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Statement of

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Overview

Chair Horn, Ranking Member Babin, and Members of the subcommittee, I am pleased to have this opportunity to discuss the amended FY 2020 budget request for NASA's Science Mission Directorate (SMD). Before I go further, I want to thank you for your commitment to NASA and to SMD; our directorate is in a strong position thanks to your leadership and bipartisan support.

SMD leverages space-, air-, and ground-based assets to answer fundamental questions about Earth, the solar system and the universe, and our place in the cosmos. Our scientists, engineers, and technologists work with a global community of researchers to provide the scientific discoveries that advance critical understanding and inform decision-making. Whether through disaster response, natural resource management, planetary defense, or space weather monitoring, NASA provides tangible benefits that help protect and improve life on Earth. At the same time, NASA is leading the quest to answer some of the most pressing human questions, among them how Earth and the universe evolved, how life emerged, and whether we are alone in the universe.

The amended FY 2020 budget requests $6,393.7 million for NASA Science, including $2,712.1 million for Planetary Science, $844.8 million for Astrophysics, $352.5 million for the James Webb Space Telescope (JWST), $704.5 million for Heliophysics and $1,779.8 million for Earth Science. Today I would like to talk through how this request enables us to achieve success in three strategic focus areas: advancing national exploration goals, maintaining a balanced and integrated science program, and delivering true impact through our investments. Integrated throughout is our concerted effort to seek and execute new partnerships that will allow us to leverage the innovation, resources, and expertise of the full breadth of the global science enterprise, including other U.S. and foreign government agencies, as well as commercial, academic, and other non-governmental partners.

Advancing National Exploration Goals

Artemis is the name of NASA's lunar exploration program that will send the first woman and the next man to the South Pole of the Moon by 2024 and develop a sustainable human presence on the Moon by 2028. Artemis takes its name from the twin sister of Apollo and goddess of the Moon in Greek mythology.

NASA is working to build a sustainable, open architecture that returns humanity to our nearest neighbor. We are building for the long term, and this time are going to the Moon to stay. We are intending to design an open, durable, reusable architecture that will support exploration for decades to come. Sustainability requires reusable systems and partnerships from across the commercial sector and around the world. Robotic scientific missions delivered by commercial landers will be the first Artemis elements to land on the Moon.

The agency is incentivizing speed and drawing on commercial and international partners as it looks to land humans on the Moon within five years. NASA is completing development of both the Orion spacecraft that will carry humans to lunar orbit, and the Space Launch System (SLS) rocket that will launch Orion. NASA is pressing forward toward the Artemis 1 mission, an uncrewed test flight of Orion and SLS as an integrated system around the Moon. This will be followed by the Artemis 2 mission that will be the first test flight with human crew to the lunar vicinity aboard SLS and Orion. Then, the Artemis 3 mission will send the first crew to the lunar surface using commercial human landing services that depart from the Gateway outpost orbiting the Moon. With the rapid development of the commercial landing services and the Gateway, we will have access to more of the Moon than ever before. On May 23, 2019, NASA announced that Maxar Technologies would develop and demonstrate capabilities for the Gateway through a component called the power and propulsion element (PPE). The PPE, the first element of the Gateway, will launch to lunar orbit and fly by means of a technology called solar electric propulsion, but with three times more powerful than what has flown so far. This PPE will provide communications for human and robotic landers as well as visiting vehicles.

There is intense interest in what we can discover at the Moon. The lunar samples returned during the Apollo Program dramatically changed our view of the solar system, and scientists continue to unlock new secrets from the samples. Yet, we are just scratching the surface of knowledge about the Moon. By studying the geology of the Earth, the Moon, and Mars – the three planetary bodies we know the most about - and the ways in which they are similar and different from each other, we can learn fundamental aspects about how planets and planetary systems form. We know the Moon can tell us more about our own planet, and even our own Sun. There is so much more to learn – knowledge we can acquire with a sustained human and robotic presence on the Moon. NASA will conduct many more science investigations and technology demonstrations on the Moon ahead of a human return through its Commercial Lunar Payload Services (CLPS) initiative.

