

**Statement of
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**Before the
Committee on Science, Space and Technology
US House of Representatives**

Thank you for inviting me before this committee today. As the chairman remembers, I was delighted to come and speak about life in the universe with you in 2015.

As a planetary scientist who has worked at the Jet Propulsion Laboratory, at a university, at a small company, and at NASA, I can tell you that the strength of NASA lies in its people and its vision and mission: reaching for new heights and revealing the unknown for the benefit of humankind. At NASA, engineers, technologists and scientists work together to answer fundamental questions about the nature and fate of this planet, the solar system, the universe, how to move humans outward into the solar system, how to safely advance our aeronautics enterprise, and determine if there is life beyond Earth. These might seem like disparate challenges - but they are fundamentally linked in not just why we do them, but how we do them. NASA has excelled at this for over fifty years, and the agency truly stands on the brink of discovering life beyond this world, of moving humans to Mars, of safeguarding life on this planet through knowledge of our complex earth systems, and ushering in a new age of more efficient, safer air travel.

NASA's origin, and indeed, the first "A" in NASA, is aeronautics. Every U.S. aircraft flying today and every U.S. air traffic control tower uses NASA-developed technology

in some way. While there is great public excitement about the growing space industry, NASA is also leading the way on several revolutions in aeronautics. NASA is developing the technologies that will allow the Nation's air traffic control system to operate more safely and efficiently, even as air travel continues to grow significantly. These technologies will cut travel times and delays for passengers, reduce fuel use and emissions, and create significant savings to airlines. NASA is also at the forefront of the unmanned aerial vehicle, or drone, revolution. In close coordination with the FAA, NASA is developing the technologies that will allow the safe integration of these systems into the national airspace. In the last year, NASA has announced plans to work closely with U.S. industry to develop the next generation of experimental aircraft. These "X-planes" will test new technologies that will make air travel faster, safer, and more efficient. Imagine traveling anywhere in the world in six hours? Or imagine a hyperefficient and quite electric airplane? NASA is already working on X-planes to do just that. Finally, NASA's Aeronautics program plays an important role researching and testing hypersonic and supersonic principles and technologies. This is a critical area of research in support of our national security agencies, but also important to understanding how spacecraft can safely enter the atmosphere of Earth and Mars.

All of the science at NASA- planetary science, earth science, astrophysics and heliophysics- allow us to daily rewrite textbooks as our spacecraft data reveal how our universe works. Not only all of these areas of science are deeply connected, they are all necessary to achieving one of my passions as a scientist – discovering an Earth-like planets around another star, an Earth 2.0. NASA is embarked on this great search, but it requires knowing how this planet works and understanding why we only have one current Earth in our own solar system, how habitable planets interact with their parent star, and how planetary systems form and change over time. All four areas of science at NASA help us answer these questions, pushing the boundaries of human knowledge toward that ultimate discovery of an Earth 2.0.

As a child, I learned about the nine planets of our solar system, and later learned to live with only eight. Over the past three years, the Kepler space telescope has found over 3000 planets around other stars, looking at only a very small portion of our galaxy. This tells us that just about every star we see in the night sky has a planetary system. Later this year, NASA will launch a follow-on to the Kepler mission, the Transiting Exoplanet Survey Satellite or TESS, that will find a planet in the habitable zone around nearby stars. Shortly after that, the next great observatory, the James Webb Space Telescope will launch and allow us to analyze the atmospheres of some of these habitable zone planets, looking for gases like carbon dioxide, methane, or water that could indicate potential habitability. When I talk to students, I tell them that when I was their age I wanted to grow up to study our nine planets- but now they will have thousands, each one helping us to answer fundamental questions we have on the workings of our own planet. For whether it is the study of Venus, Saturn's moon Titan, or planets around other stars, we look to other worlds to better understand the physical processes that govern our own world. For example, I study volcanoes on Venus and seas on Titan to help us better constrain how volcanoes erupt and how seas interact with atmospheres on all planets, including Earth.

When we look at other planets, it always comes back to the fundamental question of habitability - Are we alone? Our studies of other planets have informed us that the habitable zone is not just a place, but it can also be a time. For example, early in their histories both Venus and Mars were likely to be habitable. But just like in the Goldilocks story, Venus became too hot and Mars became too cold, while the Earth has persisted in being able to maintain moderate temperatures to allow liquid water to be stable on its surface. It is this liquid water that we believe to be critical to the evolution and sustenance of life. On Mars, our robotic rovers and orbiters have provided data that tells us that water was stable for very long time periods- as much as a billion years- on its surface early in its history, about 3 billion years ago. This was the same time period during which life evolved here on Earth in the oceans, formed from the building blocks of life- amino acids- that have been delivered all

over the solar system by comets and asteroids. The conditions on Mars were so similar to those on Earth that astrobiologists look at Mars as one of the most likely places beyond Earth to have harbored- and maybe still harbor - life. Other targets in our solar system include the watery worlds of Europa and Enceladus, and my favorite Titan, with its seas of liquid hydrocarbons. But Mars is the closest, and the most accessible for exploration—and the most like our own Earth.

After about a billion years of favorable conditions on Mars, the planet lost its magnetic field, its unprotected atmosphere began to be stripped away by the solar wind, and Mars' water retreated underground, was lost to space, and froze into its small polar caps. Life either went extinct, or retreated underground with the water. Finding fossil evidence of past life on Mars is not going to be easy, and I strongly believe it will take Mars astronauts to find indications of life. Their work on the red planet will find not just indications of life, but ample evidence to help us understand the similarities and differences between life here on Earth and life that evolved on another world, and the implications of that for us, and for life beyond our solar system.

