Where Are the Flying Cars?

Will the digital revolution actually transform the process of innovation? A professor from NYU spent three years with NASA’s engineers and scientists to uncover the significant opportunities and challenges involved with new models for R&D work.

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It’s the 21st century, and despite an incessant buzz around innovation (not to burst your bubble), we see no flying cars, and have not returned to the moon since the ’70s. Can the new web-enabled models of innovation accelerate the pace of research and development (R&D) on these future-enabling technologies? What does it mean to be an engineer or a scientist in such a future?

Growing up, I hoped to fly on a daily basis with an android companion, and yet today I still drive to work and write on a computer that is only a thinner and faster version of the one I had as a kid. The only robot I have is a floor vacuum cleaner, which often gets stuck. What really happened? Is this the 21st century we dreamt of? This frustration of being nowhere close to our dreams led me to investigate how the digital revolution might change the process of scientific and technological innovation, and bring the future into the present.

In order to understand the future of R&D, I first want to put things in a historical perspective. Innovation was initially led by the lone-inventors, such as Leonardo De Vinci and other famous early thinkers, who worked in their local communities. Then, the Industrial Revolution hit in the 18th century, and the first labs were born. Ever since, innovation has been initiated mainly by experts organized as groups, and by labs within large private and public organizations. Innovation has mostly been a product of such organizations and their collaborations. Could this be the primary reason we are still stuck—the tunnel vision of experts, or the disabling nature of bureaucracy in such organizations? Some assert now is the time for change, to democratize innovation, and to use tools that digital revolution gave us to open the boundaries
of innovation process to everyone. Will the digital revolution be as transformational to the innovation process as the industrial one?

The new web-based models for innovation, usually referred as open, peer-production, or distributed innovation [1,2], is inspired by the open-source software movement. This movement has demonstrated the possibility of successful innovation outside the traditional economic, and organizational boundaries. Worldwide, thousands of individuals freely develop highly sophisticated products, successfully competing with dominant designs of an industry laden with proprietary software products. This phenomenon is now spilling over from software design to a wide array of product and service classes, and makes me wonder if the same philosophy, organizational structure, and openness can also produce scientific and technological innovation? As the digital footprint of many products increases and computational sciences become prominent, many argue that this will be the future of R&D. In order to better understand this potential, and the future of R&D, I went to NASA and researched its R&D processes for almost three years. This was before, during, and after they experimented with open web-based models for innovation as an approach for solving their most strategic R&D challenges. While there I conducted an in-depth longitudinal field study, which uncovered major opportunities and challenges involved in the open innovation model.

NASA AND OPEN INNOVATION
I began my study by first searching for leading organizations that were experimenting with new models of innovation. After interviewing many such companies in various sectors (such as IBM, Starbucks, Pfizer, Lego, and Procter & Gamble), I realized the open innovation model is often used for marketing reasons, with no interaction or impact on the core R&D process of the organization. However, upon meeting the head of Space Life Science at NASA (the U.S. National Aeronautics and Space Administration), I realized their approach was very different. NASA tackled their most strategic R&D challenges by experimenting through new online, open innovation models. They designed the open innovation experiment and held it simultaneously and in parallel with the traditional models to attempt to solve their technological and scientific R&D challenges. This meant their R&D professionals were deeply engaged in the experiment and formulated challenges for open innovation online platforms. This willingness to test new models of R&D fascinated me. Akin to an anthropologist going to the Amazon, I set out to the Houston Space center, equipped with my field research methodology tools, and ready to delve into the world of space and open innovation.

I designed my study as an in-depth longitudinal field study to be conducted at NASA's Space Life Science Directorate (SLSD) and in its related units between 2009—2012 (with periodic follow ups from 2012 to present). The SLSD focuses on research and development in life sciences. Its mission is to optimize human health and performance through all phases of spaceflight especially in response to risks, such as radiation, bone loss, and vision impairment (challenges similar to those described in the movie “The Martian”). In the three-year time period, I collected data and conducted iterative cycles of analysis and collection; both pre- and post-open innovation experiments. As the study was designed to be longitudinal, I collected all data before, during, and after the open innovation experiment. My aim was to understand the day-to-day experience of organizational members working in open innovation context. I, therefore, collected data from abundant sources, both qualitative and quantitative. My primary data sources came from field research methods like observation, interviews, and project work documents. I sought to immerse myself fully in the work-world of the people I was studying. For instance, I participated in a summer training session for interns, sat in weekly meetings, spent entire days in each of the numerous R&D units and labs, joined in conferences, as well as participated in the debriefing to astronauts on their last shuttle flight, which was also attended by friends and family. I

