

Testimony of

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before the

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Chairman Babin, Ranking Member Bera, and Members of the House Committee on Science,
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Thank you for the opportunity to appear before you today at this important hearing. I speak to you today as a scientist with more than 40 years of spaceflight related research, largely funded by grants from NASA's planetary science division. I also have the honor to serve as Co-Chair of the Committee on Astrobiology and Planetary Sciences (CAPS) of the National Academies of Sciences, Engineering and Medicine. However, I want to note that my testimony today is my own and should not be taken as reflecting any consensus views or advice from CAPS or the

National Academies. The views I express today are based on my personal assessment of information and presentations made available to CAPS as it has been monitoring the implementation of the planetary science decadal survey. CAPS is one of five subcommittees of the Academies' Space Studies Board—each of which is charged to assist the federal government in integrating and planning programs in space sciences by providing advice on the implementation of decadal survey recommendations. I have the honor of co-chairing CAPS along with Dr. Christopher House of The Pennsylvania State University. We are particularly honored to chair this important committee at a time when it embarks on its work with a new charter from the Academies that will enable our committee to issue short, topical reports that will provide guidance to federal agencies that support astrobiology and planetary science research. The scope of CAPS spans space-based and supporting ground-based planetary research within our own planetary system, including, for example, geosciences, atmospheres, particles and fields of planets, moons, rings, and small bodies, as well as astrobiology, sample analysis, planetary astronomy, and planetary protection. The CAPS's scope also includes appropriate cross-disciplinary areas and consideration of budget and programmatic aspects of the implementation of the decadal survey.

Chairman Babin, I would like to thank you and the committee for giving me the opportunity to present to you today some personal perspectives on the implementation of the most recent 2011 decadal survey in planetary sciences—"Vision and Voyages for Planetary Sciences in the Decade 2013-2022." Because others this morning will give the committee comprehensive reports on the status of the Mars 2020 and Europa Clipper missions, my testimony will focus on some of

the driving principles that underpinned the decadal survey's recommendations for these missions and other elements of the planetary science program at NASA.

It is also worth noting that as we meet today, an ad hoc committee (not CAPS) has been established by the Academies on the request of NASA to review the response of NASA's Planetary Science program to the 2011 decadal survey. That committee's work is well underway and it is charged to recommend any actions that could be taken to optimize the science value of the planetary science program including how to take into account emergent discoveries since the publication of the decadal survey in the context of current and forecasted resources available to NASA. The midterm review committee is also being asked to provide guidance about implementation of the decadal's recommended mission portfolio and decision rules for the remaining years of the current decadal survey, but it is specifically charged to not "revisit or redefine the scientific priorities or mission recommendations from [Vision and Voyages]." The midterm study is also undertaking the review of the Mars exploration architecture called for by the Congress in the most recent NASA authorization legislation. I am also pleased to report that NASA and the Academies have also acted expeditiously to initiate the other two studies called for in that legislation on science strategies for exoplanet discovery and characterization and for astrobiology and the search for life. All three of these studies will provide critical inputs into the upcoming decadal surveys in astronomy and astrophysics and in planetary sciences that are expected to get underway in December 2018 and the Spring of 2020, respectively.

Mr. Chairman, I would like first to remind us all what a National Academies decadal survey in space science is supposed to be. Decadal surveys are carried out with a cadence of

approximately 10 years for each space science discipline. The National Academies have conducted decadal surveys for more than 50 years, since astronomers first developed a strategic plan for ground-based astronomy in the 1964 report “Ground-Based Astronomy: A Ten-Year Program.” The committees and supporting panels that carry out the decadal surveys are drawn from the broad community associated with the discipline in review, and these volunteers comprise some of the nation’s leading scientists and engineers. The Academies’ decadal surveys are notable in their ability to sample thoroughly the research interests, aspirations, and needs of a scientific community. Through a rigorous process lasting about 2 years, a primary survey committee and “thematic” supporting panels of community members construct a prioritized program of science goals and objectives and define an executable strategy for achieving them. Decadal survey reports to agencies and other government entities play a critical role in defining the nation’s agenda in that science area for the following 10 years, and often beyond. Eleven decadal surveys have now been completed and in 2015 the Academies released a so-called “survey of surveys” report—“The Space Science Decadal Surveys: Lessons Learned and Best Practices”. Mr Chairman, I would recommend to you and the members of the committee that report’s accounting of lessons learned on the decadal process. You will see therein a reflection of what I believe is the widely-held belief of the space science research community that the decadal surveys have been a model in the world of science for how community consensus can be achieved—on science goals and on a program of activities to achieve them.

Mr. Chairman, I would like to return for a moment to the science of astrobiology and in particular the search for life. CAPS has collaborated with the Academies’ Committee on Astronomy and Astrophysics to assemble a committee drawn from the planetary and astronomy

research communities under the leadership of Dr. James Kasting, also a CAPS member, to organize a workshop held in December 2016 on facilitating an expert dialogue on the current status of extraterrestrial life detection and related issues. That workshop considered important questions such as:

- What is our current understanding of the limits of life and life's interactions with the environments of planets and moons?
- Are we today positioned to design, build and conduct experiments or observations capable of life detection remotely or in situ in our own solar system and from afar on extrasolar worlds?
- How could targeted research help advance the state of the art for life detection, including instrumentation and precursor research, to successfully address these challenges?

