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Statement of

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Chairman Babin, Chairwoman Comstock, Ranking Member Edwards, Ranking Member Lipinski, and Members of the Subcommittees, I am pleased to have the opportunity to appear before you to discuss astrophysics research underway at NASA and our roadmap to the future.

Enduring Questions

How did our universe begin and evolve? How did the familiar night sky of galaxies, stars, and planets come to be? And, one of the greatest questions of all time, are we alone in the universe?

These are the enduring questions of humanity. For the first time in human history, we are capable of answering these questions scientifically. We are answering these questions by making precise measurements of the universe using the world's most capable collection of space observatories. We are probing back in time with the Hubble Space Telescope by detecting exquisitely faint infrared signals from galaxies that formed about 13 billion years ago – only 400 million years after the Big Bang and ever closer to the beginning of time. We are fine tuning our calculation of the expansion rate of the universe and the properties of dark energy by refining the measured distance to remote galaxies with Hubble and by weighing the million degree gas in distant clusters of galaxies with the Chandra X-ray Observatory. Chandra and the Fermi Gamma-ray Space Telescope are observing high energy photons from very distant quasars in order to set limits on the nature of the "space-time foam" – a feature predicted by quantum mechanics about the roughness of space and time at sub-atomic scales. Hubble and Chandra work together to gather evidence about the nature of supermassive black holes, including data showing how they formed in the early universe and how they triggered the birth of new stars in the first galaxies. The Nuclear Spectroscopic Telescope Array is peering through the thick blankets of gas and dust in the most active galaxies to reveal the most massive known black holes at their centers.

NASA's space observatories are used by astronomers from around the world to make fundamental discoveries about the universe we live in. Every two years, these missions are reviewed by a panel of senior astronomers to confirm that their continued operation is cost effective and scientifically productive. In June 2016, following a thorough Senior Review, NASA approved all of these missions to continue their science operations for another two years, contingent on the Astrophysics Division receiving the funding requested in the FY 2017 President's Budget Request.

NASA is developing two new missions to advance our understanding of the universe. The James Webb Space Telescope, launching in 2018, will observe the first stars and galaxies formed after the Big Bang. The Wide-field Infrared Survey Telescope, or WFIRST, launching in the mid-2020s, will measure the expansion history of the universe and constrain the properties of the dark energy that is accelerating that expansion.

Learning about the origins of the universe – how it began and how it evolved, is critical to understanding how planets formed and whether planets could evolve that are capable of harboring life.

Exoplanets

Our knowledge of planets outside of our solar system, or exoplanets, has exploded in the last twenty years. From antiquity through almost the entire twentieth century, people wondered and dreamed about life beyond Earth without knowing whether planets orbiting other stars were common or rare. Thanks to pioneering discoveries made with ground based observatories, followed by the Kepler Space Telescope mission, we now know that planets orbiting other stars are common. Not only is the Sun not unique in having a planetary system, but most of the stars in the sky have planetary systems of their own. Future generations will look at the night sky in a completely different way than we did when we were young. Where we once may have guessed whether or not there were unknown worlds waiting to be discovered, our children will grow up knowing that there are billions and billions of planets in our Galaxy.

How have we learned this? By using the same methods that we always use to solve the mysteries of the universe – by determining what measurements are needed to advance our knowledge, developing innovative new instruments capable of making those measurements, by designing new telescopes that collect the light needed for those discoveries, and then by careful analysis and attention to detail to eliminate sources of error. In this case, the Kepler team detected thousands of exoplanets using a method that was developed by noticing that the light from some stars dims just a tiny bit in a regular way. The Kepler Space Telescope is an example of this. Kepler detects exoplanets by measuring the tiny, periodic dimming caused by planets crossing in front of their parent stars. Some have likened this to standing on the steps of the Capitol Building and attempting to observe a ladybug crossing in front of a lighthouse in Washington state. The measurement needed is a tiny change in the brightness of a star, the innovative new instrument is an ultraprecise photometer, the telescope is one that can point at the same stars for years on end without wobbling, and the careful data analysis must separate the dimming caused by exoplanets from all other possible reasons for the starlight to vary. For four straight years, Kepler continuously measured the light from each of the 150,000 stars in its field-of-view and discovered over 5,000 exoplanet candidates.

While Kepler was NASA's first mission dedicated to the search for exoplanets, and the first capable of detecting Earth-size exoplanets orbiting a Sun-like star, it is not NASA's only mission involved in the search. Hubble's sharp vision has been used to detect some of farthest planets that have ever been found and to determine their atmospheric composition by observing the parent star's light filtered through the exoplanet's atmosphere. Spitzer has used the same technique of transit spectroscopy to determine the temperature and atmospheric compositions of several distant exoplanets.

The exoplanets discovered so far are astounding in the diversity of their size and characteristics. HAT-P-11b is about the size of Neptune, with an atmosphere laden with water vapor. 55 Cancri e (Janssen) is a hot, rocky planet locked by gravity with one side always facing its star and the other permanently plunged in darkness; wild swings in temperature hint at a surface that may be bubbling with rivers of lava. HD 189733b is a scorching alien world, where it possibly rains glass – sideways – in howling 4,500 mph winds. 51 Pegasi b (Dimidium)is about half of the mass of Jupiter, but speeds around its sun in a blistering four days instead of the twelve years that it takes Jupiter to make an orbit. We now know that tidally locked planets and "hot Jupiters" are very common in the universe, although we have nothing like them in our solar system. But the most compelling search is for a type of planet found in our solar system – one that, like the Earth, is capable of supporting life.