Table 1. The open innovation platforms and communities used by NASA Space Life Science Directorate

<table>
<thead>
<tr>
<th>Platform</th>
<th>Established</th>
<th>Registered Solvers</th>
<th>Type of Problems Posted</th>
<th>Range of Participants</th>
<th>Average Range of Awards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innocentive</td>
<td>2001</td>
<td>355,000 +</td>
<td>Scientific and technological problems, modular and complex</td>
<td>Wide range - scientists, technologists and business [Most with advanced degrees]</td>
<td>$10k$–$25k$</td>
</tr>
<tr>
<td>TopCoder</td>
<td>2000</td>
<td>400,000 +</td>
<td>Computer science and web design problems, mostly modular</td>
<td>Software engineers, computer scientists, web-designers</td>
<td>$1000$–$20k$</td>
</tr>
<tr>
<td>Yet2</td>
<td>1999</td>
<td>130,000 +</td>
<td>Technological problems, mostly modular</td>
<td>Engineers, technologists, entrepreneurs and small businesses</td>
<td>$5k$–$100k$</td>
</tr>
</tbody>
</table>
would start my mornings by reading space news and went to bed reading about life on Mars and why haven’t we made it there yet. I interviewed all the scientists and engineers in relevant labs; they shared their project documents, which enabled me to study further. I proudly wore a NASA name tag, albeit temporary, and people generously welcomed me into their professional world, for which I am forever grateful.

Once the open innovation experiment began, I collected data not only from NASA, but also from open innovation platforms. For instance, when looking at the external solvers who participated in the experiment, I gathered data on type and number, professional background, geographical location, proposed solutions, award amounts, and more. This comprehensive data collection enabled me to study the interaction between the traditional R&D model—that is, worldwide experts working in a leading organization—and the new world of online communities, hosting a wide range of professionals and amateurs looking to solve challenging problems.

**SCIENTIFIC BREAKTHROUGH AT AN UNPRECEDENTED SPEED**

NASA SLS&D’s R&D professionals decided to experiment with the usage of open innovation platforms and communities to seek solutions for some major R&D challenges in strategy planning for that year. The experiment, which was expected to last one year, was conducted in parallel with traditional R&D work on these problems. For one year, NASA’s R&D professionals worked on these problems both internally and contracting and collaborating with domain experts from other organizations, following the best practices of traditional R&D model. Simultaneously, they posted these challenges online on three of the most leading open innovation platforms and communities: Innocentive (https://www.innocentive.com/), Topcoder (https://www.topcoder.com/), and Yet2.com (http://www.yet2.com/) (see Table 1). On these platforms, anyone can try and solve these problems, usually members of such online communities come from a range of industries and have diverse professional backgrounds (from students, to working professionals and retired professionals, spread across the globe). The R&D professionals met with the platform providers a few times, who began the process by providing a one-day introductory workshop, and then created short problem descriptions that were posted online for two to three months on open platforms.

In total, 14 R&D problems from 11 R&D units related to a variety of scientific and technological fields like microbiology, heliophysics, mechanical engineering, radiation, material science, medical devices, and more, were posted on the three open platforms. These were the most important and strategic R&D challenges for that year. One hundred NASA professionals along with their collaborators and contractors worked on these problems; while 3,000 individuals from 80 countries belonging to various industries also worked on the same problem set on the open innovation platforms (see Figure 1). Three months after the experiment began, approximately 300 solutions were submitted. The quality of proposed solutions exceeded expectations and surprised NASA’s R&D. Upon evaluation, it was concluded that three problems were solved completely and four to six, partially. All the solutions were turned in within astonishingly short timeframes with a few even surpassing their solution criteria. In the speed and success of the open process was mesmerizing.

One solution in particular, became known as the “home run” of the open innovation experiment. Prediction of solar particle events, popularly known as solar storms (see Figure 2), is a well-known and well-researched problem both at NASA and within the global heliophysics community. Solar storms are extremely dangerous to current and future space missions and are considered a known threat to satellite-based communication. A severe solar storm could disable satellites and the Internet, ground all aviation, silence telecommunication...
tions, and damage the electric grid. Significant financial and intellectual resources are invested by the heliophysics community and radiation experts, within NASA and worldwide, towards the development of better solar events forecasts. At the time, the best algorithms could predict a flare just one to two hours in advance, with 50 percent accuracy and a two-sigma confidence interval. The open innovation challenge sought an algorithm that could predict an event anywhere between four and 24 hours in advance. This problem was posted in December 2009, with an award amount of $30,000. Within a three-month period, more than 500 individuals expressed interest in trying to solve this problem, and 11 submitted solutions. The winning submission came from a semi-retired radio engineer from rural New Hampshire. His solution brought an approach that was entirely outside of the discipline and traditions of heliophysics. Using ground radio-based equipment instead of the traditional satellite-based data, he created an algorithm that could forecast solar flares eight hours in advance, with 75 percent accuracy and a three-sigma confidence level, well beyond the expected result. When the heliophysicists and radiation professionals at NASA tested his solution on their operational systems, they achieved even higher accuracy between 80 to 85 percent. The head of the R&D unit that worked on this problem was stunned.

