Title: Open Innovation at NASA: a New Business Model for Advancing Human Health and Performance Innovations

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Abstract

This paper describes a new business model for advancing NASA human health and performance innovations and demonstrates how open innovation shaped its development. A 45% research and technology development budget reduction drove formulation of a strategic plan grounded in collaboration. We describe the strategy execution, including adoption and results of open innovation initiatives, the challenges of cultural change, and the development of virtual centers and a knowledge management tool to educate and engage the workforce and promote cultural change.

Formulating the Strategy

This paper describes a new business model for advancing human health and performance innovations at the NASA Human Health and Performance Directorate (HH&P), formerly the Space Life Sciences Directorate (HH&P), at the Johnson Space Center (JSC), and demonstrates how open innovation shaped the development of this new business model. In 2005, the human research and development program experienced a 45% reduction in its budget. While the reduction resulted in a loss of

some core capabilities including personnel, contracts and grants, the mission to keep astronauts healthy and productive in space remained the same. In response, the HH&P leadership formulated a new strategy grounded in collaboration to advance its mission and improve organizational performance and efficiency. The Space Life Sciences Strategy was published in May of 2007, and was updated and refined as the Human Health and Performance Strategy in 2012.

Overarching goals focused on driving innovation in human health and performance through collaboration, with an emphasis on solutions that both meet NASA needs and benefit life on Earth. Key strategies included establishing strategic relationships to leverage the resources of others, and developing a forward looking and flexible business model that would transform the HH&P to a learning organization more adaptable to change—one that would specifically challenge existing paradigms such as the "not invented here" syndrome. Another key strategy included the development of an integrated risk management approach to guide the prioritization and management of human health and performance activities. These goals and strategies led to NASA's pioneering of open innovation to successfully address technical problems, and ultimately to the development of a knowledge management tool that educates employees about innovative problem solving techniques.

Strategy Execution: Setting the Stage for Open Innovation

To inform its collaborative strategy execution, the HH&P conducted a two-year benchmark with twenty external organizations in academia, industry and other government organizations in 2007. Several key findings guided the directorate's

pursuit of collaborative initiatives[1]. In particular, benchmark results indicated a 100% correlation between the need to form alliances or collaborations and the ability to achieve innovation goals among the organizations interviewed—all said they could not effectively or efficiently innovate or achieve their strategic goals without collaborating. Organizations formed partnerships to supplement internal resources and competencies; to acquire novel ideas and approaches to problem solving; to acquire needed services, licenses or patents; and to further develop and execute strategic plans. Prior to developing the 2007 strategic plan and conducting the benchmark, the HH&P primarily pursued its goals via internal development efforts or through traditional approaches to partnering such as research grant funding opportunities. These new findings validated the collaborative strategy and facilitated HH&P leadership's willingness to accept and advance new ideas for innovating.

A significant undertaking of the HH&P is managing human system risks for space flight (such as loss of bone or exposure to radiation) to enable successful long-duration human space exploration. This includes identifying and characterizing the risks, and then finding or developing technologies, research or services to mitigate them. Consequently, a key element to the successful execution of the strategy was the development of a human system risk management process and the identification of 32 human system risks. This comprehensive risk management system allows us to target specific high priority areas conducive to partnering and collaborative innovation, and provides the foundation for problem statement formulation and successful open innovation problem solving as described below.

Assessment of and experimentation with various novel methodologies to

provide solutions for diverse, unmet technical challenges, was also a part of HH&P's strategy execution. Research by Dr. Karim Lakhani[2], from Harvard University, inspired interest in an open innovation approach to problem solving. Now primed to try new approaches, the HH&P leadership conducted several workshops with Dr. Lakhani on open innovation and cultural change to inform the organization about these new problem solving techniques and the challenges associated with creating cultural change. These efforts led to HH&P's open innovation experiments.

Advancing Open Innovation at NASA

Initially, HH&P's open innovation (OI) approach was intended to expand existing search capabilities for novel technologies (via the established Technology Watch process) to mitigate the top human health and performance risks in space flight. Some high priority areas where mitigation solutions were not readily available were targeted for an OI approach to problem solving. As will be discussed below, the competitions actually provided technology solutions in addition to enhancing HH&P's Technology Watch capabilities, and as a result the HH&P expanded its concept of the OI approach to directly provide technical solutions.

