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Open Collaboration: A Problem Solving Strategy That *Is* Redefining NASA's Innovative Spirit

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In 2010, NASA's Space Life Sciences Directorate announced the successful results from pilot experiments with open innovation methodologies. Specifically, utilization of internet based external crowdsourcing platforms to solve challenging problems in human health and performance related to the future of spaceflight. The follow-up to this success was an internal crowdsourcing pilot program entitled NASA@work, which was supported by the InnoCentive@work software platform. The objective of the NASA@work pilot was to connect the collective knowledge of individuals from all areas within the NASA organization via a private web based environment. The platform provided a venue for NASA Challenge Owners, those looking for solutions or new ideas, to pose challenges to internal solvers, those within NASA with the skill and desire to create solutions. The pilot was launched in 57 days, a record for InnoCentive and NASA, and ran for three months with a total of 20 challenges posted Agency wide. The NASA@work pilot attracted over 6,000 participants throughout NASA with a total of 183 contributing solvers for the 20 challenges posted. At the time of the pilot's closure, solvers provided viable solutions and ideas for 17 of the 20 posted challenges. The solver community provided feedback on the pilot describing it as a barrier breaking activity, conveying that there was a satisfaction associated with helping co-workers, that it was "fun" to think about problems outside normal work boundaries, and it was nice to learn what challenges others were facing across the agency. The results and the feedback from the solver community have demonstrated the power and utility of an internal collaboration tool, such as NASA@work.

I. INTRODUCTION

With a growing focus on, open government initiatives, NASA has proactively investigated, tested and proven the effectiveness of new business models, tools and strategies that support collaborative innovation and an increasingly open style of government. Specifically, the Space Life Sciences Directorate (SLSD) at NASA Johnson Space Center has experimented with a number of different innovation methodologies including: public crowdsourcing, consortium and partnership building and most recently an internal crowdsourcing platform. The goal of utilizing open innovation techniques, such as crowdsourcing and consortium based methodologies, is to take advantage of the power of groups of people/experts outside an organization to help solve problems or bring in new and novel ideas. In 2010, NASA completed two pilot programs with two companies, InnoCentive and yet2.com testing the external collaborative innovation components (Rando, Fogarty, Baumann, Richard, & Davis, 2010).

InnoCentive's approach includes leveraging the power of the crowd through an innovative methodology referred to as crowdsourcing. Crowdsourcing is a technique that leverages a group of global solvers and their expertise through competitions or challenges to produce solutions to problems an organization is facing or unable to solve from within. Yet2.com's approach and primary service is identifying and building a network of experts not traditionally reached through an organization's established routes, such as NASA's Small Business Innovation Research calls (SBIRs) or traditional market research activities. Yet2.com acts as a technology scout utilizing a proprietary database including contacts within small businesses, venture capitalists, independent researchers, academia, and entrepreneurs.

The challenges posted with the InnoCentive pilot yielded 11 awarded solutions out of seven total challenges posted. The six technical needs posted with yet2.com yielded a substantial number of contacts not previously identified through traditional partnership routes utilized by NASA. The results of the pilot programs illustrated the power behind these methodologies for solving tough problems and utilizing resources within the organization more effectively. The rationale behind open innovation methodologies and why this approach has proven effective is that innovation often occurs at the margins of disciplines and within domains that are not necessarily associated with the original problem area. The innovative idea often requires a fresh perspective from an individual or group not bound to the same constraints in thinking about the problem as the domain experts.

Based on the success of the external pilot programs, an internal crowdsourcing pilot program entitled: NASA@work was initiated. NASA@work is a web based platform supported and developed by InnoCentive. Unlike external crowdsourcing, the objective of an internal crowdsourcing based platform, such as NASA@work, is to leverage the breadth and depth of the expertise already present within the organization. NASA includes an extensive number of experts that are not only discipline diverse but are also geographically dispersed. This presents a challenge for NASA, specifically with being able to fully utilize its workforce and its resources that are spread across 10 centers agency-wide. The objective of the NASA@work pilot was to connect the collective knowledge of individuals from all areas within the NASA organization via a private web based environment. The platform provided a venue for NASA Challenge Owners, those looking for solutions or new ideas, to pose challenges to internal solvers, those within NASA with the skill and desire to create solutions.

