

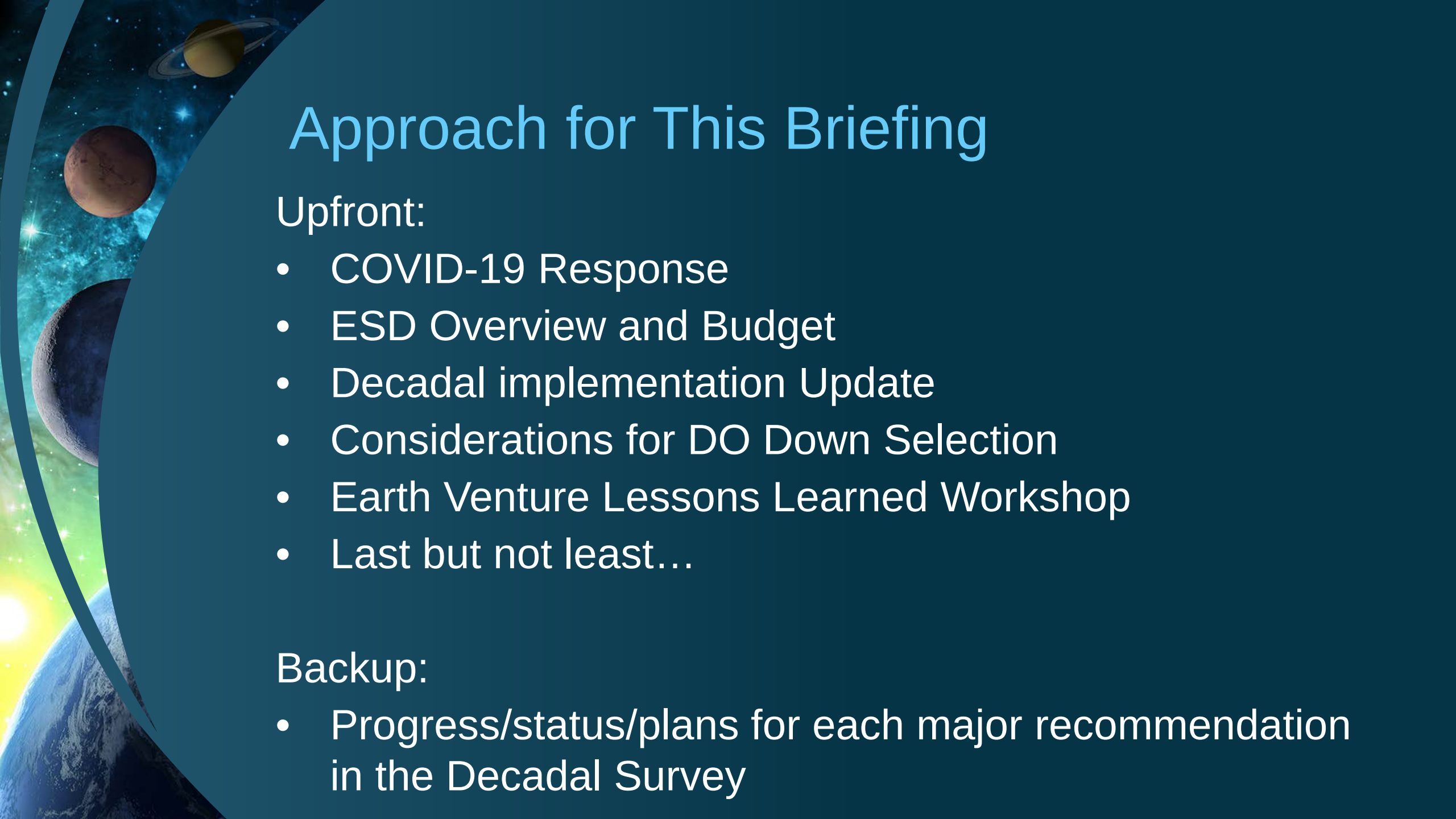


EXPLORE SCIENCE

Overview for CESAS

Sandra A. Cauffman
Director (Acting)
Earth Science Division

March 31, 2020

A space-themed background featuring a curved view of Earth's horizon at the bottom left, with a bright sun or star partially visible. Above the horizon, several celestial bodies are shown: a crescent moon, a reddish planet (Mars), and a yellow planet with rings (Saturn). The background is a deep blue with scattered white stars and a nebula-like glow.

Approach for This Briefing

Upfront:

- COVID-19 Response
- ESD Overview and Budget
- Decadal implementation Update
- Considerations for DO Down Selection
- Earth Venture Lessons Learned Workshop
- Last but not least...

Backup:

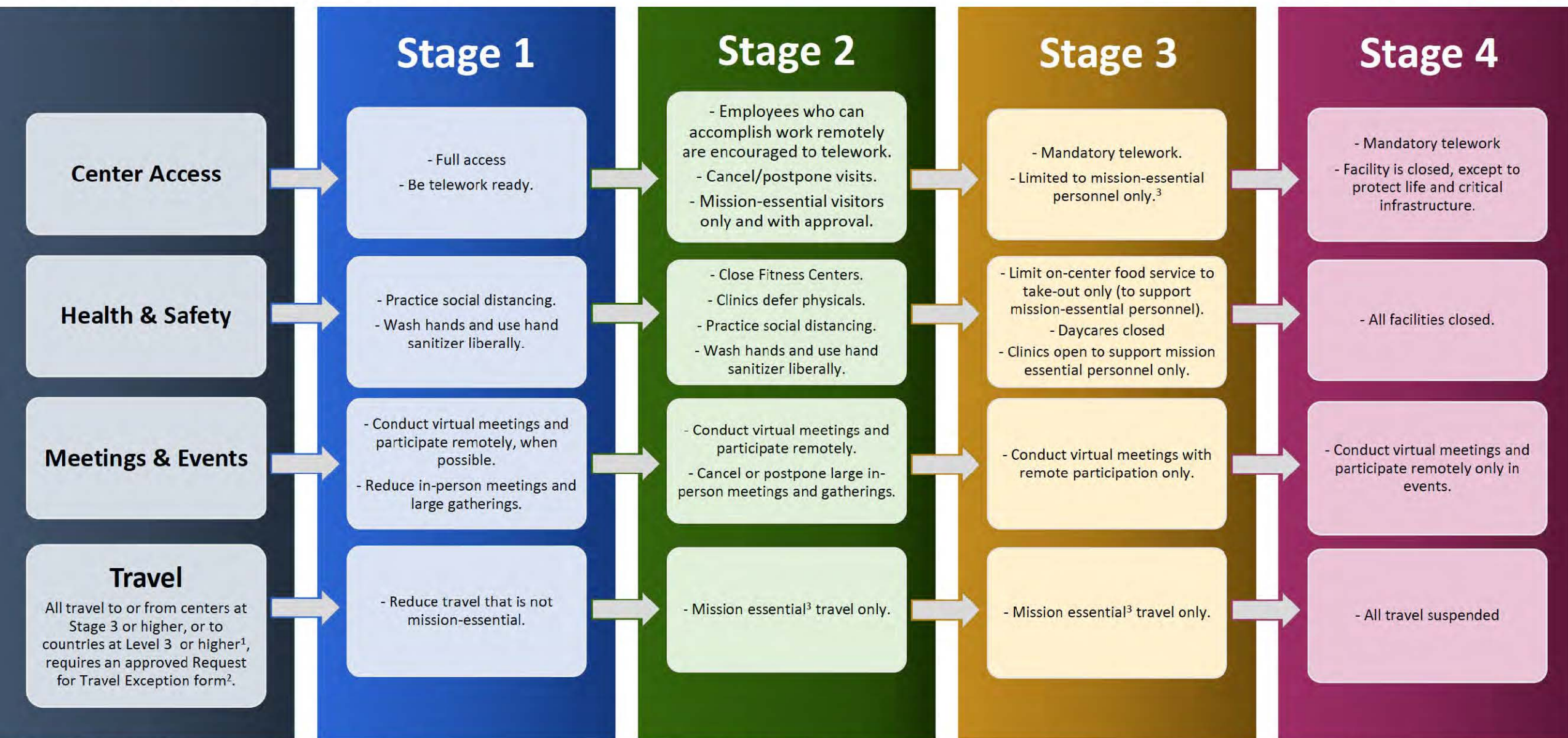
- Progress/status/plans for each major recommendation in the Decadal Survey

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COVID-19 Response

NASA Response Framework

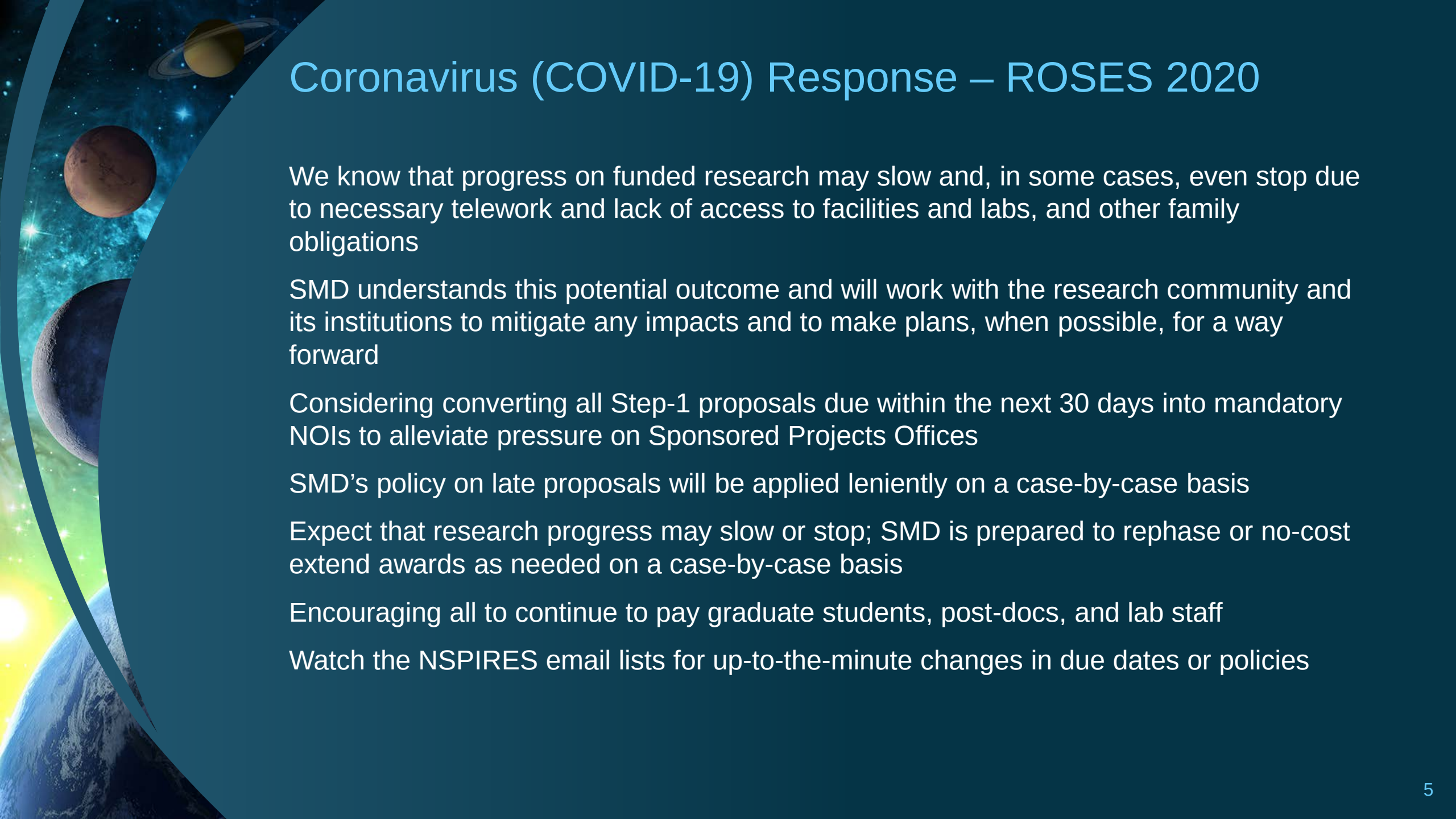
* This guidance applies to NASA civil servants. Contract employees should reach out to their contracting officer's representative.



1. For the latest CDC international travel information, go to <https://www.cdc.gov/coronavirus/2019-ncov/travelers/index.html>

2. The Request for Travel Exception form is available on the NASA People website.

3. Mission Essential is defined as: work that must be performed to maintain mission/project operations or schedules AND cannot be performed remotely/virtually; OR work that has a justifiable impact on the safety of human life or the protection of property, AND there is a reasonable likelihood that the safety of human life or the protection of property would be compromised by a delay in the performance of the work.



Coronavirus (COVID-19) Response – ROSES 2020

We know that progress on funded research may slow and, in some cases, even stop due to necessary telework and lack of access to facilities and labs, and other family obligations

SMD understands this potential outcome and will work with the research community and its institutions to mitigate any impacts and to make plans, when possible, for a way forward

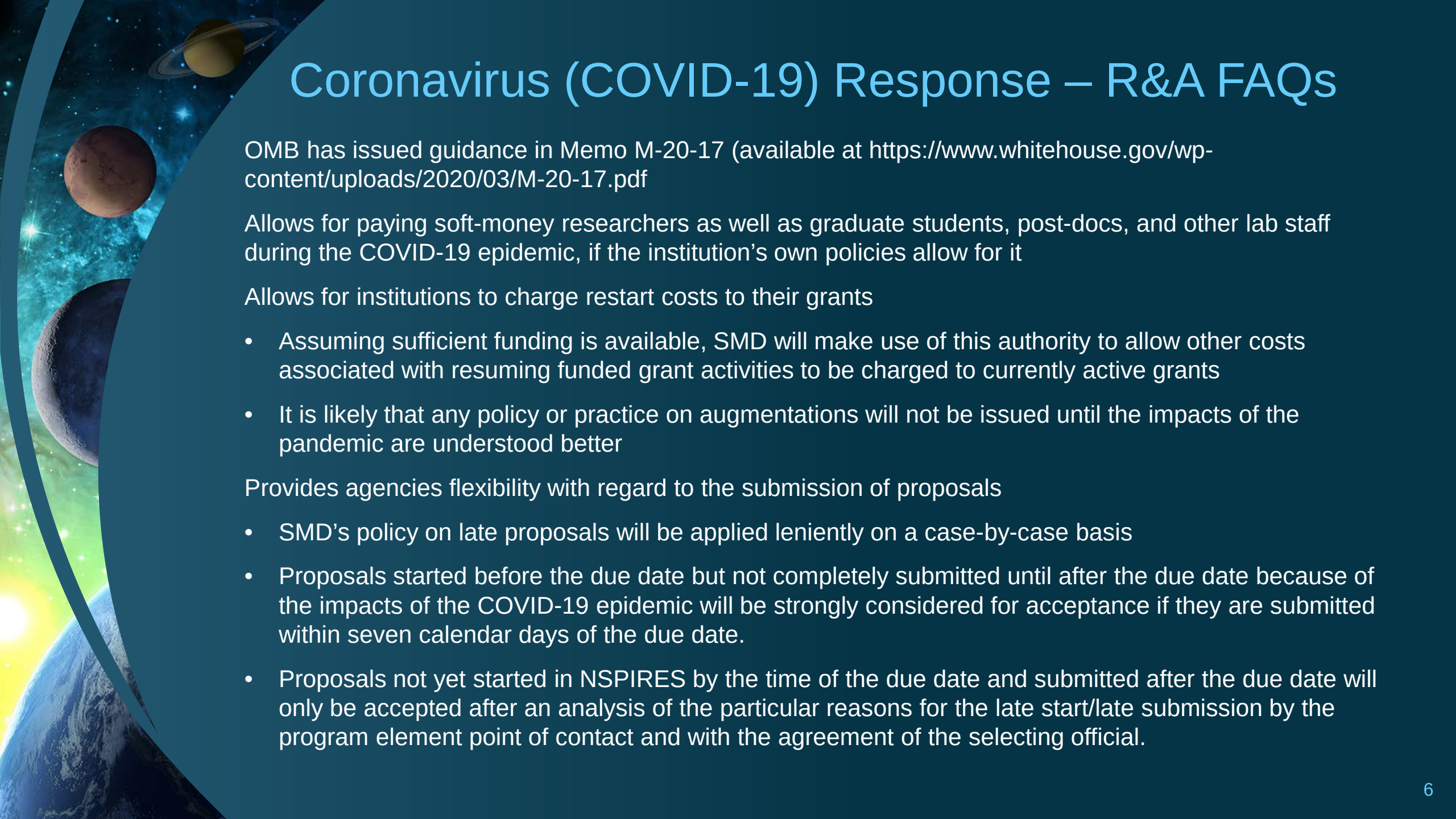
Considering converting all Step-1 proposals due within the next 30 days into mandatory NOIs to alleviate pressure on Sponsored Projects Offices

SMD's policy on late proposals will be applied leniently on a case-by-case basis

Expect that research progress may slow or stop; SMD is prepared to rephase or no-cost extend awards as needed on a case-by-case basis

Encouraging all to continue to pay graduate students, post-docs, and lab staff

Watch the NSPIRES email lists for up-to-the-minute changes in due dates or policies



Coronavirus (COVID-19) Response – R&A FAQs

OMB has issued guidance in Memo M-20-17 (available at <https://www.whitehouse.gov/wp-content/uploads/2020/03/M-20-17.pdf>)

Allows for paying soft-money researchers as well as graduate students, post-docs, and other lab staff during the COVID-19 epidemic, if the institution's own policies allow for it

Allows for institutions to charge restart costs to their grants

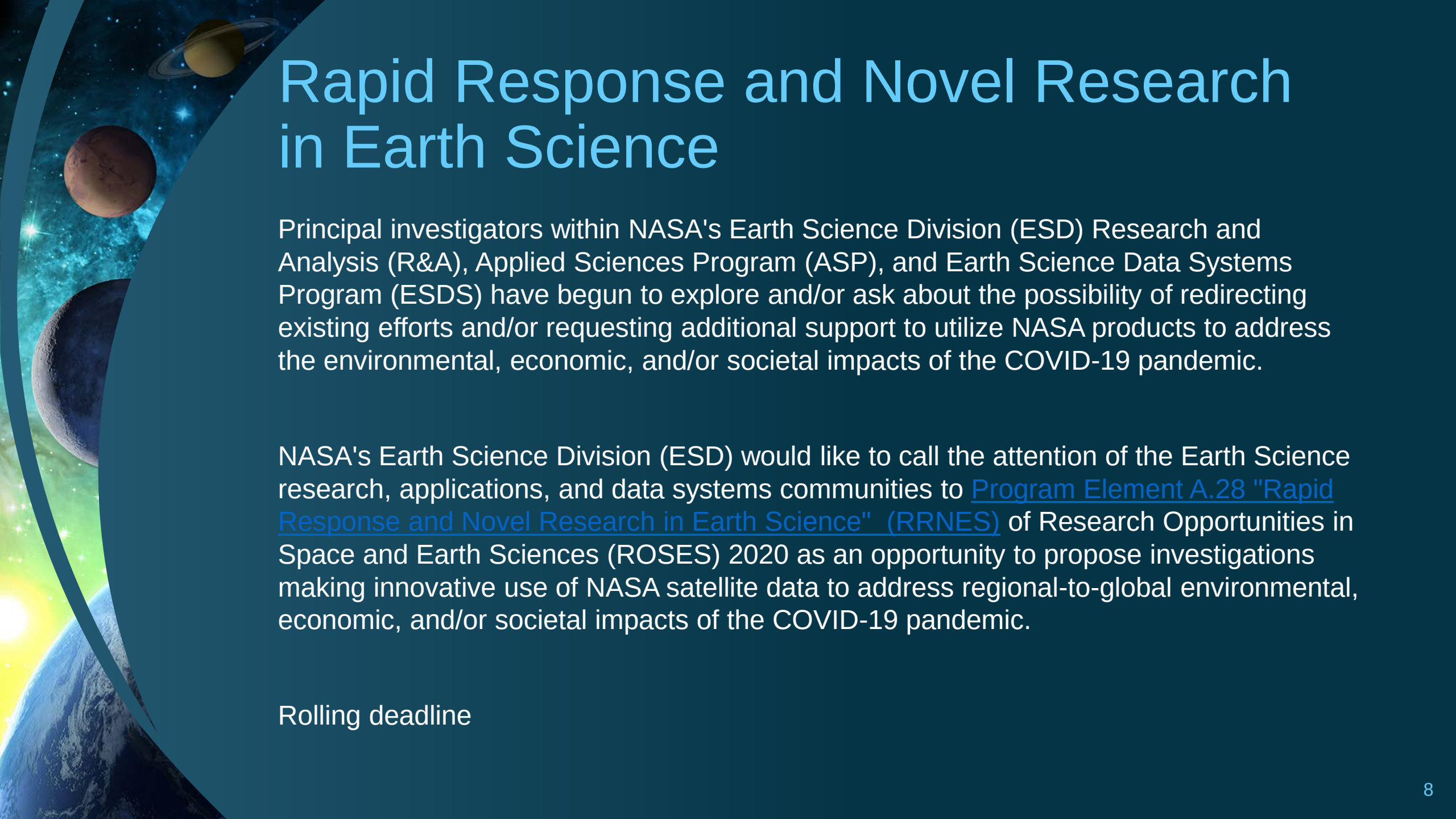
- Assuming sufficient funding is available, SMD will make use of this authority to allow other costs associated with resuming funded grant activities to be charged to currently active grants
- It is likely that any policy or practice on augmentations will not be issued until the impacts of the pandemic are understood better

Provides agencies flexibility with regard to the submission of proposals

- SMD's policy on late proposals will be applied leniently on a case-by-case basis
- Proposals started before the due date but not completely submitted until after the due date because of the impacts of the COVID-19 epidemic will be strongly considered for acceptance if they are submitted within seven calendar days of the due date.
- Proposals not yet started in NSPIRES by the time of the due date and submitted after the due date will only be accepted after an analysis of the particular reasons for the late start/late submission by the program element point of contact and with the agreement of the selecting official.

NASA Participates in COVID-19 High Performance Computing Consortium

- On March 29, the White House announced the formation of a public-private partnership to make high performance computing cycles available to researchers to “significantly advance the pace of scientific discovery in the fight to stop the virus.”
- Participants include industry, academic institutions, laboratories from DOE, and other agencies (NASA, NSF).
- Researchers are invited to submit COVID-19 related research proposals to the consortium via the [online portal](#) which will then be reviewed and matched with computing resources from one of the partner institutions.
- An expert panel of top scientists and computing researchers will work with proposers to quickly assess the public health benefit of the work and coordinate the allocation of the group’s powerful computing assets.
- The consortium now includes 16 systems offering a total of 330 petaflops; additional capacity will be added through present and future partners.
- NASA is providing computational and subject matter (1 microbiologists and 2 MDPHs from ESD) experts to support the review process.

A space-themed background featuring a curved view of Earth's horizon at the bottom left, with a bright sun or star partially visible. Above the horizon, several celestial bodies are shown: a crescent moon, a reddish planet (Mars), and a yellow planet with rings (Saturn). The background is a deep blue with scattered white stars and nebulae.

Rapid Response and Novel Research in Earth Science

Principal investigators within NASA's Earth Science Division (ESD) Research and Analysis (R&A), Applied Sciences Program (ASP), and Earth Science Data Systems Program (ESDS) have begun to explore and/or ask about the possibility of redirecting existing efforts and/or requesting additional support to utilize NASA products to address the environmental, economic, and/or societal impacts of the COVID-19 pandemic.

NASA's Earth Science Division (ESD) would like to call the attention of the Earth Science research, applications, and data systems communities to [Program Element A.28 "Rapid Response and Novel Research in Earth Science" \(RRNES\)](#) of Research Opportunities in Space and Earth Sciences (ROSES) 2020 as an opportunity to propose investigations making innovative use of NASA satellite data to address regional-to-global environmental, economic, and/or societal impacts of the COVID-19 pandemic.

Rolling deadline

The background of the slide is a composite of two cosmic images. The top half features a dark blue and black space scene with a bright, glowing blue nebula on the right side and several distant stars. The bottom half shows a vibrant orange and yellow nebula on the left, transitioning into a greenish-blue nebula on the right, with numerous stars scattered throughout.

ESD Overview and Budget Update

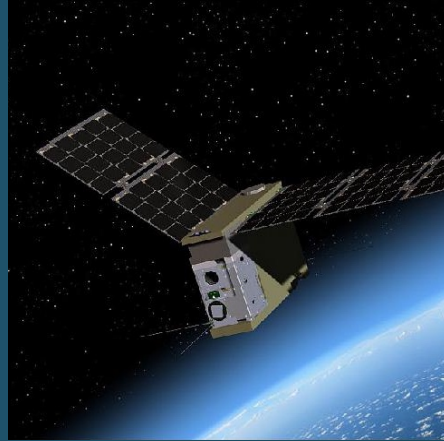
Earth Science Overview

Strategic Objective

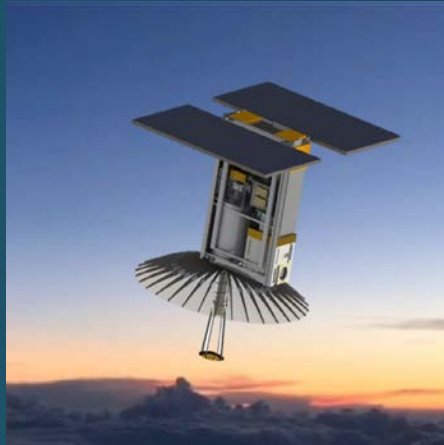
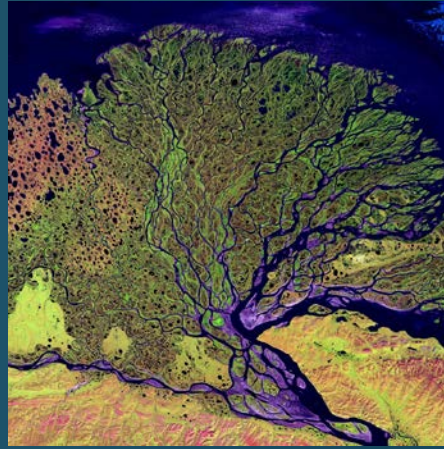
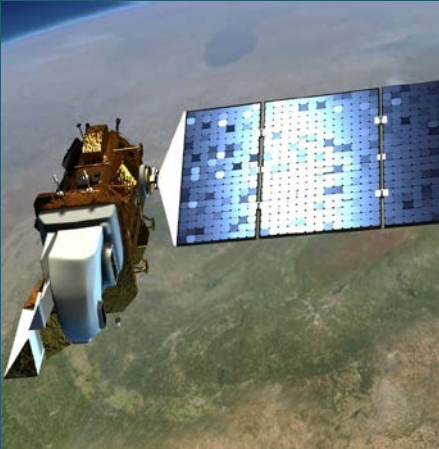
- Advance knowledge of Earth as a system to meet the challenges of environmental change and to improve life on our planet

Major Activities

- Build and operate Earth observing satellite missions, many with international and interagency partners
- Conduct and sponsor cutting-edge, interdisciplinary research
 - Field campaigns and airborne missions to complement and validate satellite measurements
 - Analyses of NASA and non-NASA mission data
 - Numerical modeling of the Earth System
- Make high-quality data products available to broad science, applications, and private sector communities, and to other federal, state and local government agencies
- Develop and demonstrate applications delivering societal benefit, support resource management, and build user capacity
- Advance Earth observation technologies, including development and demonstration of science-focused CubeSat/SmallSat instrumentation and constellations, to complement global climate observations



Earth Science



- Supports 15 orbital Program of Record missions/instruments identified and recommended by 2007 Decadal Survey and emphasized in the 2017 Decadal Survey
- Includes robust SmallSat/CubeSat programs for science and technology development
- Implements Decadal-recommended Flight/Technology activities, including Earth Venture-Continuity
- Conducts pre-formulation Decadal mission/observing system studies for Designated Observables in preparation for Decadal wedge, opening in FY21
- Provides substantial support to national and interagency satellite programs and international partnerships, including Landsat
- Expands commercial/private sector integration through Commercial SmallSat Data Acquisition, commercial hosting in GEO and LEO, and partnerships with Google, Microsoft, Conservation International, and Mercy Corps

NASA EARTH FLEET

OPERATING & FUTURE

INVEST/CUBESATS

RainCube
CSIM-FD
CubeRRT
TEMPEST-D
CIRiS
HARP
CTIM
HyTI
SNoOPI
NACHOS

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

NASA EARTH FLEET

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(PRE) FORMULATION ●
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PRIMARY OPS ●
EXTENDED OPS ●

CYGNSS (8)
NISTAR, EPIC (DISCOVER/NOAA)

CLOUDSAT (CSA)

TERRA (JAXA, CSA)

AQUA (JAXA, AEB)

AURA (NSO, FMI, UKSA)

CALIPSO (CNES)

GPM (JAXA)

LANDSAT 7 (USGS)

LANDSAT 8 (USGS)

OCO-2

SMAP

SUOMI NPP (NOAA) (JAXA)

GRACE-FO (2) (DLR)

ICESAT-2

PACE (NSO)

TEMPO

MAIA

GEOCARB

SWOT (CNES)

LANDSAT-9 (USGS) SENTINEL-6 Michael Freilich/B (ESA)

TROPICS (6)

NISAR (ISRO)

TSIS-2

PREFIRE (2)

GLIMR

ISS INSTRUMENTS

EMIT

CLARREO-PF

GEDI

SAGE III

OCO-3

TSIS-1

ECOSTRESS

LIS

JPSS-2, 3 & 4 INSTRUMENTS

OMPS-Limb

LIBERA

03.03.20

NASA EARTH FLEET

OPERATING & FUTURE
President's FY21 Budget Request

INVEST/CUBESATS

RainCube
CSIM-FD
CubeRRT
TEMPEST-D
CIRiS
HARP
CTIM
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SNoOPI
NACHOS

(PRE) FORMULATION ●
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SWOT (CNES)
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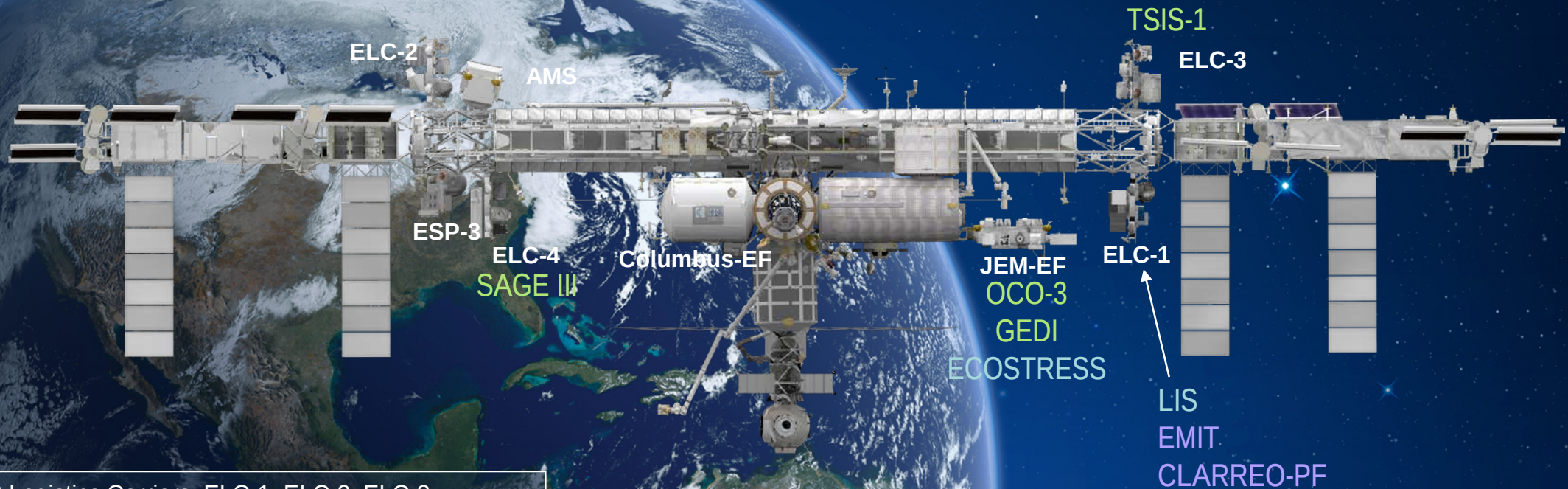
ISS INSTRUMENTS
EMIT
GEDI
SAGE III
OCO-3
TSIS-1
ECOSTRESS
LIS

JPSS-2, 3 & 4 INSTRUMENTS

OMPS-Limb
LIBERA

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 ●

INTERNATIONAL SPACE STATION

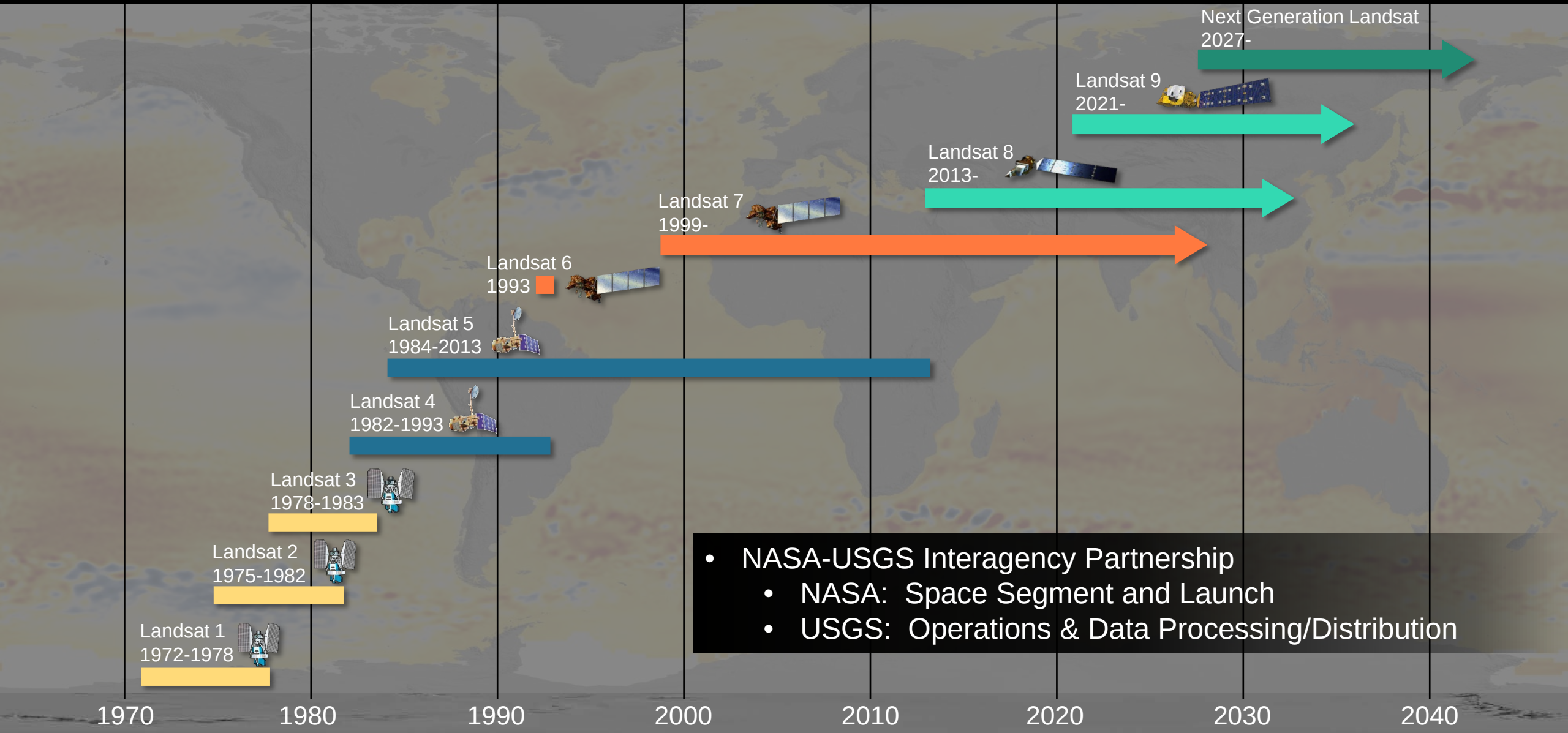
EARTH SCIENCE OPERATING MISSIONS
President's FY 21 Budget Request

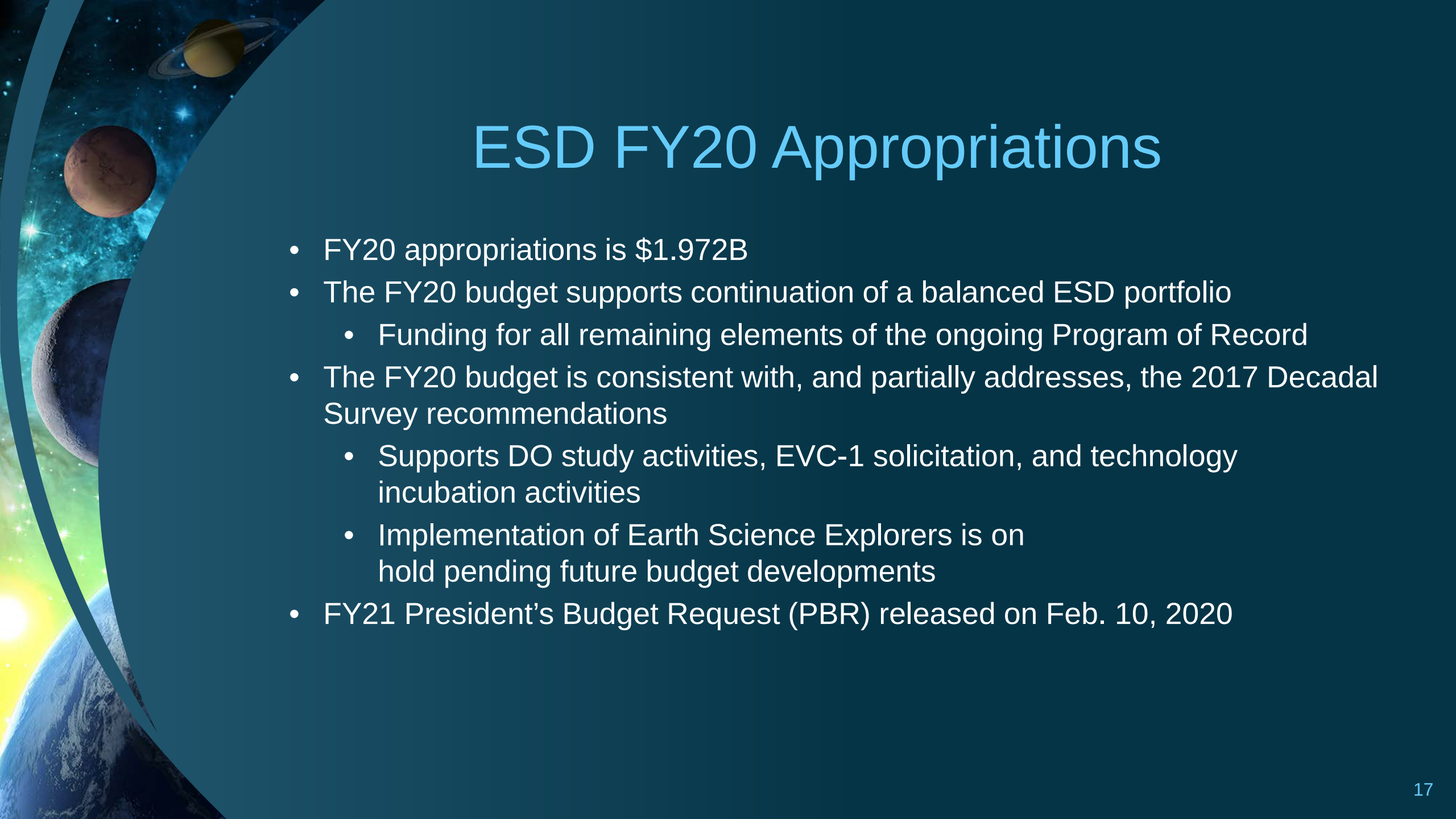


EXPRESS Logistics Carriers: ELC-1, ELC-2, ELC-3
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(PRE) FORMULATION ●
IMPLEMENTATION ●
PRIMARY OPS ●
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Building on the Landsat Legacy



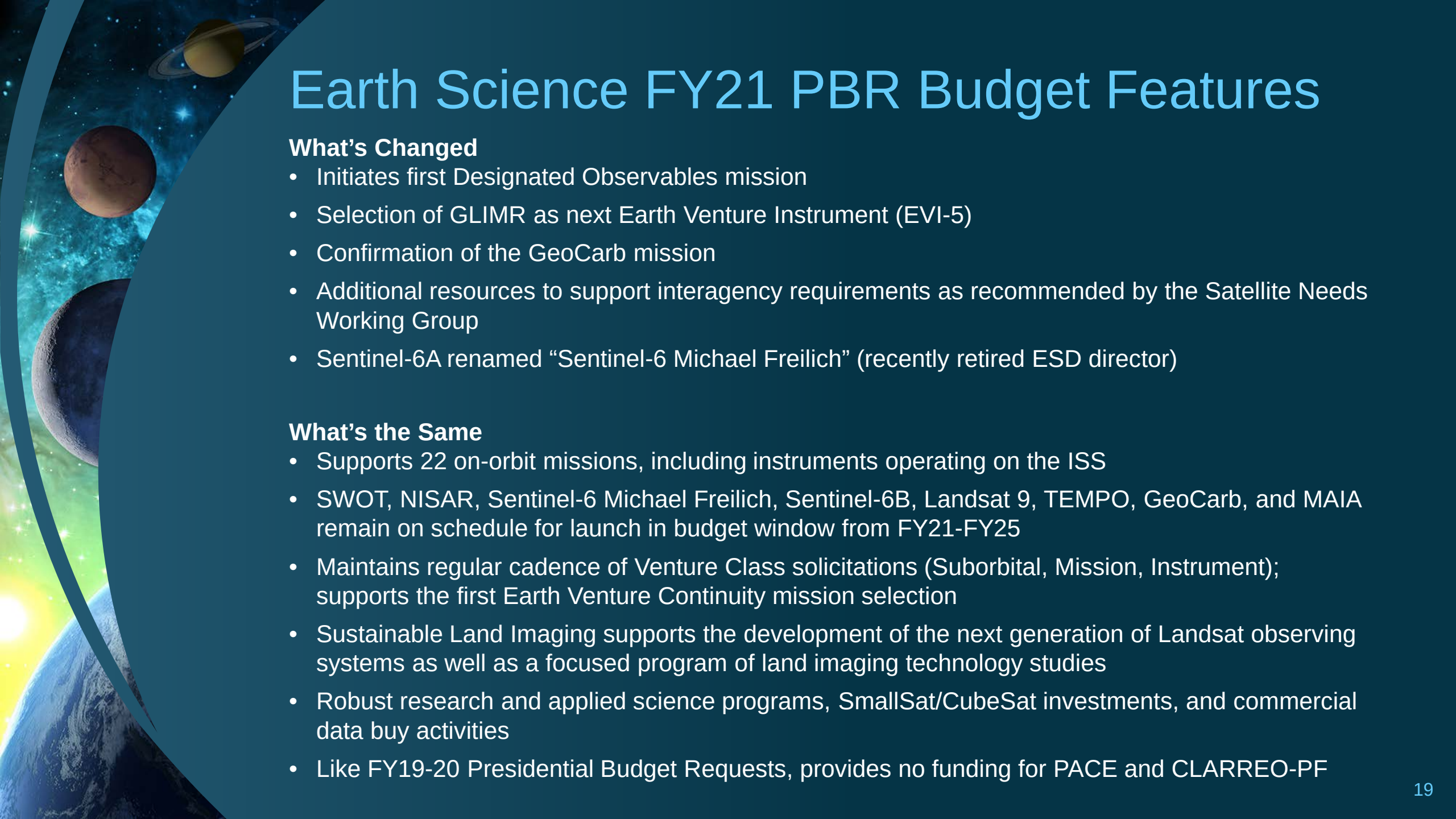
The background of the slide features a deep blue space theme. On the left side, there is a vertical strip showing a bright yellow sun at the bottom, followed by the blue and white horizon of Earth. Above Earth, a grey, cratered moon is visible. Further up, a reddish-brown planet (Mars) and a yellow planet with a ring system (Saturn) are shown against a backdrop of a blue and green nebula and distant stars.

