"Human Space Flight – In a Whole New Context for a Whole New World"

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Abstract

The paper touches on the past, present, and future of human and robotic space flight. The main thesis is that a new animating framework is needed based upon strategic engagement and that spans across national and international sectors. Three overarching goals and objectives for space activity within this framework are put forward and explored. "Off the Earth-For the Earth," the motto of the ISS Expedition 34 crew, is proposed as a fitting name for this framework. Within this larger, overarching context, capabilities and investments that address large societal challenges and create unlimited opportunities can be sustained and maximized.

I. Overview

Humans, satellites as our eyes and ears in space, and our robotic appendages have not only travelled near and far into the Heavens– we have made the immediate regions beyond Earth's shores interwoven into our lives. We no longer just visit outer space – we are living and working there every day on the International Space Station (ISS). We rely on space systems to conduct our lives.

With the ISS, permanent human presence in space marks a first in human history. We have literally left our Earth-bound cradle. Our robotic presence and knowledge is expanding at a revolutionary pace, beckoning outwards. New rockets, spacecraft and technologies are being fielded, including new commercial capabilities. A rich global array of satellite, robotic, and human activity continues to emerge and grow throughout all regions of space between the Earth, its Moon, and their orbits.

The regions around the Moon are increasingly used for gravity assist operations of commercial and international satellites, or the placement of scientific spacecraft. We will bring an asteroid to orbit here for our scientific and exploration research. Longer-term use of these strategic areas for deployment, repair, stationing of spacecraft and other assets is rich. The Earth-Moon Lagrangian points are of increasing interest. These strategic rivers of the solar system provide locations for the viewing of the Moon's surface, including its far side, low energy access to its surface and to the other Lagrangian regions, which have great value for the study of the solar system and the Sun. Lastly, these regions provide the equivalent of sea-lanes for the exploration of the solar system, staging grounds for human and robotic missions to the planets and the retrieval of materials and resources.

In the past few years, the Moon itself has gone from a seemingly dry, rocky desert to a wet body teaming with resources. Our black and white images are coming alive in vibrant reflected colors from elements and minerals. Combined with a revolution occurring in advanced digital fabrication, a vast array of future opportunities are emerging for using space resources to fashion a host of products. The implications of this combination, like humanity's first creation and harnessing of fire, are profound.[2]

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[2] Neil Gershenfeld, "How to Make Almost Anything: The Digital Fabrication Revolution," Foreign Affairs, November/December 2012.

Our understanding of the nature and history of Mars, with its implications to our planet and our ability to potentially live on the Martian surface and other bodies, is also increasing. Last summer, we dropped a rover on Mars via a sky crane with a heat shield gathering necessary entry data needed for a larger Mars human lander, and a radiation monitor to investigate the Mars radiation environment for humans. The palpable global excitement in the landing of Curiosity rover and its day to day activity is evidence of a growing awareness, appreciation and kinship with our broader planetary neighborhood.

Going even further out, our awareness of planetary systems of other nearby stars over the last 10 years continues to exponentially grow, stoking interest in possible habitable planets and bodies around other stars that may hold advanced life. We now estimate that our Milky Way galaxy alone holds on the order of 100 billion planets.[3] We are beginning to understand the deepest parts of our universe, glimpsing to the edge of its birth and therefore our own.[4]

Yet, today, a paradox exists. Despite the increased relevance and scope of space activity, the norm is to take space activities for granted and, as a result, allow national support to come into question. In Washington, D.C., discussions over differences in priorities and potential destinations rather than a fostering of synergies or identifying areas of mutual interest, consume much of the debate on the future of America's space program. There is no shortage of plans on what to do, and where to go. There is no shortage of passionate feelings about how to do it. These overall feelings affect our views on the role of NASA, the level of funding needed, and the required scope of activity. In the absence of a unifying framework that relates to the larger world that America's human and robotic space program are a part of, debates stay narrow, discussion focused on specific hardware elements or the means to narrow ends. How did we get to this point?

II. **Then to Now to Next**

Forty-four years ago as Neil, Buzz and Mike hurtled towards the Moon; their craft was fueled by a Cold War that divided the world into black and white. The 3.5 billion people on the planet were focused largely on issues of a local and national scope – although the global challenges we now face were emerging. In outer space itself, there was little evidence of human activity. Our knowledge of our celestial neighborhood, the greater heavens beyond, and our inexorable connection to them was just awakening.