II. METHODS

The pilot program began in June 2010 and ran through the end of October 2010. The program included a total of twenty challenges to be utilized across the agency. Two challenges were allocated per center including: Ames, Dryden, Glenn, Goddard, Head Quarters, Johnson, Jet Propulsion Laboratory, Kennedy, Langley, Marshall, and Stennis. Dryden and Marshall elected to defer their challenges and Glenn submitted one for program participation. The surplus challenges were redistributed by lottery to Head Quarters, Johnson, Langley and Ames (see Table 1). The development of internal infrastructure to support challenge development was critical and included the following roles: Executive Champion, Program Champions, Center Champions and the InnoCentive Program Management. The primary function of the Executive Champion was to facilitate the adoption of the program by leadership and personnel. Additionally, the Executive Champion was initially responsible for fostering an environment and culture of change through the organization. The role of Program Champion was essential to implementation of the platform, coordination of all Center Champion activities and managing the day-to-day business aspect of the program. The Program Champion was also responsible for development of infrastructure and resources to support the activity from a grass roots level perspective.

To support the program processes and challenge development at the center level, the role of center champion was created and assigned to personnel residing at each center. The Center Champion was crucial for providing center management assistance to the Program Champions and their home centers. Program Champions and Center Champions participated in all stages of the program and challenge process including: identification of challenge owners and challenges, technical review of challenge drafts, facilitation and review of challenge solutions and awards, and lessons learned debriefings.

The InnoCentive Program Management team provided extensive support to the NASA management team including: NASA@work platform capability training, challenge development, drafting and platform support throughout the pilot program. Between June and August the NASA and InnoCentive program teams completed the, Single Sign On implementation, technical development, training and solicitation of challenges. The challenge development workshops were offered to assist the centers with the identification and development of challenges. Challenges are focused problem statements that are written in such a way as to solicit input from a wide audience across NASA. The NASA solver community includes NASA Civil Servants and Contractors who have a username and password and access to the NASA domain. All were invited to participate. For the purposes of this paper, the solver community is further defined as those Solvers who signed into the NASA@work platform to view the challenges and those who actively contributed to discussions or provided solutions.

The program was divided into four phases that occurred over a three month period (see Tables 2-5). The challenges were posted in increments of five every two weeks and each challenge was open to Solvers for a period four weeks. The challenge owners were encouraged to interact and provide feedback to the contributing Solvers. Training was provided on the evaluation and rewarding methods that the challenge owners could employ. The challenge owners would have a total of two to four weeks to review the proposed solutions once the challenge closed. The challenges were marketed to the employees of NASA through headquarters emails that were sent broadly to all civil servants at all centers. Center specific email announcements were also sent to target the entire workforce at each center. Due to the abbreviated three month pilot schedule, only the minimum amount of communication was sent via email to ensure these messages did not become an irritation. With each new phase of the program and challenges, an email was sent to all solvers who had logged in to alert them that new challenges had been posted. Additionally, one final Headquarters email was sent to the Civil Servant distribution at each center reminding the agency that there were new challenges and to ignite healthy competition by highlighting the individual participation at each center.

The program was designed to provide an award structure that supported financial awards, recognition, and personal satisfaction. Each challenge provided a small cash award within existing NASA award programs, and each winning solver also received a certificate of recognition from the NASA Chief Technologist. Challenge owners had the liberty to award partial or multiple awards for incomplete solutions or good ideas from many solvers. In addition, challenge owners were also able to award certificates of recognition to those solvers who provided valuable input but were not necessarily the origin of the winning solution. Due to government restrictions, contractor employees were unable to receive any financial award from NASA associated with a winning solution. Contractors did receive a certificate of recognition from NASA for their contributions to a successful challenge solution and their parent companies were contacted independently to recognize their employees in a similar manner. All winning solvers and certificate of recognition recipients were also formally recognized in a ceremony amongst their peers at NASA's Project Management Challenge conference in February 2011. Additionally, each center/center champion was asked to coordinate a recognition/awards ceremony for the participants at their home centers.