The HH&P leadership kicked off its OI pilot study by asking project managers to identify twelve technology needs where human spaceflight risk mitigation solutions did not exist. In order to determine if the technology needs were suitable for an OI pilot project, a workshop was conducted with Dr. Gary Pisano of Harvard University using

criteria published in the article "*Which Kind of Collaboration is Right for You*?"[3] This led to a number of technology needs that fit the criteria for an OI competition. Later, the HH&P determined that this initial "homework" and problem formulation contributed greatly to the success of these early OI pilot projects.

The next step required a market survey of OI providers, followed by a competitive procurement that resulted in selection of two OI providers, InnoCentive and yet2.com. A third company, TopCoder, was also made available to NASA through a Harvard study under Dr. Lakhani[4].

From late 2009 through 2010, the HH&P initiated four pilot projects in open innovation searching for technical solutions to an identified set of technology needs. Given the allocated funding profile, competitions were first run on the three OI provider platforms external to NASA mentioned above. Funding was later received to conduct an internal pilot project within NASA across its ten field centers using an InnoCentive platform customized as NASA@work.

Six HH&P challenges were selected to run on the InnoCentive platform; a seventh challenge was added to give the engineering directorate at JSC an opportunity to conduct a competition. These first seven challenges were conducted in two phases and are listed in table 1.

Initial InnoCentive Challenge Topics
1. Food packaging to maintain quality for 5 years 2. Compact (one cubic foot, 20 pound) exercise device for capsules 3. Solar proton event predictive capability for 24 hours 4. Coordinated sensor swarms for planetary research 5. Accurate tracking of medical consumables in flight 6. Motivational enhancement for exercise 7. Inflight Laundry System

Table 1.0, Seven Initial HH&P Challenge Topics

InnoCentive has a solver network of several hundred thousand individuals, and seeks solutions to challenges posed through a competitive prize mechanism. NASA worked with InnoCentive to create a section on the InnoCentive website called the NASA Pavilion to highlight its challenges.

The timing of the HH&P OI initiative was fortuitous as the White House Office of Science and Technology Policy (OSTP) was engaged in advancing the Office of Management and Budget Guidance on the Use of Challenges and Prizes to Promote Open Government[5], and unveiled a government-wide prize competition platform called challenge.gov shortly after the launch of HH&P's OI pilot program. The NASA challenges were listed on challenge.gov for greater visibility for NASA and to demonstrate an effective use of this new approach to problem solving for the U.S. Federal Agencies. NASA's success in its OI efforts ultimately led to OSTP requesting that NASA develop and lead the Center of Excellence for Collaborative Innovation (CoECI)[6], which serves as a resource across the U.S. Federal government to advance the use of

open innovation.

The HH&P also ran six challenges with yet2.com, a technology search firm that provides a platform aimed at matching organizations capable of solving a particular problem posed by an originating organization (results are presented in Table 3 below). HH&P leadership originally debated whether to run side-by-side competitions of the same technology challenges on InnoCentive and yet2.com to provide comparative results, but decided that doing so would provide more opportunities for its project managers to run unique challenges. One challenge (food packaging) was run on both platforms and is described below. Another competition using TopCoder, an OI provider with a solver network of several hundred thousand individuals, was conducted to find an optimization algorithm for a lunar medical kit. This challenge was sponsored by Harvard University's contract with TopCoder, with NASA formulating the challenge.

Lastly, HH&P conducted challenges internally using NASA@work, where NASA challenges were run on the InnoCentive platform and solutions to problems were sought across the ten agency centers. Two challenge opportunities were offered to each of the ten NASA centers and the twenty challenges were conducted in a four-month time period from June-October 2010. The ability to run challenges at all ten NASA centers greatly increased the visibility of OI problem solving capabilities and promoted the use of OI across all of NASA.

To effectively evaluate proposed solutions, HH&P leadership developed a two-tier

system for assessing competition results. The first phase involved the challenge owner assembling a technical team to assess the merits of the submission based upon the criteria developed for each challenge. The technical team developed a recommendation as to whether or not to make an award, which could include a partial award in the case of InnoCentive, and presented that recommendation to a management team that included directorate leadership, discipline expert management, and legal counsel. Awards were considered and authorized by this leadership team. The prizes were then issued by the vendors.