Neil saw into the future of our planet as he watched out of the window of the Apollo capsule. On his return to Earth, he stated, "It's a peculiar sensation to watch the Earth sink away and become smaller and smaller. The geographic features fade leaving only the continental forms as you depart farther from earth. No national boundaries can be seen, and as the globe becomes smaller and smaller you remember another statistic. It holds three and a half billion people, and of that three and a half billion one half are hungry and two thirds live in poverty. You shudder to think that this problem will be much worse during the remainder of our lifetime, and at the end of the century, the population of Earth will be six or seven billion…To solve the problem of feeding this population and protecting this planet for the use of that population is going to take an international approach far beyond any cooperative effort ever seen in history. I suppose we have to ask ourselves whether international cooperation on this scale is even possible?"[5]

Today, the challenges Neil saw have come to pass – and then some. In parallel, the opportunities presented by science and technology to deal with these challenges have grown exponentially. To effectively deal with today's challenges and stimulate tomorrow's economic and human growth, relationships and engagement as Neil foresaw remain key requirements. Spaceflight is a part of this unfolding human story. U.S. space efforts exist in an

[3] The July 2013 issue of *Scientific American* includes a "map" of the known exo-planets that are helping scientists to derive their overall estimates on the number of planets in our universe.
http://www.scientificamerican.com/article.cfm?id=exoplanets-cosmic-map-extraterrestrial-life#

[4] In March of this year, the European Space Agency's Planck telescope released images showing the universe at roughly 400,000 years after the Big Bang. "Planck Mission Brings Universe into Sharp Focus," NASA Press Release 13-079, 20 March 2013.

[5] Neil Armstrong, "Commencement Address," Miami University. June 4, 1970, as quoted in a homily by the Rev. Mariann Budde, Memorial Service for Neil Armstrong, National Cathedral, Washington, D.C., 13 September, 2012.

environment very different from the competitive geo-political cauldron from which they emerged. While it is generally recognized that space has become "complex, congested, and contested" - how to deal with these characteristics and their relationship or lack thereof to human space flight - has led to a rich divergence of views and a vibrant debate that reflects the growth of actors and interests in space.

An overarching framework and objectives is needed based upon humans and robots working together to unleash a great wave of growth and discovery. To enable this potential, a framework based on strategic engagement is needed that encompasses the United States Government, commercial, and international sectors, focuses on near-term "wins," and overall addresses three objectives. These objectives are to:

1) Create efforts for humanity's well-being and long-term survival with an audacity, vibrancy and a focus on the collective goodwill.

2) Increase our emerging space capabilities to express national power, while expanding and enabling alignment across government sectors and the geostrategic interests of the United States.

3) Open space to private citizens and companies—accelerating job creation and wealth generation thereby enhancing the intrinsic human desire for freedom and expansion.

III. Off the Earth for the Earth

The ISS expedition 34 crew, in space from October 2012 until March of this year, conceived the motto of "Off the Earth...For the Earth." It was the symbol of their mission patch and their work exemplified it. *Off the Earth for the Earth*, offers an animating title for the framework for America's space program based on today's needs and tomorrow's opportunities. The pieces for starting to implement this framework exist – starting with the full realization of the potential of the ISS. The ISS provides an unparalleled capability for space-based research as well as a unique venue for developing technologies for future human space exploration. ISS supports research across a diverse array of disciplines, including high-energy particle physics, Earth remote sensing and space sciences, molecular and cellular biotechnology, human physiology (including bone and muscle research), radiation, plant and cultivation, combustion, fluids, materials science, and biology.

In parallel, another step was recently announced. In this effort, we will seek to identify, capture, and move a small asteroid to a trans-lunar orbit – all within the next decade. This mission will combine robotic and human efforts already underway within NASA, meet numerous large global and national objectives, allow for commercial involvement, and mark an important step forward. We are expanding human and robotic presence and activity outwards to encompass all of the Earth-Moon system (cislunar space). With this next phase in place, the expansion of our human journey to Mars and beyond will occur – with no limits on our future.

Off the Earth for the Earth offers an implementation framework that is measured, collaborative, and focused on the long-term sustainment and growth of human and robotic activity. This confluence will not be enabled by one-time ventures into space that leave behind no infrastructure, like Apollo, but rather by slow, steady progress that builds enduring capabilities on a remarkable canvas. Space can increasingly tie together, enable, and empower the explosion occurring in our global knowledge, problem solving, development, and exploration.

The ISS and the whole region of cislunar space represent an inflection point in the Space Age, and perhaps even human history. The leveraging of robotic and human space efforts, starting in this area, will be profound, ranging from improving life here on Earth, to helping to confront and solve fundamental national and planetary challenges , to tapping the infinite resources beyond Earth's shores, and unleashing human potential from the shackle of gravity that has limited and shaped humanity's development - up to now.

