

# Inspiring Innovation and Creativity at APL

Ann E. Kedia and Jerry A. Krill

## ABSTRACT

*Since 2010, the Johns Hopkins University Applied Physics Laboratory (APL) has been executing a strategy to enhance innovation at the Lab, both in its culture and in its practices. The expectation has been that this environment will increase the prospects for APL staff members to create new defining innovations—game-changing developments that profoundly advance science, engineering, and national security capabilities—even as the global innovation ecosystem rapidly changes. Established research findings on innovation principles, along with APL’s own experiments, informed the development of an integrated, complementary suite of innovation initiatives. This article tells the story of how these initiatives were introduced and how they have impacted, and continue to impact, APL’s culture and creative ideas.*

## INTRODUCTION

One of the good ideas Steven Johnson recounts in his book *Where Good Ideas Come From*<sup>1</sup> is the creation of satellite navigation. Its inventors, William Guier and George Weiffenbach, describe the innovation climate at APL in the late 1950s when they conceived of this innovation: “APL was a superb environment for inquisitive young kids [i.e., early-career staff]. . . . It was an environment that encouraged people to think broadly and generally about task problems, and one in which inquisitive kids felt free to follow their curiosity . . . [and after] an initial success could turn to colleagues who were broadly expert in relevant fields.”<sup>2</sup> They recall the APL cafeteria as “a site of productive shoptalk between the physicists, technicians, mathematicians, and proto-hackers who worked there.”<sup>1</sup> Johnson attributes APL’s success to its being “a platform that encouraged and amplified hunches, that allowed those hunches to be connected

with other minds that had relevant expertise . . . an environment that let two ‘kids’ stumble across an idea at the cafeteria and build an entire career around it.”

During this same time frame, APL researchers conducted experiments with captured German V2 rockets, snapping the first photos of Earth from space.<sup>3,4</sup> After the V2 rocket inventory began to run out, APL leaders partnered with Aerojet to create the first research rocket; it was aptly named Aerobee—*Aero* for Aerojet and *bee* for APL’s Bumblebee program.<sup>3,4</sup> Investigators also invented and tested the electricity-foraging automata, Ferdinand and the Beast, during that time.<sup>5</sup>

Over the decades as APL grew, so did the complexity of the tasks the government asked APL to tackle and the rules and oversight audits the government imposed on the work. Cafeteria conversations often gave way to quick lunches at desks, formerly broad work statements

were finely chopped into narrow task descriptions, and even a walk around the APL pond—a favorite walk during which to discuss technical problems—proved infeasible because the Canadian geese had established residency and maintained their dominion near the pond with many “land mines.”<sup>6</sup> Buildings that had contained relatively open and collaborative laboratory spaces gave way to specialty labs and mostly semiprivate staff offices in the evolution of work spaces.

At the same time, global trends in science and technology (S&T) began to change with increasing speed. Once the province of US government funding, with access allowing labs like APL to receive advance notice of new developments, S&T was becoming increasingly global and commercial. This change meant that

research breakthroughs might occur at any time and any place, potentially limiting the ability of government-aligned organizations like APL to respond quickly to the opportunity or threat that such breakthroughs might represent. Further, the breadth of global S&T expanded greatly to include such new disciplines as cyber and biosecurity. Breakthroughs increasingly occurred in the seams between technical and scientific disciplines, thus requiring increased multidisciplinary collaborations.

As the 2010 decade dawned, APL director Ralph Semmel realized that even though the Lab was doing quite well with a broad sponsor base and in key strategic roles, global events required it to “up its game” in innovation and to even surpass the “hotbed of innovation” that it had been described as decades earlier.<sup>1</sup> Achieving this



Figure 1. Timeline of APL strategic initiatives and innovation enablers.

vision would require an expansive, well-executed strategy based on internal experimentation and established research on innovation principles, while always looking to increase APL's impact in providing critical contributions to critical challenges. A look back on the decade shows how this vision was achieved.

## LAUNCH OF THE STRATEGY

In 2011 the director and APL's Executive Council (EC) embarked on a series of strategic decisions and experimental initiatives in key directions to enhance efficiency, excellence, and innovation at APL. These forward-leaning initiatives spanned the entire decade,

as illustrated in Figure 1, and many directly impacted culture and creativity at APL. This article describes many of the initiatives.

One of the first strategic decisions was also to eliminate a number of policies and procedures to help transform a workplace bound by highly regulated practices to one of empowerment and measured risk-taking. Rather than continue in an environment where staff members are hesitant to explore ideas for fear of rules hindering their pursuit, the EC and director wanted to create a culture where staff members confidently pursue their good ideas and feel empowered to act. Dr. Semmel selected one of the most unpopular policies, one prohibiting Frisbee playing on the Central Green (a large outdoor area in the middle of the Lab's main campus), as the first to

