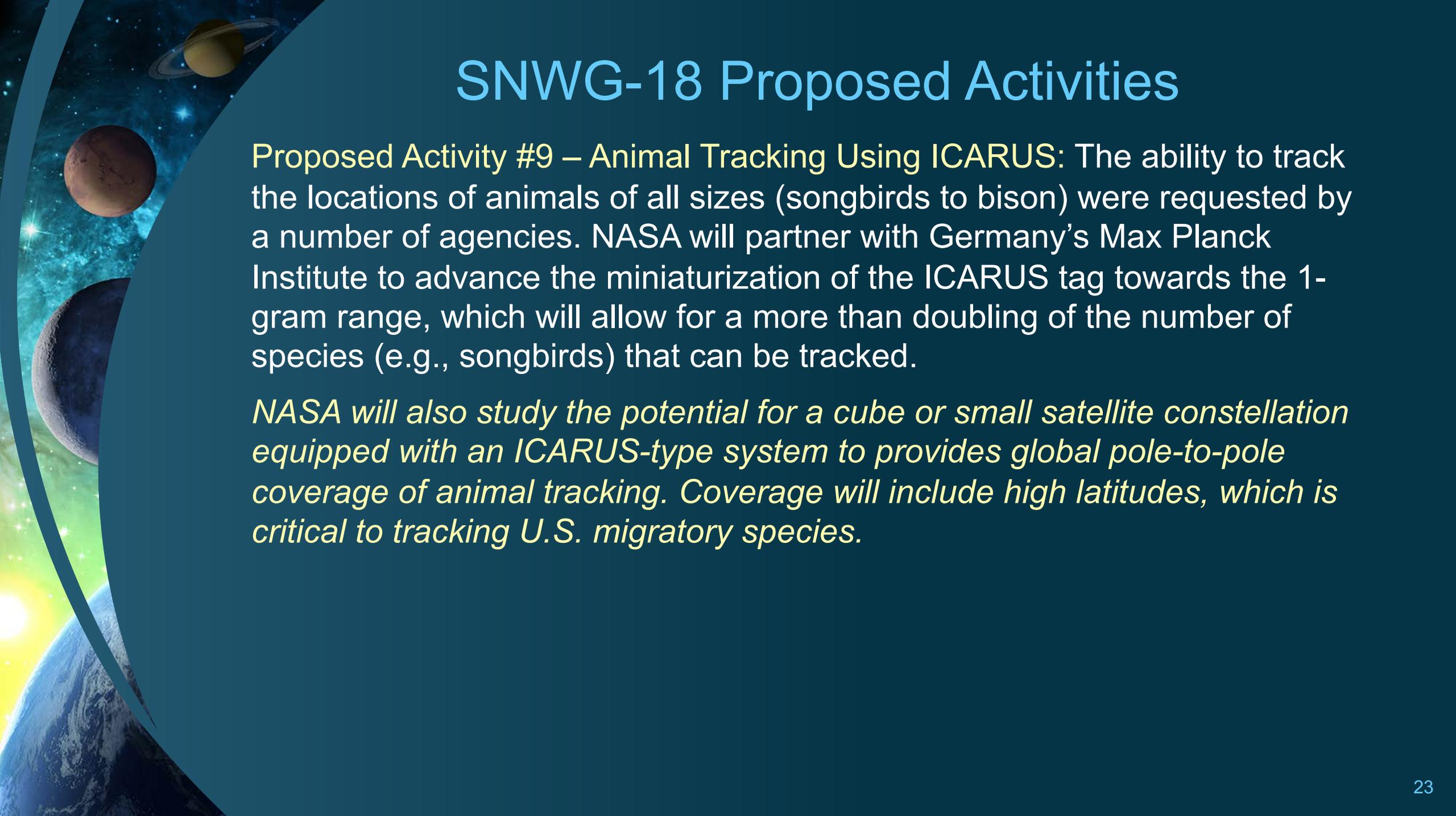
*This activity will provide hourly trace gas mixing ratios of various trace gases of interest (e.g., O<sub>3</sub>, NO<sub>2</sub>, HCHO) at multiple altitude levels from the surface to the tropopause, which will allow the Satellite Need agencies to evaluate their monitoring data and to better understand air quality exceedances.*

The background of the slide is a dark blue space-themed image. On the left side, there is a vertical strip showing various celestial bodies: at the top, a yellow planet with rings (Saturn); below it, a reddish planet (Mars); then a grey, cratered planet (the Moon); and at the bottom, the blue and white horizon of Earth. The background is filled with small white stars and a nebula-like glow in shades of blue and green.

# SNWG-18 Proposed Activities

Proposed Activity #8 – Low Latency Freeboard & Ice Thickness Products over the Great Lakes: NASA would develop a 3-day low latency ICESat-2 product over the Great Lakes region, specifically: sea ice freeboard, sea/lake ice thickness, vegetation and canopy height, and inland water elevation.

*ICESat-2 transects across the Great Lakes are recorded every few days, but the data are delivered 45 days later. These low latency products will be made available within 3 days of the acquisition enabling decision support capability.*

The background of the slide is a dark blue space scene. On the left side, there is a vertical strip showing a yellow sun at the bottom, the Earth's horizon, and several celestial bodies: a crescent moon, a reddish planet (Mars), and a yellow planet with rings (Saturn). The rest of the background is a deep blue with scattered white stars.

# SNWG-18 Proposed Activities

**Proposed Activity #9 – Animal Tracking Using ICARUS:** The ability to track the locations of animals of all sizes (songbirds to bison) were requested by a number of agencies. NASA will partner with Germany's Max Planck Institute to advance the miniaturization of the ICARUS tag towards the 1-gram range, which will allow for a more than doubling of the number of species (e.g., songbirds) that can be tracked.

*NASA will also study the potential for a cube or small satellite constellation equipped with an ICARUS-type system to provides global pole-to-pole coverage of animal tracking. Coverage will include high latitudes, which is critical to tracking U.S. migratory species.*

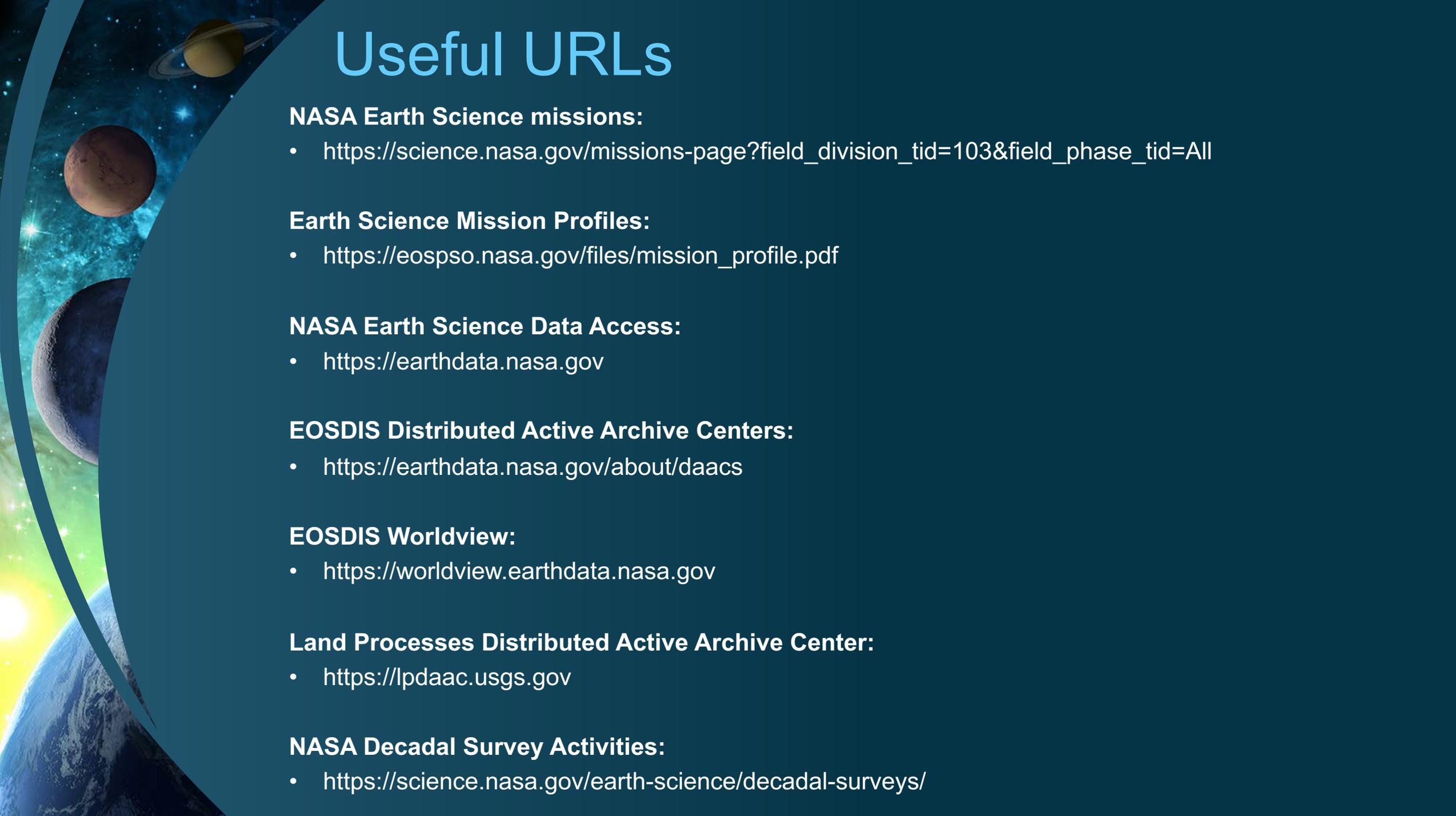
# Related Activities

**Assess the Scientific Value of Ultra-High Resolution Commercial Imagery:** NASA has completed the Commercial Smallsat Data Acquisition Program (CSDAP) Pilot Evaluations (originally known as the Private-Sector Small Constellation Satellite Data Product Pilot) in early 2020.

- *The researchers assessed the value and utility of data for science and application purposes. The final assessments reports is available from the CSDAP website (<https://earthdata.nasa.gov/esds/small-satellite-data-buy-program>).*

**Evaluate the Scientific Value of DESIS Hyperspectral Imagery:** DLR Earth Sensing Imaging Spectrometer (DESI) imagery is a commercial instrument on the International Space Station with spectral range of (400 to 1000) nm, which includes the visual to near-infrared spectrum (VIS-NIR).

- *NASA has an agreement in place for unlimited access to DESIS data for scientific use until the summer of 2021. All U.S. Government agencies can request data using this agreement.*

A space-themed background featuring a curved view of Earth at the bottom left, with various celestial bodies including Saturn, Mars, and the Moon against a starry blue and green sky.

# Useful URLs

## **NASA Earth Science missions:**

- [https://science.nasa.gov/missions-page?field\\_division\\_tid=103&field\\_phase\\_tid=All](https://science.nasa.gov/missions-page?field_division_tid=103&field_phase_tid=All)

## **Earth Science Mission Profiles:**

- [https://eospsa.nasa.gov/files/mission\\_profile.pdf](https://eospsa.nasa.gov/files/mission_profile.pdf)

## **NASA Earth Science Data Access:**

- <https://earthdata.nasa.gov>

## **EOSDIS Distributed Active Archive Centers:**

- <https://earthdata.nasa.gov/about/daacs>

## **EOSDIS Worldview:**

- <https://worldview.earthdata.nasa.gov>

## **Land Processes Distributed Active Archive Center:**

- <https://lpdaac.usgs.gov>

## **NASA Decadal Survey Activities:**

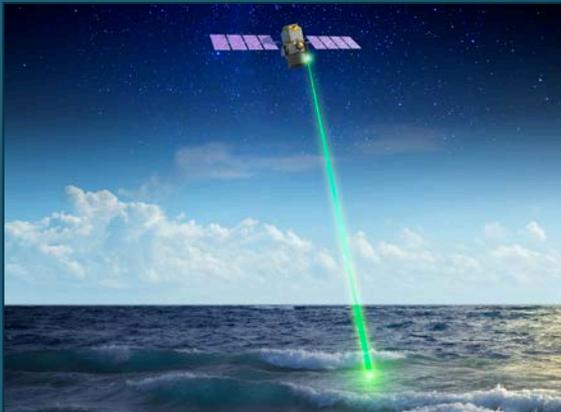
- <https://science.nasa.gov/earth-science/decadal-surveys/>

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# Earth Science Overview

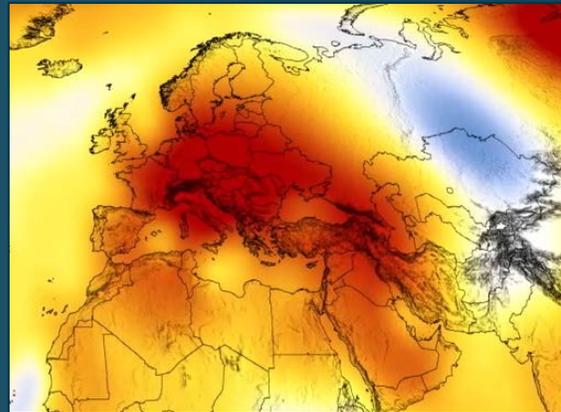
# NASA Earth Science Division Elements

## Flight



- Develops, launches, and operates NASA's fleet of Earth-observing satellites, instruments, and aircraft.
- Manages data systems to make data and information products freely and openly available.

## Research & Analysis



- Supports integrative research that advances knowledge of the Earth as a system.
- Includes six focus areas plus field campaigns, modeling, and scientific computing.

## Applied Sciences



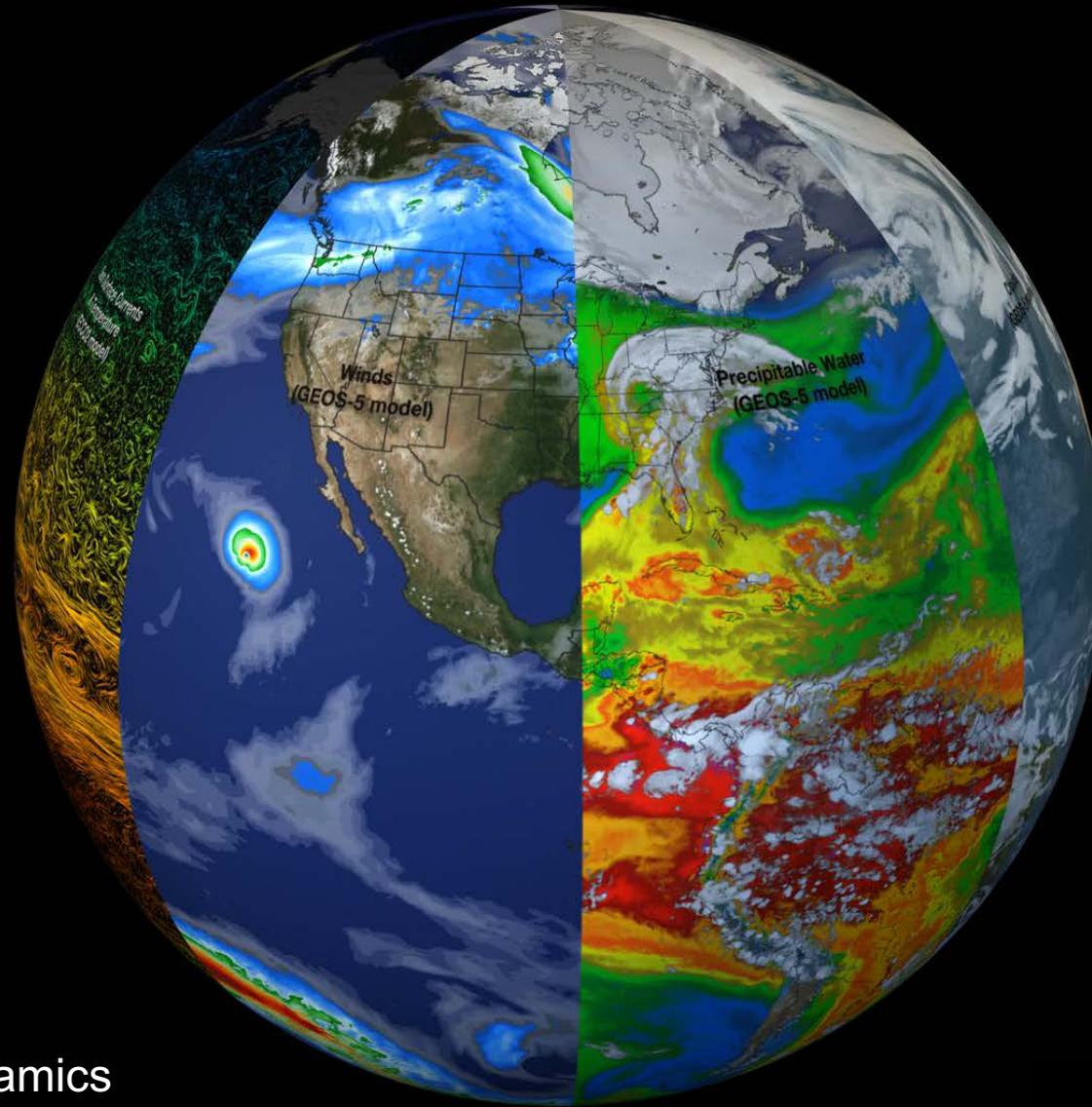
- Develops and supports use of Earth observations and scientific knowledge for private and public planning and decisions.
- Activities include disaster response support and capacity building.

