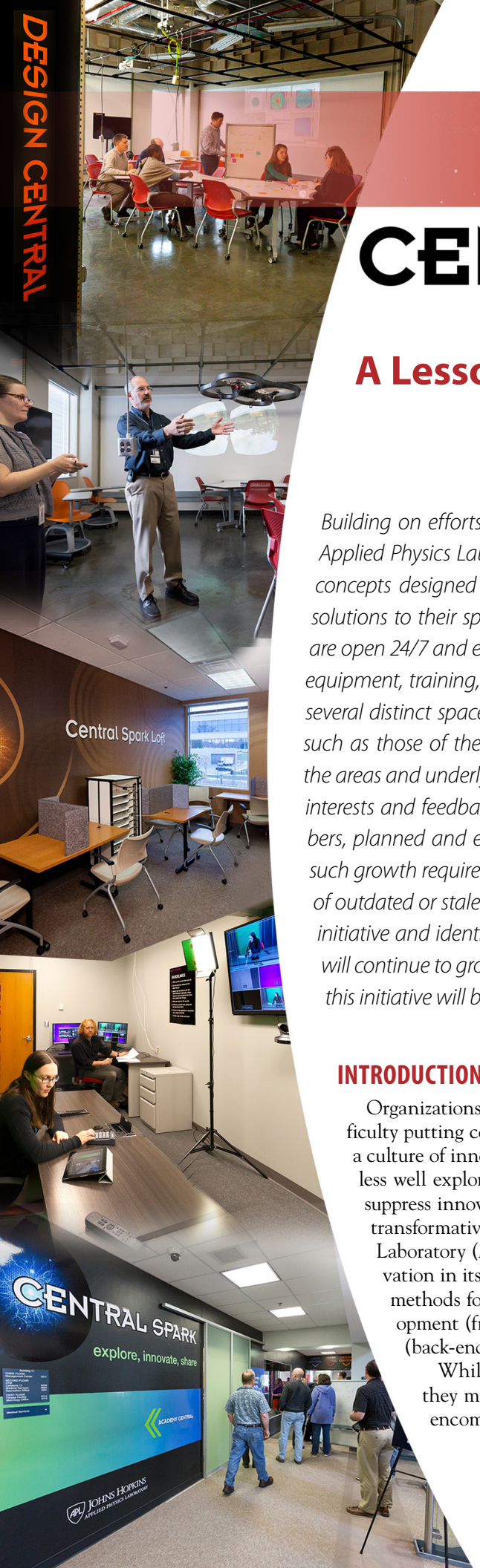

CENTRAL SPARK

A Lessons-Learned Perspective

Ann G. Darrin and Ann E. Kedia

Building on efforts to promote a culture of innovation at the Johns Hopkins University Applied Physics Laboratory (APL), Central Spark is a collection of exploratory spaces and concepts designed to provide APL staff members with new means to develop creative solutions to their sponsors' most difficult challenges. Areas associated with Central Spark are open 24/7 and encourage creative exploration and risk taking through the provision of equipment, training, and resources in a creative environment. Central Spark is made up of several distinct spaces that draw on recently popularized approaches to problem solving, such as those of the maker movement and design thinking, and Central Spark connects the areas and underlying concepts. It is a flexible facility that will evolve with staff members' interests and feedback. A diverse support base, including APL's leadership and staff members, planned and executed Central Spark to ensure future growth and success. Inspiring such growth requires ongoing assessment of effectiveness and performance and shedding of outdated or stale ideas. This article assesses the key factors that led to the success of this initiative and identifies areas for improvement. The recurring theme is that Central Spark will continue to grow and adapt as a framework for innovation, and lessons learned from this initiative will be applied to future innovation spaces at APL.