III. RESULTS

The NASA@work pilot attracted over 6,000 participants NASA wide with a total of 183 contributing solvers for the 20 challenges posted (see Table 1). A total of 381 discussion posts were made by the solvers and the challenge owners. Across the 20 challenges 89% of all the submitted solutions and 67% of the total discussion posts came from personnel center outside of the challenge owner's home center. On average 4.3 centers collaborated with another center on each challenge. At the time of the pilot's closure, solvers provided viable solutions or ideas for 17 of the 20 posted challenges.

Phase I

The five challenges posted during Phase 1 (see Table 2) yielded 10 full and partial challenge awards and 8 certificates of recognition for the solutions provided during the posting period. The "Responsive Solar Cell for Variable Environmental Power Generation" challenge posted by Goddard awarded/recognized two solvers from outside and two from within Goddard for their solutions. The "Environmental Temperature Management During the Lunar Night" challenge posted by Johnson awarded/recognized two solvers from outside the center. The "Method for Detecting Particle Velocity and Size in a Hot Gas Jet" challenge posted by Kennedy did not award/recognize any solvers for this challenge. The "Creating a NASA Intern Space" challenge posted by Ames awarded/recognized six solvers outsiders Ames for their contributions. The "Cooling of a Self Contained Portable HSDAS Unit" challenge posted by Stennis awarded/recognized two solvers from other centers for their solutions.

Phase II

The five challenges posted during Phase 2 (see Table 3) yielded eight full and partial challenge awards seven certificates of recognition for the solutions provided. "The High Temperature Wire Attachment Method" challenge posted by Kennedy awarded/recognized three solvers from solvers outside the posting center. The "Low Impact Robotic Sensor Platform for Field Science" challenge posted by Ames awarded/recognized three solvers from solvers outside the posting center. The "Non-invasive Means to Detect Internal Leakage" challenge posted by Johnson awarded/recognized one solver from outside the posting center. The "Creating a Video Search Engine" challenge posted by Jet Propulsion Laboratory awarded/recognized three solvers from outside the posting center. The "Coordination of Sensor Swarms for Extraterrestrial Research" challenge posted by Langley awarded/recognized one solver from outside the posting center.

Phase III

The five challenges posted during Phase III (see Table 4) yielded 10 full and partial challenge awards and four certificates of recognition for the solutions provided. The "Explorable 3-D Interior of the International Space Station" challenge posted by Jet Propulsion Laboratory awarded/recognized one solver from outside the posting center. The "Determining the Outer Mold Line (OML) of an Inflatable Aerodynamic Decelerator" challenge posted by Langley awarded/recognized two solvers from outside the posting center. The "Increasing the Reporting of New Technologies with New Technology Reports" posted by Head Quarters awarded/recognized six solvers from outside the posting center. The "Alternate Approach in Design/Material for Electron Radiation Protection" challenge posted by Goddard awarded/recognized one solver from outside the posting center. The "Interactive 3-D Technology for Video Teleconferencing" challenge posted by Stennis did not award any solvers from outside the posting center.

Phase IV

The five final challenges that were posted during Phase IV (see Table 5) yielded 10 full and partial challenge awards and eight certificates of recognition. The "Adjusting the Cultural Paradigm to Enable the Proliferation of Web 2.0 Tools" challenge posted by Langley awarded/recognized three solvers from outside the posting center. The "Measuring Gas Concentrations in Microliter Samples" challenge posted by Ames awarded/recognized one solver from outside the posting center. The "Constant Force Loading Methods for Partial Gravity Simulation" challenge posted by Glenn awarded/recognized three solvers from outside the posting center. The "If and When Life is Discovered on Mars How Can we Determine if it is Truly Indigenous Mars Life" challenge posted by Langley did not award/recognize any solvers. The "Non-flammable Stowage Bags" challenge by Johnson awarded/recognized five solvers from outside the posting center.