ESD FY20 Appropriations

- FY20 appropriations is \$1.972B
- The FY20 budget supports continuation of a balanced ESD portfolio
 - Funding for all remaining elements of the ongoing Program of Record
- The FY20 budget is consistent with, and partially addresses, the 2017 Decadal Survey recommendations
 - Supports DO study activities, EVC-1 solicitation, and technology incubation activities
 - Implementation of Earth Science Explorers is on hold pending future budget developments
- FY21 President's Budget Request (PBR) released on Feb. 10, 2020

FY21 Science Budget Request Summary (\$M)

	Actual FY 19	Request FY 20	Enacted FY 20	Request FY 21	Out-years			
					FY 22	FY 23	FY 24	FY 25
<u>Science</u>	<u>6,886.6</u>	<u>6,393.7</u>	<u>7,138.9</u>	<u>6,306.5</u>	<u>6,553.5</u>	<u>6,575.7</u>	<u>6,705.2</u>	<u>6,766.9</u>
<u>Earth Science</u>	<u>1,931.0</u>	<u>1,779.8</u>	<u>1,971.8</u>	<u>1,768.1</u>	<u>1,878.2</u>	<u>1,846.1</u>	<u>1,834.5</u>	<u>1,984.6</u>
Earth Science Research	454.1	447.9		447.3	471.9	494.1	528.5	530.3
Earth Systematic Missions	932.7	719.2		608.3	706.1	695.6	640.7	797.3
Earth System Science Pathfinder	223.8	275.4		338.9	301.2	251.6	241.8	234.4
Earth Science Data Systems	202.0	214.4		245.4	259.9	263.2	278.7	277.7
Earth Science Technology	63.4	69.6		74.2	82.8	84.6	86.4	86.4
Applied Sciences	55.1	53.3		53.9	56.3	57.0	58.5	58.5
<u>Planetary Science</u>	<u>2,746.7</u>	<u>2,712.1</u>	<u>2,713.4</u>	<u>2,659.6</u>	<u>2,800.9</u>	<u>2,714.9</u>	<u>2,904.8</u>	<u>2,830.7</u>
Planetary Science Research	276.6	266.2		305.4	288.6	285.1	295.2	286.7
Planetary Defense	150.0	150.0	160.0	150.0	147.2	97.6	98.0	98.0
Lunar Discovery and Exploration	188.0	300.0	300.0	451.5	517.3	491.3	458.3	458.3
Discovery	409.5	502.7		484.3	424.4	434.8	570.1	505.8
New Frontiers	93.0	190.4		179.0	314.3	332.8	326.9	285.0
Mars Exploration	712.7	546.5	570.0	528.5	588.4	671.2	798.7	855.3
Outer Planets and Ocean Worlds	793.6	608.4		414.4	370.7	239.4	192.3	171.7
Radioisotope Power	123.3	147.9	147.9	146.3	150.1	162.8	165.4	169.8
<u>Astrophysics</u>	<u>1,191.1</u>	<u>844.8</u>	<u>1,306.2</u>	<u>831.0</u>	<u>891.2</u>	<u>1,000.9</u>	<u>959.7</u>	<u>975.5</u>
Astrophysics Research	222.8	250.7		269.7	279.1	327.2	314.9	331.1
Cosmic Origins	222.8	185.3		124.0	123.2	120.0	122.4	122.4
Physics of the Cosmos	151.2	148.4		143.9	160.8	155.3	169.8	154.1
Exoplanet Exploration	367.9	46.4		47.2	50.4	47.6	51.6	52.2
Astrophysics Explorer	226.5	214.1		246.2	277.7	350.8	301.0	315.6
<u>James Webb Space Telescope</u>	<u>305.1</u>	<u>352.6</u>	<u>423.0</u>	<u>414.7</u>	<u>175.4</u>	<u>172.0</u>	<u>172.0</u>	<u>172.0</u>
<u>Heliophysics</u>	<u>712.7</u>	<u>704.5</u>	<u>724.5</u>	<u>633.1</u>	<u>807.8</u>	<u>841.8</u>	<u>834.1</u>	<u>804.1</u>
Heliophysics Research	248.9	237.0		230.5	218.7	225.2	224.0	224.5
Living with a Star	135.3	107.6		127.9	134.5	246.4	225.5	233.3
Solar Terrestrial Probes	180.5	177.9	183.2	126.3	262.2	202.6	195.6	115.5
Heliophysics Explorer Program	147.9	182.0	182.0	148.4	192.4	167.6	189.0	230.8



Earth Science FY21 PBR Budget Features

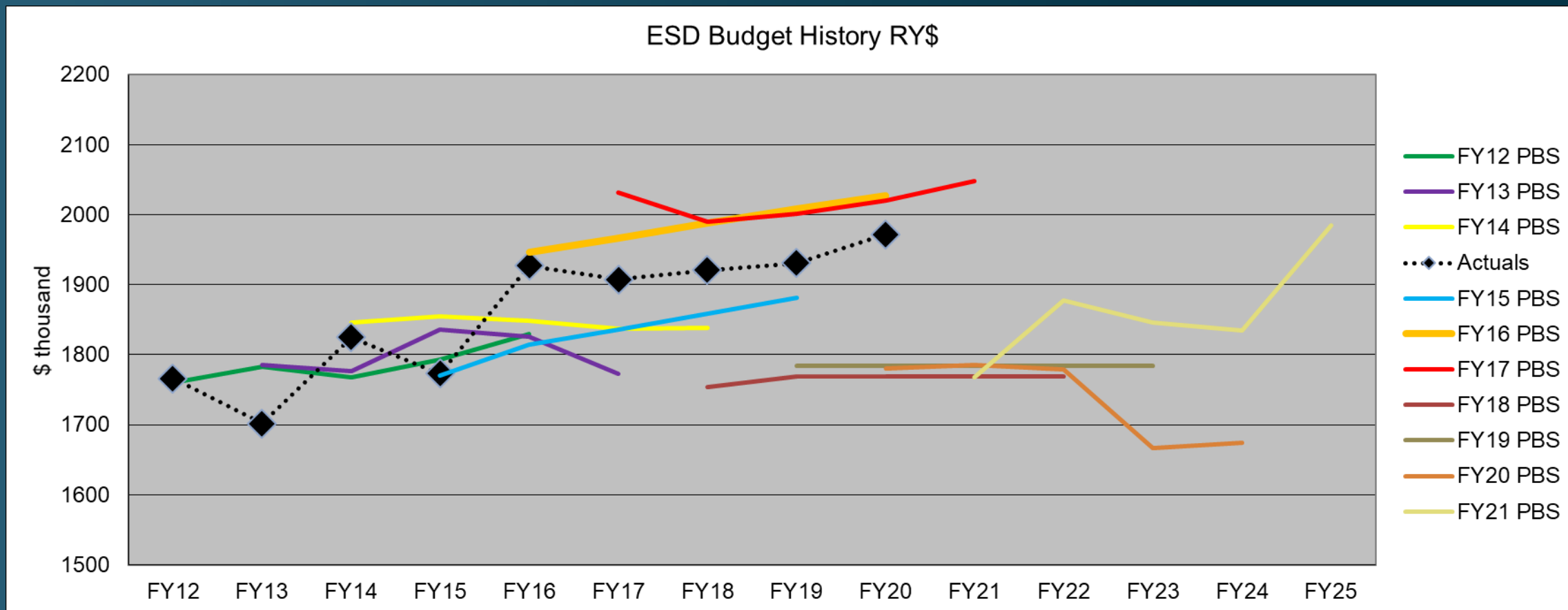
What's Changed

- Initiates first Designated Observables mission
- Selection of GLIMR as next Earth Venture Instrument (EVI-5)
- Confirmation of the GeoCarb mission
- Additional resources to support interagency requirements as recommended by the Satellite Needs Working Group
- Sentinel-6A renamed “Sentinel-6 Michael Freilich” (recently retired ESD director)

What's the Same

- Supports 22 on-orbit missions, including instruments operating on the ISS
- SWOT, NISAR, Sentinel-6 Michael Freilich, Sentinel-6B, Landsat 9, TEMPO, GeoCarb, and MAIA remain on schedule for launch in budget window from FY21-FY25
- Maintains regular cadence of Venture Class solicitations (Suborbital, Mission, Instrument); supports the first Earth Venture Continuity mission selection
- Sustainable Land Imaging supports the development of the next generation of Landsat observing systems as well as a focused program of land imaging technology studies
- Robust research and applied science programs, SmallSat/CubeSat investments, and commercial data buy activities
- Like FY19-20 Presidential Budget Requests, provides no funding for PACE and CLARREO-PF

ESD Budget History



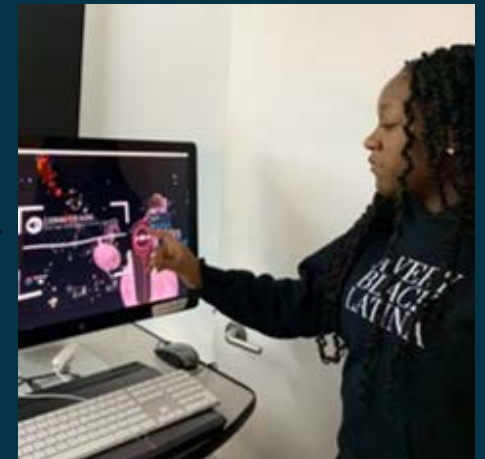


Planned Accomplishments FY20-21

- Selection of Libera, first Earth Venture Continuity mission under the 2017 Earth Science Decadal Survey recommendation, targeted for radiation budget
- Release of Announcement of Opportunity for EVM-3, including an enhanced operations option for NOAA
- Initiation of Earth Venture Sub-Orbital-3 campaigns throughout FY20 and FY21
 - Airborne science campaigns slated to deploy across the country this spring have rescheduled their field activity until later in the year: DeltaX, Dynamics and Chemistry of the Summer Stratosphere (DCOTTs), and Sub-Mesoscale Ocean Dynamics Experiment (S-MODE)
- Complete System Integration Reviews (SIRs) for Landsat 9, SWOT, NISAR
- Launch six InVEST CubeSats: HARP (3U), CIRiS (6U), CTIM (6U), SNoOPI, TACOS and HyTI (6U) in budget window
- Launch Sentinel-6 Michael Freilich, Landsat-9 and TEMPO
- NASA to select next Health & Air Quality Applied Sciences Team with rapid-result projects in collaboration with businesses and state and local governments
- NASA/USAID SERVIR Amazonia Hub to have first full year of activities and operation

2019 International Space Apps Challenge

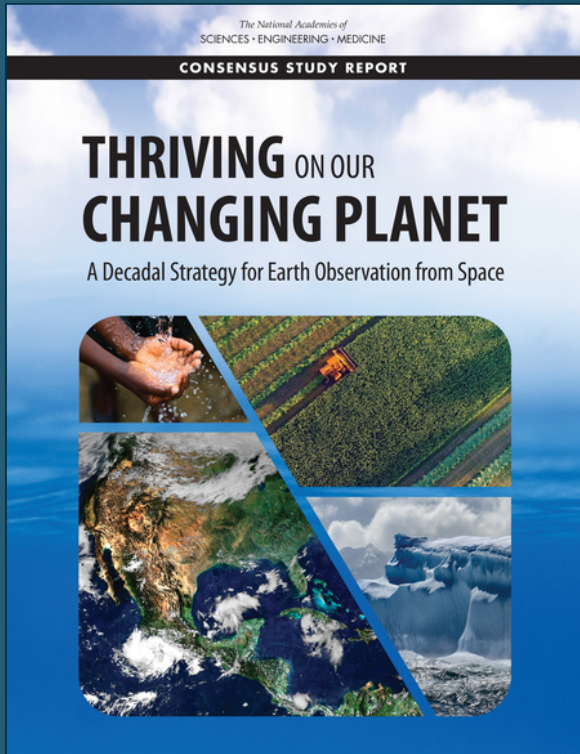
- International Space Apps Challenge hackathon took place within 48 hours in cities around the world through 225 events, 71 countries, 3,381 teams, and 55 million plus users reached using #SpaceApps
- Coders, scientists, designers, storytellers, makers, builders, and technologists coming together to address challenges on Earth and in space
- Pairing NASA's data with problem solvers across the globe for exciting, collaborative, scientific exploration
- 29,000+ registrations
- 37.5% of volunteer event leads were women
- Space Apps 2019: Global winners announced Jan. 22, 2020
- Space Apps 2020:
 - February 2020: Local event registration will open
 - July 2020: Participant registration opens
 - August 2020: Challenges will be posted
 - Oct. 2-4, 2020: Space Apps 2020



The background of the slide is a cosmic scene. The top half features a dark blue space with a bright blue nebula on the right and scattered white stars. The bottom half is a gradient of orange and yellow, also filled with numerous white stars of varying sizes. A dark blue horizontal band separates the two cosmic images, serving as the background for the title text.

Decadal Implementation Update

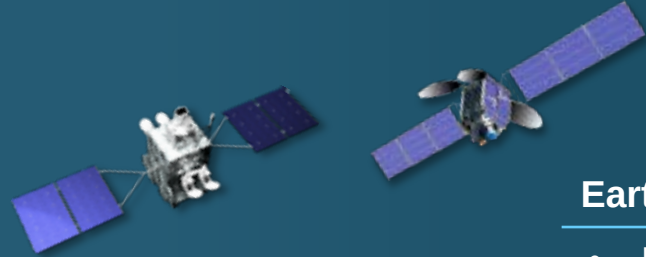
2017 Decadal Survey Snapshot



ESD is working with the community to translate the recommendations into an executable program and, for Flight, a portfolio of specific, realistic, launch-ordered missions and solicitations

- Publicly released Jan. 5, 2018
- Supports the ESD (and international) Program of Record and endorses existing balances in ESD portfolio
- Prioritizes observations rather than specific missions and allows implementation flexibility
- Emphasis on competition as cost-control method
- Explicitly encourages and notes value of international partnerships
- Recommends “Continuity Measurement” strand (\$150M full mission cost cap) as an addition to the existing Venture-class program
- Identifies 5 “Designated” Observables for mandatory acquisition (Aerosols; Clouds, Convection & Precipitation; Mass Change; Surface Biology & Geology; Surface Deformation & Change)
- Introduces a new competed “Explorer” flight line with \$350M cost constraint, 3 observables to be chosen by ESD from among 6 identified
- Calls for “Decadal Incubation Program” between Technology, R&A, and Flight to mature specific technologies for important – but presently immature – measurements (preparation for next Decadal): Planetary Boundary Layer (PBL) and Surface Topography and Vegetation (ST&V)
- Decadal new mission budget wedge opens late FY21

2017 Decadal Survey Progress Highlights



Earth Venture-Continuity

- 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

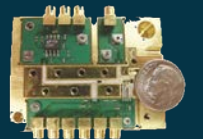
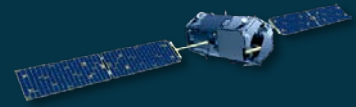
- DS recommended a new competed Explorer flight line with \$350M cost constraint
- Implement 3 of 7 Targeted Observables
- Framework for program established
- Implementation on hold pending budget developments

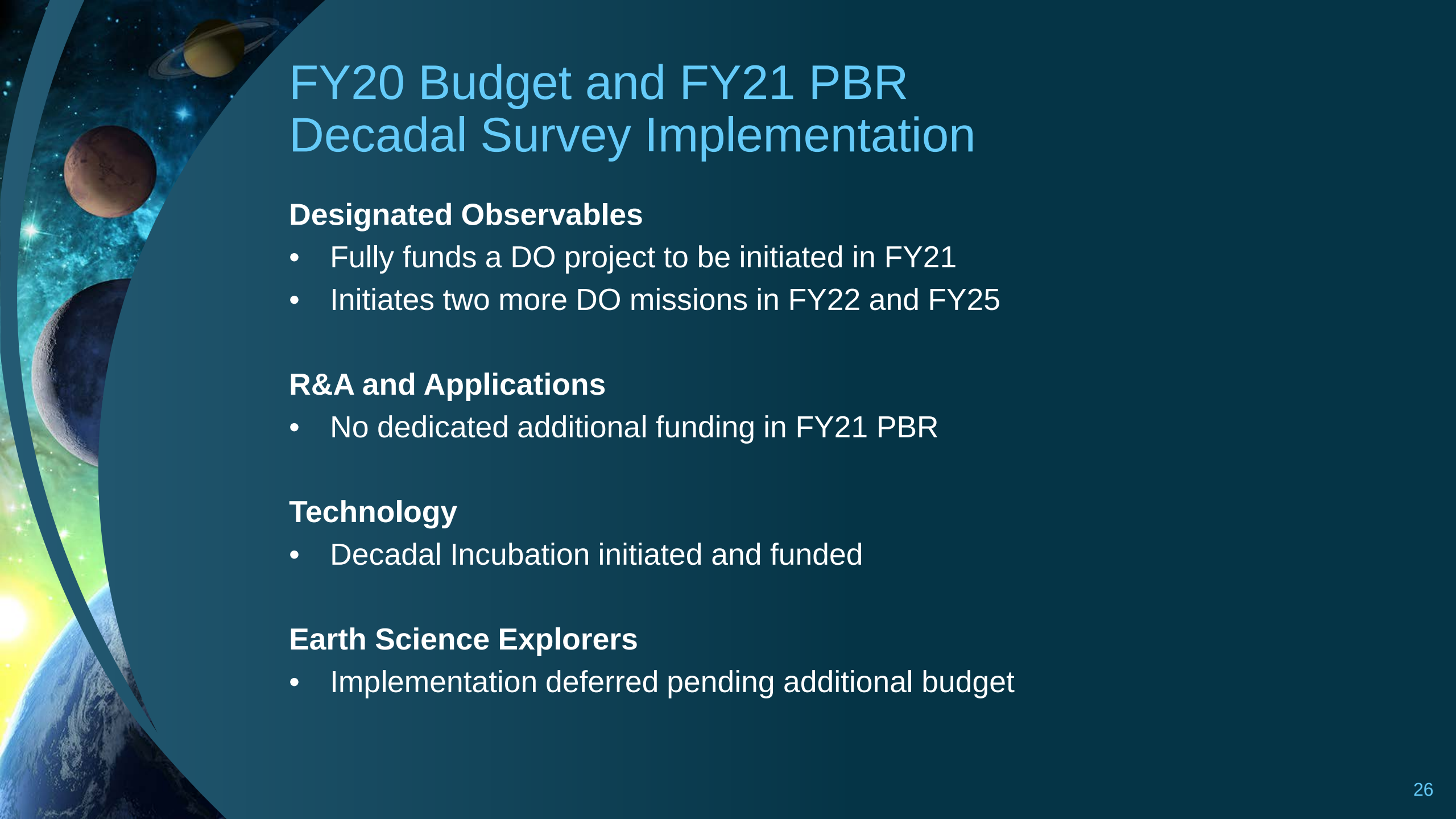
Decadal Incubation

- 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
- Fully funds a DO project to be initiated in FY21
- Initiates two more DO missions in FY22 and FY25



A decorative background on the left side of the slide featuring a curved, semi-circular frame. Inside the frame, there is a depiction of outer space with a bright yellow sun at the bottom left, a blue and white Earth at the bottom, and several other celestial bodies including a reddish planet (Mars), a yellow planet with rings (Saturn), and a grey cratered planet (Moon) in the upper left. The background of the slide is a solid dark blue.

FY20 Budget and FY21 PBR Decadal Survey Implementation

Designated Observables

- Fully funds a DO project to be initiated in FY21
- Initiates two more DO missions in FY22 and FY25

R&A and Applications

- No dedicated additional funding in FY21 PBR

Technology

- Decadal Incubation initiated and funded

Earth Science Explorers

- Implementation deferred pending additional budget

Earth Science Division's Venture Opportunities

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

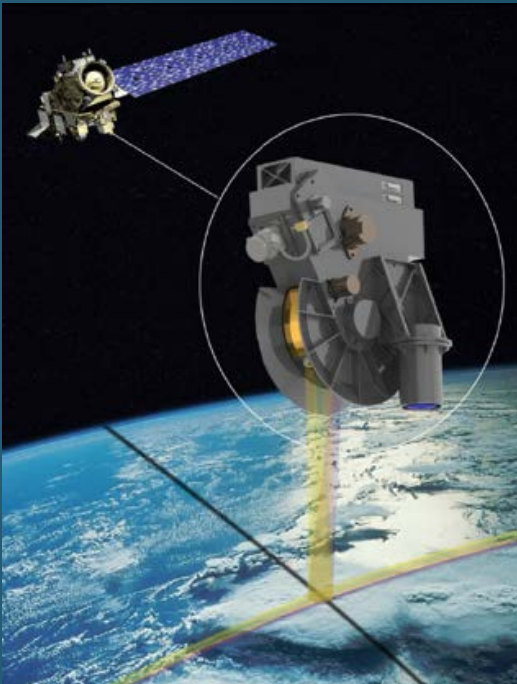
Open solicitation - In Review

Completed solicitation

EVM-3 will include an Enhanced Operations Option jointly with NOAA

Earth Venture Continuity-1: Libera

(Li'be-ra), named for the daughter of Ceres in ancient Roman mythology



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

- Measures integrated shortwave (0.3–5 μm), longwave (5–50 μm), total (0.3–>100 μm) and (new) split-shortwave (0.7–5 μm) 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:

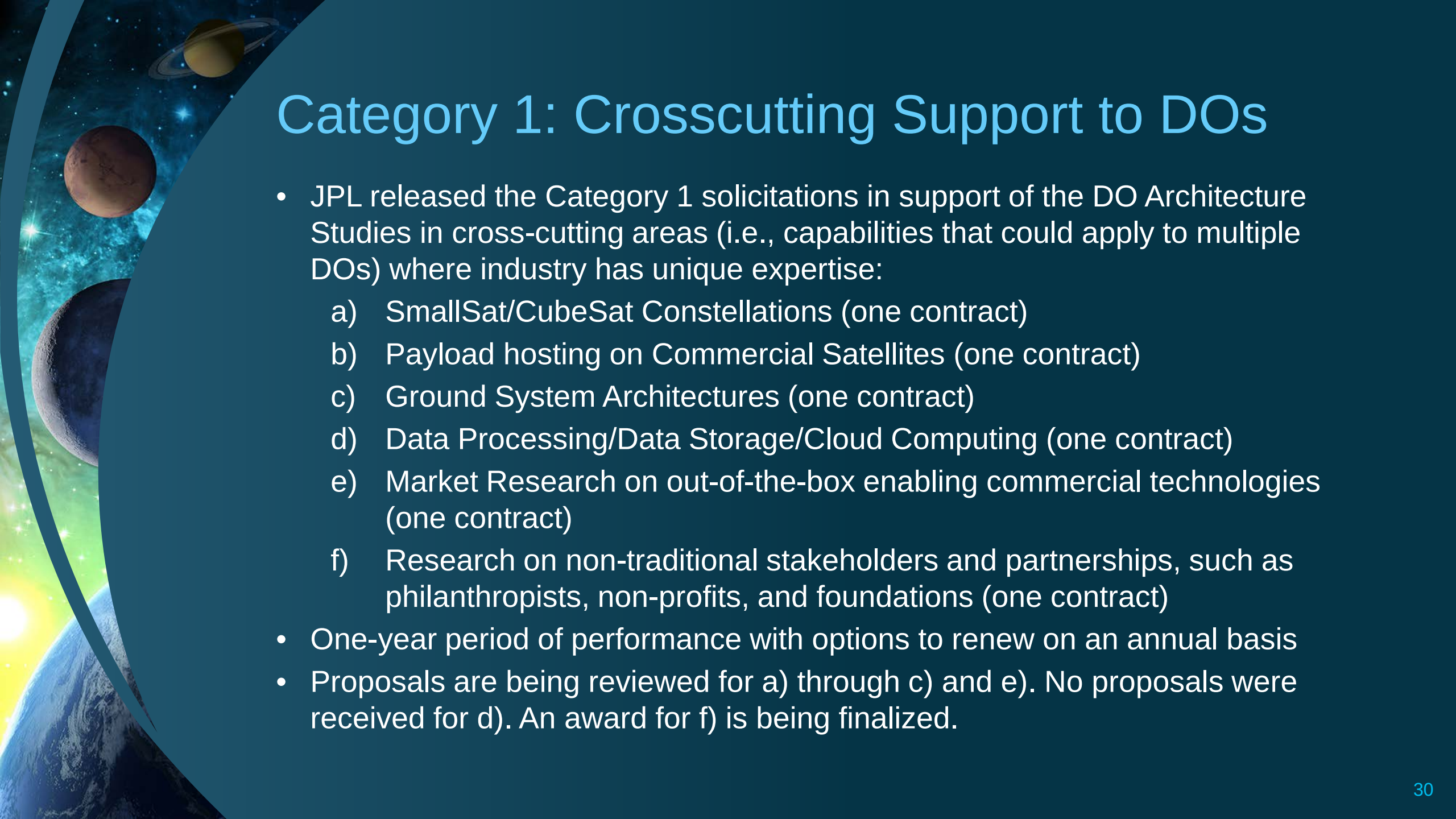
- JPSS-3
- 2027 launch
- 5-year mission
- Follows pattern of CERES hosted on JPSS-1

Participating Organizations			
Investigation Management and Instrument Development		Science	
 LASP	PI Institution, Mission and Investigation Leadership, L1 Data Processing, MOC	JPL/CSU	Deputy PI and Science Team Leadership
		LBL	Climate OSSE and Model Testing
	Flight Instrument Support, AI&T, Instrument and Calibration Science	UA	Surface Energy Budget
	Detector Development and Characterization	CSU	Science Data Continuity Validation
		UM	Infrared Radiation Budget
 Space Dynamics	Pre-flight Calibration	CIRES/NOAA	Angular Distribution Models

DO Industry Engagement: Updates on Solicitations

	Description	Supported Activity	Date of solicitation
Category 1	Cross-cutting expertise in specific areas	All of the DOs	Dec 2019
Category 2	Support to HQ	HQ Decadal Strategy	TBD
Category 3	Technology Demonstrations	Specific to each DO	Inputs received from study teams*
Category 4	Applications Support	All of the DOs	March 2020

* Some of these requests overlap with existing ESTO or SBIR tasks, so those are being augmented. We are also looking into how to do quicker solicitations (2-3 months in lieu of 6-9 months) to have solicitations in FY20.



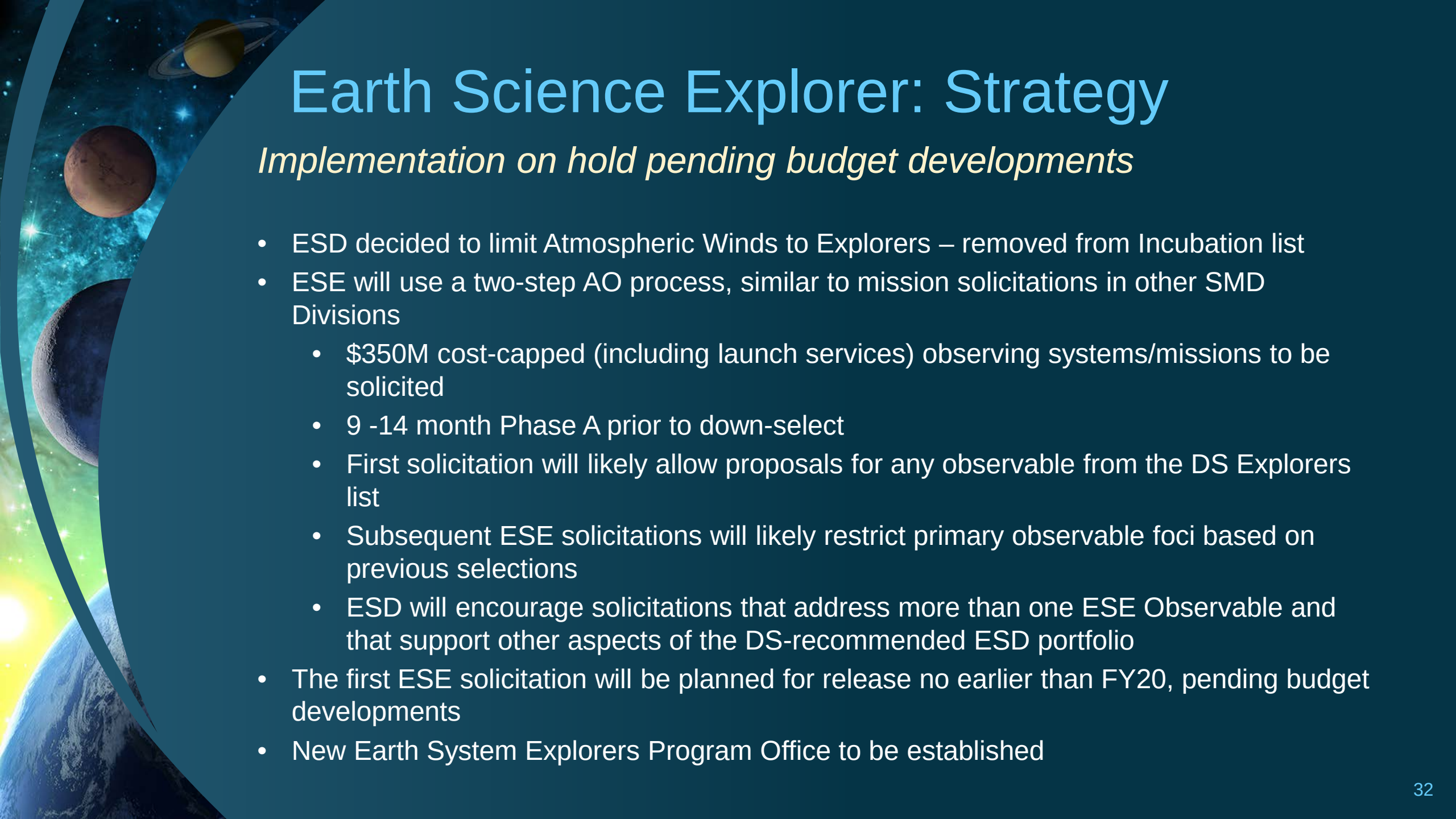
Category 1: Crosscutting Support to DOs

- JPL released the Category 1 solicitations in support of the DO Architecture Studies in cross-cutting areas (i.e., capabilities that could apply to multiple DOs) where industry has unique expertise:
 - a) SmallSat/CubeSat Constellations (one contract)
 - b) Payload hosting on Commercial Satellites (one contract)
 - c) Ground System Architectures (one contract)
 - d) Data Processing/Data Storage/Cloud Computing (one contract)
 - e) Market Research on out-of-the-box enabling commercial technologies (one contract)
 - f) Research on non-traditional stakeholders and partnerships, such as philanthropists, non-profits, and foundations (one contract)
- One-year period of performance with options to renew on an annual basis
- Proposals are being reviewed for a) through c) and e). No proposals were received for d). An award for f) is being finalized.

The background of the slide features a deep blue space theme. On the left side, there is a vertical strip showing a bright yellow sun at the bottom, followed by the blue and white horizon of Earth. Above Earth, the dark, cratered surface of the Moon is visible. Further up, a reddish-brown planet (Mars) and a yellow planet with a prominent ring system (Saturn) are shown against a backdrop of distant stars and nebulae. A large, semi-transparent dark blue circle is positioned on the right side of the slide, partially overlapping the text area.

Category 4: Applications Support to DOs

- ESD is working with JPL & LaRC to release the Category 4 solicitations to fund industry to help in the assessment of Applications Communities in support of the DO studies.
 - JPL is handling the Category 4 for SBG
 - LaRC is handling the Category 4 for A-CCP, SDC, and MC
- This industry support complements work by the DO team in identifying new users, preparing the Community Assessment Report, and ongoing engagement with non-research users.
- Intent is to broaden engagement with user communities beyond traditional and customary ones (e.g., federal agencies) and reach new users and audiences, especially private sector and non-profits.
- One-year period of performance with options to renew on an annual basis.



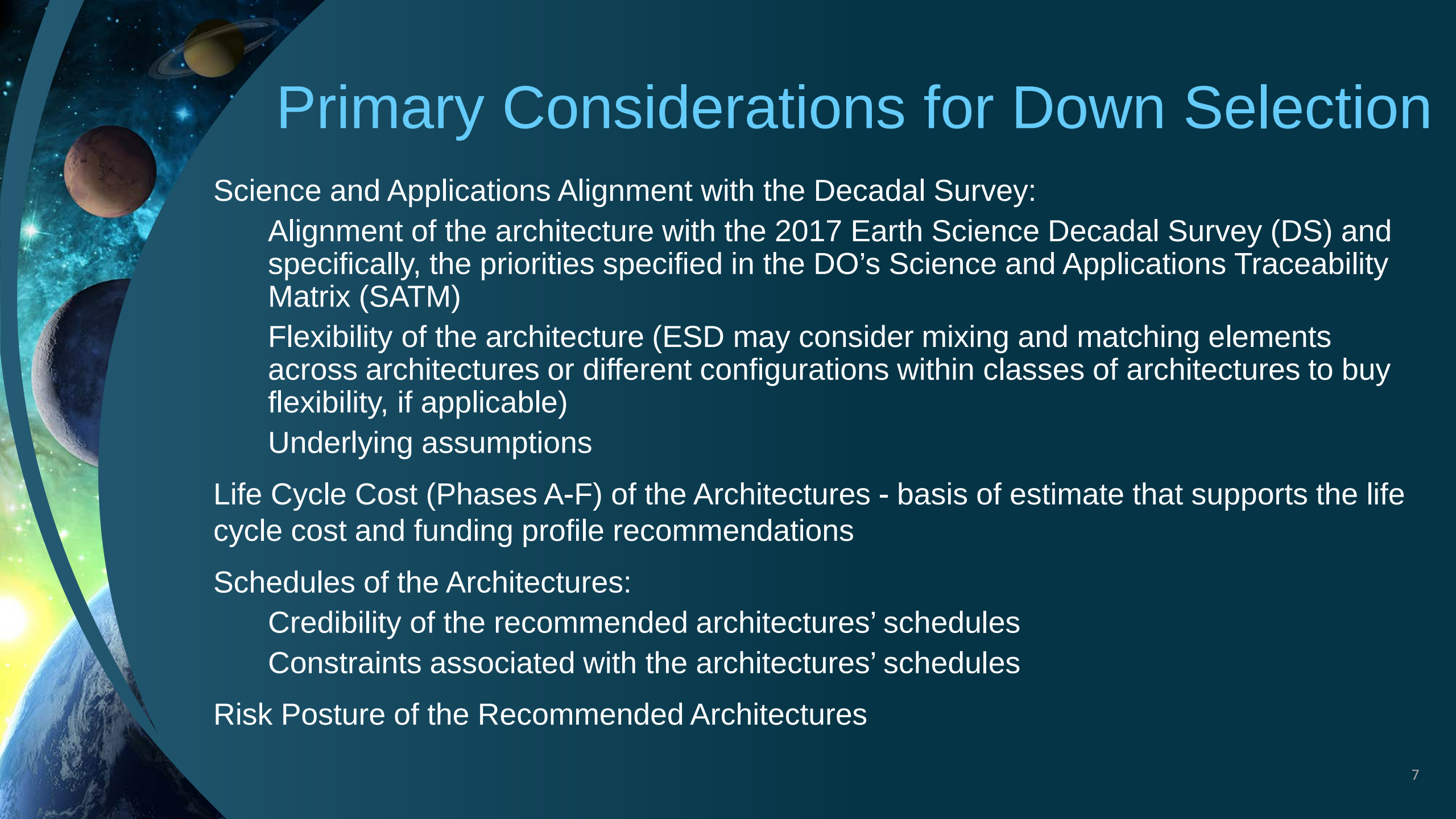
Earth Science Explorer: Strategy

Implementation on hold pending budget developments

- ESD decided to limit Atmospheric Winds to Explorers – removed from Incubation list
- ESE will use a two-step AO process, similar to mission solicitations in other SMD Divisions
 - \$350M cost-capped (including launch services) observing systems/missions to be solicited
 - 9 -14 month Phase A prior to down-select
 - First solicitation will likely allow proposals for any observable from the DS Explorers list
 - Subsequent ESE solicitations will likely restrict primary observable foci based on previous selections
 - ESD will encourage solicitations that address more than one ESE Observable and that support other aspects of the DS-recommended ESD portfolio
- The first ESE solicitation will be planned for release no earlier than FY20, pending budget developments
- New Earth System Explorers Program Office to be established

The background of the slide is a cosmic image featuring a dark blue nebula in the upper right and a bright orange and yellow nebula in the lower left, with numerous stars scattered throughout.

Considerations for DO Final Architecture Down Selection



Primary Considerations for Down Selection

Science and Applications Alignment with the Decadal Survey:

- Alignment of the architecture with the 2017 Earth Science Decadal Survey (DS) and specifically, the priorities specified in the DO's Science and Applications Traceability Matrix (SATM)

- Flexibility of the architecture (ESD may consider mixing and matching elements across architectures or different configurations within classes of architectures to buy flexibility, if applicable)

- Underlying assumptions

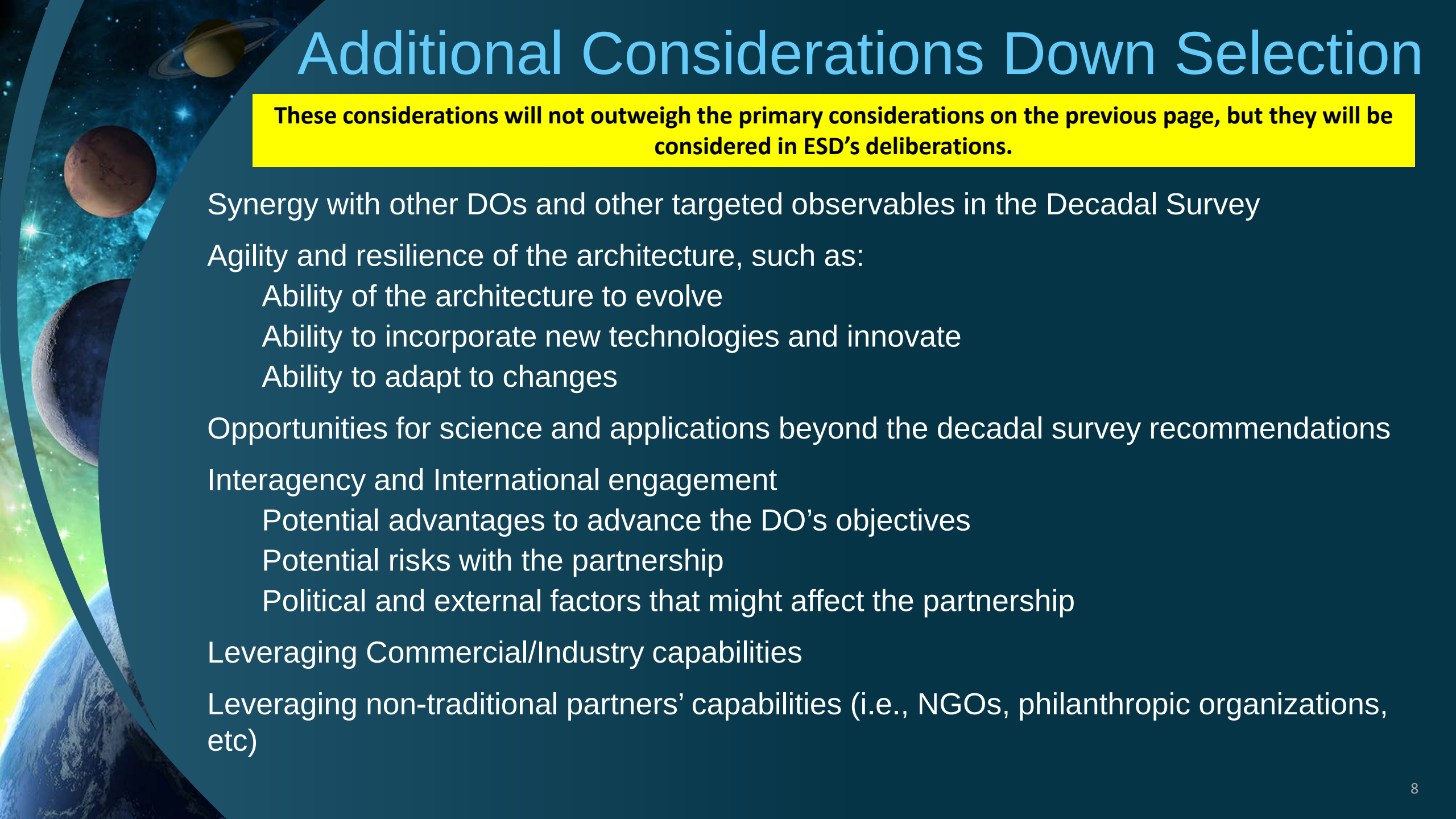
Life Cycle Cost (Phases A-F) of the Architectures - basis of estimate that supports the life cycle cost and funding profile recommendations

Schedules of the Architectures:

- Credibility of the recommended architectures' schedules

- Constraints associated with the architectures' schedules

Risk Posture of the Recommended Architectures



Additional Considerations Down Selection

These considerations will not outweigh the primary considerations on the previous page, but they will be considered in ESD's deliberations.

Synergy with other DOs and other targeted observables in the Decadal Survey

Agility and resilience of the architecture, such as:

- Ability of the architecture to evolve
- Ability to incorporate new technologies and innovate
- Ability to adapt to changes

Opportunities for science and applications beyond the decadal survey recommendations

Interagency and International engagement

- Potential advantages to advance the DO's objectives
- Potential risks with the partnership
- Political and external factors that might affect the partnership

Leveraging Commercial/Industry capabilities

Leveraging non-traditional partners' capabilities (i.e., NGOs, philanthropic organizations, etc)

The background of the slide is a composite of two cosmic images. The top half features a dark space filled with numerous small, bright stars and a prominent, wispy blue nebula on the right side. The bottom half is dominated by a bright, glowing orange and yellow nebula, with a cluster of stars visible on the right. A solid dark blue horizontal band runs across the middle of the slide, serving as a backdrop for the title text.