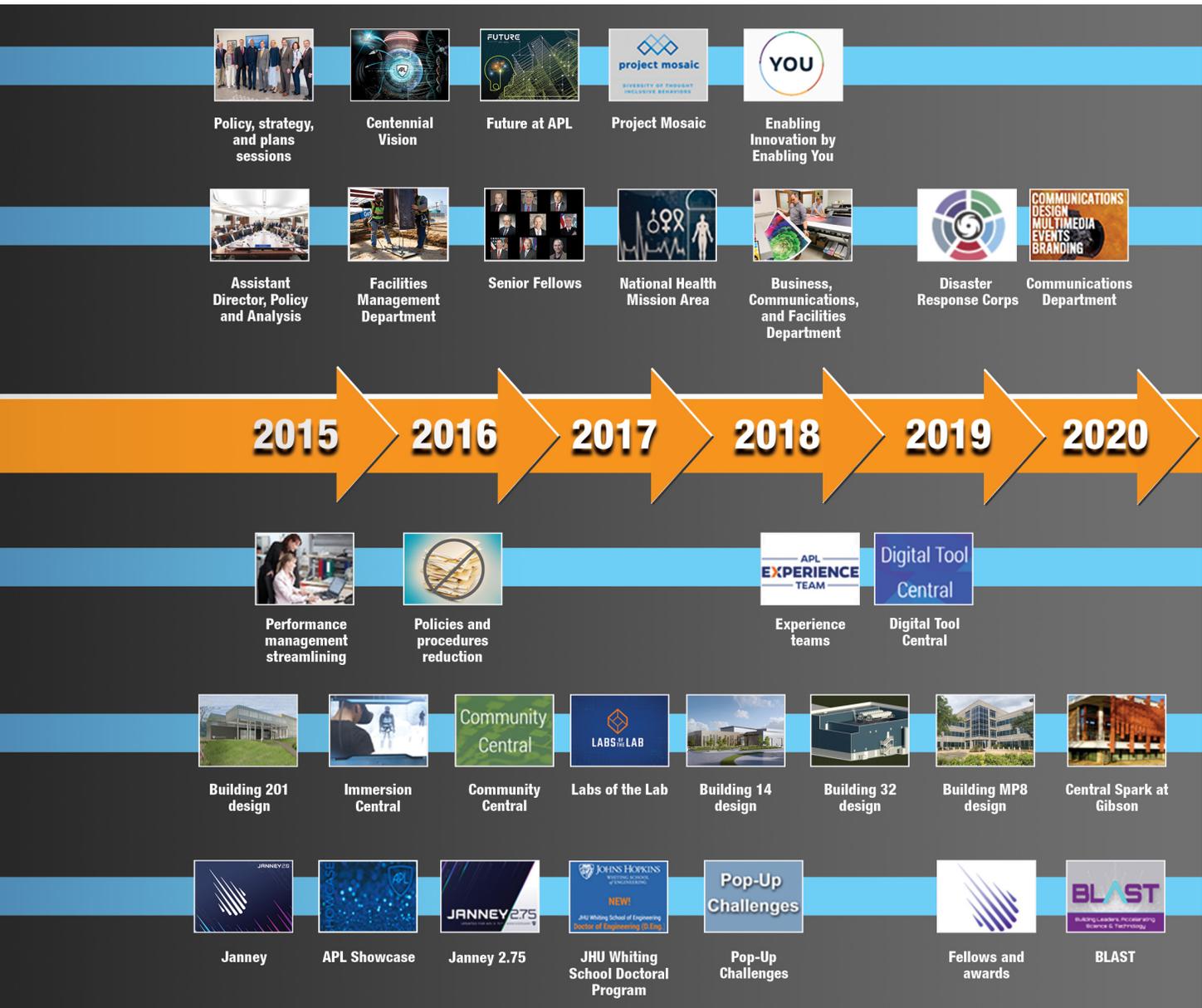


Figure 1. (Continued) Timeline of APL strategic initiatives and innovation enablers.

eliminate, and he would announce it while unveiling the first major innovation initiative.

### The First Major Initiative: Ignition Grants

APL's first formal Labwide innovation experiment, the Ignition Grants<sup>7</sup> program, was designed to encourage and stimulate innovative ideas and invite participation by all staff to foster and deepen the culture of creating game-changing concepts. The program was designed to provide seed funding for exploration of bold, long-term concepts beyond more traditional nearer-term projects. The idea was suggested by APL staff members, who also played a major role in designing the grant selection process.

The program comprises multiple annual cycles of themed technical challenges. Staff members can propose solutions to the challenges to compete for funding for short-duration, small-budget grants to explore their ideas. Individuals or teams post descriptions of their ideas on APL's online idea platform, where the APL community can provide immediate feedback on and suggestions for improvements to the proposals. Staff members then vote online to select the top proposals for funding. Winners receive grants that can fund up to 160 hours of staff time to conduct initial research, undertake feasibility studies, and perhaps even build early prototypes. Not only are the top-voted proposals funded, but their exposure also gives program managers the opportunity to provide additional funding to ideas of particular interest to them. Generally, 12 to 17 Ignition Grants are funded each year.

At a town hall meeting, Dr. Semmel announced the new program and the culture shifts underlying it. After describing the Ignition Grants initiative, he tossed into the crowd inaugural Frisbees that had been branded to



**Figure 2.** The commemorative Ignition Grants Frisbee. Tossed out by Dr. Semmel at the unveiling of the Lab's first formal innovation program, the Frisbee served as notice that things were changing at APL and that the Ignition Grants initiative was only the beginning.

commemorate the event (Figure 2). He then invited the staff to adjourn to throw the Frisbees on the Central Green to signify a new era, a culture of "yes."

The first cycle of Ignition Grants proved popular, and many staff members commented that introducing the program was a bold move and that the crowdsourcing process for selecting winners showed that management trusted them. Since the inception of the program to the time of this writing, more than 1,200 ideas have been proposed and voted on by more than 2,600 people (>35% of the staff). Within 2 years of the policy banning Frisbees on the Central Green being rescinded, the number of policy documents was reduced by almost 75%, from over 300 policies, with those policies remaining generally related to legal or regulatory requirements.

