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Social Innovation Concepts at NASA: Integrating International Development Challenges and Hands-On Prototyping with Spacecraft Design Training

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The NASA Johnson Space Center Social Innovation program has been designed to encourage innovation within the NASA community that benefits both NASA's core mission as well as human needs domestically and internationally. By encouraging internal and external collaboration and providing resources including the new Johnson Space Center "Sandbox" design shop, new innovations are anticipated. Technologies developed for the human exploration of space share similar requirements with appropriate technology for the developing world. The technology goals of keeping people alive in a difficult environment involve addressing requirements for low maintenance and robustness and often include using renewable energy sources. Technologies developed to address these challenges have crossover between these engineering fields. Innovations in either field may have applicability in both. This program is intended to be an alternative method of developing technologies and expertise within the NASA community, while simultaneously demonstrating NASA relevance and contribution to improving life here on Earth. By recognizing that innovation can come from unexplored and unexpected places, this program can create an environment where NASA engineers are able to collaborate with non-traditional partners in addressing critical NASA needs.

Nomenclature

<i>ETDP</i>	=	Exploration Technology Development Program
<i>HRP</i>	=	Human Research Program
<i>LEO</i>	=	Low Earth Orbit
<i>STEM</i>	=	Science, Technology, Engineering and Math

I. Introduction

In the public eye, NASA is a symbol of taking on the impossible and succeeding against incredible odds. It's a place where rocket scientists do things that the rest of the world admires. The Apollo Moon landing of 1969 captured the world's imagination and collectively the world saw what humans are capable of. NASA still captures the attention of the world today, but spaceflight is considered a bit more routine. Space disasters and colossal failures still get the world's attention, because somehow humans travelling into space are where dreams are made and great risks are taken. In the early days, many NASA workers cited the Apollo program as their inspiration to study science and math and eventually come to work for NASA. Today, NASA's younger workforce cites the movie Apollo 13 and the dramatic problem-solving and rescue of Jim Lovell, Fred Haise, and Jack Swigert. In the view of the world, NASA has and can in the future solve the toughest challenges of human exploration.

Now for the inside scoop on NASA – our space program bureaucracy is 50 years old, and as any large government bureaucracy we have gotten expensive, slow, and increasingly intolerant of risk. For the last 38 years, we have kept

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human explorers either on the ground, or at the most, 225 miles above the Earth. Of course, the risks of that commute are high, including a reentry into the Earth's atmosphere slowing down from 20,000 mph to zero and the spacecraft surviving temperatures of 3,000 degrees. NASA is right now, extremely competent at building, designing, operating, and returning very complex spacecraft that can leave and reenter the Earth's atmosphere and even sustain life in the vacuum of space for weeks and even a few months without resupply from Earth.

NASA will someday take humans to Mars for long periods of time – measured in years, not weeks or months. And, in contrast to Low Earth Orbit (LEO), there is no easy return in the case of emergency. The truth is that NASA cannot accomplish this type of mission with our current technology or with our current way of thinking. We are currently a Low Earth Orbit space-faring nation, not an extended-duration and remote-destination spacefaring nation. For this Mars mission, we will be constrained in the amount of things (both mass and volume/size) we can take with us. Keep in mind, the largest rocket ever built and flown –the Saturn V – took three men to the relatively close Moon for only a three day stay on the surface. Even in the most slimmed down mission, we're looking at dozens of Saturn V rockets to get humans to Mars.

II. Shared Terrestrial and Spacecraft Challenges

President Obama has directed NASA and its partners to develop technologies for space exploration that can also benefit life here on Earth. On April 15, 2010, the President's speech at NASA Kennedy Space Center, 'Remarks by the President on Space Exploration in the 21st Century', included these statements: "And we will extend the life of the International Space Station likely by more than five years, while actually using it for its intended purpose: conducting advanced research that can help improve the daily lives of people here on Earth, as well as testing and improving upon our capabilities in space. This includes technologies like more efficient life support systems that will help reduce the cost of future missions," and, "Our goal is the capacity for people to work and learn and operate and live safely beyond the Earth for extended periods of time, ultimately in ways that are more sustainable and even indefinite."