## Technology



- Develops and demonstrates technologies for future satellite and airborne missions: Instruments, Information Systems, Components, InSpace Validation (CubeSat and SmallSat form factors).

# NASA Earth System Science



Atmospheric Composition  
Carbon Cycle and Ecosystems  
Climate Variability and Change  
Earth Surface and Interior  
Water and Energy Cycle  
Weather and Atmospheric Dynamics

# Applied Sciences Highlights

## Ecological Forecasting, Health & Air Quality, Disasters, and Water Resources

- Call for land and marine conservation apps projects
- Call for next Health & Air Quality Applied Sciences Team
- Disasters adding more risk and resilience

## Missions & Applications

- More Early Adopter events to engage applications communities during mission development. Users prepare for data, learn about new research, and advocate

## Communications

- Applied Sciences is redesigning its website: [appliedsciences.nasa.gov](https://appliedsciences.nasa.gov)

## Western Water

- Applications Office doing user assessments for Rio Grande and Missouri River basins in 2020

## NASA Harvest

- Food Security team advancing uses of Earth observations for humanitarian pursuits, domestic economy, and resilience in food systems



*NASA Administrator Jim Bridenstine addresses the Harvest Outreach and Stakeholder Interaction Day, June 25, 2019 in Washington, D.C. Photo credit: NASA/Aubrey Gemignani*

# Applied Sciences Highlights

## Impact Assessments

- Chances for Earth scientists and economists to work together on projects calculating value and benefits – in societal and economic terms – from uses of Earth observations. Website: [RFF.org/VALUABLES](http://RFF.org/VALUABLES)

## SERVIR

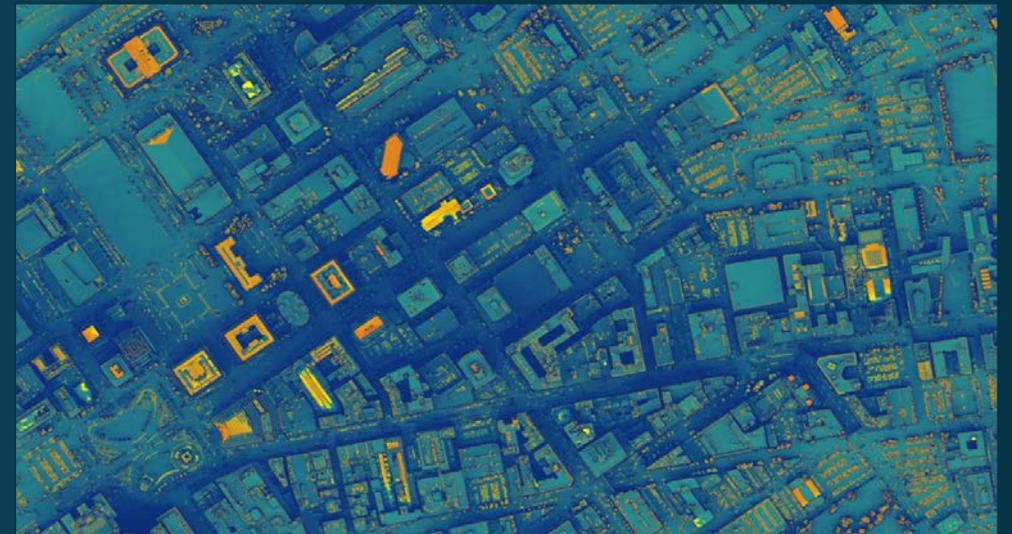
- Third SERVIR Applied Science Team supporting 20 projects across 5 hubs on 3 continents; Amazonia newest hub
- SERVIR Annual Global Exchange in February 2020

## ARSET Trainings

- More than 10 professional-level, hands-on events for 10,000+ people in 130+ nations
- Includes trainings on IMERG for flood and drought hazards, agriculture, air quality
- Most delivered in English and Spanish

## DEVELOP

- Will again conduct 50+ feasibility studies applying Earth observations with local decision making in 35+ U.S. states



*NASA DEVELOP researchers combined aerial and satellite data to calculate the energy potential of rooftop solar panels in downtown Cleveland, helping city managers work toward sustainability goals.*

# Earth Science Technology Program Elements

ESTO manages, on average, 120 active technology development projects. More than 830 projects have completed since 1998.

## Advanced Technology Initiatives: ACT and InVEST

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Advanced Component Technologies (ACT)  
Critical components and subsystems for advanced instruments and observing systems

- 12 projects awarded in 2018
- Solicitations planned in FY20 and FY22
- Average award: \$1.2M (2-3 years)
- Average selection rate: 16.4%

In-Space Validation of Earth Science Technologies (InVEST)

On-orbit technology validation and risk reduction for small instruments and instrument systems.

- 4 projects selected in FY18
- Solicitations planned in FY21 and FY24
- Average award: \$3-5M (3 years)
- Average selection rate: 18.3%

## Instrument Incubator Program (IIP)

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Earth remote sensing instrument development from concept through breadboard and demonstration

- 19 projects awarded in Oct 2019
- Solicitations planned in FY21 and FY23
- Average award: \$4.5M (3 years)
- Average selection rate: 23.2%

## Decadal Incubation

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Maturation of observing systems, instrument technology, and measurement concepts for Planetary Boundary Layer and Surface Topography and Vegetation observables through technology development, modeling/system design, analysis activities, and small-scale pilot demonstrations

- 2 Study teams awarded in FY20
- Solicitation planned in FY21

## Advanced Information Systems Technology (AIST)

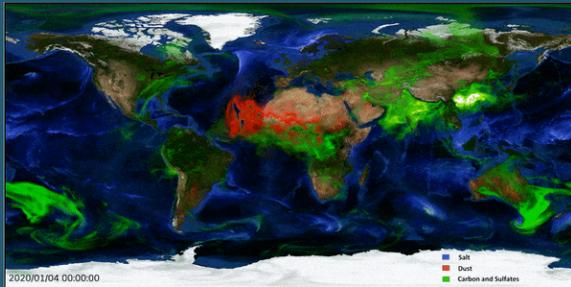
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Innovative on-orbit and ground capabilities for communication, processing, and management of remotely sensed data and the efficient generation of data products

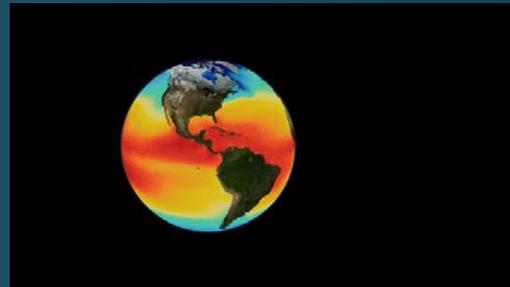
- 22 projects awarded in Sept 2019
- Solicitations planned in FY21 and FY23
- Average award: \$1.2M (2 years)
- Average selection rate: 19.6%

# Examples of Earth Observations From Global to Local Scales

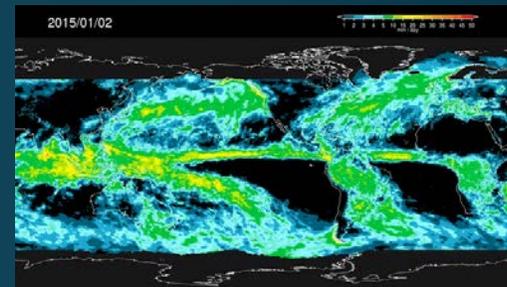
Aerosols



Sea Surface Temperature



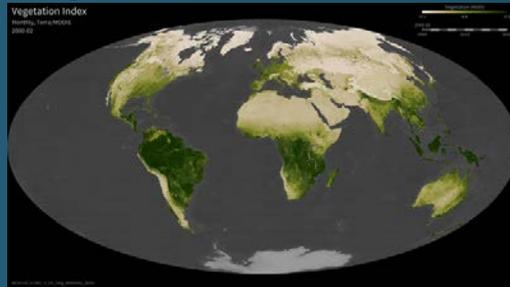
Precipitation



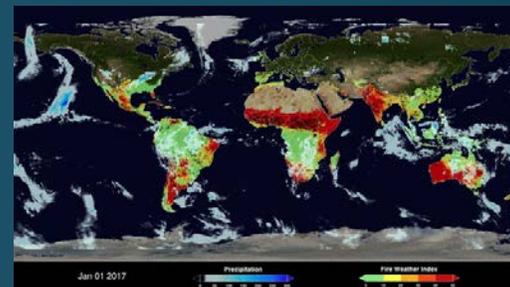
Sea Surface Salinity



Vegetation



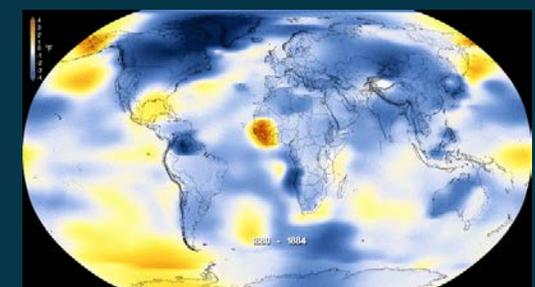
Active Fires



Sea Surface Density



Land Temperature



# NASA EARTH FLEET

OPERATING & FUTURE THROUGH 2023

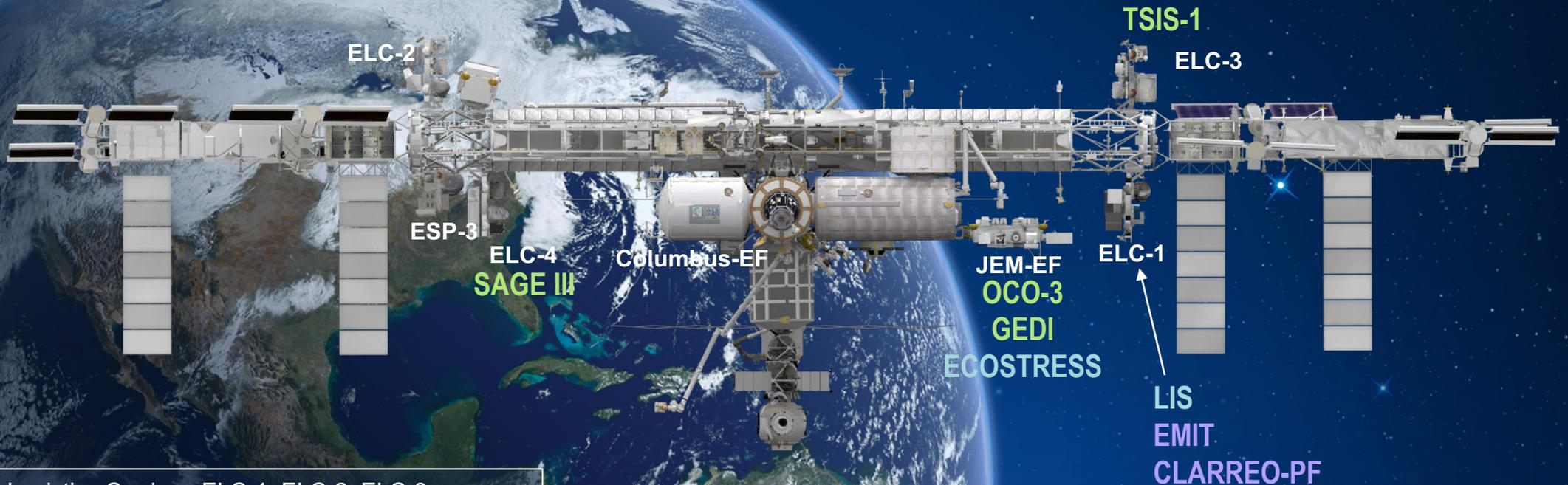


03.31.20

PACE and CLARREO-PF are proposed for termination in the FY21 Budget Request

# INTERNATIONAL SPACE STATION

## EARTH SCIENCE OPERATING MISSIONS

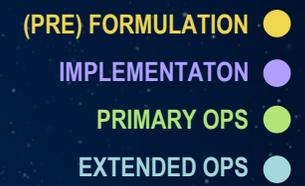


EXPRESS Logistics Carriers: ELC-1, ELC-2, ELC-3  
External Stowage Platforms: ESP-3  
Columbus External Payload Facility: Columbus-EF  
Kibo External Payload Facility: JEM-EF

(PRE) FORMULATION ●  
IMPLEMENTATION ●  
PRIMARY OPS ●  
EXTENDED OPS ●

# NASA EARTH FLEET

INTERNATIONAL COLLABORATIONS



# ESD Partnership Missions in Development



Sentinel-6 Michael Freilich/B  
ABC LRD: 2021 (MF)/2026 (B)  
Ocean Altimetry

Partner: NOAA

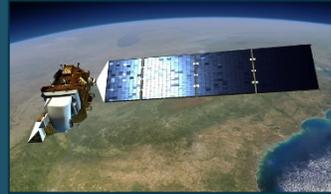
- Science data dissemination
- Ground stations

Partner: ESA

- Spacecraft bus
- Science instruments (Poseidon-4 Altimeter, DORIS, GNSS POD)
- Satellite control center (during LEOP)

Partner: EUMETSAT

- Mission/System coordinator,
- Satellite control center (Ops)
- Science data processing
- Science data dissemination
- Data archiving
- Ground stations



Landsat 9  
ABC LRD: 2021  
Land Imaging

Partner: USGS

- Ground system
- Mission Operations



SWOT  
ABC LDR: 2022  
Sea surface & freshwater  
height, slope

Partner: CNES (France)

- Spacecraft bus
- Science instruments (Nadir Altimeter, DORIS, KaRIn RF Unit subsystem)

Partner: CSA (Canada)

- Klystrons for KaRIn

Partner: UKSA (UK)

- Duplexers for KaRIn



NISAR  
ABC LDR: 2022  
Cryosphere,  
ecosystems, deformation

Partner: ISRO (India)

- S-Band SAR
- Spacecraft bus
- Spacecraft operations
- Science Downlink
- S-Band processing



PACE  
ABC LDR: 2024  
Ocean Color (ocean,  
aerosols, clouds),  
Polarimetry

Partner: SRON  
(Netherlands)

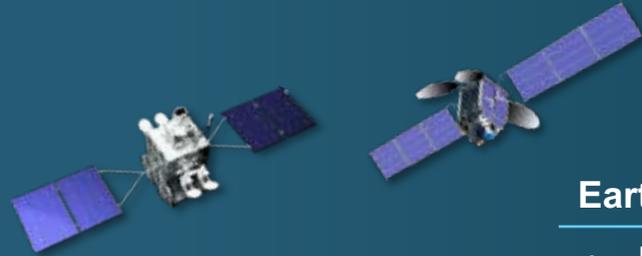
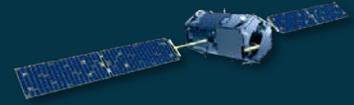
- SPEXOne polarimeter

Partner: UMBC

- HARP-2 polarimeter

ABC: Agency Baseline Commitment  
LRD: Launch Readiness Date

# 2017 Decadal Survey Progress Highlights



## Earth Venture-Continuity (in ESSP)

- DS recommended new Earth Venture Continuity Measurement strand (\$150M full mission cost cap)
- In December 2018, ESD released EVC-1 solicitation targeted for radiation budget measurements
- In February 2020, Libera (LASP) selected

## Earth Science Explorers

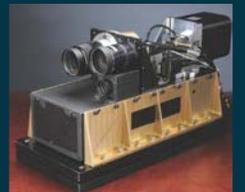
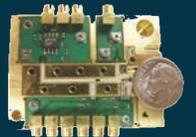
- DS recommended a new competed Explorer flight line with \$350M cost constraint
- Implement 3 of 7 Targeted Observables
- Framework for program established
- **Implementation on hold pending budget developments**