Some of the creative ideas born out of the program include an inexpensive, satellite-linked expendable buoy<sup>8</sup> to measure ocean waves; a civilian cybersecurity program that crowdsources threat detection; and a novel concept for an inexpensive earplug, the Anti-Blast Earplug (ABLE), to protect warfighters' hearing against explosive blasts.<sup>9</sup> The ABLE went on to win an APL annual prize for best Ignition Grant of the year for creativity and potential for impact.<sup>10</sup>

The program has continued to expand, with challenges seeking solutions in response to world events. In 2017, after Hurricane Maria, APL technical experts in communications volunteered to help restore communications in Puerto Rico. In 2018, when a soccer team was trapped in a flooded cave in Thailand, APL staff members recognized that their critical expertise and technologies were suited for assisting in the rescue. However, lack of connection with the rescue team prohibited a practical response. The standing senior advisory group (SAG) of chief scientists, engineers, and analysts that the director had established was convened to advise on matters of innovation and technical initiatives. The SAG agreed that APL could play a role and that many staff members would be interested in contributing their capabilities in disaster responses. Seeing the broad staff member interest in assisting in these two events, APL leadership concluded that the Lab could play an essential role in disaster recovery through the appropriate channels. The result was the concept of the Disaster Response Corps, a joint venture between APL's National Health and Homeland Protection Mission Areas. It leveraged these mission areas' strong preexisting partnerships with the other Johns Hopkins organizations already well integrated with the national and international disaster response communities.

To introduce the initiative and gain insight into the potential technologies, expertise, and operational experiences of APL staff members, the Humanitarian Engineering and Logistics Preparedness (HELP) Ignition Grants cycle was launched. Participating staff members were challenged to (1) propose technologies already

developed for other programs that might be applicable in disaster situations; (2) identify any relevant staff skills and expertise, such as Navy scuba diving or licensed ham radio operation; and (3) propose new capabilities that could be developed if funds were provided. After an overwhelmingly positive response from staff members, the Disaster Response Corps was armed with a database of internal capabilities to support many of the core functions of disaster response.

The HELP Ignition Grants cycle led to several successes, earning it a 2019 Impact Award from Innovation Leader.<sup>11</sup> For example, during the 2019 Ebola outbreak in the Congo, the smartphone application used to track pre-infection activities of infected individuals for contact tracing would not operate because there was no internet service in the region.<sup>12</sup> APL staff members were able to leverage their technical expertise to modify the application with the data accessed and stored locally, and this technical modification restored the application's operational capability in the region.

Another example is the design and implementation of software that processed large image data sets from aerial and space assets. Using deep-learning algorithms designed to find flooding, blocked roads, and damaged buildings, the team created files viewable via Google Earth and other geospatial visualization tools. They leveraged experience with geospatial information systems engineering, image processing, machine learning, and human-computer interaction to provide a solution that was used during the aftermath of Hurricane Dorian in 2019.<sup>13</sup>

The Ignition Grants program has also found success outside of APL. As US government sponsors learned of the quality and creativity of winning Ignition Grants ideas, some asked to fund their own challenge cycles to inspire ideas for particularly difficult problems they are trying to solve. During these cycles, called Pop-up Challenges, each participating sponsor selects proposals for direct funding. Observing the results of this initiative, APL's parent organization, Johns Hopkins University, decided to launch a university-wide version of the approach, known as Idea Lab.<sup>14</sup> Other research laboratories have adopted similar approaches.

The success of the Ignition Grants program is evidenced by the level of staff participation and the quality of ideas, as well as by other organizations' adaptations of the concept for their own use. At the end of the program's first year, annual APL intellectual property (IP) disclosures had jumped 80%, attributable in large part to the number of new ideas born out of the Ignition Grants program. Over the last decade the number of annual APL IP disclosures has risen by a factor of nearly 2.5. Since the number of APL staff members has also increased, it may be more appropriate to consider the growth in the number of IP disclosures per technical staff member. By that measure, the number of IP dis-

closures per technical staff member has grown by more than 100% over the last decade.

## Management Forum

With the first innovation initiative, Ignition Grants, underway, the next step was to create a senior team responsible for proposing and executing innovation and staff development initiatives as part of a comprehensive program. APL already had two executive forums reporting to the EC. The Mission Area Forum, led by the assistant director of programs and consisting of all mission area executives, coordinates program portfolios, sponsor needs, and opportunities to ensure multi-mission collaborations, as appropriate. The Operations Forum, led at the time by the assistant director of operations, consists of the operations executives from across the Lab and ensures efficient and effective operation of business, information technology (IT), and human resources systems. However, the "line side" of the executive leadership, the managing executives, were not members of either forum but still had the responsibility for staff development and technical excellence, with the majority of the staff reporting to them via branch and group supervisors.

To bridge this gap, the EC established the Management Forum, led by the assistant director of science and technology and consisting of managing executives responsible for staff development and Labwide innovation initiatives. Before this new forum was created, the Information Technology Services Department had initiated a program, called Connexus (pronounced "connects us"), to better foster staff collaborations using IT tools. This program was transformed into the APL Innovation Program Office, charged with implementing the innovation initiatives identified by the Management Forum.