This vision is directly in-line with the concepts pursued in this paper. For example, long duration spaceflight, as anticipated for planetary missions, will require hardware that is less prone to failure and generally more rigorous and sustainable than the current state-of-the-art. Sustainable Environmental Control and Life Support Systems (SECLSS) may be developed to function for long periods of time in harsh environments, with limited maintenance and resupply. Water recovery, air revitalization, habitation, food and power systems may benefit from considering sustainability a design goal. A long-duration planetary outpost will require sustainable life support technologies that are capable of functioning for years with minimum resupply and maintenance. While life support resources such as water and air will remain in short supply, the availability of gravity, energy, and natural resources on the planetary surface allow for innovation in the design of outpost technologies, potentially including the adoption of terrestrial technologies previously not feasible for short duration microgravity flight.

Technologies developed for the human exploration of space share similar requirements with appropriate technology for the developing world. The technology goals of keeping people alive in a difficult environment involve addressing requirements for low maintenance and robustness and often include using renewable energy sources. Specifically concerning water recovery systems, spacecraft wastewater streams and developing world surface and ground water are similar in contaminants and purification goals. Technologies developed to address these challenges have crossover between these engineering fields, including the use of solar power, ultraviolet disinfection, and reverse osmosis membranes. Innovations in either field may have applicability in both.

The UN Millennium Development Goals¹ are pretty uniformly agreed to as global needs and challenges - food, poverty alleviation, health, sustainable energy, clean air, and global partnerships. Let's consider the 50% of the world's population who live in remote areas, without access to healthcare, clean water, energy, or even clean air. The challenges of remoteness are tough. NASA can't even solve them. Figure 1 maps some of the UN Millennium Development Goals to NASA's long duration spacecraft needs, highlighting some of the similarities between these applications.

UN MDGs

NASA Technical Needs

Figure 1. Comparison of the United Nations Millennium Development Goals with NASA’s long duration spacecraft needs as identified by advanced development groups within NASA. Thematic connections are for illustration only. The authors recognize that specific technical innovations may be connected across several common needs. Likewise, specific technical designs and hardware prototypes may only be part of the connection between these fields, while cross pollination of innovative thinking and exposure to external collaborations may yield the greater benefits.

III. Rationale

The exploration of space is inherently borderless. One of the most common observations made by returning first-time space fliers is how striking it is to see the Earth without the political boundaries drawn on maps. It is also common to hear how fragile the Earth looks, with its thin blanket of air that is the only thing between us and the harsh vacuum and temperature extremes of space. In no other area of national policy is there so little intrinsic emphasis on borders. Also, the language of math and science easily transcends the usual limitations of spoken and written language. With America’s leadership in space, comes the potential to engage in noble and pure diplomacy, targeted at the creative, dreaming, and educational aspects of childhood and adolescence. America’s 15 partner nations in the International Space Station Program would be a good start to the multi-lateral effort to enhance education. And while science and math, and rockets and space ships are compelling enough in the “science as diplomacy” argument, there is another nuance that is intriguing, given the nature of this article. Since NASA is trying to figure out how to sustain life in harsh and remote locations in a sustainable way, is there an opportunity to engage those at “base of the pyramid” in rural, remote, and harsh environments and work together to solve some of the toughest technical and sociological challenges in the human experience? Such engagement would need to be facilitated by intermediaries who are already engaged with communities to help innovate and design solutions to these problems, so there would be an already-in-place way to connect, and as a place for members of a remote

community to contribute to causes locally that would benefit themselves while at the same time benefitting the toughest technical challenges facing humanity as they strive to explore the outer reaches of space.

A. Workforce development and retention

There is a growing trend in our professional workforce – the need for them to contribute to something larger than themselves and to make the world a better place. Oftentimes sustainability comes along as a key desire for contribution. NASA is just one example of a large and bureaucratic organization that could benefit from some revitalization and from a source of creative spirit and innovation. Not only would retention be improved, but retention would be targeted right at the professionals who NASA most wants to keep, those who think out of the box and aren't afraid to work and get their hands dirty.