INTRODUCTION

Organizations talk broadly and urgently about the need for innovation yet have difficulty putting concepts into practice. There is a significant body of research on instilling a culture of innovation,[1] but introducing innovation into systems engineering practices is less well explored. However, evidence suggests that rigid systems processes can actually suppress innovation.[2] Because of its increasing need to conceive of and rapidly develop transformative concepts for sponsors, the Johns Hopkins University Applied Physics Laboratory (APL) was motivated to create an environment and culture to foster innovation in its systems engineering processes. APL introduced significant changes in its methods for concept formulation, mock-up construction, and early prototype development (front-end innovation) as well as in system design, integration, and testing (back-end innovation).

While most organizations create opportunities for innovation, to be successful they must also create and encourage a thriving environment of innovation that encompasses not only specific processes but also the organizational culture. The

APL Management Forum, a group of leaders representing each sector and department within APL, identified the need for APL to create such an environment. This article describes the approach to creating Central Spark, a flexible facility that provides an environment conducive to innovative thinking and problem solving, giving APL staff members the freedom to collaborate and develop ideas outside the confines of daily work assignments. It also describes methods of assessment used to evaluate the success of the effort to date as well as plan for the future.

With a staff of more than 5000, APL is a university-affiliated research center (a strategic government-sponsored research center associated with a university) whose mission is to develop practical solutions to critical challenges facing national security. In addition to national security work, APL participates in the full cycle of space exploration, from grant research through development and operation of spacecraft. This work increasingly requires creation of game-changing, or transformative, concepts. APL seeks to provide affordable capabilities with shorter development schedules and lower production costs by creatively adapting processes and managing risk.

In 2010, APL's Director launched a signature initiative to enhance the Laboratory's culture and practices of innovation by embedding approaches to innovation into APL's systems engineering practices. The first step was identification of culture-changing principles in the research literature; this was followed by development of a framework based on systems engineering principles. The systems-oriented innovation framework informs and organizes the design and introduction of new efforts. The framework features four phases:

1. Gain situational awareness and preparedness to ensure an adequate technology base
2. Identify key challenges and create conceptual solutions
3. Explore via prototypes
4. Transition to operational use

The initial focus of this innovation framework was on increasing staff awareness and preparedness by creating opportunities for the staff to participate, collaborate, and network. Early efforts included leveraging crowd-sourced ideas generated through seedling grants (a program APL calls Ignition Grants) and introducing

MORE ABOUT THE MAKER MOVEMENT

The maker movement is an extension of DIY, or do-it-yourself, culture, but with a greater focus on technology. It began in the mid-1990s when several new technology-focused nonprofit organizations provided equipment and facilities that allowed their members to work on technology projects individually or in collaboration with communities of experts.

Another event that helped spearhead the movement was the Massachusetts Institute of Technology (MIT) course "How to Make (Almost) Anything," which was first offered in 1998 and is still taught today. Developed by MIT professor Neil Gershenfeld, the course gave students the opportunity to work with laser cutters, 3-D printers, computer numerical control (CNC) machines, and other industrial fabrication equipment in a hands-on lab.

MIT later appointed Gershenfeld as director of the institute's new Center for Bits and Atoms (CBA), and starting in 2003, CBA began standing up fabrication laboratories, or "Fab Labs," around the world. Each Fab Lab is a maker lab that gives the local community access to a common suite of equipment—a rapid prototyper, a vinyl cutter, a laser cutter, a CNC milling machine, and an electronics workbench for prototyping circuits—with the goal of "democratizing access to the tools for technical invention." There are now nearly 100 such laboratories in the United States and more than 400 worldwide.

Makers use Fab Labs and other community-operated maker labs to pursue engineering-oriented endeavors such as robotics, electronics, and 3-D printing, as well as woodworking, metalworking, and traditional arts and crafts. Making is not necessarily synonymous with inventing, and therefore reuse of existing designs published on websites and in print is encouraged.

Enthusiasm for the movement has grown so much that makers now have a unique outlet to share their creations: Maker Faire. At Maker Faire events held annually around the United States and beyond, tinkerers and technology enthusiasts gather to share their work and celebrate the concept of making.

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design thinking and maker principles into the Laboratory's systems practices. APL also began to emphasize access to global technologies to search for enabling technology opportunities and potential research collaborators to feed concept development. Additionally, the Laboratory had the opportunity to explore a more innovative approach to agile engineering development as described below.