In preparation for APL's 75th anniversary that would occur in 2017, Dr. Semmel led the EC through a reexamination of APL's core purpose, big hairy audacious goal (BHAG, a term coined by Jim Collins and Jerry Porras<sup>15</sup>), core values, and future vision, together known as the Centennial Vision (shown on the inside back cover of this issue). He then asked various groups and constituencies around APL for comments and input on the EC's ideas.

The Lab's core purpose, to make "critical contributions to critical challenges," remained its mantra, but in recognition that some of these critical contributions would be especially significant, Dr. Semmel proposed the BHAG to "create defining innovations that ensure our nation's preeminence in the 21st century." As described by Dr. Semmel in the 75th anniversary issue of the *Johns Hopkins APL Technical Digest*,<sup>16</sup> defining innovations are the most profound of APL's critical contributions, with only about one occurring per decade—nine as of this writing. APL's innovation strategy and the teams created

to implement it focus on increasing the prospects for staff members to create defining innovations.

### Innovation Framework

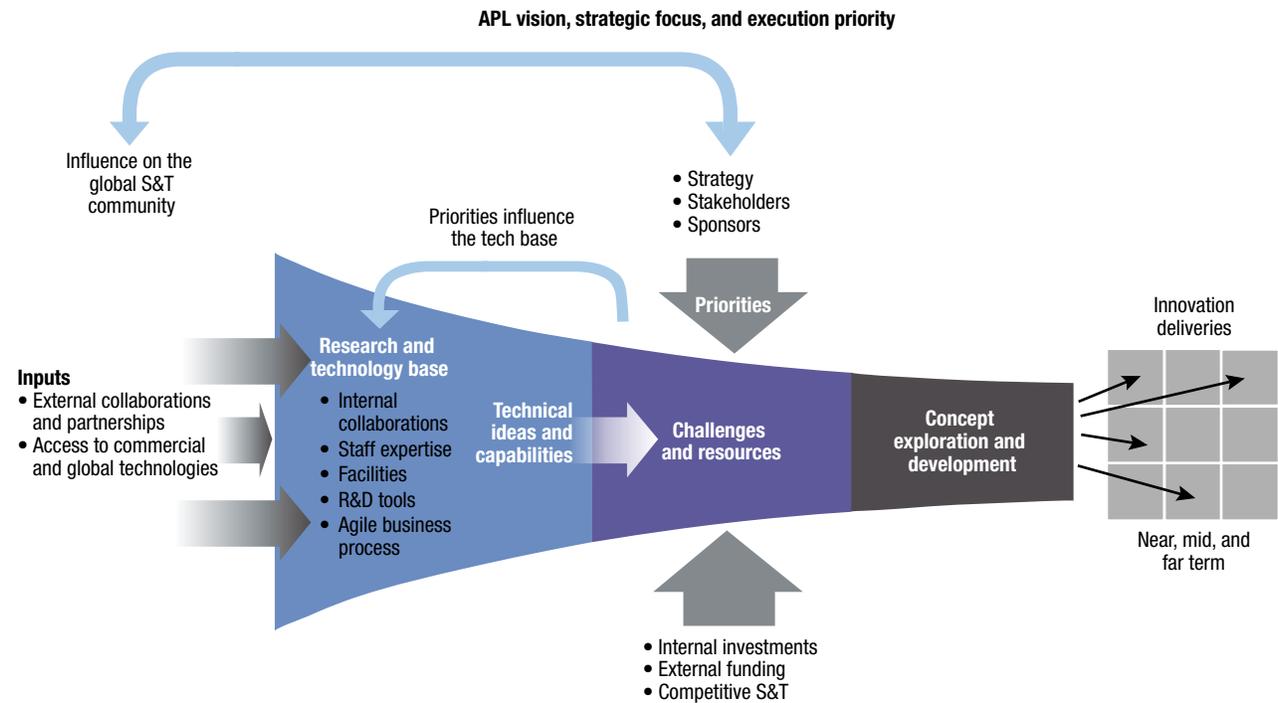
When considering how to implement innovation initiatives at the Lab, one of the Management Forum’s first tasks was to decide which innovation initiatives were important for APL. (See the work by Krill et al. about how to “engineer” innovation into systems engineering practices and organizations.<sup>6,17</sup>) There were two prerequisites to reaching this decision: (1) developing foundational principles based on the large body of literature devoted to innovation, and (2) developing a functional innovation framework from which they could identify gaps in empowerment, idea generation, and innovation execution.

After an extensive review of the research-oriented literature, the forum focused on the “three P’s” outlined by Fayard and Weeks<sup>18</sup>—proximity, privacy, and permission—as its highest-level operating principles. Proximity is about casual interactions with staff members—the watercooler conversations and chance meetings giving staff members the opportunity to talk, potentially leading to the emergence of new ideas and fresh new collaborations. Privacy means that staff members have places where they can retreat and be alone to think and work. Fortunately, APL already had many

private or semiprivate offices, so that principle was relatively covered. Permission refers to the culture of empowerment that Lab leadership began addressing early on and demonstrated with the Frisbee toss. The principles align with more recent research<sup>19,20</sup> indicating that the most innovative teams and individuals demonstrate a high degree of collaborative networking and building on others’ ideas.

Lab leadership shared these principles, which have implications for both physical space and social interactions, with staff and gathered feedback, determining that the proximity principle should be the main focus of the Lab’s initiatives. The preceding years of growth and increased complexity had limited the Lab’s collaboration spaces, the breadth of its tasks, and opportunities for staff members to familiarize themselves with technical developments across the Lab. The goal was to enhance the work environment to empower the staff to think broadly about APL’s sponsors’ critical challenges, beyond their immediate assignments, and to provide them with greater opportunities to join and create collaborative networks for learning and work.