## Decadal Incubation (in ESTO)

- DS calls for Incubation Program to mature specific technologies for important — but presently immature — measurements (preparation for next Decadal)
- Solicitations for Study Teams (PBL and STV) released on March 14, 2019; selections made on December 3, 2019
- Decadal Incubation initiated and funded

## Designated Observables

- DS identified 5 Designated Observables (DOs) for mandatory acquisition
- In 2018 ESD initiated 4 multi-center DO studies, continued in 2019:
  - Combined: Aerosols-Clouds, Convection & Precipitation
  - Mass Change
  - Surface Biology & Geology
  - Surface Deformation & Change
- First DO Architecture Down Select by the end of Calendar Year 2020 to enter pre-Phase A
- FY21 Budget Request fully funds a DO project to be initiated in FY21, and initiates two more in FY23, and FY26



# ESSP Program: Earth Venture Overview

The ESSP portfolio Earth Venture Class element has four strands:

## EV Suborbital (EVS)

- Suborbital/airborne investigations
- 5 year duration
- Cost capped at \$150M per solicitation
- Solicited every ~4 years

## EV Mission (EVM)

- Small complete missions
- 5 years to launch
- Class-D\* allowable
- Small-sat or stand-alone payload as par of larger missions
- Cost capped at \$180M
- Solicited every ~4 years

## EV Instrument (EVI)

- Spaceborne instruments for flight on Missions of Opportunity (MoO)
- $\leq 5$  years for development
- Class-C\* or Class-D\* allowable
- \$30M-\$100M total cost for development and operations
- Solicited every ~3 years

## EV Continuity (EVC)

- Spaceborne instrument or missions
- Cost capped at \$150M per solicitation
- Solicited every ~3 years
- Specifically seeks to lower the cost for long-term acquisition of key “continuity” observations, rewarding innovation in mission-to-mission cost reduction through technology infusion, programmatic efficiency, and/or other means

\*Four risk levels or classifications (A, B, C and D) have been characterized in the NPR 8705.4 Risk Classification for NASA Payloads by considering factors such as criticality to the Agency Strategic Plan, national significance, complexity, mission lifetime, cost and other relevant factors. Class C is medium priority, medium national significance, medium to low complexity and cost while Class D is considered low in all these aspects

# Earth Science Division's Venture Opportunities

Mission	Mission Type	Release Date	Selection Date	Major Milestone
<b>EVS-1</b> (EV-1) (AirMoss, ATTREX, CARVE, DISCOVER-AQ, HS3)	5 Suborbital Airborne Campaigns	2009	2010	Completed KDP-F
<b>EVM-1</b> (CYGNSS)	Class D SmallSat Constellation	2011	2012	Launched Dec. 2016
<b>EVI-1</b> (TEMPO)	Class C Geostationary Hosted Instrument	2011	2012	Delivered to storage Dec. 2018
<b>EVI-2</b> (ECOSTRESS & GEDI)	Class C & Class D ISS-hosted Instruments	2013	2014	Launched June & Dec. 2018
<b>EVS-2</b> (ACT-America, ATOM, NAAMES, ORACLES, OMG, CORAL)	6 Suborbital Airborne Campaigns	2013	2014	CORAL and NAAMES Completed KDP-F
<b>EVI-3</b> (MAIA & TROPICS)	Class C LEO Hosted Instrument & Class D CubeSat Constellation	2015	2016	Delivery NLT 2021
<b>EVM-2</b> (GeoCarb)	Class D Geostationary Hosted Instrument	2015	2016	Launch ~2021
<b>EVI-4</b> (EMIT & PREFIRE)	Class C ISS-hosted Instrument & Class D Twin CubeSats	2016	2018	Delivery NLT 2021
<b>EVS-3</b> (ACTIVATE, DCOTTS, IMPACTS, Delta-X, SMODE)	5 Suborbital Airborne Campaigns	2017	2018	Passed Initial Confirmation Review, 2 began deployments
<b>EVI-5</b> (GLIMR)	Class C Geostationary Hosted Instrument	2018	2019	Delivery NLT 2024
<b>EVC-1 (Libera)</b>	Class C JPSS-Hosted Radiation Budget Instrument	2018	2020	Delivery NLT 2025
<b>EVM-3</b>	Full Orbital	2020	2021	Launch ~2025
<b>EVI-6</b>	Instrument Only	2020	2021	Delivery NLT 2026
<b>EVS-4</b>	Suborbital Airborne Campaigns	2022	2023	N/A
<b>EVC-2</b>	Continuity Measurements	2022	2023	Delivery NLT 2027
<b>EVM-4</b>	Full Orbital	2024	2025	Launch ~2029
<b>EVI-7</b>	Instrument Only	2023	2024	Delivery NLT 2028
<b>EVC-3</b>	Continuity Measurements	2025	2026	Delivery NLT 2030
<b>EVS-5</b>	Suborbital Airborne Campaigns	2026	2027	N/A

**EVS**  
Sustained sub-orbital investigations (~4 years)

**EVM**  
Complete, self-contained, small missions (~4 years)

**EVI**  
Full function, facility-class instruments Missions of Opportunity (MoO) (~3 years)

**EVC**  
Complete missions or hosted instruments targeting "continuity" measurements (~3 years)

Open solicitation - In Review

Completed solicitation

# Commercial SmallSat Data Acquisition

- NASA recognizes the growing importance and potential of new and unique Earth observation data products provided by the commercial sector and believes that a vibrant commercial Earth observation ecosystem of open and commercial data from this growing market segment benefits NASA and its partners.
- Program Objectives:
  - Continuous and repeatable process to onramp, evaluate and purchase data from commercial satellites to advance Earth Science research and applications
- Status:
  - Request for Information (RFI) for a pilot released in Winter 2017 → contracts awarded to Planet, DigitalGlobe (Maxar), and Spire Global in October 2018 → PI evaluations completed January 2020 → Report released in April 2020
  - An independent assessment of calibration and geolocation conducted
  - Evaluations completed in January 2020 → Longer-term contracts for sustained scientific use
- Future:
  - Each 12-18 months, an RFI will be issued
  - All contracts will contain a *standardized scientific use license* to minimize the effort by NASA and confusion by users on how data can be used
  - Data from selected vendors will be evaluated by teams of Principal Investigators (PIs) *selected through the annual Research Opportunities in Space and Earth Science (ROSES) solicitation*
  - All *data purchased* by NASA will be made *available to NASA funded researchers* with a uniform scientific use license.
  - RFI for second on-ramp released September 2019

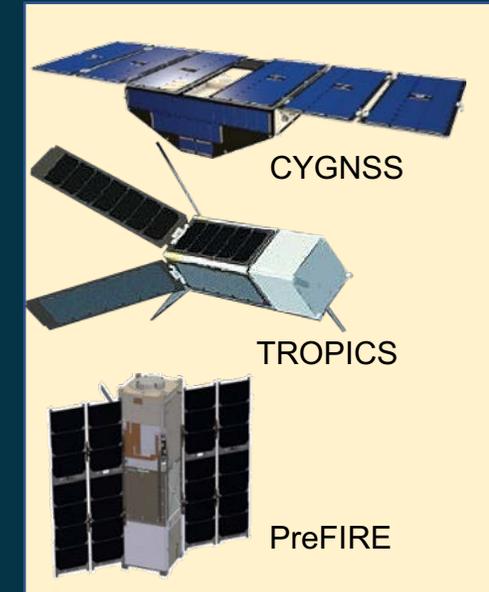
# Commercial SmallSat Data Acquisition Program: Update

- Completed Commercial SmallSat Data Acquisition Program Pilot Evaluations (known as Private-Sector Small Constellation Satellite Data Product Pilot) early 2020.
  - NASA ESD identified 41 existing projects to evaluate data from DigitalGlobe Inc. (now known as Maxar), Planet Labs Inc., and Spire Global.
- Results from pilot program indicated data are of sufficient quality for continued access.
  - NASA HQ published a summary report from the individual project reports for each vendor.
- Pilot program has transitioned to the Commercial Smallsat Data Acquisition Program
  - Entered into a long-term contract with Planet for unlimited access to PlanetScope data for NASA research activities.
- Next Request for Information (RFI) for on-ramp of new commercial vendors will be released September 2020.
- For more information, please visit Commercial SmallSat Data Acquisition Program at <https://earthdata.nasa.gov/csdap>.

# CubeSats, SmallSats, Constellations and Hosted Payloads

## Small Satellite Solutions

- **Venture Class Launch Services:** Investment in new, low-cost (<\$15M/launch), commercial launch vehicles capable of orbiting small payloads to LEO – science control of launch schedule and orbits
- **CYGNSS (Cyclone Global Navigation Satellite System):** Homogeneous tropical constellation of 8 micro-satellites using reflected GPS to measure surface winds/air-sea interactions, especially valuable/unique in the precipitation-dominated, dynamic, eyewalls of tropical storms and hurricanes – frequent tropical sampling from 1 orbit plane
- **TROPICS (Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of SmallSats):** Homogeneous tropical constellation of 6 CubeSats to measure atmospheric profiles in storms/hurricanes – frequent sampling from 2-3 orbit planes
- **PreFIRE:** 2-satellite CubeSat constellation to measure Far-IR emissions primarily from the Arctic
- **In-Space Validation of Earth Science Technologies (InVEST):** On-orbit CubeSat-based technology validation and risk reduction that could not otherwise be fully tested using ground/airborne systems; leading to miniaturized science payload development
  - CSIM/CTIM provide a new SmallSat architecture approach for future TSI and SSI continuity measurements
  - SLI-T instrument development for Landsat-10, future SLI consideration (6 projects ongoing)
  - Tempest-D produced exceptional precipitation measurements of Hurricane Dorian



## Hosted Payload solutions

- **TEMPO** (instrument on NASA-arranged geo comsat) - MAXAR
- **MAIA** (instrument on NASA-arranged LEO satellite) – General Atomics, Electromagnetics Systems Group
- **GeoCarb** (instrument on PI-arranged geo comsat)
- GLIMR (NASA to provide “access to space”).

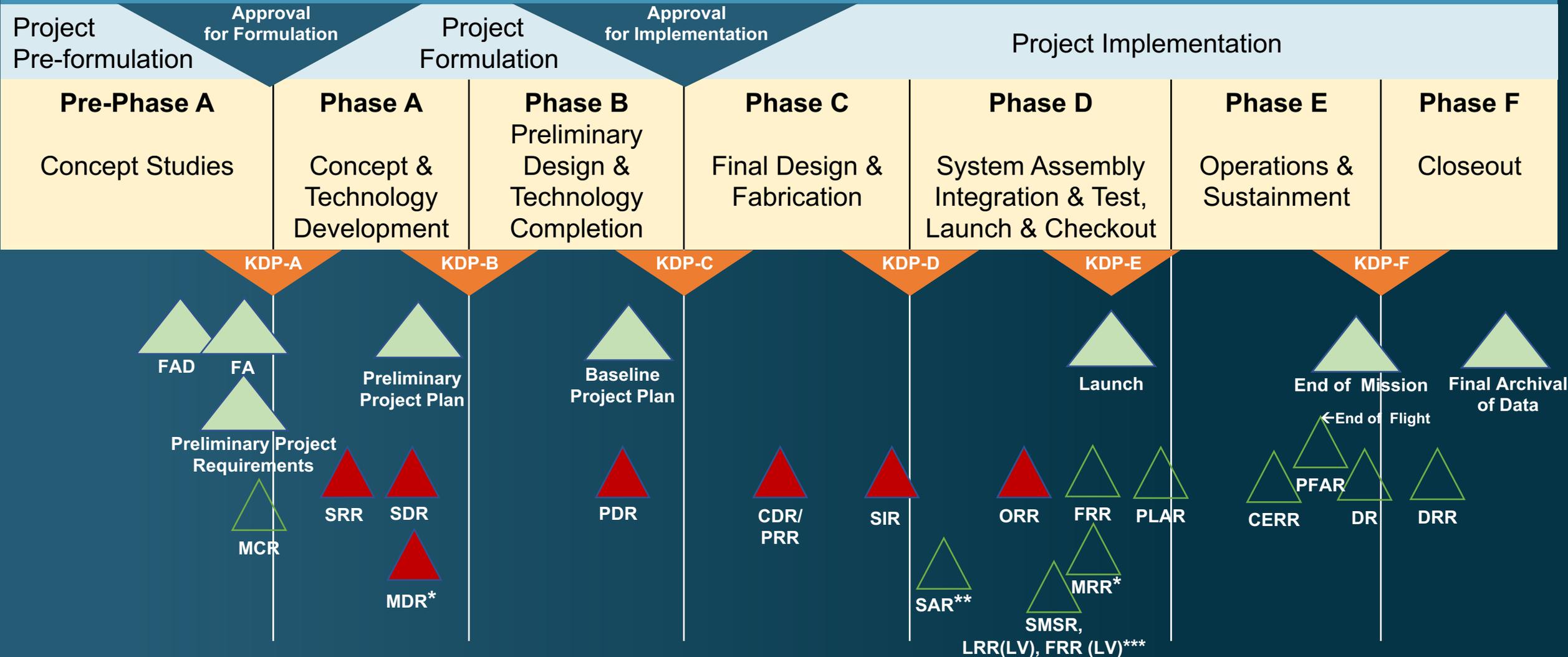


The background of the slide is a composite of two cosmic images. The top half features a dark blue and black space filled with numerous small white stars and a prominent, bright blue nebula on the right side. The bottom half shows a similar starry field but with a warm, orange-to-yellow glow on the left side, transitioning into a greenish-blue glow on the right. The text is centered in a dark blue horizontal band that spans the width of the image.

# Mission Life Cycle and Upcoming Launches

# NASA Life-Cycle Phases

## Project Life Cycle



KDP Key Decision Point | ▲ Reviews that require Standing Review Boards (SRBs)  
 \* For Robotic Missions SRR and MDR may be combined | \*\* For Human Space Flight | \*\*\* Other Reviews



# Projects by Life Cycle Phase

Project Life Cycle						
Project Pre-formulation	Project Formulation		Project Implementation		Project Operations	Project Closeout
	Approval (for implementation)					
Pre-Phase A	Phase A	Phase B	Phase C	Phase D	Phase E	Phase F
Libera SLI	GLIMR TSIS-2	PREFIRE	GeoCarb EMIT CLARREO PF MAIA NISAR PACE SWOT	Landsat 9 Sentinel-6 Michael Freilich TROPICS* TEMPO*	<u>OCO-3</u> <u>GEDI</u> <u>ICESat-2</u> <u>GRACE FO</u> <u>ECOSTRESS</u> OMPS-Limb <u>SAGE III – ISS</u> <u>TSIS-1</u> Aqua Aura CALIPSO CloudSat CYGNSS DSCOVR GPM Landsat 7 Landsat 8 LIS on ISS OCO-2 SMAP Suomi NPP Terra	GRACE OSTM/Jason-2 QuikSCAT RapidScat TCTE SORCE
Designated Observable Studies						
ACCP SBG SDC MC						

Underlined denotes Prime Ops  
\*In Storage

# 2019 Launches



- **OCO-3 instrument launched to ISS May 4**
- Investigating the distribution of carbon dioxide as it relates to growing urban populations and changing patterns of fossil fuel combustion



- **HARP CubeSat launched to ISS on Nov. 2; deployment expected in February 2020**
- Will collect data about clouds and aerosols and their impact on weather, climate and air quality



- **CIRiS-BATC CubeSat launched to ISS Dec. 5; deployment expected in February 2020**
- Will collect, process and calibrate infrared images of Earth's temperature for the first time from a SmallSat