Along with all of this activity and knowledge, a diverse set of challenges and opportunities have cropped up in the near-Earth region of space. Challenges include issues such as the general absence of recognized norms of behavior in space, an increasing number of space actors, orbital debris, frequency interference, and the connection of cyber

and terrestrial threats to our space activities.[6] For example, human-created space debris encompasses over 21,000 space objects, roughly larger than 10 cm that are now tracked. There are hundreds of thousands of additional objects detected that are too small to track, but capable of creating significant damage.[7] The roughly 1,000 active satellites and the six humans now working in space all must contend with this growing challenge.

Opportunities that have emerged include possible mitigation and removal of debris, repair, re-fueling and retrieval of assets, expanded access to and sharing of information derived from space, the extension of satellites and other capabilities beyond today's busy orbits and challenges, and access and use of space resources. All of these matters are broader than our traditional focus on a peer national rival and reflect the overall nature of how national security has evolved. Greater transparency and confidence building measures (TCBMS), including U.S. leadership in establishing a global space situational awareness framework, and norms of "good" behavior, including a possible international Code of Conduct for space, are components that reflect a focus on opportunities, and engagement in the creation a geo-strategic environment that accentuates the positive use of technologies and applications.[8] At the same time there is still the matter of traditional geo-political power calculation, particularly with the advent of new space actors, such as China.

Planetary threats and challenges extending beyond national borders continue to proliferate, impacting our understanding of global security related areas to include the environment, energy, and possible civilization-level impacts, such as massive solar weather-related disruptions, pandemics, famines, and asteroid impacts. Our knowledge of the multitude of asteroids and cometary bodies that traverse our planetary neighborhood increases daily. The recent impact of a 17 meter object near Chelyabinsk, Russia was both a reminder of the potential threat of these objects, but also of our incomplete view of thousands of them. At the same time, we are also just beginning to understand the role of impact events in the evolution of Earth's life and climate. In 1859, only rudimentary telegraph wires were in place, but telegraph systems all over Europe and North America failed, in some cases dramatically as a result of a massive solar coronal ejection event. What would happen if an 1859-level solar storm occurred today? The National Research Council and Organization of Economic Cooperation and Development (OECD) have produced reports that have focused on the space weather threat, its implications, and our overall lack of knowledge and preparedness.[9] At the same time, the Sun's energy tapped by satellites may prove to be an important energy source for use in-space and possibly on Earth. As Head of Air Force Space Command General William Shelton has stated, the "big sky" approach (in which everyone pursues their own interests and is not concerned about other actors and players) is no longer enough.[10]

Off the Earth – For the Earth offers a different way to frame human and robotic space flight. It recognizes the interdependency of these efforts, it focus on building from what we have – not re-building a black and white photograph of a time that has past, and it recognizes that we are in space and need to continue to work together to build an unlimited future.

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[6] Other related issues deal with the trends of both smaller systems (potentially calling for more launches); bigger systems in GEO, in the opposite direction, in part due to bandwidth and slot scarcity; growing interest in servicing and on-orbit life increase (and sparing); the overall high number of launch vehicles and costs given current demand; discussions on the disaggregation of satellite architectures and the spreading of current assets onto commercial and international platforms; and with growing access to all of cislunar space, the ability to also use distance and other regions to enhance architectures and capabilities.

[7] *Orbital Debris Frequently Asked Questions,* NASA's Orbital Debris Program Office, 2012, http://orbitaldebris.jsc.nasa.gov/faqs.html.

[8] For a summary of U.S. initiatives and involvement in these areas, see Department of State Deputy Assistant Secretary, Bureau of Arms Control, Verification and Compliance Frank Rose's comments at a Space Situational Awareness meeting held in Tokyo, Japan on 27 February 2013 - http://www.state.gov/t/avc/rls/2013/205288.htm.

[9] Solar and Space Physics: A Science for a Technological Society, Committee on a Decadal Strategy for Solar and Space Physics (Heliophysics); Space Studies Board; Aeronautics and Space Engineering Board; Division of Earth and Physical Sciences; National Research Council, Washington, DC: The National Academies Press, 2012. Future Global Shocks: Improving Risk Governance, Organization of Economic Cooperation and Development (OECD), 2011, doi: 10.1787/9789264114586-en.

[10] General William Shelton, Commander, U.S. Space Command, Remarks, National Space Club, 25 September 2012.

IV. Going Forward

Today's budget and overall fiscal and political environment is very different from the halcyon days of the past. By focusing on value to Earth, removing threats and challenges, and collaborating across a wide variety of partners, national funding becomes a subordinate variable – not the only variable that defines the scope of our efforts. The intersection of soft power, international relationships, public sector interests, scientific robotic and human spaceflight becomes the focus of our space efforts that continue to aim outwards. We can build from on hand capabilities and emerging capabilities provided by a host of private, government and international sources. In this manner, activity would be established at a sustained pace, gradually opening up space beyond today's reach.