To find such habitable exoplanets, we are looking for planets that are the right size – planets that are not so big that they have miles-deep, high pressure atmospheres, and not so small that they cannot retain an atmosphere – and the right temperature. They must receive the right amount of heat from their star to support liquid water – not too hot and not too cold. To date, we have found nine roughly Earth-sized planets in the habitable zone of their parent stars, but this type of planet lies at the very boundary of what is detectable by our current fleet of telescopes. The exoplanets discovered by Kepler are generally too far away to allow detailed follow-up studies of their atmospheric composition.

We eagerly await the launch of the James Webb Space Telescope in 2018 to probe deeper into the origins of the universe and to carefully examine the makeup of known exoplanets through both transit spectroscopy and direct imaging. And two new observatories coming on line will contribute to our search for exoplanets: TESS, the transiting exoplanet survey satellite, and WFIRST, the wide-field infrared survey telescope.

Upcoming Missions

TESS will launch in 2017 or 2018 and will use Kepler's transit method to search for exoplanets around the nearest and brightest stars in the sky. TESS will provide a catalog of the many types of exoplanets that are out there. These exoplanets will be among the best targets for further study. Many of the stars that TESS observes will be smaller than the Sun; this makes it easier to find rocky exoplanets in the habitable zone. Exoplanets orbiting bright stars are the best candidates for using the Webb Telescope to measure their atmospheric composition. Exoplanets orbiting the nearest stars are the best candidates for direct imaging using a coronagraph, such as the one that WFIRST will have.

WFIRST, in addition to studying dark energy, will carry a revolutionary coronagraph instrument that will block the light of stars to let us see directly see exoplanets and measure their light. The WFIRST coronagraph instrument will be capable of seeing exoplanets that are up to one billion times fainter than their parent star. For the first time, we will be able to measure the light directly from an exoplanet like Jupiter or Neptune in our solar system. Although not sensitive enough to see an Earth-like planet, the WFIRST coronagraph will demonstrate the technology needed to accomplish that measurement when coupled with a larger telescope.

A Steady Cadence of Missions

For over forty years we have used the Decadal Survey process to determine the most compelling science questions to be addressed in the next decade. This process is managed by the National Academy of Sciences, which brings together America's leading scientists to recommend a course of exploration for the next decade. The Decadal Survey named Hubble as the highest priority large space mission in 1972, Chandra in 1982, and Spitzer in 1991; all have fundamentally changed the way we understand the universe and continue to produce world-class science. Our next large observatories were also top recommendations of the Decadal Survey: Webb in 2001, and WFIRST in the most recent study, in 2010.

As the time approaches to conduct the next Decadal Survey, we are initiating mission concept studies that will provide solid information to help the Decadal Survey Committee make informed decisions. At the recommendation of our advisory groups, we have identified four large mission concepts to study. Teams have been formed to study each of these mission concepts to determine what science could and should be done, what new technologies exist to enable new discoveries, what technology is needed, what these new missions might look like, and what these new missions might cost. We will also form teams soon to study medium-size mission concepts, and all of this information will be provided to the decadal survey team. While our current study activities are focused on medium and large-sized missions (given the long lead time needed to develop the concepts and technologies associated with them), we continue to support a balanced portfolio that also includes competed smaller missions.

What type of science might we expect from future NASA space observatories?

An x-ray surveyor might discover the first generation of supermassive black holes in the infant universe, unravel the structure of the cosmic web and determine its impact on the evolution of galaxies, and determine the influence of dark matter on the evolution of the universe.

A far-infrared surveyor might find bio-signatures in the atmosphere of exoplanets (perhaps methane, ozone, or carbon dioxide, which could indicate the presence of life), map the beginnings of chemistry, and explain the origins of dust and the molecules that form the cradle of life.

An ultraviolet/visible/infrared surveyor could be designed with a very large mirror that could capture the first starlight in the early universe, map the distribution of nearby dark matter with unprecedented resolution, detect water worlds and biomarkers on distant Earth-like planets, and image icy plumes from the moons of giant planets in our solar system.

And a habitable exoplanet imaging mission could search for signs of habitability in the atmospheres of exoplanets.

In addition, in 2017 NASA will initiate studies of medium-size Astrophysics Probe missions. The astrophysics community has informed NASA that such missions could be capable of compelling astrophysics research with more modest capabilities than the large missions already under study.

NASA's portfolio of future observatories will also include small, Principal Investigator-led missions selected through competitive announcements of opportunity within the Explorers Program. NASA is targeting the release of a draft Announcement of Opportunity (AO) for a medium-class Astrophysics Explorer and related solicitation for a Mission of Opportunity (MoO) in early Summer 2016, and releasing the final AO and MoO solicitation in late Summer/early Fall 2016.

Summary

Like Hubble, Chandra, Spitzer, Fermi, Kepler, and NuSTAR before them, the James Webb Space Telescope, the Transiting Exoplanet Survey Satellite, and the Wide Field Infrared Survey Telescope will fundamentally alter our understanding of the universe and our place in it. We are generating ideas now that the next Decadal Survey Committee will need to recommend the science that will carry us even further – whether to explore deeper in time to the origins of our universe, to unlock the hidden universe of dark matter, or to detect evidence of life beyond our solar system. Regardless of our path, it is certain that we will continue to push boundaries to answer humanity's enduring questions.

We are fortunate to live in a country that values curiosity and discovery as inherently noble quests. We are fortunate to have a national workforce that is capable of innovation and spectacular achievements. And at NASA we are thankful to Congress for affording us the opportunity to answer some of humanity's most fundamental questions.

Thank you for listening, and I would be happy to answer any questions you have.