InnoCentive Competition Results

The InnoCentive competition produced a dramatic global response and success rate that was not anticipated by the NASA team. Nearly 2900 project rooms were opened from 80 different countries, results that surprised the authors. In the seven challenges run on the InnoCentive platform, full or partial awards were issued for all seven.

Challenge	Submissions	Award
Data-Driven Forecasting of Solar Events ➢ Resulting model showed a high percent correct (~95%) but with an equally high false alarm rate. Potential for coupling with other modeling efforts.	11	$30,000
Food Packaging and Protection ➢ Monitoring other packaging team evaluations of flexible graphene material proposed as solution.	22	$11,000 (3 partial)
Compact Aerobic Resistive Exercise Device Mechanism ➢ Technology was included in Advanced Exercise Concepts trade space for consideration.	95	$20,000

Coordination of Sensor Swarms for Extraterrestrial Research	37	$18,000 (3)
Medical Consumable Tracking	56	$15,000 (3)
Augmenting the Exercise Experience	18	$10,000
Simple Microgravity Laundry System	108	$7,500

Table 2.0, InnoCentive Pilot Results

In later reflection, the initial workshop in 2009 using criteria to determine whether a particular problem fit an OI solution model and working through the challenge statement development was thought to contribute to these early successes. As shown above in Table 2.0, one of these first seven challenges sought an algorithm to predict a solar particle event and generated a great deal of attention external to NASA. Previous research and development efforts had led to solar particle event predictive capabilities of a few hours. This InnoCentive challenge sought an algorithm that could predict an event from 4-24 hours in advance, with a 50% accuracy and two-sigma confidence interval. A retired radiofrequency engineer provided the winning solution, accurate to 8 hours at an 85% accuracy and a three-sigma confidence interval. The U.S. Chief Technology Officer at that time wrote and spoke about the result as a great example of a "citizen scientist" helping to solve a government problem. The challenge winner had not previously worked for NASA.

Another challenge resulted in the identification of a unique material (flexible graphite) for food packaging for very long duration space missions. This novel material met a number of the success criteria, prompting NASA to issue a partial award. In this case, a Russian materials scientist found the winning material from an industry

not related to food packaging, and the HH&P challenge team later procured the material for testing. While the material fragmented too easily to be a replacement for food packaging, the team felt the experience was very valuable in considering technologies outside of the traditional food-packaging industry. A report detailing the winners of the seven public challenges that NASA executed with InnoCentive, including solver testimonial and lessons learned, may be viewed on the InnoCentive web site.[7]

yet2.com Competition Results

The HH&P ran six competitions on the yet2.com platform with a global response similar to the InnoCentive pilot with 234 new leads from many different countries; results are listed in Table 3.

Technical Need	Total Leads	Active Leads
Hip Bone Microarchitecture Measurement ➢ Pilot study quantifying changes in sheep bone microarchitecture for preclinical validation expected to be completed by the end of FY13 ➢ Provides foundation for a research proposal to validate this technology in a population of spinal cord injured subjects	51	5
Water Disinfection and Monitoring ➢ **P**rovided a status of state-of-the-art water disinfection and monitoring alternatives, which indicated a need for NASA to develop new technologies for our specialized needs during spaceflight	61	8
Food Packaging and Protection ➢ Evaluation of one lead as partner underway	29	5

Radioprotectants	28	6
Extraterrestrial Life Differentiation	31	1
Portable Imaging	34	5

Table 3.0, yet2.com Results

One competition identified several approaches that were new to both academia and industry for imaging the architecture of bone. The challenge owner felt that these new connections were valuable additions to the existing professional network for addressing the problem of imaging the bone architecture, and that the proposed approaches were previously not recognized by NASA.

A second challenge was conducted to find technologies that would permit real-time microbial monitoring of water quality on orbit, a capability that does not yet exist for space flight. This challenge owner also commented that several valid novel ideas were received, which would be monitored for development and considered for future use by NASA.

A third competition, the food packaging challenge, found additional novel ideas to pursue that were complimentary to the InnoCentive results. Later work described below demonstrated the success of first running an internal competition (NASA@work) followed by external completions. The HH&P management team now believes this is an ideal approach for OI competition utilization: first conduct an internal challenge to fine-tune or gather initial inputs for a challenge topic, and then consider one or more external competitions to gather needed results.

TopCoder Competition Results

The TopCoder pilot competition was conducted in a remarkably brief period of ten days and generated over 2800 submissions from nearly 500 individuals.