Qualitative Results

Closeout interviews were completed with each NASA center. These interviews included the Center Champion(s), Challenge Owner(s). The results of the interviews showed that the platform created an environment where real time answers could be shared. It was felt that the agency wide collaboration will help with communication, creating new connections and, as summarized by one participant, "Bring attention to the Centers and Management the need for fresh ideas and perspectives to some common and old problems". Many felt that the tool highlighted their center's innovative culture and bright minds as a showcase to the rest of the agency. Additionally, challenges requiring technical results were far less successful than challenges that needed theoretical solutions. It was indicated that the available community to address a technical challenge may not be willing to spend the time it takes for a small reward. Challenge owners proposed solutions to the awards program that included everything from larger results based awards to removing direct financial inducements all together and offering long term assignments on funded programs instead.

A survey was conducted with the Contributing Solvers. A Contributing Solver is anyone who logs into the site and has posted at least one discussion thread, idea or solution over the 90-day program period. The total size of this group was 163 solvers who posted to one or more of the 20 NASA Challenges. A total of 50 solvers responded to the survey equalling a 30% survey response rate. The solvers that contributed solutions to the NASA@work site indicated that the number one reason for going to the site initially was the opportunity to solve, followed by curiosity and the chance to collaborate with fellow NASA colleagues. The solvers indicated that the pilot gave them the opportunity to "exercise" their mind beyond their current work load and a chance to learn about what is going on throughout the agency while participating in a program that is "barrier-breaking". 62% of the Solvers indicated interest in continued participation with the NASA@work program.

IV. DISCUSSION

It was found that certain challenges were more successful in attracting solvers and potential solutions than others. The challenges could be categorized into two types; technical and theoretical challenges. Technical challenges were those that required scientific detail and would often require significant effort to solve or locate a solver and solution that already exists. Examples of this challenge type include the "Outer Mode Line" or the "Sensor Swarm Challenges". Theoretical challenges were the type of challenges that required out of the box thinking or varied backgrounds were needed to contribute to a novel idea or solution. Example challenges that fit this category were "Life on Mars" and the "Web 2.0 Tools". The theoretical challenges generated more discussion posts as compared to the technical challenges. Consequently, the satisfaction of the challenge owners was significantly higher theoretical challenge owners. One hypothesis is that the award amounts are just not enough to draw in the time it takes to generate a technical solution. A second theory is that technical challenges have a limited pool of talent available or that the challenge owner's expectations were too high.

The solver solutions to the challenges could be placed into three categories including: 1) Random solutions were considered as the solutions provided by solvers without background in the challenge area who posted lower valued solutions. 2) Repeat solutions that have been seen and tried before but served to spark conversation in the group. 3) Revealing solutions included contributions that were responsible for the collaborative sparks where the dialogue was valuable in advancing the challenge. Future program efforts should focus on nurturing this environment of responses.

The key findings of the pilot program indicated that the future of NASA@work as a successful collaborative platform is attainable. Future implementation efforts should focus on the following areas: promoting and encouraging collaboration, assisting challenge owners in the development of problem statements for challenges, encouraging the organization to openly collaborate and evolve solutions, allow challenge owners to recognize contributions from solvers in a variety of ways, and provide feedback to the solver community and share success stories with the agency The results of this pilot have shown that to create a sustainable innovation engine within NASA, an engaged group of people is required to manage the process at each enter. The NASA@work pilot program and the Innovation Team at the Johnson Space Center's Space Life Sciences Directorate created a core team allocated to serve as this innovation catalyst. This established team will continue to play important roles in future programs and the open government initiative.