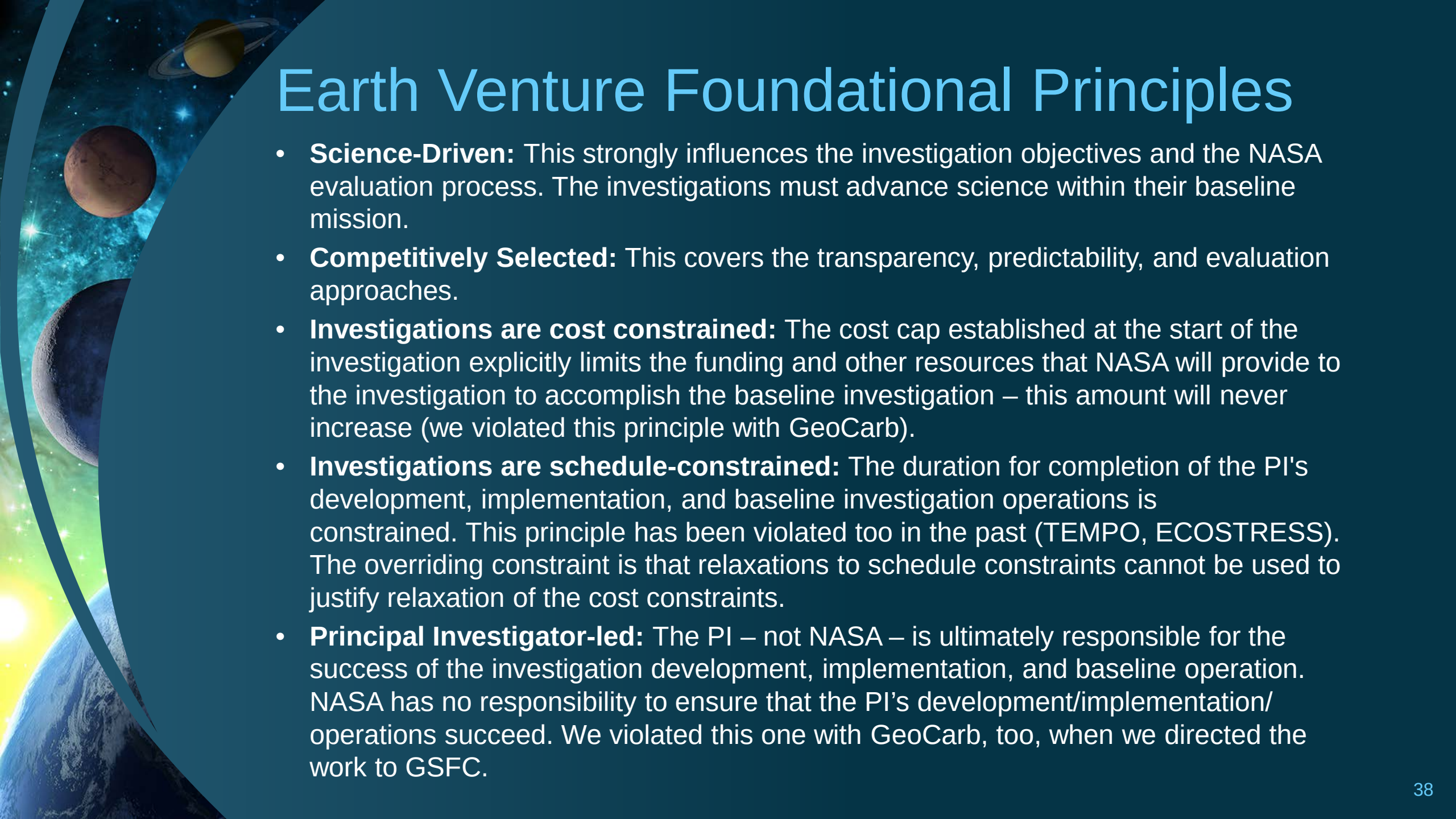
Earth Venture Lessons Learned Workshop

The background of the slide is a deep blue space scene. On the left side, there is a vertical sequence of celestial bodies: a yellow planet with rings (Saturn) at the top, followed by a reddish planet (Mars), then a grey cratered planet (the Moon), and finally the blue and white horizon of Earth at the bottom. The background is filled with small white stars and a soft blue nebula-like glow.

Earth Venture Lessons Learned Workshop

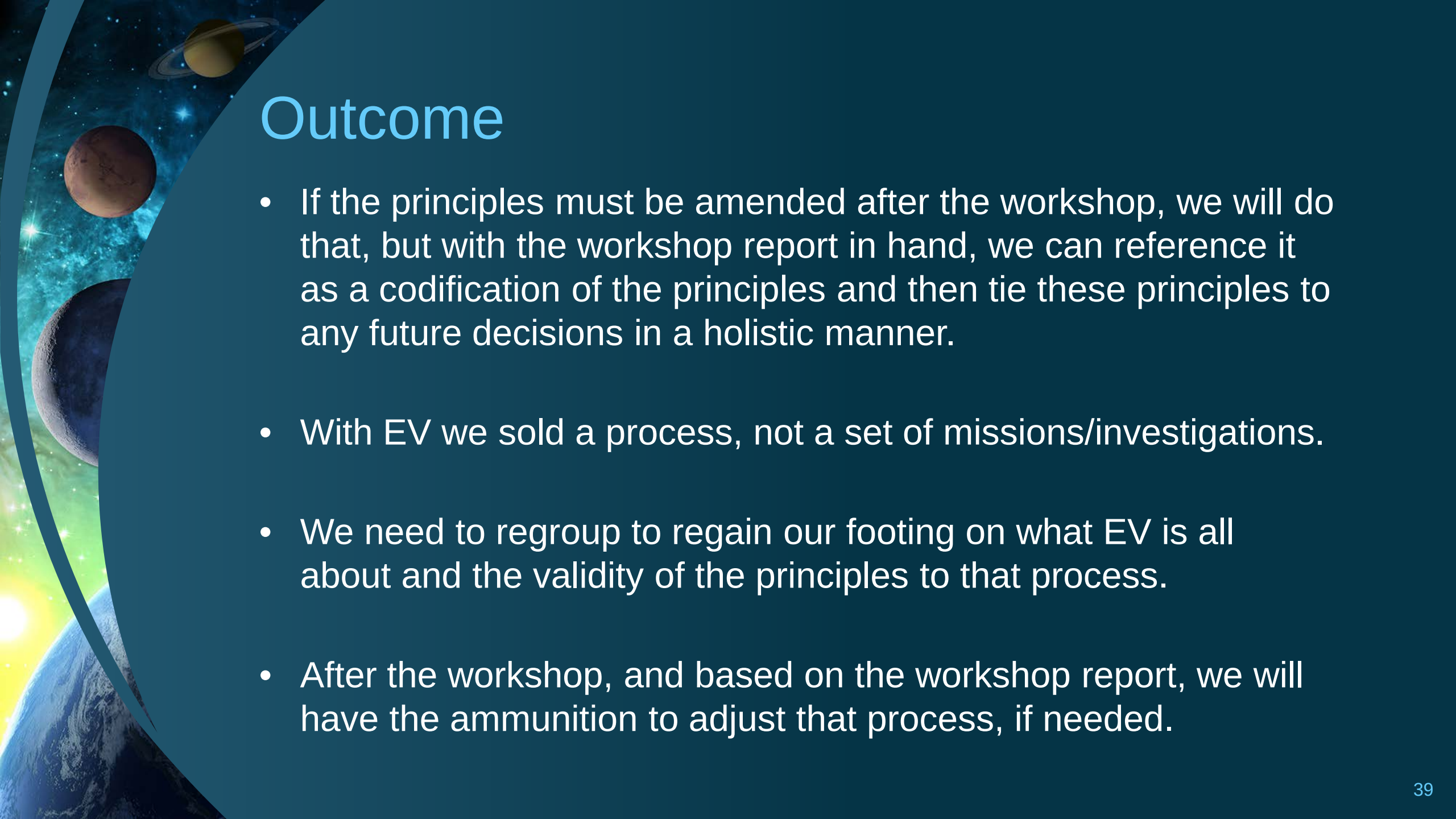
Objective: We would like to commission written statements and explanations of the foundational principles and approaches underlying and enabling EV

- Earth Venture started about 10 years ago – it is time to evaluate what's working and what's not
- There will be no recommendations and the review should be streamlined – need a report that includes transcripts of presentations and discussions
- Most of the workshop report will probably contain EV investigation “war stories”, lessons learned, including some compilations of approaches and achievements regarding hosted payloads and instruments on the ISS
 - We are mostly interested in clear presentations on the foundational principles

A decorative background on the left side of the slide featuring a curved view of Earth's horizon at the bottom, transitioning into a deep space scene with a bright yellow sun, a crescent moon, a reddish planet (Mars), and a ringed planet (Saturn) against a starry blue and green nebula.

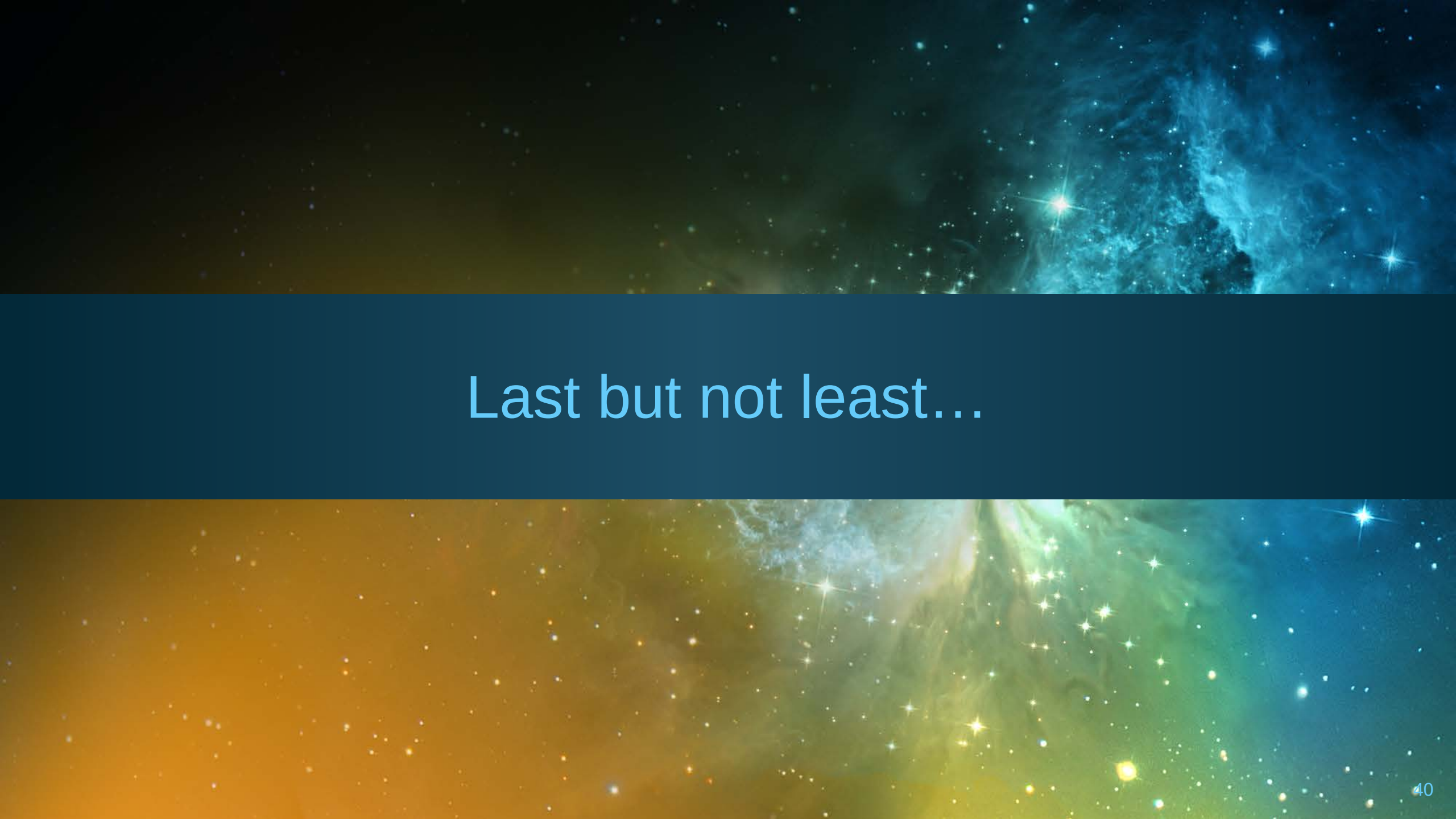
Earth Venture Foundational Principles

- **Science-Driven:** This strongly influences the investigation objectives and the NASA evaluation process. The investigations must advance science within their baseline mission.
- **Competitively Selected:** This covers the transparency, predictability, and evaluation approaches.
- **Investigations are cost constrained:** The cost cap established at the start of the investigation explicitly limits the funding and other resources that NASA will provide to the investigation to accomplish the baseline investigation – this amount will never increase (we violated this principle with GeoCarb).
- **Investigations are schedule-constrained:** The duration for completion of the PI's development, implementation, and baseline investigation operations is constrained. This principle has been violated too in the past (TEMPO, ECOSTRESS). The overriding constraint is that relaxations to schedule constraints cannot be used to justify relaxation of the cost constraints.
- **Principal Investigator-led:** The PI – not NASA – is ultimately responsible for the success of the investigation development, implementation, and baseline operation. NASA has no responsibility to ensure that the PI's development/implementation/operations succeed. We violated this one with GeoCarb, too, when we directed the work to GSFC.

A space-themed background featuring a curved view of Earth's horizon at the bottom left, with a bright sun or star partially visible. Above the horizon, several celestial bodies are shown: a crescent moon, a reddish planet (Mars), and a yellow planet with rings (Saturn). The background is a deep blue with scattered white stars.

Outcome

- If the principles must be amended after the workshop, we will do that, but with the workshop report in hand, we can reference it as a codification of the principles and then tie these principles to any future decisions in a holistic manner.
- With EV we sold a process, not a set of missions/investigations.
- We need to regroup to regain our footing on what EV is all about and the validity of the principles to that process.
- After the workshop, and based on the workshop report, we will have the ammunition to adjust that process, if needed.

The background of the slide is a composite of two cosmic images. The top half features a dark space filled with numerous small, distant stars and a prominent, wispy blue nebula on the right side. The bottom half shows a similar starry field but with a large, vibrant orange and yellow nebula on the left, transitioning into a greenish-blue nebula on the right. A solid dark blue horizontal band runs across the middle of the slide, containing the text.

Last but not least...

NEW Academies Study: “Future Use of NASA Airborne Platforms to Advance Earth Science Priorities”

- NASA ESD and NASEM have entered into an agreement to “conduct a fast-track study to inform NASA’s future investments in suborbital airborne facilities.”
- This study will consider how airborne platforms could maximize contributions and/or provide unique inputs to integrated (satellite/airborne/surface/modeling) approaches to answering the science questions posed in the 2018 Decadal Survey. There is particular interest in the role of “large” platforms (e.g., DC-8 size or larger)
- Committee members were solicited (3/4, nominations due 3/16) in the following areas: atmospheric chemistry, meteorology, climate science, airborne and satellite observations of the components of the Earth system, remote sensing technologies, uninhabited airborne systems, and modeling.
- The study will be conducted with oversight from the Division on Earth and Life Studies Board on Atmospheric Sciences and Climate, in collaboration with the Division on Engineering and Physical Sciences Space Studies Board.

Earth Science Division ROSES-20 Opportunities

Element #	Short Title	Prog. Comp.	Due Date
A.2	Land Cover Land Use Change	R&A	6/1/20
A.3	Ocean Biology and Biogeochemistry	R&A	7/23/20
A.5	Carbon Cycle Science	R&A	TBD
A.6	Carbon Monitoring System	R&A	10/16/20
A.7	Biodiversity	R&A	6/25/20
A.8	GEDI Science Team	R&A/ESSP Res.	6/16/20
A.9	Physical Oceanography	R&A	6/25/20
A.13	Ocean Salinity Field Campaign	R&A	TBD
A.14	Ocean Surface Topography Science Team	R&A/ESM Res.	10/8/20
A.16	Modeling, Analysis, and Prediction	R&A	6/30/20
A.17	Cryospheric Science	R&A	6/30/20
A.18	Atmospheric Composition: Upper Atmospheric Composition Observations	R&A	9/17/20
A.19	Atmospheric Composition: Laboratory Research	R&A	8/13/20
A.23	Atmospheric Composition: Campaign Data Analysis and Modeling	R&A	9/18/20
A.24	Terrestrial Hydrology	R&A	11/18/20
A.26	Earth Surface and Interior	R&A	6/2/20
A.27	CYGNSS Competed Science Team	R&A/ESSP Res.	9/18/20
A.28	Rapid Response and Novel Earth Science^	R&A	Rolling
A.30	US Participating Investigator*	R&A	7/16/20
A.32	New Investigator Program in Earth Science	R&A/F&NI	TBD
A.34	Studies with ICESat-2	R&A/ESM Res.	TBD
A.38	Health and Air Quality Applied Science Team	Appl. Sci.	5/29/20
A.39	Ecological Forecasting	Appl. Sci.	8/14/20
A.41	Citizen Science for Earth Systems Program	ESDS	TBD
A.42	Commercial SmallSat Data Evaluation Team	ESDS	TBD
A.44	Advanced Component Technology	ESTO	TBD
A.45	In-space Validation of Earth Science Technologies	ESTO	TBD

^ Includes COVID-19 response
– see 3/27 NSPIRES
announcement

* Will be done using double-
blind review process

Note: watch NSPIRES for
changes!

ESD Role in Interagency Activities - Selected

- NASA/ESD is heavily involved in a variety of interagency activities – what follows is a limited subset of those in which we are most engaged (with numerous working groups, reports, etc.)
- National Science and Technology Council
 - Committee on Environment
 - o Subcommittee on Global Change Research (US Global Change Research Program)
 - o Ocean Science Subcommittee
 - o Interagency Arctic Research Policy Committee
 - o US Group on Earth Observations Subcommittee
 - Committee on Homeland and National Security
 - o Resilience S&T Subcommittee
- Office of the Federal Coordinator for Meteorological Services and Supporting Research (incl. Earth System Prediction Capability)
- National Invasive Species Council

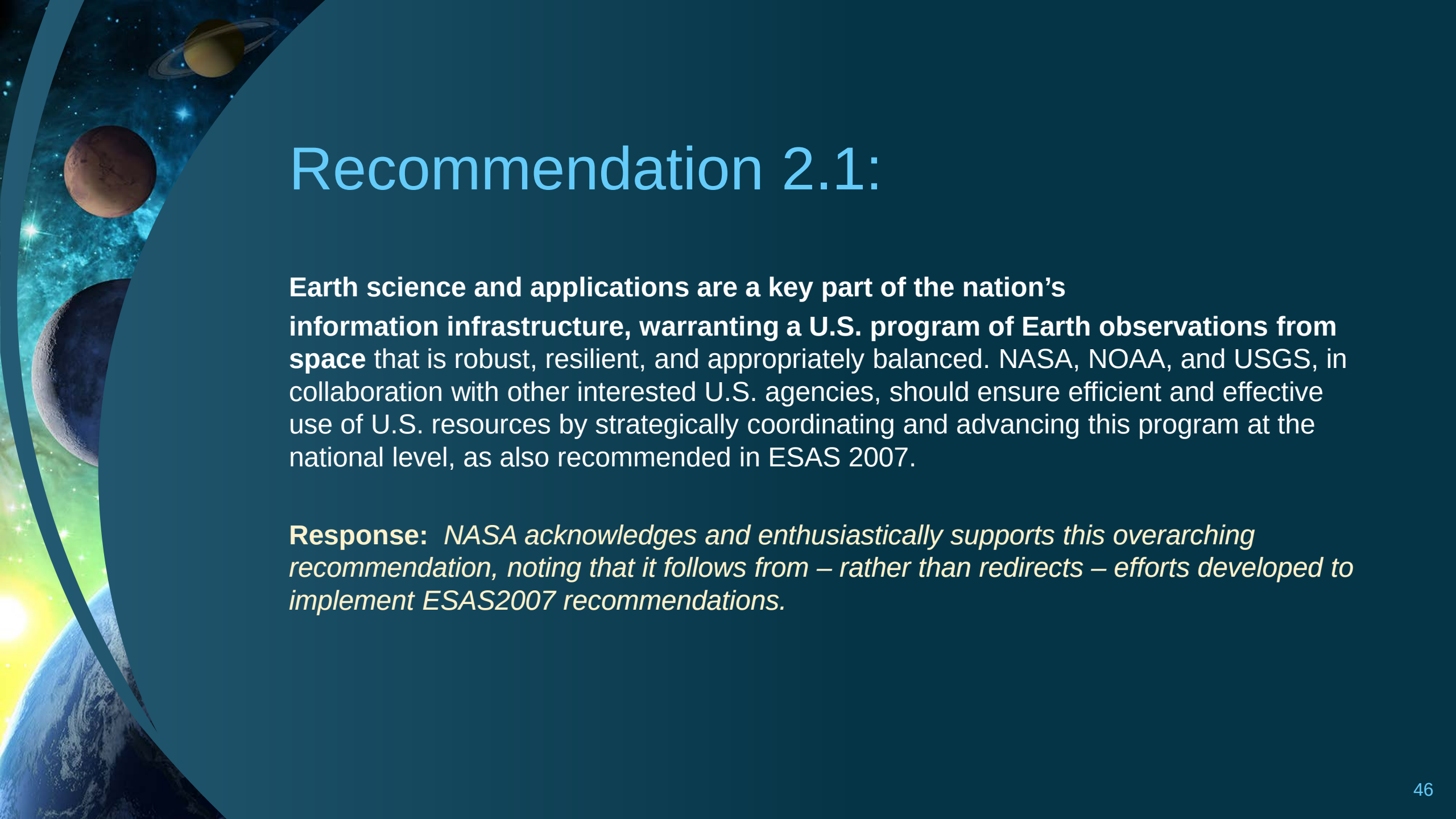
Questions?



NASA Earth Observing Satellites since 1958

The background of the slide is a composite of two cosmic images. The top half features a dark blue and black space scene with a bright, wispy blue nebula on the right and several sharp, bright stars. The bottom half shows a vibrant orange and yellow nebula on the left, transitioning into a greenish-blue nebula on the right, with numerous bright stars scattered throughout.

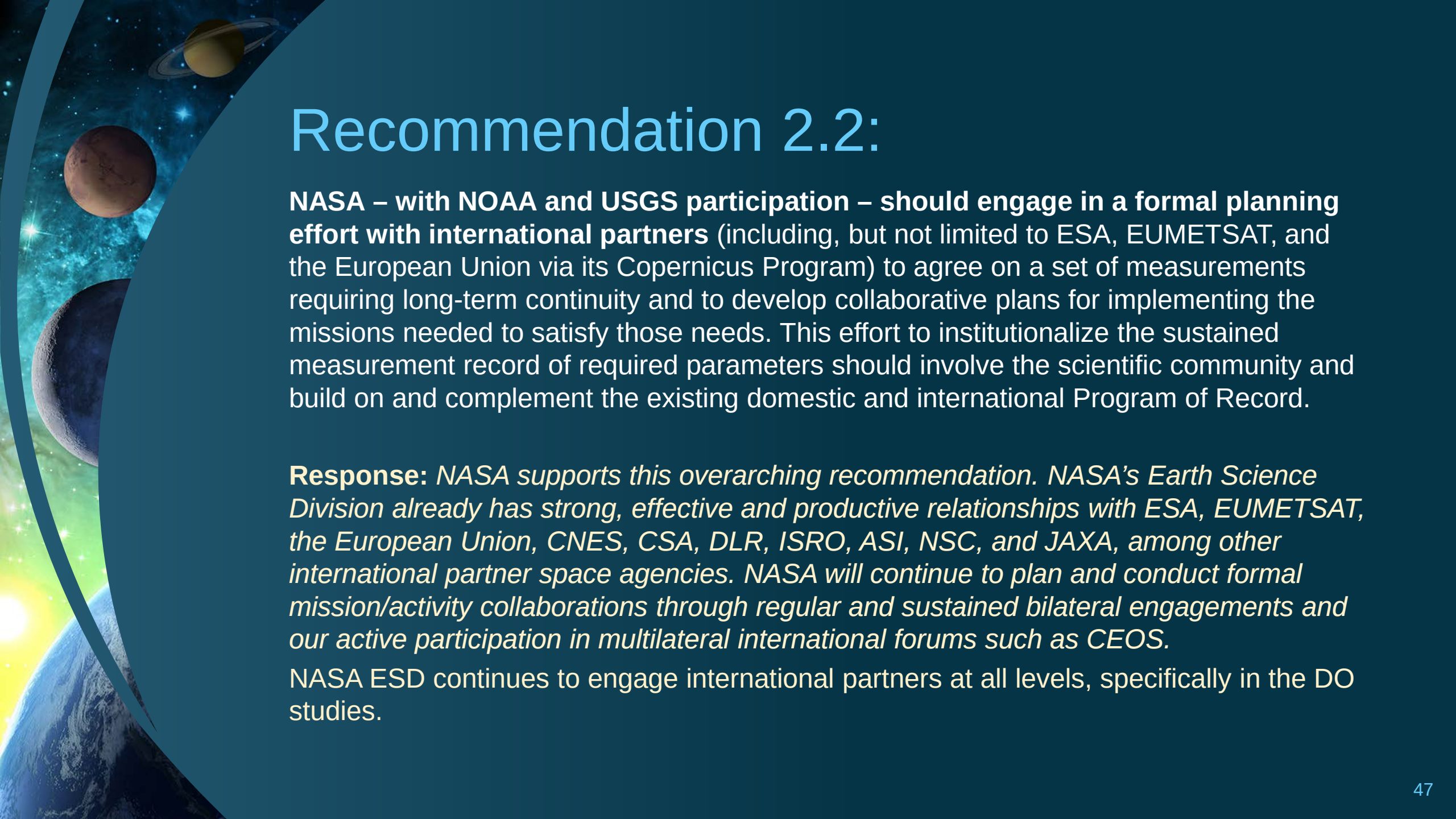
Backup

The background of the slide is a deep blue space scene. On the left side, there is a vertical strip showing a bright yellow sun at the bottom, followed by the blue and white horizon of Earth. Above Earth, the dark, cratered surface of the Moon is visible. Further up, a reddish-brown planet (Mars) and a yellow planet with a ring system (Saturn) are shown against a backdrop of distant stars and nebulae. A large, semi-transparent blue arc curves across the top and left side of the slide, framing the text.

Recommendation 2.1:

Earth science and applications are a key part of the nation's information infrastructure, warranting a U.S. program of Earth observations from space that is robust, resilient, and appropriately balanced. NASA, NOAA, and USGS, in collaboration with other interested U.S. agencies, should ensure efficient and effective use of U.S. resources by strategically coordinating and advancing this program at the national level, as also recommended in ESAS 2007.

Response: *NASA acknowledges and enthusiastically supports this overarching recommendation, noting that it follows from – rather than redirects – efforts developed to implement ESAS2007 recommendations.*

The background of the slide features a deep blue space theme. On the left side, there is a vertical strip showing a yellow planet with rings at the top, a reddish planet in the middle, and a grey cratered planet at the bottom. The bottom left corner shows a curved horizon of the Earth with blue oceans and white clouds. The rest of the background is a dark blue gradient with faint white stars and nebulae.

Recommendation 2.2:

NASA – with NOAA and USGS participation – should engage in a formal planning effort with international partners (including, but not limited to ESA, EUMETSAT, and the European Union via its Copernicus Program) to agree on a set of measurements requiring long-term continuity and to develop collaborative plans for implementing the missions needed to satisfy those needs. This effort to institutionalize the sustained measurement record of required parameters should involve the scientific community and build on and complement the existing domestic and international Program of Record.

Response: *NASA supports this overarching recommendation. NASA's Earth Science Division already has strong, effective and productive relationships with ESA, EUMETSAT, the European Union, CNES, CSA, DLR, ISRO, ASI, NSC, and JAXA, among other international partner space agencies. NASA will continue to plan and conduct formal mission/activity collaborations through regular and sustained bilateral engagements and our active participation in multilateral international forums such as CEOS.*

NASA ESD continues to engage international partners at all levels, specifically in the DO studies.



Collaboration on Missions & Technology

The Opportunity: Copernicus Evolution, new ESA EE and 2017 NRC Earth Science Decadal Survey

- The recent identification of six new Copernicus High-Priority Candidate Missions (HPCM), of new ESA research missions (EE9, EE10) and the release of the 2017 U.S. National Research Council (NRC) Decadal Survey for Earth Science and Applications from Space presents an opportunity for identification of future strategic collaboration and coordination opportunities in missions and technology.
- Anticipated opportunities lie in the following ESA EO mission and technology areas and the related Earth Science Decadal Survey Targeted Observables (TOs):
 - Recent European Union Ministerial significantly augmented Copernicus budget

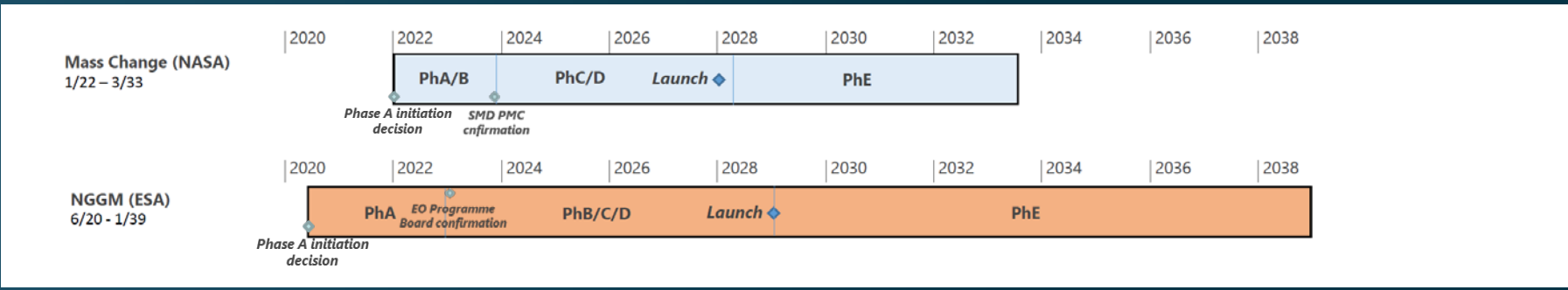
Notional timeline for Copernicus Evolution, new ESA EE and 2017 Decadal Survey studies/missions with key decision points to NASA Formulation (Phase A) initiation in following slides

Copernicus Evolution and 2017 NRC Earth Science Decadal Survey Full Life Cycle Notional Timelines (1 of 3)

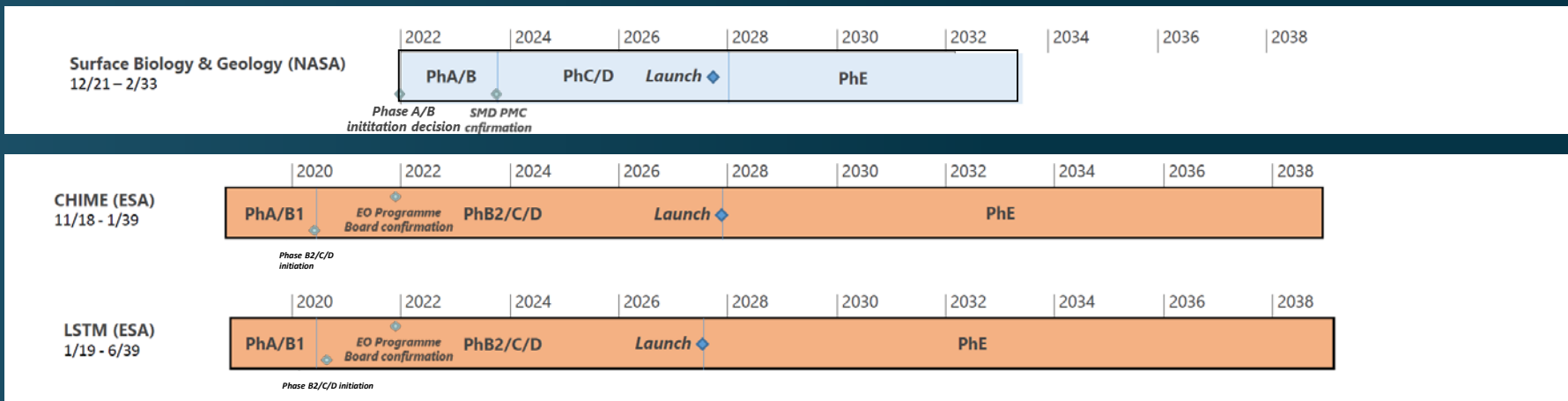
Assumes MC is one of the first DO projects (subject to budget developments). SBG and A/CCP are currently identified to be most likely first DO projects.

Assumes SBG is one of the first DO projects (subject to budget developments). SBG and A/CCP are currently identified to be the most likely first DO projects.

NGGM (Next Generation Gravity Mission) ⇔ **MC** (Mass Change) Designated Observable (DO)



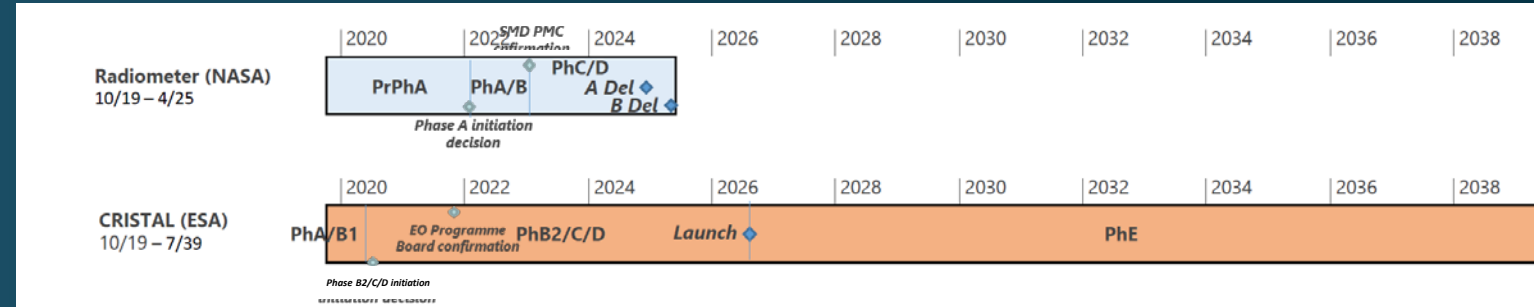
CHIME (Copernicus Hyperspectral Imaging Mission) ⇔ **SBG** (Surface Biology & Geology) DO



Copernicus Evolution and 2017 NRC Earth Science Decadal Survey Full Life Cycle Notional Timelines (2 of 3)

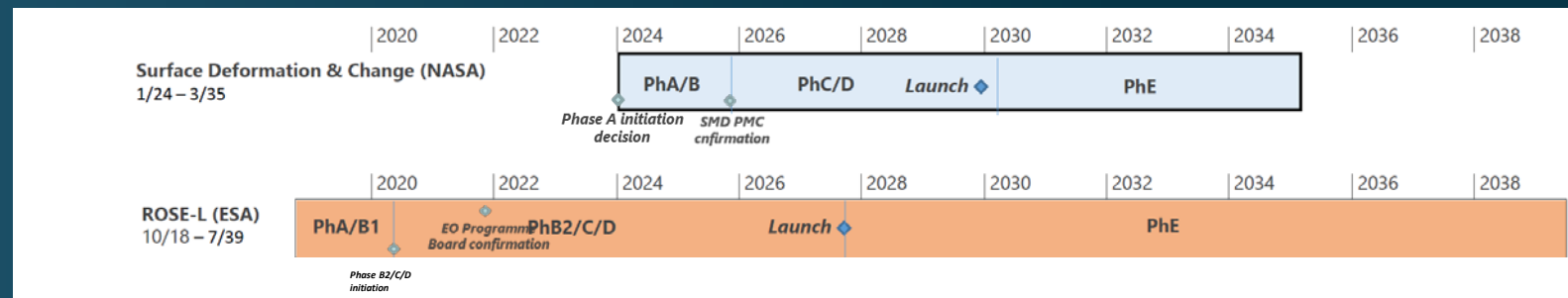
CRISTAL (Copernicus Polar Ice and Snow Topography Mission) ⇔ Snow Depth & Snow Water Equivalent and Ice Elevation ESE TOs

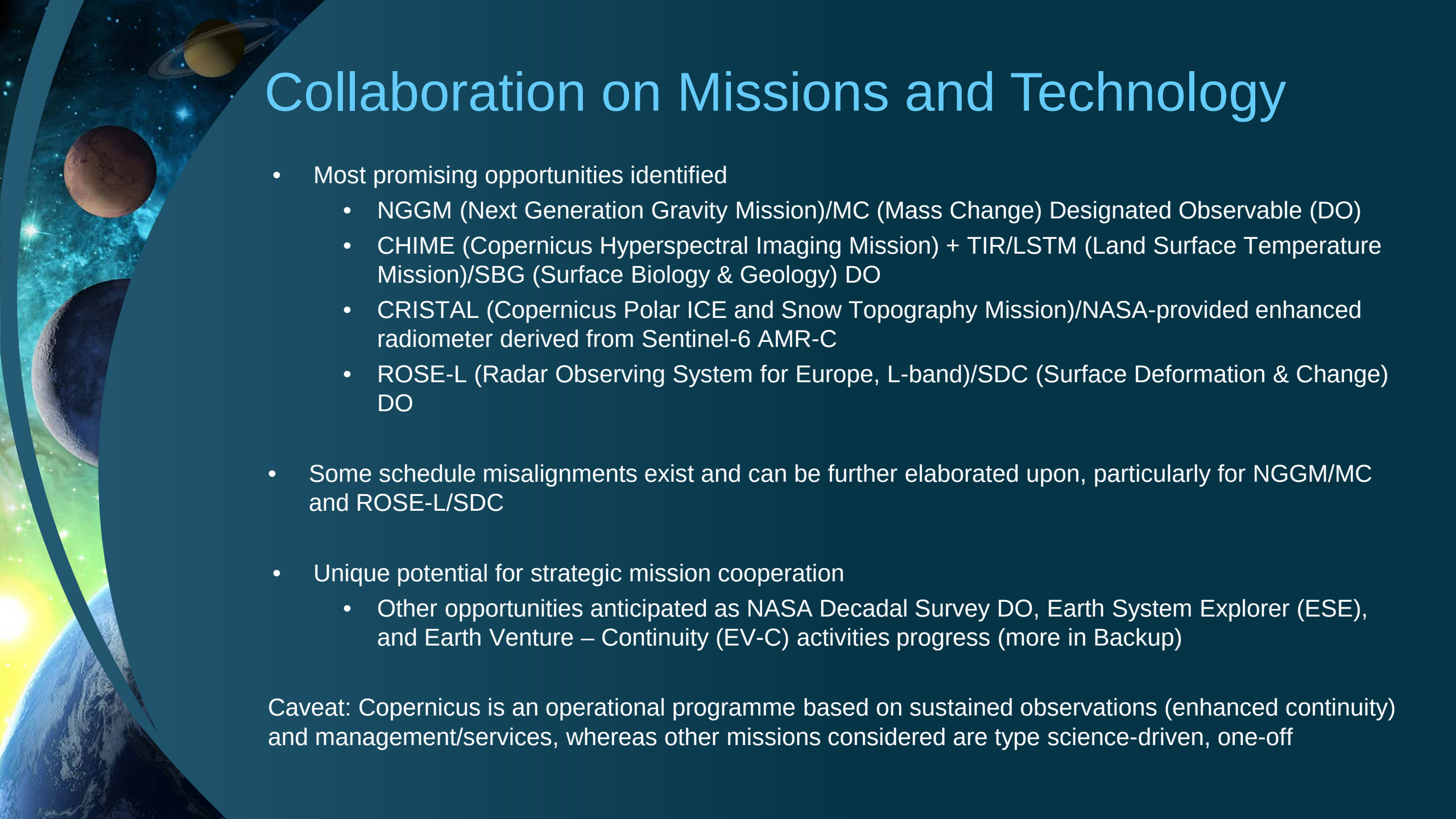
Assumes Radiometer study is initiated in Q4CY2019 and outcome enables project implementation.



ROSE-L (Radar Observing System for Europe, L-band) ⇔ SDC (Surface Deformation & Change) DO

Assumes SDC is one of later DO projects. This is consistent with current plans (subject to budget developments).

