Statement of Mark V. Sykes
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Planetary Science Institute

Before the Subcommittee on Space
United States House of Representatives

June 11, 2019

Chairwoman Horn, Ranking Member Babin, and Members of the Committee, thank you for the opportunity to appear before you today. My name is Mark V. Sykes. I am CEO and Director of the non-profit corporation Planetary Science Institute, which celebrates 47 years of active participation in American solar system exploration. PSI supports more than 110 PhDs in 29 States, the District of Columbia, and a number of foreign locations. It is involved with almost every NASA solar system exploration mission. I have been a member of the planetary community for more than 35 years and have had the honor of serving as Chair of the Division for Planetary Sciences of the American Astronomical Society, chairing and serving on numerous NASA advisory groups and review panels, and serving as a founding Steering Committee member and subsequently Chair of the NASA Small Bodies Assessment Group. I am a Co-Investigator on the NASA Dawn mission to Vesta and Ceres, which formally ends with this month after 20 years since mission formulation. The views I express today are my own, and do not necessarily represent those of the Planetary Science Institute or any other organization or committee.

Summary of Comments to the Committee

The Committee has requested my testimony regarding the National Aeronautics and Space Administration's (NASA's) activities and plans for its Earth and space science programs, including the Earth Science, Planetary Science, Astrophysics, and Heliophysics divisions of the Science Mission Directorate (SMD), and associated issues. My key points to the Committee are (in no particular order):

<u>Giving the Administration Authorization to Restructure NASA</u>

- The Administration's proposed Fiscal Year budget amendment to give the Administration authority to restructure the agency as necessary in support of establishment of a US strategic presence on the Moon would pose, if implemented, a grave danger to the future of all American space science and our nation's space program in general.

Near-Earth Object Camera (NEOCam)

- The decision by the NASA Administrator to proceed with this mission is a substantial and important contribution to science, planetary defense, in situ resource utilization and finding future targets for human exploration.

- This is a singular accomplishment for the PI, Dr. Amy Mainzer, whose vision, leadership and management skills are responsible for creating a team and designing a mission that promises remarkable discoveries, the retirement of the Congressional mandate, and the necessary groundwork for expanding the future of our species into space.

- This mission builds on the successful NEOWISE mission, the PI of which is also Dr. Amy Mainzer. The deep heritage brought to NEOCam design and operations, maximizes its likelihood of success under the continuing leadership of Dr. Mainzer.

Returning Humans to the Moon by 2024

- Science provides essential support to the success of all human operations on the Moon, whether short or long-term.

- Science support should include rover reconnaissance and assaying of potential resources accessible to the South Pole station as soon as possible to lay the groundwork for sustainable surface operations beginning in 2028 or later.

- Planning for human operations should include telepresence and autonomous robotic operations for basic science, resource production experiments, facility fabrication, and other efforts.

- The plan under the Space Exploration Initiative for the development of astronomy on the Moon in concert with expanding human activity has been largely superseded over the past 30 years by the successful development of space-based observatories.

- Human operations on the Moon may significantly affect the lunar exosphere, increasing the need enhance its study in the near term while it is still relatively "pristine." The effects of human operations must be monitored and mitigation strategies developed in advance of return to the Moon.

Strengthening NASA's Planetary Research and Data Analysis Programs

- NASA should provide the data necessary to demonstrate that it has complied with the Planetary Decadal recommendation for R&A funding. This would be program element budgets at a minimum, with all assumptions and adjustments explained.

- Transparency is key. This includes program element budgets, directions and charges given to review panels, description of selection procedures (what information is conveyed from review panels to program officers, how are proposals ranked).

- Competition is essential to maximizing "bang for the buck."

- Maximizing return to the taxpaying public is undermined with hiding proposal costs from review panels and funneling research and data analysis funds uncompeted to NASA center scientists.

- Data analysis programs are no substitute for mission science teams

Giving the Administration Authorization to Restructure NASA

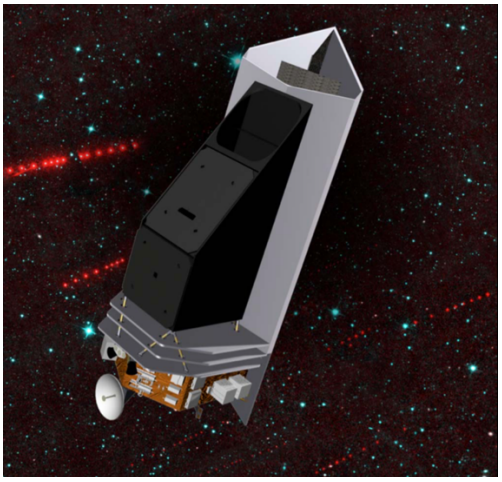
In the President's proposed Fiscal Year 2020 budget amendments, the Administration asks for the authority "to transfer funds between appropriations accounts in the event that the Administrator determines that the transfers are necessary in support of establishment of a U.S. strategic presence on the Moon. The language authorizes transfers in this fiscal year and in subsequent fiscal years, including for funds appropriated in prior Acts."