The forum developed and evolved a systems-oriented innovation framework to inform and organize the design and introduction of new initiatives (Figure 3). It features four phases: (1) gain situational awareness and preparedness to ensure an adequate **research and technology base**; (2) continually **identify key challenges and**



**Figure 3.** Evolved APL innovation framework. The framework includes four phases: (1) gain situational awareness and preparedness to ensure an adequate research and technology base; (2) continually identify key challenges and provide resources to address the challenges with innovative ideas; (3) create conceptual solutions, including development and exploration with prototypes; and (4) transition ideas to operational use in partnership with sponsors.

**provide resources** to address the challenges with innovative ideas; (3) **create conceptual solutions**, including **development and exploration** with prototypes; and (4) **transition ideas** to operational use in partnership with sponsors. The forum focused on innovation outcomes, especially breakthrough critical contributions to increase the prospects for defining innovations, recognizing that APL's culture would evolve to mirror this focus. Over time, the group identified a set of initiatives that have been implemented primarily by the Innovation Program Office.

The framework supports the following objectives:

1. **Create revolutionary concepts:** First and foremost, create revolutionary concepts that could lead to defining innovations consistent with APL's organizational mission. The initiatives should promote proposals of concepts that would not have a funding opportunity via traditional independent research and development (IRAD) processes because of their high technical risk, broader problem scope, or long-term nature.
2. **Encourage entrepreneurial collaboration:** Create a climate of cross-enterprise, cross-discipline, entrepreneurial collaboration. This objective is in recognition that novel ideas can come from inclusive teams that invite members to contribute their unique perspectives stemming from their educational, technical, cultural, and personal backgrounds.<sup>19</sup> This goal includes staff participation levels in initiatives designed to foster collaborations, both internally and also externally in the global innovation ecosystem.
3. **Promote idea generation:** The goal is to increase the total number of novel ideas generated across all programs and initiatives, recognizing that it takes many ideas for one really good idea to emerge.<sup>20</sup> The initiatives' practices and empowerment should permeate the culture to increase the number of novel ideas being proposed across the spectrum of programs.

Both objectives 2 and 3 clearly support the success of objective 1.

The Management Forum developed and tracks metrics and indicators associated with all the innovation initiatives. For example, the increase in IP disclosures since the inception of the Ignition Grants program is an indicator that objective 3 is being met. Although some of these indicators are subjective or anecdotal, the information is nevertheless helpful in characterizing areas of value and areas for improvement. These performance metrics are shared online with all staff members and regularly reviewed by leadership for future program enhancements. They primarily indicate levels of staff participation, staff experiences, and game-changing ideas being pursued through the innovation programs. The framework has evolved as the Management Forum has gained greater experience in how innovation initiatives have impacted creativity and innovation. The Management Forum has consistently advocated for gathering feedback from the staff and asking staff members to design their own innovation initiatives; this is perhaps the greatest single factor in the success of the initiatives.

## THE NEXT MAJOR INITIATIVES

With the management structure and innovation framework in place, and the success of the first major innovation initiative, Ignition Grants, Lab leadership felt well prepared and excited to launch additional programs. Many of these initiatives are described below.

### Central Spark

In keeping with the focus on gathering staff input, an Ignition Grant cycle requested ideas for the next innovation experiment APL should consider. The top two staff-voted proposals were to develop (1) a maker space and (2) a space and team to lead exercises in design thinking. Both ideas were catching on around the country, and APL staff members wanted to experiment with tinkering and ideation. The two winning teams were encouraged to use their Ignition Grant funds to work together to develop an encompassing concept for a collaborative innovation center.



**Figure 4.** Different views of Central Spark. Left is Maker Central, in the middle is Design Central, and to the right is Central Park, a common area outside of the main innovation areas where staff members can sit and think or meet in small groups.

The Management Forum considered the resulting concept and realized that enabling staff members from across the Lab to gather in a dedicated space clearly aligned with the Lab's increasing focus on proximity, but members of the forum were unsure how to gain enough funding to create the center. It would ideally need to be centrally located in a high-traffic, visible location, a crossroads from across the campus. Dr. Semmel encouraged the Management Forum to “think boldly” and to ensure the high quality of whatever innovation initiatives were to be implemented.

What resulted, with the director's support, was APL's first Labwide innovation center, named Central Spark—a center to “spark” innovations.<sup>21,22</sup> Central Spark is organized into centers aligned with the systems development process, beginning with needs identification via design thinking through prototype fabrication and testing in the maker area. Anchor activities for technical development and experimentation begin in Design Central, the design-thinking area that includes gaming, modeling and simulation, and software app prototyping, and end in Maker Central, a maker space featuring modular electronics and 3-D printers. These spaces are shown in Figure 4.

The most recent addition, Immersion Central, offers access to the latest augmented/virtual reality (AR/VR) technologies. This space was added at the request of visionary staff members who had ideas about how AR/VR could benefit many APL projects, and AR/VR visualizations have since been used in APL's mechanical designs for spacecraft and other programs. Some of these efforts are described in a 2020 *Digest* issue.<sup>23</sup> Taking the Central Spark concept even further, APL's Space Exploration Sector created ICEland (for instrument, concept, and evaluation) to make advanced instrumentation freely available to all staff members to promote opportunities for collaboration on sponsor-aligned work.