The Lunar Discovery and Exploration Program (LDEP), established within SMD, advances an integrated, innovative and sustainable strategy for exploration. LDEP is rooted not only in fostering improved collaboration across the Agency, but on truly leveraging interagency, international, and commercial partnerships to enable the payloads and services that will address the Nation's lunar exploration, science and technology demonstration goals. The synergy between robotic and human exploration assets enables valuable opportunities for science that cut across our science disciplines, allowing us to take advantage of the Moon both as a destination and as a unique vantage point to discover the secrets of the universe, and through it protect and improve life on Earth.

Our two-phased effort to implementing the exploration science goals, demarcated by the first human return mission to the lunar surface in 2024, has already begun. In November 2018, NASA selected nine U.S. companies to bid on delivery services to the lunar surface through CLPS contracts. Lunar payloads from a variety of customers, including NASA, will fly on contracted missions starting in 2020, enabling critical technology demonstrations and scientific observations. In February 2019, NASA also selected 10 proposals for the Development and Advancement of Lunar Instrumentation (DALI) program, which will support instruments that will fly on future lunar missions. Building on these efforts, the amended budget request includes $90 million for the purchase of commercial services to deliver a rover to the Moon. These additional funds will allow SMD, through our commercial partners, to send a robotic mission to

explore the Moon's polar regions in advance of the Artemis program's first human landing. Interfaces like these enable us to increase our understanding of the lunar surface while advancing the interests of both science and human exploration, setting us up for success for the 2024 human landing and our sustained presence on the Moon. Most recently, on May 31, we announced the selection of the first commercial Moon landing service providers that will deliver science and technology payloads as part of CLPS. These missions will acquire new science measurements and enable important technology demonstrations, whose data will inform the development of future landers and other exploration systems needed for astronauts to return to the Moon by 2024.

LDEP also enables continued operations of NASA's Lunar Reconnaissance Orbiter (LRO), which marks its tenth anniversary this month. LRO continues to help scientists characterize the lunar surface, providing insights into lunar resource analysis that could support future human exploration.

Maintaining a Balanced Science Program

NASA remains focused on exploring even those worlds that humans may never visit, building missions that are changing not only what we know, but also how we think. NASA robotic missions have visited all the planets of the solar system, and the Parker Solar Probe has broken the record as the closest spacecraft ever to the Sun. While the long-lived Opportunity Rover has finally ceased functioning, the even longer-lived Voyager spacecraft have left the solar system. The search for life beyond Earth takes its next step with our planned mission to Europa. The unparalleled James Webb Space Telescope (Webb) will open a new chapter in humanity's ongoing quest to explore and understand our universe.

To ensure not only leadership today, but also tomorrow, SMD is committed to executing a balanced and integrated science program that is informed by the decadal surveys of the National Academies of Science, Engineering and Medicine. We strike this balance by delivering success in strategic flagship missions as well as achieving the right cadence of competed opportunities led by principal investigators (PIs) to empower the best and brightest in the science community.

In Planetary Science, NASA's robust Mars Exploration Program is providing both ground-breaking science and the critical precursor data and information we need to support future human missions to the Red Planet. Mars remains the Agency's horizon goal for human space exploration. A vigorous Mars Exploration program is essential to our pursuit of this goal. The budget request supports continued progress of the Mars 2020 rover, which – after an intensive effort to identify the most promising landing site – will head to the Jezero Crater following a July 2020 launch. A precursor to human missions to Mars, Mars 2020 will continue to search for evidence of life on the Red Planet and collect a cache of core samples. In 2020, NASA will commence studies and development of a Mars Sample Return mission – the highest-priority strategic mission identified by the scientific community in the most recent planetary science decadal survey and endorsed in the 2018 midterm assessment – that would allow for the return of the Mars 2020 rover samples. Leveraging commercial and international partnerships, such as with the European Space Agency, this mission may launch as early as 2026.

In parallel, the cutting-edge Europa Clipper, a strategic mission to fly by Jupiter's moon, will be our first step in exploring ocean worlds and their potential habitability for extraterrestrial life.

Earlier this year, on New Year's Day, NASA celebrated the first flyby of the Kuiper Belt object called MU69/Ultima Thule with our New Horizons mission. The data collected from over four billion miles away from Earth will help answer basic questions about the surface properties, geology, and atmospheres of these primitive bodies.

In December 2018, NASA's first asteroid sampling mission, the Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer (OSIRIS-REx), entered orbit around Bennu, the smallest object a spacecraft has ever orbited. In 2020, OSIRIS-REx will have completed its mapping of Bennu, informing selection of the most promising sample collection site. Its measurements of this potentially hazardous object (Bennu's orbit could bring it relatively close to Earth at the end of the next century), will not only shed light on the early history of our Solar System, but will also inform the design of future missions to mitigate possible asteroid impacts on Earth.