Individuals in TopCoder competitions could submit solutions more than once. The successful competition led to the acquisition of an open source license for an algorithm that enhanced the effectiveness of a proposed lunar medical kit, which was limited to weight, and contents, with a maximum weight allowed of 45 kilograms. The contest asked participants to optimize the design for a kit to address a range of medical issues given the weight constraints. This algorithm was incorporated into the existing Integrated Medical Model (IMM), a database and algorithm that seeks to predict the likelihood of medical events during defined space flight missions and to optimize the medical systems for space flight vehicles. The algorithm for the lunar medical kit helped optimize the kit for the expected medical issues given the weight constraints of the kit and improved the design capabilities of this model for future medical kits.

The lunar medical kit competition demonstrated how rapidly software could be developed using external competitions. . The successful TopCoder algorithm competition was adopted as a model to develop the NASA Tournament Lab (NTL) by Jason Crusan at NASA Headquarters, which runs challenges for organizations across the agency in multiple disciplines. As of October 2014, the NTL has run 33 competitions (25 complete and 8 in work). Of those competitions, 24 were conducted for NASA (18 complete and 6 in work), and 9 challenges for other federal agencies

NASA@work (an InnoCentive platform)

A NASA@work pilot, conducted from June to October 2010, provided some very good technical solutions to the twenty challenges that were run across all ten NASA centers (Table 4).

Center	Challenges Posted	Registered Solvers	Discussion Posts	Participants
Ames	3	310	18	11
Dryden	0	146	13	9
Glenn	1	467	12	9
Goddard	2	564	101	13
Jet Propulsion Lab	2	1	0	0
Johnson	3	1380	46	29
Kennedy	2	1067	73	39
Langley	4	425	31	12
Marshall	0	700	23	14
Stennis	2	148	22	5
Headquarters	1	267	15	9

Table 4.0, NASA@work Center Participation

In addition to numerous successful challenge outcomes from the pilot, one intangible result is that the competitions connected individuals across the agency that had not previously worked together. One limitation specific to NASA for this first set of competitions involved restrictions for contractor participation, and as a result participation at some centers may have been significantly reduced. However, the

NASA@work pilot success represented significant work by the information technology team. An internal team working with InnoCentive solved the ability to post agency-wide challenges that allowed solvers from any center to login with appropriate NASA credentials. This permits challenge owners to post challenges from any of the 10 NASA centers and seek solutions from anywhere in the agency. Finally, results from the pilot demonstrated that it might be possible to use NASA@work to effectively seek team members on new or existing projects from a variety of disciplines across the agency.

Pilot Project Summary

Based upon the successful results from the initial pilots in open innovation, NASA has procured long-term contracts with InnoCentive and yet2.com. The TopCoder platform is also available from the NASA Tournament Lab and Harvard to conduct prize competitions for NASA and other federal agencies.

Virtual Centers to Advance Collaborative Innovation

Two virtual centers, the NASA Human Health and Performance Center (NHHPC) and the Center of Excellence for Collaborative Innovation (CoECI) were established to facilitate collaboration and sharing of innovation best practices among government, industry, academic, and non-profit members. The NHHPC,[8] established in October 2010 by HH&P, serves as a convening organization to advance human health and performance innovations that benefit life in space and on Earth through collaborative projects among member

organizations. As mentioned previously, NASA established CoECI in November 2011 at the request of OSTP to provide education and assistance to other federal agencies in running open innovation prize competitions. CoECI has conducted three workshops for U.S. federal agencies in May and June of 2012, and August of 2013, and as of October 2014 has had engagements with 16 federal agencies in both conducting prize competitions and in consultations about prize competitions. In addition to serving as a resource for other U.S. Federal Agencies, CoECI provides NASA employees with guidance in the use of and access to the NTL, InnoCentive, yet.com, and NASA@work platforms. Both centers are managed and staffed by HH&P personnel, with CoECI being directed by NASA Headquarters.

Ongoing Work/Results

Another evolving project addresses vision impairment and increased intracranial pressure (VIIP), a new human system risk for space flight that has emerged in the last several years and involves visual impairment of astronauts. A key aspect of understanding and managing this problem requires the measurement of intracranial pressure during space flight to determine its contribution to the development of VIIP and its clinical severity. No technology exists at present to measure the intracranial pressure non-invasively. The HH&P project manager conducted several OI competitions to search for non-invasive monitoring capabilities, beginning with a NASA@work competition. The top three NASA winners recommended that the HH&P team reconsider some technologies that had previously been considered but were now more mature. This was followed by external competitions on InnoCentive and

yet2.com. Four new solutions were found, two each on InnoCentive and yet2.com that provided new leads in creating the ability to monitor the intracranial pressure non-invasively (Table 5.0).