V. CONCLUSION

Innovation is an inherently social activity; the best ideas emerge when the questions that need to be asked are effectively identified and can be asked to a broad diverse audience. NASA@work provided the platform and ability for the community to share and collaborate on new ideas or important problems. The community faces various gaps in knowledge or technology within the organization. To reduce these gaps, project teams require an efficient and effective means to access a wide range of ideas. NASA@work highlights the efficiency of a collaborative innovation and challenge based process by tapping into the vast resources present across the agency.

Five common themes emerged from the NASA@work pilot evaluation. These five themes included: 1) NASA@work provided a new mode of interaction and demonstrated that the agency community was interested in participating and advancing the technical needs of the organization. 2) Networks and communities of practice can be identified via the platform and challenge owners and project teams can quickly identify and expand their existing network of experts for further collaboration. 3) NASA possesses a large degree of tacit experience because of its size and diversity. Drawing upon these experiences bring untapped expertise to current technological and research needs. 4) The timing is right to foster a collaborative environment utilizing an open system where good ideas can be shared and collectively refined to become great solutions. 5) Within the organization lays undocumented knowledge from the past 50 years of spaceflight experience.

The value of the NASA@work pilot was visible in the level of engagement that occurred across the agency. In a short three month period, 6,043 Solvers from ten centers joined the community. The ability to capture this experience in a structured and searchable format provides great long-term benefits. Organizations that have the courage and willingness to embrace an innovative methodology that creates an open and collaborative environment can achieve a sustainable culture of innovation.

VI. REFERENCES

Rando, C., Fogarty, J., Richard, E., Baumann, D., Davis, J. (2010). *Investment in Open Innovation Service Providers: NASA's Innovative Strategy for Solving Space Exploration Challenges*. Proceedings from the 61st International Astronautical Congress, Prague, CZ.

VII. APPENDIX

Center	**Challenges Posted**	**Registered Solvers**	**Discussion Posts**	**Challenge Participants**
Ames	3	310	18	11
Dryden	0	146	13	9
Glenn	1	467	12	9
Goddard	2	564	101	13
Jet Propulsion Laboratory	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
Head Quarters	1	267	15	9

Table 1: Challenge Participation at Each NASA Center

Table 1 displays the number of challenges posted per center, the number of registered solvers from each center, the number of discussion posts per center and the total number of challenge participants from each center.

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Challenge Title	Challenge Summary	NASA Center
Responsive Solar Cell for Variable Environmental Power Generation	Solar panels are of great utility for multiple NASA missions and are one of the novel technology foci indicated by the Office of the Chief Technologist. We are looking to increase the quantum efficiency of solar cells by gathering more wavelengths of light in the UV and IR range and being able to “tune” the wavelength window as conditions dictate. We would be interested in any ideas, theories, models, etc. that anyone has on the subject.	Goddard
Environmental Temperature Management During the Lunar Night	Temperate fluxations on the surface of the moon are extreme. Lunar daytime temperates can reach up to 400K and plummet to 40K during the lunar night. Considering the length of the lunar night is 14.75 days, it is imperative to manage environmental temperatures in order to ensure the survival of batteries and other critical systems. The objective of this Challenge is to identify novel means of moderating the environment temperature during the lunar night. The solution should be suitable for use at any latitude.	Johnson
Method for Detecting Particle Velocity and Size in a Hot Gas Jet	When a hot gas jet (1000 C, <3000 m/s) impacts a granular surface (<1 mm particles) at 90 degrees, particles are accelerated in all directions. We would like to map the radial distribution and velocities of particles coming out as a result of the jet interaction. Information about particle size and shape are also desired. The situation could be modelled, however that assumes you know something about the granular surface ahead of time like particle size distribution, particle shape and particle density. You would also have to take into consideration, particle – particle interactions which is much more complicated. What we really want to know is: At some fixed distance away from the center of the gas jet (radially), how many particles are present over time, what are their size, distribution and velocity (speed and direction)?	Kennedy
Creating NASA Intern Space	NASA Ames is considering developing a customized social networking and new media communications platform for use by NASA interns, mentors, and managers. Suggestions are being sought for what functionality such a site should have in order to make it applicable to all of NASA following its trial period at NASA Ames.	Ames
Cooling of a Self Contained Portable HSDAS Unit	The Seeker is looking for a method to cool down outdoor electronic equipment. The equipment is characterized as a portable, self-contained, high speed data acquisition system (HSDAS) which is housed in a Class II Division 1 Group B explosion safe enclosure (to ensure safe operation in a hydrogen environment). Due to heat generated by the electronic equipment and due to external heat (sun radiation and air temperature), an excessive amount of heat is accumulated near the electronics, compromising the safe and reliable operation of the unit.	Stennis