B. Lessons learned from terrestrial engineering applications

NASA has a great history of making technological advancements out of necessity (flying to the Moon and operating in space) that end up benefitting the Earth. Think of cell phones, microelectronics, lightweight materials, medical devices and you'll see NASA somewhere in the genesis of those technologies. As we look to the challenges of the developing world, however, there are some important distinctions that make NASA's technologies unlikely to solve these problems. First, for a human space mission, the tolerance for failure is low and, consequently, great costs will be paid by NASA for technology to work. LEO mission requirements and a lack of cost discipline results in skyrocketing space program costs (often the subject of space news articles) and also in many cases to overdesign and high system complexity. For the space shuttle, this means that it takes numerous people on the ground to monitor the particulars on every system. And while this works and results in many successful and safe space missions to low Earth orbit, the same philosophy would not likely be appropriate for the developing world where cost and available skills are major drivers. Imagine a water system for a house or small village that required a team of five scientists on the clock 24 hours a day to monitor the subsystems. The water system in the developing world would likely not have the same resources available.

What is more likely than NASA spinoffs for the developing world is "spin-in" where advancements made and lessons learned FROM the developing world are applied to design and technology for NASA's future long duration human space exploration missions. It may be that the Opuntia cactus used in rural Mexico as a nutrient and coagulant and fiber source, may be an ideal plant to be grown in space, requiring very little water to grow and yet providing many benefits. Perhaps the refrigeration technique used in Africa, wherein two inset clay pots surrounded by water can yield evaporative cooling effects, may be the basis for a zero-power and simple refrigerator for astronauts on Mars. NASA should be on the lookout for these types of solutions that already exist on our planet and apply them to human-kind's space exploration goals. The potential for engagement of the global community to identify and communicate and promote these solutions for human space explorers is enormous.

Another benefit of NASA's engagement with the global development community would be working side-by-side with other engineers and social entrepreneurs who are addressing similar challenges to those facing NASA. This could involve sending creative, smart, talented NASA engineers on training and development assignments to work on the ground in developing countries alongside other creative, talented, smart sustainable development professionals who are already trying to tackle remote community challenges in energy, water, and healthcare diagnostics and delivery. NASA already pays to train its engineers in classrooms across the country and certainly it can be argued that hands-on experiential learning assignments can be at least as valuable - if not more. So, from a taxpayer perspective, there would really be no more cost and merely an increase in effectiveness, appropriateness, and payback on the training. Imagine a NASA engineer whose job it is to eventually design power and energy systems for a two year mission to Mars, taking six months to work in a South American mountain village alongside development engineers who are trying to figure out how to provide reliable power to a village that will never be on the electrical grid due to geography. This tiger team of creative engineers will have to think about remoteness, scarcity of materials and spare parts, and the lack of specialist repair services. Together, they will confront the challenges of remoteness and system reliability. Those engineers will also forge lasting relationships that may lead to future as-of-yet-unimagined inventions and useful projects. That NASA engineer will return to the agency as a far more experienced and creative engineer who will have a very robust perspective on systems engineering in remote locations. Aside from sending the engineer to Mars for the experience, this would be the next-best training.

IV. Current Social Innovation Activities

A. Collaboration with the United States Agency for International Development (USAID)

The change in presidential administration in 2009 yielded a shift in priorities in the NASA administration, which has led to some high level discussions and collaborations between the NASA and the US Agency for International Development (USAID), including a recently signed memorandum of understanding². First, the two agencies have hosted two successful high level workshops called LAUNCH³. The first workshop centered on the aspect of clean water and brought 10 top innovators in the field to Kennedy Space Center to discuss their approaches and interact with each other, hopefully leading to new partnerships and interactions. The second workshop was focused on human health and included IDEO and Nike among others and using the same approach of inviting the top innovators in the field to interact with sponsor agencies and with each other.

Another potential collaboration between USAID and NASA is oriented toward the identification of potential Spin-off technologies for the developing world. This would probably be in the form of a database and may help make connections between problems and solutions that have gone missed in the past. This is useful, and should be done, but as described above has limited potential for innovation and new solutions to intractable problems facing both NASA and the global community.

Other discussions with USAID have focused on the potential for employee rotational assignments between USAID and NASA. In our (the authors) opinion, the potential for interaction between USAID and NASA lies in the degree to which the best and the brightest from the two communities can get together on the ground and get their hands dirty in the tough problems of common interest.