Review of the research literature emphasized the three P's—proximity, privacy, and permission.[3] The first P, proximity, is achieved via access to associates and shared resources and work areas. The second P, privacy, is reflected in a location where interactions are uninterrupted. The final P, permission, encourages use of the physical space and adoption of a culture that highlights informality and an element of free thinking with few rules. These terms, easily understood by staff, align with recent research[3–6] indicating that the most innovative teams, and even individuals, demonstrate a high degree of collaborative networking. Therefore, APL adopted these concepts as operating principles and focused on enhancing its work environment to empower its staff members to think beyond those problems assigned to them, engaging greater opportunities to join and create collaborative networks for learning and engineering. In addition, the Laboratory asked staff members to design their own innovation initiatives. Staff engagement is perhaps the greatest single indicator in the success of APL's innovation initiatives to date. Some of these efforts are discussed in the "Success Stories" section.

Central Spark is one result of this focus on innovation. It is a collection of exploratory areas designed to provide APL staff members with new means to collaborate, learn, and develop creative solutions to their sponsors' most difficult challenges. Central Spark is open 24/7 and facilitates a culture of innovation, creative exploration, and risk taking through the provision of equipment, training, and resources in a creative environment. Several distinct spaces make up Central Spark:

- **Academy Central** is an area where staff members can hold events focused on knowledge sharing and learning. Subject matter experts regularly share their perspectives in this space. Courses offered in Academy Central cover topics including environmental impacts on sensor and system performance, practical machine learning in MATLAB, Coursera, Arduino, and agile development.

- **Design Central** encourages and promotes design thinking, an iterative, exploratory approach to tackling problems by revealing the fundamental issues facing a project. The space is equipped with the tools and resources to support modeling and simulation, applications, gaming, and more.

- **Maker Central** is fitted with cutting-edge technologies and tools that staff can use to tinker, build, and create in support various types of work, including electronic, electromechanical, sensors, and robotics projects.

- **Media Central** has video equipment staff members can use to transform or explore ideas using high-quality visuals. The space contains fixed and mobile cameras, a green screen, and computers with professional video editing software tools.

- **Central Park** is a common area where staff members can pause and think, either individually or in small groups, outside of the main innovation areas. The space provides comfortable and movable seating and can be used for impromptu meetings, breakout sessions, and more.

- **The Loft** is a quiet space that provides an area for staff members from nearby buildings to work and think outside of the traditional office environment and then explore ideas in other nearby Central Spark areas. The space is equipped with a laptop docking and charging station, desks, and space dividers.
- **21 Spark Avenue** offers a large conference room for hosting meetings.
- **Agile Central** focuses on training, tools, and knowledge sharing in all areas related to agile software systems engineering and program management.

By creating this innovative environment, APL leadership hopes to achieve the following:

- Enhanced individual and group development through knowledge sharing (skill development)
- Networks through which to share ideas, concepts, and solutions
- Expedited access to both human and capital resources
- A collaborative maker environment within the Lab
- Connection to external innovation spaces
- Future solutions for sponsors through use of the maker infrastructure
- Increased external awareness of the initiative (from major conferences to journal clubs)

The concept of Central Spark is to provide social, organizational, and resource-driven support in a highly functional, innovative environment. The setting is intended to be inspiring and informal, giving users a place to think. As such, the effort is intentionally nonprescriptive; the areas' purposes and functions are intended to grow in an organic manner. The concept follows principles outlined in the *Harvard Business Review* article "Who Moved my Cube?,"[3] providing the three P's essential to a creative and innovative work environment.

MORE ABOUT DESIGN THINKING

Historically, design has occurred toward the end of the development process, and in some cases designers have had limited roles in developing and testing ideas before being tasked with turning those ideas into designs. With design thinking, creating solutions that meet users' needs is the emphasis, not a downstream step in a rigidly defined process. In addition to this focus on the user, multidisciplinary collaboration and iterative experimentation are also hallmarks of design thinking.