Solution Mechanisms	Outcomes	Results
NASA @ Work	Top three NASA "winners" directed us to take a second look at developers already known	
InnoCentive Potential $15K Award	638 Solutions Submitted 581 Rejected by InnoCentive 11 Rejected by NASA 46 Reviewed by NASA	2 New Potential Solutions
yet2.com	81 Leads Identified 63 Rejected High Interest Solutions: 3 Other Interesting Solutions: 5 Potential Complementary Technologies: 6	2 New Potential Solutions

Table 5.0, Non-Invasive Intracranial Pressure Challenges

This series of competitions demonstrated the value of first searching internally within NASA, followed by external competitions. The project manager noted that while some solutions were previously known, the OI competitions produced search results at a reduced cost compared to previous search efforts.

While beyond the scope of this paper, CoECI has conducted several competitions for NASA in other disciplines and programs, such as the Longeron Challenge[9] for the

International Space Station (ISS) and NASA's Asteroid Grand Challenge Series[10]. The CoECI team has also run competitions for several other federal agencies that have spanned multiple disciplines.

The internal crowdsourcing platform, NASA@work, has continued to grow and now boasts over 13,000 solvers NASA-wide, which is over 20% of the NASA population. Active participation (those solvers who have submitted to a challenge or participated in a discussion on the platform) has seen over a 150% growth each year since the platform's re-launch in August of 2011 (now over 700 solvers). Metrics are collected to benchmark performance and to understand how to effectively engage our solver community and increase awareness and participation about this internal platform across the agency. Based on this collected data, challenges are consistently launched every 2-3 weeks to retain a high level of interest and participation from solvers (usually 2-4 challenges on the platform at any one time with an average of 40-45 posts per challenge), ranging from a variety of topics (both technical and non-technical). Solvers are rewarded based on an award system that was recently developed with input from the NASA@work community (solvers first submitted non-monetary award ideas that they would value and then voted on their favorite submissions). This reward system both motivates solvers to participate in these challenges and further connects them with others at NASA, encouraging collaboration and connection within the community.

As was described above, a strategic approach to utilize OI activities begins with NASA@work to first seek internal input and refine a topic or challenge. NASA@work is well suited for the following types of challenges: generating new ideas, developing new concepts, adding structure or definition to a problem or

challenge, and reaching out to the community in a knowledge or technology survey (surveying the community for specific information that is needed). This versatility allows the NASA@work platform to be used in many different ways by its challenge owners and increases the ability for effective collaboration across the agency.

The Challenges of Cultural Change

Despite the dramatic success of its open innovation initiatives, transforming the HH&P organization from one that was predominately internally focused to one that embraced collaboration and open innovation to solve technical problems was challenging. The workforce was accustomed to highly structured work processes and project management requirements, and recognition of individuals and teams was based upon the outcomes of established problem solving mechanisms or peer-reviewed publications. Despite the HH&P's many communication efforts prior to the rollout of the OI pilot results, many in the directorate did not have a good understanding of what open innovation was or how it could benefit them, or of the expanded partnering opportunities offered by the NHHPC. As a result, when the OI success stories were presented to the HH&P project leadership group in January 2011, many felt threatened by a perceived (but not accurate) possibility of having their jobs outsourced instead of welcoming a new tool to advance their projects. Others acknowledged the possible benefit of a more collaborative business model, but asked for guidelines on how to use these new tools, and how to decide when to use them. Further, given the broad array of traditional methods for engaging with outside entities through various research grant funding or procurement mechanisms, many

also did not have a good working knowledge of all of the established methods available for their use either. While unexpected, these responses inspired the HH&P leadership to develop a concept for a strategic innovation framework, which evolved into the development of the Solution Mechanism Guide.