If implemented, this would pose a grave danger to the American space program altogether. It would allow for the restructuring of the agency. Space science could be radically reduced or expunged. All of this would occur without any Congressional oversight.

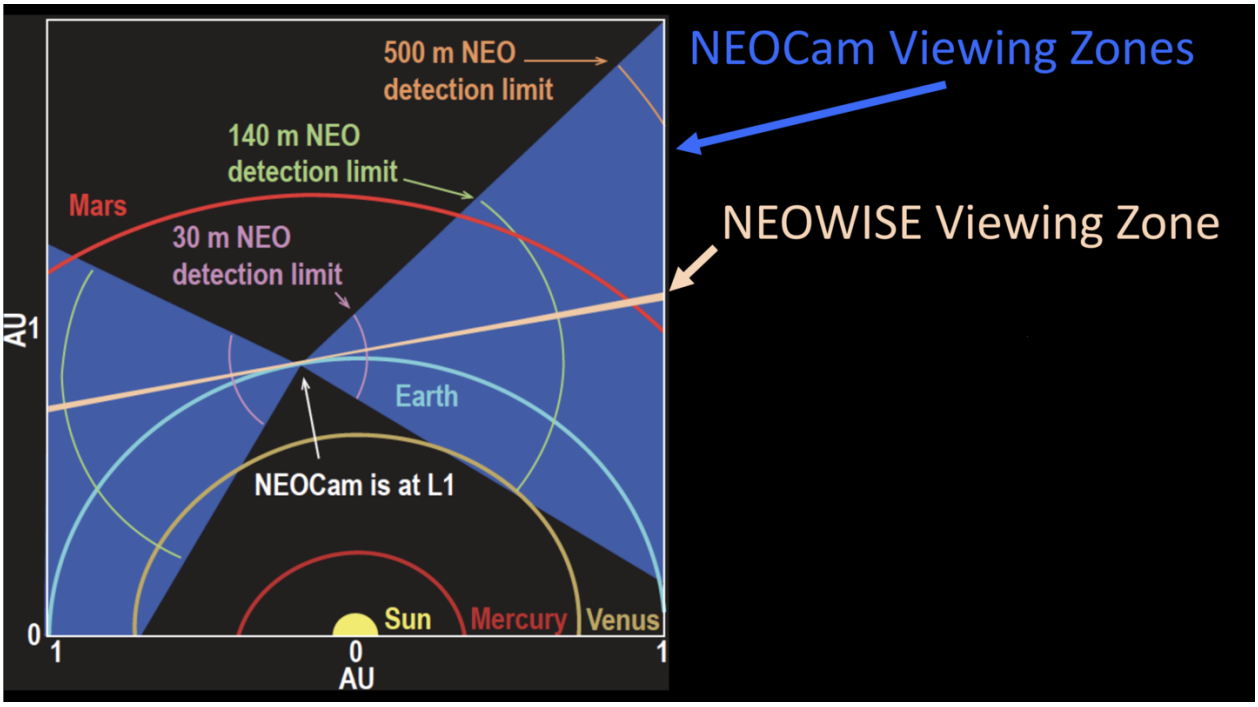
It does not matter who is the Administrator, the party in power, or the President today or tomorrow. This cannot be allowed under any circumstances.

Near-Earth Object Camera (NEOCam)

NEOCam was originally designed as an exploration mission to find, track, and characterize small bodies throughout the solar system. It was optimized for near-Earth object search and discovery, leveraging experience from the retasking of the Wide-field Infrared Survey Explorer (WISE) to search for near-Earth objects (NEOWISE). NEOCam is expected to discover ~100,000 new NEOs and millions of main belt asteroids.



It is a heavily reviewed project, first submitted to the Discovery program in 2005 and ranked Category II (recommended for acceptance, but at lower priority than Category I). It was submitted again in 2011 and received technology development funding which was applied to the development of new high-performance infrared detector material. It was submitted to the Discovery program in 2015 and awarded Phase A funding. Though not one of the two missions selected at the time for flight, it was given extended Phase A funding and refocused as a planetary defense mission.



One advantage of NEOCam over ground-based telescopes in searching for NEOs that could potentially hit the Earth is that it scans the sky interior to the orbit of the Earth as well as exterior. Ground-based telescopes only observe at night and so can only search for asteroids when they are outside the Earth's orbit. In five years it will detect 2/3 of "potentially hazardous

objects" (PHAs) greater than 140m in diameter (the Chelyabinsk bolide was ~20m in diameter before it struck the Earth's atmosphere and ultimately exploded over Russia in 2013).