Tim Brown, president and CEO of the design and innovation consulting firm IDEO, defines design thinking as "a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success."

The process, applicable in any discipline or industry, is not defined by a set of linear steps, but rather a system of overlapping spaces: inspiration, ideation, and implementation. Inspiration is the circumstance that drives the pursuit of solutions; it could be a problem or a perceived opportunity. In the ideation space, ideas and potential solutions are generated, developed, and tested through rapid prototyping (development of quick and simple rather than complex and costly prototypes). Implementation is the "path that leads from the project stage into people's lives." Ideas often cycle though the first two spaces as they are explored and refined.

Design thinking principles have a natural synergy with concepts of the maker culture. Both movements promote innovation through collaboration, exploration, and creation.

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To implement these ideas, as a first step, the team built a framework using a shared vision. The second step, based on research, included pilot projects and testing. Next, the team analyzed and fine-tuned the vision and created a set of concepts of operation for the activities. The team engaged other staff members in all aspects of the development and operation, and a program manager oversaw all activities. Design thinking supported both the concepts of operation as well as the physical and virtual design of the space.

Additional factors critical to the success of Central Spark include:

- Staff empowerment in the design and development of the space
- Organic growth—evolution of the space through use of the space
- Trust—implementation of a set of minimum rules for use of the space
- Openness and flexibility to allow staff to easily access the space and interact with each other in the space
- Visible support from top management
- Endorsement by APL's Director
- Support of senior management
- Ongoing communication and marketing to maintain momentum and engagement with staff

The Management Forum captured lessons learned during a brainstorming session and then developed a report card to track metrics and to note areas for improvement and future growth.

CHRONOLOGY AND LESSONS LEARNED

The following sections describe lessons learned during the development and implementation of Central Spark.

2012–Spring 2013

Build a Framework/Develop a Model

The Management Forum held two planning meetings dedicated to developing concepts for creating a cultural change that would foster a more innovative environment. From these meetings and intensive literature searches, a plan, customized to APL, was developed, with activities starting in the spring of 2013.

Spring–Fall 2013

Develop Pilot Projects and Test—Build on Past Successes

During the summer of 2013, separate pilot projects explored both the maker space concept (with Arduinos) and design thinking. Ignition Grants funded these two projects. The grant process is community driven and promotes discussion and debate, with staff members voting on finalists. These two teams determined that their impact would be greater if they joined forces and opted to combine. A cross-enterprise team conducted additional research by attending the Maker Faire.

Fall 2013–Winter 2014

Create a Shared Vision and Build a Set of Concepts of Operation

In the fall of 2013, the Management Forum wrote a white paper describing the shared vision of Central Spark. The team developed concepts of operation for each of the elements of the facility, following the three P's. In addition, the team detailed the overall management of the facility. The goal was for staff across the entire Lab to have a stake in the success of the endeavor, and achieving this goal was also a key consideration.

Create a Movement—Let the Staff Lead

Because of the government sequestration in the fall of 2013 and increased pressure to conserve resources, the decision to move forward was deferred until late December/early January 2014. At that time, the Management Forum decided to proceed with the proposed plan, which APL's Director would announce to staff at an all-hands meeting in April. Immediately after the team made the decision to move forward, it shared the vision and solicited input from approximately 75 staff members. Many of these staff members are still activity involved in the initiative.

January 2014

After presentations to the APL's Director and his investment strategy team, funding was approved and implementation began. Individual design teams met and finalized requirements. Demolition of the existing space began. Designs were finalized and long-lead construction items were purchased. Branding concepts, including a website and videos, were reviewed and finalized.

February 2014

Construction commenced. Staffing and initial concepts of operation were developed. The Central Spark website, where staff could easily access information, ask questions, schedule or attend events, and generally learn about what was happening in the space, was beta tested.

March 2014

Construction was completed, smaller rooms were furnished, and the Maker Lab was moved into the Maker Central space.