However, the story does not end with a rosy picture of scientific breakthrough, ribbons, and awards. Adopting the open innovation model raised several serious challenges that neither NASA’s management nor its scientists and engineers had foreseen. In particular, it led scientists and engineers to re-examine their roles and professional identities.

Figure 2. An example of a solar storm.
THE ROLE OF AN ENGINEER OR A SCIENTIST IN THE OPEN INNOVATION MODEL

Moving forward to integrate open innovation at NASA, turning the experiment into a day-to-day reality proved a far greater challenge than expected. The open web-based models raised multiple questions for the scientists and engineers. What does it mean to use such a model to solve all of their work projects? How will their roles be defined then? Should they continue in the same work model (in a lab, in an organization), or instead work like the scientists and engineers in open, online communities? These questions had no clear answers. The open innovation communities were preoccupied with their online participants. This left a lot of room for interpretation. Some scientists and engineers adopted this model and re-invented their role while others saw it as a threat to their identity and how they were trained and rejected the model completely. This ability to re-think one’s role turned out to be crucial in adopting new web-based innovation models [3].

Those who adopted this model and became orchestrators of external innovators invited everyone to solve NASA's problems, as they themselves developed new capabilities and skills to manage this new way of conducting R&D. They shifted their attention to the individuals outside the boundaries of their organization. One of the scientists addressed this approach in a blog post, calling on “you” (i.e., anyone) to become the next rocket scientist:

For over half a century, NASA has inspired people across the world to look to the heavens and wonder what secrets are hidden within the cosmos. Solving those mysteries has long been the domain of lab-coat wearing scientists in government agencies and universities. However, with the advent of the Internet, social web, and open source data, it has become possible for anyone to make scientific discoveries about our universe. Find out how you can actively contribute to space exploration and how the collective power of the Internet is enabling the future of scientific research [4].

Indeed, if you, the reader, want to be a part of solving NASA’s R&D challenges, there are two important initiatives aimed at opening NASA’s innovation process and adopting web-based models for R&D currently visit open.NASA (https://open.nasa.gov/) and the NASA Tournament Lab (http://www.nasa.gov/coeci/ntl).

This transformation raises questions about the type of training aspiring engineers and scientists should receive. The existing educational and professional training programs teach and reward individual problem solving, rather than producing solutions by orchestrating crowds of solvers or the integrating knowledge from different disciplines. As suggested in this study, a potential shift in the role of an R&D professional offers important implications for innovation-related policies, given that currently, resource allocation, incentives, and attribution and award systems all focus exclusively on problem solving and not on solution seeking.

An alternative approach to open innovation is not to define the roles of scientists and engineers in organizations, but rather let them select their role and their projects, similar to the model of the open innovation online platforms. These platforms and communities produce knowledge and innovation in a way that fundamentally stands in contrast to the control-based approach of regular organizations. Many scholars and practitioners question the efficacy of this open approach and its ability to produce stable and high-quality knowledge products. This issue led me to join a cross-disciplinary study that investigated how individuals take roles upon themselves in Wikipedia and whether over time, these roles create a cumulative stable production of knowledge. We found at an individual level, there was a high degree of mobility across roles and articles. Whereby individuals transitioned between roles and articles, and many got into the platform quickly, took a role in one article, and then left. Despite this freedom and mobility on the individual level, we found at the organizational level, over time, there was stability for these emergent roles. We called this dualistic nature of knowledge co-production “turbulent stability” [5]. These results suggest the plausibility of new ways of organizing for knowledge production, without traditional management mechanisms. Perhaps organizations need to see themselves as platforms with a small team of full-time employees working to orchestrate knowledge production and a large base of individuals who choose the right job for themselves. Think about it, if we each choose the right project and the right role for ourselves, will our creative prowess be unleashed and R&D productivity skyrocket?

References


Biography

Hila Lifshitz-Assaf is an assistant professor of information, operations, and management sciences at New York University Stern School of Business. She is also a faculty associate at the Berkman Center for Internet and Society at Harvard University. Her research received multiple awards and commendations, including the cross disciplinary INSPIRE grant from the National Science Foundation.

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