When I started as Chief Scientist, I was moving houses and sorting through some old files. I grew up in a NASA family and I found an old newspaper interview with my father that he did when he became head of the space station in 1986. His excitement came through in the interview as he talked about how the space station would lay the groundwork for humans to get to Mars in 20 years. I read this not too long after having given a speech saying the same thing -- over 20 years later. Mars will always remain twenty years in the future for NASA without bipartisan support and the commitment to make it happen. It can be done without major increases in budget and without revolutions in technology. It just needs focus, a constancy of purpose, and leadership.

NASA has never been closer to being able to send humans to Mars than today. NASA has a sustainable plan to get humans to Mars orbit by 2032, and land thereafter.

This plan is built on the research NASA does every day on the International Space Station to prepare humans for longer duration spaceflight. It is built upon the progress NASA has made in the development of the Space Launch System and Orion. By the mid-2020's, NASA's work on the ISS will be largely complete and SLS and Orion will be ready for work. The next step is then a habitat in orbit around the moon by the mid-2020s, where NASA can test what will be the prototype for a Mars transfer vehicle, the next step in living and operating independently from the Earth. In the vicinity of the moon, we can learn about the higher radiation environment, learn distant operations, and finalize the development of long-duration life support systems needed for the 2-3 year trip to Mars and back. If the international partners or the commercial sector want to go to the surface of the Moon, as the commercial sector is well on its way to doing, NASA will be able to participate in those efforts. In fact, NASA is already supporting some of these commercial lunar efforts through its Advanced Exploration Systems division. But in both low Earth orbit and on the surface of the Moon, the 2020's will be the decade of NASA moving out, and the private sector moving in.

By 2032, NASA will be ready for the first human round-trip mission to Mars, starting out with an orbital mission like we did with Apollo. Depending on budget and technology readiness, a surface landing should follow in the late 2030s. Entry, descent and landing (EDL) technologies are still the tallest tent pole in humans to the Mars surface, and NASA looks forward to partnering with SpaceX on Red Dragon to move those technologies forward. In addition, a round-trip demonstration returning a sample from Mars in the 2020s would help push EDL technologies and prepare us for a human landing as soon as possible.

As the National Academies concluded in their most recent study of human spaceflight, Mars is the goal for the human exploration program and it is key that we keep our eyes on this prize. Doing things we have never done before, pushing the limits- this is the proper role and should be the focus of NASA. This big push is what will enable the next generation of tech spinoffs to be capitalized on by the private

sector. With focus and determination, we are on our way to make this happen. When nations try to do great things- tough things- that no one has done before- they move their country forward, economically, strategically, inspirationally.

But as exciting as it is to talk about humans to Mars, it is important to remember that the only planet we can actually live on is this one. When I study planets, it always comes back to the question of Earth – how can we use this information to improve life here. Ours is a complex planet with oceans, a biosphere, and an atmosphere interacting in ways that we can uniquely study from the vantage point of space. From space, we are able to collect deep and continuing data sets of Earth that are directly beneficial to our economy, our national security, and to each one of us everyday.

The data gathered from NASA's earth observing satellites and aircraft, coupled with NASA's support of fundamental research and analysis of this data, enables us to better understand and predict our weather, more efficiently grow our crops, make better land use and urban planning decisions, and respond to natural disasters and wildfires. Satellite observations of crops help us predict food security needs not just in this country, but around the world, which is critical for national security. Our satellites and airborne data are helping us understand the rapid rate of change we see in the Arctic from melting sea ice, the loss of ice mass in Greenland and western Antarctica, changing patterns of vegetation, and rising sea levels. Our satellites help us to monitor storms, gain understanding of how hurricanes develop and strengthen, and provide the next generation of instrumentation for better weather forecasting.

Water has always been and always will be a precious resource, and a potential source of world conflict. Our satellites today are giving us an unprecedented view of the global water cycle. GPM tracks precipitation around the globe, JASON-2 warns us of El Nino or La Nina and monitors sea level, SMAP provide information on soil moisture and GRACE tells us whether and how much groundwater is being depleted,

or too saturated- warning us of possible floods to come. IceBridge helps us understand what is going on at the poles until IceSAT 2 launches, and the Surface Water Ocean Topography mission in 2021 will be able to monitor lake and river levels- giving us complete intelligence on the water cycle- not just here, but around the world. These data aren't just important for scientists trying to understand our water cycle- these data help farmers plan how to water crops, help water resource managers plan for and deal with too much or too little rain, and help warn us of possible droughts or floods in countries around the world.

For example, NASA developed a system that processes satellite data to track field-by-field water use to help water managers balance their water resources. This system is now being used by water managers in fifteen states, including Florida, Texas, California, and Oregon. A smartphone app version has been developed to get the same field-scale maps of water consumption to farmers.

None of what NASA does is possible without a constant emphasis on technology-changing the way we do things by investing in the future. From investments in small spacecraft and instrument technologies that have helped lead to the revolution in commercial industry of small spacecraft to technologies that have helped humans live on the ISS that have spun off things ranging from nutritional supplements in all baby formulas to water purification systems used in disaster zones, every NASA investment in technology is an investment in the US economy that typically returns much broader benefits to humankind.

Over the last several years as Chief Scientist, I had the opportunity to represent NASA, speaking to school kids not just in this country but all around the world. NASA truly does inspire the next generation- the Mars generation. They see NASA as a shining example of American ingenuity, American leadership- American can do. NASA has accomplished great things- and NASA now reaches to do new great things- find life on other worlds, walk on the surface of Mars, use our space data to help

sustain and prosper life here. It just takes a commitment and focus. With your support of NASA, you don't have to wait for the future to happen, you can create it.