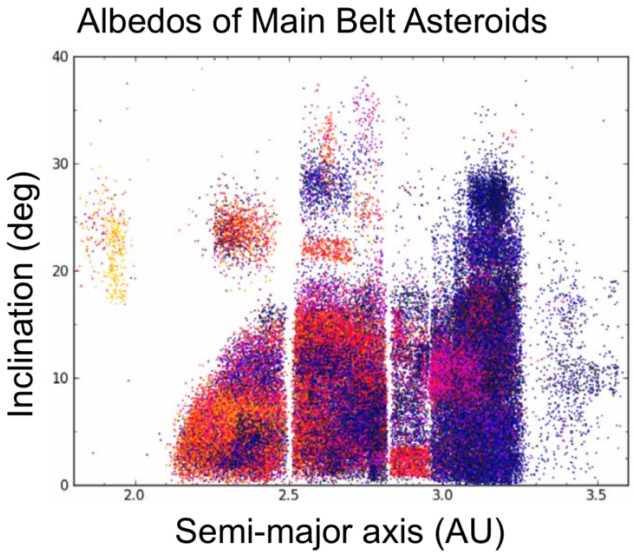
The strength of NEOCam lies in its use of thermal infrared light to search for asteroids. Asteroids are some of the brightest things in the sky at these wavelengths, greatly increasing the survey power of a modest size telescope. By looking at their emitted heat, instead of reflected light, NEOCam is able to detect the very dark objects missed by optical telescopes as well as measure the sizes for all objects detected.

As a planetary defense mission, the three goals of NEOCam will be to:

(1) identify impact hazards to the Earth posed by NEOs (both asteroids and comets) by performing a comprehensive survey of the NEO population;
(2) obtain detailed physical characterization data for individual objects that are likely to pose an impact hazard;
(3) characterize the entire population of potentially hazardous NEOs to inform potential mitigation strategies by assisting the determination of impact energies through accurate object size determination and physical properties.

NEOCam will determine asteroid sizes and albedos, which are important factors in determining the threat of a particular object. It will be able to identify sources of NEOs from the population of main belt objects and comets, which will provide insights into the likely physical properties of that fraction of the NEO population not detected by NEOCam.

A science definition team report commissioned by NASA and published in 2017 concluded that NEOCam was the most cost-effective means by which the Congressional mandate of finding asteroids hazardous to the Earth would be accomplished in combination with existing ground-based surveys.

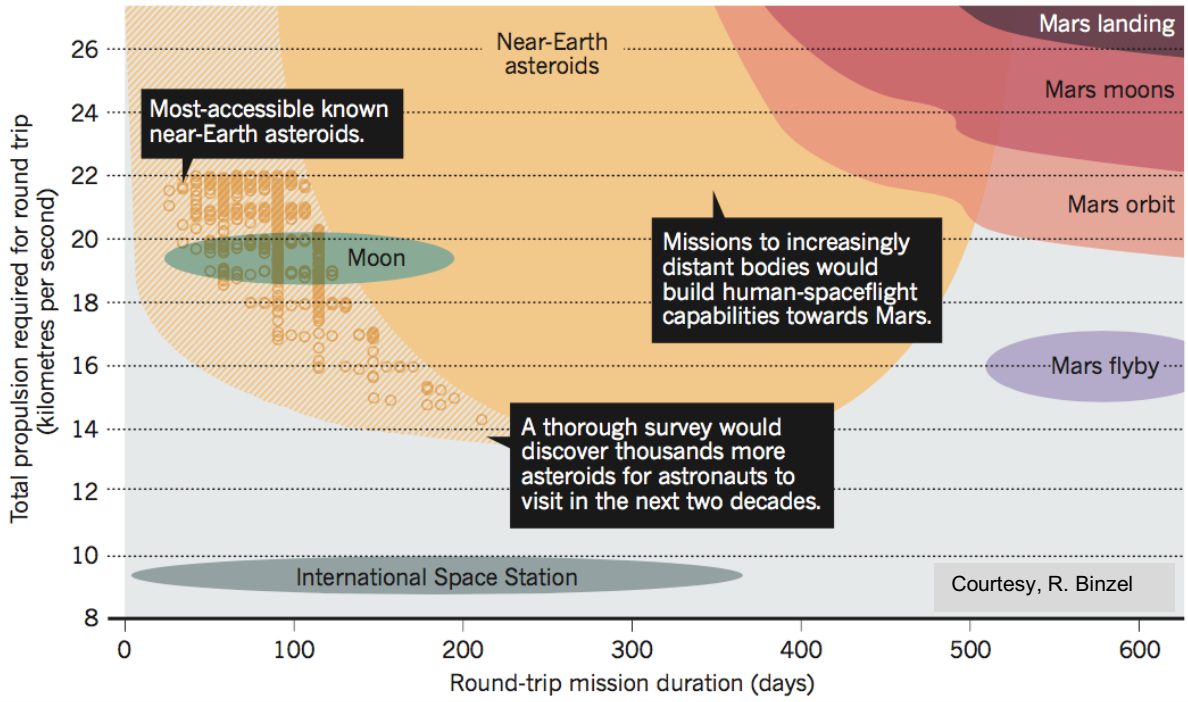


While no longer a science mission, NEOCam will still be providing a treasure trove of data that will more than double the known main belt asteroids and provide diameter and albedo information on more than 15 times the number of objects than currently.