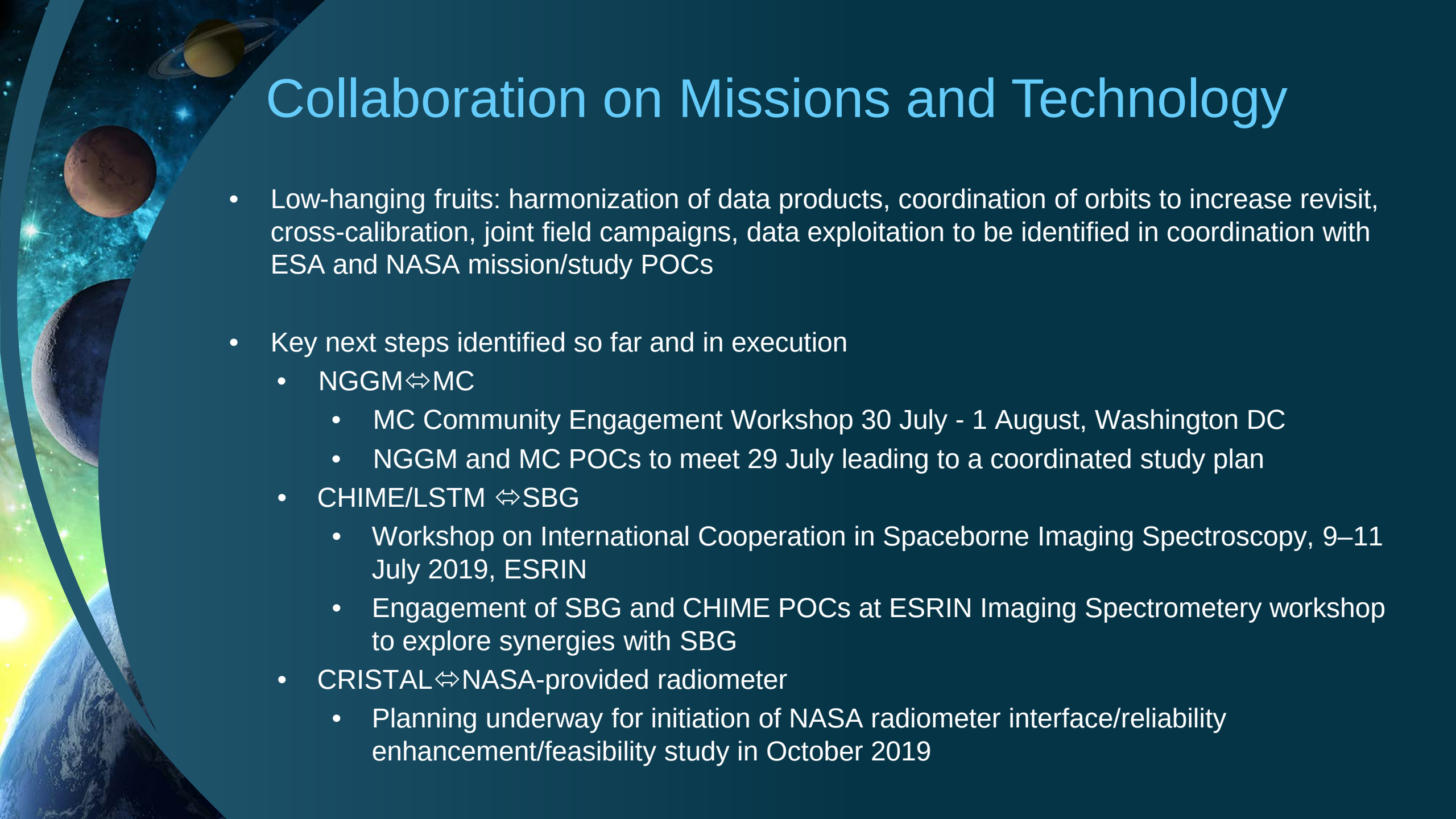




Collaboration on Missions and Technology

- Most promising opportunities identified
 - NGGM (Next Generation Gravity Mission)/MC (Mass Change) Designated Observable (DO)
 - CHIME (Copernicus Hyperspectral Imaging Mission) + TIR/LSTM (Land Surface Temperature Mission)/SBG (Surface Biology & Geology) DO
 - CRISTAL (Copernicus Polar ICE and Snow Topography Mission)/NASA-provided enhanced radiometer derived from Sentinel-6 AMR-C
 - ROSE-L (Radar Observing System for Europe, L-band)/SDC (Surface Deformation & Change) DO
- Some schedule misalignments exist and can be further elaborated upon, particularly for NGGM/MC and ROSE-L/SDC
- Unique potential for strategic mission cooperation
 - Other opportunities anticipated as NASA Decadal Survey DO, Earth System Explorer (ESE), and Earth Venture – Continuity (EV-C) activities progress (more in Backup)

Caveat: Copernicus is an operational programme based on sustained observations (enhanced continuity) and management/services, whereas other missions considered are type science-driven, one-off



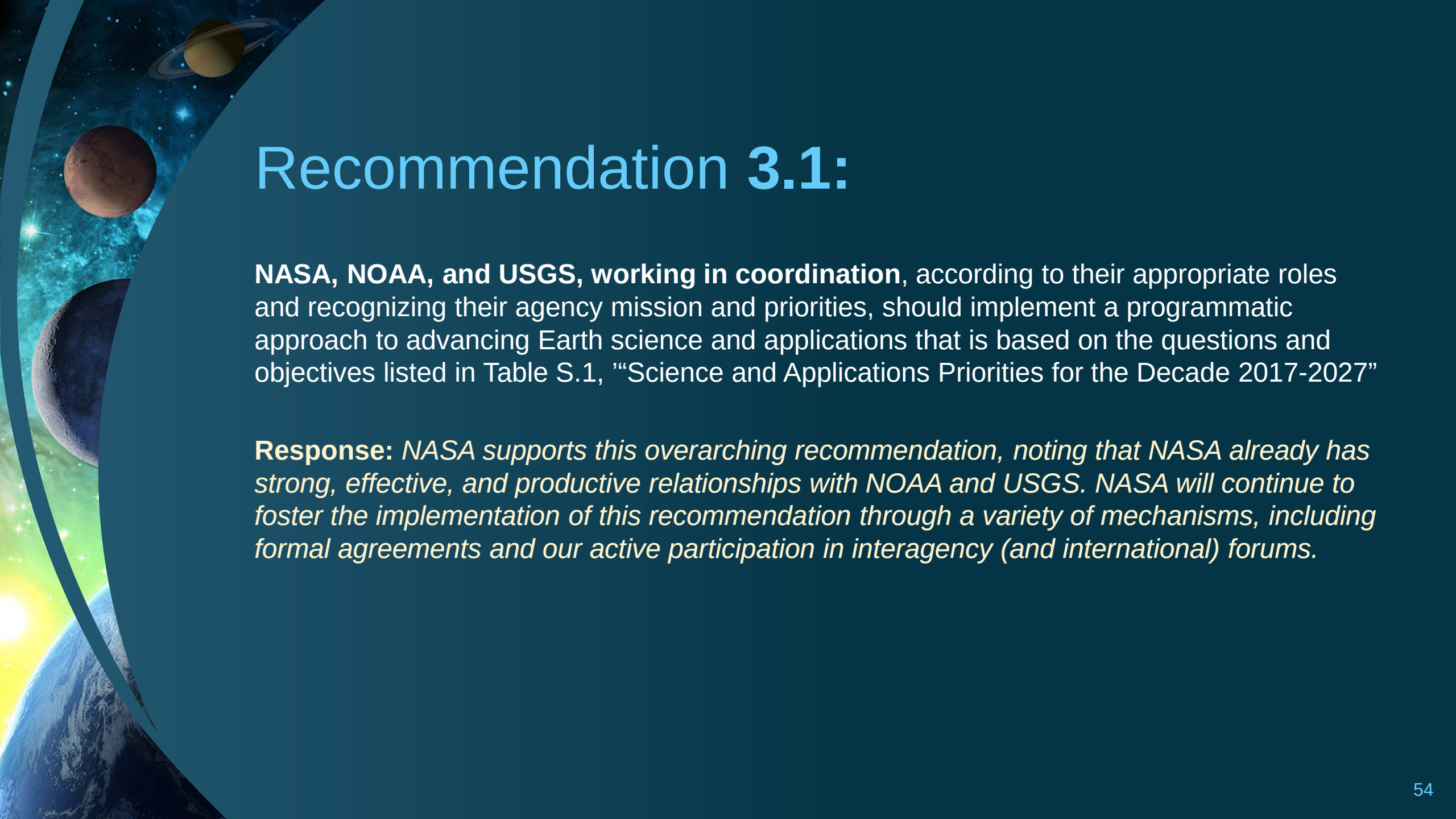
Collaboration on Missions and Technology

- Low-hanging fruits: harmonization of data products, coordination of orbits to increase revisit, cross-calibration, joint field campaigns, data exploitation to be identified in coordination with ESA and NASA mission/study POCs
- Key next steps identified so far and in execution
 - NGGM ↔ MC
 - MC Community Engagement Workshop 30 July - 1 August, Washington DC
 - NGGM and MC POCs to meet 29 July leading to a coordinated study plan
 - CHIME/LSTM ↔ SBG
 - Workshop on International Cooperation in Spaceborne Imaging Spectroscopy, 9–11 July 2019, ESRIN
 - Engagement of SBG and CHIME POCs at ESRIN Imaging Spectrometry workshop to explore synergies with SBG
 - CRISTAL ↔ NASA-provided radiometer
 - Planning underway for initiation of NASA radiometer interface/reliability enhancement/feasibility study in October 2019

The background of the slide features a deep blue space theme. On the left side, there is a vertical strip showing a bright yellow sun at the bottom, followed by the blue and white horizon of Earth. Above Earth, the dark, cratered surface of the Moon is visible. Further up, a reddish-brown planet (Mars) and a yellow planet with a ring system (Saturn) are depicted against a backdrop of stars and nebulae. A large, semi-transparent dark blue arc curves across the top and left portions of the slide, framing the title and the top of the list.

International Engagement

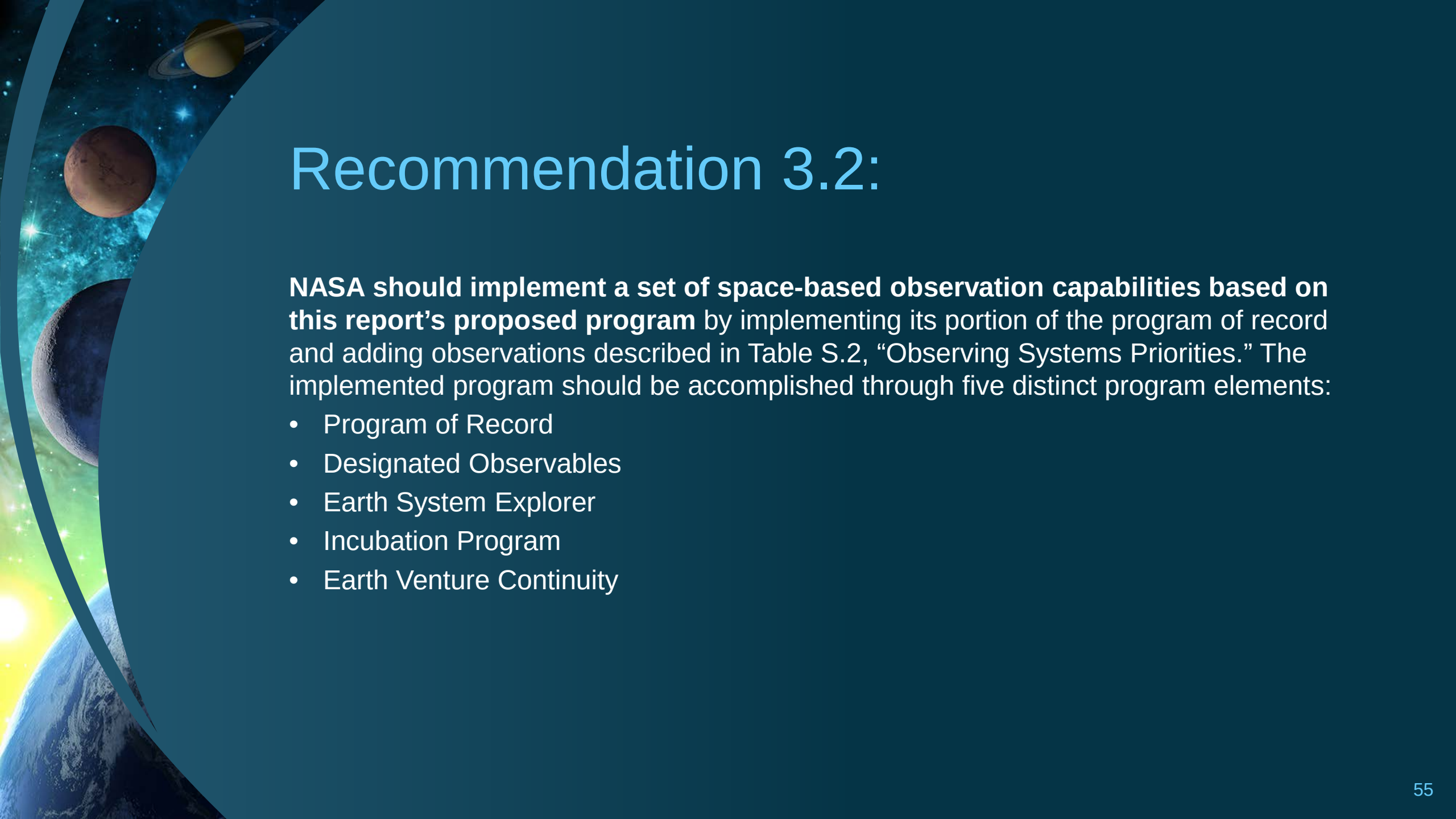
- ESD leadership has conducted focused Decadal Survey telecons/meetings with international partners
 - JAXA, CNES, DLR, ESA, EUMETSAT, CSA
 - Further discussions with the broader international community continue
- Discussions are ongoing to explore potential international partnerships
 - Some directed international partnerships may originate from ESD
 - Multi-center DO studies are engaging potential international partners
- **ESD will make final partnership determinations** and then codify in necessary international agreements

The background of the slide is a deep blue space scene. On the left side, there is a vertical strip showing a bright yellow sun at the bottom, followed by the blue and white horizon of Earth. Above Earth, the dark, cratered surface of the Moon is visible. Further up, a reddish-brown planet (Mars) and a yellow planet with a ring system (Saturn) are shown against a backdrop of distant stars and nebulae. A large, light blue curved shape, resembling a stylized 'C' or a protective shield, frames the text on the right side of the slide.

Recommendation 3.1:

NASA, NOAA, and USGS, working in coordination, according to their appropriate roles and recognizing their agency mission and priorities, should implement a programmatic approach to advancing Earth science and applications that is based on the questions and objectives listed in Table S.1, “Science and Applications Priorities for the Decade 2017-2027”

Response: *NASA supports this overarching recommendation, noting that NASA already has strong, effective, and productive relationships with NOAA and USGS. NASA will continue to foster the implementation of this recommendation through a variety of mechanisms, including formal agreements and our active participation in interagency (and international) forums.*

The background of the slide is a dark blue space-themed image. On the left side, there is a vertical strip showing a bright yellow sun at the bottom, followed by the blue and white horizon of Earth, a grey cratered moon, a reddish-brown planet (Mars), and a yellow planet with rings (Saturn) at the top. The rest of the slide has a solid dark blue background.

Recommendation 3.2:

NASA should implement a set of space-based observation capabilities based on this report's proposed program by implementing its portion of the program of record and adding observations described in Table S.2, "Observing Systems Priorities." The implemented program should be accomplished through five distinct program elements:

- Program of Record
- Designated Observables
- Earth System Explorer
- Incubation Program
- Earth Venture Continuity

The background of the slide is a composite of two cosmic images. The top half features a dark blue and black space scene with a bright, wispy blue nebula on the right and several sharp, bright stars. The bottom half shows a vibrant orange and yellow nebula on the left, transitioning into a greenish-blue nebula on the right, with numerous stars scattered throughout.

Program of Record

NASA EARTH FLEET

OPERATING & FUTURE THROUGH 2023

SWOT (CNES)

LANDSAT-9 (USGS) SENTINEL-6 Michael Freilich/B (ESA)

TROPICS (6)

GEOCARB

NISAR (ISRO)

MAIA

TSIS-2

TEMPO

PREFIRE (2)

PACE (NSO)

GLIMR

ICESAT-2

GRACE-FO (2) (DLR)

CYGNSS (8)

NISTAR, EPIC (DSCOVR/NOAA)

ISS INSTRUMENTS

CLOUDSAT (CSA)

EMIT

CLARREO-PF

GEDI

SAGE III

OCO-3

TSIS-1

ECOSTRESS

LIS

TERRA (JAXA, CSA)

AQUA (JAXA, AEB)

AURA (NSO, FMI, UKSA)

CALIPSO (CNES)

GPM (JAXA)

LANDSAT 7 (USGS)

LANDSAT 8 (USGS)

OCO-2

SMAP

SUOMI NPP (NOAA) (JAXA)

JPSS-2, 3 & 4 INSTRUMENTS

OMPS-Limb

LIBERA

INVEST/CUBESATS

RainCube

CSIM-FD

CubeRRT

TEMPEST-D

CIRiS

HARP

CTIM

HyTI

SNoOPI

NACHOS

(PRE) FORMULATION ●

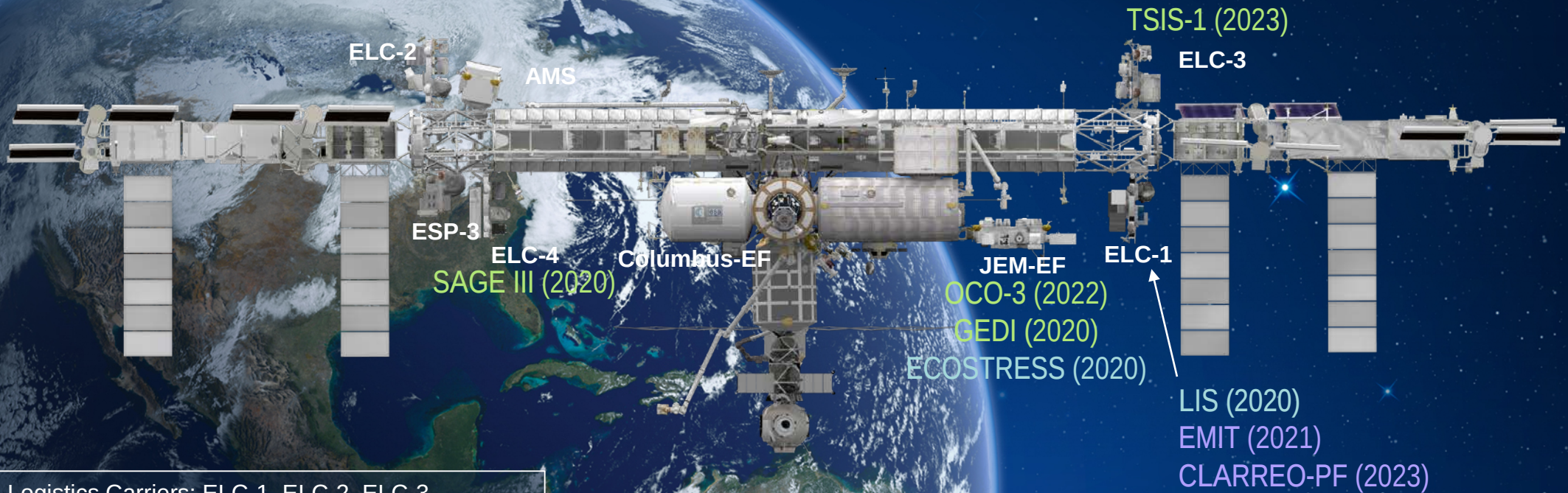
IMPLEMENTATION ●

PRIMARY OPS ●

EXTENDED OPS ●

INTERNATIONAL SPACE STATION

EARTH SCIENCE OPERATING MISSIONS



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

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

NASA EARTH FLEET

INTERNATIONAL COLLABORATIONS



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

ESD Partnership Missions in Development



Sentinel-6 Michael Freilich/B
ABC: 2021/2026
Ocean Altimetry

Partner: NOAA

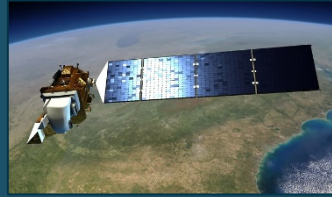
- Science data dissemination
- Ground stations

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: 2021
Land Imaging

Partner: USGS

- Ground system
- Mission Operations



SWOT
ABC: 2022
Sea surface & fresh water
height, slope

Partner: CNES

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

Partner: CSA

- Klystrons for KaRIn

Partner: UKSA

- Duplexers for KaRIn



NISAR
ABC: 2022
Cryosphere,
ecosystems, deformation

Partner: ISRO

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



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

Partner: SRON

- SPEXOne polarimeter

Partner: UMBC

- HARP-2 polarimeter

ABC=Agency Baseline Commitment

ESD Launches

Past: OCO-3



May 4, 2019

OCO-3

Investigate important questions about the distribution of carbon dioxide on Earth as it relates to growing urban populations and changing patterns of fossil fuel combustion

**Sentinel-6
Michael Freilich**

Provide ongoing measurements of global sea level rise, and support operational oceanography, improving forecasts of ocean currents as well as wind and wave conditions.

Future: Sentinel-6 Michael Freilich



November 2020

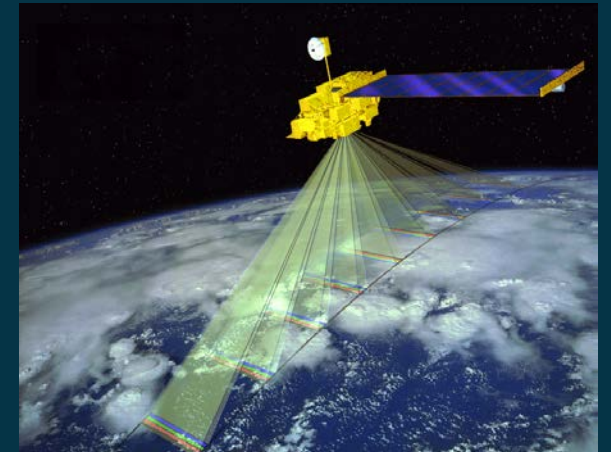
Recent and Upcoming Notable Flight Program Events

- OCO-3 instrument successfully launched to **ISS May 4, 2019** - operating
- Earth Science Decadal Survey Designated Observable studies are **underway**
- CYGNSS successfully **completed its prime mission** in April 2019 and moved into extended operations
- TEMPO instrument **delivered to storage** December 2018 – **host contract awarded** to MAXAR July 2019, with planned launch in 2022
- LIS on ISS successfully **completed its prime mission** in June 2019 and moved into extended operations
- EVC-1 proposals were received in July 2019 and are currently **under review**
- EVI-5 selection: **GLIMR** (ocean biology, chemistry, and ecology from geostationary orbit)
- ECOSTRESS successfully **completed its prime mission** in August 2019 and moved into extended operations
- OSTM/Jason-2 **mission ended** October 2019 after 11 years
- HARP CubeSat **launched to ISS** on November 2, 2019 deployment expected late January 2020
- CIRiS-BATC CubeSat **launched 5** December 2019
- TROPICS scheduled **to be delivered to storage** in December 2019 – evaluating launch options
- Terra **celebrated 20 years** in orbit in December 2019
- **SORCE mission will end** in February 2020, after 17 years in-orbit
- Sentinel-6A **launch scheduled for November 2020**
- Senior Review – ESD's mission extension process – **will be conducted in 2020**

Thank you, OSTM/Jason-2 for 11 years of amazing ocean science!



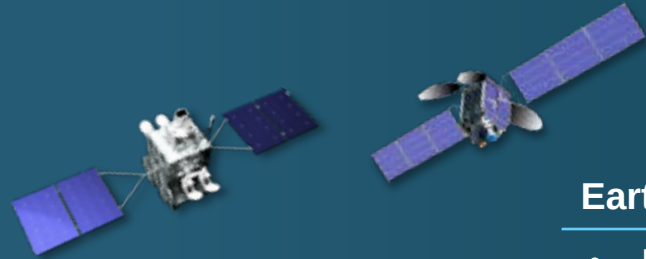
Congratulations, Terra, NASA's EOS Flagship, for 20 years in orbit!



The background of the slide is a composite of two cosmic images. The top half features a dark blue and black space scene with a bright, glowing blue nebula on the right side and several distant stars. The bottom half shows a vibrant orange and yellow nebula on the left, transitioning into a greenish-blue nebula on the right, with numerous stars scattered throughout.

Observing System Priorities

2017 Decadal Survey Progress Highlights



Earth Venture-Continuity

- 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
- Selection made in February 2020

Earth Science Explorers

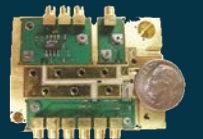
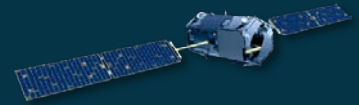
- DS recommended a new competed Explorer flight line with \$350M cost constraint
- Framework for program established
- Implementation on hold pending budget developments

Decadal Incubation

- 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
- Decadal Incubation initiated and funded through the budget window

Designated Observables

- DS identified 5 Designated Observables for mandatory acquisition
- In 2018 ESD initiated 4 multi-center Designated Observables studies, continued in 2019:
 - Combined: Aerosols-Clouds, Convection & Precipitation
 - Mass Change
 - Surface Biology & Geology
 - Surface Deformation & Change
- First Designated Observables Annual Review held in September 2019
- First Designated Observables Architecture Down Select by the end of Calendar Year 2020
- Fully funds a DO project to be initiated in FY21 through the budget window
- Initiates two more DO missions in FY22 and FY25



DO Study Points of Contact

Study	Program Executive	Program Scientist	Program Applications Lead	Technology POC	Centers Study Coordinator
ACCP	Tahani Amer	Hal Maring (<i>Alternates:</i> Gail Skofronick-Jackson, Barry Lefer)	John Haynes (<i>Alternate:</i> David Green)	Amber Emory (<i>Alternate:</i> Bob Connerton)	Vickie Moran (GSFC)
SBG	Marissa Herron	Woody Turner (<i>Alternates:</i> Ben Phillips, Laura Lorenzoni)	Woody Turner (<i>Alternate:</i> Brad Doorn)	Bob Connerton (<i>Alternate:</i> Mike Little)	Jamie Nastal (JPL)
SDC	Mitra Dutta	Gerald Bawden (<i>Alternates:</i> Hank Margolis, Mike Falkowski)	Emily Sylak-Glassman	Bob Bauer (<i>Alternate:</i> Bob Connerton)	Paul Rosen (JPL)
MC	Amanda Whitehurst	Lucia Tsaoussi (<i>Alternate:</i> Jared Entin)	Brad Doorn	Bob Connerton (<i>Alternate:</i> Parminder Ghuman)	Bernard Bienstock (JPL)

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Aerosol, Cloud, Convection and Precipitation (ACCP)

8 Science Objectives (*see SATM for # Mapping*) **Traceable to the 2017 Decadal Survey**



**Low Cloud
Feedback** (1)

Aerosol (6)
Redistribution

Convective (3)
**Storm
Systems**

**High Cloud
Feedback** (2)

**Cold Cloud &
Precipitation** (4)

Aerosol (7,8)
**Absorption,
Direct &
Indirect Effects
on Radiation**



**Aerosol Attribution
& Air Quality** (5)

Mission Study on Aerosol, Clouds, Convection & Precipitation

ACCP Applications



13 Enabled Applications

Climate Modeling

Aviation Industry
and Safety

Operational Air
Quality Forecasting

Storm Forecasting
and Modeling

Improved Numerical
Weather Prediction

Aerosols and
Precipitation
Interaction

Inform Air Quality
Regulation

Human Health Studies &
Health Risk Estimation

Wildfires

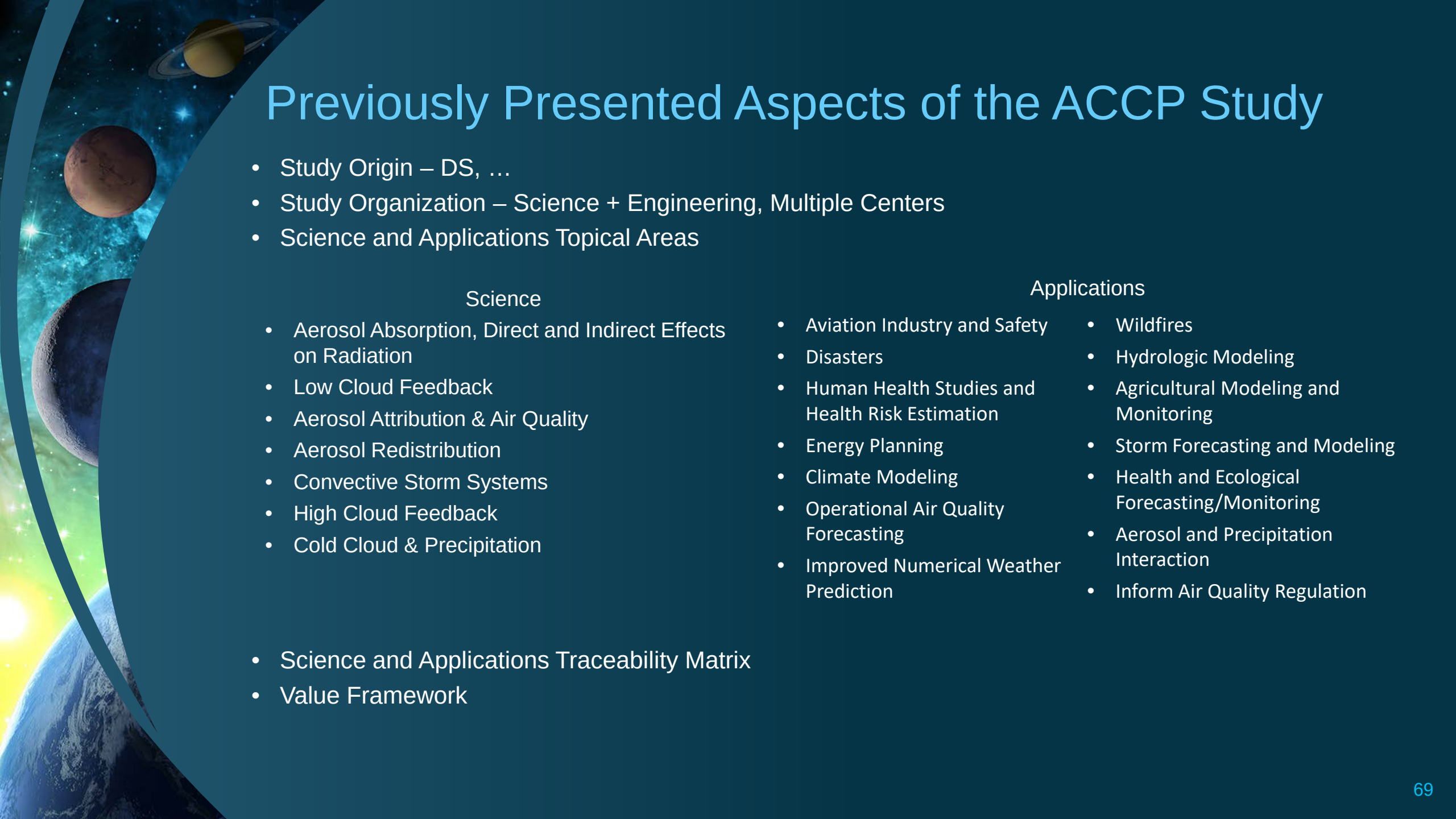
Disasters

Energy Planning

Hydrologic
Modeling

Health and Ecological
Forecasting/Monitoring

Agricultural
Modeling &
Monitoring



Previously Presented Aspects of the ACCCP Study

- Study Origin – DS, ...
- Study Organization – Science + Engineering, Multiple Centers
- Science and Applications Topical Areas

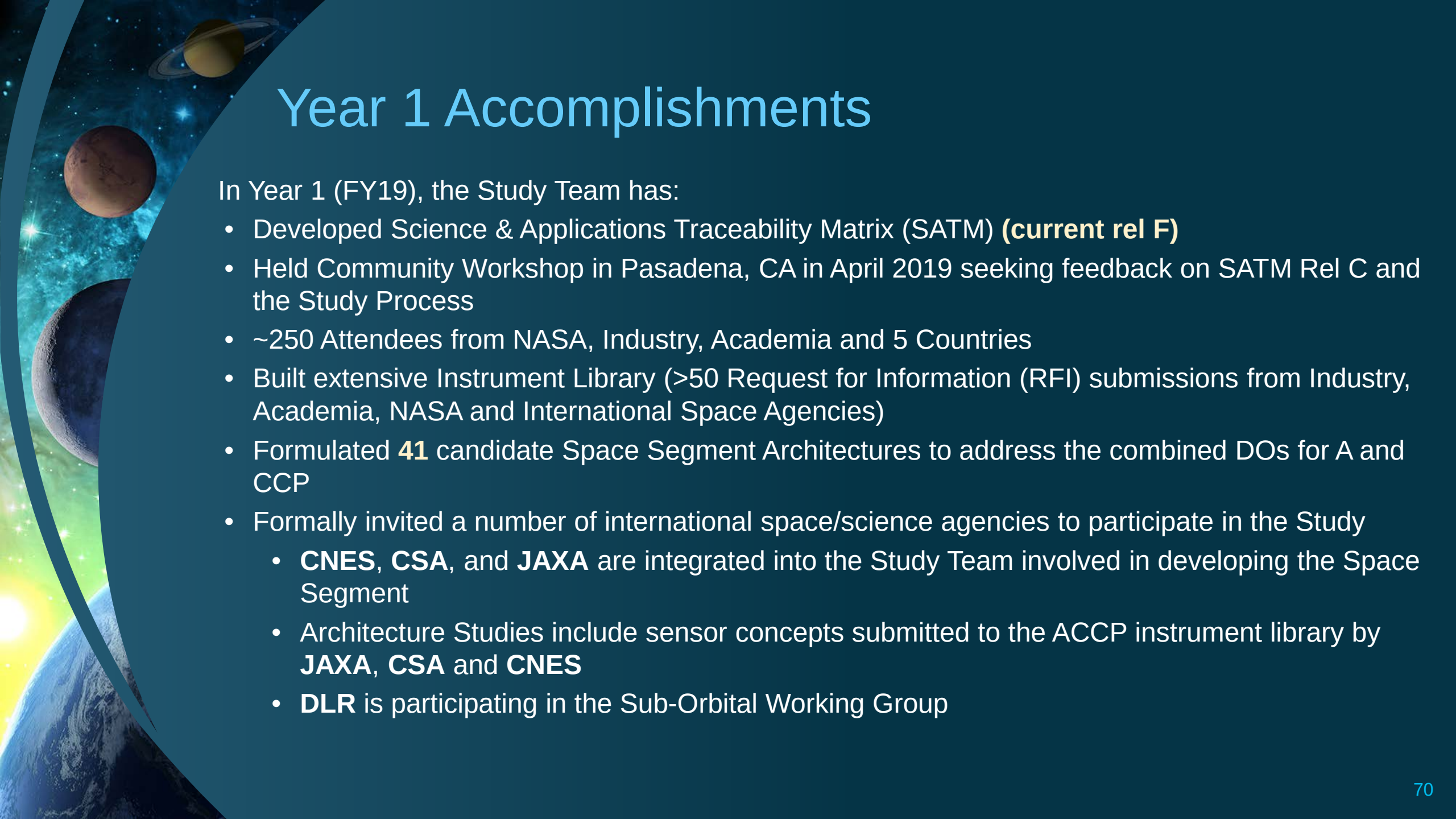
Science

- Aerosol Absorption, Direct and Indirect Effects on Radiation
- Low Cloud Feedback
- Aerosol Attribution & Air Quality
- Aerosol Redistribution
- Convective Storm Systems
- High Cloud Feedback
- Cold Cloud & Precipitation

- Science and Applications Traceability Matrix
- Value Framework

Applications

- | | |
|---|--|
| <ul style="list-style-type: none">• Aviation Industry and Safety• Disasters• Human Health Studies and Health Risk Estimation• Energy Planning• Climate Modeling• Operational Air Quality Forecasting• Improved Numerical Weather Prediction | <ul style="list-style-type: none">• Wildfires• Hydrologic Modeling• Agricultural Modeling and Monitoring• Storm Forecasting and Modeling• Health and Ecological Forecasting/Monitoring• Aerosol and Precipitation Interaction• Inform Air Quality Regulation |
|---|--|



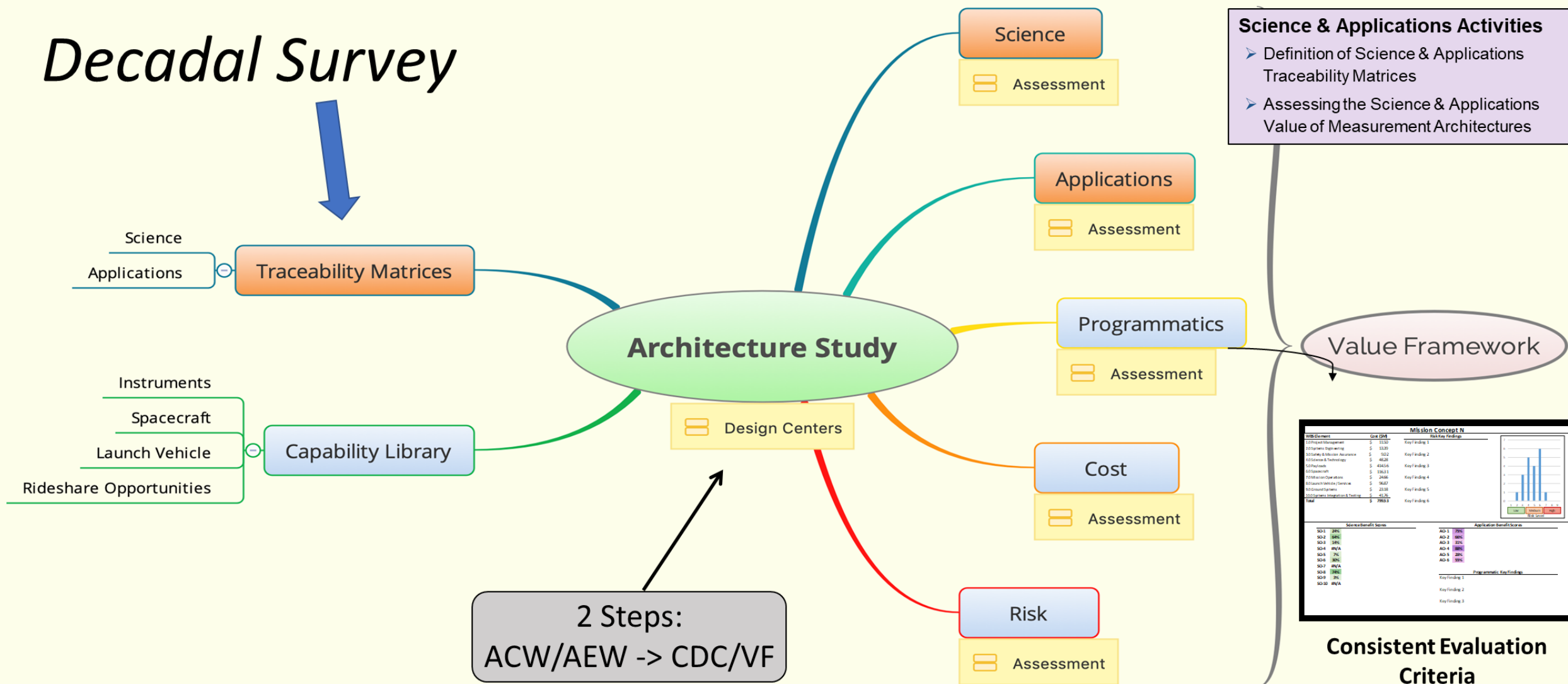
Year 1 Accomplishments

In Year 1 (FY19), the Study Team has:

- Developed Science & Applications Traceability Matrix (SATM) (**current rel F**)
- Held Community Workshop in Pasadena, CA in April 2019 seeking feedback on SATM Rel C and the Study Process
- ~250 Attendees from NASA, Industry, Academia and 5 Countries
- Built extensive Instrument Library (>50 Request for Information (RFI) submissions from Industry, Academia, NASA and International Space Agencies)
- Formulated **41** candidate Space Segment Architectures to address the combined DOs for A and CCP
- Formally invited a number of international space/science agencies to participate in the Study
 - **CNES, CSA, and JAXA** are integrated into the Study Team involved in developing the Space Segment
 - Architecture Studies include sensor concepts submitted to the ACCP instrument library by **JAXA, CSA** and **CNES**
 - **DLR** is participating in the Sub-Orbital Working Group

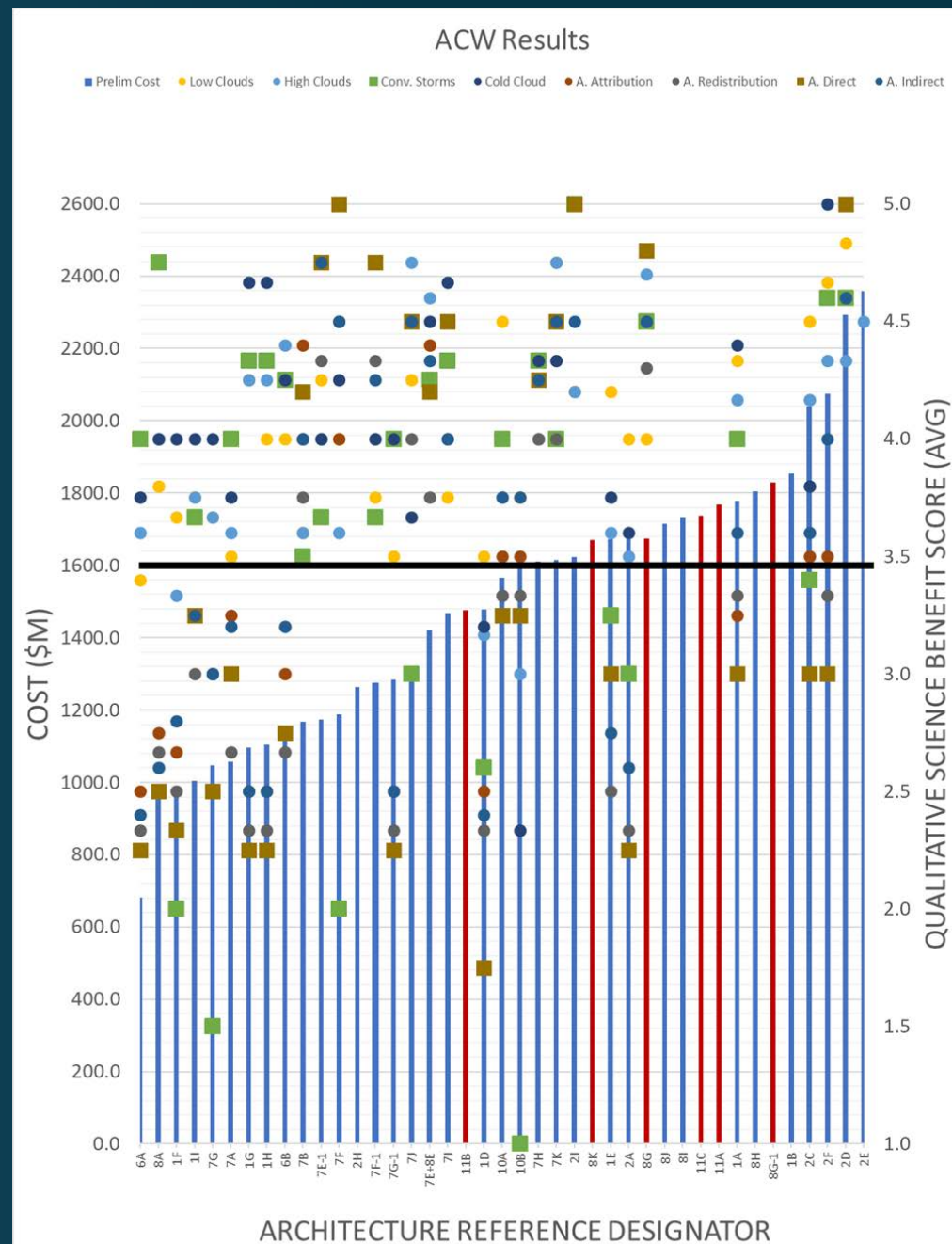
ACCP Study Approach

Decadal Survey

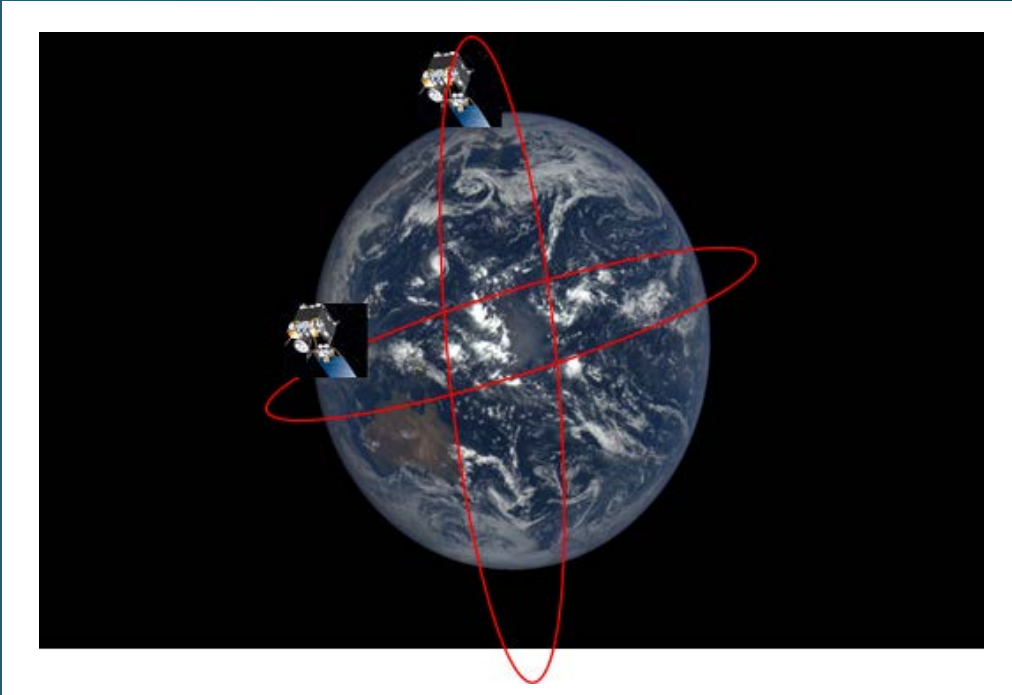


Architectures Constructed to Date

- The bar chart to the right provides a summary of the 41 Observing Systems constructed to date
- Orbits considered so far are polar sun-synchronous 450km, 1:30p.m. Ascending Node Crossing and 407km, 65deg/35deg Incl
- The cost numbers are very preliminary and are used for relativistic assessment
- We expect to ultimately study multiple Mission Implementations associated with ~3 Science Implementations more deeply
- Completed detailed designs for Architecture 8G in October 2020 at GSFC and Architecture 8K in January 2020 at JPL with contributions from CNES and CSA
- Elements of Architectures 11A-11C and 8G-1 are in study now