# ESD Upcoming Launches

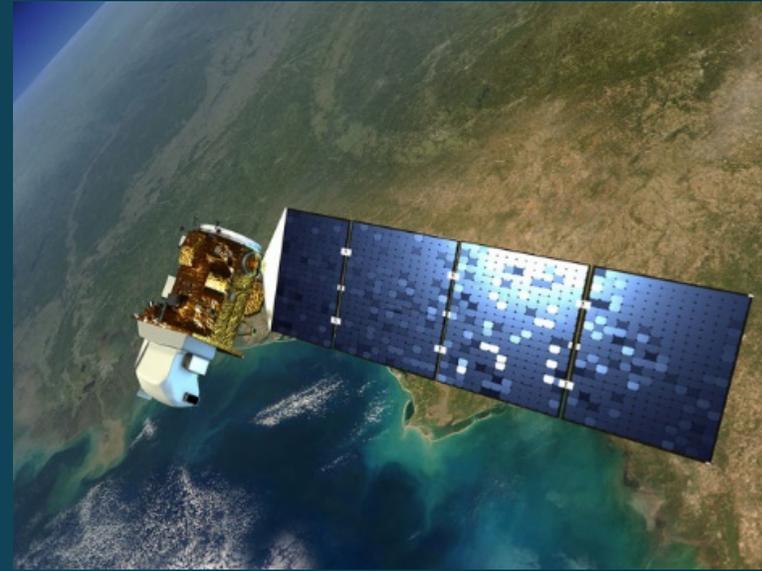
## Sentinel-6 Michael Freilich



November 2020

Provide ongoing measurements of global sea level rise, and support operational oceanography, improving forecasts of ocean currents as well as wind and wave conditions. *(With NOAA, ESA, EUMETSAT)*

## Landsat 9



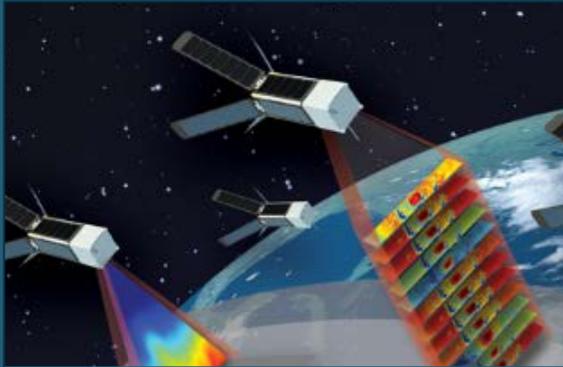
June 2021

Designed and operated to repeatedly observe the global land surface at a moderate scale that shows both natural and human-induced change. *(With USGS)*

# Upcoming Launches

Dates May Change in Response to COVID-19

## TROPICS



- 2022
- Monitor tropical cyclones with six CubeSats in three orbital planes using scanning microwave radiometers to measure temperature, humidity precipitation and cloud properties

## MAIA



- 2022
- Make radiometric and polarimetric measurements with twin-camera instruments to characterize size, composition and quantity of particulate matter in air pollution

## PACE



- 2022
- Advance the assessment of ocean health by measuring the distribution of phytoplankton
- Provide detailed information about the atmosphere and ocean

## TEMPO

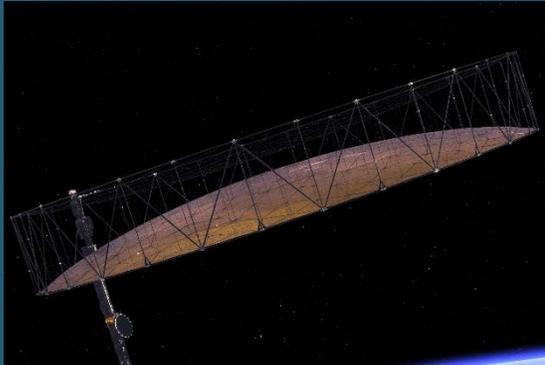


- 2022
- First space-based instrument to monitor major air pollutants across North American continent every daylight hour at high-spatial resolution

# Upcoming Launches

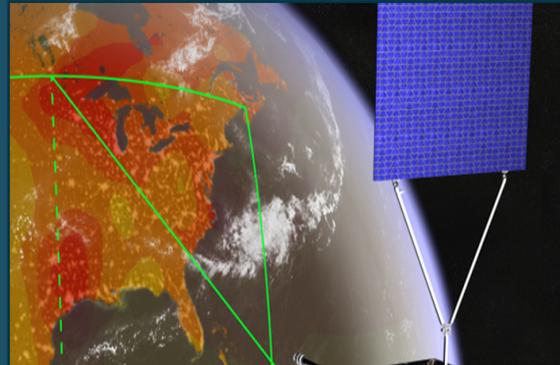
Dates May Change in Response to COVID-19

## NISAR



- 2022
- Systematic measurements of highly spatial and temporally complex processes ranging from ecosystem disturbances, to ice sheet collapse and natural hazards including earthquakes, volcanoes, and landslides (With ISRO)

## GeoCarb



- 2022
- Advance understanding of global carbon cycle by mapping concentrations of key carbon gasses from geostationary orbit over the Americas

## PREFIRE



- 2022
- Two 3U CubeSats to probe a little-studied portion of the radiant energy emitted by Earth for clues about Arctic warming, sea ice loss and ice-sheet melting

## SWOT



- 2022
- Observe fine details of ocean's surface topography and measure how water bodies change over time.
- With CNES, CSA, UK Space Agency

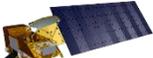
# Timeline of Current and Future Earth Science Missions

## NASA Earth Science Focus Areas

- Atmospheric Composition ■
- Carbon Cycle and Ecosystems ■
- Climate Variability and Change ■
- Earth Surface and Interior ■
- Water and Energy Cycle ■
- Weather and Atmospheric Dynamics ■

2002

**Aqua**




2015

**DSCOVR**  
**EPIC** ■  
**NISTAR** ■  
**SMAP**





2017

**JPSS-1**  
**\*OMPS-L** ■  
**CERES** ■ ■  
**ISS**  
**SAGE III** ■  
**TSIS-1** ■  
**LIS** ■





2006

**CloudSat**  
**CALIPSO**





2013

**\*Landsat 8**



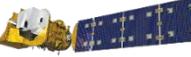

2019

**ISS**  
**OCO-3** ■ ■




2021

**Landsat 9**  
**ISS**  
**EMIT**





2023

**TSIS-2**  
**ISS**  
**CLARREO-PF**





2025

**Sentinel 6B**




2027

**JPSS-3**  
**Libera** ■  
**\*OMPS-L** ■




2004

**Aura**




2014

**OCO-2** ■ ■  
**GPM** ■ ■ ■





2018

**ICESat-2**  
**GRACE-FO**  
**ISS**  
**GEDI** ■ ■  
**ECOSTRESS** ■






2020

**Sentinel-6**  
**Michael Freilich**




2022

**NISAR** ■ ■ ■ ■  
**SWOT** ■ ■ ■  
**MAIA** ■  
**TROPICS** ■ ■  
**GeoCarb** ■ ■  
**TEMPO** ■  
**JPSS-2**  
**\*OMPS-L** ■  
**CERES** ■ ■  
**PREFIRE** ■ ■










2024

**PACE**




2026

**GLIMR**




2031

**JPSS-4**  
**\*OMPS-L** ■




*\*Operations not funded by ESD*

The background of the slide is a composite image of space. The top half features a dark blue and black field with a prominent blue nebula on the right side and several bright, multi-pointed stars. The bottom half shows a similar field but with a large, glowing orange and yellow nebula on the left side, transitioning into a greenish-blue field on the right. The text is centered in a dark blue horizontal band that spans the width of the image.

# Mission Profiles

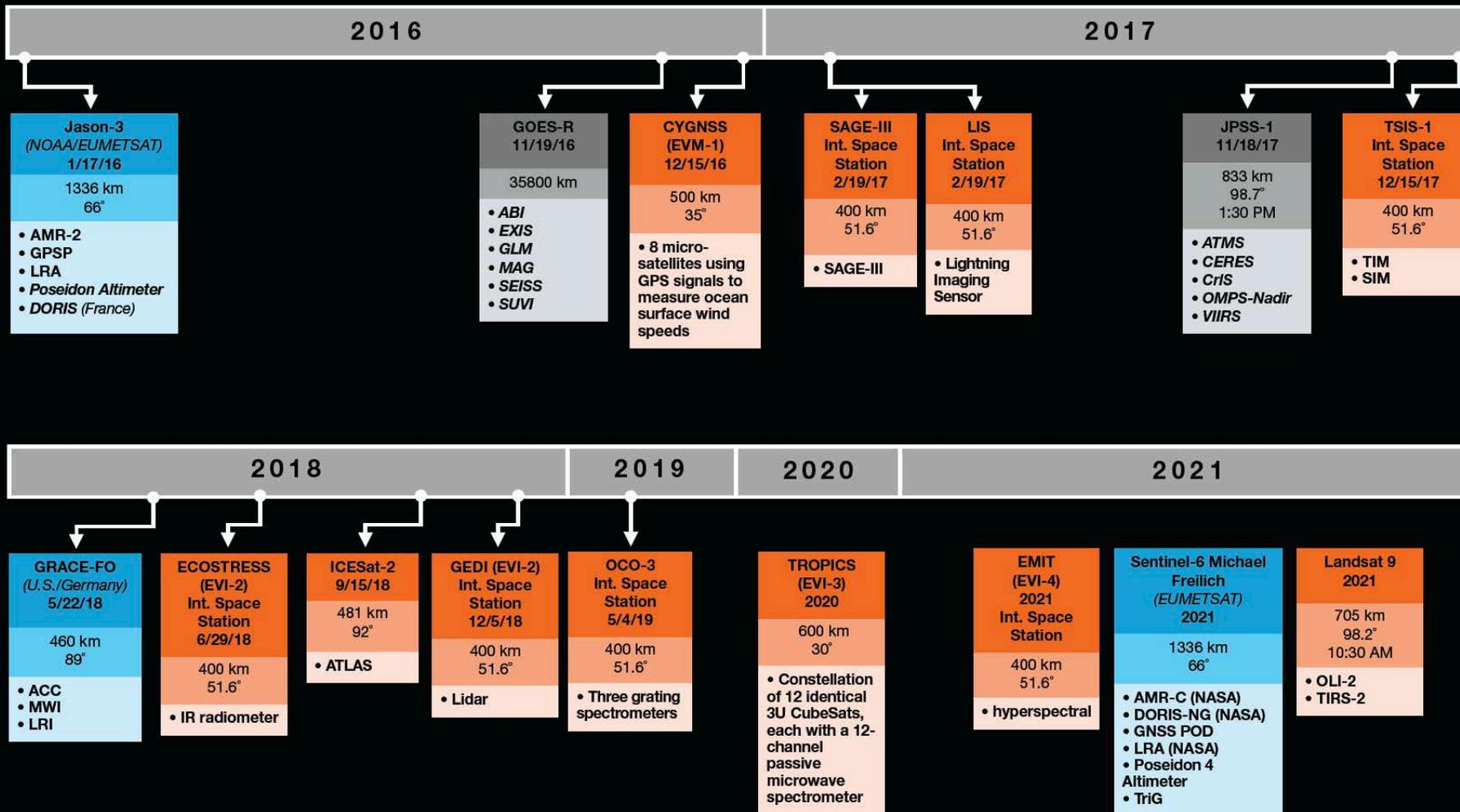
[eosps.nasa.gov/files/mission\\_profile.pdf](https://eosps.nasa.gov/files/mission_profile.pdf)

# Earth Science Mission Profile 2016 - 2021

Revised:  
April 3, 2020



Click the mission name below for a detailed description.



Spacecraft not provided by NASA    Other agency spacecraft of interest

Items in italics not funded by NASA.

Future mission launch dates indicate agency baseline commitment (ABC) schedule confidence levels.



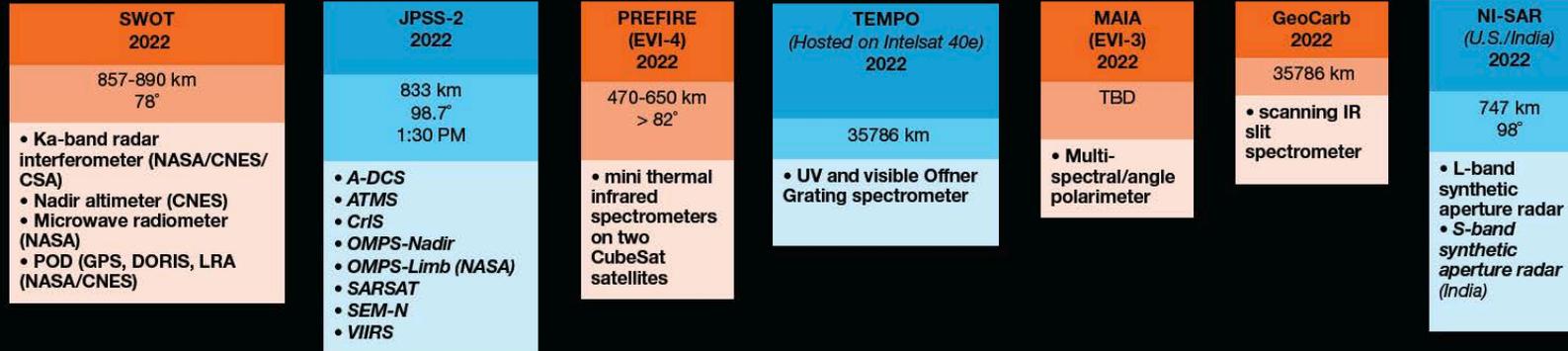
# Earth Science Mission Profile 2022 - 2031

Revised:  
April 3, 2020



Click the mission name below for a detailed description.

## 2022



## 2023

## 2024

## 2025

## 2026

## 2031



Spacecraft not provided by NASA    Other agency spacecraft of interest

Items in italics not funded by NASA.

Future mission launch dates indicate agency baseline commitment (ABC) schedule confidence levels.



The background of the slide is a composite of two cosmic images. The top half features a dark blue and black space filled with numerous small, bright stars and a prominent, glowing blue nebula on the right side. The bottom half shows a similar starry field but with a warm, orange-to-yellow glow on the left side, transitioning into a greenish-blue glow on the right. The text 'Current Operating Missions' is centered in a white, sans-serif font across the dark blue horizontal band that separates the two images.

# Current Operating Missions

# Landsat 7

Launched: April 15, 1999 • Status: Extended Operations (Phase E)

**Mission Science Objectives:** Extend the 40+ years of Landsat land surface observations to study, predict, and understand the consequences of land surface dynamics. It has a single payload, the Enhanced Thematic Mapper Plus (ETM+). ETM+ is an eight-band multispectral scanning radiometer capable of providing high-resolution image information of the Earth's surface. It detects spectrally-filtered radiation at visible, near-infrared, short-wave, and thermal infrared frequency bands from the sun-lit Earth. Nominal ground sample distances or "pixel" sizes are 15 meters in a single panchromatic band; 30 meters in 6 visible, near-wave and short-wave infrared bands; and 60 meters in the thermal infrared band.

## Key Science Products:

- Moderate resolution maps of land cover/land use change over multiple decades including deforestation, agricultural extensification and urbanization.
- Documentation of ecosystem fragmentation and connectivity.
- Identification and quantification of regional to continental scale sources and sinks of carbon.

**Mission Description:** S/C: Landsat 6 bus built by Lockheed Martin Missiles and Space (LMMS)

**Instrument:** Enhanced Thematic Mapper Plus (ETM+)

**Mass:** 2200kg

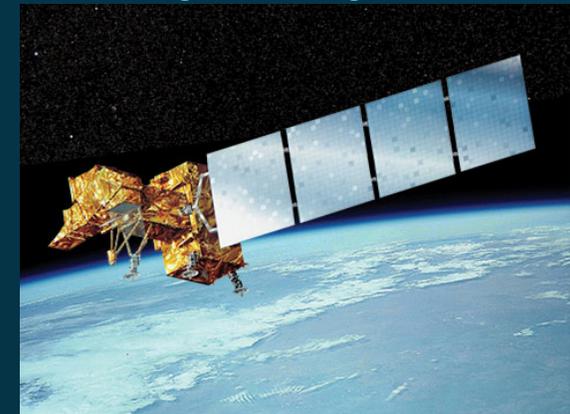
**Launch Vehicle:** McDonnell Douglas Delta II

**Orbit:** ~705km, Sun-synch, 98.22° inclination, ~9:45 AM MLTDN (drifting)

**Prime Mission Lifetime:** 5 years

**Mission Project Management:** NASA/USGS

[landsat.gsfc.nasa.gov/landsat-7](https://landsat.gsfc.nasa.gov/landsat-7)



# Terra

Launched: Dec. 18, 1999 • Status: Extended Operations (Phase E)

## Mission Science Objectives:

- Provide comprehensive global measurements of Earth's atmosphere, land, cryosphere and oceans for making discoveries of Earth as a system.
- Build calibrated datasets that extend and improve past satellite records.
- Distinguish impacts of human activity versus natural variability.
- Measure effects of clouds, aerosols and greenhouse gases on Earth's total energy balance.
- Provide better estimates of global terrestrial and marine productivity.
- Improve medium- and long-range weather forecasts, and climate prediction.
- Enable improved methods of disaster prediction and mitigation.