Advancing Cultural Change – the Solution Mechanism Guide (SMG)

The establishment of CoECI and the acquisition of ongoing OI platform contracts provided stability for using OI tools on a consistent basis to add novel problem-solving approaches to the traditionally used methods. However, to ensure continued use and full adoption of these innovation tools by employees within HH&P, it was imperative that a formal process be established to encourage their use and provide the necessary knowledge and resources in order to utilize them fully. The initial responses from the OI rollout meeting in January 20111 were further confirmed by results of an benchmarking effort demonstrating a strong consensus from employees within the directorate requesting a guide or resource tool that would help them navigate the innovation playing field; to know when OI activities were a suitable fit for their needs, or when existing mechanisms offered a better approach[11]. To address these needs and to create a culture more open to novel problem solving mechanisms, the HH&P created a knowledge management tool that educates employees about innovative problem solving mechanisms and assists them in selecting a project management approach given specific resources and constraints.

This tool, called the Solution Mechanism Guide (SMG) is a web-based, interactive guide that leverages existing and innovative problem solving methods and presents the information in a unique user experience so that the employee is empowered

to make the best decision about which problem solving tool best meets their needs. By integrating new and innovative methods with existing or traditional problem solving tools, the SMG seamlessly introduces open innovation and collaboration concepts within HH&P to more effectively address human health and performance risks. The SMG is aimed at teaching the features and benefits of novel problem solving tools such as open innovation to address human health and performance risks, as well as drive the necessary culture change to integrate these methodologies into day-to-day HH&P project management. This kind of hands-on experience and interaction will help technical personnel seek solutions outside of NASA and avoid the "not invented here" resistance to change.

The alpha-version was introduced to the directorate in a series of evaluation tests using focus groups in the summer and fall of 2013. Results indicated that users liked the overall look and feel of the tool (91%), found the tool easy to navigate and use (66%), felt that a lot of the information was new to them (78%), felt that the tool provided helpful information (75%), and thought that they would likely use this tool on the job (62%). Given this positive feedback, HH&P utilized the NASA Tournament Lab (NTL) to conduct a series of competitions on the TopCoder platform to develop the beta-version of the SMG, a web-based and interactive version that was completed in October 2014. This beta-version is currently going through evaluation testing utilizing a larger number of personnel to obtain needed feedback to further refine and finalize the features and content of the SMG for use by the HH&P directorate. We anticipate the SMG will be available to all employees in early 2015. Once fully implemented, objective (and voluntary subjective data) will be collected to determine the frequency of use, utility, and

ultimate effectiveness of the SMG. A great deal of interest has been expressed in the concept, design, development, and implementation of the SMG both within and outside of NASA, and we plan to share this tool with others to further improve the tool's design and use. The SMG may address the needs in other diverse organizations that seek to successfully implement and utilize OI activities within their organization.

Awards – Separating the internal "hero solver" from the external solver

As a Harvard Business School PhD student, Hila Lifshitz-Assaf, conducted a field study of the directorate's organizational change efforts, including adoption of OI methodology, from 2009 – 2012 which led to several findings that will aid the HH&P as it continues this effort. Her dissertation[12] included an in-depth longitudinal field study of NASA's experimentation with opening knowledge boundaries through Web platforms and communities that led to scientific innovation and significant R&D process and professional identity changes. Dr. Lifshitz obtained her PhD based on this fieldwork at NASA.

One finding was that all of the media attention was focused on the external prizewinners during the OI competitions (for example the winner of the solar flare challenge being recognized as a citizen scientist by the US Chief Technology Officer). In general, the feedback was that we had separated the internal hero scientist or engineer from the external winner.

To address this observation, HH&P conducted internal award ceremonies recognizing all challenge owners by senior management with some nominal cash awards. When further budget cuts occurred, financial awards were no longer possible, and NASA challenge

owners were recognized by senior management, certificates and recognition. For internal competitions (NASA@work), the focus shifted to non-monetary awards for solvers on the NASA@work platform. A series of NASA@work competitions were conducted to establish a formal award system for the NASA@work platform, and NASA@work participants were first asked for their ideas for non-monetary awards that would be meaningful to employees. Top submissions were then selected and included in a second challenge on the NASA@work platform in which employees could then vote for their favorite awards; those awards with the highest votes were then used to create the NASA@work reward system (six eligible awards as summarized in Table 6.0). This reward system has been created with solver input, adding more meaning and value to both the challenges and the rewards. Under this new reward system, winners have been recognized with options such as "lunch with the director" or experiencing a "cool NASA tour" at the winner's center. In conjunction with these types of awards, the HH&P continues to evaluate other performance awards to recognize those employees that are willing to try novel problem solving techniques.