NEOCam will provide new insights into the number, orbital distribution and physical properties of main belt objects, Jovian Trojans and comets. It will determine the origins of collisional families and NEOs. It will characterize currently rare populations of Earth Trojans and the population of asteroids interior to Earth's orbit. It will provide the most comprehensive collection of comet orbit distributions, sizes, and CO/CO_2 abundances.

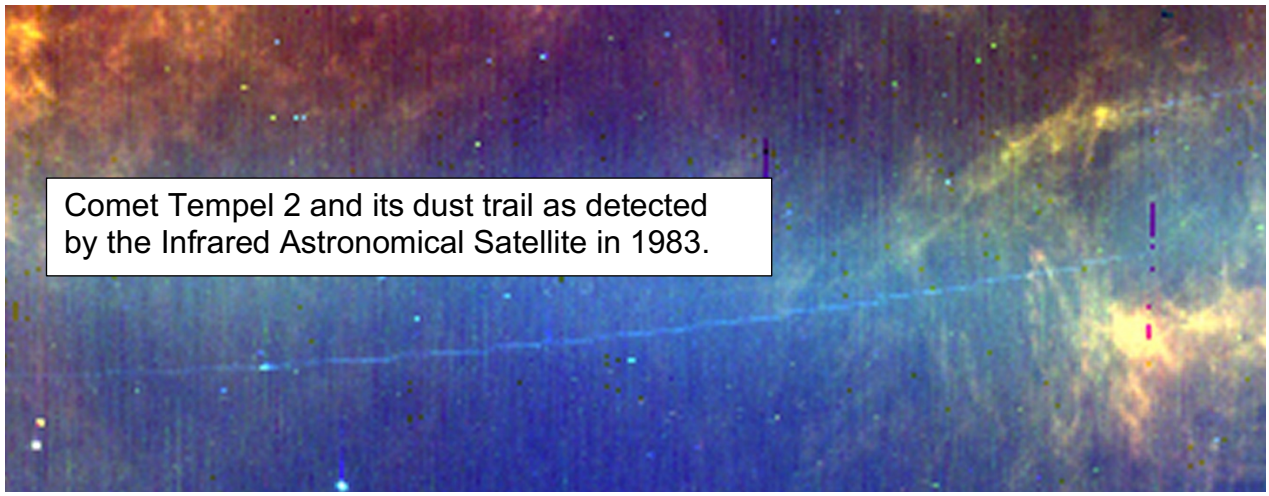
Another large benefit of the NEOCam mission is that among the large population of NEOs it will discover will be a subpopulation whose orbits are easier to get to than lunar orbit with very short round-trip mission times. This will enable:

- Inexpensive, short-duration sample return missions, allowing for collection of materials that formed throughout the solar system (the origin locations of NEOs)
- Numerous dark targets (potential water source) for resource recovery demonstration experiments
- Numerous targets for human missions, requiring less energy that needed to achieve lunar orbit for a wide range of short to long stay times