Architecture 8G (2 Med Sats)



SSG—1st Launch

GPM Orbit

Payload

Radar13

Lidar09

Radio9B

Radio10

Polar 07

Mass: 211kg

Power: 538W

Data: 99Mbps

Spacecraft

AICM Custom

SSP—2nd Launch

Polar Sun Synchronous Orbit

Payload

Radar13

Lidar 05

Radio07

Polar 07

Spec 03 TICFIRE

Mass: 551.9kg

Power: 841W

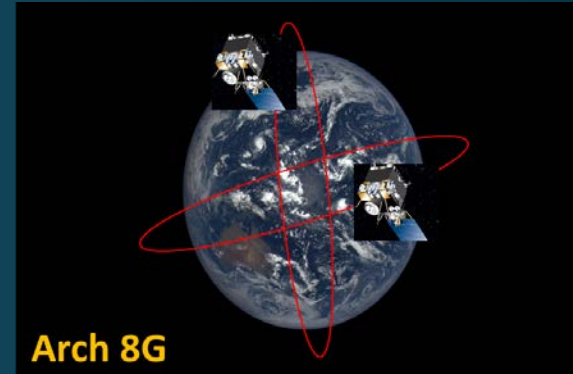
Data: 113 Mbps

Spacecraft

LeoStar3 with Augmented
Power

Architectures - Detailed Study

SATM Goals/ Objectives	Unique Science Implementation Strategies	Mission Implementation Strategies (CDCs)
SATM Rel F 5 Goals 8 Objectives	Seasonal Vertically Resolved Cloud & Aerosol Process & AT VARIOUS TIMES OF DAY GPM + PSS	8G 2 Med SC 8K 1 Med SC 1 ESPA Grande SC 2 ESPA SmallSats
	Seasonal Vertically Resolved Cloud & Aerosol Process OVER SEVERAL MINUTE TIME SCALES TO GET TIME EVOLUTION PSS only	11A 1 Med SC (Descoped) 1 ESPA Grande SC 4 ESPA SmallSats
	Seasonal Vertically Resolved Cloud & Aerosol Process OVER SEVERAL MINUTE TIME SCALES & AT VARIOUS TIMES OF DAY (Compromises Vertical Measurements for Sampling) GPM + PSS	11B 1 Med SC 5 ESPA SmallSats 11C 2 ESPA Grande 5 ESPA SmallSats

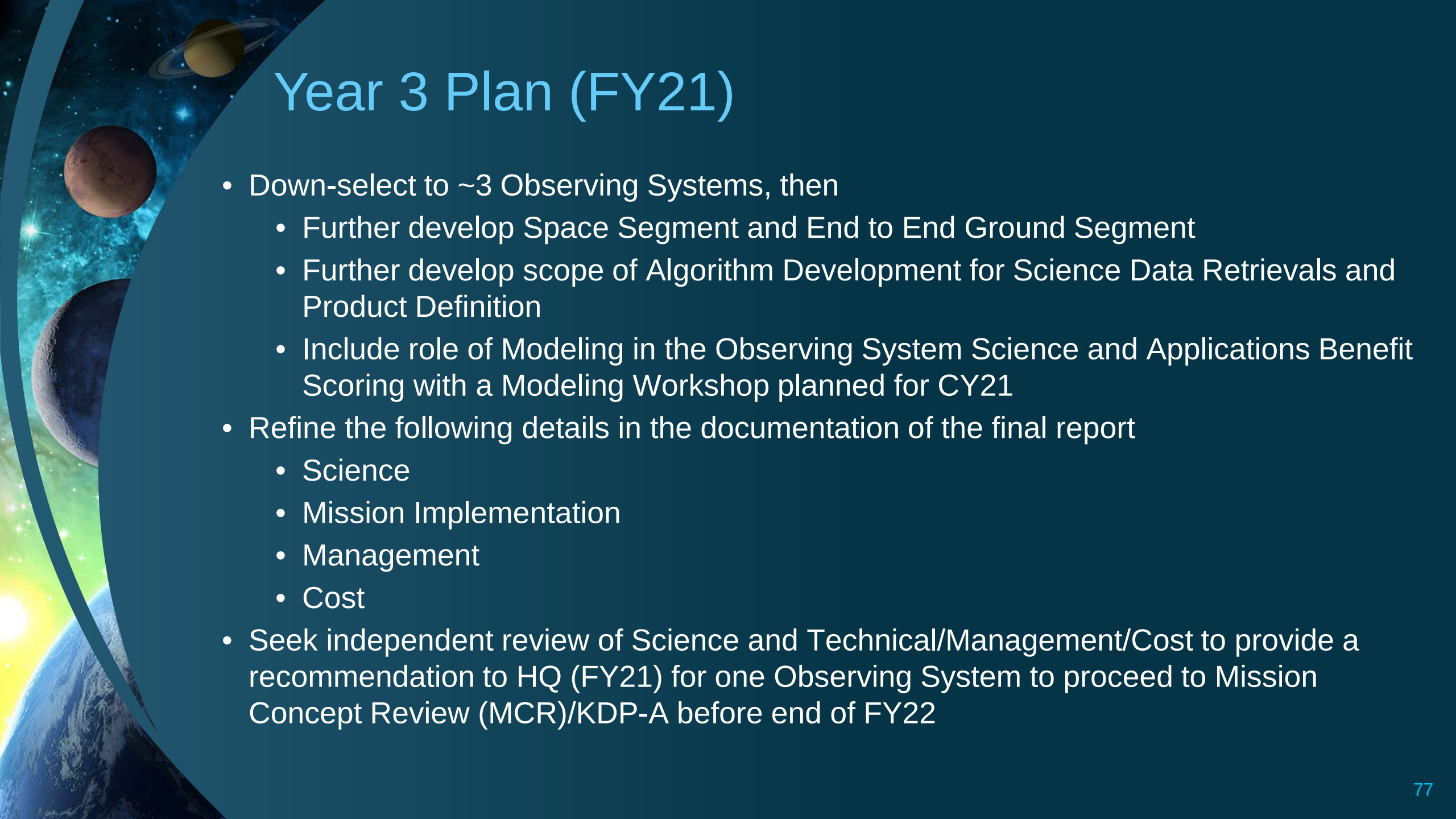


Study Status Update

- SCC/Community Independent Review of Architecture 8G Science Value conducted in 3 day workshop in December 2019
 - Architecture 8G evaluated by the SCC as “very high science value balancing the needs and desires of the various communities for ACCP science/measurements in A-Train and GPM orbits, while also being novel and transformative science”
 - Architecture 8G also balanced the interests of Centers, Industry, and International Partners (CNES and CSA)
- Special studies started at LaRC (to be completed in March/April 2020) to include JAXA radar contribution
 - Special Study #1--include JAXA radar in Architecture 8G
 - Special Study #2—JAXA radar on dedicated, optimized spacecraft as a separable element that could be included within other Architectures (e.g. Architecture 11C)
- Full team review of Architecture 8G initial **Science, Programmatic (Cost, Risk and Other Programmatic Factors), and Applications evaluations** completed Feb. 12-13, 2020 (updates planned)
- 3rd Collaborative Design Center (CDC) Study started at MSFC (to be completed in April 2020) providing Small Sat building blocks for Architectures 11A-C
- Architecture 8K Science, Programmatic, and Applications evaluations underway (scheduled to be completed in late March 2020)

Upcoming Near Term Schedule

- March 11-13, 2020 Sub-Orbital Workshop
 - Add Sub-Orbital program to complete Observing Systems targeting aspects of the Science objectives that can only or best be achieved via in-situ measurements
- March 13, 2020 Complete JAXA Special Study at LaRC
- March 17–April 23, 2020—Study Small Sats of Architecture 11A, 11B, and 11C at MSFC
- End March 2020—Complete Evaluation of Architecture 8K and Update Evaluation of Architecture 8G
 - science benefits (via Observing System Simulation Experiments (OSSEs) and other Simulations) performed by the SIT (refer to: https://gmao.gsfc.nasa.gov/observing_sys_science/OSSE)
 - technical feasibility/risk for the Instruments (via Technology Readiness Assessments)
 - programmatic feasibility/risk (via more Detailed Cost Modeling)
- May 2020 Architecture Study planned at LaRC & Complete Evaluation of Architectures 11A, 11B, 11C
- July 2020 Architecture Study TBD planned at GRC
- August 2020 Full Team Science Review
- September 2020 Sub-Orbital Workshop to design Sub-Orbital Architectures that meet Sub-Orbital Science Objectives from March Workshop
- October 2020 Architecture Study TBD planned at GSFC



Year 3 Plan (FY21)

- Down-select to ~3 Observing Systems, then
 - Further develop Space Segment and End to End Ground Segment
 - Further develop scope of Algorithm Development for Science Data Retrievals and Product Definition
 - Include role of Modeling in the Observing System Science and Applications Benefit Scoring with a Modeling Workshop planned for CY21
- Refine the following details in the documentation of the final report
 - Science
 - Mission Implementation
 - Management
 - Cost
- Seek independent review of Science and Technical/Management/Cost to provide a recommendation to HQ (FY21) for one Observing System to proceed to Mission Concept Review (MCR)/KDP-A before end of FY22

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Mass Change (MC)

Mass Change (MC) Study Update

Team accomplishments:

- Mass Change **Science and Applications Traceability Matrix (SATM)** is completed and posted on the NASA MC website. Community engagement in the development of the SATM initiated at the Community Workshop (July 2019) and at a later stage with discipline focused telecons:
 - Oct. 30: Earth Surface and Interior
 - Nov. 15: Global Hydrological Cycle and Water Resources
 - Nov. 19: Climate Variability and Change
- MC SATM was presented at the **Mass Change Study AGU Town Hall**, Dec. 12, 2019
- Mass Change Applications Survey released online June 14, 2019
- Mass change applications poster session at AGU on Dec. 13, 2019 confirmed great interest in mass change observations (e.g. applications related to water resources, agriculture, weather services). Performance targets involve increased spatial resolution, temporal resolution, and accuracy in data products relative to the current program of record

Mass Change (MC) Study Update (cont.)

Team accomplishments (cont.):

- Three categories of architectures were identified: Satellite-to-satellite tracking (SST), Gravity Gradiometer (GG), and Precise Orbit Determination (POD). The team has communicated with the community the developed MC architecture tree, at the workshop and AGU, and it is considered complete and comprehensive.
- The team has engaged the community, including international partners and the private sector, in inventorying technology development priorities, and scoping the associated maturity level and technology trade space.
 - Advancements and improvements in **accelerometer** technology
 - **Laser Ranging Improvements** - the future for SST measurements
 - Development to support Tech Demo opportunities to advance future technologies for:
 - CubeSat and **SmallSat** technologies
 - **Gradiometer** and Quantum Sensing technologies
- Team Meeting at NASA Ames - Feb 11-12, 2020: the team discussed the value framework and the science performance simulations for the identified architecture options.



International Partnerships

- **ESA:** Phase 0 study complete, Phase A initiates next year. NASA & ESA letter exchange for joint studies and the development of mission requirements document for a potential joint future mission (NASA HQ & ESA). ESA prepares for a successful 2022 Ministerial such that Phase B can initiate (Bender constellation).
- **CNES:** Phase 0 study began January 2020. Future schedule is more uncertain. Lower concept maturity (MARVEL constellation design targeting ITRF in addition to MC).
- **Germany** (HGF/GFZ, DLR, MPI, AEI): Phase 0 funding request pending. Initiating discussions with DLR. High heritage with successful partnerships on GRACE and GRACE-FO.

Different levels of maturity exist for each partnership concept, as well as different schedules.

International partnerships are a component of the MC observing system downselect, and will affect the cost of the future mission.

Mass Change Designated Observable Study
8 Most Important Science Objectives
Traceable to the 2017 Decadal Survey

Climate
Hydrology
Earth Surface and Interior

Ice Sheets (3)

Sea Level (1)
Ocean Heat (2)

Freshwater Storage (4)

Earthquakes (6)

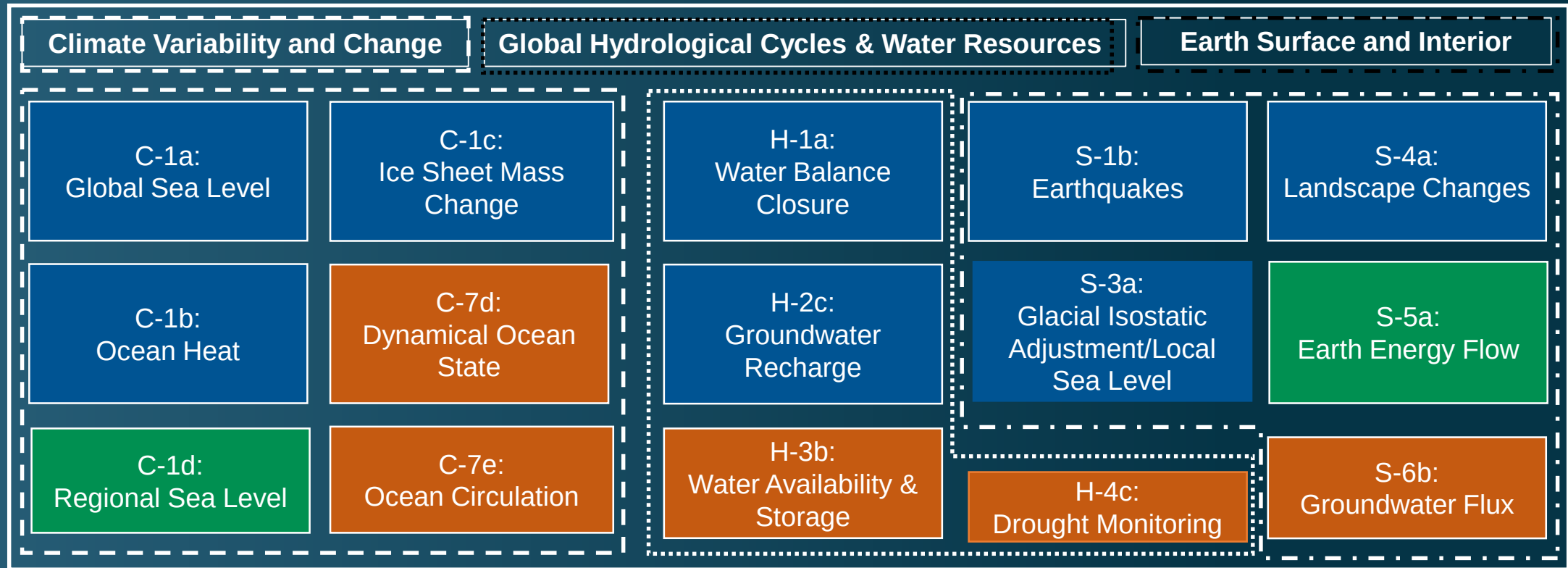
Landscape Changes (8)

Groundwater Storage (5)

**Glacial Isostatic Adjustment
and Local Sea Level (7)**

Decadal Survey Science and Application Objectives for Mass Change

A Diverse Set of Objectives Spanning Three Panels



DS Prescribed Weights [Importance]

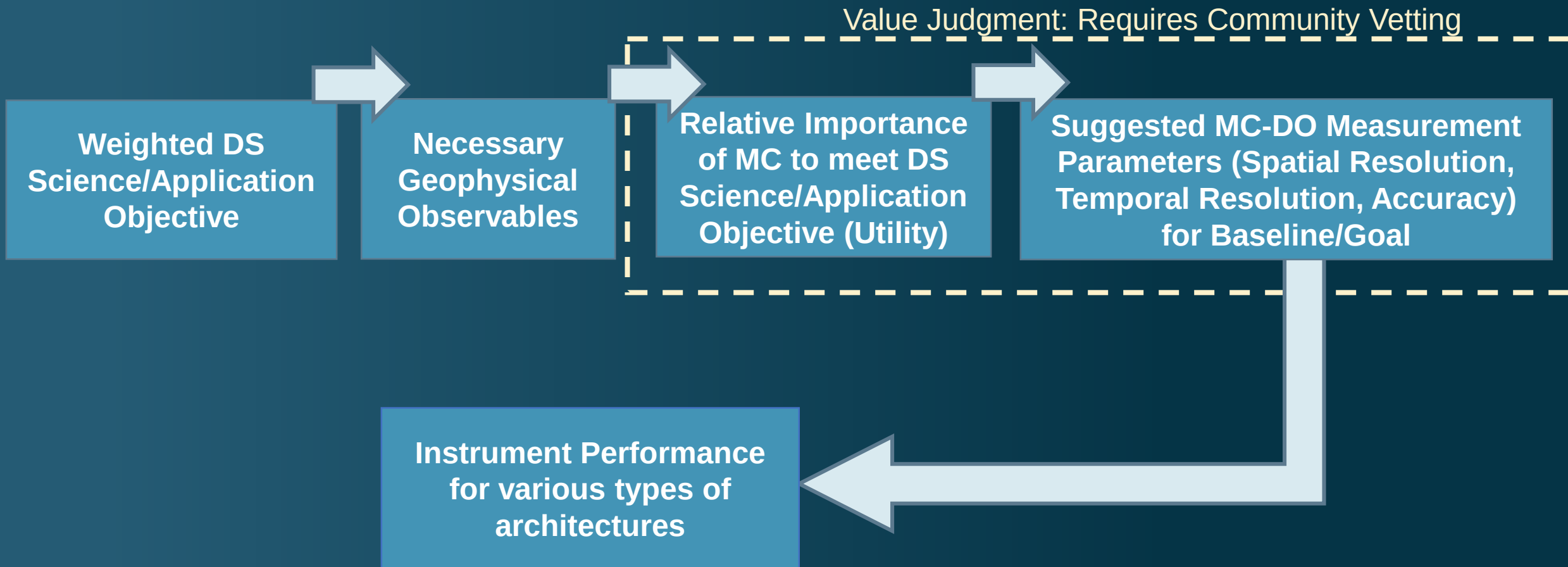
Most Important
Highest weight

Very Important
Medium weight

Important
Lower Weight

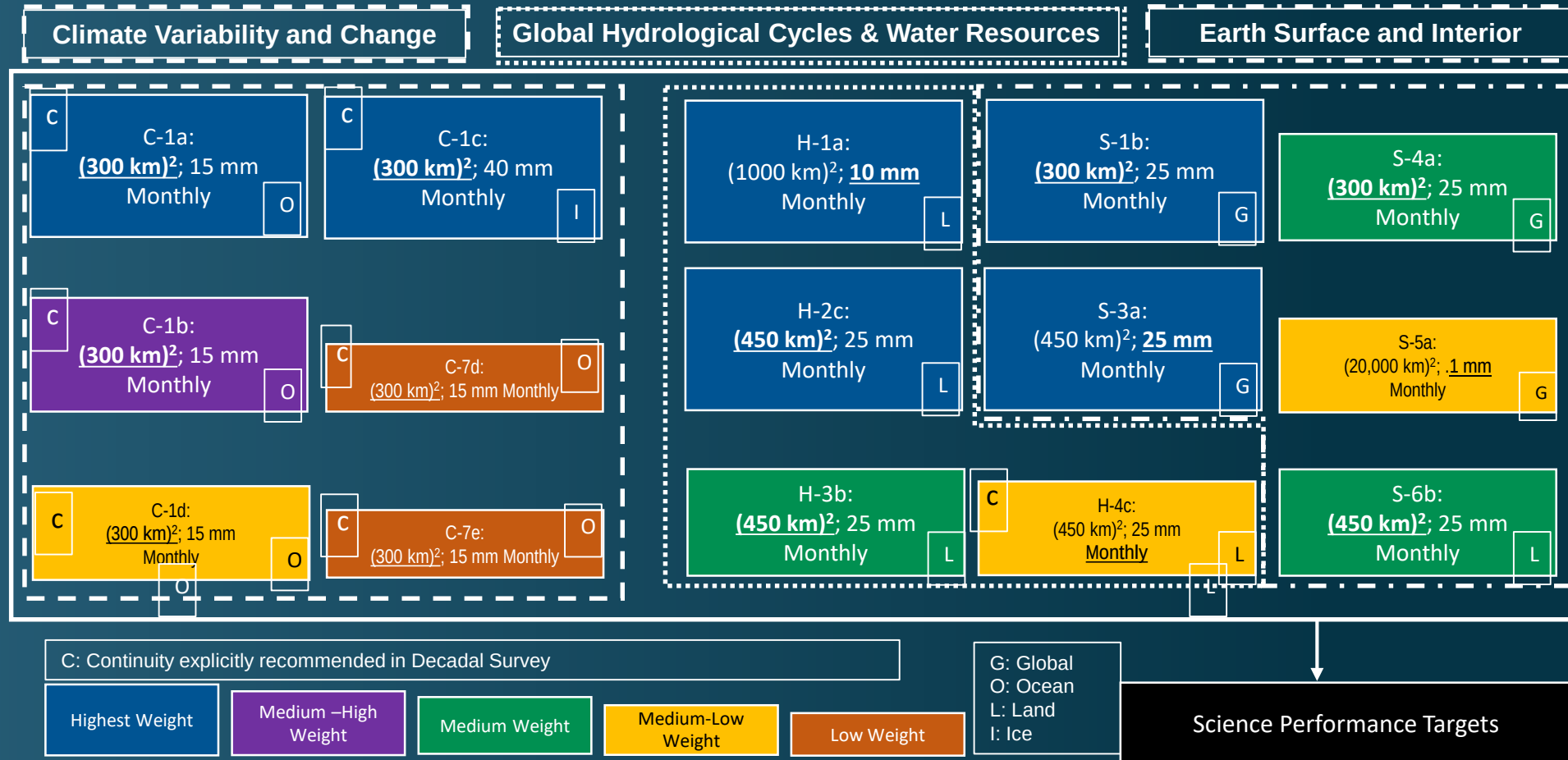
Science Performance Targets

MC Interpretation of DS Objectives

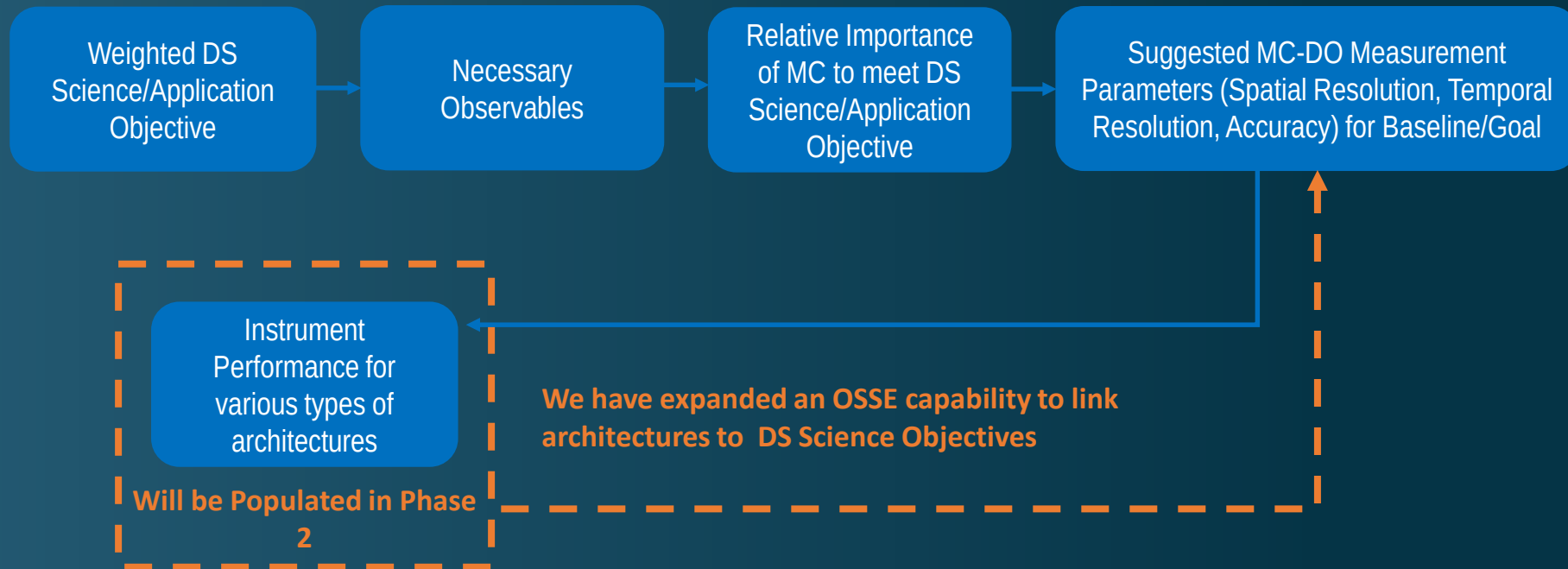


Suggested Measurement Parameters for Baseline

Weighting Combines DS Weights with MC Weights | Most Important Parameter Is Underlined | Units: Equivalent Water Height



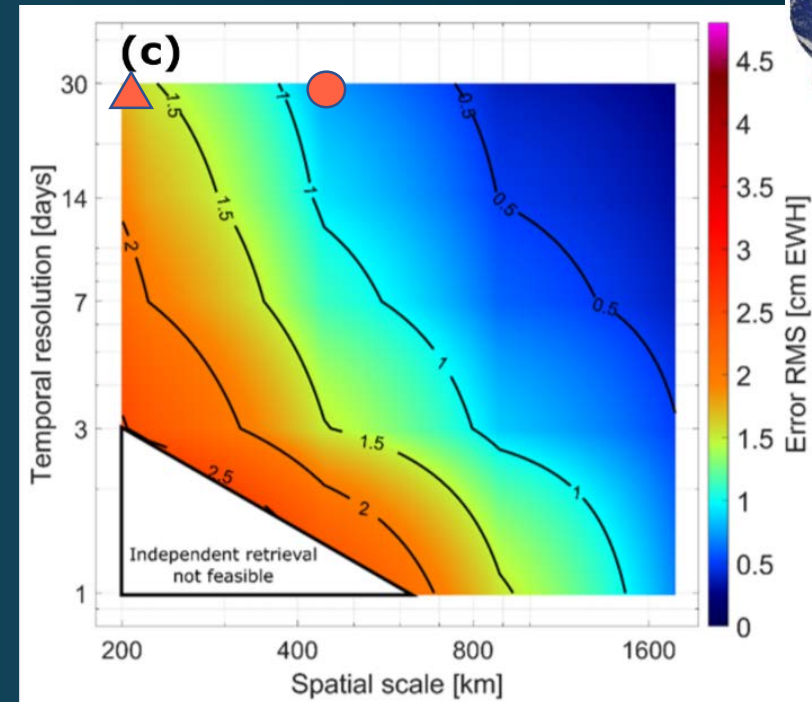
Linking Architectures to Science Performance



A Framework to Link Architectures to Science Objectives

Developed a framework to **simultaneously assess the performance of any architecture across a space-time continuum**. This allows for a direct relation between architectural choices and science performance.

- H-3b Baseline:
(450 km)²; Monthly; 25 mm
- ▲ H-3b Goal:
(200 km)²; Monthly; 25 mm



Hauk and Wiese, in prep



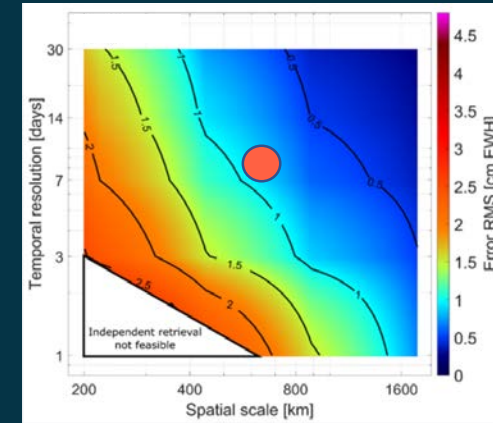
Determining Science Value in Phase 2

Must assign a science value to each architecture assessed in Phase 2 in an objective manner

The SATM has been constructed in a way to enable this

$$SV(a) = \sum_{n=1}^{15} (W_n) P_n = \sum_{n=1}^{15} \left(W_n \frac{\text{Spatial_Res}_n}{\text{Spatial_Res}(a)} \frac{\text{Temporal_Res}_n}{\text{Temporal_Res}(a)} \frac{\text{Accuracy}_n}{\text{Accuracy}(a)} \right)$$

C C-1a: (300 km) ² ; 15 mm Monthly O	C C-1c: (300 km) ² ; 40 mm Monthly I	H-1a: (1000 km) ² ; 10 mm Monthly L	S-1b: (300 km) ² ; 25 mm Monthly G	S-4a: (300 km) ² ; 25 mm Monthly G
C C-1b: (300 km) ² ; 15 mm Monthly O	C C-7d: (300 km) ² ; 15 mm Monthly O	H-2c: (450 km) ² ; 25 mm Monthly L	S-3a: (450 km) ² ; 25 mm Monthly G	S-5a: (20,000 km) ² ; 1 mm Monthly G
C C-1d: (300 km) ² ; 15 mm Monthly O	C C-7e: (300 km) ² ; 15 mm Monthly O	H-3b: (450 km) ² ; 25 mm Monthly L	H-4c: (450 km) ² ; 25 mm Monthly L	S-6b: (450 km) ² ; 25 mm Monthly L

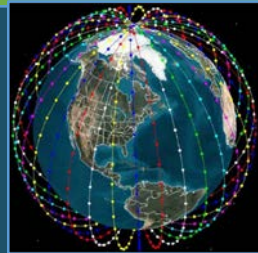


where:

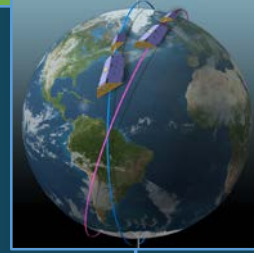
- a is a specific architecture being considered
- W_n is the combination of prescribed DS weights with the mass change weights
- Two of three of $\frac{\text{Spatial_Res}(a)}{\text{Spatial_Res}_n}$, $\frac{\text{Temporal_Res}(a)}{\text{Temporal_Res}_n}$, and $\frac{\text{Accuracy}(a)}{\text{Accuracy}_n}$ will be held constant—the two to hold constant will depend on the specific n

Mass Change Architecture Summary

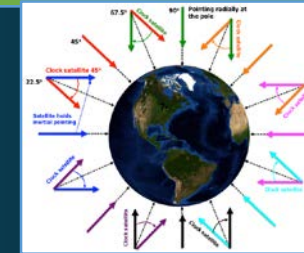
POD Precise orbit determination



SST Satellite-to-satellite tracking



GG Gravity gradiometer



Inclination	Altitude	# Sats	Accel.
~90°	~500 km	~25	ES
~70°	~350 km	~50	Opto.
	LEO/ MEO	~100	

Inclination	Altitude	# Sats
~90°	~500 km	1
~70°	~350 km	2
	LEO/ MEO	

Single in-line pair

Inclination	Altitude	Ranging	Accel.
~90°	~500 km	MWI	ES
~70°	~350 km	LRI	Hybrid
	LEO/ MEO	Freq. Comb	GRS
		CCLR	Opto.

Single pendulum pair

Inclination	Altitude	Ranging	Accel.
~90°	~500 km	MWI	ES
~70°	~350 km	LRI	Hybrid
	LEO/ MEO	Freq. Comb	GRS
		CCLR	Opto.

Two in-line pairs

Inclination	Altitude	Ranging	Accel.
~90°	~500 km	MWI	ES
~70°	~350 km	LRI	Hybrid
	LEO/ MEO	Freq. Comb	GRS
		CCLR	Opto.

N-pair SmallSats

Inclination	Altitude	Ranging	Accel.
~90°	~500 km	MWI	ES
~70°	~350 km	LRI	Hybrid
	LEO/ MEO	Freq. Comb	GRS
		CCLR	Opto.

MARVEL concept

Inclination	Altitude	Ranging	Accel.
~90°	~500 km	MWI	ES
~70°	~350 km	LRI	Hybrid
	LEO/ MEO	Freq. Comb	GRS
		CCLR	Opto.

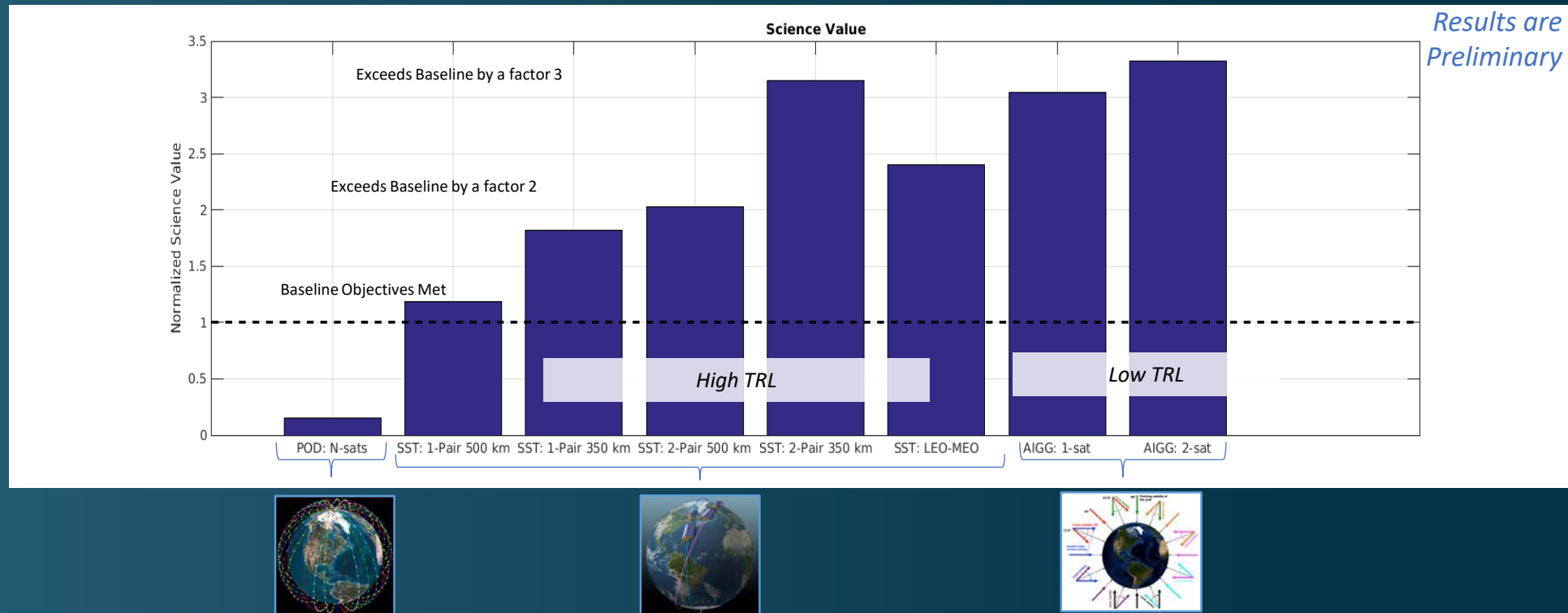
- ★ Discussions with DLR
- ★ Favored by ESA
- ★ Favored by CNES

Highlighted boxes = Orbit & technology trade space

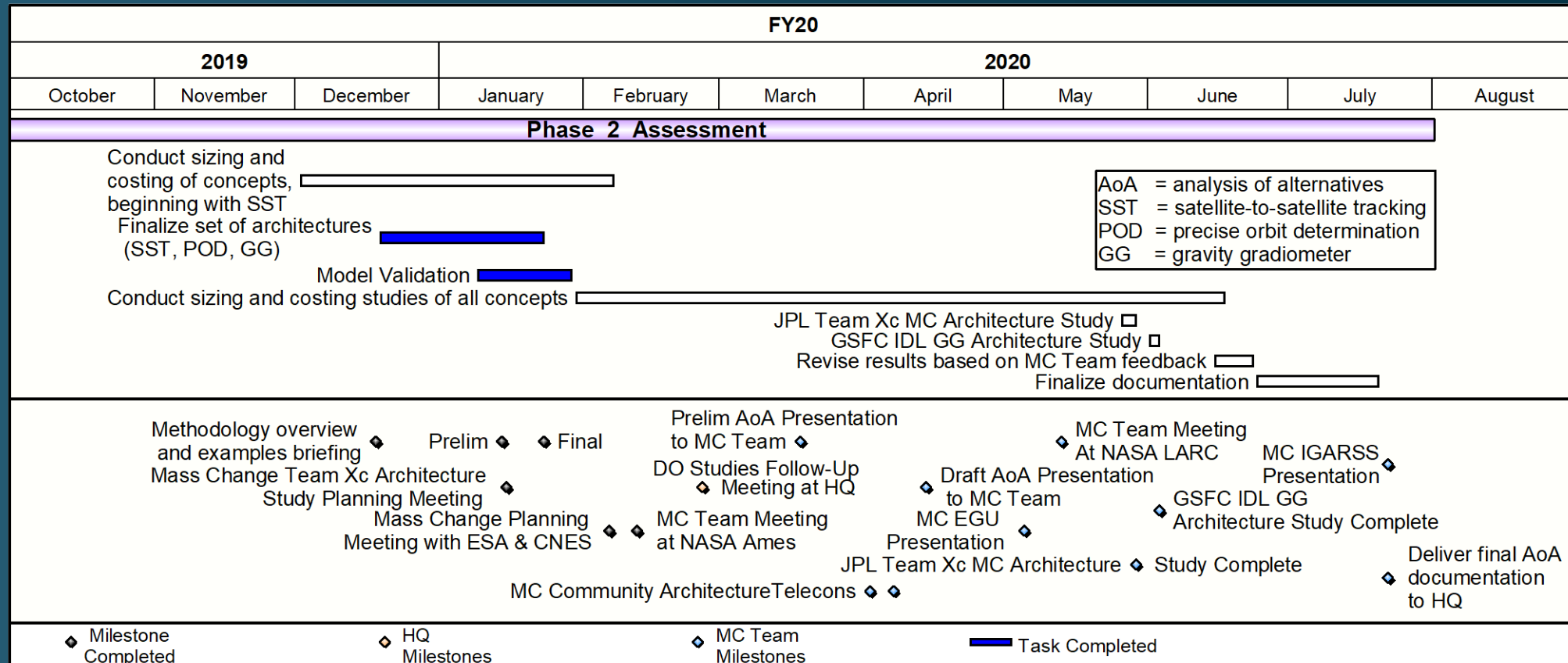
Science Value Methodology is Complete

Architectures are assessed directly against targets in the SATM to provide a quantitative science value to each architecture

Architecture Performance



Phase 2 Schedule



The background of the slide is a composite of two cosmic images. The top half features a dark blue and black space scene with a prominent, glowing blue nebula on the right side and several bright stars. The bottom half shows a vibrant orange and yellow nebula on the left, transitioning into a greenish-blue nebula on the right, with numerous stars scattered throughout.

Surface Biology and Geology (SBG)

Mission Study on Surface Biology and Geology

SBG Science and Applications Objectives from the 5 Decadal Survey Panels

Flows of energy, carbon, water, and nutrients sustaining the life cycle of terrestrial and marine ecosystems

Variability of the land surface and the fluxes of water, energy and momentum

Composition and temperature of volcanic products immediately following eruptions

Snow accumulation, melt, and spectral albedo

Inventory the world's volcanos and geology of exposed land surfaces

The global carbon cycle and associated climate and ecosystem impacts

Monthly terrestrial CO₂ fluxes at 100 km scale

Functional traits and diversity of terrestrial and aquatic vegetation

Land and water use effects, surface temperatures, evapotranspiration

Water balance from headwaters to the continent

Surface Biology and Geology (SBG) Update

- Phase 2 Assessment of Architectures Well Underway
 - From ~61 Architectures to ~25 Architectures Currently
- RTI Applications Study Initiated
- Dec. 13: AGU Sessions
- Jan. 28 - 29: Co-Leads Meeting
- Request and Approval for Pathfinder and OSSE Precursor Activities
- ASI TIR Collaboration and Feasibility Study
- Feb. 11-13: ECOSTRESS Science and Applications Team Meeting
- Feb. 24-27: PACE Mission CDR
- Feb. 26: DO Studies Follow-Up Meeting
- March 9: RFI posted (WH-01-20); Request for additional instrument information
 - <https://beta.sam.gov/opp/2fa0878f18924a6d85dd40136329a2b2/view>

SBG: Upcoming Key Dates

Date	Milestone
March 2020	ASI and ESA Technical Interface Meetings (Postponed by Coronavirus)
March 2020	Collaborative Design Session (LaRC Design Studio)
April 2020	Collaborative Design Session (JPL Team I/X)
May 2020	Collaborative Design Session (GSFC MDL)
May 27-29, 2020	SBG Community Workshop
July 2020	SBG Architecture Recommendations to HQ
Aug. - Sept. 2020	HQ Architecture Selection
December 2020	AGU Town Hall
2020 - 2021	SBG Study Final Report Preparation
2020 - 2021	SBG MCR Preparation
Spring 2021	SBG Community Workshop
September 2021	SBG MCR

SBG: International Collaboration

Partner	Correspondence	Instrument Type	Contribution	Science Benefit
ISRO	Discussions India-US Civil Space Nov 2019	VSWIR	Launch 2nd VSWIR instrument & satellite	4-day revisit
ASI	Exchange of letters & ASI commitment	TIR	Spacecraft, Launch, Operations	3-day revisit
CHIME (ESA)	Technical Interface Meetings	VSWIR	Data Exchange	2-3-day revisit
LSTM (ESA)	Discussions	TIR	Data Exchange	1-2-day revisit
TRISHNA (CNES, ISRO)	Discussions	TIR	Data Exchange	1-2-day revisit
Australian Space Agency	Discussions	N/A	Cal/Val	Reduced Data Product Uncertainty
DESIS (DLR)	Formal Data Buy	VSWIR	Data Exchange	Algorithm Maturation
HISUI (Japan)	Science Team Membership, NASA USPI Award (2019-2024)	VSWIR	Data Exchange	Algorithm Maturation
PRISMA (ASI)	Discussions	VSWIR	Data Exchange	Algorithm Maturation
EnMAP (DLR)	Science Advisory Group Participation USPI Award (2019-2024)	VSWIR	Data Exchange	Algorithm Maturation

SBG: What Have We Learned

- SBG science and applications communities prioritize:
 - High spatial resolution, high SNR spectral imaging
 - Global sampling of land and coastal ocean
 - Shortest possible revisit frequency
- A single flagship/large VSWIR/TIR platform is cost prohibitive
 - Pursuing architectures with separate VSWIR and TIR components ($\Rightarrow$ 2 spacecraft)
- Have cast the net widely and identified ~2 dozen high-value, affordable ($\leq$ \$650M) SBG architectures
- International partnerships are critical to maximizing value within the budget guideline
- Have made significant progress in understanding Applications value as a function of latency and other factors
- Have assessed multiple calibration (both on-board and vicarious) and their applicability to specific architectures
- Websites: sbg.jpl.nasa.gov; science.nasa.gov/earth-science/decadal-sbg

The background of the slide is a composite of two cosmic images. The top half features a dark blue and black space scene with a prominent, bright blue nebula on the right side and several distant stars. The bottom half shows a vibrant orange and yellow nebula on the left, transitioning into a greenish-blue nebula on the right, with numerous stars scattered throughout.

