Reflections on Human Space Flight and Science Productivity for the Review of Human Space Flight Committee

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I want to provide the Review of Human Space Flight Committee with some reflections on the potential for the Constellation architecture, and also more generally on any new human spaceflight architecture, for science in addition to that which would be done on the lunar surface. Many of these thoughts have already been sent in to Chris Chyba, but I wanted to formally enter them here as well. These reflections relate to the prospect of human and perhaps robotic servicing of science missions, and the importance that human space flight planning carefully consider the value of such efforts for the many avenues of space science that are not based on the lunar surface. NASA has not made a credible attempt to evaluate such opportunities, a neglect that does disservice to the U.S. human space flight enterprise. It is important to understand that such efforts can benefit not only science, but can advance our technological competitiveness and national pride in ways that human space flight is often counted on to do without attached science.

As an astronomer, I've been thinking about this for a number of years, ever since I authored a paper (with co-authors John Mather and Hal Yorke) that revisited the old presumption that the lunar surface is a great place for astronomical telescopes. This paper, available in the journal Space Policy and at arXiv:astro-ph/0401274 concluded that, in general, it is not. Free space is, for many reasons, a far better venue for astronomical discovery than the lunar surface. I testified on this topic at the 2004 House Space and Aeronautics Subcommittee hearing "Lunar Science & Resources: Future Options". I also served on the 2007 NRC panel "The Scientific Context for Exploration of the Moon" as more or less a token astronomer, trying to keep that effort clearly focused about what astronomy was truly enabled by the lunar surface and what was not. Most recently, I've been working with Harley Thronson and his informal NASA GSFC Future In-Space Operations working group (FISOWG) to assess the opportunities that human space flight in the VSE generation might bring to astronomy. We've done some work with Northrop-Grumman, Boeing, Ball, and Lockheed Martin on developing concepts for in-space operations that would benefit astronomical research. These industry partners are intrigued and excited about the potential here. Much of the FISOWG work has been posted at http://www.futureinspaceoperations.com .

Human space flight has demonstrated its capability to enable astronomical discovery, as exemplified by HST in the servicing effort for that observatory. As major astronomical observatories can be forseen with $5B+ budgets, the idea of offering unique reuse and restorative capabilities to those observatories with servicing becomes noteworthy, if not necessarily required. The trajectory of technology development for astronomical focal plane hardware is extremely steep, and opportunities to retrofit these observatories with cutting-edge equipment is enormously enabling. Even for system maintenance — replacing malfunctioning subsystems, retanking of cryogen and propellants, etc., such valuable observatories can be thought of as

having many lives. We think this way routinely about our ground-based observatories. Why not those in space?

In addition, we have to understand that the size of launchers sets stringent limits on the size of future space telescopes. With present launchers, the James Webb Space Telescope (JWST) is pretty much the biggest telescope we're ever going to be able to loft. Ares V heavy lift should allow us to do much better, but a bigger launcher doesn't provide us with a scalable design that gets us even larger telescopes. In-space construction does. Assembling large telescopes from pieces launched separately allows us to dream in a credible way about much larger telescopes. ISS has provided us with a wealth of experience and understanding about building large structures in space. So both ISS and HST provide us with human space flight lessons that could really help guide the future of space astronomy.

It is certainly the case that teleoperated robotic agents could, in principle, do much of this work. I prefer not to distinguish between such robots and astronauts without a more serious capability analysis, which has yet to be done, although requested of NASA for some years. Except for the aborted development of a robotic system for servicing HST, there has been little or no investment in future capabilities in this area. Since HST is a facility that was never designed for robotic servicing, even this brief development program was of limited value in thinking more broadly about the future. But we do know that capabilities offered by such virtual presence are increasing dramatically, with a steep slope dictated by Moore's law. Robots and telepresence are getting better fast! While such teleoperation might be done from the Earth, it might well also be done by astronauts on site (offering minimal latency) who don't need to be doing what can be considered to be risky extra-vehicular activity.