Once construction of Central Spark began, the core staff involved recognized the need to manage the space differently than other labs at APL. Badge access, or restricted access, is common in most APL facilities, primarily to ensure security. A core design tenet of the open, unclassified spaces in Central Spark was unmonitored access for both personal and professional work. Staff members, with senior leadership support, proposed 24/7 access for any type of work and no requirement for users to swipe badges for entry. This significant shift in one of the three P's—permission—directly empowered the staff, through both proactive messaging from the leadership and the minimally restrictive policy, to use this space to pursue any innovation effort, whether for sponsor-related work or on their own time for personal pursuits.

Staff members continue to seek additional ways to embed this “low-process” approach in the space. Equipment and consumable materials requests are handled



**Figure 5.** A view of the entrance to the new, expanded Central Spark relocated to what was originally the R. E. Gibson Library. After this photo was taken, the equipment and furniture for collaborations were added and the facility opened to APL staff.

via staff members jotting details on a whiteboard in the space, rather than the more traditional approach of entering them in a complicated, or access-restricted, materials ordering system. Users with ideas for new capabilities in the space are empowered to pitch their ideas. Rather than developing a lengthy policy on the training required to use the space, staff members proposed (and implemented) a mandatory orientation tour for users. The tour, which staff members take before their first use of Central Spark, covers the capabilities and safe use of the space itself and highlights training required for specific pieces of potentially hazardous equipment.

The space and the low-process approach to using it have resonated with the staff, as indicated by the more than 175,000 visits in 2019. Staff members recount going to Central Spark to tinker, meeting experts in other areas there, and jointly conceiving a new concept leading to sponsor funding. Users have also reported that the 3-D printing capabilities in Central Spark helped them better understand the value of APL's sophisticated mechanical fabrication facilities, encouraging them to collaborate on new projects with staff members in those facilities.

In 2020 Central Spark moved to a much larger area that was once home to the R. E. Gibson Library. A photo of the new facility is shown in Figure 5.

## Tech Splash

In addition to the EC and Management Forum innovation programs, homegrown initiatives began springing up around the Lab, some directed at individual departments and sectors and others directed at the entire Lab. Tech Splash is one example. Conceived by the head of the Research and Exploratory Development Department (REDD), the program enables staff to easily discover what others are doing across the Lab. The hope is that this knowledge leads to more collaborative teaming.

This initiative aligns with the principle of proximity—albeit virtual proximity—featuring short, catchy, often humorous videos about the technical work of and concepts being explored by staff members all over the Lab.

The series has proven so popular, with over 140 videos produced as of this writing, that it has spurred spin-off initiatives. One example is “Mission Area Minutes,” short videos that highlight summaries and updates from the Lab’s mission areas. Another spin-off is “Labs of the Lab,” featuring short virtual tours of some of APL’s technical labs and facilities. Several Tech Splash videos have appeared on APL’s YouTube channel, with nearly nine million views of the video on the Modular Prosthetic Limb.<sup>24</sup>

### Speaker Series

While Tech Splash offers a quick glimpse into work being done around the Lab, staff members often want to take a deeper dive and engage directly with the subject-matter experts doing the work. Several speaker series give staff members that opportunity. One example is the APL Showcase. Conceived of by the director’s SAG (mentioned earlier), approved by the EC, and coordinated by the managing executives of REDD and the National Security Analysis Department (NSAD) along with the Innovation Program Office, the APL Showcase is the premier technical talk series featuring APL speakers. Occurring on the third Tuesday of each month, each showcase consists of two or three briefings on key projects and initiatives occurring at the Lab.

### Innovation Fest

Building on the success of all these initiatives, in 2015 the Management Forum and the Innovation Program Office conceived and launched Innovation Fest, a monthlong series of events to celebrate innovation across the Lab and to inspire even more of it. During Innovation Fest, staff members participate in a broad range of activities, such as finding lost, crashed spacecraft on the moon while gaining experience in machine learning applied to orbital surveillance data; vying against colleagues in an escape-room-like challenge while learning principles of cyber hacking; competing in a contest to design the future APL campus and buildings while providing input into the Lab’s long-range planning; and joining the highly popular “Great Lab Crawl” to visit and learn more about labs across APL.

A long-standing annual event that now coincides with Innovation Fest is the APL Achievement Awards.<sup>25</sup> APL-wide annual awards originated in 1986 to recognize staff members’ scholarly publications. The list of annual awards steadily expanded to celebrate achievements and efforts in more domains. Awards for IRAD projects were added in 1989, followed by awards for inventions in 2000 and the Alvin R. Eaton

Award (named for the former associate director) for achievements that cannot be discussed publicly in 2001 (although this award was presented privately until 2016). In 2012 all the awards plus new ones were combined into an annual awards program. Several awards recognizing enterprise and mission accomplishments and celebrating innovation were added. The awards ceremony is open to all APL staff members; APL award nominees are specially invited and encouraged to bring guests. Typically, more than 100 staff members are awarded plaques and up to \$1,000 for their achievements in more than 20 award categories.