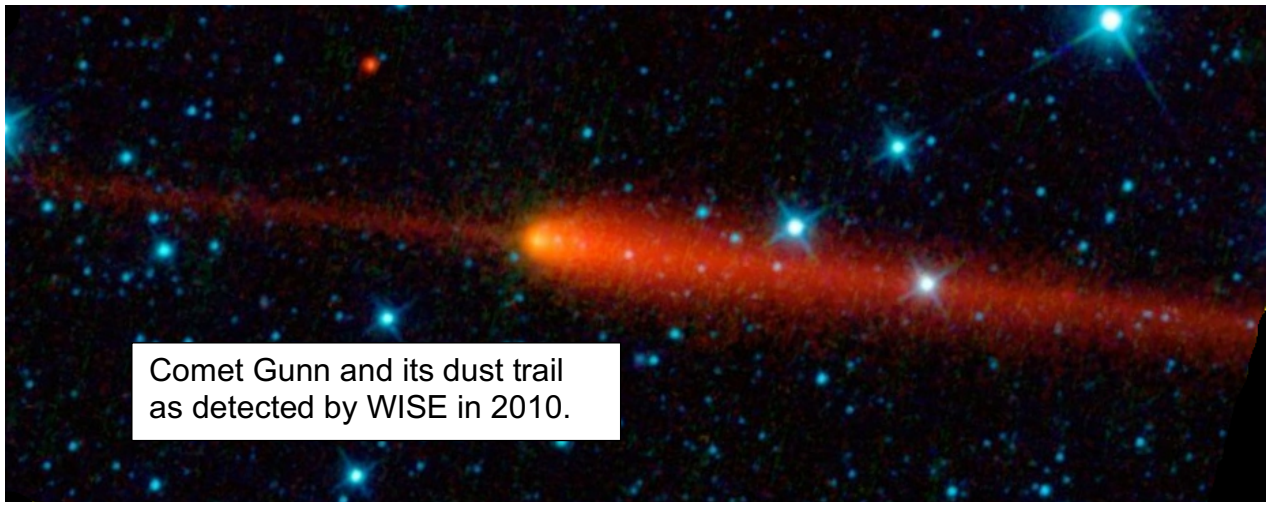


One of my non-defense interests in NEOCam is that it will detect cometary dust trails. Cometary dust trails are fundamental to understanding the composition and origin of comets, the origin of the zodiacal dust cloud, the origin of meteor streams, and the hazardous environment for spacecraft approaching comets.

No mission provides as much value to as many diverse endeavors, from science to human exploration to planetary defense, as NEOCam. It's refinement over 15 years by its PI, Dr. Amy Mainzer, is a testimony not just to their dedication and diligence, but to the steadfast quality of work they have provided so that everyone may benefit from their efforts.



Comet Tempel 2 and its dust trail as detected by the Infrared Astronomical Satellite in 1983.



Comet Gunn and its dust trail as detected by WISE in 2010.

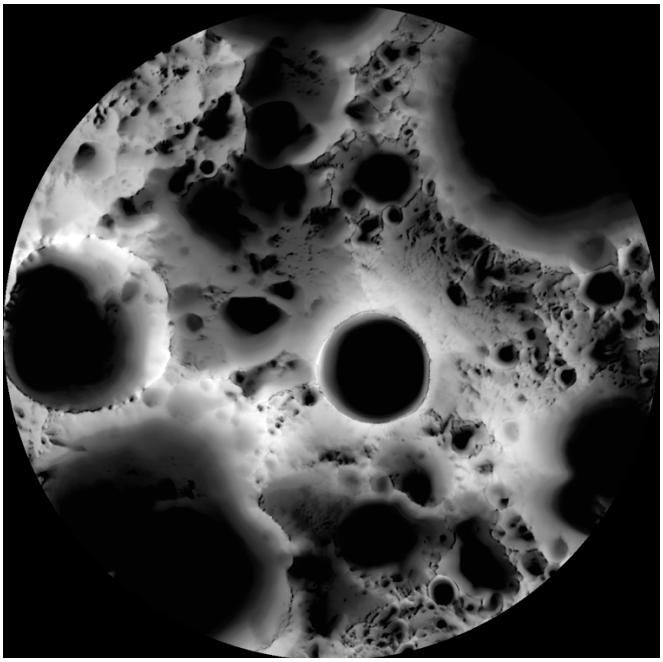
Returning Humans to the Moon by 2024

Science in Support of Human Exploration

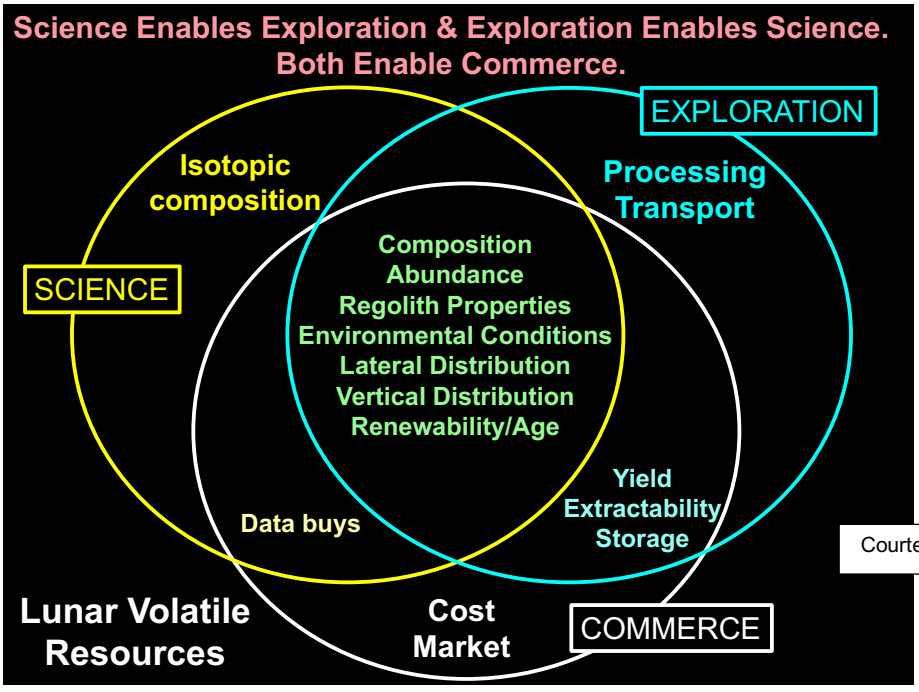
Science will provide critical support to a human return to the Moon. This applies to lunar landing site determination and getting from one point to the other on the lunar surface.