Table 2: Phase 1 NASA@work challenges

Table 2 provides the titles and summaries for the five center challenges posted during Phase 1 of the NASA@work pilot program.

Challenge Title	**Challenge Summary**	**NASA Center**
High Temperature Wire Attachment Method	The Electrostatics & Surface Physics Laboratory (ESPL) at the Kennedy Space Center (KSC) is developing a technology to remove or repel dust from surfaces electrodynamically. This work will support surface operations on the Moon, Mars, asteroids or other dusty bodies in space. The Electrodynamic Dust Shield (EDS) uses electrodes embedded in a surface to generate a multiphase travelling electrodynamic wave. To power the EDS, wire electrodes have to be attached to the Copper pads. A wire attachment method that is conductive, heat and vacuum resistant and can strongly attach to metal/polymer surfaces is required.	Kennedy
Low Impact Robotic Sensor Platform for Land Survey	Many regions of scientific interest are physically/biologically fragile. Because of their fragility, systematic human surveys can damage or destroy the scientific value of such sites. Good results have been obtained using small rovers, but they have limitations, e.g. evaluating instruments on booms allows sensing over/around obstacles, but leaves the rover unstable in rough terrain and aggravates instrument vibration, motion, and uncertainty in position/orientation. This challenge is seeking brainstorms and "eureka moments" for alternative sensor platforms.	Ames
Coordination of Sensor Swarms for Extraterrestrial Research	Within this Challenge a winning solution should provide an algorithm or protocol that describes how simple sensors (A) communicate information, amongst themselves and to a central data collector (B) make decisions about what to measure 'on the fly' or where to go if locomotion is possible. Swarming should result in emergent behaviour creating "intelligence" and have distributed coordination so that there is no single point of failure.	Langley
Non-invasive Means to Detect Internal Leakage	Many vehicle fluid and gas systems utilize redundant seals or check valves in series. Traditionally verifying the integrity of these redundant seals has required the addition of test ports which require additional seals that introduce external leak paths, additional weight and add system complexity. For the case where test ports are not possible due to extremely small volumes, limited access, weight constraints, etc. it sets up a situation where one seal could fail and personnel would not be aware they were down to one level of protection. The Challenge is to monitor the pressure in a small volume between seals (or valves) non-invasively.	Johnson
Creating a Video Search Engine	Video is an effective means of capturing data, such as, design reviews, or lessons-learned symposia. Once these data have been captured, however, we lack the ability to search for content within it at a later date. In response to this difficulty, we are seeking suggestions for ways to create a video search engine, a system to search for content within video data. We believe that most of the necessary technology for such a system either exists already or is nearing completion.	Jet Propulsion Laboratory

Table 3: Phase 2 NASA@work challenges

Table 3 provides the titles and summaries for the five center challenges posted during Phase 2 of the NASA@work pilot program.