Surface Deformation and Change (SDC)

Surface Deformation and Change Observables

Glaciers Ice Sheets Dynamics

Volcanic Unrest

Hydrology

Forest Biomass

Wetlands Dynamics

Disturbance

Agriculture

Sea Ice Dynamics

Sea Level

Tectonics

Earthquakes

Response

Landslides

Surface Water

Coastal Processes

Subsidence

12

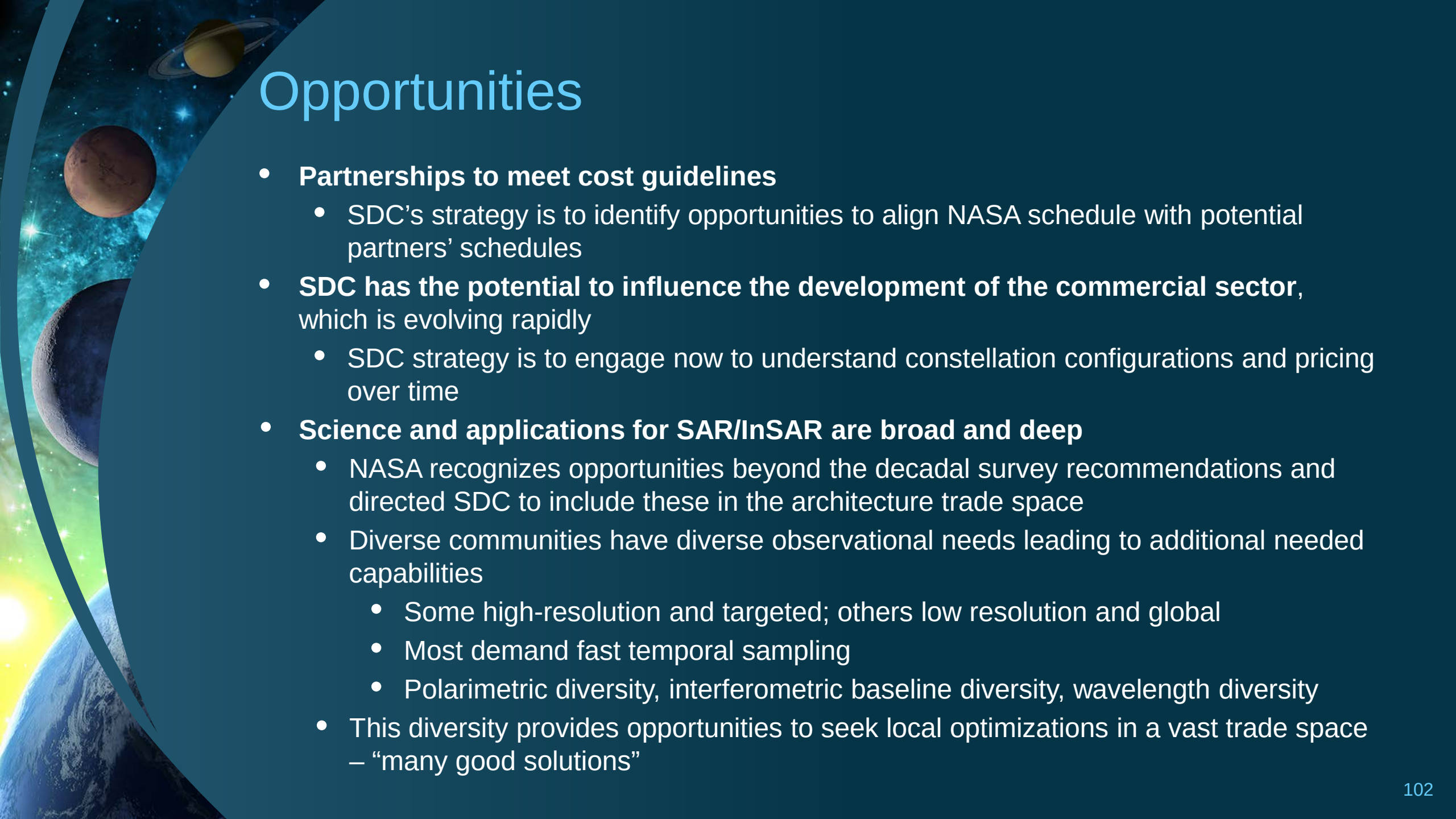
Unique Aspects of Surface Deformation and Change (SDC) Designated Observable Study

- **Prescribed sensor:** an *affordable synthetic aperture radar-based* system or systems that would meet the Decadal Survey recommendations
- **Added observables:** *Keep non-geodetic measurements and downstream sciences in the trade space (i.e. ecosystems, soil moisture, hydrology), though not emphasized in Decadal Survey*
 - *Requires additional exploration of SATM*
- **Study Duration: 5 Years**
 - *Complicates the engagement with commercial and international partners which can be quite dynamic*
 - *Still 1-2 years away from down-selection*
- **Engagement:** There are literally dozens of potential *partnerships*, data sources, alliances, domestic and *international*



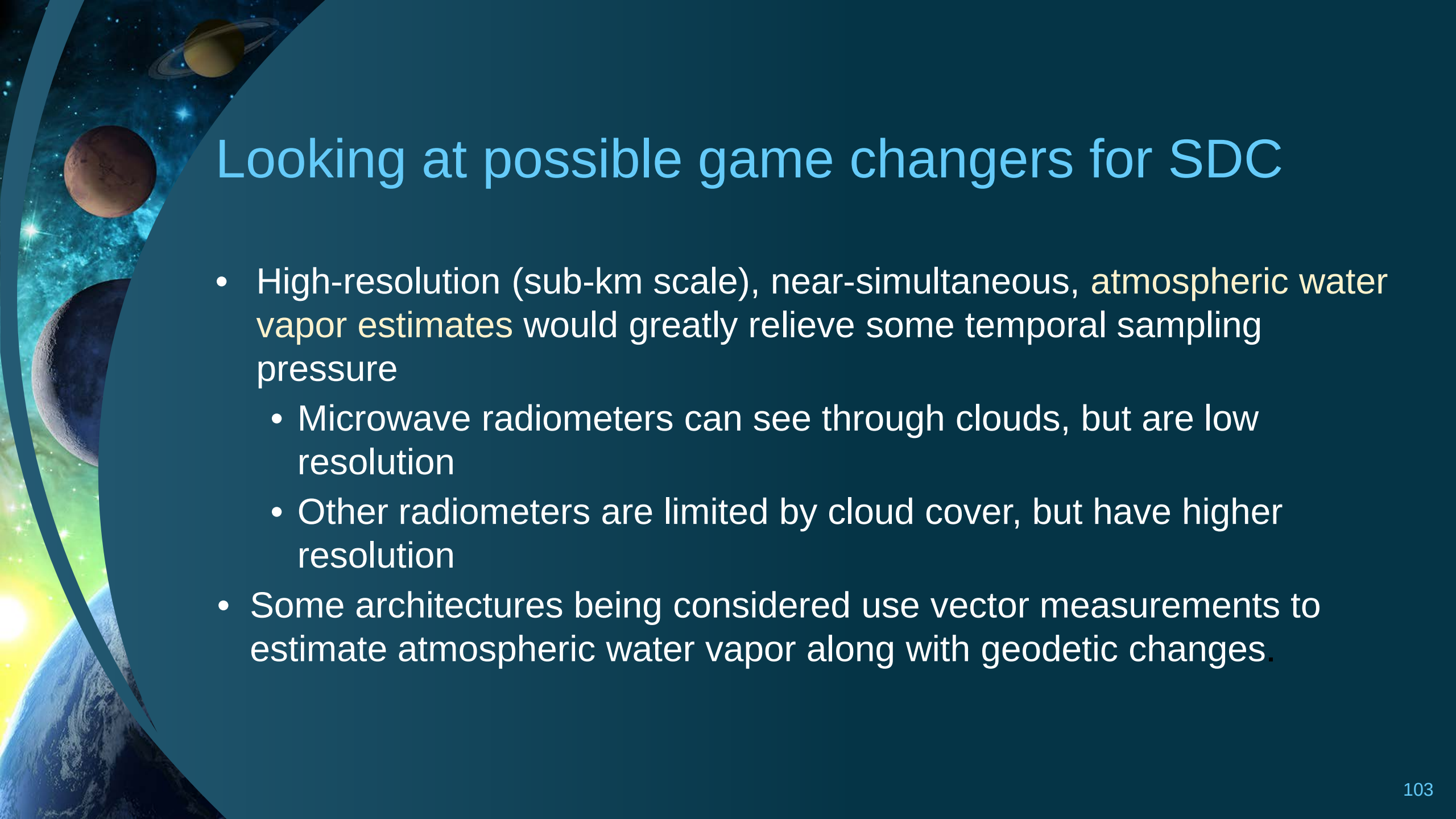
What SDC has learned to date

- SDC SATM development has uncovered a desire by Research and Applications community for expanded capabilities:
 - For InSAR, 12-days → 6-hr sampling
 - For SAR, strong national (applications) interest in the imagery and polarimetry
 - → \$500M A-F cost cap will be a challenge
- Exploration of small-sat trade space and new technologies found no immediate silver bullets of cost reduction
 - The NASA Small Spacecraft Missions Program not designed for low-cost
 - Large antennas and power continue to dominate cost models
- X-band SAR commercial sector is blossoming
 - There is a potential for data buys for specific science targets and applications (e.g. cryosphere, urgent response)

A space-themed background featuring a curved view of Earth's horizon at the bottom left, transitioning into a deep blue space filled with stars and nebulae. Several celestial bodies are visible: a yellow planet with rings (Saturn) in the upper left, a reddish planet (Mars) in the middle left, and a grey, cratered moon in the lower left. The overall aesthetic is futuristic and scientific.

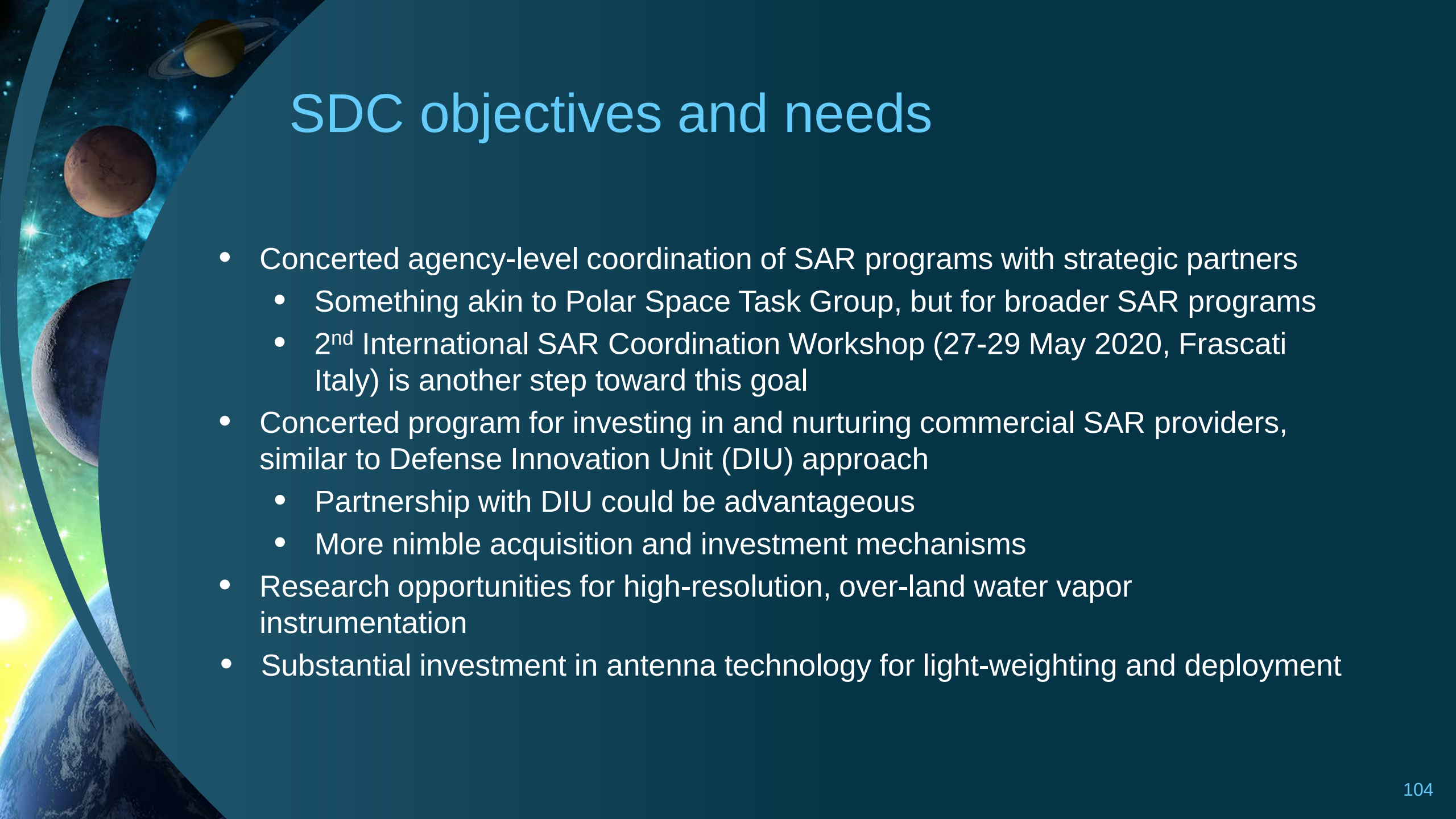
Opportunities

- **Partnerships to meet cost guidelines**
 - SDC's strategy is to identify opportunities to align NASA schedule with potential partners' schedules
- **SDC has the potential to influence the development of the commercial sector,** which is evolving rapidly
 - SDC strategy is to engage now to understand constellation configurations and pricing over time
- **Science and applications for SAR/InSAR are broad and deep**
 - NASA recognizes opportunities beyond the decadal survey recommendations and directed SDC to include these in the architecture trade space
 - Diverse communities have diverse observational needs leading to additional needed capabilities
 - Some high-resolution and targeted; others low resolution and global
 - Most demand fast temporal sampling
 - Polarimetric diversity, interferometric baseline diversity, wavelength diversity
 - This diversity provides opportunities to seek local optimizations in a vast trade space
 - “many good solutions”

A space-themed background featuring a curved view of Earth's horizon at the bottom left, with a bright sun or star partially visible. Above the horizon, several celestial bodies are shown: a crescent moon, a reddish planet (Mars), and a yellow planet with rings (Saturn). The background is a deep blue with scattered white stars and a nebula-like glow.

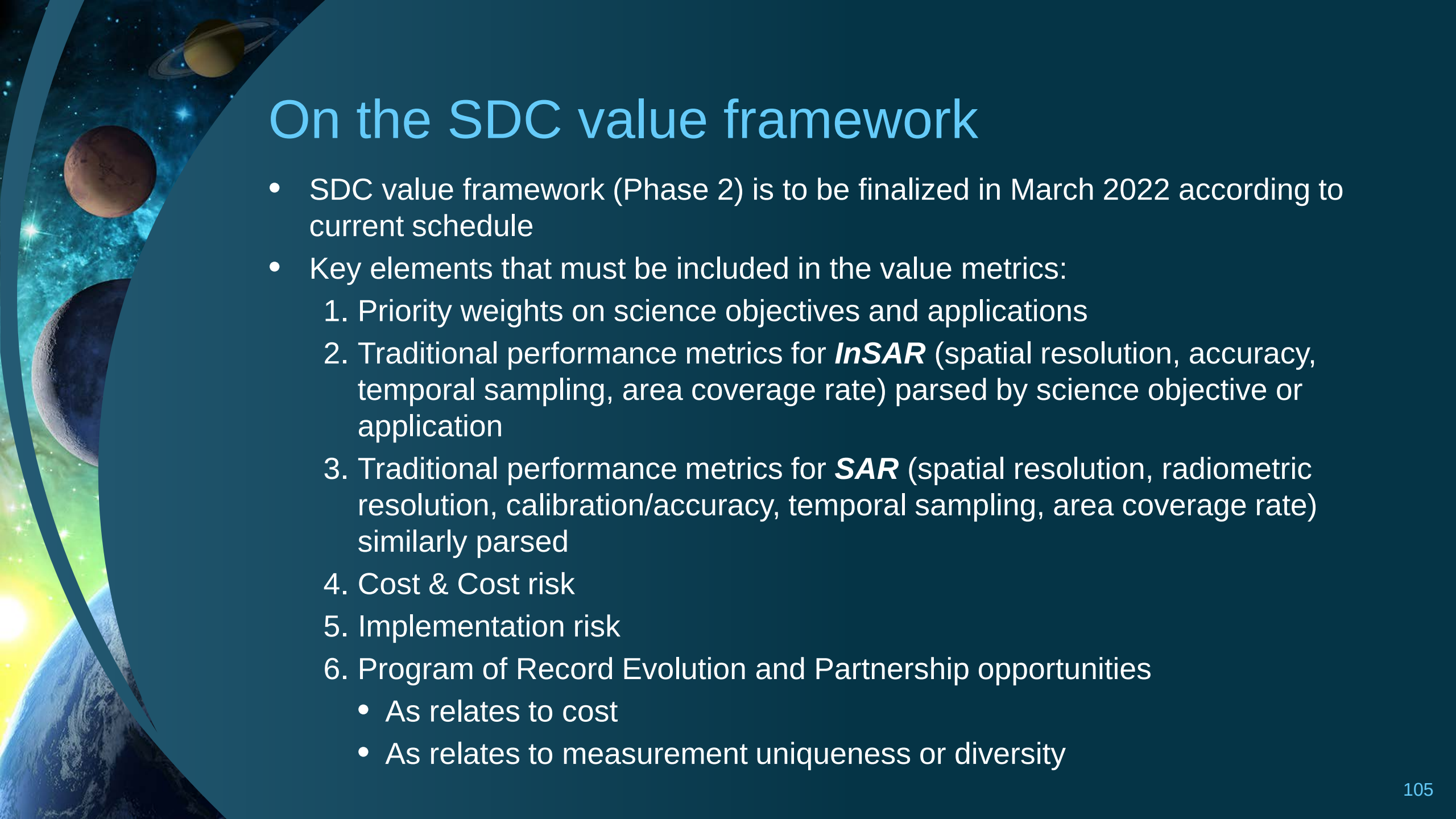
Looking at possible game changers for SDC

- High-resolution (sub-km scale), near-simultaneous, atmospheric water vapor estimates would greatly relieve some temporal sampling pressure
 - Microwave radiometers can see through clouds, but are low resolution
 - Other radiometers are limited by cloud cover, but have higher resolution
- Some architectures being considered use vector measurements to estimate atmospheric water vapor along with geodetic changes.



SDC objectives and needs

- Concerted agency-level coordination of SAR programs with strategic partners
 - Something akin to Polar Space Task Group, but for broader SAR programs
 - 2nd International SAR Coordination Workshop (27-29 May 2020, Frascati Italy) is another step toward this goal
- Concerted program for investing in and nurturing commercial SAR providers, similar to Defense Innovation Unit (DIU) approach
 - Partnership with DIU could be advantageous
 - More nimble acquisition and investment mechanisms
- Research opportunities for high-resolution, over-land water vapor instrumentation
- Substantial investment in antenna technology for light-weighting and deployment



On the SDC value framework

- SDC value framework (Phase 2) is to be finalized in March 2022 according to current schedule
- Key elements that must be included in the value metrics:
 1. Priority weights on science objectives and applications
 2. Traditional performance metrics for **InSAR** (spatial resolution, accuracy, temporal sampling, area coverage rate) parsed by science objective or application
 3. Traditional performance metrics for **SAR** (spatial resolution, radiometric resolution, calibration/accuracy, temporal sampling, area coverage rate) similarly parsed
 4. Cost & Cost risk
 5. Implementation risk
 6. Program of Record Evolution and Partnership opportunities
 - As relates to cost
 - As relates to measurement uniqueness or diversity

Surface Deformation and Change (SDC) Designated Observable Study Plan

2017 Earth Science Decadal Survey

Community Workshop *Surface Deformation and Change*

May 19-21, 2020

California Institute of Technology, Pasadena, CA

SAVE THE DATE

Shape the future of synthetic aperture radar (SAR) research and applications following the 2017 Decadal Survey as an advocate for your community's needs, priorities and desired characteristics of observations.

We invite you to join us for our 2020 Community Workshop to:

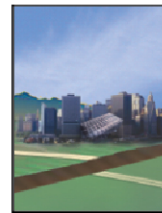
- ❖ **Present** your research and applications to demonstrate the crucial contributions of current and future SAR missions.
- ❖ **Refine** the science and applications goals for SDC to inform the needs for specific observations acquired through potential supporting architectures.
- ❖ **Finalize** discussions initiated in our 2019 Research and Applications Workshop ([📅](#)), Technology Workshop ([📅](#)) and AGU Town Hall session ([📅](#)).



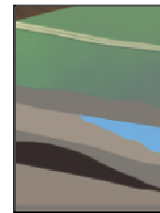
Solid Earth



Ecosystems



Geohazards



Hydrology



Cryosphere

This workshop will be the last chance to discuss and share your thoughts before the SDC Study Team develops potential concepts for observing architectures and strategies. Be there!



For more information: Ala Khazendar (ala@pl.nasa.gov)
Andrew Molthan (andrew.molthan@nasa.gov)
NASA SDC Team

Earth Venture Continuity-1 (EVC-1)

Solicitation was released on Dec. 19, 2018

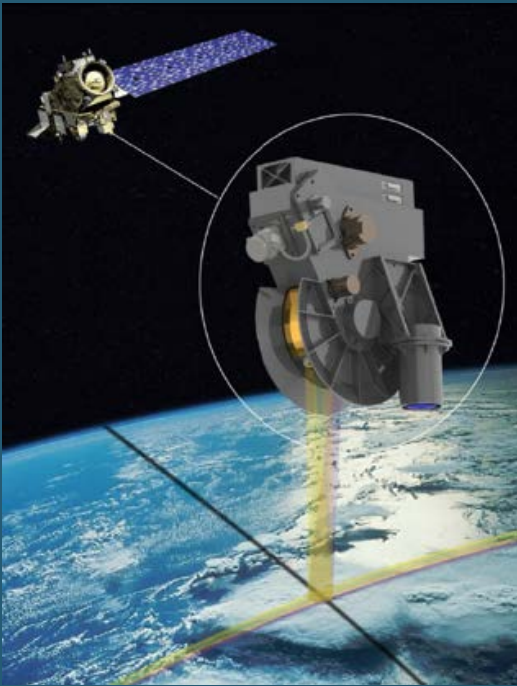
- <https://nspires.nasaprs.com>
- Solicitation #: NNH17ZDA004O-EVC1

Schedule was updated following the government shutdown:

- Pre-proposal WebEx/Teleconference: Feb. 28, 2019
- Mandatory Notices of Intent (NOI) due: April 26, 2019, 11:59 PM EDT
- Last Date for submission of Questions: July 12, 2019, 11:59 pm EDT
- Proposals due: July 26, 2019, 11:59 PM EDT
 - Due Date for Receipt of Electronic Proposals in NSPIRES: July 26, 2019, 11:59 pm EDT
 - Due Date for Receipt of Proposal CD-ROMs: July 31, 2019, 4:30 pm EDT
- Currently evaluating proposals
- Selection Early January 2020

Earth Venture Continuity-1: Libera

(Li'be-ra), named for the daughter of Ceres in ancient Roman mythology



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

- Measures integrated shortwave (0.3–5 μm), longwave (5–50 μm), total (0.3–>100 μm) and (new) split-shortwave (0.7–5 μm) 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

Participating Organizations			
Investigation Management and Instrument Development		Science	
 LASP	PI Institution, Mission and Investigation Leadership, L1 Data Processing, MOC	JPL/CSU	Deputy PI and Science Team Leadership
		LBL	Climate OSSE and Model Testing
	Flight Instrument Support, AI&T, Instrument and Calibration Science	UA	Surface Energy Budget
	Detector Development and Characterization	CSU	Science Data Continuity Validation
		UM	Infrared Radiation Budget
 Space Dynamics	Pre-flight Calibration	CIRES/NOAA	Angular Distribution Models

Earth Science Division's Venture Opportunities

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

EVM-3 will include an Enhanced Operations Option jointly with NOAA

The background of the slide is a composite of two cosmic images. The top half features a dark blue and black space scene with a prominent blue nebula on the right and several bright stars. The bottom half shows a vibrant orange and yellow nebula on the left, transitioning into a greenish-blue nebula on the right, with numerous stars scattered throughout.

Incubation Program Updates

Decadal Survey Incubation Program

- A new program element in the 2017 Decadal Survey, focused on investment for priority observation capabilities needing advancement prior to cost-effective implementation
- Two elements: Planetary Boundary Layer (PBL), and Surface Topography and Vegetation (STV)
- Supports maturation of mission, instrument, technology, and/or measurement concepts to address specific high priority science (for 2027-2037 decade)
- Assigned to ESTO to manage, however, will be run as a partnership between ESTO and R&A
- Anticipate a mix of Activities:
 - Technology development activities
 - Modeling/system design and analysis activities
 - Small scale pilot demonstrations
 - Typically 1-3 year activities

Incubation Observables Summary from the Decadal Survey

Observable	Science/Applications Summary	Candidate Measurement Approach	Measurement Requirements
Planetary Boundary Layer (PBL)	Diurnal 3D PBL thermodynamic properties and 2D PBL structure to understand the impact of PBL processes on weather and AQ through high vertical and temporal profiling of PBL temperature, moisture and heights	Microwave, hyperspectral IR sounder(s) (e.g., in GEO or small sat constellation), GPS radio occultation for diurnal PBL temperature and humidity and heights; water vapor profiling DIAL lidar; and lidar for PBL height	- From high resolution and diurnally resolved 2D/3D measurements of PBL 200 m vertical resolution for 3D variables (Temp, Humidity, Horz. wind vector) with 2-3 hour temporal resolution and 20 km horizontal resolution
Surface Topography and Vegetation (ST&V)	High-resolution global topography including bare surface land topography, ice topography, vegetation structure, and shallow water bathymetry	Radar; or lidar	- Contiguous 5m sampling with 0.1m vertical accuracy from space - Contiguous 1m sampling with 0.1 m vertical accuracy with aircraft - With seasonal repeat

Decadal Survey Incubation - Today

- ROSES-19 Element A.54 - **Decadal Survey Incubation Study Teams: Planetary Boundary Layer (PBL) and Surface Topography and Vegetation (STV)**
 - Released March 2019; led by Program Scientists.
 - “...to identify methods and activities for improving the understanding of and advancing the maturity of the technologies applicable to these two TOs and their associated science and applications priorities.
- Two study teams selected in early Nov. 2019 – one for PBL, one for STV
- Each team is to produce a white paper that will help inform the next solicitation in FY21 and funding in FY22+
 - Outline potential future methods and activity areas, such as modeling and Observing System Simulations Experiments (OSSEs); field campaigns; and a range of potential observing system architectures utilizing emerging sensor and information technologies.
 - Other deliverables include: an interim report; presentations to NASA Headquarters; and a preliminary Science and Applications Traceability Matrix (SATM)
 - Each Study Team is required to collect community input for white papers
- Nine 1-year (FY20) augmentations of existing projects also made (PBL & STV)

PBL Selected Study Team

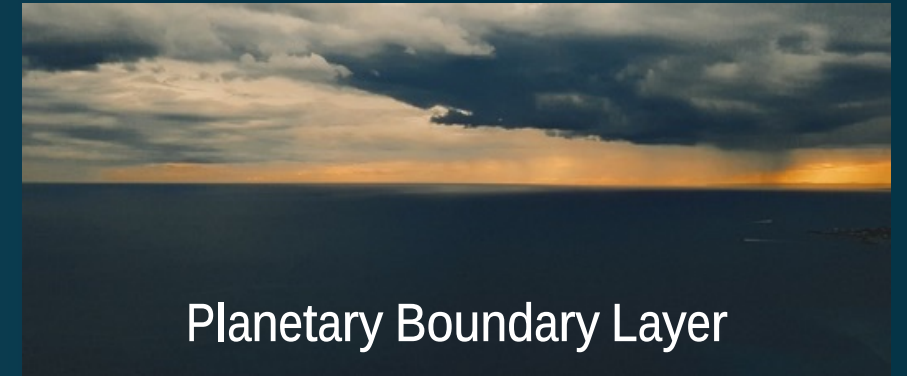
Science Lead: Joao Teixeira (JPL)
Technology Co-Lead: Jeff Piepmeier (GSFC)
Tech. Deputy Co-Lead: Amin Nehrir (LaRC)

11 Additional PI Team Members:

Chi Ao	JPL
Matthew Lebsock	JPL
Carol Anne Clayson	Woods Hole Oceanographic Instit.
Ann Fridlind	NASA GISS
Will McCarty	NASA GSFC/GMAO
Joe Santanello	NASA GSFC
Dave Turner	NOAA
Haydee Salmun	Hunter College CUNY
Xubin Zeng	University of Arizona
Zhien Wang	University of Colorado
Shuyi Chen	University of Washington

Community Workshop to be held May 19-21, 2020 in Columbia, MD for more information go to <https://sites.google.com/view/pblmeeting/home>

For more information send “subscribe” to PBL-study-announcements@lists.nasa.gov



Planetary Boundary Layer

Augmentations

- *Ceilmeter Data Analysis*, PI: Milt Halem (UMBC)
- *Satellite Lidar PBL Height Retrieval*, PI: Steve Palm (GSFC/SSAI)
- *Atmospheric Boundary Layer Lidar Pathfinder (ABLE)*, PI: Amin Nehrir (LaRC)
- *Vapor In-Cloud Profiling Radar (VIPR)*, PI: Matthew Lebsock (JPL)

STV Selected Study Team

Science Lead: Andrea Donnellan (JPL)

Technology Co-Lead: David Harding (GSFC)

9 Additional PI Team Members:

Alex Gardner JPL

Cathleen Jones JPL

Paul Lundgren JPL

Yunling Lou JPL

Sassan Saatchi JPL

Marc Simard JPL

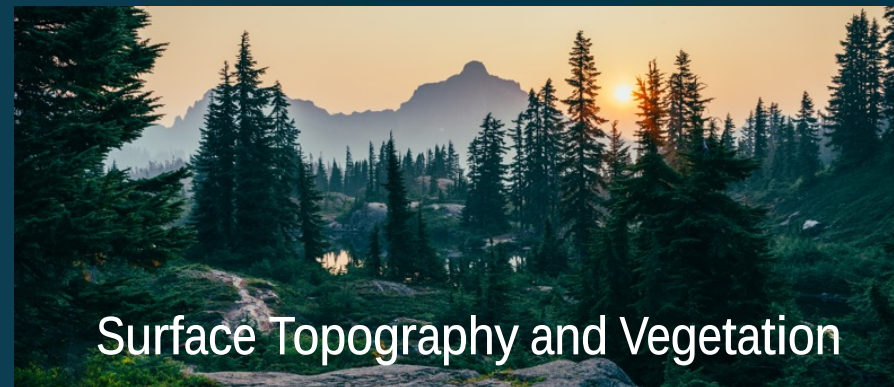
Robert Treuhaft JPL

Jason Stoker USGS Reston

Konrad Wessels George Mason University

STV Community Workshop: planning for the week of Aug. 3, 2020

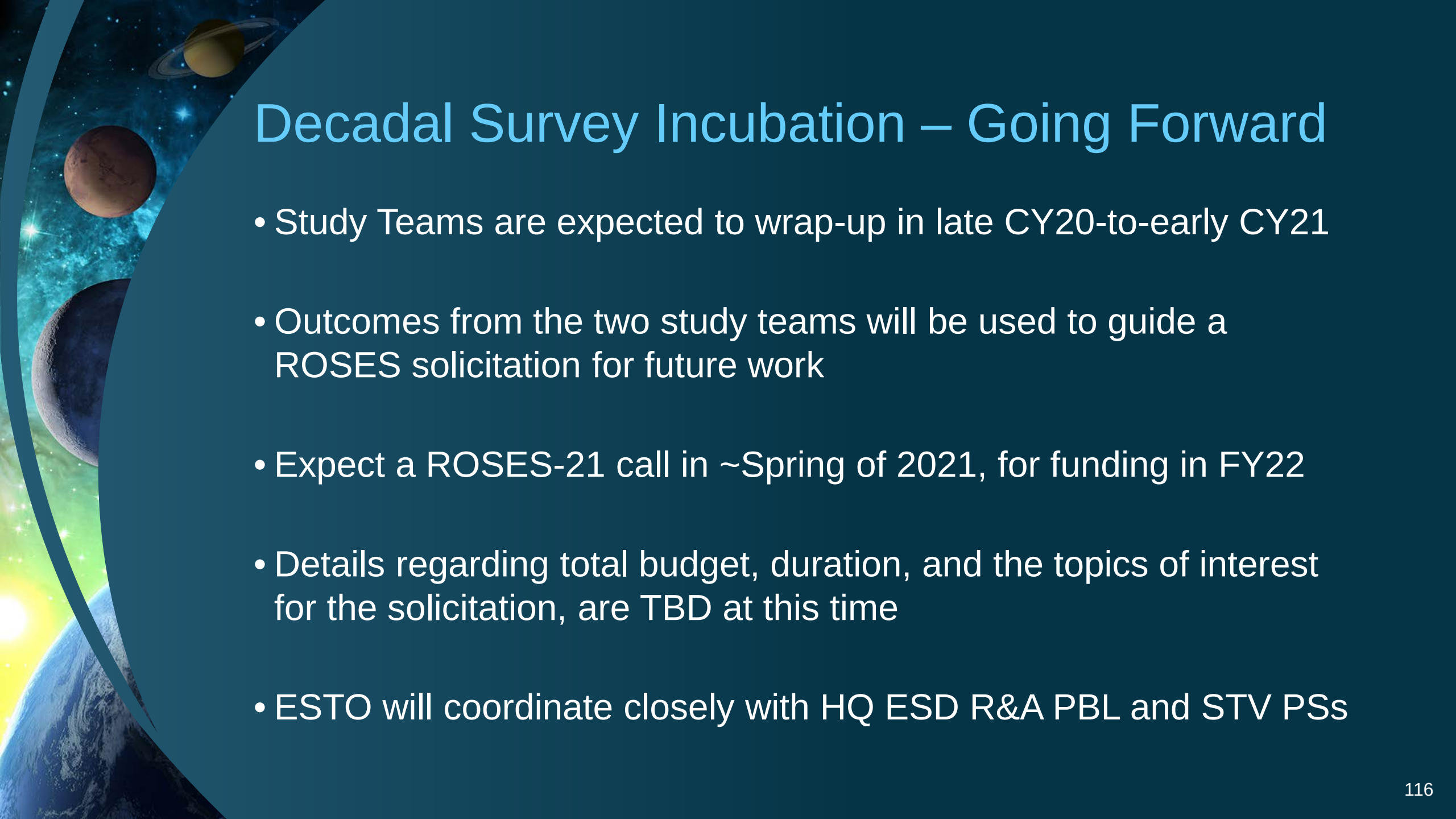
For more information contact stv-leads@jpl.nasa.gov



Surface Topography and Vegetation

Augmentations

- *G-LiHT Upgrade*, PI: Bruce Cook (GSFC)
- *Advanced Optical DEMS*, PI: Jim Tucker (GSFC)
- *ICESat-2-GEDI Fusion*, PI: Scott Luthcke (GSFC)
- *UAVSAR Imager*, PI: Andrea Donnellan (JPL)
- *Lidar Bathymetry (FINESST)*, PI: Jeffrey Thayer (U of Colorado)

A decorative background on the left side of the slide featuring a curved view of space. It includes a bright yellow sun at the bottom left, a blue and white Earth horizon, a grey cratered moon, a reddish-brown Mars, and a yellow Saturn with its rings at the top. The background is a deep blue with some nebulae and stars.

Decadal Survey Incubation – Going Forward

- Study Teams are expected to wrap-up in late CY20-to-early CY21
- Outcomes from the two study teams will be used to guide a ROSES solicitation for future work
- Expect a ROSES-21 call in ~Spring of 2021, for funding in FY22
- Details regarding total budget, duration, and the topics of interest for the solicitation, are TBD at this time
- ESTO will coordinate closely with HQ ESD R&A PBL and STV PSs

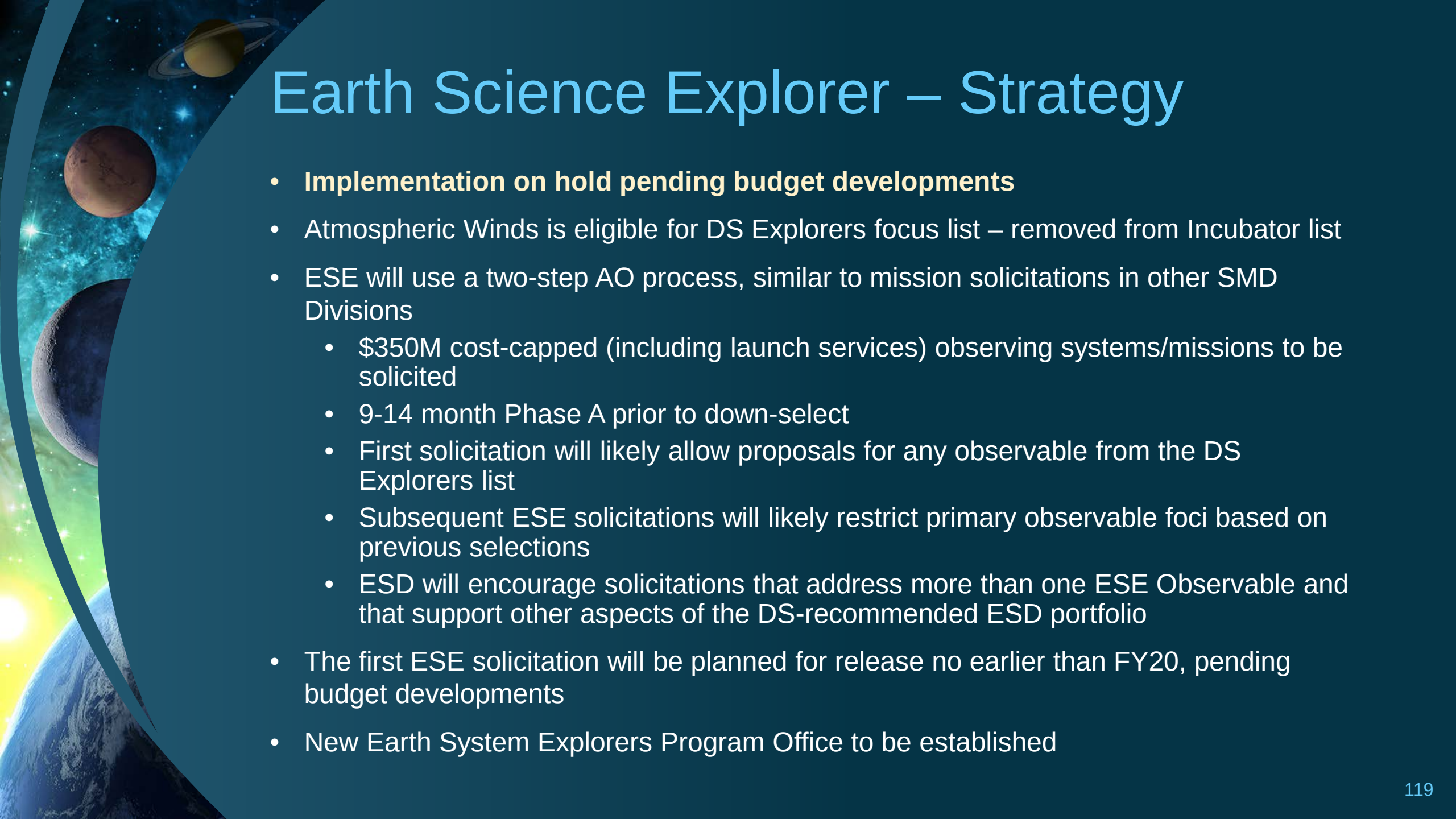
Decadal Survey Incubation – Points of Contact

Program Manager: Robert Bauer/ESTO (robert.bauer@nasa.gov)

Topic	Program Science Lead	Technology Lead
Planetary Boundary Layer (PBL)	Gail Skofronick-Jackson (gail.s.jackson@nasa.gov)	Amber Emory (amber.emory@nasa.gov)
Surface Topography & Vegetation (STV)	Ben Phillips (ben.phillips@nasa.gov)	Bob Connerton (robert.m.connerton@nasa.gov)

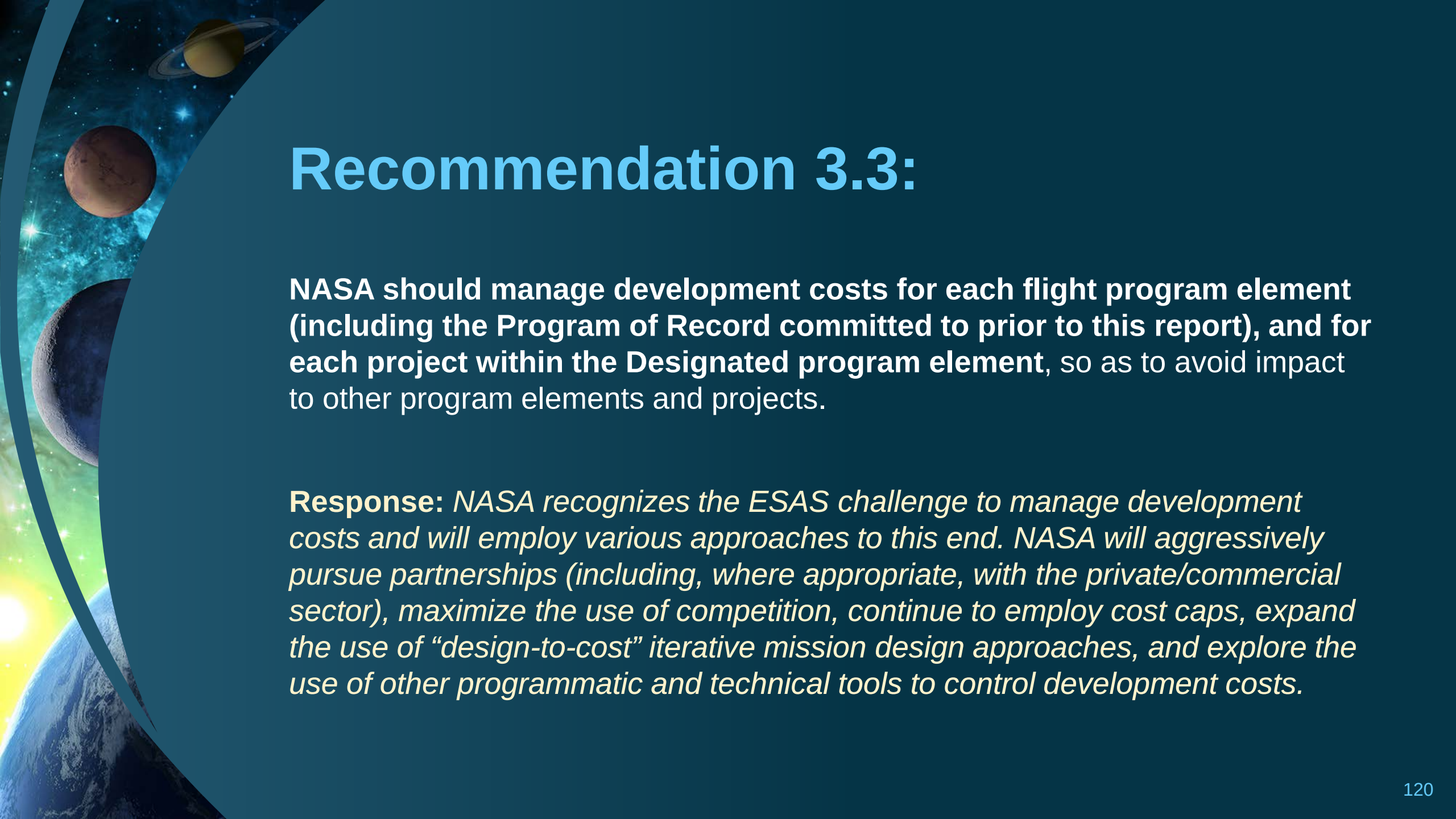
The background of the slide is a composite of two cosmic images. The top half features a dark blue and black space scene with a bright, wispy blue nebula on the right and several sharp, bright stars. The bottom half shows a vibrant orange and yellow nebula on the left, transitioning into a greenish-blue nebula on the right, with numerous stars scattered throughout.