The national policy environment that directs NASA's efforts, when holistically surveyed, seems to begin to complement key parts of an *Off the Earth for the Earth* approach. There exists a focus on the dynamic nature of importance of space in today's world: the need for strategic engagement, the interrelationship of national security, civil, and commercial sectors and issues, the importance of the development of space and the overarching role of human expansion beyond low-Earth orbit.

For the next decade at least, human spaceflight can serve as a tool that can be factored into larger national-level goals and interests. Human and robotic space flight synergies can be forged. There is also an opportunity to increase the global perception of NASA's human space flight program as part of an overall "force for good" in space that can help lead, extend and ensure U.S. presence, and help to shape other national behaviors in a positive manner – such as efforts to limit orbital debris, develop recognized positive norms of behavior to sustain the space environment, and increase the stakes behind these efforts. Space development and international engagement can both be used to directly underpin and animate national security and diplomatic objectives geared towards our long-term national and global future. It is interesting to note as the United States is struggling to find common ground in the political realm with Russia, the US and Russia are cooperating on the ISS with a level of trust that has never existed. Space could play a larger role in the global political environment. Likewise, NASA's scientific and robotic efforts can reach out to other nations whose focus, at this time, is on developing their domestic capacity and resources. Augmentation and support of alliances can become more of an explicit focus.

The human expansion and development of space and the use of the material and energy resources of space become a prominent focus in this approach. Specific destinations become elements within this approach– not ends in themselves. The development of space, to include U.S. leadership in the exploration, access to and use of lunar, solar, and asteroid resources, offers an organizing principle and place where robotic and human efforts also intersect in space. We have already begun to realize Gerald K. O'Neill's vision of space development coupled with settlement and human expansion into the solar system.[11]

Over the past year, NASA and its partners have started a number of studies on the movement from the ISS to create an eco-system of human presence, activity and capabilities that encompasses all of Earth-Moon space, including the planned asteroid capture and movement within the next decade. Discussions have begun on the role, interaction, and impact that this development can have on other government and commercial actors, and on the international community. Close collaboration around scientific robotic and human space activities is also occurring.

With its completion, the ISS offers a key facility to broaden the use of space, derive returns, and open markets, while serving as a "gateway" to Mars and rest of the solar system. The Curiosity rover has thermal paint that was observed and validated on the outside of the ISS as part of a materials experiment. The ISS will host a crew that will simulate the length of a Mars mission. We will use the ISS and the Asteroid mission to test technologies and operations that will help form a foundation for future exploration. The ISS can also demonstrate that a new economy for space based research is possible. The ISS is already sparking disruptive innovation in the low earth orbit transportation market – creating lower cost and eventual access to space for the breadth of the public. The ISS will demonstrate that there is an economic advantage to space-based research. There have been some positive signs already in pharmaceuticals, aging-related remedies, and other important areas.[12] In addition, the ISS also provides a

[11] Gerald K. O'Neil, *The High Frontier: Human Colonies in Space*, William Morrow and Company, 1977.
[12] *ISS Benefits for Humanity*, NASA along with the other ISS Space Agencies, 2012, http://www.nasa.gov/pdf/626862main_ISS_Benefit_for_Humanity.pdf.

place to develop interfaces and standards for systems, test of systems, and demonstrate in-situ resource utilization capabilities, such as 3-D parts printing – all relevant to future space development and exploration.

V. Conclusion

With a framework based on strategic engagement and objectives that resonate with the challenges and opportunities presented by today's world, tangible, achievable near-term activities can expand capabilities and operational experience. New hardware and operational techniques can be extended to these longer-term and broader national goals and objectives. In this manner all the components necessary to achieve a major long- term objective can be incrementally built up over time – the jigsaw pieces increasingly having an overall frame in which to fit. Larger strategic goals and objectives can lend urgency to the effort and show measurable progress. All of this can be done in a manner that is globally relevant and conducted on an international, multilateral basis. Cislunar space becomes about a lot more than simply a "place" – it becomes the setting for the next phase of our human journey.

We have begun to set the infrastructure in place to allow humans to routinely live and travel into the solar system. In this century, we will be developing systems to terra-form planets. We will build the knowledge to allow humans to live throughout the solar system. We will bring people and nations together to work together on projects of consequence and magnitude both in space and on Earth. We will continue to make footsteps in the enduring human journey of discovery and growth. The solar system beckons.