In November 2018, the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) lander (selected through the competitive Discovery program) reached the Martian surface, marking the Agency's eighth successful soft landing on the Red Planet. A robot geologist, InSight will yield new discoveries about the Martian interior, providing an unprecedented look at its core structure and heat flow. Cruising behind InSight were two experimental, briefcase-sized spacecraft named Mars Cube One (MarCO) – the first ever planetary CubeSats – which successfully relayed data back to Earth from the InSight lander during its descent to the Martian surface.

The budget request supports continued development of the next Discovery missions, Lucy and Psyche, which have the potential to open new windows on one of the earliest periods in the history of our solar system.

Built as a cohesive program for Near-Earth Object (NEO) detection and mitigation technology development, NASA's Planetary Defense Program will continue to fund the NEO Observations project and development of a space-based infrared instrument for detecting NEOs with this year's budget request. Meanwhile, the Double Asteroid Redirection Test (DART) to demonstrate the kinetic impact technique for asteroid deflection will continue to make progress towards its planned 2021 launch.

Turning to our investments in Astrophysics, the 2020 budget request accommodates the funds needed to support the revised March 2021 launch date of the James Webb Space Telescope, the largest and most powerful space telescope to be developed to date. Webb will join NASA's family of observatories to examine the first stars and galaxies that formed, viewing the atmospheres of nearby planets outside our solar system and informing our understanding of the evolution of our own solar system. In order to maintain a balanced science program that optimizes overall scientific return, the FY 2020 budget request again proposes termination of the Wide Field Infrared Survey Telescope (WFIRST), given its significant cost and higher priorities within NASA.

The budget request also supports operations for the airborne Stratospheric Observatory for Infrared Astronomy (SOFIA), a partnership with the German Aerospace Center that allows astronomers to study the solar system and beyond in ways that are not possible with ground-based telescopes.

In 2018, after nine years of searching for planets outside our Solar System, NASA bid farewell to the Kepler mission. Kepler discovered almost 2,700 new exoplanets, bringing the total from all sources to over 3,900 known exoplanets. Kepler's legacy serves as the foundation for NASA's next planet-hunting mission, the Transiting Exoplanet Survey Satellite (TESS), launched in April 2018. Just 10 months into science operations, TESS had confirmed 15 new exoplanets, 5 new multi-planet systems, and 639 exoplanet candidates. During its two-year primary mission, TESS will observe nearly the whole sky, providing a rich catalog of worlds around nearby stars, including valuable targets for Webb to explore.

The Heliophysics Division adopts a holistic approach to the study of the Sun and its connection to Earth and other planets – venturing to the very edge of the Sun's influence and beyond. In December 2018, Voyager 2 exited the heliosphere, the protective bubble of particles and magnetic fields created by the Sun, a milestone only achieved once before – by Voyager 1 in 2012. In over 40 years in space, Voyager 2 has traveled a staggering 18.5 billion miles and is NASA's longest-running mission.

In 2018, several successful launches expanded the Heliophysics System Observatory, including the August 2018 launch of the Parker Solar Probe. Having completed its first of 24 planned orbits around the Sun in January 2019, Parker Solar Probe has already made two passes within 15 million miles of our star.

In July 2018, NASA selected the Interstellar Mapping and Acceleration Probe (IMAP), a strategic mission identified as a priority in the most recent solar and space physics decadal survey, to launch in 2024 to study the boundary of the outer solar system where the solar wind ends. Further expanding our understanding of the heliosphere, in 2020, NASA will launch Solar Orbiter, a joint collaboration led by the European Space Agency, into orbit around the Sun.

Launching in 2019, the Ionospheric Connection Explorer (ICON) instrument will help provide the most comprehensive observations of the ionosphere – a region of charged particles in Earth's upper atmosphere. ICON will join the Global-scale Observations of the Limb and Disk (GOLD) instrument, which has been studying the dynamics of the ionosphere since its launch in 2018 as the first NASA science mission to fly as a commercially hosted payload.