Servicing, maintenance, and construction/deployment of the largest free-space telescopes are capabilities that have huge ramifications for science productivity. It is thus surprising and disappointing that NASA has given these ideas rather little attention. As we understand, this is for two reasons. First of all, ESMD and the Constellation project office see such efforts as a distraction from what they believe to be their sole fundamental goal, which at least for now is to carry people to the ISS and, eventually, return of humans to the lunar surface. They listen to our ideas, and they answer our questions, but they have shown next to no interest in developing these ideas. Secondly, SMD is, perhaps justifiably, extremely hesitant about coupling its efforts to human space flight, in large part because the costs are unknown and likely to be substantial. While transportation of humans and equipment for HST servicing was paid for by SOMD, our astronomy community has been told by NASA HQ in no uncertain terms that, henceforth, we'll pay for what we use, whether that be sending astronauts to visit telescopes, or developing the robots that could to the job.

It has occurred to us that maybe it is time to reconsider both of these reasons. To the extent that our nation doesn't have to meet a largely arbitrary deadline for lunar return, which has been driving ESMD, the potential for "distraction" claimed by the Constellation office might not be as serious as it was made out to us. To the extent that a national goal for human space flight is to prove national technological strength, which is manifested in national pride and has been termed "soft power", servicing, maintenance, and construction of large space telescopes could be seen (much as for HST servicing) as challenges that could serve those goals as they also serve

science. In that respect, the full cost of astronaut-based servicing of space telescopes should not necessarily be billed entirely to astronomy, but rather shared across multiple NASA space directorates. The way it is now, SMD is reluctant to commit to human space flight because of the cost, and ESMD is reluctant to commit to science because it is felt that science efforts are some kind of lesser exploration.

Maybe the cost-sharing arrangement for HST was correct after all, and drawing a budgetary line that separates human exploration and science is artificial and naïve.

For astronomy, most of our future missions would operate at the second Earth-Sun Lagrange point. That location has huge advantages over LEO in terms of power availability, line-of-sight communications, minimal debris threat, and easy thermal management. At about four lunar distances, this operations site is perhaps only barely convenient to a cis-lunar human transportation architecture, and with a two-way latency of 10 seconds, is not particularly convenient for telepresence from the Earth. But it is now understood that Earth-Sun Lagrange points are connected to the much more accessible Earth-Moon Lagrange points by dynamical pathways that are incredibly economical in propulsion. An Earth-Moon Lagrange point can be used as a servicing/maintenance/construction "job site" that is connected to the Earth-Sun Lagrange point "ops site" by a few months of transit time and a few tens-of meters/sec delta-V. That job site is not optimal for observatory operations, but as a job site it is nearly ideal, offering nearly continuous solar power, and relatively manageable latency, as well as a few-day return time to Earth or, in the case of a serious emergency (such as a solar flare event) a half-day down to the lunar surface, where shielding could be available. The Earth-Moon Lagrange points are, for a lunar-capable space transportation architecture, supremely accessible.

This concept, of an Earth-Moon Lagrange point job site that would benefit science as well as exploration of more distant locations such as Mars, was developed in some detail in the Decadal Planning Team (DPT) efforts early in this decade. I understand the records of the DPT have been supplied to the Review committee.

I'd like to see NASA take a hard look at the opportunities that future human space flight could offer science that would be done in free space. To the extent that a new transportation architecture is now being developed for human space flight, the opportunities that architecture might offer science need to be evaluated, where that science return should not be narrowly limited to just what can be done on the lunar surface. The recent "Launching Science" report from the NRC addresses many of these opportunities, but largely sidesteps human space flight. The recent appropriation of $20M for NASA to investigate servicing opportunity will be useful, but is a one-year funded earmark, and not a part of the proposed agency plan. Your committee is charged with helping the nation chart the future for human space flight, so it seems that such considerations are most relevant to your task. Human space flight should not be limited to just the Moon, and it is naive to presume that if it isn't about the Moon (or perhaps NEOs), then it can only be about Mars, which clearly has to be a distant goal. In fact, "Moon, Mars, and beyond" neglects precisely these locations in cis-lunar space that are so scientifically exciting, and that transcend the lunar surface. The opportunities there are not about rocks and dust, but about free space. The astronauts that go there may not leave footprints, and they may not leave flags planted in dust but they will do great things, and brand new things, that the nation can take deep pride in.

That's what exploration is about. We saw that on HST servicing missions, as well as for each expedition to ISS that has built new capability into that facility.

Please let me know if I can be of any help to you in these matters. With regard to servicing of astronomical missions with Constellation, our FISO group has a network of people who have collectively given the matter some serious thought.

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