### Project Catalyst

Building on the success of Ignition Grants, APL introduced two much larger grants, Combustion Grants and Propulsion Grants, in 2015. The three types of grants, Ignition, Combustion, and Propulsion, each with a unique selection method, funding amount, and execution time frame, were collectively branded as Project Catalyst (see Figure 6). The goal for Project Catalyst is to encourage staff members to think even more boldly and take even bigger risks that could lead to disruptive ideas and breakthroughs in solving critical challenges. Dr. Semmel conceived these new grants as a way to better channel research into truly extraordinary ideas that are not in line with mission area strategies or sponsor timelines but just might yield a defining innovation. The creation of Combustion and Propulsion Grants was also in response to staff feedback requesting opportunities for follow-on funding and larger sums of funding to enable them to more fully realize winning Ignition Grant ideas. As part of the process, staff members brief their ideas and results, increasing Labwide awareness of technical developments.

### Combustion Grants

In keeping with the theme of sparking innovation, each Combustion Grant provides funding for 400 staff-hours, enabling winners to explore ideas requiring more funding than an Ignition Grant provides or to do follow-on work on an idea previously funded by an Ignition Grant. Combustion Grants, with more time and budget allocated, focus on longer-term, higher-risk ideas beyond present visions. Staff members anonymously propose ideas in a simple online format where they describe the novelty of the idea, the significant technical challenge, and the potential for impact. Staff members volunteer as anonymous peer reviewers in their respective areas of technical expertise and review others’ proposals. There are three peer reviewers for each proposal, and typically 80–90 proposals are submitted in each of the two annual cycles. A team of chief engineers and scientists then selects the top-rated proposals for funding. The program now funds 25 ideas each year, 12–13 from each cycle.

Recent work of an APL neuroscientist and her team is one of many Combustion Grant success stories. She had been thinking about phase-based neuron propagation and talking to a roboticist. She theorized that it might be possible to develop an approach to phase-based control of robotic swarms that would minimize computational cost and maximize scalability and performance through novel emergent behaviors, with application in GPS-denied areas. She won a Combustion Grant to explore this idea. See the article by Hwang et al. in this issue for more details on the work. The results look promising, and she and a colleague recently earned a million-dollar US National Science Foundation (NSF) grant for phase-based swarming control.<sup>26</sup> The idea was initially funded as an Ignition Grant through its crowd-sourcing selection process and then went on to secure follow-on Combustion Grant funding as well as NSF funding through their respective review processes. This Combustion Grant also seeded another Combustion Grant in 2019 for work to endow autonomous agents with cognition, and this led to a related Propulsion Grant for a project called “Fourier-Analytic Theory of Emergence” in 2020. This is one example where a team required seed funding to begin exploring an idea and then follow-on funding(s) to make significant progress.

### Propulsion Grants

The premise for Propulsion Grants is that incremental research toward a game-changing concept or technology can sometimes be accelerated with a well-placed risk-resolving “bet” in the form of a prototype, experiment, or computer model to discover or prove an idea. Proposing an accelerated approach to a bold, transformative idea of potentially high impact is the primary selection basis for Propulsion Grants. Unlike Ignition and Combustion Grants, which are funded within one

fiscal year, Propulsion Grants are designed as multiyear projects with a series of annual re-competitions for next-year funding.

For the first year, APL sector leaders define particularly difficult challenges in their respective operational domains, such as undersea detection or human-artificial intelligence collaboration. Each sector then solicits abstracts on ideas that address these challenges from staff across APL. Line managers, program managers, and chief scientists and engineers team to review abstracts and select ideas that are particularly impactful and risky, yet promising. The principal investigators of the selected ideas then develop more detailed proposals. Of these 40–50 detailed proposals, 8 (2 per each APL sector) are awarded 1 staff-year of funding.

**PROJECT CATALYST**  
APL's three funding opportunities for bold, high-risk and transformational ideas that will ensure our nation's preeminence in the 21st century  
\$9.5M/year funding for your innovative ideas through Ignition, Combustion, and Propulsion Grants!

**IG**  
**IGNITION GRANTS**  
LIGHT THE FUSE  
Up to \$20K funding!  
Spring and fall cycles  
Innovative ideas to solve themed challenges  
Crowd-sourced & peer selected ideas

**CG**  
**COMBUSTION GRANTS**  
TURN UP THE HEAT  
Up to \$50K funding!  
Continuous open call  
High-risk, high-impact technical ideas  
Anonymous idea submission & peer review

**PG**  
**PROPULSION GRANTS**  
DISRUPT THE FUTURE  
Up to \$1.3M funding!  
4-year challenge cycles  
Disruptive ideas to solve sector/dept. specific challenges  
Idea & proposal submissions, inclusive teams



**Figure 6.** Project Catalyst. The program consists of Ignition Grants, Combustion Grants, and multiyear Propulsion Grants. The image at the top describes each element of the program. The image at the bottom shows a participants briefing an idea.

While the sector management selects the year-1 projects for its sector's challenges, which are aligned with sponsor challenges, the Management Forum selects the projects, generally aligned not only with sponsor challenges but also with Lab goals, that are awarded funding in years 2 and 3. At the end of the first year, the eight teams present their accomplishments and propose follow-on tasks for the second year. Of these eight teams, four are selected for year-2 funding of 1.5 staff-years for each team. At the end of year 2, these four projects compete for two year-3 continuation projects at 2 staff-years of funding each. Therefore, projects that win funding for all three years receive 4.5 staff-years of internal funding. Each year a cycle commences, including eight year-1, four year-2, and two year-3 projects, for a total of 18 staff-years of funding. Every year a new cycle of year-1 grants are selected to provide continuous funding opportunities for game-changing ideas.