NASA@work Reward System			
Winner Level:	**Description:**	**Reward:**	
NASA@work Challenge Winner	Win 1 Challenge and you are eligible to select any reward at the 'Challenge Winner' level.	**Astronaut Autographed Item:** personalized astronaut autograph for the winner	**Cool NASA Experience:** a cool tour for the winner at their center
NASA@work Challenge Pro	Win 2 challenges and you are eligible to select any reward at the 'Challenge Winner' or	**Recognition by Center Director and Agency Management**: a meeting or lunch with the winner's Center	**NASA External Public Recognition**: public recognition on the

	'Challenge Pro' Level.	Director and/or with Agency Management	NASA@work external website; tweets by multiple NASA handles
NASA@work Challenge Champ	Win 3 challenges and you are eligible to select any reward at the 'Challenge Winner', 'Challenge Pro', or 'Challenge Champ' Level.	**Item Flown in Space:** a NASA@work sticker-badge that was flown in space	
NASA@work Challenge Master	Win 4 or more challenges and you are eligible to select a reward at any NASA@work Challenge Level including the 'Challenge Master' Level.	**Social Media Recognition from Astronaut:** Social media recognition (e.g., Tweet) recognition from an astronaut	

Table 6.0, NASA@work Reward System

Empowerment

NASA@work drives employee empowerment by providing an easy to learn and use OI platform and by providing the opportunity to effectively collaborate across the agency in order to solve a common problem and/or reach a common goal. This resource becomes an opportunity for employees to connect and collaborate, building a strong network of subject matter experts across a highly effective organization.

The SMG empowers users to assess and select the mechanism that best suits their needs when addressing specific problems and/or risks. This increase in knowledge and

improvement in decision making will lead to the selection of the optimal problem solving tool, may reduce the cost of search (as evidenced by the VIIP example described above) and advances ongoing cultural change by promoting the use of OI problem solving tools.

Forward work

The directorate was reorganized and renamed the Human Health and Performance Directorate in late 2012 as part of the overall strategy execution effort. The HH&P has defined its portfolio of work through 32 human system risks and concerns, each of which now has a detailed risk analysis. This analysis contains a set of deliverables for research, technology and services aimed at mitigating the risk for long-duration human space flight. These risks are managed in a weekly Human System Risk Board (HSRB) where the progress of mitigating the risk is assessed against technical, cost and schedule issues. The HSRB now plans to use the SMG to help guide the approach to risk mitigation and to deploy novel problem solving means such as OI when indicated. The SMG provides the essentials of solution mechanisms such as contracts, small business proposals, grants, prizes, etc. The HH&P hopes to more routinely utilize novel problem solving tools such as OI by rationally assessing the risk mitigation approach and trying new methodologies where appropriate.

Another key product to develop is a set of comparative metrics across the various problem-solving methodologies. The HH&P plans to develop metrics that compare the effectiveness of various tools for cost, success rate, time for utilization (e.g., weeks versus months or years), and infusion into space flight solutions. These metrics will be captured in the SMG to better inform problem solvers of the utilities of various problem-

solving tools. Case studies (such as the VIIP example above) will be captured in the SMG to disseminate lessons learned for the training of all problem solvers.

Finally, NASA plans to expand the number of OI competition platforms through an open procurement as different platforms serve different needs for problem solving. Any platforms that are obtained will be managed under the CoECI umbrella, and will be included in the SMG to further disseminate the opportunities and lessons learned for all problem-solving tools available at NASA.

Conclusions

Since 2007, the HH&P has pursued and achieved a vigorous implementation of our 2007 strategy with significant results. We have improved collaboration through two virtual centers, produced early open innovation results that were widely recognized as the leading edge in federal agency innovation, conducted a comprehensive reorganization, and established a 2012 strategy based on the successful execution of the 2007 strategy. We correctly anticipated great change within NASA, charted an effective course of action to address current and future challenges, and continue to evolve with the development of the SMG to improve decision making and project management as a part of an overall strategic framework for addressing human health and performance risks in spaceflight. Our overall approach will now be to regularly asses our portfolio of work (the 32 human system risks), to utilize the SMG to routinely deploy novel problem solving tools such as OI, and to develop and disseminate comparative metrics highlight the value of novel problem solving tools.

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