B. Collaboration with Engineers Without Borders-USA

The Engineers Without Borders-USA Johnson Space Center Chapter⁴ is an association of Johnson Space Center (JSC) employees, contractors and other professionals in the Houston/Clear Lake area who volunteer their time to participate in the projects and efforts of Engineers Without Borders-USA. The organization has had dedicated volunteers contributing time and resources to programs in Rwanda and Mexico since 2004. Many of the volunteer NASA engineers who have contributed their time have stated that, by directly engaging in the concept, design and implementation of a technology solution, they have built critical engineering skills that benefit their day jobs at NASA. Now, through these social innovation initiatives, the Engineers Without Borders-USA JSC chapter is able to better integrate these humanitarian engineering programs with addressing some of NASA's critical needs. Part of this collaboration is through the JSC SandBox facility, described below.

C. Johnson Space Center "Sandbox"

It is in NASA's interest to enable civil servant and contractor volunteers to create and innovate in a safe environment for causes of mutual interest to NASA and the global development community. Many of NASA's toughest technical challenges are related to future human exploration missions that will be long duration and to remote and resource-constrained environments. While resources such as clean water, air, energy, and healthcare will be limited on such missions, so will the ability to resupply and repair. On Earth, these challenges exist in some parts of the U.S. and widely in the developing world. Employees volunteering to address these terrestrial challenges will be acquiring valuable insight and will contribute to how NASA can address and solve those same challenges beyond low Earth orbit.

The "Sandbox" is a pilot facility at NASA Johnson Space Center developed by a team that included the authors, whose purpose is to encourage and facilitate JSC employees to get hands-on experience with designing, building, and testing innovative technologies that pertain to NASA's mission. The Sandbox offers a safe place for employees to create and collaborate with members of the workforce with whom they would not otherwise interact. Employee-directed projects can be of two types: 1) official tasks (with permission of supervisor for civil servants, and within the scope of contracts for contractors) where a flexible, basic shop space is useful to explore and test concepts, and 2) activities where the employees are off the clock, but are working on projects that maintain and enhance our workforce's ability to create and innovate for the benefit of human space exploration (and not in conflict with

contractor employee contracts). The Sandbox offers a space where hands-on training on machine shop tools and fabrication is provided in an action-learning environment for the workforce.

This project is intended to be an alternative method of developing technologies and expertise within the NASA community, while simultaneously demonstrating NASA relevance and contribution to improving life here on Earth. By recognizing that innovation can come from unexplored and unexpected places, this project can create an environment where NASA engineers are able to collaborate with non-traditional partners in addressing critical NASA needs.

Figure 2. The Johnson Space Center Sandbox.

A candidate pilot program was proposed for the Sandbox. This proposal includes four phases. An initial planning phase to develop the project challenge, identify an “A-team” from the JSC community to work on the challenge, and establish partnerships with organizations to provide immersion opportunities. The first operational phase will pitch the JSC team against volunteer, high school, university, company and non-profit teams competing in the design challenge. The JSC team will be “handicapped” by developing their technology openly, publishing designs and testing results. At the end of this phase, the JSC team will be judged alongside other entrants.

In the following phase, the JSC team is proposed to travel to immersion locations to further develop expertise and experience in specific challenge-related fields. For example, a water recovery project may place JSC engineers in Bangladesh with a non-profit treating arsenic in the surface water, or in Israel at a major sea water desalination plant. In the final phase, the JSC team will reconvene to develop a higher fidelity technology, that will hopefully integrate results and experience gained through the challenge and immersion phases and would deliver a technology worthy of integration into NASA’s mainstream technology development activities. Meanwhile, the technology development efforts may well result in direct applicability in resource constrained environments here on Earth.

V. Conclusion

By encouraging internal and external collaboration and providing resources including the new Johnson Space Center “Sandbox” design shop, new innovations are anticipated. This program is intended to be an alternative method of developing technologies and expertise within the NASA community, while simultaneously demonstrating NASA relevance and contribution to improving life here on Earth. By recognizing that innovation can come from unexplored and unexpected places, this program can create an environment where NASA engineers are able to collaborate with non-traditional partners in addressing critical NASA needs.

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