Spring 2014

A great deal of attention was devoted to planning the roll-out of Central Spark. The team developed a formal orientation program with trained guides, and hundreds of staff members participated in orientations. There was a soft opening to assure that everything was in place, and classes provided staff members with information and access. Key to success was the use of APL's custom social networking site (Cooler) and the dedicated Central Spark website.

April 2014

Class schedules and informational and training videos were posted, and after an opening ceremony, Central Spark opened for innovation!

MEASURES OF SUCCESS

APL is endeavoring to measure the value of its initiatives to increase innovation. It has developed measures and indicators of progress, a relatively unexplored area in the literature, by identifying candidate leading and lagging indicators of innovation. These measures, when analyzed as a group, serve as potential indicators of innovation. The team

is now collecting data for analysis. Preliminary results indicate that the initiatives are beginning to change APL's culture in key areas and are yielding new concepts. There are also soft success factors, such as staff engagement, new hires inspired to join the Lab, and the ability to showcase capabilities for sponsors.

With regard to leading indicators of front-end innovation, the premise, based on the literature, is that staff who voluntarily participate in activities online or in Central Spark (i.e., exhibit empowerment) will engage in networking and collaboration (i.e., exhibit permission and proximity). The team can measure related initiatives to get a sense of leading indicators. For example, APL produces a series of short videos, called Tech Splash videos, that explore and explain some of the Laboratory's most intriguing innovations and ideas. Video views are tracked. The team also measures popularity and participation levels across the APL's innovation initiatives by reviewing online participation statistics and conducting staff surveys.

To date, APL's innovation experiments have been more popular than expected. For example, in the first 3 days after Central Spark opened, nearly half of APL staff members visited the center. Training for Maker Central activities and in design thinking had a monthlong backlog for 6 months even after more courses and volunteer teachers were added; the training is still in strong demand.

However, the bottom line for front-end innovation is results—that is, new transformative concepts that are sufficiently compelling to attract additional funding for development and, ultimately, fielding to the satisfaction of the users. This is clearly a lagging indicator, but already the team can measure the number of new concepts that likely would not have been identified otherwise, as well as which of those concepts are continuing to attract either internal or external funding. For example, APL's annual number of invention disclosures increased by more than 80% when the Ignition Grants program was introduced in 2011 and has continued at nearly this rate every year thereafter. This indicates either an increase in the number of concepts or at least an increased awareness in the value of reporting them. The team is monitoring what fraction of new Ignition Grant-funded concepts continues to be pursued, indicating the perceived value of the concepts.

SUCCESS STORIES

We designed the Central Spark space with the three P's— proximity, privacy, and permission—as a framework, and there are many success stories that illustrate these concepts. Central Spark provides staff with easy access to resources (space, supplies, and other staff) and an open culture where chance encounters and serendipitous interactions are encouraged and positive outcomes have a much higher chance of producing results.

Maker Central Courses Improve APL Technical Interaction

Many APL staff members have attended training courses showing them how to use the equipment (e.g., a CNC machine and 3-D printers) in Maker Central. Staff members in APL's machine shop as well as in engineering roles have described improved and more efficient interaction as a result of this training. The engineers now better understand the equipment limitations and the manufacturing terminology, which has resulted in better outcomes for APL's sponsors (e.g., 3-D printing and additive manufacturing) as well as improved skills of and relationships among staff members.

Courses Spark Staff Interaction and Potential Solutions for Sponsors

In Academy Central, staff members identify courses they would like to teach and take. Staff members volunteer to design and teach courses to share their knowledge and, in the process, expand their interconnections with other staff members who have similar or adjacent interests. These interactions have led to the emergence of potential sponsor solutions.

The Arduino course has been one of the most popular courses. This course was funded by an Ignition Grant and is offered to APL staff. Several staff members who took the course and previously did not know each other decided to collaborate on a sponsor problem one of the staff members was working on. They volunteered time in Central Spark and then ultimately received funding to develop a communications solution using equipment and electronics provided in Central Spark. Development of the system prototype was successful, and the prototype is now being demonstrated to sponsors.