Earth Science Explorer's Updates



Earth Science Explorer – Strategy

- **Implementation on hold pending budget developments**
- Atmospheric Winds is eligible for DS Explorers focus list – removed from Incubator list
- ESE will use a two-step AO process, similar to mission solicitations in other SMD Divisions
 - \$350M cost-capped (including launch services) observing systems/missions to be solicited
 - 9-14 month Phase A prior to down-select
 - First solicitation will likely allow proposals for any observable from the DS Explorers list
 - Subsequent ESE solicitations will likely restrict primary observable foci based on previous selections
 - ESD will encourage solicitations that address more than one ESE Observable and that support other aspects of the DS-recommended ESD portfolio
- The first ESE solicitation will be planned for release no earlier than FY20, pending budget developments
- New Earth System Explorers Program Office to be established

The background of the slide features a deep blue space theme. On the left side, there is a vertical strip showing a celestial scene with a bright yellow sun or star at the bottom, a blue and white horizon of Earth, and several celestial bodies including a reddish planet (Mars), a grey cratered moon, and a yellow planet with rings (Saturn) further up. The main area of the slide is a solid dark blue.

Recommendation 3.3:

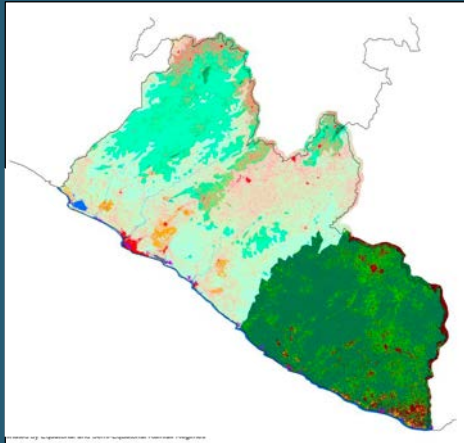
NASA should manage development costs for each flight program element (including the Program of Record committed to prior to this report), and for each project within the Designated program element, so as to avoid impact to other program elements and projects.

Response: *NASA recognizes the ESAS challenge to manage development costs and will employ various approaches to this end. NASA will aggressively pursue partnerships (including, where appropriate, with the private/commercial sector), maximize the use of competition, continue to employ cost caps, expand the use of “design-to-cost” iterative mission design approaches, and explore the use of other programmatic and technical tools to control development costs.*

Earth Science Partnerships

Harnessing commercial and non-governmental partnerships to amplify our work to understand the Earth as an integrated system and enable societal benefit by essentially leveraging the expertise of NASA and the partners to achieve together what neither could alone.

Key Accomplishments in 2019 with Current Partners



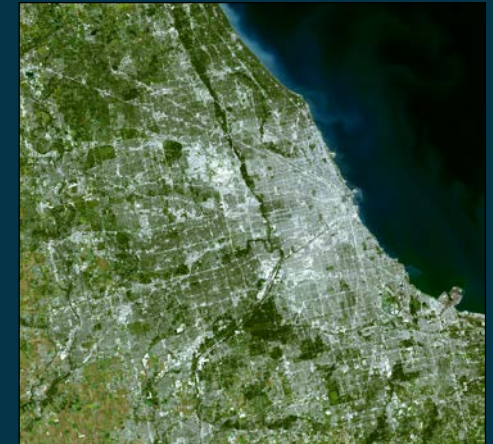
Advancing the ability of remote sensing to inform economic valuation of ecosystem services



Increasing the public's access to and use of Earth observations to explore our planet - Published three Google Earth stories aligned with NASA's *Earth* book



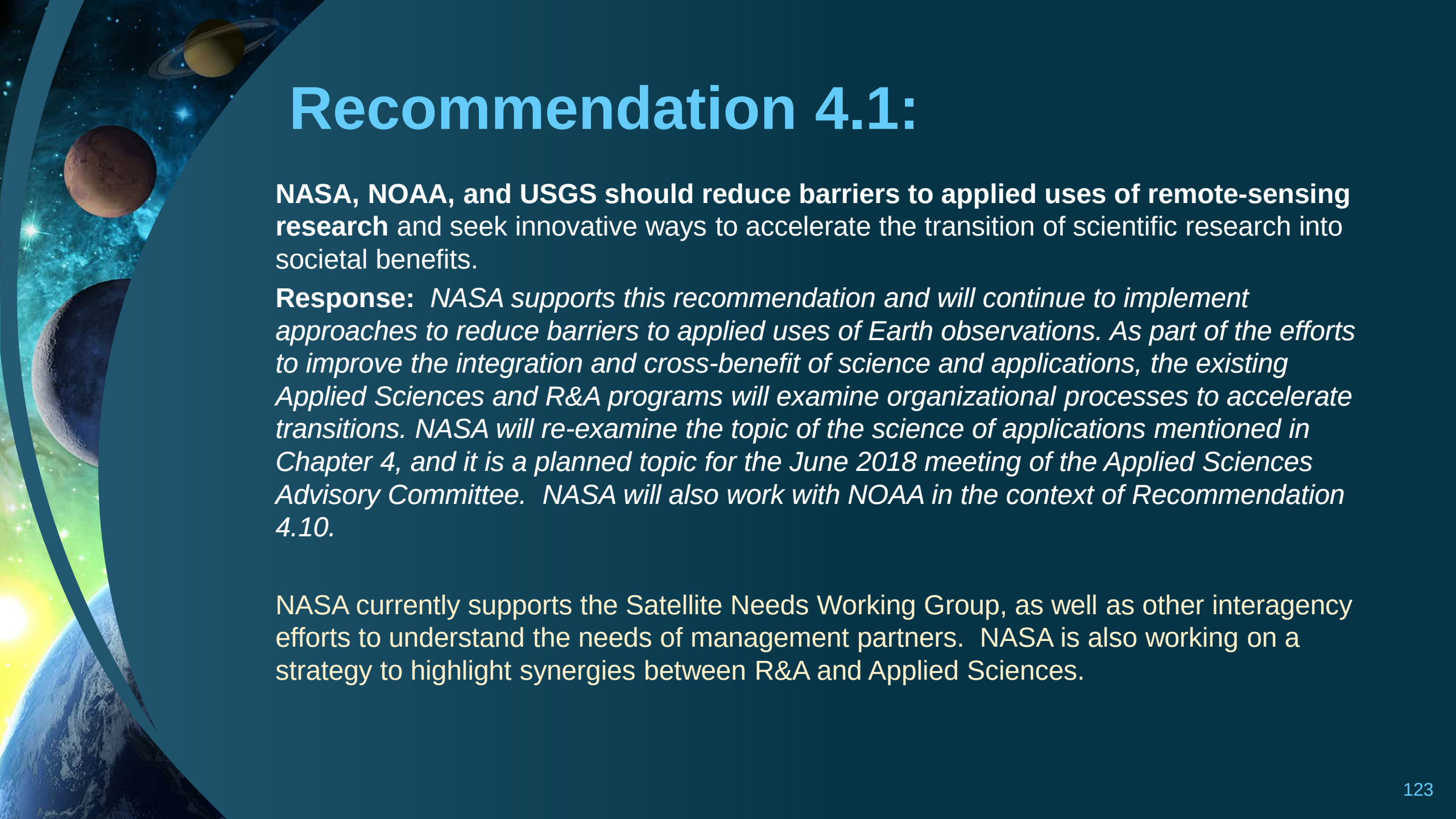
Integrating Earth observations into humanitarian decision making to strengthen global resilience to environmental shocks and stressors. Signed Space Act Agreement with Mercy Corps



Supporting decision making in smart cities by integrating Earth observations into cloud-based services - Microsoft Azure now offering NASA and other Earth observations

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 to be 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 a 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***
 - 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**

The background of the slide is a deep blue space scene. On the left side, there is a vertical sequence of celestial bodies: a yellow planet with a ring system (like Saturn) at the top, followed by a reddish-brown planet (like Mars), and then a grey, cratered planet (like the Moon). Below these, a portion of the Earth's blue and white horizon is visible. The rest of the background is a dark blue field filled with numerous small, bright white stars and some faint, wispy nebulae in shades of blue and green.

Recommendation 4.1:

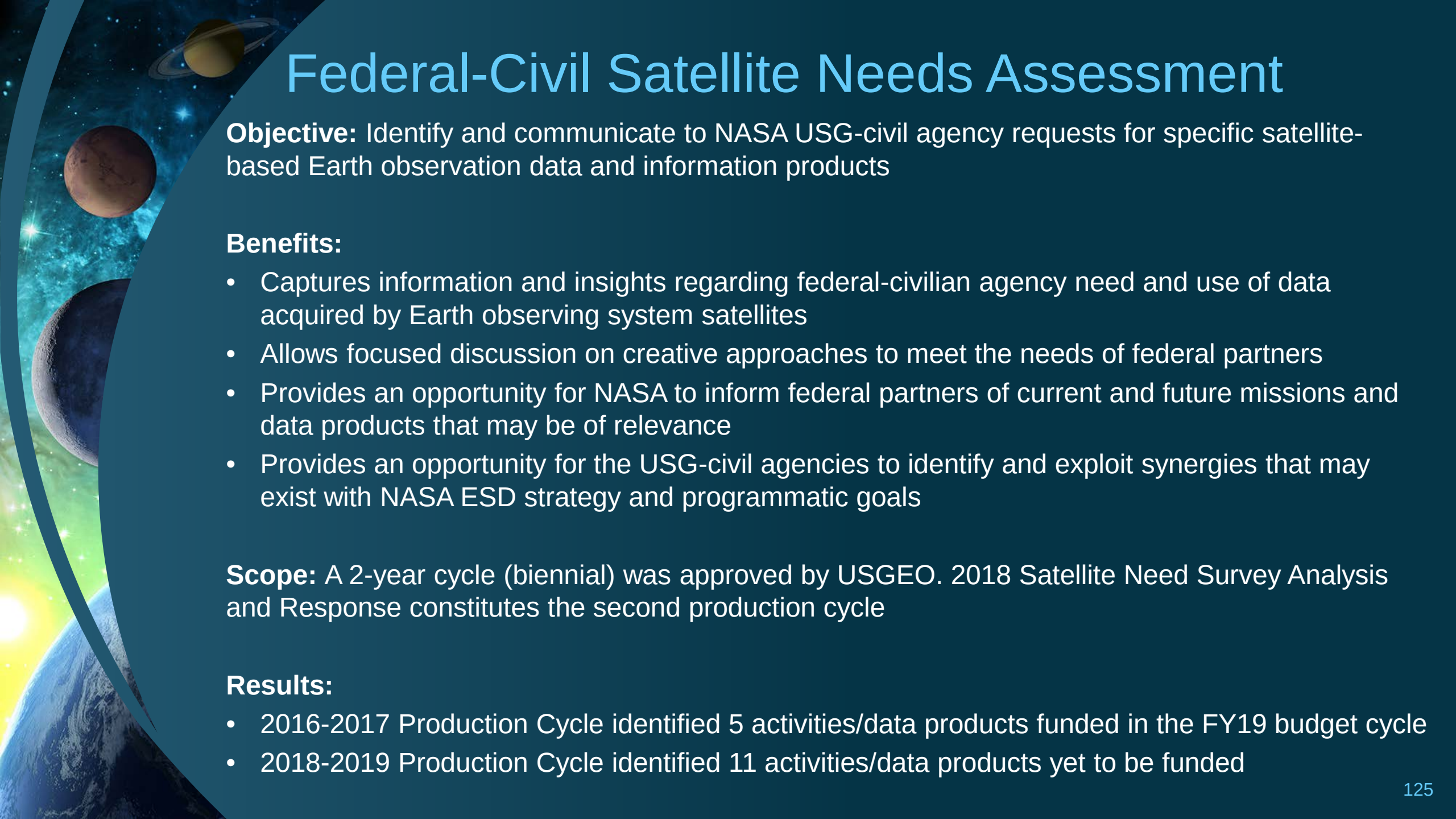
NASA, NOAA, and USGS should reduce barriers to applied uses of remote-sensing research and seek innovative ways to accelerate the transition of scientific research into societal benefits.

Response: *NASA supports this recommendation and will continue to implement approaches to reduce barriers to applied uses of Earth observations. As part of the efforts to improve the integration and cross-benefit of science and applications, the existing Applied Sciences and R&A programs will examine organizational processes to accelerate transitions. NASA will re-examine the topic of the science of applications mentioned in Chapter 4, and it is a planned topic for the June 2018 meeting of the Applied Sciences Advisory Committee. NASA will also work with NOAA in the context of Recommendation 4.10.*

NASA currently supports the Satellite Needs Working Group, as well as other interagency efforts to understand the needs of management partners. NASA is also working on a strategy to highlight synergies between R&A and Applied Sciences.

The background of the slide is a composite of two cosmic images. The top half features a dark blue and black space scene with a bright, glowing blue nebula on the right side and several distant stars. The bottom half shows a vibrant orange and yellow nebula on the left, transitioning into a greenish-blue nebula on the right, with numerous stars scattered throughout.

Satellite Needs Working Group



Federal-Civil Satellite Needs Assessment

Objective: Identify and communicate to NASA USG-civil agency requests for specific satellite-based Earth observation data and information products

Benefits:

- Captures information and insights regarding federal-civilian agency need and use of data acquired by Earth observing system satellites
- Allows focused discussion on creative approaches to meet the needs of federal partners
- Provides an opportunity for NASA to inform federal partners of current and future missions and data products that may be of relevance
- Provides an opportunity for the USG-civil agencies to identify and exploit synergies that may exist with NASA ESD strategy and programmatic goals

Scope: A 2-year cycle (biennial) was approved by USGEO. 2018 Satellite Need Survey Analysis and Response constitutes the second production cycle

Results:

- 2016-2017 Production Cycle identified 5 activities/data products funded in the FY19 budget cycle
- 2018-2019 Production Cycle identified 11 activities/data products yet to be funded

The background of the slide is a composite of two cosmic images. The top half features a dark blue and black space scene with a bright, wispy blue nebula on the right and several distant stars. The bottom half shows a vibrant orange and yellow nebula on the left, transitioning into a greenish-blue area on the right, also filled with stars. A solid dark blue horizontal band spans the width of the slide, serving as a backdrop for the title text.

Cross-Benefits of Applications and Research

THRIVING ON OUR CHANGING PLANET

A Decadal Strategy for Earth Observation from Space



ELEMENTS OF DECADAL STRATEGY

- I. Embrace **Innovative Methodologies** for Integrated Science/Applications
- II. ~~Commit to Sustained Science and Applications~~
- III. **Amplify the Cross-Benefit of Science and Applications**
- IV. ~~Leverage External Resources and Partnerships~~
- V. Institutionalize **Programmatic Agility and Balance**
- VI. Exploit **External Trends** in Technology and User Needs
- VII. Expand Use of **Competition**
- VIII. Pursue **Ambitious Science**, Despite Constraints

Amplify the Cross-Benefit of Applications and Research

Highlights from the DS's three paragraphs include:

- Curiosity-inspired science will always be central to Earth observation and analysis. But a growing portion of our science is use-inspired or closely related to the applications it enables.
- Inspiration goes both ways: science inspires applications scientists and engineers, and end-use needs can inspire research scientists and engineers.
- Embedding science in the applications process often reveals new and inspirational scientific questions driven by those end-uses not well-recognized by research scientists.
- ... programs with both science and applications elements need to explicitly identify the connection, and define opportunities to amplify the cross-benefit, and organization structures and processes need to be adapted when possible to integrate, rather than segregate, science and operations/applications.

ESD and Cross-Benefit

- NASA Earth Science has supported activities in research, applied research, and applications for years (not in equal proportions).
- The Decadal Survey acknowledges some of ESD's activities to support the cross-benefit, yet it calls to amplify this work.
- “Amplify” suggests both that more is needed and that more awareness is needed for the activities and successes that do occur.
 - Issues of Production and Perception

Over last year, relevant pairs of ESD managers in R&A and Applied Sciences:

- Examined examples of successful two-way interactions to date
- Considered high-potential opportunities in the near- and longer-term

Efforts to Amplify Cross-benefit include:

- Activities by and across ESD Programs, especially R&A and Applied Sciences
- Activities within broader Earth science community (ESD in conjunction with other organizations)

Examples of ESD Activities Linking Applications and Research

Co-Managed Initiatives

Joint Team Meetings and Solicitations

Designed Funding Transitions

Applied Sciences Teams

Integrated Science Teams

Integrated Directed Work

Earth Science Trainings

Assessment Participation

Field Campaigns

High Mountain Asia

The High Mountain Asia initiative involves managers from both AppSci and R&A. Projects & team meetings foster research-policy-management discussions, helping to identify new and unique research questions.

Health & Air Quality Applied Sciences Team

AppSci's HAQAST sponsors researchers (historically funded by R&A) to meet with and listen to state & local officials. They discuss users' challenges and co-design projects. Dedicated funding supports agile, short-term "Tiger Team" applications projects. Researchers build capacity to talk with users and learn about users' pain points and challenges that may need new research.

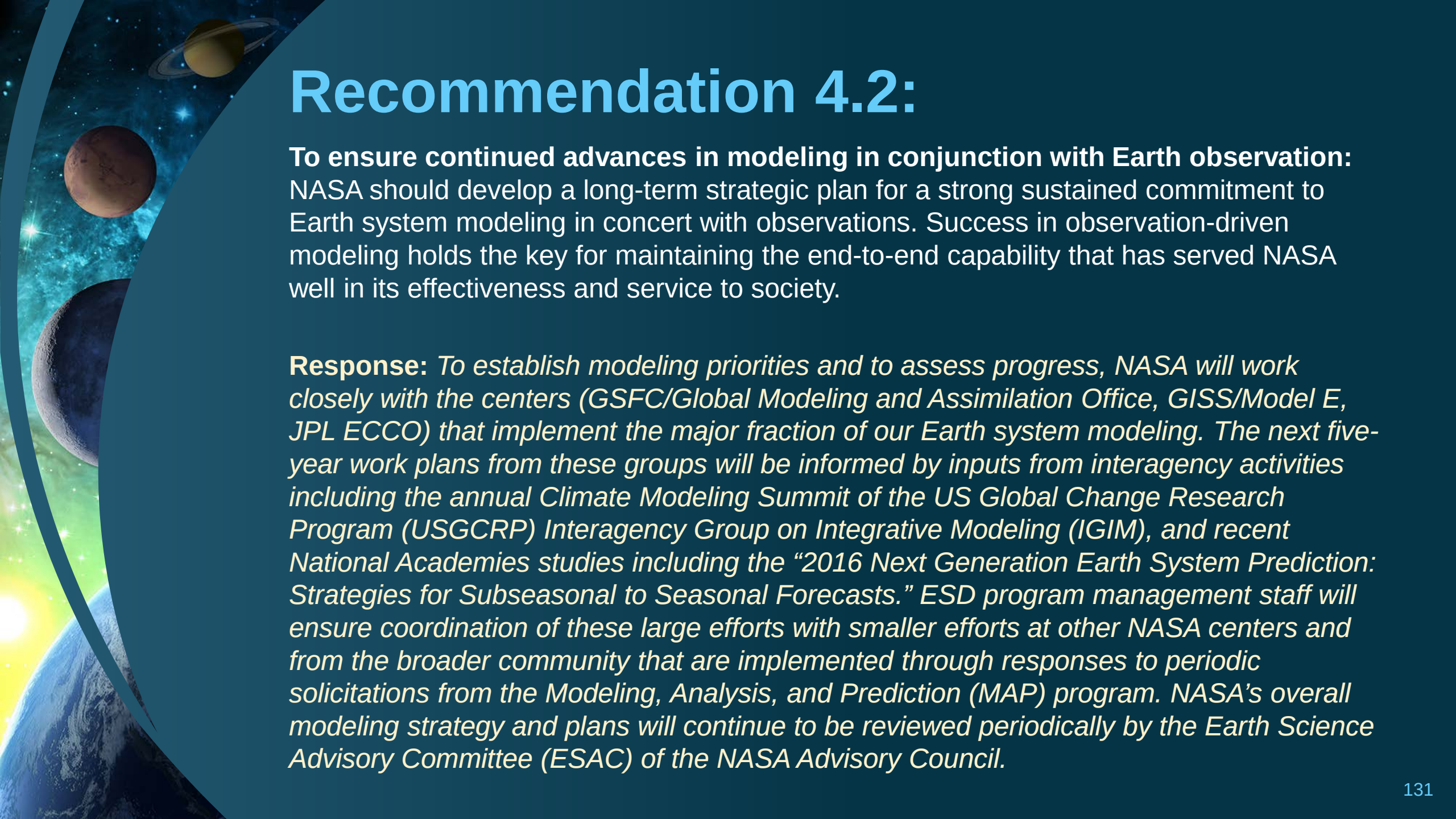
Approach to Further Amplify Cross-Benefit

ESD is committed to enabling a more integrated approach that supports cross-benefit – create a continual interplay in enabling impacts for society and in the generation of fundamental and applied knowledge about the Earth system.

Involves the data we collect and the information products we provide

Involves consideration of questions and gaps collected from managers along with priorities of researchers (Designated Observables are examples)

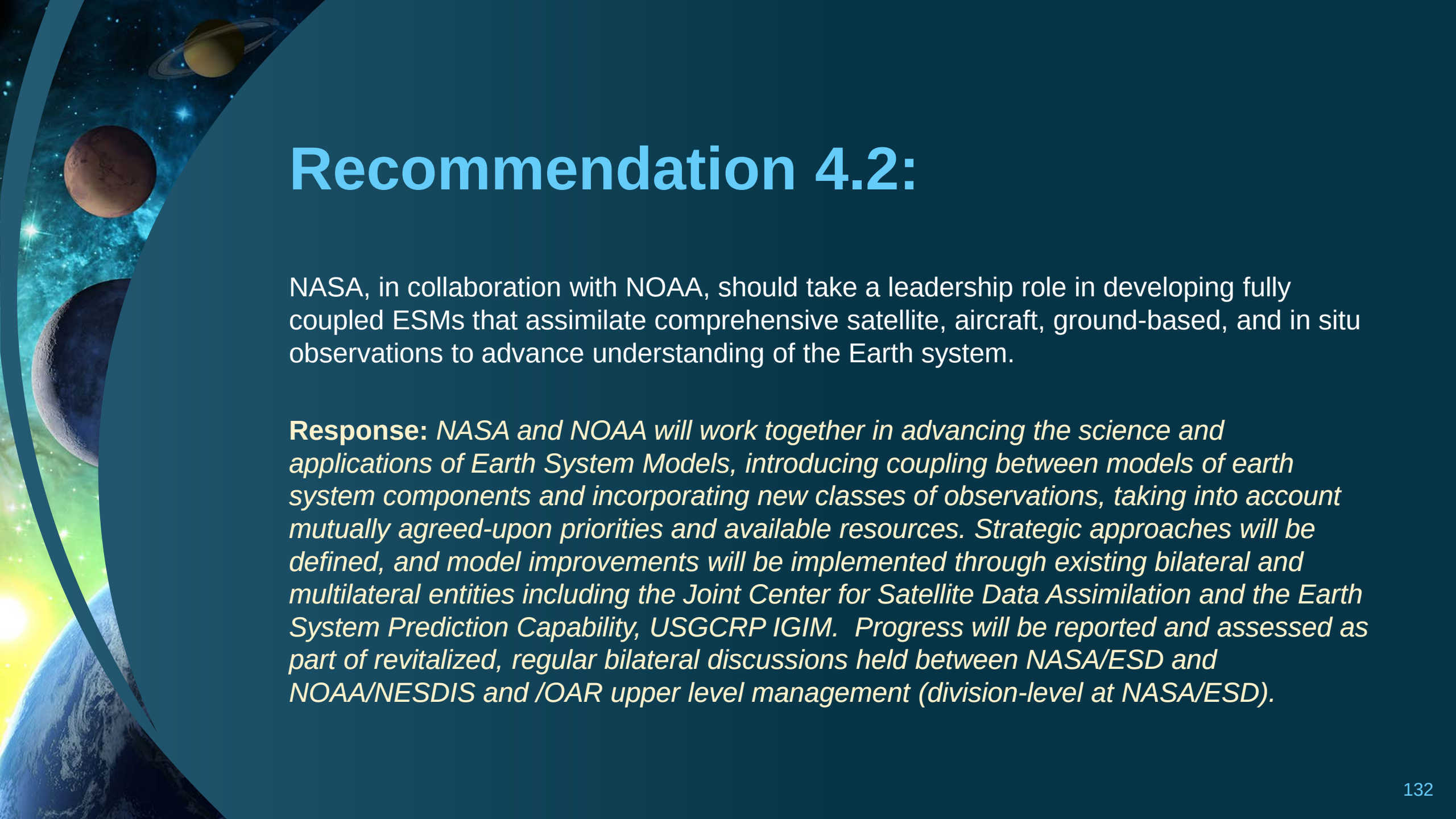
- Applied team supports connections of users back to R&A in articulating gaps, re-doubles efforts to connect with R&A and stay abreast of research results
- R&A incorporates broader views, and Focus Areas include Applied colleagues more Involves Flight, ESTO, Data Systems, and all parts of ESD
- More connections to broader sets of organizations while also maintaining ESD's independence to explore fundamental research & experimental observations

A decorative background on the left side of the slide featuring a curved, semi-circular shape. Inside this shape, there are images of 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) at the bottom. The background is a deep blue space with white stars and a bright yellow sun or star at the bottom left.

Recommendation 4.2:

To ensure continued advances in modeling in conjunction with Earth observation: NASA should develop a long-term strategic plan for a strong sustained commitment to Earth system modeling in concert with observations. Success in observation-driven modeling holds the key for maintaining the end-to-end capability that has served NASA well in its effectiveness and service to society.

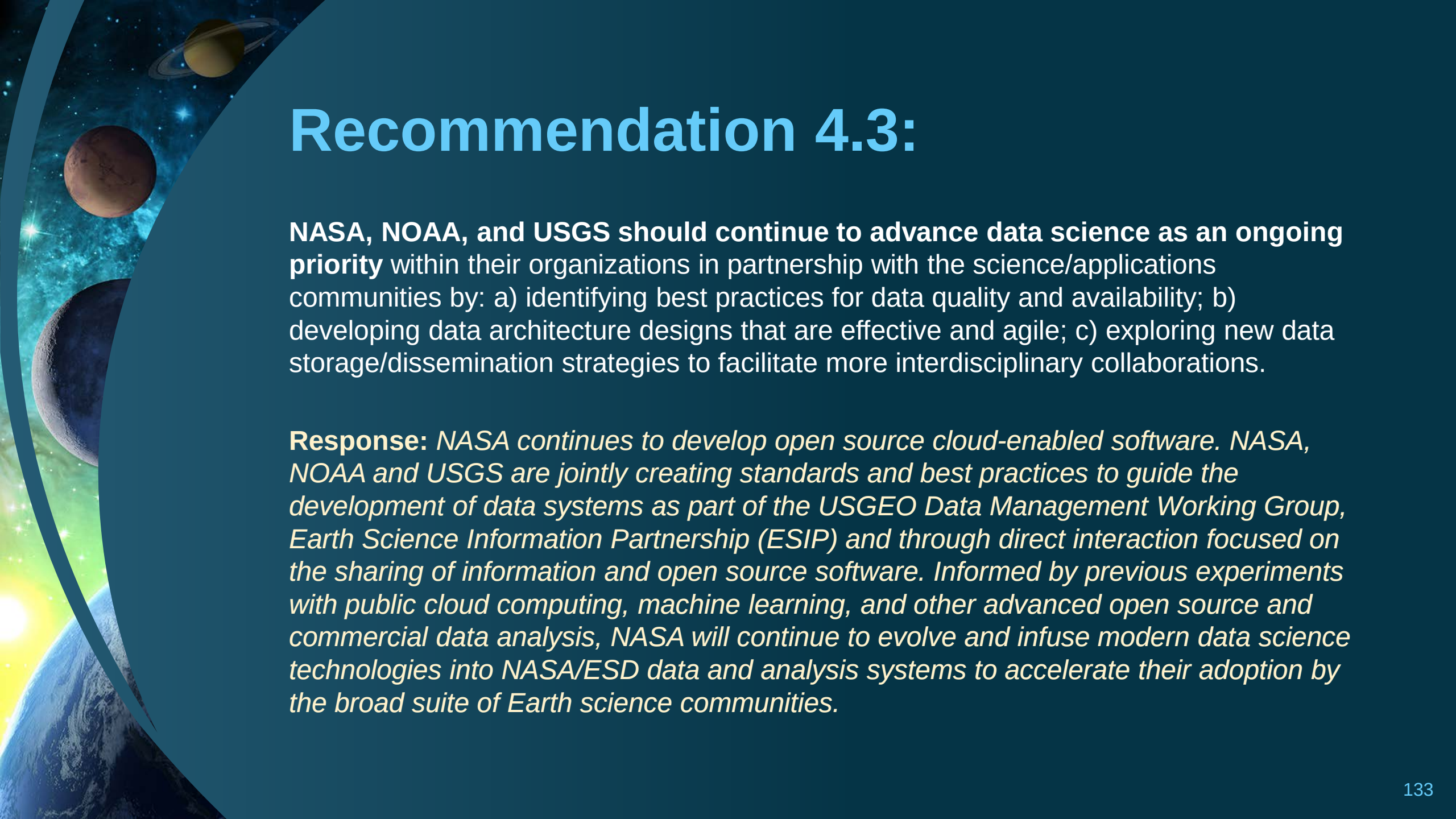
Response: *To establish modeling priorities and to assess progress, NASA will work closely with the centers (GSFC/Global Modeling and Assimilation Office, GISS/Model E, JPL ECCO) that implement the major fraction of our Earth system modeling. The next five-year work plans from these groups will be informed by inputs from interagency activities including the annual Climate Modeling Summit of the US Global Change Research Program (USGCRP) Interagency Group on Integrative Modeling (IGIM), and recent National Academies studies including the “2016 Next Generation Earth System Prediction: Strategies for Subseasonal to Seasonal Forecasts.” ESD program management staff will ensure coordination of these large efforts with smaller efforts at other NASA centers and from the broader community that are implemented through responses to periodic solicitations from the Modeling, Analysis, and Prediction (MAP) program. NASA’s overall modeling strategy and plans will continue to be reviewed periodically by the Earth Science Advisory Committee (ESAC) of the NASA Advisory Council.*

The background of the slide is a deep blue space scene. On the left side, there is a vertical strip showing a bright yellow sun or star at the bottom, with the blue and white horizon of Earth curving upwards. Above Earth, the dark, cratered surface of the Moon is visible. Further up, a reddish-brown planet (Mars) and a yellow planet with a ring system (Saturn) are shown against a backdrop of distant stars and nebulae. A large, semi-transparent blue circle is positioned on the right side of the slide, partially overlapping the text area.

Recommendation 4.2:

NASA, in collaboration with NOAA, should take a leadership role in developing fully coupled ESMs that assimilate comprehensive satellite, aircraft, ground-based, and in situ observations to advance understanding of the Earth system.

Response: *NASA and NOAA will work together in advancing the science and applications of Earth System Models, introducing coupling between models of earth system components and incorporating new classes of observations, taking into account mutually agreed-upon priorities and available resources. Strategic approaches will be defined, and model improvements will be implemented through existing bilateral and multilateral entities including the Joint Center for Satellite Data Assimilation and the Earth System Prediction Capability, USGCRP IGIM. Progress will be reported and assessed as part of revitalized, regular bilateral discussions held between NASA/ESD and NOAA/NESDIS and /OAR upper level management (division-level at NASA/ESD).*

A decorative background on the left side of the slide featuring a vertical strip of space imagery. It includes a yellow planet with rings at the top, a reddish planet in the middle, and a crescent moon at the bottom, all set against a starry blue and green cosmic backdrop. A large, dark blue curved shape overlaps the right side of this strip.

Recommendation 4.3:

NASA, NOAA, and USGS should continue to advance data science as an ongoing priority within their organizations in partnership with the science/applications communities by: a) identifying best practices for data quality and availability; b) developing data architecture designs that are effective and agile; c) exploring new data storage/dissemination strategies to facilitate more interdisciplinary collaborations.

Response: *NASA continues to develop open source cloud-enabled software. NASA, NOAA and USGS are jointly creating standards and best practices to guide the development of data systems as part of the USGEO Data Management Working Group, Earth Science Information Partnership (ESIP) and through direct interaction focused on the sharing of information and open source software. Informed by previous experiments with public cloud computing, machine learning, and other advanced open source and commercial data analysis, NASA will continue to evolve and infuse modern data science technologies into NASA/ESD data and analysis systems to accelerate their adoption by the broad suite of Earth science communities.*

Big Data: Earth Science

Challenge

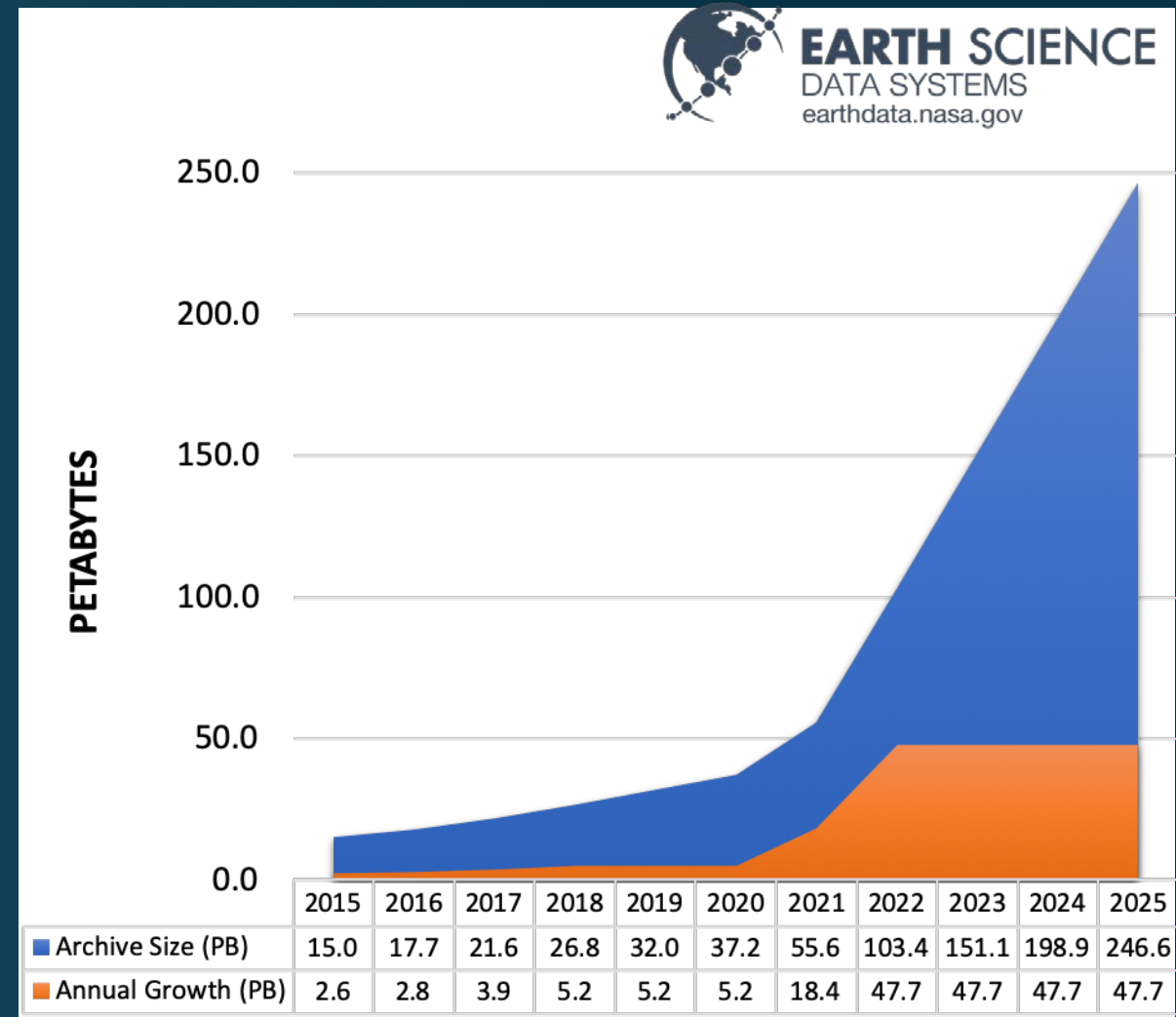
- Volume of data in NASA Earth science archives to increase to 250 Petabytes by 2025

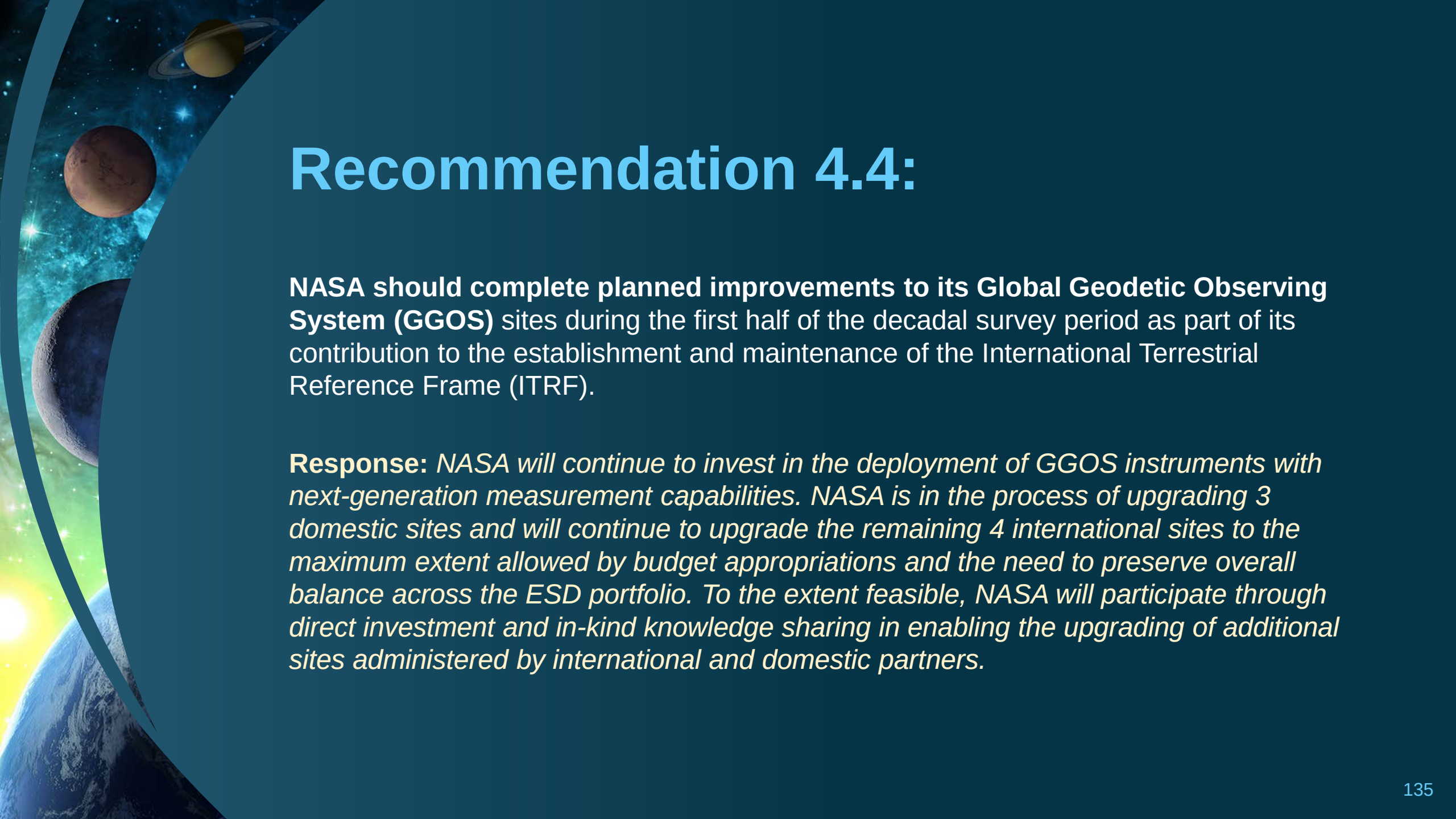
Need

- Efficiently handle storage and computation needs for large data volumes through new data management technologies and architectures

New paradigm

- Cloud offers performance and cost benefits
- Realize storage, processing and operational efficiencies
- Improve cross-archive center collaboration
- Enable users to work across multiple datasets managed by different archives without transmitting data over networks
- Supporting open science with open source software and open data



A space-themed background featuring a deep blue gradient with a large, curved, lighter blue shape on the left side. In the background, there are several celestial bodies: a yellow planet with rings (Saturn) at the top left, a reddish planet (Mars) below it, and a grey, cratered planet (the Moon) further down. The bottom left corner shows a curved horizon of the Earth with blue oceans and white clouds. The overall lighting is soft, with some star-like points of light scattered throughout.

Recommendation 4.4:

NASA should complete planned improvements to its Global Geodetic Observing System (GGOS) sites during the first half of the decadal survey period as part of its contribution to the establishment and maintenance of the International Terrestrial Reference Frame (ITRF).