NASA continues to work with its agency partners to reduce gaps between space weather research and operations. The budget supports the Heliophysics Space Weather Science and Applications project to further strengthen the feedback between fundamental research and operational forecasting needs by improving the transition of science results into operational products. The budget also provides for a potential new Small Explorer-class space weather mission. This will lay the groundwork for a future Space Weather Mission line to focus on resolving fundamental science problems required to improve space weather prediction, and serve as a pathfinder for observation technology for the National Oceanic and Atmospheric Administration's operational space weather missions.

In 2018, NASA launched two strategic missions recommended by the 2007 Earth Science decadal survey: Gravity Recovery and Climate Experiment Follow-On (GRACE-FO); and Ice, Cloud and land Elevation Satellite-2 (ICESat-2). The twin satellites of GRACE-FO are continuing the original GRACE mission's 15-year legacy (2002-2017) of measuring the changing mass of ice sheets and glaciers and tracking Earth's water movement across the planet. ICESat-2, the follow-on to NASA's ICESat mission (2003-2009), is providing unprecedented data on the topography of ice, forests, and oceans. In November 2018, the Operation IceBridge 2018 Antarctic Field Campaign concluded successfully after flying under ICESat-2 orbits to validate and verify the new satellite's measurements.

In addition, NASA Earth Science is collaborating with the Human Exploration and Operations Mission Directorate to utilize the International Space Station (ISS) for Earth observations. NASA Earth Science launched two low-cost, competitively selected missions to the ISS in 2018. The ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) instrument is measuring agricultural water use, vegetation stress, and drought warning conditions. In December 2018, the similarly low-cost, competitively selected Global Ecosystem Dynamics Investigation (GEDI) vegetation canopy lidar instrument was launched to the ISS and is now embarked on its science mission to make 3D maps of the world's forests.

The FY 2020 budget request also funds continued progress of Landsat 9 for a launch as early as FY 2021. As part of the Sustained Land Imaging program architecture, Landsat 9 will enable continuity of the critical, long-term land imaging data record begun in 1972 with NASA's joint agency partner, the U.S. Geological Survey. Consistent with the FY 2019 budget request, the FY 2020 request proposes termination of the Plankton Aerosol Cloud ocean Ecosystem (PACE), and Climate Absolute Radiance and Refractivity Observatory Pathfinder (CLARREO-PF) missions.

NASA Earth Science continues to explore innovative partnerships and new approaches, including the acquisition of commercial data products from small satellite constellations. In September 2018, the Earth Science Division awarded contracts to three commercial data products providers. Through this pilot program, NASA-funded researchers will examine the scientific value of the data to help determine the utility of the private sector's constellation-based products for advancing NASA's science and applications development goals. The 2020 budget request continues support for the integration of NASA Earth Science efforts with non-governmental partners through these and other activities, such as commercial hosting and new partnerships (such as the NASA-Conservation International collaboration announced in February 2018).

Finally, upcoming selections and opportunities will demonstrate NASA's continued commitment to PI-led, competed opportunities, a priority highlighted in the most recent decadal surveys of the scientific communities we support. By the end of FY 2019, NASA plans to select the next New Frontiers mission for Planetary Science, the next Heliophysics Explorer missions, and the Earth Venture Instruments-5 (EVI-5) instrument. We also plan to release Announcements of Opportunity for the next Discovery mission, and the next Astrophysics Small Explorer and Mission of Opportunity missions. Our 2020 budget request puts us in an even stronger footing to achieve the right mix of large strategic missions and competed small and medium-class opportunities. For example, it enables us to fully support competed Astrophysics missions at the decadal survey-recommended cadence, fully fund Earth Science's planned future solicitations in all three competed strands, and implement the Heliophysics' DRIVE (Diversify, Realize, Integrate, Venture, Educate) initiative, increasing the competed research program to about 15 percent of the budget request.

Delivering Impact

I have talked about many NASA programs, but I would like to leave you with an important message -- that NASA science directly supports decision-making, helping improve our society and quality of life. Our Earth Science program teams with government and commercial partners in the U.S. and internationally to use the measurements and understanding to develop and demonstrate applications that provide direct benefit to our Nation, and indeed all of humanity.