A proceedings report that will document the workshop, including summaries of individual presentations and ensuing discussions will be published by the National Academies very shortly and will provide invaluable input into the exoplanet and astrobiology studies now getting underway and which are of such interest to this committee. More information on the workshop and the current state of the challenge of the science of the search for life can be found in Dr. Kasting's testimony to the Committee on Science, Space and Technology on April 26, 2017.

Mr. Chairman it is also worth noting that astrobiology is increasingly at the heart of our exploration of the solar system. CAPS has heard about these exciting science opportunities through NASA, opportunities such as: the scientific program of the *Opportunity* and *Curiosity*

rovers that are roaming the martian surface and the 2020 rover that is under development; the Psyche and Lucy missions that will provide context to our understanding of the origin of habitable worlds and the formation of organic-rich planetary bodies, respectively; the development of the Europa Clipper mission and the planning for a potential future landing on the surface of Europa; and of course the inclusion of Ocean Worlds in New Frontiers 4.

Indeed in the Vision and Voyages decadal survey, astrobiology was at the heart of the scientific rationale for two of the top large flagship mission recommendations. The compelling science that drove the survey to recommend the concepts “Mars Astrobiology Explorer-Cacher Descope”—now being implemented as Mars 2020—and “Jupiter Europa Orbiter Descope”—now being implemented as Europa Clipper— were:

- Perform in situ science on Mars samples to look for evidence of ancient life or prebiotic chemistry; and collect, document, and package samples for future collection and return to Earth; and
- Explore Europa to investigate its habitability.

Since the release of the decadal survey report in 2011, CAPS has been receiving frequent reports on the implementation of these priorities by NASA. Since then the committee co-chairs have reported to the Space Studies Board at its semi-annual meetings and repeatedly at the most recent SSB meetings. I, Chris House and our predecessor co-chairs have reported to the board our personal assessment that the Planetary Science Division is in a good state and the decadal’s priorities are being pursued. In particular we have noted that the Mars 2020 astrobiology/sample-

caching rover mission continues its development toward a 2020 launch; the Europa Clipper mission to explore Europa and investigate its habitability is in Phase B (design phase); two Discovery-class missions have been selected (Psyche, M-[or metal]-type asteroid orbiter and Lucy, multi-Trojan asteroid flyby), and another one is in extended Phase A (NEOCam) development; and finally the next New Frontiers class mission proposals were submitted April 28th of this year and are currently being assessed.

Mr. Chairman, one of the most exciting possibilities in space science today is the opportunity we have to find evidence for extant, or extinct, extraterrestrial life in the solar system. In that regard, our current suite of astrobiology missions is key to the future of planetary science. The opportunity to explore Europa in detail is therefore all the more exciting. With this in mind, I am sure CAPS—and indeed the planetary midterm review committee—will continue to consider the impacts of the evolution of NASA’s plans to explore Europa. The multiple flyby Europa Clipper mission is, I believe, highly responsive to the decadal survey in science and cost. Indeed it is my personal view, and one that I have expressed in other forums (such as when I was chair of the Outer Planets Assessment Group—a group supported by NASA to provide community input to Dr. Green and the Planetary Science Division), that the Europa Clipper mission is in many ways superior to the original Jupiter Europa orbiter mission considered by the decadal. The Clipper design solves many thorny engineering problems, which I can discuss if you wish. Important from a CAPS perspective, the evolution of the Jupiter Europa orbiter to the Europa Clipper is in my view just the sort of outcome we would hope for as the result of decadal recommendations.

I would now like to address the possibility of a Europa lander. No mission to land on Europa was proposed to the survey committee and panels as the decadal was being conducted. It is, however, worth noting that two Europa lander concepts were briefly discussed, but not prioritized, in the 2003 decadal survey for planetary science, “New Frontiers in the Solar System: An Integrated Exploration Strategy.” Today we all know that NASA has been directed to add a lander to the overall Europa exploration program and to launch the Europa Clipper on a Space Launch System (SLS) vehicle. Mr. Chairman, I am sure you will recognize that a key concern for the decadal survey panels and steering committee was to understand the risks associated with cost and affordability, as well as risks associated with complexity and the state of technology development. There is, in addition, the programmatic challenge posed to the overall planetary science program by the development of another large, strategic mission so close in time with Mars 2020 and Europa Clipper. That said, there is also the scientific opportunity afforded by landing on Europa, the opportunity to address one of the greatest scientific questions—is there life, extant life, beyond the Earth? These are all issues that I expect CAPS will continue to consider and on which we may issue future reports as we consider our task to provide advice on the implementation of the decadal survey. I also expect the midterm review committee’s report that will be published in the Spring of 2018 will also consider these opportunities and challenges. Understanding these issues is key to pursuing another key goal of the Vision and Voyages decadal survey—maintaining a balance across the whole planetary sciences program at NASA.