The lunar polar regions are density imaged. By merging many images of the South Pole at different times, maps of illumination are created, revealing the shadowed regions of Shackleton crater near the center and other shadowed craters along with areas that receive more light. Images can also be used to construct terrain maps that include local slopes and indicate areas of surface roughness. This is also produced by laser altimeters. The existence of potential water ice in some of these shadowed regions are determined from neutron spectrometers on orbital assets,

though at low spatial resolution. Water ice has been directly detected in such polar regions by spectroscopy of indirectly illuminated areas.



Volatiles are key to any long-term human operations on the Moon, including commercial activities if they arise. The volume of available water, how it will be extracted and processed for use on the lunar surface awaits future investigations in situ. So, an early rover or rovers will need to be deployed early on in the 2024 initiative, to lay the ground work necessary for the planned sustainable human presence, to commence in 2028.



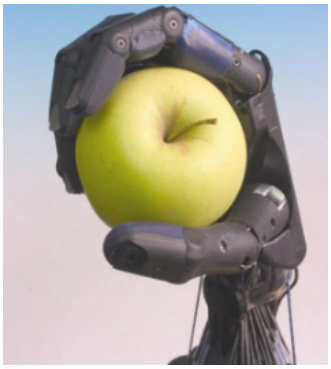
Courtesy, Clive Neal

The Advantage of Telepresence and Autonomous Robotic Exploration

Space requires the extension of human presence in an unforgiving environment of vacuum and radiation. Fifty years ago, the logical choice was to shield human bodies within a spacesuit in order to operate outside spacecraft and on the surface of the Moon. Since then, technology has allowed us to extend our presence electronically to the point of being able to immerse ourselves in a remote environment and to interact with it as though we were physically present – telepresence. This should be a core capability that we take with us as we return to the Moon.

This require human proximity to minimize latency of action and reaction, and create that sense of 'being there' (a kinesthetic limit of ~0.4 seconds). The advantage of telepresence is that you can operate in a hostile environment, interacting with a surface at spatial scales not determined by the size of your gloves, at wavelengths and over wavelengths not limited by what you can see through a visor, with a precision that is not limited by the motor control of a human body.

On earth, this technology is manifested in everyday communications (cell phones and business conferencing), in surgery, in mines, and in nuclear reactors.



On the Moon, we will be overseeing resource mining and processing, loading and unloading supply vehicles, the construction of habitats out of lunar materials. We need telepresence to accomplish all this in a practical manner, which has the additional benefit of decreasing risk to

astronauts. There will be some purposes for suited travel, but ultimately most will be through an immersive interface.

Autonomous robotic exploration is also required to explore the lunar resources to understand if they are viable for use to not only sustain humans on the lunar surface, but if they can be used to establish public-private partnerships with the commercial sector for long-term exploitation. Such a robotic campaign will potentially set the foundation for an expansion of the space economy.

Together, telepresence and autonomous robotic exploration will allow us to explore and operate in more challenging environments that was done during Apollo.

Astronomy from the Moon?

During the Space Exploration Initiative under President George H. W. Bush, in 1990, it was thought that astronomical observatories on the Moon offered the benefits of enormous scientific return and large community interaction. We envisioned the long-term goal of lunar based astronomy as the development of a diverse facility covering at all wavelengths of the electromagnetic spectrum.

Today, the dramatic improvement in capabilities for free-space observatories make the Moon a less compelling focus for investment in astronomical development.

One possible benefit to astronomy of having a human presence on the Moon, and hence in near-Moon space, would be to have the capability of maintaining large astronomical facilities at Earth-Sun L2.

Human Operations Impact on Science

During Apollo 12, the gas cloud surrounding an astronaut moving by was sufficient to saturate the Apollo 12 atmosphere experiment, indicating a rise in atmospheric density by at least two orders of magnitude. Gases can lurk for a long time as regolith night-time condensates to be released again at daytime temperatures. After Apollo 14 left, continuous monitoring showed that it requires years for local atmospheric pressure to return to normal.

Measurements of the lunar exosphere provide insights into the sources of hydrogen and water in the lunar soil and how water migrates to the shadowed polar regions. It also provides insights into the lunar interior and seismic activity. If evidence for a water source beneath the surface was found, that would have a large impact on the potential locations for human activity.