Seedling Grant Transitions into $500,000 NASA Grant

In addition to the successes of Central Spark, other innovation efforts have achieved great results. For example, in 2010, APL staff presented a "what-if?" idea, Swarm Flyby Gravimetry, as a poster at the Low-Cost Planetary Missions Conference. In 2012, the APL team further developed this idea and won crowd-sourced funding through the Ignition Grants initiative. The Ignition Grants experience gave the APL team enough confidence that it could credibly seek external funding. In 2014, the team pursued external funding, and the idea was selected for a NASA Innovative Advanced Concepts (NIAC) phase 1 grant of $100,000. This NIAC phase 1 research established feasibility, gave preliminary performance estimates, and culminated in a paper that was presented at the American Astronomical Society conference in January 2015. Based on the phase 1 research, the idea was selected for a NIAC phase 2 grant of $500,000. This transition from a "what-if?" idea to phase 2 NIAC funding is illustrative of the innovative outcomes APL is striving to create.

NEXT INNOVATION SPACE CONCEPTS

Some of the key qualities of the Central Spark design, including open access to capabilities, an architectural layout that encourages teaching and collaboration, simple procedures based on trust, and cutting-edge equipment, should be scalable. APL management recognizes that lessons learned during the Central Spark experiment are not only valuable in enhancing the use and capabilities of Central Spark but are also valuable when taking the concept to the next levels of scale.

The next opportunity to put the lessons learned into practice is with the establishment of a first-in-kind (for APL) center of excellence called the Intelligent Systems Center (ISC). It is expected to cost about an order of magnitude more than Central Spark. The goals for this center include the following:

- Encourage new cross-disciplinary concepts by bringing together, in a single location, experts and their labs from multiple disciplines including information sciences, robotics, autonomy, and neuroscience.

A concept drawing of the exterior of the ISC.

A concept drawing of the interior of the ISC.

- Provide an open campus setting outside APL's primary security perimeter to facilitate visits and resident collaborations among students, faculty, and international researchers.
- Provide an architecture that enables mobility of a wide variety of robot configurations.
- Provide connection to satellite facilities for special applications.

Specific lessons learned from the Central Spark facility that are being applied to the ISC include the following:

- Offer an open lab layout but include features that facilitate private conversations and individual privacy.
- Let staff design the layout and concept of use.
- Ensure adaptability and flexibility in design.
- Empower users to reconfigure and adapt the space.

Beyond the ISC, scheduled to open in December 2015, plans are underway for construction of a new APL building. Its design is expected to build from the lessons learned from both Central Spark and the ISC. Plans for the building will be finalized after more experience and lessons learned are gained; a potential ground-breaking is planned in 2017. The building is expected to:

- House the Research and Exploratory Development Department staff
- Along with the APL Space Center, solidify the APL South Campus as an open campus for noncleared collaborators and visitors
- Feature more open-access centers of excellence
- Include the latest design thinking on providing a climate conducive to innovation and creativity through a combination of open design yet private alcoves and meeting rooms

SUMMARY

Through innovation initiatives to empower and network its staff, APL has recast its systems engineering repertoire to include the following:[7]

- Popularization of design thinking and crowd sourcing to create conceptual solutions to particularly difficult problems during concept development
- Introduction of gaming methodologies for developing and testing concepts of operations
- A library of models and simulations that can be reused and modified for analysis of concepts during engineering trade-off studies
- Training and tools to build "apps" as prototype software
- Training for prototyping and experimentation via a new, open-access maker space to learn new fabrication and prototyping techniques, with such tools as 3-D printers, numerical milling machines, and popular computer processors
- Improved access to collaborative opportunities and awareness of expertise across and, increasingly, outside the organization

These innovation-promoting efforts are ongoing systematized activities and therefore will continue to grow and evolve. The next phase will include extensions and enhancements to the current Central Spark space, creation of additional flexible maker spaces supporting staff working on direct and indirect projects, and creation of additional small test set-up areas.

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CENTRAL PARK

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