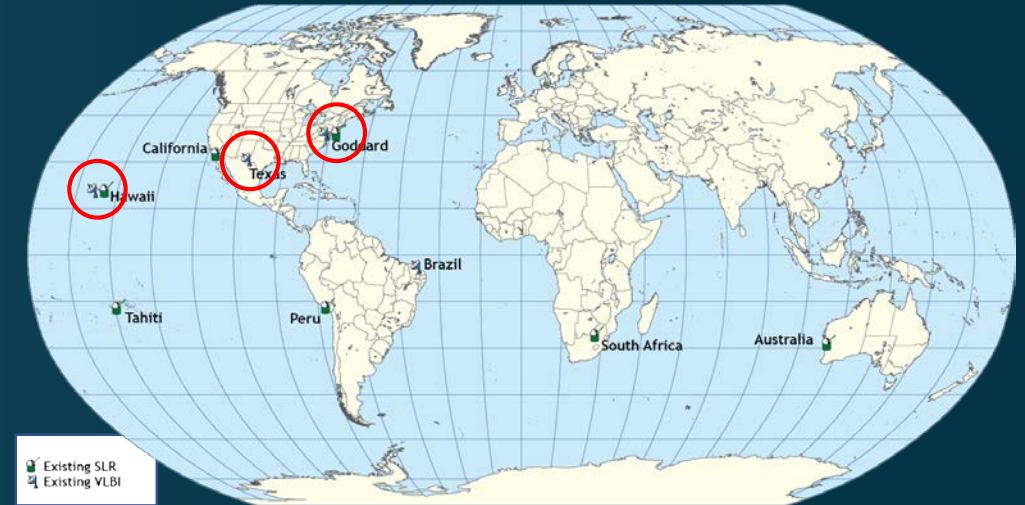
Response: *NASA will continue to invest in the deployment of GGOS instruments with next-generation measurement capabilities. NASA is in the process of upgrading 3 domestic sites and will continue to upgrade the remaining 4 international sites to the maximum extent allowed by budget appropriations and the need to preserve overall balance across the ESD portfolio. To the extent feasible, NASA will participate through direct investment and in-kind knowledge sharing in enabling the upgrading of additional sites administered by international and domestic partners.*



NASA's Network – Leading the Way To mm Accuracy

- NASA was the first to develop and deploy the next-generation systems into a network
- As of 2019:
 - 3 new VLBI Global Observing System stations provide enhanced observability for more reliable EOPs and improved ITRF (HI, TX, MD)
 - 60+ upgraded Global Navigation Satellite System (GNSS) stations comprise a state of the art network supporting more accurate and rapid positioning for moving platforms, science observations, and applications (global)
 - 3 new Space Geodesy SLR Systems in production (TX, Norway, MD)
- Bringing along the international community through leadership in multilateral forums, collaboration, outreach, and sharing expertise

NASA Space Geodesy Network (NSGN)



Global GNSS Network (GGN)





Network Deployment Accomplishments

SGP was the first to demonstrate an integrated next-generation site at the Goddard Geophysical and Astronomical Observatory (GGAO)



Prototype Next-Generation stations at GGAO
2013

Network Deployment Accomplishments



The next-gen VLBI at Kōke'e Park, HI, is in operations

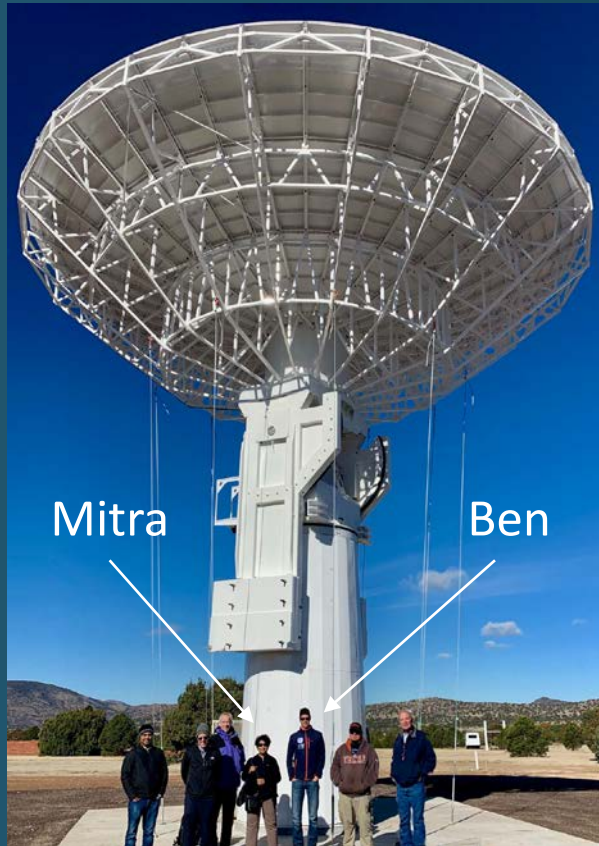


Kōke'e Park Geophysical Observatory, Hawaii
2016

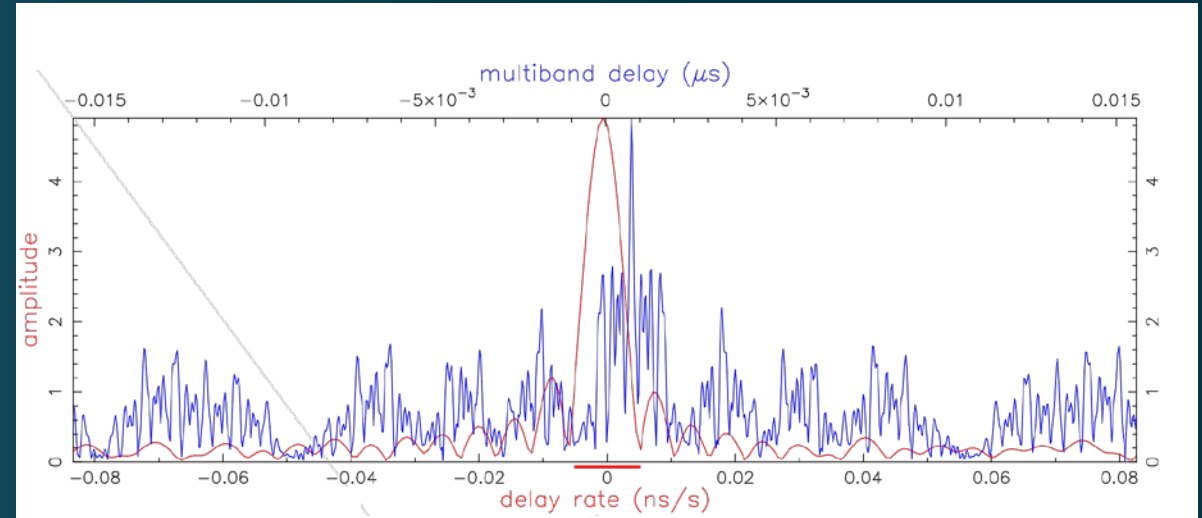
Network Deployment Accomplishments



The next-gen VLBI at McDonald Geodetic Observatory, TX, saw first light in July



McDonald Geodetic Observatory, Texas
2019



First interferometric fringes were obtained between the new station and the Goddard (Maryland) and Westford (Massachusetts) stations observing quasar 0059+581

Network Deployment Accomplishments



GGN upgraded with multi-GNSS receivers providing measurements from all major Global Navigation Satellite Systems: GPS, GLONASS, BeiDou, and Galileo, as well as QZSS and IRNSS, where available, with GPS data provided in real-time through NASA's data system



Typical GGN station w/antenna and radome, mounted on a deep drilled (~10 m) braced monument
2019

The background of the slide is a deep blue space scene. On the left side, there is a vertical strip showing a bright yellow sun at the bottom, followed by the blue and white horizon of Earth, and then a grey, cratered moon. Above the moon are two other planets: a reddish-brown one and a yellow one with a ring system, resembling Saturn. The rest of the background is a dark blue field with scattered white stars and nebulae.

Recommendation 4.5:

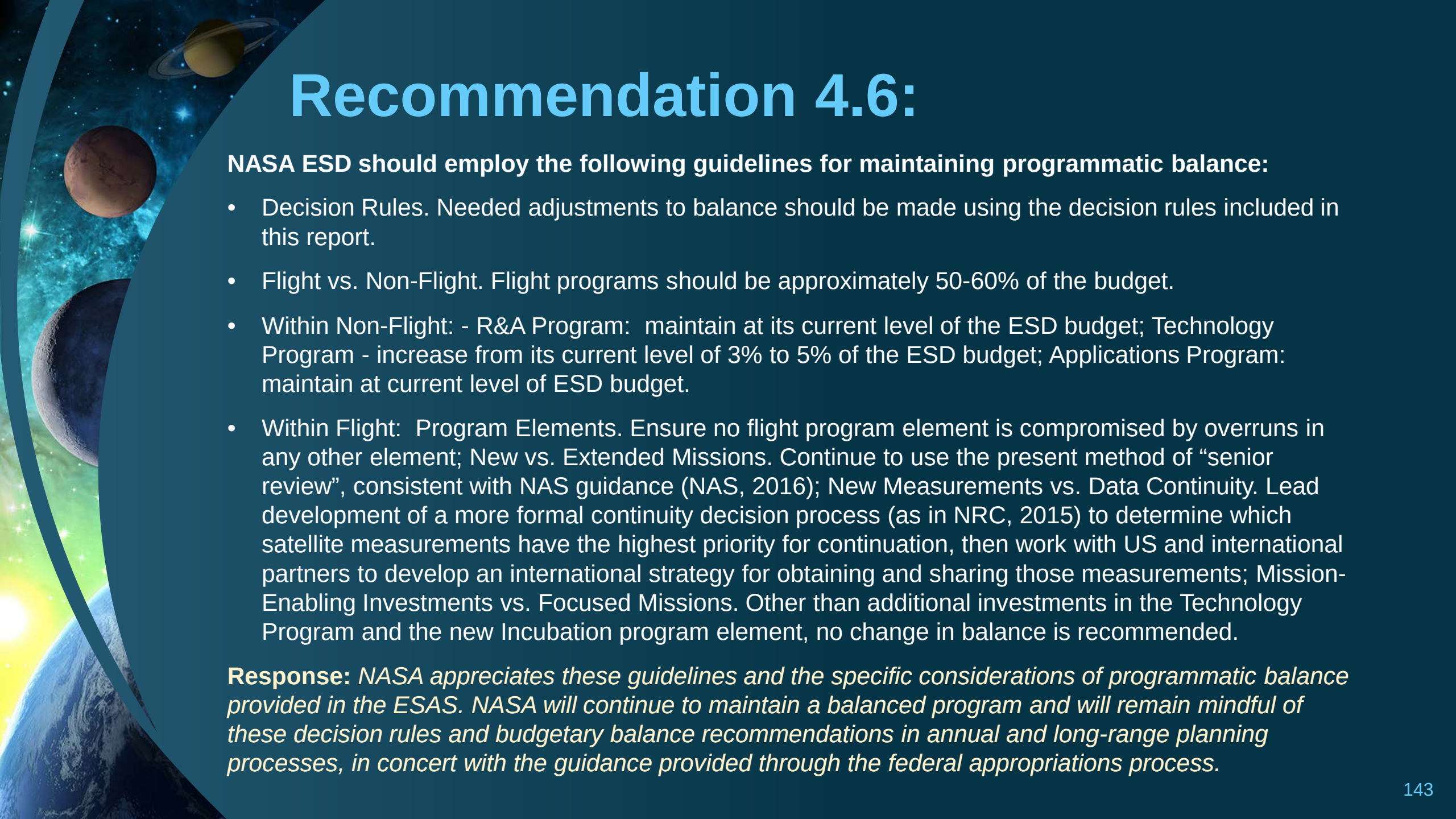
Because expanded and extended international partnerships can benefit the nation: NASA should consider enhancing existing partnerships and seeking new partnerships when implementing the observation priorities of this Decadal Survey.

Response: *NASA fully agrees and will continue to pursue multiple top-down and bottom-up approaches to identifying, formalizing, and executing international partnerships covering the full range of flight mission collaborations, data system interoperability collaborations, research/analysis scientific collaborations including field campaigns and major interdisciplinary/multi-mission analyses (such as IMBIE), technology demonstrations, and applications development and testing.*

The background of the slide features a deep blue space theme. On the left side, there is a vertical strip showing a bright yellow sun at the bottom, followed by the blue and white horizon of Earth. Above Earth, the dark, cratered surface of the Moon is visible. Further up, a reddish-brown planet (Mars) and a yellow planet with a ring system (Saturn) are depicted against a backdrop of stars and nebulae. A large, semi-transparent dark blue arc curves across the top and left portions of the slide, framing the title and the top of the list.

International Engagement

- ESD leadership has conducted focused Decadal Survey telecons/meetings with international partners
 - JAXA, CNES, DLR, ESA, EUMETSAT, CSA
 - Further discussions with the broader international community continue
- Discussions are ongoing to explore potential international partnerships
 - Some directed international partnerships may originate from ESD
 - Multi-center DO studies are engaging potential international partners
- **ESD will make final partnership determinations** and then codify in necessary international agreements

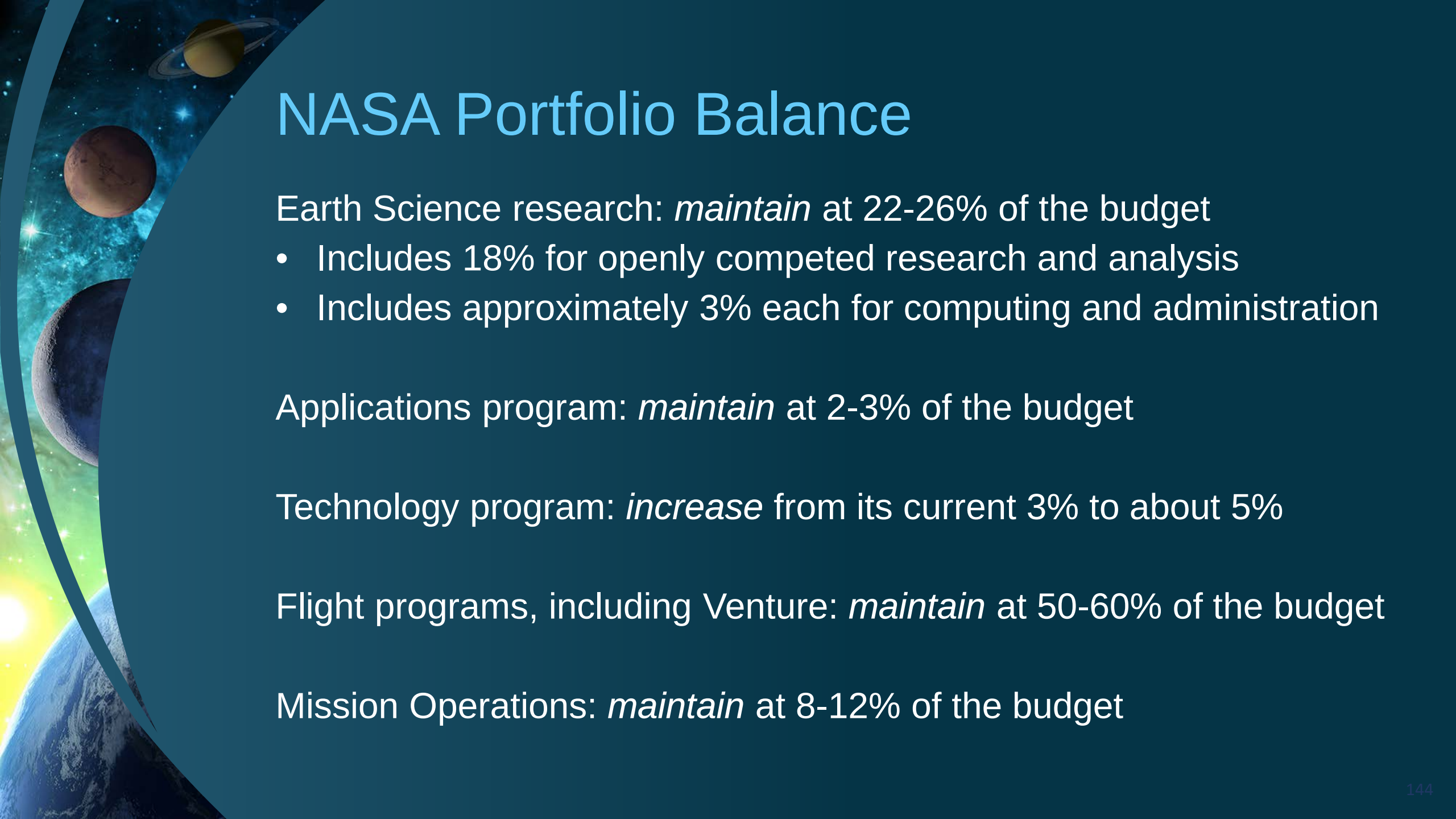


Recommendation 4.6:

NASA ESD should employ the following guidelines for maintaining programmatic balance:

- Decision Rules. Needed adjustments to balance should be made using the decision rules included in this report.
- Flight vs. Non-Flight. Flight programs should be approximately 50-60% of the budget.
- Within Non-Flight: - R&A Program: maintain at its current level of the ESD budget; Technology Program - increase from its current level of 3% to 5% of the ESD budget; Applications Program: maintain at current level of ESD budget.
- Within Flight: Program Elements. Ensure no flight program element is compromised by overruns in any other element; New vs. Extended Missions. Continue to use the present method of “senior review”, consistent with NAS guidance (NAS, 2016); New Measurements vs. Data Continuity. Lead development of a more formal continuity decision process (as in NRC, 2015) to determine which satellite measurements have the highest priority for continuation, then work with US and international partners to develop an international strategy for obtaining and sharing those measurements; Mission-Enabling Investments vs. Focused Missions. Other than additional investments in the Technology Program and the new Incubation program element, no change in balance is recommended.

Response: *NASA appreciates these guidelines and the specific considerations of programmatic balance provided in the ESAS. NASA will continue to maintain a balanced program and will remain mindful of these decision rules and budgetary balance recommendations in annual and long-range planning processes, in concert with the guidance provided through the federal appropriations process.*

A vertical decorative graphic on the left side of the slide, featuring a stylized blue and white arc. The background of the slide is a deep blue space scene with various celestial bodies: a yellow planet with rings (Saturn) at the top, a reddish planet (Mars) below it, a grey cratered moon, and a portion of the Earth's blue and white horizon at the bottom left. Numerous small white stars are scattered across the dark blue background.

NASA Portfolio Balance

Earth Science research: *maintain* at 22-26% of the budget

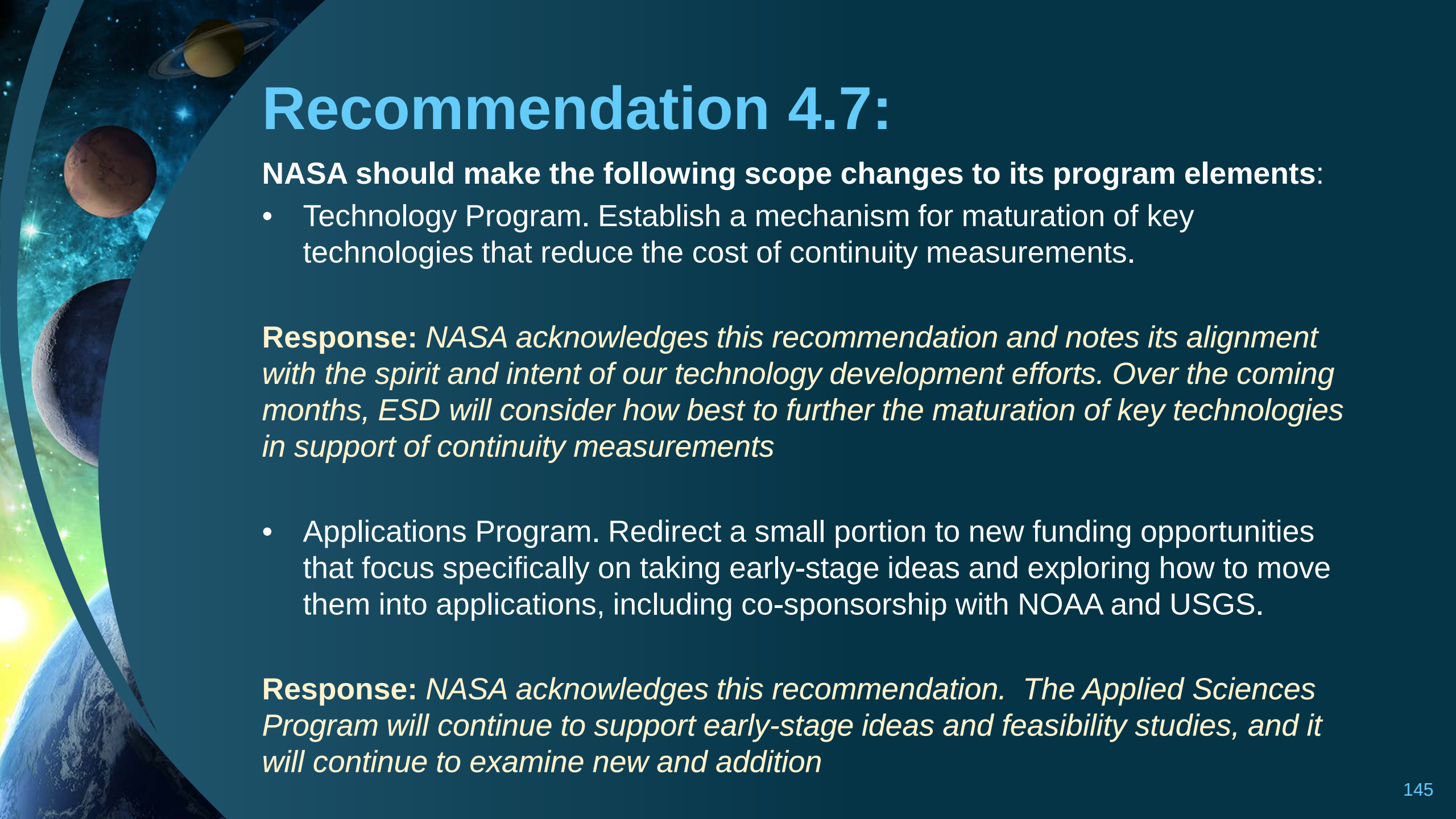
- Includes 18% for openly competed research and analysis
- Includes approximately 3% each for computing and administration

Applications program: *maintain* at 2-3% of the budget

Technology program: *increase* from its current 3% to about 5%

Flight programs, including Venture: *maintain* at 50-60% of the budget

Mission Operations: *maintain* at 8-12% of the budget



Recommendation 4.7:

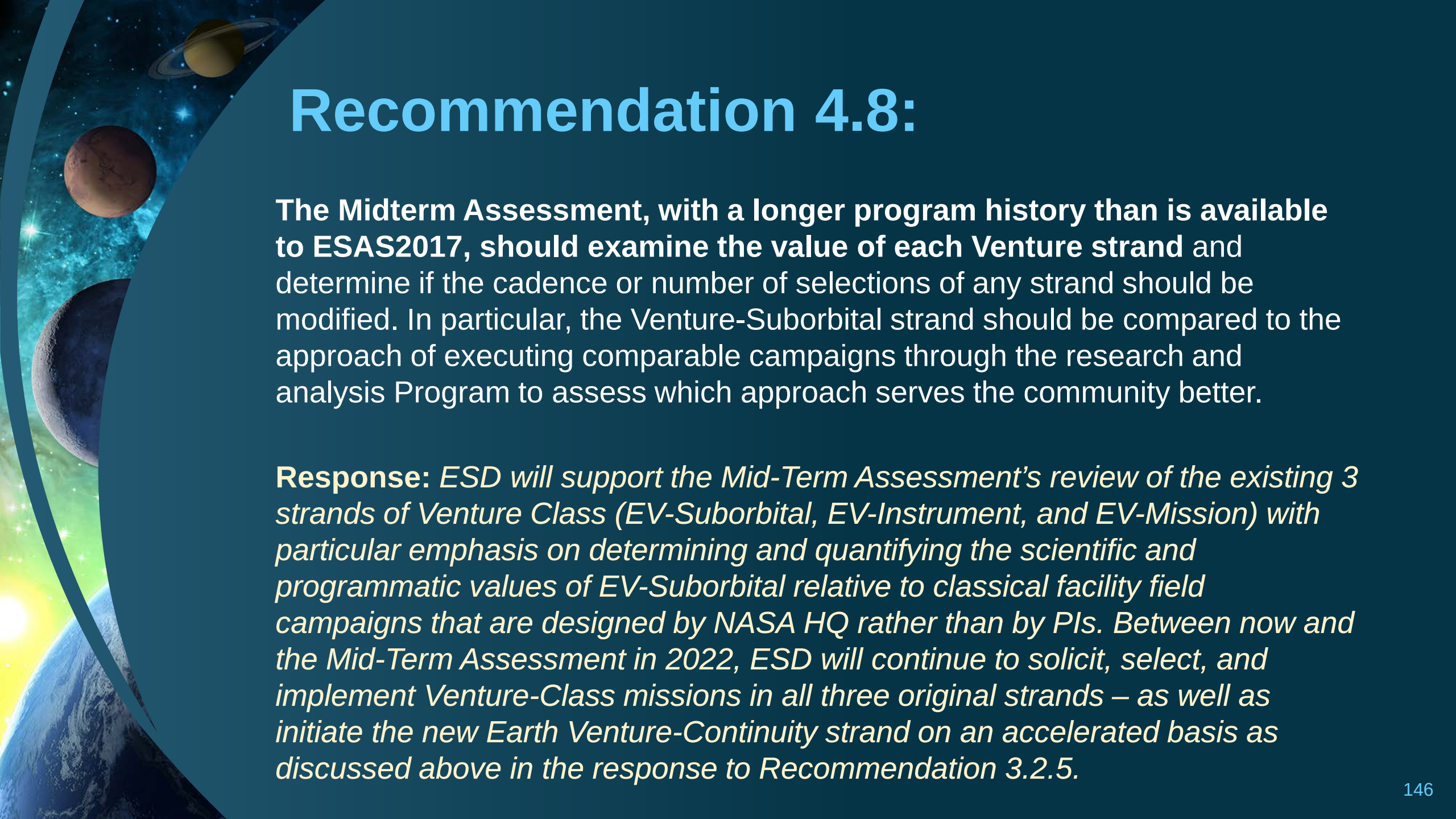
NASA should make the following scope changes to its program elements:

- Technology Program. Establish a mechanism for maturation of key technologies that reduce the cost of continuity measurements.

Response: *NASA acknowledges this recommendation and notes its alignment with the spirit and intent of our technology development efforts. Over the coming months, ESD will consider how best to further the maturation of key technologies in support of continuity measurements*

- Applications Program. Redirect a small portion to new funding opportunities that focus specifically on taking early-stage ideas and exploring how to move them into applications, including co-sponsorship with NOAA and USGS.

Response: *NASA acknowledges this recommendation. The Applied Sciences Program will continue to support early-stage ideas and feasibility studies, and it will continue to examine new and addition*

The background of the slide features a deep blue space theme. On the left side, there is a vertical strip showing a yellow planet with rings at the top, a reddish-brown planet in the middle, and a grey, cratered planet at the bottom. The bottom left corner shows a curved horizon of the Earth with blue oceans and white clouds. The rest of the background is a dark blue gradient with scattered white stars and a faint nebula-like glow.

Recommendation 4.8:

The Midterm Assessment, with a longer program history than is available to ESAS2017, should examine the value of each Venture strand and determine if the cadence or number of selections of any strand should be modified. In particular, the Venture-Suborbital strand should be compared to the approach of executing comparable campaigns through the research and analysis Program to assess which approach serves the community better.

Response: *ESD will support the Mid-Term Assessment's review of the existing 3 strands of Venture Class (EV-Suborbital, EV-Instrument, and EV-Mission) with particular emphasis on determining and quantifying the scientific and programmatic values of EV-Suborbital relative to classical facility field campaigns that are designed by NASA HQ rather than by PIs. Between now and the Mid-Term Assessment in 2022, ESD will continue to solicit, select, and implement Venture-Class missions in all three original strands – as well as initiate the new Earth Venture-Continuity strand on an accelerated basis as discussed above in the response to Recommendation 3.2.5.*

Earth Science Division's Venture Opportunities

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

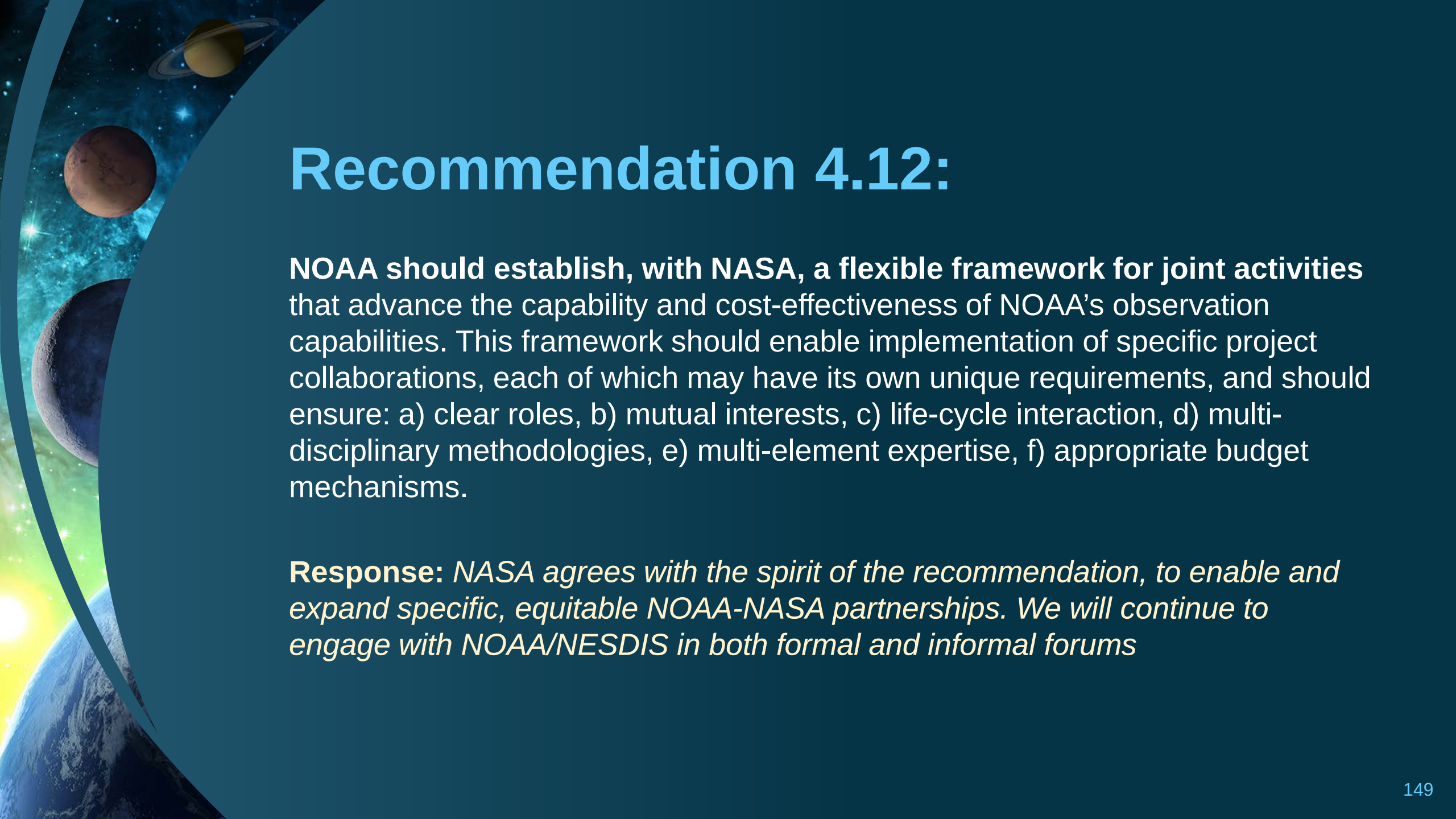
EVM-3 will include an Enhanced Operations Option jointly with NOAA

The background of the slide is a deep blue space scene. On the left side, there is a vertical strip showing a bright yellow sun or star at the bottom, with the blue and white horizon of Earth curving upwards. Above Earth, there are several celestial bodies: a crescent moon, a reddish planet (Mars), and a yellow planet with rings (Saturn). The rest of the background is a dark blue field filled with numerous small white stars and some nebulae.

Recommendation 4.10:

NOAA should further leverage use of NASA, USGS, and international satellite observations to meet diverse needs of its line organizations, including those unrelated to weather—and thus not lose the opportunity to capitalize on substantial investments made by other organizations. As one step to accomplish this, NOAA should establish a budget line [similar to what is done for JPSS and GOES-R] in order to: a) facilitate access to and use of data from these non-NOAA sources, and b) demonstrate resulting benefits through broadened collaboration with the NASA Applications and similar programs.

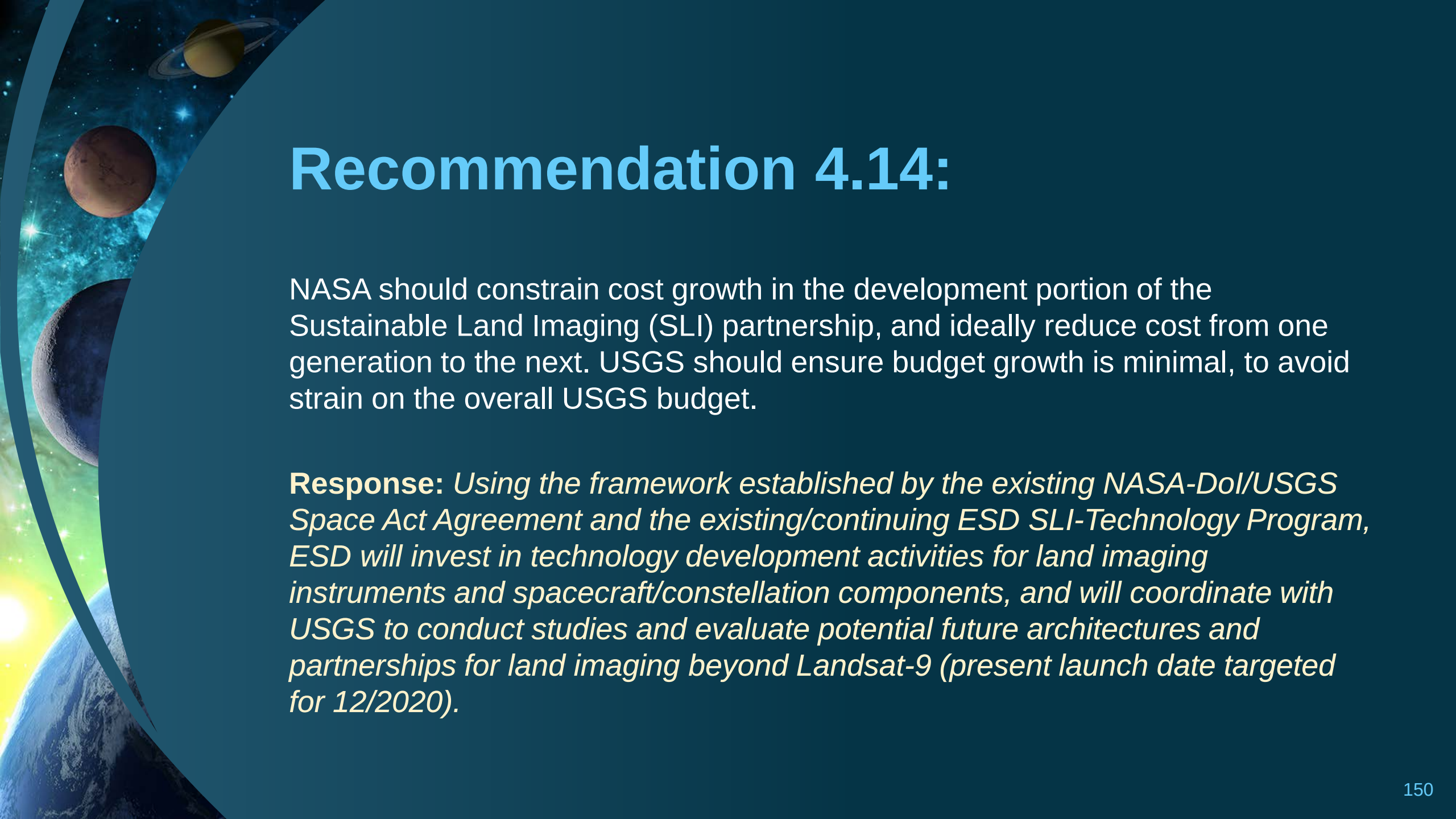
Response: *At NOAA's initiation and subject to the agreement of all parties, NASA stands ready and willing to engage with NOAA and to consider ways to expand formal and specific collaborations between NASA Applications-funded and NOAA-funded investigations.*

The background of the slide is a deep blue space scene. On the left side, there is a vertical strip showing a bright yellow sun at the bottom, followed by the blue and white horizon of Earth. Above Earth, there is a large, dark, cratered moon. Further up, there is a reddish-brown planet (Mars) and a yellow planet with a prominent ring system (Saturn). The background is filled with numerous small, bright stars and a soft blue nebula.

Recommendation 4.12:

NOAA should establish, with NASA, a flexible framework for joint activities that advance the capability and cost-effectiveness of NOAA's observation capabilities. This framework should enable implementation of specific project collaborations, each of which may have its own unique requirements, and should ensure: a) clear roles, b) mutual interests, c) life-cycle interaction, d) multi-disciplinary methodologies, e) multi-element expertise, f) appropriate budget mechanisms.

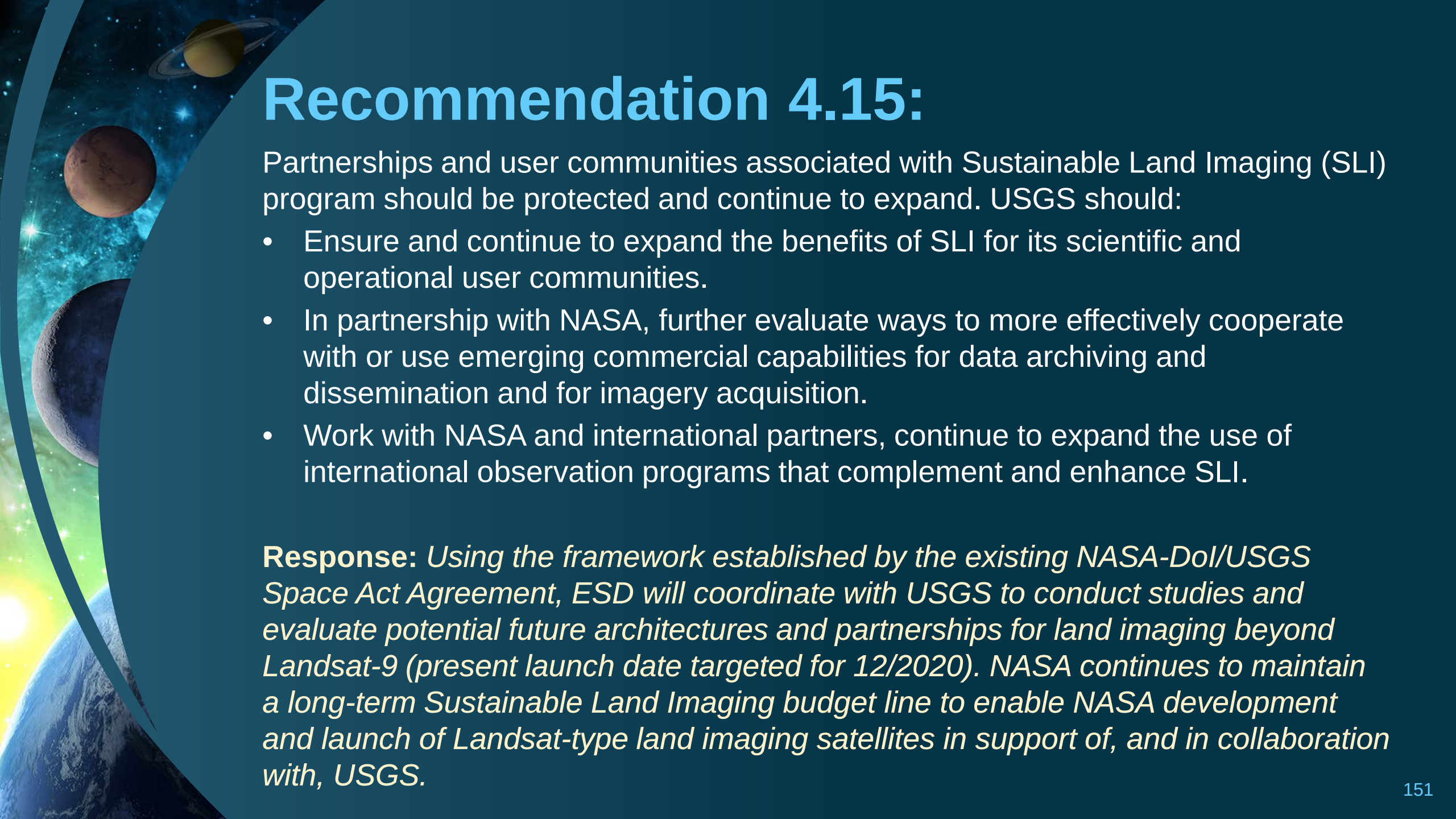
Response: *NASA agrees with the spirit of the recommendation, to enable and expand specific, equitable NOAA-NASA partnerships. We will continue to engage with NOAA/NESDIS in both formal and informal forums*

A decorative background on the left side of the slide featuring a curved view of space. It includes a yellow planet with rings (Saturn), a reddish planet (Mars), and a grey cratered planet (the Moon) against a starry blue and green cosmic backdrop. A portion of the Earth's blue and white horizon is visible at the bottom left.

Recommendation 4.14:

NASA should constrain cost growth in the development portion of the Sustainable Land Imaging (SLI) partnership, and ideally reduce cost from one generation to the next. USGS should ensure budget growth is minimal, to avoid strain on the overall USGS budget.

Response: *Using the framework established by the existing NASA-DoI/USGS Space Act Agreement and the existing/continuing ESD SLI-Technology Program, ESD will invest in technology development activities for land imaging instruments and spacecraft/constellation components, and will coordinate with USGS to conduct studies and evaluate potential future architectures and partnerships for land imaging beyond Landsat-9 (present launch date targeted for 12/2020).*

A space-themed background featuring a curved view of Earth's horizon at the bottom left, transitioning into a deep blue space filled with stars and nebulae. Several celestial bodies are visible: a yellow planet with rings (Saturn) in the upper left, a reddish planet (Mars) in the middle left, and a grey, cratered moon-like body in the lower left. A large, light blue curved shape frames the right side of the slide.

Recommendation 4.15:

Partnerships and user communities associated with Sustainable Land Imaging (SLI) program should be protected and continue to expand. USGS should:

- Ensure and continue to expand the benefits of SLI for its scientific and operational user communities.
- In partnership with NASA, further evaluate ways to more effectively cooperate with or use emerging commercial capabilities for data archiving and dissemination and for imagery acquisition.
- Work with NASA and international partners, continue to expand the use of international observation programs that complement and enhance SLI.

Response: *Using the framework established by the existing NASA-DoI/USGS Space Act Agreement, ESD will coordinate with USGS to conduct studies and evaluate potential future architectures and partnerships for land imaging beyond Landsat-9 (present launch date targeted for 12/2020). NASA continues to maintain a long-term Sustainable Land Imaging budget line to enable NASA development and launch of Landsat-type land imaging satellites in support of, and in collaboration with, USGS.*

Building on the Landsat Legacy