Substantial human operations at the South Pole, particularly once resource reclamation activities commence in earnest, could have a significant impact on the lunar exosphere. Perhaps dominate it, effectively ending its scientific study. This motivates several things:

- Prioritize lunar exosphere studies in the near term, before a return to the Moon
- Monitor the effect of human activity on the lunar environment

- Develop mitigation strategies to mitigate the contamination of the lunar environment, before a return to the Moon

Strengthening NASA's Planetary Research and Data Analysis Programs

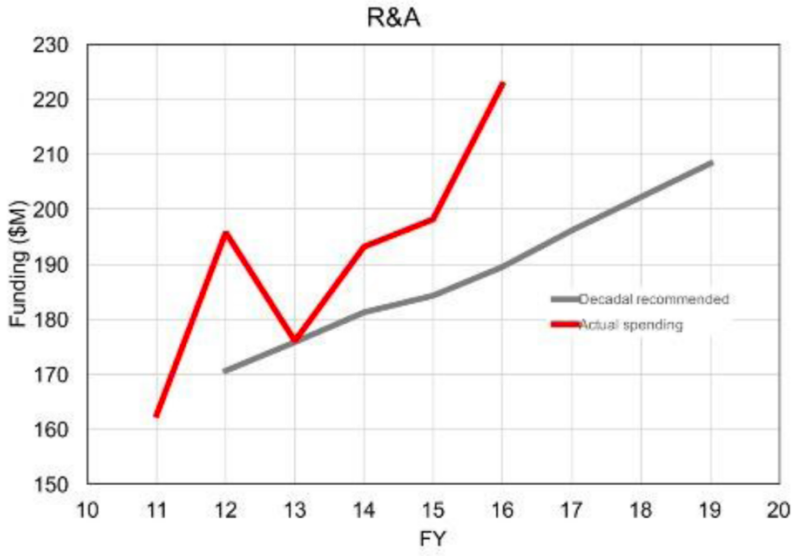
The importance of NASA's planetary research and data analysis programs was reflected in the following recommendation from the most recent planetary decadal survey:

"…**the committee recommends that NASA increase the research and analysis budget for planetary science by 5 percent above the total finally approved FY2011 expenditures in the first year of the coming decade, and increase the budget by 1.5 percent above the inflation level for each successive year of the decade." (p54)**

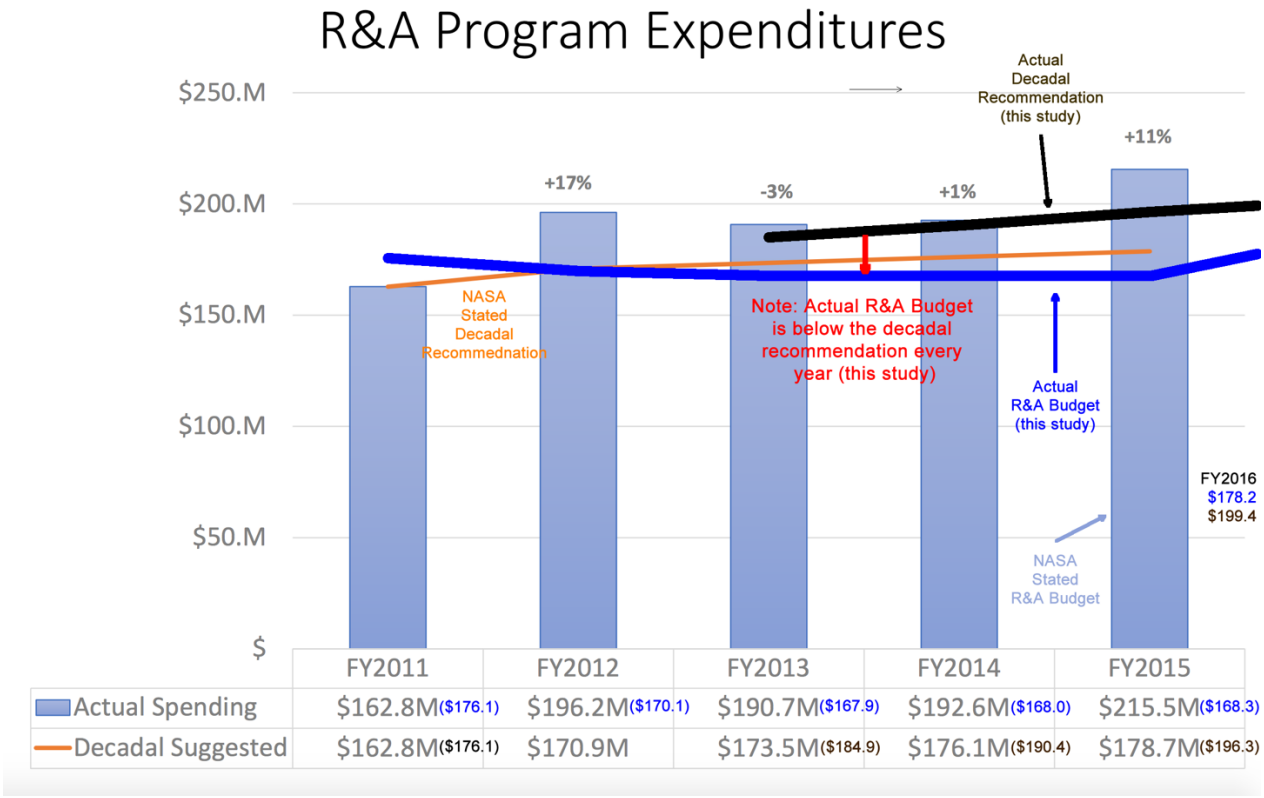
"It is also possible that the budget picture could be less favorable than the committee has assumed. **If cuts to the program are necessary, the first approach should be descoping or delaying Flagship missions. Changes to the New Frontiers or Discovery programs should be considered only if adjustments to Flagship missions cannot solve the problem. And high priority should be placed on preserving funding for research and analysis programs and for technology development.**" (bold in original text)

Did NASA Comply with the Planetary Decadal Recommendation for R&A Funding?