**Mission Description:** S/C: Custom (Lockheed Martin)

## Instruments:

- ASTER: Advanced Spaceborne Thermal Emission Radiometer (METI)
- CERES: Clouds and Earth's Radiant Energy System (LaRC)
- MISR: Multiangle Imaging SpectroRadiometer (JPL)
- MODIS: MODerate Resolution Imaging Spectroradiometer (GSFC)
- MOPITT: Measurement Of Pollution In The Troposphere (CSA)

**Mass:** 4864 kg

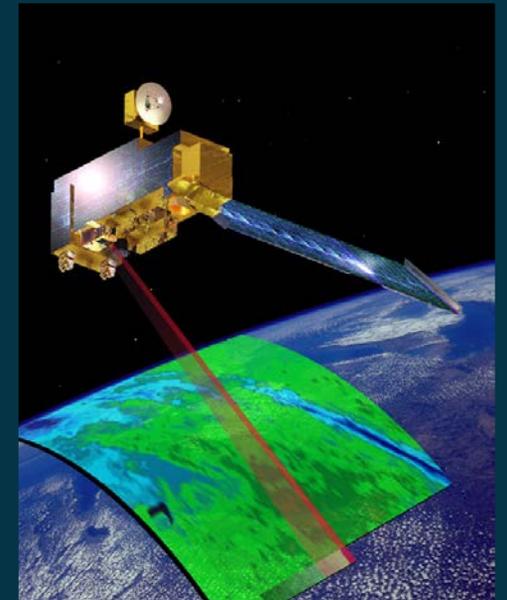
**Launch Vehicle:** Atlas IIAS

**Orbit:** 705 km, Sun-synch, 98.22° inclination, ~10:30 AM LT DN

**Prime Mission Lifetime:** 6 years

**Mission Project Management:** GSFC

[terra.nasa.gov](http://terra.nasa.gov)



# Aqua

Launched: May 4, 2002 • Status: Extended Operations (Phase E)

## Mission Science Objectives:

- Advance understanding of the factors that control the global water and energy cycles.
- Assess natural and anthropogenic climate forcings (especially by greenhouse gases and aerosols), climate variations and feedbacks.
- Examine the processes involved in atmosphere-surface interactions.
- Address issues related to diurnal cycles in cloud properties and to indirect effects of aerosols on clouds.
- Produce an integrated climate data record for detecting decadal changes in Earth's radiation budget from the surface to the top of the atmosphere (TOA).
- Contribute to improved operational weather prediction and other practical uses of Earth science data.

**Mission Description:** S/C: Common Spacecraft (Northrop Grumman)

## Instruments:

- Sounding Unit (AMSU), Humidity Sounder for Brazil (HSB); not operating
- Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) (JAXA); not operating
- Clouds and the Earth's Radiant Energy System (CERES) (LaRC), Moderate Resolution Imaging
- Spectroradiometer (MODIS)(GSFC)

**Mass:** 2850 kg

**Launch Vehicle:** Delta II 7920-10L

**Orbit:** 705 km, Sun-synch, 98.22° inclination, 1:30 PM LTAN

**Prime Mission Lifetime:** 6 years

**Mission Project Management:** GSFC

[aqua.nasa.gov](http://aqua.nasa.gov)



# Aura

Launched: July 15, 2004 • Status: Extended Operations (Phase E)

## Mission Science Objectives:

- Monitoring the stratospheric ozone column, as part of the long-term record of stratospheric ozone depletion.
- Profile measurements of stratospheric ozone and chemical constituents controlling ozone loss.
- Dynamics of the upper troposphere and stratosphere.
- Measurement of tropospheric constituents that control air quality.
- Measurement of aerosol and cloud properties.
- Quantify changes in atmospheric constituents associated with the climate change.

**Mission Description:** S/C: Common Spacecraft (Northrop Grumman)

## Instruments:

- Microwave Limb Sounder (MLS) (JPL)
- Ozone Monitoring Instrument (OMI) (NSO/FNMI)
- High Resolution Dynamics Limb Sounder (HIRDLS) (RAL/UCAR); not operating
- Tropospheric Emission Spectrometer (TES) (JPL); not operating

**Mass:** 1765 kg

**Launch Vehicle:** Delta II 7920-10L

**Orbit:** 705 km, Sun-synch, 98.22° inclination, ~1:30 PM LTAN

**Prime Mission Lifetime:** 6 years

**Mission Project Management:** GSFC

[aura.gsfc.nasa.gov](http://aura.gsfc.nasa.gov)



# Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)

Launched: April 28, 2006 • Status: Extended Operations (Phase E)

## Mission Science Objectives:

- Produce a global uniformly-calibrated aerosol and cloud data set.
- Identify cloud ice-water phase and aerosol type.
- Improve understanding of aerosol and cloud effects on Earth's radiation budget.
- Improve aerosol and cloud information from other A-train sensors.
- Improve predictive capability for climate, weather, air quality.

**Mission Description:** S/C: PROTEUS (CNES)

## Instruments:

- Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) (LaRC)
- Infrared Imaging Radiometer (IIR) (CNES)
- Wide Field-of-view Camera (WFC) (LaRC)

**Mass:** 635 kg

**Launch Vehicle:** Delta II 7420-10C

**Orbit:** ~688 km (-1m/day), ~98.22° inclination (drifting),  
~1:58 PM LTAN (drifting)

**Prime Mission Lifetime:** 3 years

**Principal Investigator:** David Winker/LaRC

**Mission Project Management:** LaRC

[calipso.larc.nasa.gov](http://calipso.larc.nasa.gov)



# Suomi National Polar-orbiting Partnership (Suomi NPP)

Launched: Oct. 28, 2011 • Status: Extended Operations (Phase E)

## Mission Science Objectives:

- **Bridge Mission:** Provide NASA with new observations to continue the time series for a selected group of global change observations initiated by the Earth Observing System (EOS) Terra, Aqua, and Aura missions.
- **Risk Reduction:** Provide the operational community with pre-operational risk reduction demonstration and validation for selected JPSS instruments, and algorithms, as well as ground processing.

## Key Science Products:

- **OMPS:** Atmospheric ozone.
- **VIIRS:** Land cover and vegetation biophysical properties; Sea and land surface temperatures, Clouds and aerosols; Ocean biological and biogeochemical properties.
- **CrIS/ATMS:** Temperature and moisture profiles in the atmosphere
- **CERES:** Earth radiation budget and TOA fluxes

**Mission Description:** BCP 2000, Ball Aerospace

## Instruments:

- Visible/Infrared Imaging Radiometer Suite (VIIRS) (Raytheon-IPO provided)
- Cross-track Infrared Sounder (CrIS), (ITT-IPO Provided)
- Ozone Mapping and Profiling Suite (OMPS), (Ball Aerospace-IPO Provided)
- Advanced Technology Microwave Sounder (ATMS), Northrop Grumman
- Clouds and the Earth's Radiant Energy System (CERES), Northrop Grumman

**Mass:** 2270 kg

**Launch Vehicle:** Delta II 7920

**Orbit:** 824 km Sun-sync, ~98° inclination, ~1:30pm crossing time

**Prime Mission Lifetime:** 5 years

**Mission Project Management:** GSFC

[nasa.gov/mission\\_pages/NPP/  
main/index.html](http://nasa.gov/mission_pages/NPP/main/index.html)



# Landsat 8/Landsat Data Continuity Mission (LDCM)

Launched: Feb. 11, 2013 • Status: Extended Operations (Phase E)

## Mission Science Objective:

- Extend the 40+ years of Landsat land surface observations to study, predict, and understand the consequences of land surface dynamics.

## Key Science Products:

- Moderate resolution maps of land cover/land use change over multiple decades including deforestation, agricultural extensification and urbanization.
- Documentation of ecosystem fragmentation and connectivity.
- Identification and quantification of regional to continental scale sources and sinks of carbon.
- The first high-resolution image mosaic of Antarctica for the International Polar Year.

**Mission Description:** S/C: LEOStar-3 (Northrop Grumman)

## Instruments:

- Operational Land Imager (OLI) panchromatic, 15m GSD multi-spectral, 30m GSD, 185km swath (Ball)
- Thermal Infrared Sensor (TIRS), 120m GSD (GSFC)

**Mass:** 2668 kg

**Launch Vehicle:** Atlas V 401

**Orbit:** 705 km, Sun-synch, ~98.22° inclination, ~10:15 am LTDN

**Prime Mission Lifetime:** 5 years

**Mission Project Management:** GSFC

[landsat.gsfc.nasa.gov/landsat-8/](https://landsat.gsfc.nasa.gov/landsat-8/)



# Global Precipitation Measurement (GPM)

Launched: Feb. 27, 2014 • Status: Extended Operations (Phase E)

## Mission Science Objective:

- Initiates the measurement of global precipitation, providing uniformly calibrated measurements every 3 hours for scientific research and societal applications.

## Key Science Products:

- Precipitation intensity and distribution, instantaneous precipitation rate, 3-hourly precipitation rate.
- Daily and monthly precipitation accumulation, latent heat distribution and outreach precipitation products.

**Mission Description:** S/C: In-house (GSFC)

## Instruments:

- Dual-frequency Precipitation Radar (DPR) (JAXA)
- GPM Microwave Imager (GMI) (Ball)

**Mass:** 3304 kg

**Launch Vehicle:** H-IIA 202A (JAXA)

**Orbit:** 65° inclination, 407 km

**Prime Mission Lifetime:** 3 years

**Mission Project Management:** GSFC

[nasa.gov/mission\\_pages/GPM/main/index.html](https://nasa.gov/mission_pages/GPM/main/index.html)



# Orbiting Carbon Observatory-2 (OCO-2)

Launched: July 2, 2014 • Status: Extended Operations (Phase E)

## Mission Science Objective:

- Collect space-based global measurements of atmospheric CO<sub>2</sub> with the precision, resolution, and coverage needed to characterize its sources and sinks on regional scales and quantify their variability over the seasonal cycle.

## Key Science Products:

- Estimates of the column-averaged CO<sub>2</sub> dry air mole fraction (XCO<sub>2</sub>) on regional scales ( $\geq 1000$  km), collected in cloud-free scenes over  $\geq 80\%$  of range of latitudes on the sunlit hemisphere at monthly intervals for 2 years.

**Mission Description:** S/C: LEOStar-2 (Northrop Grumman)

## Instrument:

- 3-Channel Imaging Grating Spectrometer (JPL/Hamilton Sundstrand)

**Mass:** 457 kg

**Launch Vehicle:** Delta II 7320

**Orbit:** 705km, Sun-synch, 98.2° inclination, ~1:26 PM LTAN

**Prime Mission Lifetime:** 2 years

**Mission Project Management:** JPL

[oco.jpl.nasa.gov](http://oco.jpl.nasa.gov)



# Soil Moisture Active-Passive (SMAP)

Launched: Jan. 31, 2015 • Status: Extended Operations (Phase E)

## Mission Science Objective:

- Make pioneering space-based measurements of soil moisture and freeze/thaw state (hydrosphere state) to enable understanding of natural seasonal variations and to characterize their impacts on surface energy, water, and carbon balances.

## Key Science Products:

- Soil Moisture estimate of top 5 cm of soil at 10km spatial resolution and 3-day average intervals over the global land area, excluding regions of snow and ice, frozen ground, mountainous topography, open water, urban areas, and vegetation water content greater than 5kg m<sup>-2</sup> (averaged over the spatial resolution scale).
- Freeze/thaw state north of 45N latitude which includes the boreal forest zone.

**Mission Description:** S/C: In-house (JPL)

## Instruments:

- L-Band Radar (JPL); not operating
- L-Band Radiometer (GSFC)
- Shared 6m rotating (~15 rpm) antenna (JPL)

**Mass:** 1157 kg

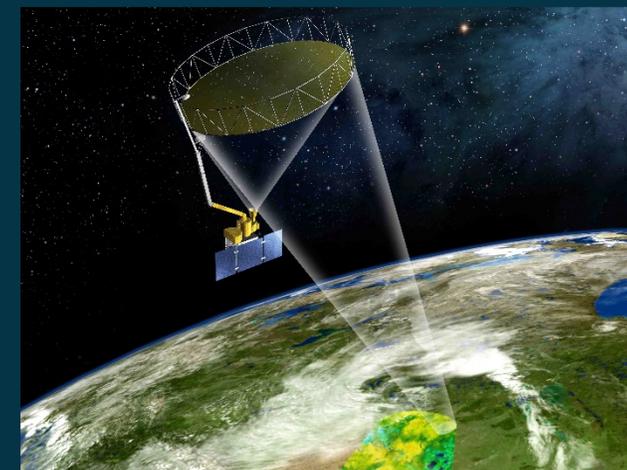
**Launch Vehicle:** Delta II 7320

**Orbit:** 685 km altitude, Sun-synch, ~6:00 AM/PM LTDN/LTAN

**Prime Mission Lifetime:** 3 years

**Mission Project Management:** JPL

[smap.jpl.nasa.gov](http://smap.jpl.nasa.gov)



# Deep Space Climate Observatory (DSCOVR)

Launched: Feb. 11, 2015 • Status: Extended Operations (Phase E)

## Mission Science Objectives:

- Continue solar wind measurements in support of space weather requirements (primary).
- Observe the Earth from L1 (secondary).
- Measure the energetic particle environment at L1 (tertiary).

## Mission Description:

- Organizations: NOAA, NASA GSFC, USAF
- S/C: SMEX (GSFC)

## Instruments:

- Plasma–Magnetometer (PlasMag) (NOAA)
- Magnetometer
- Faraday Cup
- Electron Spectrometer
- Earth Polychromatic Imaging Camera (EPIC) (NASA)
- NIST Advanced Radiometer (NISTAR) (NASA)

**Mass:** 570 kg

**Launch Vehicle:** Falcon 9 v 1.1 (USAF)

**Orbit:** L1 Lissajous

**Prime Mission Lifetime:** 3 years

**Mission Project Management:** GSFC

[solarsystem.nasa.gov/missions/DSCOVR/in-depth](https://solarsystem.nasa.gov/missions/DSCOVR/in-depth)



# Cloudsat

Launched: April 28, 2016 • Status: Extended Operations (Phase E)

## Mission Science Objectives:

- Provide space-based global surveys of cloud profiles and cloud physical properties with the seasonal and geographical variation needed to evaluate the way clouds are parameterized in global models, thereby contributing to predictions of weather, climate, and the cloud-climate feedback problem.
- CloudSat flies a 94-GHz Cloud Profiling Radar (CPR) that makes global observations of the liquid water and ice content in clouds.

## Key Science Products:

- Cloud geometric profile, W-band brightness temperature, cloud type, cloud liquid and ice water content, cloud layer optical depth, atmospheric radiative fluxes and heating rates, precipitation (rain and snow) incidence and surface rain rate (RR), rain water content profile and surface RR, snow particle size distribution profiles and snowfall rate.

**Mission Description:** S/C: bus designed and built by Ball Aerospace

**Instruments:** Cloud Profiling Radar (CPR)

**Mass:** 847kg

**Launch Vehicle:** McDonnell Douglas Delta II

**Orbit:** ~688km, ~98.22° inclination (drifting), ~1:58 PM MLTAN

**Prime Mission Lifetime:** 3 years

**Principal Investigator:** Graeme Stephens

**Mission Project Management:** NASA/CSA/USAF

[jpl.nasa.gov/missions/cloudsat](http://jpl.nasa.gov/missions/cloudsat)



# Cyclone Global Navigation Satellite System (CYGNSS)

Launched: Dec. 15, 2016 • Status: Extended Operations (Phase E)

## Mission Science Objectives:

- Understand the coupling between ocean surface properties, moist atmospheric thermodynamics, radiation and convective dynamics in the inner core of tropical cyclones (TC).
- Measure ocean surface wind speed in all precipitating conditions, including in TC eyewalls.
- Measure ocean surface wind speed in TC inner cores to resolve genesis and rapid intensification.
- Support operational hurricane forecast community assessment of data products.

## Key Science Products:

- Wind speed in ungridded coordinate system without precision geolocation.
- Gridded wind field with precision geolocation.
- Gridded ocean surface roughness with precision geolocation.
- Data assimilation wind field, operational wind field.

