SCIENCE AND EXPLORATION SYNERGIES - 2050. C. R. Neal[1], 1Dept. Civil & Env. Eng. & Earth Sciences, University of Notre Dame, Notre Dame, IN 46556, USA (neal.1@nd.edu).

Introduction: The structure of NASA separates planetary science from exploration, with planetary science being located in the Planetary Science Division (PSD) of the Science Mission Directorate (SMD), and planetary exploration in the Human Exploration and Operations Mission Directorate (HEOMD). However, some current and missions in formulation are starting to blur this separation. This presentation examines the possibilities for better integration of science and exploration between now and 2050 to maximize the return from planetary missions. As the Lunar Reconnaissance Orbiter Camera (LROC) motto states, which was the mantra of the late Mike Wargo, “Scientia facultas Explorationsis, Exploratio facultas Scientiae” or in poorly translated English vernacular “Science facilitates Exploration, Exploration facilitates Science”.

Current Synergies: Science and exploration synergies are being pursued by the LRO and Mars 2020 missions. The LRO mission was born out of the Vision for Space Exploration during the Bush administration [1]. It was part of the then Exploration Systems Mission Directorate and was formulated to yield information to reduce risk for future human landings on the Moon [2]. The objectives/requirements definition team meeting for this mission represented the creation of the Lunar Exploration Analysis Group (LEAG) in 2004 at the LPI [3]. After launch on 18 June 2009 and 2 years of operation, this directed exploration mission transitioned to SMD-PSD and became a science mission. LRO has been and continues to be a highly successful mission and it is now in its third extended science mission that is producing excellent science (and exploration) data that informs us not only about the Moon, but processes relevant to other planetary bodies in the Solar System. The LRO mission is considered to be the archetypal example of exploration and science cooperation that NASA has flown to date.

Another example of science and exploration synergy is the Mars 2020 PSD science mission [4]. Here, two instruments are funded through HEOMD – the Mars OXygen ISRU Experiment (MOXIE) and the Mars Environmental Dynamics Analyzer (MEDA). Gathering information to facilitate human exploration of the current horizon destination, Mars, is a step along the path towards one day sending humans to the red planet. As with LRO, this mission will yield data that will inform both science and exploration.

Missed Opportunities? The two examples above are a great start to forging better synergies between science and exploration. However, there are a number of recent missed opportunities that highlight the need for better communication and integration between the two mission directorates. The first is the Korea Pathfinder Lunar Orbiter (KPLO), which is scheduled to launch in December 2018 [5]. The Advanced Exploration Systems (AES) division of HEOMD has facilitated NASA involvement in this mission [6], and proposals have been submitted from US investigators to place instruments on this orbiter. However, there is currently no official NASA science involvement in KPLO, although a participating scientist program has been promised.

With current US Space Policy focused on an asteroid as a near-term human exploration target, it is good to see SMD-PSD involvement in the Japanese Hayabusa-2 mission [7]. The recently launched New Frontiers-3 selection, OSIRIS-REx sample return science mission to the asteroid Bennu is replete with significant scientific objectives and will return ≥60g of sample [8]. However, it is unclear if the exploration potential of either the Hayabusa-2 or OSIRIS-REx asteroid sample return missions have been explored by HEOMD from either an ISRU and/or risk-reduction perspective.

Developing Future Synergies: There are definite overlaps between planetary science and human space exploration for certain Solar System destinations, namely asteroids, the Moon, and Mars. There is now an opportunity for long-range planning so that science and exploration goals can be combined to produce more capable and effective missions (either competed or directed) than would be achieved by SMD-PSD or HEOMD alone. By blurring the lines between different mission directorates, any “turf war” could be defused, cooperation enhanced, and the NASA budget would be more effectively used. One option could be for a portion of the budget to be dedicated for science and exploration purposes. Such a budget could be used to facilitate competed missions that would advance human exploration and planetary science. This budget would be administered by PSD and HEOMD personnel that are intimately involved in understanding the specific destination targets. Another avenue to facilitate inter-mission-directorate cooperation is to elevate all human destination targets to program status, similar to the current Mars Exploration Program that currently resides in PSD. The asteroid, lunar, and martian science and exploration programs would be jointly administered by SMD-PSD and HEOMD. Obviously these administrative changes would require a Planetary Science and Exploration budget, but the result would be increased science return as well as increased impetus toward human space exploration beyond LEO.
Example of Science and Exploration Synergy: Lunar surface volatiles represent a highly important science and exploration target. This example presented is one that I am familiar with, given my background, but there are other examples for asteroids and Mars. The presence of volatile deposits at the lunar poles has been unequivocally demonstrated by the LRO-CROSS mission [9]. Volatiles are also present within the Moon, as shown by sample analyses of pyroclastic deposits (e.g., [10]) and also from orbital data (e.g., [11]). These deposits have implications for the delivery of volatiles to the terrestrial planets, lunar formation, and those at the poles may contain the building blocks of life. These aspects address several major questions in the NASA’s current science plan [12]. The current decadal survey for SMD-PSD [13] indicates that lunar volatiles are an important science target to be addressed by future missions. The surface volatiles also represent potential resources that would enable human exploration through production of life support consumables as well as rocket fuel for either return journeys back to Earth or to enable deep space exploration. HEOMD actually has a mission in formulation to explore a polar region for volatiles with a rover [14]. The Resource Prospector Mission (RPM) will address several lunar Strategic Knowledge Gaps [15] in terms of polar volatiles. The problem is that RPM has minimal, although critical, cabability and the mission duration is only several days. If there was a campaign to explore lunar volatiles through a Lunar Science and Exploration Program, it is probable that more capable rovers would be available. Given the international missions to the Moon this century (China = 3, including one lander; India = 1; European Space Agency = 1; Japan = 1), international cooperation/collaboration with such a campaign is certainly an option. Russia has already unveiled a lunar polar campaign [16] through a series of missions that will be conducted in collaboration with the European Space Agency. SMD-PSD has initiated discussions on how US scientists can be involved with such missions. Given the resource-oriented nature of these polar missions, it would be advantageous for HEOMD to also be at the table for such discussions.

Vision 2050: Science and exploration synergies have the potential to advance us into the Solar System, through expansion of knowledge and literally by sending humans well beyond LEO. By having science and exploration work together, advances will be made much faster than at present. We are seeing the beginnings of such cooperation but it could be much more effective. This requires a modest rethinking of how missions to certain destinations are funded and operated. The synergies between science and exploration could be developed and enhanced by creating joint programs specific to targets of mutual interest – asteroids, the Moon, and Mars, as I noted above. However, by 2050 these initial programs could be brought together under a Science and Exploration Division or even a Mission Directorate. This entity would focus on long-term planning for integrating science with expanding the human race beyond the LEO and potentially beyond Mars. And let’s not forget about the currently burgeoning space commerce sector. Involving this sector in the initial robotic precursor Science and Exploration missions could result in more significant public-private partnerships being developed in the future. This would be facilitated by the new division/mission directorate focused on science and exploration synergies. Once humans visit an asteroid or land on the Moon and Mars, they will be conducting scientific investigations as they explore these new worlds – just as the Apollo astronauts did all those decades ago. The necessary robotic precursor missions can do the same - Scientia facultas Exploratio, Exploratio facultae Scientiae.

Summary: Better communication and collaboration between science and exploration will be mutually beneficial for planetary science and human exploration. Forging this relationship has begun, but this appears to be on a mission-by-mission basis. Long-range planning that involves SMD-PSD and HEOMD strategic partnerships have the potential to achieve so much more than they could alone. Illustrations of such partnerships are presented here, but how they are implemented is up for discussion.