As noted in the decadal, the statement of task for the survey called for the creation of a prioritized list of flight investigations for the decade 2013-2022. A prioritized list implies that the elements of the list have been judged and ordered with respect to a set of appropriate criteria.

Four criteria were used by the decadal steering committee as it made the difficult choices among a suite of very compelling science opportunities across the breadth of solar system exploration. The first and most important was science return per dollar. Science return was judged with respect to the key science themes, namely:

- Building new worlds—understanding solar system beginnings,
- Planetary habitats—searching for the requirements for life, and
- Workings of solar systems—revealing planetary processes through time.

The second criterion was programmatic balance—striving to achieve an appropriate balance among mission targets across the solar system and an appropriate mix of small (e.g., Discovery class), medium (e.g., New Frontiers class), and large (flagship) missions. The other two criteria were technological readiness and availability of trajectory opportunities within the 2013-2022-time period. Costs and technical risks were estimated via the independent Cost and Technical Evaluation (CATE) process developed by the Aerospace Corporation for the National Academies. In addition, the decadal recommendations were placed into a context of likely resources available, that is, the Planetary Science Division's budget for the decade in question. A nominal projected budget, as well as both an enhanced and a more cost-constrained budget for the decade were considered.

The decadal survey went on to recommend that NASA's suite of planetary missions for the decade 2013-2022 should consist of a balanced mix of Discovery, New Frontiers, and large missions, enabling both a steady stream of new discoveries and the capability to address larger

challenges such as sample return missions and outer planet exploration. The program recommended in the decadal was designed to achieve such a balance. To prevent the balance among mission classes from becoming skewed, the decadal noted that it is crucial that all missions, particularly the most-costly ones, be initiated with a good understanding of their probable costs. The CATE process was designed specifically to address this issue by taking a realistic approach to cost estimation—albeit of early proof-of-concept designs. It is also important that there be an appropriate balance among the many potential targets in the solar system. Achieving this balance was one of the key factors informing the recommendations for medium and large missions presented in the decadal. These considerations also led to the decadal recommending among its flagship class of missions, investigations of Uranus and Neptune—targets that represent a wholly distinct class of planet, the so-called ice giants. The ice giants are one of the great remaining unknowns in the solar system, the only class of planet that has never been explored in detail, and one tied directly to the plethora of exoplanet discoveries. The decadal recommended that the third-highest-priority flagship mission was the Uranus Orbiter and Probe mission and that, if the budget allowed, it should be initiated the exploration of the ice giants in the decade 2013-2022 even if both of what are now Mars 2020 and Europa Clipper take place.

I note here that NASA takes such recommendations seriously. An ice giant mission study, put together by a science definition team, has recently been released by NASA. Similarly, a Europa lander mission study, put together by its own science definition team, has also been released. Both of these reports are, in my view, beautiful and visionary documents which fully capture the scientific promise and excitement of NASA's exploration of the solar system. And such reports

can also be regarded as “pre-next-decadal,” in the sense that they can feed forward to the deliberations of the next planetary science decadal survey.

Regarding decadal recommendations, issues of balance across the solar system and balance among mission sizes are related. For example, it is difficult to investigate targets in the outer solar system with small or in some cases even medium-class missions. Though I note here the successful reconnaissance of the Pluto system by New Horizons and ongoing, focused studies of Jupiter by the Juno orbiter, which just flew over the Great Red Spot (pictures of which you may have seen). These two missions are part of NASA’s medium-class, New Frontiers portfolio. Nevertheless, some targets are ideally suited to small missions. The decadal’s recommendations reflect this fact and implicitly assume that Discovery missions will address important questions whose exploration does not require the capability provided by medium or large missions.

A scientifically appropriate balance of solar system exploration activities must be found by selecting the set of missions that best addresses the highest priorities among the overarching science questions associated with the three crosscutting science themes identified by the comprehensive community-consensus-building process that the decadal survey represents. As we in CAPS consider the implementation of the decadal survey’s recommendations, we will do so in accordance with this principle.

Mr. Chairman, as a second grader I watched the liftoff of John Glenn and Friendship 7 and as a teenager I watched Neil Armstrong walk on the Moon. Over these past three score years NASA’s exploration of the solar system from Mercury out to Pluto and beyond has revolutionized our

conception of ourselves and our planet. But I believe, given our ongoing discoveries and characterization of planets around other stars and the very real possibility of detecting extant life in an ocean world in the outer solar system, that we are approaching an even greater revolution in our understanding of our place in the Universe. Without doubt, NASA's planetary science program has the real and present potential of leading to a true paradigm shift in human knowledge and awareness as we continue to explore the origins of our solar system and the life it sustains.

In conclusion, I thank you for giving me the opportunity to testify today and welcome any questions you may have.