**Mission Description:** S/C: 8 microsattellites (SwRI)

## Instruments:

- Delay Doppler Mapping Instrument (DDMI) on each S/C (SSTUS)

**Mass:** 18 kg (each S/C)

**Launch Vehicle:** Small Class, Deployment module (SNC)

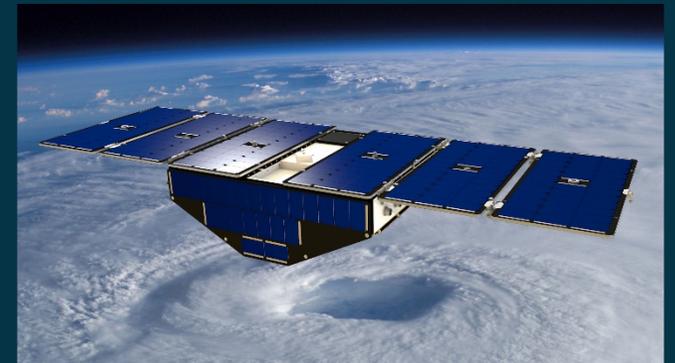
**Orbit:** 520 km altitude, 35° inclination

**Prime Mission Lifetime:** 2 years

**Principal Investigator:** Chris Ruf/U. Mich.

**Mission Project Management:** SwRI

[nasa.gov/cygnss](https://nasa.gov/cygnss)



# Stratospheric Aerosols and Gas Experiment-III (SAGE-III) on International Space Station

Launched: Feb. 19, 2017 • Status: Prime Operations (Phase E)

## Mission Science Objective:

- Monitor the vertical distribution of aerosols, ozone and other trace gases in Earth's stratosphere and troposphere to enhance understanding of ozone recovery and climate change processes in the upper atmosphere.

## Key Science Products:

- Solar transmission, Aerosol extinction, Ozone, NO<sub>2</sub>, H<sub>2</sub>O, Mesospheric Ozone, Ozone (lunar) and NO<sub>3</sub> (lunar)

**Mission Description:** S/C: International Space Station/ELC-4

## Instrument:

- UV/VIS/NIR Grating Spectrometer (LaRC)

## Pointing System:

- Hexapod (ESA)

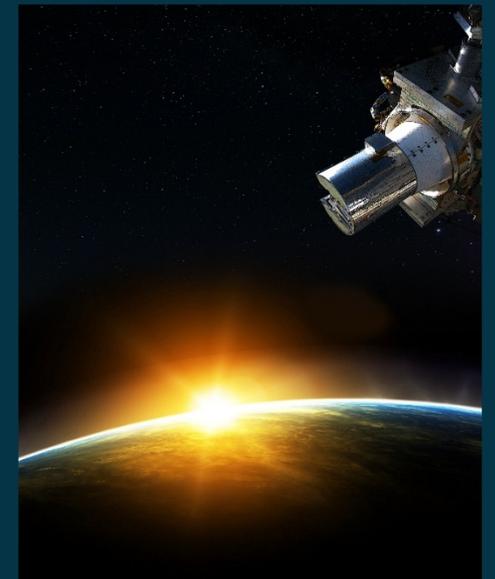
**Launch Vehicle:** Space-X Falcon 9 Dragon

**Orbit:** 330-410 km, 51.6° inclination

**Prime Mission Lifetime:** 3 years

**Mission Project Management:** LaRC

[nasa.gov/sage3-iss](https://nasa.gov/sage3-iss)



# Light Imaging Sensor (LIS) on ISS

Launched: February 19, 2017 • Status: Extended Operations (Phase E)

## Mission Science Objectives:

- Acquire and investigate the global distribution and variability of total (ground and cloud) lightning. Advance the understanding of underlying and interrelated processes (ie. precipitation and storm processes, release and transport of latent heat, atmospheric chemistry, global electric circuit, ionospheric and magnetospheric physics, and lightning physics).
- LIS extends the TRMM time series observations, expands latitudinal coverage, provides near real-time data to operational users and enables cross-sensor calibrations.

**Key Science Products:** Global lightning (amount, rate, radiant energy) during the day and night. Near real-time (NRT) lightning events, groups and flashes. Non-quality controlled (NQC) daily lightning events, groups and flashes. NRT and NQC background images.

**Mission Description:** S/C: Hosted payload on DoD Space Test Program-Houston 5 (STP-H5) on the International Space Station/ELC Site 1

**Instrument:** Lightning Imaging Sensor (LIS)

**Mass:** 25 Kg

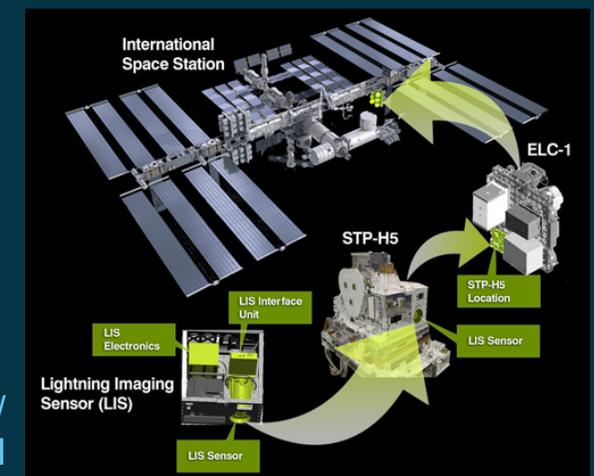
**Launch Vehicle:** SpaceX Falcon 9

**Orbit:** ~409km, 51.6° inclination

**Prime Mission Lifetime:** 2 years

**Mission Project Management:** NASA

[ghrc.nsstc.nasa.gov/lightning/overview\\_lis\\_instrument.html](http://ghrc.nsstc.nasa.gov/lightning/overview_lis_instrument.html)



# Total and Spectral Solar Irradiance Sensor-1 (TSIS-1) on International Space Station

Launched: Dec. 15, 2017 • Status: Prime Operations (Phase E)

## **Mission Science Objective:**

To provide total and spectral solar irradiance measurements needed to maintain the 40+ year climate data record.

## **Key Science Products:**

Total solar irradiance (TSI) and Solar spectral irradiance (SSI)

**Mission Description:** S/C: International Space Station/ELC-3

## **Instruments:**

- Spectral Irradiance Monitor (SIM) (LASP)
- Total Irradiance Monitor (TIM) (LASP)

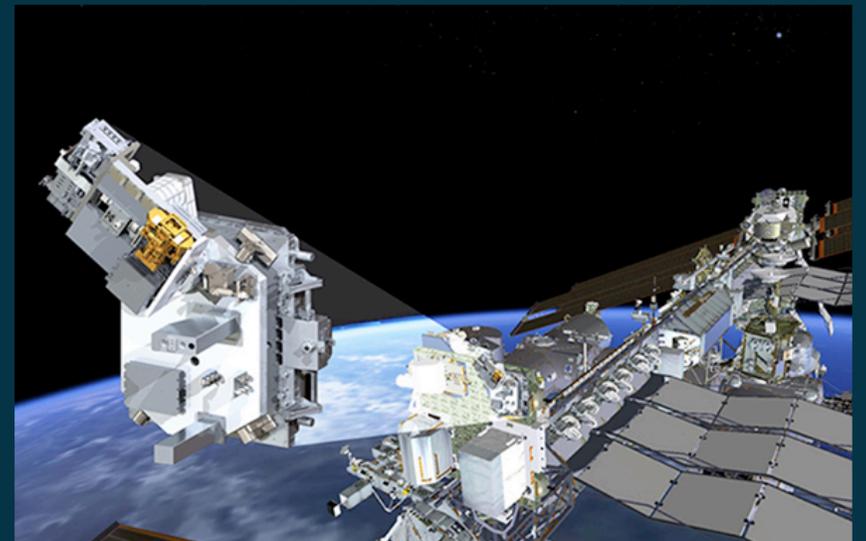
**Launch Vehicle:** Space-X Falcon 9 Dragon

**Orbit:** 330-410 km, 51.6° inclination

**Prime Mission Lifetime:** 5 years

**Mission Project Management:** GSFC

[nasa.gov/goddard/tsis-1](https://nasa.gov/goddard/tsis-1)



# GRACE-FOLLOW ON (GFO)

Launched: May 22, 2018 • Status: Prime Operations (Phase E)

## Mission Science Objectives:

To obtain the same high resolution global models of Earth's gravity field, including how it varies over time, as the pathfinder GRACE mission, launched in 2002 and operated for 15 years until it was decommissioned in 2017. GFO also includes a technology demonstration Laser Ranging Interferometer to support future GRACE-like missions.

## Key Science Products:

- Estimates of the global high-resolution models of the Earth's gravity field for a period of up to five years at a precision and temporal sampling equivalent to that achieved with GRACE.
- Globally distributed profiles each day of the bending angle due to the refraction of GNSS signals by the ionosphere and the atmosphere, using GPS limb-sounding.
- The inter-satellite laser ranging interferometer demonstrates satellite-to-satellite interferometry in low Earth orbit.

**Mission Description:** S/C: 2 satellites designed and built by Airbus Defence & Space, Germany

**Instruments:** Accelerometer, Laser Ranging Interferometer (LRI), Microwave Instrument (MWI), Laser Retro-Reflector

**Mass:** 600.2kg each

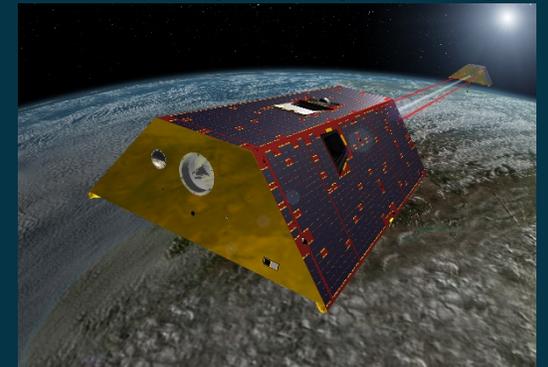
**Launch Vehicle:** SpaceX Falcon 9

**Orbit:** 491km, near-circular polar orbit, 89° inclination

**Prime Mission Lifetime:** 5 years

**Mission Project Management:** Partnership with the German Research Centre for Geosciences (GFZ) and NASA

[gracefo.jpl.nasa.gov](http://gracefo.jpl.nasa.gov)



# Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)

Launched: June 29, 2018 • Status: Extended Operations (Phase E)

## Mission Science Objectives:

- Identify critical thresholds of water use and water stress in key climate sensitive biomes
- Detect the timing, location, and predictive factors leading to plant water uptake decline and/or cessation over the diurnal cycle.
- Measure agricultural water consumptive use over the contiguous United States (CONUS) at spatiotemporal scales applicable to improve drought estimation accuracy.

## Key Science Products:

- Land Surface Temperature and Emissivity, Evapotranspiration, Evaporative Stress Index, Water Use Efficiency

- **Mission Description:**

S/C: International Space Station/JEM-EF Site 10

## Instrument:

- Thermal Infrared Radiometer (JPL)

**Launch Vehicle:** Space-X Falcon 9 Dragon

**Orbit:** 330-410 km, 51.6° inclination

**Prime Mission Lifetime:** 1 year

**Principal Investigator:** Simon Hook/JPL

**Mission Project Management:** JPL

[ecostress.jpl.nasa.gov](http://ecostress.jpl.nasa.gov)



# Ice, Cloud and Land Elevation Satellite-2 (ICESat-2)

Launched: Sept. 15, 2018 • Prime Operations (Phase E)

## **Mission Science Objective:**

- Collect altimetric measurements of the Earth's surface, optimized to measure the heights and freeboard of polar ice and global vegetation canopy.

## **Key Science Products:**

- Global surface elevation, backscatter
- Antarctic and Greenland ice sheet altimetry data
- Sea ice altimetry data
- Global land surface altimetry data
- Ocean altimetry data
- Global vegetation height

**Mission Description:** S/C: LEOStar-3 (Northrop Grumman)

## **Instrument:**

- Advanced Topographic Laser Altimeter System (ATLAS) (GSFC)

**Mass:** 1445 kg

**Launch Vehicle:** Delta II 7320

**Orbit:** 481 km, 92° inclination, 91-day repeat

**Prime Mission Lifetime:** 3 years

**Mission Project Management:** GSFC

[icesat-2.gsfc.nasa.gov](https://icesat-2.gsfc.nasa.gov)



# Global Ecosystem Dynamics Investigation (GEDI) on International Space Station

Launched: Dec. 5, 2018 • Status: Prime Operations (Phase E)

## Mission Science Objectives:

- Quantify the distribution of above-ground carbon at fine spatial resolution.
- Quantify changes in carbon resulting from disturbance and subsequent recovery.
- Quantify the spatial and temporal distribution of forest structure and its relationship to habitat quality and biodiversity.
- Quantify the sequestration potential of forests through time under changing land use and climate.

## Key Science Products:

- Canopy Height, Depth, Profile, EAGC

**Mission Description:** S/C: International Space Station/JEM-EF Site 6

## Instrument:

- Vegetation Canopy Lidar (GSFC)

**Launch Vehicle:** Space-X Falcon 9 Dragon

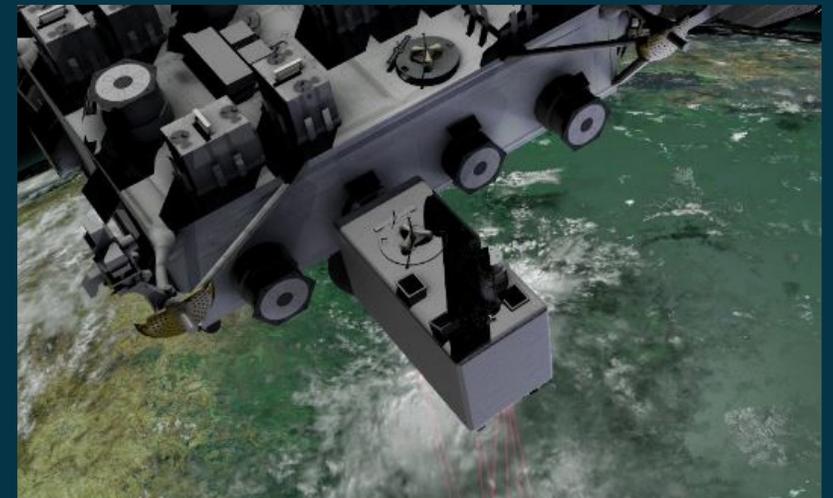
**Orbit:** 330-410 km, 51.6° inclination

**Prime Mission Lifetime:** 2 years

**Principal Investigator:** Ralph Dubayah/U. Md.

**Mission Project Management:** GSFC

[gedi.umd.edu](http://gedi.umd.edu)



# Orbiting Carbon Observatory-3 (OCO-3) on International Space Station

Launched: May 4, 2019 • Status: Prime Operations (Phase E)

## Mission Science Objectives:

- Collect space-based global measurements of atmospheric CO<sub>2</sub> with the precision, resolution, and coverage needed to characterize its sources and sinks on regional scales and quantify their variability over the seasonal cycle.
- Measurement precision and accuracy requirements same as OCO-2.
- Operation on ISS allows latitudinal coverage from 51 degrees S to 51 degrees N latitude.

## Key Science Products:

- Estimates of the column-averaged CO<sub>2</sub> dry air mole fraction (XCO<sub>2</sub>) on regional scales ( $\geq 1000$  km), collected in cloud-free scenes over  $\geq 70\%$  of range of latitudes on the sunlit hemisphere for 3 years.

## Mission Description:

- S/C: International Space Station/JEM EF Site 3

## Instrument:

- 3-Channel Grating Spectrometer (JPL/Hamilton Sundstrand)

**Mass:** 346kg

**Launch Vehicle:** Space-X Falcon 9 Dragon

**Orbit:** 330-410 km, 51.6° inclination

**Prime Mission Lifetime:** 3 years

**Mission Project Management:** JPL

[ocov3.jpl.nasa.gov](http://ocov3.jpl.nasa.gov)



The background of the slide is a composite of two cosmic images. The top half features a dark blue and black space filled with numerous small, bright stars and a prominent, glowing blue nebula on the right side. The bottom half shows a similar starry field but with a warm, golden-orange and yellowish glow, suggesting a different nebula or a different spectral filter. The text is centered in a dark blue horizontal band that spans the width of the image.

# Missions in Development and Formulation

# Sentinel-6 Michael Freilich/Sentinel-6B

LRD: Sentinel-6 Michael Freilich, 2020 • Status: Implementation (Phase D); Sentinel-6B, LRD: 2025

## Mission Science Objective:

- Provide continuity of ocean topography measurements beyond TOPEX/Poseidon, Jason-1 OSTM/Jason-2, and Jason-3 through cooperation in the European-U.S. Jason CS/Sentinel 6 program.

## Key Science Products:

- Global sea surface height, surface wave height, and GNSS Radio Occultation near-real-time operational and validated science data products.