A review of the compliance with the decadal survey recommendations was conducted by the Space Studies Board, and released in the report, "Visions into Voyages for Planetary Science in the Decade 2013-2022: A Midterm Review (2018)." The conclusion was that NASA had significantly exceeded the decadal recommendation as shown in the chart below.



In sharp contrast to the detailed support provided to demonstrate that budget for technology programs had met the decadal recommendation, there is no granularity in the support for R&A above. This was actually the third attempt by NASA to demonstrate compliance with the R&A recommendation. The first effort submitted to the panel was challenged by myself. Using budget data provided by NASA, some through Freedom of Information Act requests, I determined that NASA had underfunded the research programs by more than $90M net (below). All the data I used and assumptions I made were published on http://planetarypolicy.org. I distribute this information to members of the Midterm Review committee and they requested additional information from NASA.



In the second attempt, NASA added various lines from the federal budget, some not reproduced correctly. I pointed out the errors to the committee and they requested yet more detail from NASA. The various efforts by NASA to provide budget numbers for research and analysis programs are summarized in the table below:

NASA PSD "R&A" FUNDING REPORTED ($M)

	2011	2012	2013	2014	2015	2016
MAY 2017	162.8	196.2	190.7	192.6	215.5	
NOV 2017	245	245	256	275	281	308
FINAL	162.5	195.7	176.1	193.2	198.1	222.6
SYKES	176.1	170.1	167.9	168.0	168.3	178.2

These are substantial variations, and in the absence of any supporting detail, at least at the program element level (as is provided for technology programs), none of NASA's numbers are reproduceable.

NASA has not been forthright in addressing the question of compliance with the Planetary Decadal recommendation for R&A funding.

Management Questions Regarding R&A Programs

The management of the planetary research and data analysis programs raises many questions. The "reorganization" of these programs in 2014, merging many disparate elements (e.g., Mars Fundamental Research, Outer Planets Research, Planetary Atmospheres) into one program (Solar System Workings) has been completely unwieldy. The review process has been questioned at public meetings (where a NASA official reported recently that the success rate of getting reviewers was 20%, suggesting few proposals are being reviewed by subject matter experts). Requests for public disclosure of directions given to reviewers and details of the selection process have gone unanswered. Budget information for individual program elements, which for a time was distributed at these meetings, but is now no longer distributed.

In "R&A Lunches" at the last two Lunar and Planetary Science Conferences, NASA officials raised concerns in the planetary community by reporting (in conflicting ways) that research funds were being funneled, uncompeted, to NASA center scientists. The details of this program including its costs and impact on resources for competed research programs need to be investigated in detail and made public.

Competition is Key and is Being Undermined

Every day discoveries are being made not just by spacecraft, but by work funded by NASA research and data analysis programs. These programs lay the foundation and justifications for future missions and realize the ongoing benefit in knowledge gained from our missions sometimes decades after the data was taken.

I believe that at the core of the success of these programs is competition. Scientists compete for grants and contracts. They compete for missions (setting aside the directed large flagship missions). It is not for the faint of heart. I would argue that through this competition, the people of this country get the most "bang for their buck."

This is undermined when NASA (I believe alone among federal agencies) hides cost information from proposal review panels, and directs them not to take cost into consideration in their assessments. For the great part of my career, proposal cost (and even details) were known and factored into the assessment of a proposal. This information is important particularly when expensive proposals may not allow the funding of several lower ranked proposals – only the subject matter experts of a review panel could provide good input on the relative scientific value of several proposals in the aggregate to one expensive proposal (I was on a panel once in which our top ranked proposal was requesting all of the funds available for new awards that year and

we provided such an analysis to the program officer who used it to manage the situation successfully). Likewise, it is the review panel that is best positioned to determine whether the exceptionally low cost of a lower-ranked proposal would make it impactful.

Hiding cost reduces science return on the public investment in our research.

Data Analysis Programs are Burdened When Mission Science Teams are Underfunded

NASA missions are more complex, trying to answer more complex problems, but science teams are shrinking, as are their funding levels (see below). This pushes more mission scientists to seek more of their support from research and analysis programs, and raises the question of mission preparedness on the science side. This issue needs further study.