NASA also accumulates, archives, and distributes data collected by the Heliophysics System Observatory, a fleet of operating spacecraft. Combining the measurements from all of these observing platforms enables interdisciplinary, connected systems science across the vast spatial scales of our solar system. This collective asset enables the data, expertise, and research results to contribute directly to fundamental research on solar and space plasma physics and to the national goal of real-time space weather prediction. NASA teams support day-to-day mission operations for NASA spacecraft and data analysis to advance the state of space science and space weather modeling. NASA conducts science community-based projects to evaluate research models containing space weather information that is of value to industry and government agencies. Heliophysics data centers archive and distribute the science data from operating missions in the Living With a Star (LWS), Solar Terrestrial Probes (STP), Research, and Explorer programs. The science of heliophysics, including space weather, enables the predictions necessary to safeguard life and society on Earth and the outward journeys of human and robotic explorers. For example, the Global-scale Observations of the Limb and Disk (GOLD) mission was the first NASA

science instrument launched aboard a commercial spacecraft. From its location parked over the western hemisphere in geostationary orbit, the mission enables scientific understanding and situational awareness of ionospheric phenomena that can cause dramatic impacts on communications and other space weather effects.

In addition, NASA's Near Earth Objects Observation (NEOO) project, using ground and space-based assets, looks for Near-Earth Objects (NEOs) that have any potential to collide with Earth and characterizes them to assess if any could do significant damage to the planet. NEOs range in size from a few meters to approximately 34 kilometers, with smaller objects being two orders of magnitude more numerous than larger objects. The NEOO project supports a network of search and characterization observatories and the data processing and analysis required to understand the near-Earth population of small bodies. Since NASA's search started in 1998, the project has found over 96 percent of these objects that are 1 kilometer and larger, and about 34 percent of all those larger than 140 meters in size. NEOs discovered and characterized by the project may also be viable targets for future robotic and crewed exploration, and possible eventual candidates for asteroid mining operations.

As we begin the summer season, we are reminded that heat waves are one of the leading causes of weather-related deaths in the United States. NASA satellite data are being used, not only to track these extreme temperatures, but also to measure the height of trees, data that helps city managers determine the best places to plant more sources of crucial shade. Other satellite data are used to identify who is most at-risk when the temperatures rise, and, when combined with air quality measurements, identify when to issue heat-related advisories. Heat also brings other health-related risks, and NASA is also helping track mosquitoes. These tiny, disease-carrying, cold-blooded creatures love hot, wet weather. Public health departments from California to Maryland are taking NASA data on soil moisture, plant coverage, and land temperature to create maps that combine this information with, for example, reported outbreaks of West Nile Virus. They're using these maps to inform warnings, to define strategies for spraying, and develop more efficient and effective ways to keep Americans safe.

Conclusion

With Webb poised to look out into the cosmos and back to the time when the first stars were forming, humans landing on the Moon, and constellations of spacecraft exploring the solar system and our home planet, NASA's amended FY 2020 request supports what is truly a golden age of exploration.

With the amended FY 2020 request, SMD will help pave the way for the success of the Artemis program, initiate the first round-trip mission to the Red Planet with a Mars sample return mission, and continue investing in the groundbreaking work our scientists, engineers, and technologists do every day to answer humanity's most fundamental questions. With this investment, we will provide critical data and capabilities for future robotic and crewed missions, increase our understanding of our home planet, and move out on ambitious programs to study the far reaches of our solar system, and beyond.

Thank you for the opportunity to testify before you today. I would be pleased to respond to your questions.

Dr. Thomas Zurbuchen is the Associate Administrator for the Science Mission Directorate at the Agency's Headquarters in Washington, D.C.

Previously, Zurbuchen was a professor of space science and aerospace engineering at the University of Michigan in Ann Arbor. He was also the university's founding director of the Center for Entrepreneurship in the College of Engineering. Zurbuchen's experience includes research in solar and heliospheric physics, experimental space research, space systems, and innovation and entrepreneurship.

During his career, Zurbuchen has authored or coauthored more than 200 articles in refereed journals on solar and heliospheric phenomena. He has been involved with several NASA science missions -- Ulysses, the MESSENGER spacecraft to Mercury, and the Advanced Composition Explorer (ACE). He also has been part of two National Academy standing committees, as well as various science and technology definition teams for new NASA missions.

Zurbuchen earned his Ph.D. in physics and master of science degree in physics from the University of Bern in Switzerland.

His honors include receiving the National Science and Technology Council Presidential Early Career for Scientists and Engineers (PECASE) Award in 2004, a NASA Group Achievement Award for the agency's Ulysses mission in 2006, and the Swiss National Science Foundation's Young Researcher Award in 1996-1997.