**Mission Description:** S/C: FlexBus (ESA)

## Instruments:

- Ku/C-Band Radar Altimeter (ESA)
- DORIS (ESA)
- GNSS-Precision Orbit Determination (ESA)
- Advanced Microwave Radiometer-Climate (NASA)
- GNSS Receiver (POD)(ESA)
- Advanced Microwave Radiometer-C (NASA)
- GNSS-Radio Occultation (NASA)
- Laser Retro-Reflector Array (NASA)

**Mass:** TBD

**Launch Vehicle:** S6MF - Space X Falcon 9 (NASA), S6B TBD (NASA)

**Orbit:** 1336 km, 66° inclination, 10 day repeat

**Mission Life:** 5.5 years (7.5 years consumables)

**Mission Project Management:** JPL

[jpl.nasa.gov/missions/sentinel-6](https://jpl.nasa.gov/missions/sentinel-6)



# Landsat 9

LRD: 2021 • Status: Implementation (Phase C) *Pending on Delegation memo to officially move to Phase D*

## **Mission Science Objective:**

- As a successor to Landsat 8, extend Landsat land surface observations to study, predict, and understand the consequences of land surface dynamics.

## **Key Science Products:**

- Moderate resolution maps of land cover/land use change over multiple decades including deforestation, agricultural extensification, and urbanization; documentation of ecosystem fragmentation and connectivity; identification and quantification of regional to continental scale sources and sinks of carbon.

**Mission Description:** S/C: Northrop Grumman Space Systems

## **Instruments:**

- Operational Land Imager-2 (OLI-2) pan, 15m GSD multi-spectral, 30m GSD, 185km swath (Ball)
- Thermal Infrared Sensor-2 (TIRS-2), 120m GSD (GSFC)

**Mass:** TBD

**Launch Vehicle:** ULA-Atlas V 401

**Orbit:** 705 km, Sun-synch, 98.22° inclination,  
10:15 AM LTDN, 16-day repeat

**Mission Life:** 5 years

**Mission Project Management:** GSFC

[landsat.gsfc.nasa.gov/landsat-9](https://landsat.gsfc.nasa.gov/landsat-9)



# Timed-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of SmallSats (TROPICS)

LRD: 2022 • Status: Implementation (Phase C)

## Mission Science Objectives:

- Determine the relationships between rapidly evolving storm structures and storm intensity.
- Determine the extent that environmental moisture controls storm size, structure and intensity.
- Demonstrate that tropical storm intensity forecasts can be improved through utilization of rapid update microwave information.

## Key Science Products:

- Simultaneous soundings of precipitation structure near 90 GHz, of O<sub>2</sub> (118 GHz) and H<sub>2</sub>O vapor (183 GHz) absorption lines, and of ice structure near 206 GHz to recover storm-related temperature & moisture vertical profiles and horizontal cloud morphology.

**Mission Description:** S/C: 12 3U nanosatellites (MIT LL)

## Instruments:

- 12 channel passive microwave spectrometer (MIT LL)

**Mass:** 4 kg (each S/C)

**Launch Vehicle (3):** VCLS (TBC)

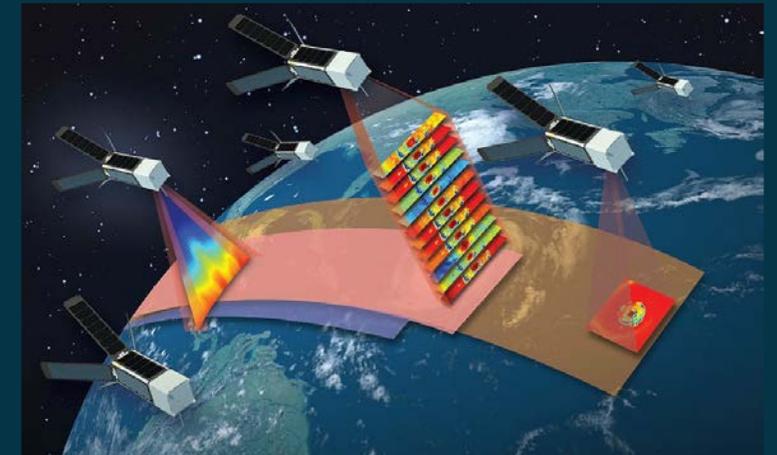
**Orbit:** 30° inclination, 600 km altitude, 3 orbital planes

**Prime Mission Lifetime :** 1 year

**Principal Investigator:** William Blackwell/MITLL.

**Mission Project Management:** MIT LL

[tropics.ll.mit.edu/CMS/tropics](https://tropics.ll.mit.edu/CMS/tropics)



# Multi-Angle Imager for Aerosols (MAIA)

LRD: 2022 • Status: Implementation (Phase C)

## Mission Science Objective:

- Determine the relative toxicity of different airborne Particulate Matter (PM) types by size and species, and concentration, and assess the impacts of particle size and composition on adverse birth outcomes, cardiovascular and respiratory disease, and premature deaths.

## Key Science Products:

- Fractional aerosol optical depths (AOD), multi-angular visible/near-infrared (VNIR) radiances, particle size and shape, aerosol absorption, short wave infrared (SWIR) polarimetric radiances.

**Mission Description:** S/C: LEO spacecraft host (TBD)

## Instruments:

- 2x UV/VNIR/SWIR pushbroom spectropolarimetric cameras on 2-axis gimbal

**Mass:** 29 kg

**Orbit:** 370-830 km Sun synch. (1030 to 1330 LT)

**Mission Life:** 36 months

**Principal Investigator:** David Diner/JPL

**Mission Project Management:** JPL

[maia.jpl.nasa.gov](http://maia.jpl.nasa.gov)



# Tropospheric Emissions: Monitoring of Pollution (TEMPO)

LRD: 2022 • Status: Implementation (Phase C)

## Mission Science Objectives:

- Collect simultaneous high temporal and spatial resolution measurements of pollutants (tropospheric gases and aerosols) over Greater North America (GNA) from GEO.
- Determine the diurnal instantaneous radiative forcings associated with pollutants and other climate agents over GNA.
- Serve as the North American component of an international constellation for air quality monitoring.

## Key Science Products:

- $\text{SO}_2$ ,  $\text{H}_2\text{CO}$ ,  $\text{NO}_2$ ,  $\text{C}_2\text{H}_2\text{O}_2$ ,  $\text{O}_3$ , AOD.

**Mission Description:** S/C: GEO spacecraft host (SMC)

## Instruments:

- UV-Vis grating spectrometer (Ball)

**Mass:** 108 kg

**Orbit:** GEO  $100 \pm 10^\circ$  W longitude preferred

**Mission Life:** 20 months

**Principal Investigator:** Kelly Chance/SAO

**Mission Project Management:** LaRC

[tempo.si.edu](http://tempo.si.edu)



# NASA-ISRO Synthetic Aperture Radar (NISAR)

LRD: 2022 • Status: Implementation (Phase C)

## Mission Science Objectives:

- Understand the response of ice sheets to climate change and the interaction of sea ice and climate.
- Understand the dynamics of carbon storage and uptake in wooded, agricultural, wetland, and permafrost systems.
- Determine the likelihood of earthquakes, volcanic eruptions, and landslides.

## Key Science Products:

- Full and reduced resolution images, interferogram and correlation data, polarimetric backscatter, soil moisture, along with cal/val products for biomass, disturbance, ice and land displacements and urgent response.

**Mission Description:** Dual frequency (L+S Band) Synthetic Aperture Radar on ISRO provided I3K S/C bus

## Instruments:

- L-Band polarimetric SAR operated as repeat pass interferometer with 12m deployable antenna (NASA)
- S-Band SAR (ISRO)
- Engineering Payload System including Payload Communication Subsystem (Ka-band high frequency transmitter, GPS Payload, Solid State Recorder (NASA), 35 Tbps/day downlink

**Mass:** 2800 kg

**Launch Vehicle:** GSLV Mark II (ISRO)

**Orbit:** 747 km, Sun-synch dawn-dusk, 98° inclination, 12 day repeat

**Mission Life:** 3 years (5 years consumables)

**Mission Project Management:** JPL (implementation center)

NASA/ISRO joint responsibility (overall mission)

[nisar.jpl.nasa.gov](http://nisar.jpl.nasa.gov)



# Climate Absolute Radiance and Refractivity Observatory (CLARREO) Pathfinder on International Space Station

LRD: 2023 • Status: Implementation (Phase C)

## **Mission Science Objectives:**

- Demonstrate essential measurement technologies for the Reflected Solar portions of the CLARREO Tier 1 Decadal Survey Mission.
- Demonstrate on orbit, high accuracy, SI-Traceable calibration.
- Demonstrate ability to transfer to other on-orbit assets.

## **Key Science Products:**

- High accuracy spectral reflectances and radiances.

**Mission Description:** S/C: International Space Station/ELC-4

## **Instrument:**

- Reflected Solar (RS) Spectrometer (LASP)

**Launch Vehicle:** Space-X Falcon 9 Dragon

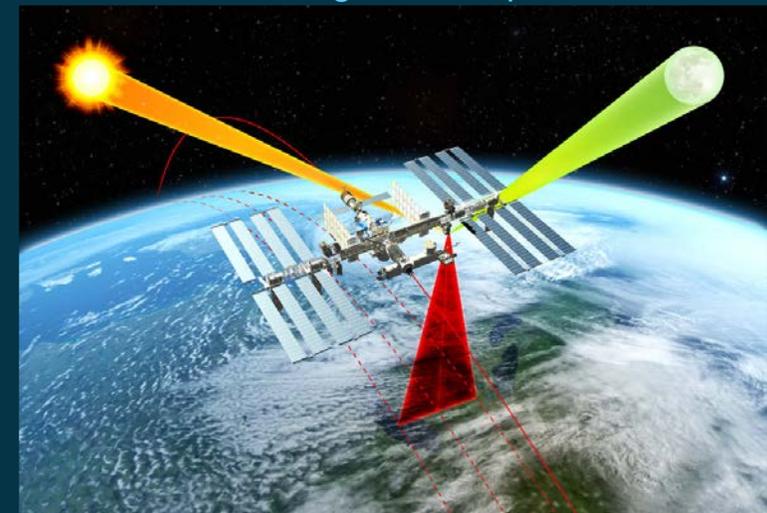
**Orbit:** 330-410 km, 51.6° inclination

**Mission Life:** 1 year

**Mission Project Management:** LaRC

*Funding is not included in the President's Budget Request for FY21*

[clarreo.larc.nasa.gov/about-pathfinder.html](http://clarreo.larc.nasa.gov/about-pathfinder.html)



# Surface Water and Ocean Topography (SWOT)

LRD: 2022 • Status: Implementation (Phase C)

## Mission Science Objectives:

- Characterize the ocean mesoscale and submesoscale circulation at spatial resolutions of 10 km and greater.
- Provide a global inventory of all terrestrial water bodies whose surface area exceeds 1 km<sup>2</sup> (lakes, reservoirs, wetlands) and rivers whose width exceeds 100 m (requirement) (50 m goal) (rivers).
- Measure the global storage change in fresh water bodies at sub-monthly, seasonal, and annual time scales.
- Estimate the global change in river discharge at sub-monthly, seasonal, and annual time scales.

## Key Science Products:

- Global SSH and slopes, Sigma-0 and wind speed, SSH std. dev., water mask, water elevations and slopes.

**Mission Description:** S/C: ISIS Standard (CNES)

## Instruments:

- Ka-band radar interferometer (KaRIn) (NASA/CNES/CSA)
- Nadir Altimeter (CNES)
- Microwave radiometer (Ku, K, Ka) (NASA)
- POD (GPS, DORIS, LRA) (NASA/CNES)

**Mass:** 2320 kg

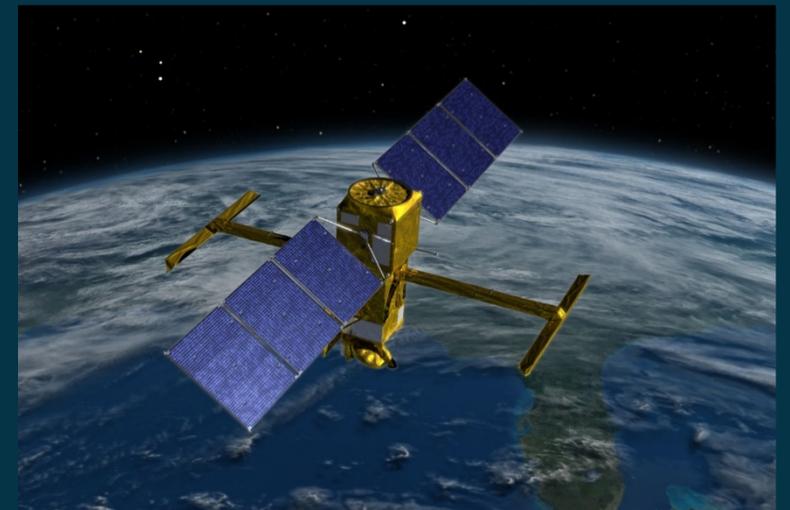
**Launch Vehicle:** SpaceX Falcon 9 (NASA)

**Orbit:** 891 km, 77.6° inclination, 21 day repeat

**Mission Life:** 3 years

**Mission Project Management:** JPL

[swot.jpl.nasa.gov](http://swot.jpl.nasa.gov)



# Plankton, Aerosol, Cloud and ocean Ecosystem (PACE)

LRD: 2024 • Status: Implementation (Phase C)\*

## Mission Science Objectives:

- Understand and quantify global biogeochemical cycling and ecosystem function in response to anthropogenic and natural environmental variability and change (primary).
- Understand and resolve/quantify the role of aerosols and clouds in physical climate, the largest uncertainty (secondary).

## Key Science Products:

- Normalized Water-Leaving Reflectances, AOD, TVOD Fraction, Cloud Top Pressure, Cloud Water Path, Aerosol OT, Aerosol Effective Radius, Aerosol Type (TBC), Aerosol Sphericity (TBC)

**Mission Description:** S/C: TBD

## Instruments:

- Ocean Color Imager (OCI)
- Polarimeters (SPEXone and HARP2)

**Mass:** TBD

**Launch Vehicle:** TBD

**Orbit:** 676.5 km, Sun-synch, 98° inclination, 12:00 PM LT DN

**Mission Life:** 3 years

**Mission Project Management:** GSFC

*\*Funding is not included in the President's Budget Request for FY21*

[pace.gsfc.nasa.gov](http://pace.gsfc.nasa.gov)



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- Polarimeters (SPEXone and HARP2)

**Mass:** TBD

**Launch Vehicle:** TBD

**Orbit:** 676.5 km, Sun-synch, 98° inclination, 12:00 PM LT DN

**Mission Life:** 3 years

**Mission Project Management:** GSFC

*\*Funding is not included in the President's Budget Request for FY21*

[pace.gsfc.nasa.gov](http://pace.gsfc.nasa.gov)



# Earth Surface Mineral Dust Source Investigation (EMIT) on International Space Station

LRD: 2022 • Status: Implementation (Phase C)

## Mission Science Objectives:

- Constrain the sign and magnitude of current dust-related radiative forcing at regional and global scales. EMIT achieves this objective through improvements in the accuracy of the maps of surface mineralogy used to initialize Earth System Models.
- Predict the increase or decrease of available dust sources under future climate scenarios. EMIT achieves this objective by initializing forecast models with current inventories of native vegetation, crops, and mineralogy of soils exposed within at-risk lands bordering arid dust source regions.

## Key Science Products:

- First of their kind maps of surface reflectance and surface mineralogy of the Earth's dust source regions and adjacent lands.
- Earth System Model results assessing current mineral dust radiative forcing impacts and future changes.

**Mission Description:** NASA ESD EVI AO-4 selection, Category 3, Risk Class C mission

**Instrument:** VSWIR-Dyson Imaging Spectrometer

**Mass:** ~188 kg, including FRAM

**Launch Vehicle:** SpaceX Falcon 9 Dragon Trunk

**Orbit:** 330-410 km, 51.6° inclination (EMIT is an ISS payload on ELC-1 FRAM-8)

**Mission Life:** 1 year after 30-day IOC

**Mission Project Management:** JPL

[science.jpl.nasa.gov/projects/EMIT](https://science.jpl.nasa.gov/projects/EMIT)



# Polar Radiant Energy in the Far Infrared Experiment (PREFIRE)

LRD: 2022 • Status: Implementation (Phase B)

## Mission Science Objectives:

- PREFIRE provides the first systematic spectrally resolved measurements of Earth's radiant Far InfraRed (FIR) energy at the poles. More than 60% of energy radiated from the cold, dry polar regions resides in far-infrared wavelengths. Energy in these bands is both dynamic and poorly characterized, yet plays a critical role in defining the rapidly evolving polar climates.