Challenge Title	**Challenge Summary**	**NASA Center**
Explorable 3-D Interior of the International Space Station	To date a website does not exist that would allow anyone to explore the ISS interior. We are seeking suggestions on how to acquire, assemble and display ISS interior data that would best showcase this phenomenal NASA asset.	Jet Propulsion Laboratory
Determining the Outer Mold Line (OML) of an Inflatable Aerodynamic Decelerator	Inflatable Aerodynamic Decelerators (IADs) are being developed to provide aeroassist, heat dissipation, and control for advanced entry vehicles to deliver science payloads and humans to orbit or to the surfaces of planets and other bodies with atmospheres. There is a critical need to properly characterize the actual outer surface location for all flight states.	Langley
Increasing the Reporting of New Technologies with New Technology Reports	NASA ensures that technologies developed by the agency are protected and made available for commercialization whenever possible. The cornerstone element of that process is the filing of New Technology Reports (NTR) by inventors. The Challenge owner and NASA Headquarters are seeking to understand perceived impediments to filing NTRs and to identify innovative methods to increase the awareness and motivations for inventors to file NTRs.	Head Quarters
Alternate Approach in Design/Material for Electron Radiation Protection	Seeking new material systems/approaches for shielding electronics equipment and personnel from ionizing radiation, specifically electrons that can also provide improvements in costs, mass, machinability and availability. The ideal solution would be a material/series of materials/approach to achieving radiation shielding for electronics for 300 krad hardness with multiple mission applications. The challenge owner is aware of existing approaches and is looking for new alternatives.	Goddard
Interactive 3-D Technology for Video Teleconferencing	To provide more robust telecommuting experience for teleconference participants, the interactions must become more realistic and provide a sense of a face-to-face communication. This challenge is looking for a new working concept for such an integrated technology.	Stennis

Table 4: Phase 3 NASA@work challenges

Table 4 provides the titles and summaries for the five center challenges posted during Phase 3 of the NASA@work pilot program.

Challenge Title	**Challenge Summary**	**NASA Center**
Adjusting the Cultural Paradigm to Enable the Proliferation of Web 2.0 Tools	IT tools are often deployed without first gaining sufficient buy-in and guidance from end users within the community. As a consequence, some parts of the organization are well suited and positioned to use these new technologies and others are unprepared. This, in turn, hampers the full use of these systems by the community. The challenge owner is looking to understand the factors that play in effective web 2.0 deployments and develop methodology to ensure the custom broad use of new tools when they are introduced.	Langley
Measuring Gas Concentrations in Microliter Samples	Micro-fluidic and well-plate technologies are commonly utilized for bioassays, combinatorial chemistry, and cell culture experiments. However, valuable research in space science and biotechnology cannot be accomplished using these technologies without significant improvements in the ability to measure gasses in these systems formats.	Ames
Constant Force Loading Methods for Partial Gravity Simulation	A critical component of the exercise counter measure simulators is the provision of a subject load device which provides a gravity-replacement load to the human. For this challenge, a novel approach is sought, whereby force fluctuations remain within +/- 5% of the set point throughout the range of displacement (18 inches) and load settings (16 – 243 lbs), ideally in infinitely-adjustable (or very small, e.g., 5 lbs. or less) load increments.	Glenn
If and When Life is Discovered on Mars, How Can we Determine if it is Truly Indigenous Mars Life?	Proposals are requested for protocols that would increase the certainty that any life discovered during missions to Mars is indigenous to Mars and does not result from man's exploration of the planet surface ('Forward Contamination'). Input from biologists and experts in habitability and planetary protection is particularly welcome.	Langley
Non-Flammable Stowage Bags	Polyethylene stowage bags are also widely used onboard the International Space Station (ISS). In order to reduce the risk of a fire onboard ISS, these standard polyethylene (and therefore flammable) bags are stored in either non-flammable bags or a metal locker. This, however, does not provide their fire protection when the bags are not stowed.	Johnson

Table 5: Phase 4 NASA@work challenges

Table 5 provides the titles and summaries for the five center challenges posted during Phase 4 of the NASA@work pilot program.