## Key Science Products:

- These measurements will be integrated into state-of-the-art local and global models to eliminate Far Infra-Red biases as a major source of uncertainty in predicted Arctic warming, sea ice loss, and ice sheet melt rates.

**Mission Description:** S/C TBD Two 3-U CubeSats in asynchronous polar orbits

## Instruments:

- Two thermal infrared spectrometers aboard two CubeSat spacecraft to spectrally sample polar radiant energy from 0 – 45  $\mu\text{m}$ .

**Mass:** 1.3 kg each CubeSat

**Launch Vehicle:** TBD

**Orbit:** Two 3U CubeSats in distinct 470–650 km altitude, near-polar (82°-98° inclination) orbits

**Mission Life:** 1 year

**Mission Project Management:** University of Wisconsin/ JPL

[science.jpl.nasa.gov/  
projects/PREFIRE](https://science.jpl.nasa.gov/projects/PREFIRE)



# Geostationary Carbon Observatory (GeoCarb)

LRD: 2022 • Status: Implementation (Phase C)

## Mission Science Objectives:

- The GeoCarb mission will develop and deploy a multi-channel, slit-scan spectrometer that will measure absorption spectra in sunlight reflected from the land to retrieve atmosphere-column concentrations of CO<sub>2</sub>, methane (CH<sub>4</sub>), CO and solar induced fluorescence (SIF) from vegetation from a geostationary orbit.

## Key Science Products:

- The column concentrations of CO<sub>2</sub>, CH<sub>4</sub>, and CO will be used to increase understanding and impact of terrestrial sources and sinks of CO<sub>2</sub> and CH<sub>4</sub>. The SIF information will enable the community to improve models for agricultural production and yield, as well as to detect changes in crop status.

**Mission Description:** S/C TBD Commercial Satellite

## Instrument:

- 4-channel slit imaging spectrometer that measures reflected near-Infra Red (IR) sunlight at wavelengths 1.61 microns (μm) and 2.06 μm for X<sub>CO<sub>2</sub></sub>, and 2.32 μm for X<sub>CH<sub>4</sub></sub> and X<sub>CO</sub>, where X denotes column-integrated average concentration. The fourth channel, 0.76 μm, measures O<sub>2</sub> column concentration, SIF, and provides valuable information on aerosol and cloud contamination.

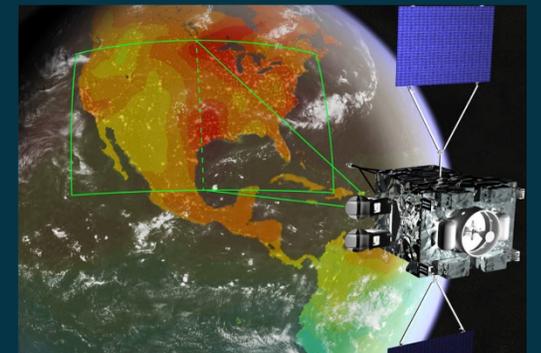
**Mass:** ~ 200kg

**Launch Vehicle:** TBD Commercial

**Orbit:** Geostationary orbit in the range of 85° +/- 10° West longitude

**Mission Life:** 3 years

**Mission Project Management:** University of Oklahoma



The background of the slide is a composite of two cosmic images. The top half features a dark blue and black space filled with numerous small, bright stars and a prominent, glowing blue nebula on the right side. The bottom half shows a similar starry field but with a warm, orange-to-yellow glow on the left side, transitioning into a greenish-blue glow on the right. The text 'Missions in Formulation' is centered in a white, sans-serif font across a dark blue horizontal band that spans the width of the image.

# Missions in Formulation

# Geostationary Littoral Imaging and Monitoring Radiometer (GLIMR)

LRD: NET 2026 • Status: Formulation (Phase A)

## Mission Science Objectives:

- Address critical science objectives relevant to coastal ecosystem health, human health, and resource management. Specifically: How physical processes that vary at timescales from hours to days impact the rates and fluxes of materials within and between aquatic coastal ecosystems; and how fluxes and rates within and between aquatic coastal ecosystems affect the formation, magnitude and trajectory of Harmful Algal Blooms and impact ecosystem and human health.

## Key Science Products:

- Coastal ocean productivity, phytoplankton community composition (including harmful algae), organic carbon stocks and fluxes, surface currents, oil extent and thickness

## Mission Description:

- Selected under EVI-5 AO solicitation. Class C payload. Hyperspectral ocean color radiometer capable of delivering high-frequency, high spatial and spectral resolution data from geostationary orbit.

## Instruments:

- A hyperspectral ocean color spectrometer (340-1040 nm) for top-of-the-atmosphere (TOA) radiance measurements and a landmark imager for Image Navigation and Registration (INR).

**Mass:** 122kg (CBE)

**Launch Vehicle:** TBD (NASA to provide “access to space”)

**Orbit:** Geostationary; 98° W ± 10° longitude

**Mission Life:** 2 years

**Mission Project Management:** University of New Hampshire

[eosps.nasa.gov/missions/geosynchronous-littoral-imaging-and-monitoring-radiometer-evi-5](https://eosps.nasa.gov/missions/geosynchronous-littoral-imaging-and-monitoring-radiometer-evi-5)



# Earth Venture Continuity-1: Libera

LRD: 2027 • Status: Formulation (Pre-Phase A)

## **Provides continuity of the Clouds and the Earth's Radiant Energy System (CERES) Earth radiation budget (ERB)**

- Measures integrated shortwave (0.3–5  $\mu\text{m}$ ), longwave (5–50  $\mu\text{m}$ ), total (0.3–>100  $\mu\text{m}$ ) and (new) split-shortwave (0.7–5  $\mu\text{m}$ ) radiance over 24 km nadir footprint.
- Includes a wide FOV camera for scene ID and simple ADM generation to pave way for future free-flyer ERB observing system

## **Innovative technology: Electrical Substitution Radiometers (ESRs) using Vertically Aligned Carbon Nanotube (VACNT) detectors; VACNT-coated blackbody calibrator**

- ESR: measured signal does not depend on gain of temperature sensor or thermal properties of system, improving calibration and accuracy

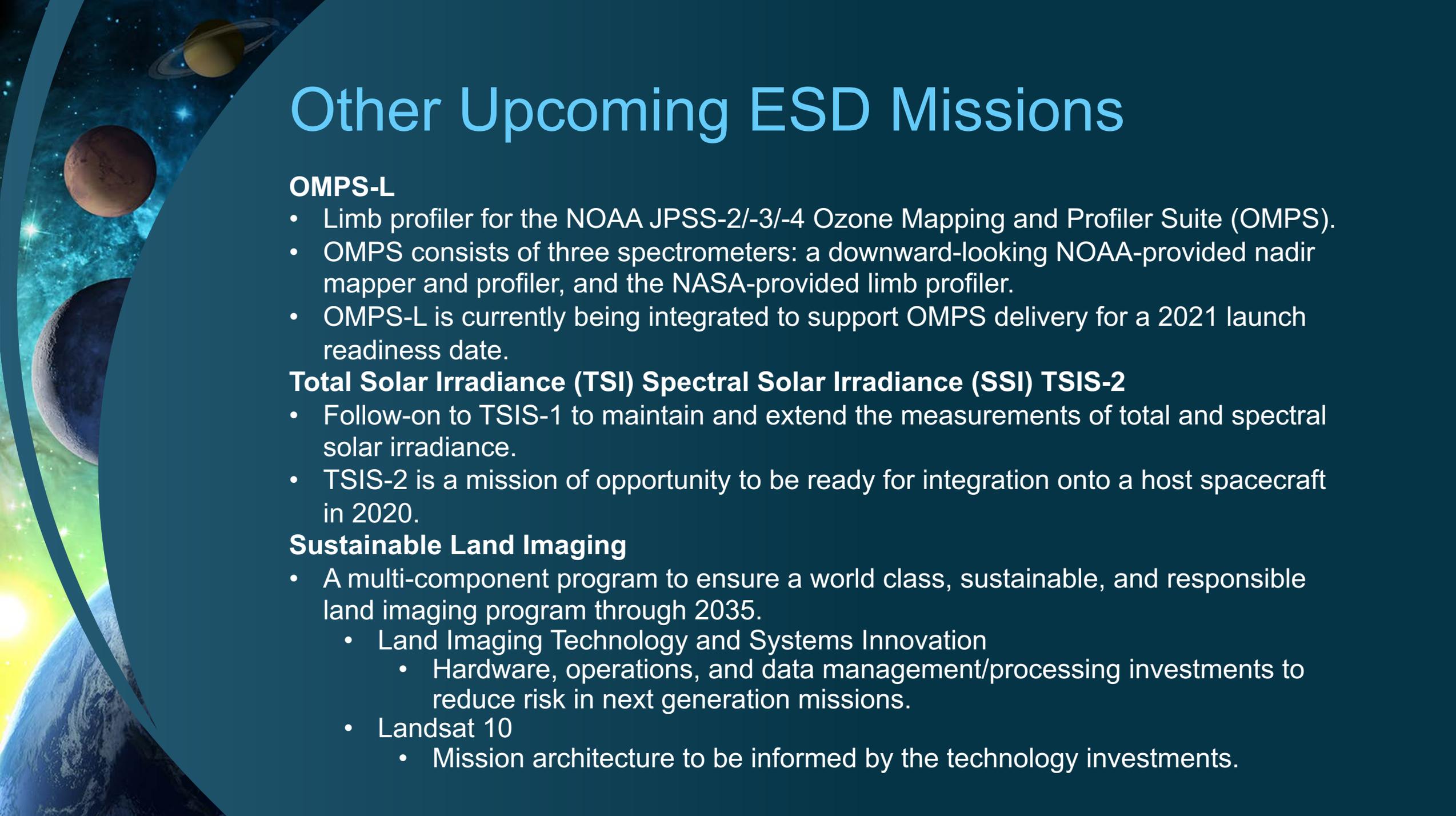
## **Operational modes:**

- Cross-track and azimuthal scanning
- On-board calibrators
- Solar and lunar viewing

## **Flight:**

- JPSS-3
- 2027 launch
- 5-year mission
- Follows pattern of CERES hosted on JPSS-1





# Other Upcoming ESD Missions

## **OMPS-L**

- Limb profiler for the NOAA JPSS-2/-3/-4 Ozone Mapping and Profiler Suite (OMPS).
- OMPS consists of three spectrometers: a downward-looking NOAA-provided nadir mapper and profiler, and the NASA-provided limb profiler.
- OMPS-L is currently being integrated to support OMPS delivery for a 2021 launch readiness date.

## **Total Solar Irradiance (TSI) Spectral Solar Irradiance (SSI) TSIS-2**

- Follow-on to TSIS-1 to maintain and extend the measurements of total and spectral solar irradiance.
- TSIS-2 is a mission of opportunity to be ready for integration onto a host spacecraft in 2020.

## **Sustainable Land Imaging**

- A multi-component program to ensure a world class, sustainable, and responsible land imaging program through 2035.
  - Land Imaging Technology and Systems Innovation
    - Hardware, operations, and data management/processing investments to reduce risk in next generation missions.
  - Landsat 10
    - Mission architecture to be informed by the technology investments.



# Other Upcoming ESD Missions (cont.)

## **Sustainable Land Imaging**

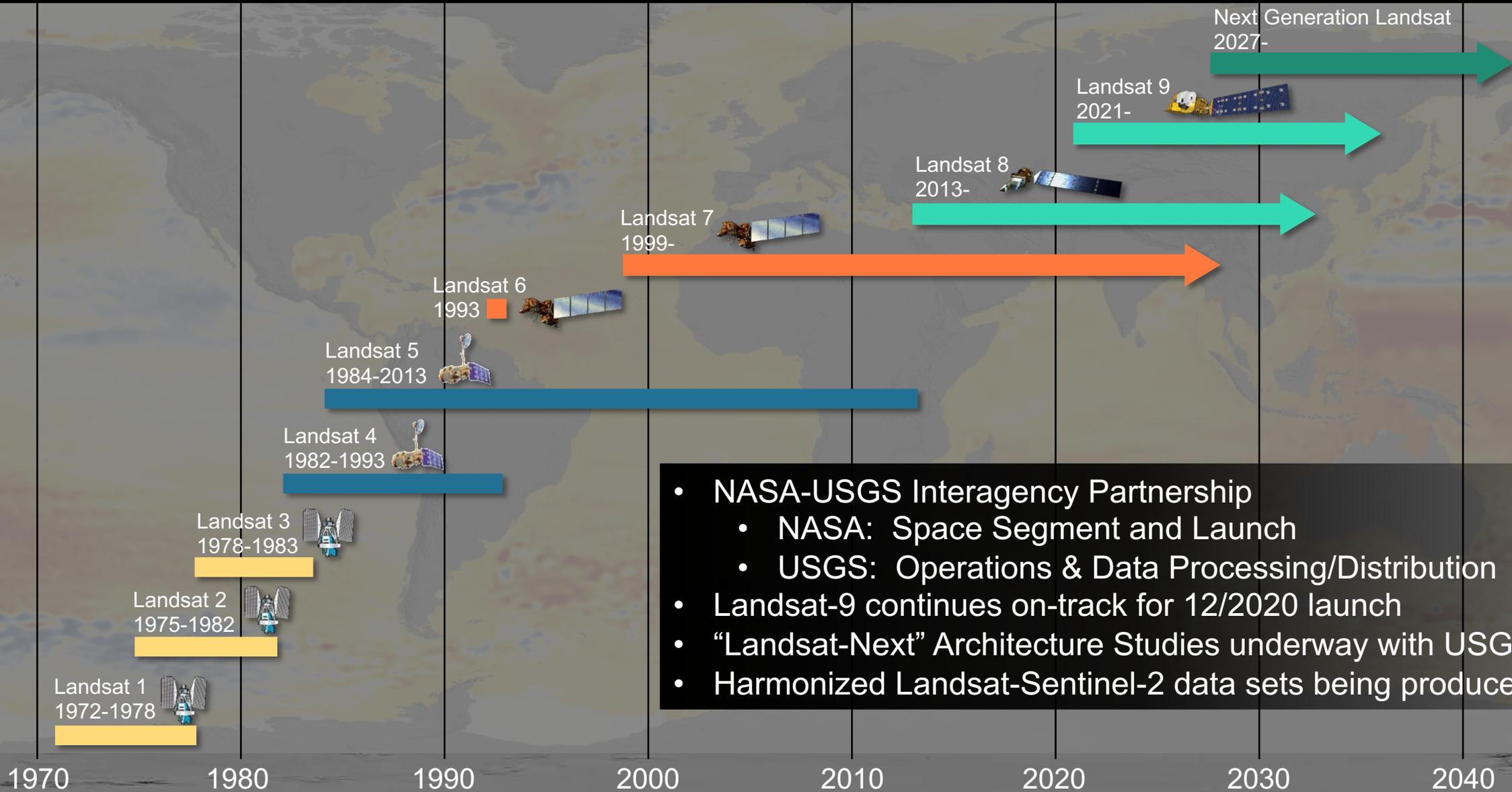
- Collaboration between NASA and DOI/USGS to ensure sustained access to land remote-sensing observations for U.S. research and operational users
- The development of a multi-decade, spaceborne system that will provide users worldwide with high-quality, global, land-imaging measurements that are compatible with the existing 47-year record for research and operational users
  - Addresses near- and longer-term issues of continuity risk
  - Evolves flexibly and responsibly through investment in, and introduction of, new sensor and system technologies
  - Supportive of Administration policy for land-imaging continuity (2019 National Plan for Civil Earth Observations)

## **Landsat Next\***

- Superspectral capability with greatly improved spatial, spectral resolution (10 meter spatial resolution, 20+ spectral bands)
- Disaggregated Landsat observing system with launch in 2028; informed by trade study results
- Acquisition strategy to explore new private sector development and ground system/operations approaches

\*Note: Text has not been approved for release beyond NASA/USGS.

# Mission Continuity: The Landsat Legacy



- NASA-USGS Interagency Partnership
  - NASA: Space Segment and Launch
  - USGS: Operations & Data Processing/Distribution
- Landsat-9 continues on-track for 12/2020 launch
- “Landsat-Next” Architecture Studies underway with USGS
- Harmonized Landsat-Sentinel-2 data sets being produced