Experimental adjustments in the program's initial years included more mentoring for proposers and early review and feedback on their proposals from chief engineers and scientists serving as challenge representatives. As grant recipients complete their projects (e.g., after year 3 or when a project is not selected for the next year of funding), APL program managers are invited to consider allocating IRAD funding or seeking external sponsor funding for the project. If no program managers are interested, the Research and Exploratory Development Mission Area endeavors to keep such advanced research funded.

Propulsion Grants' impact to APL's culture and creation of new revolutionary concepts such as those described later in this article led to the decision to nearly double the number of projects funded by the program—from 8 to 16 year-1 grants, from 4 to 7 year-2 grants, and from 2 to 3 year-3 grants. Of the 16 year-1 grants, each sector selects 3 for funding, and REDD and NSAD, whose missions are to explore future technical and operational missions, respectively, each select 2 proposals for far-future challenges (10–20 years out as compared to 5–10 years out for the sector challenges). In addition, a new year-4 grant for 1 staff-year of funding was added to support a particularly revolutionary concept completing year-3, enabling those researchers who especially need additional time to bridge the “valley of death” between S&T and development to attempt to secure follow-on funding. More recently the APL chief engineer provides voluntary review of proposals and mid-term and year-end reviews. This has led to higher-quality materials and mentoring to staff members who are not as experienced in proposals and project management.

The following example is the first project to have competitively won Propulsion Grants for all 4 years. The Space Exploration Sector selected a year-1 project proposed by a team of technologists led by David Copeland and Edward J. Birrane to explore working with national

and international communities to ensure interoperability of up to tens of thousands of commercial communication satellites planned for deployment in a number of separate and competing constellations. The project, also described in the article in this issue by Hibbitts et al., is called Advanced Network Technology for Integrating Communications in Space (ANTICS) and includes early prototype testing. The team felt that the communications companies, and the world, would be better served with planned interoperability standards analogous to the eventual interoperability of the cellular services around the world. In fact, directly mirroring the approach of the cellular community, the team's proposed approach for space and corresponding terrestrial systems, initially for 4G but also considering 5G, included first designing and modeling an LTE approach that accommodated the extreme orbital speeds and distances and then planning a validation experiment.

The space sector awarded the team with a year-1 Propulsion Grant. By the end of the first year the team had developed a candidate prototype design and had proposed to NASA that the prototype approach be tested aboard the International Space Station (ISS). On the basis of these strong outcomes from year 1, they were awarded a year-2 grant for completing and flying the prototype on the ISS. After a successful demonstration, the team proposed for year 3 that they revise the design and complete its prototype integration into the LTE services as well as begin to engage the international space-based commercial communications companies. They made significant progress in these project focus areas but at the end of year 3 had not completed working with international standards bodies to incorporate space LTE provisions nor to seriously explore the technology with a commercial company. Because the year-4 grant was expressly conceived to help successful Propulsion Grant projects that needed a little more time and funding to attain practical application, this project was the first to



**Figure 7.** Inaugural Bold Catalysts event in 2018. The event recognized 222 staff members who advanced in the Propulsion Grants program, along with 26 Catalyst Spin-Off finalists.

be awarded a year-4 grant. The team is continuing to engage the standards organizations and the commercial space community.

The idea is for Catalyst grants to enable bold moves, and the example described above illustrates the program's intent and process. Propulsion Grants support so many innovative ideas that a ceremony recognizing the boldest among them was in order. In 2018 Dr. Semmel initiated Bold Catalysts (Figure 7), an annual event to celebrate grant finalists and winners, even if they were not fully successful in their technical risk-taking or were not selected for follow-on funding through the Catalyst program. During the event, Bold Catalysts awards are presented to teams who have won continued funding, and Catalyst Spin-Off awards recognize the Ignition, Combustion, and Propulsion Grants teams working on projects that have the potential for the biggest impact for APL sponsors and who went on to receive follow-on funding via the Lab's IRAD program, by transitioning their work to sponsored programs, or through other funding sources.

The Catalyst program's goal is to increase the prospects for creating defining innovations by funding potentially game-changing technologies and concepts for advanced capabilities. The premise is that most of the grant ideas will be revolutionary,<sup>27</sup> recognizing that this measure is subjective and requires projecting how a new capability might change the nature of a mission or operation. For example, in missile defense a next-generation missile defense interceptor might be considered evolutionary. However, an integrated network of high-power laser defense weapons might be considered

revolutionary but with extremely high technical risk. As another example, a more compact atomic clock would be evolutionary, but a solid-state atomic clock on a chip might revolutionize commercial, national security, and space programs.

### The Janney Program

Within its core competencies, APL has a broad and deep footprint in the innovation ecosystem involving the government, major laboratories, academia, and industry working in the same mission areas. However, as challenges, technologies, and APL's roles evolve, Lab staff members must gain traction in new and emergent technical areas of the ecosystem by monitoring where potentially important technologies are emerging and who is working on them and collaborating on or at least becoming fast followers of critical S&T. To ensure staff awareness of and participation in the broad global ecosystem, APL launched the Janney program. Named after Stuart Janney Jr. and Stuart Janney III, father and son who, as Johns Hopkins University trustees, chaired APL's Board of Managers for nearly 38 combined years of APL's 78-year existence, the program features four tracks, as illustrated in Figure 8.

The Explore track allows APL staff members to attend unfamiliar conferences that might cover technical areas of potential value to current or future critical challenges. Staff members nominate potential conferences, and the top staff-voted conferences are selected for the application process. Interested staff members then respond to a call for applicants to attend the conferences, and a panel

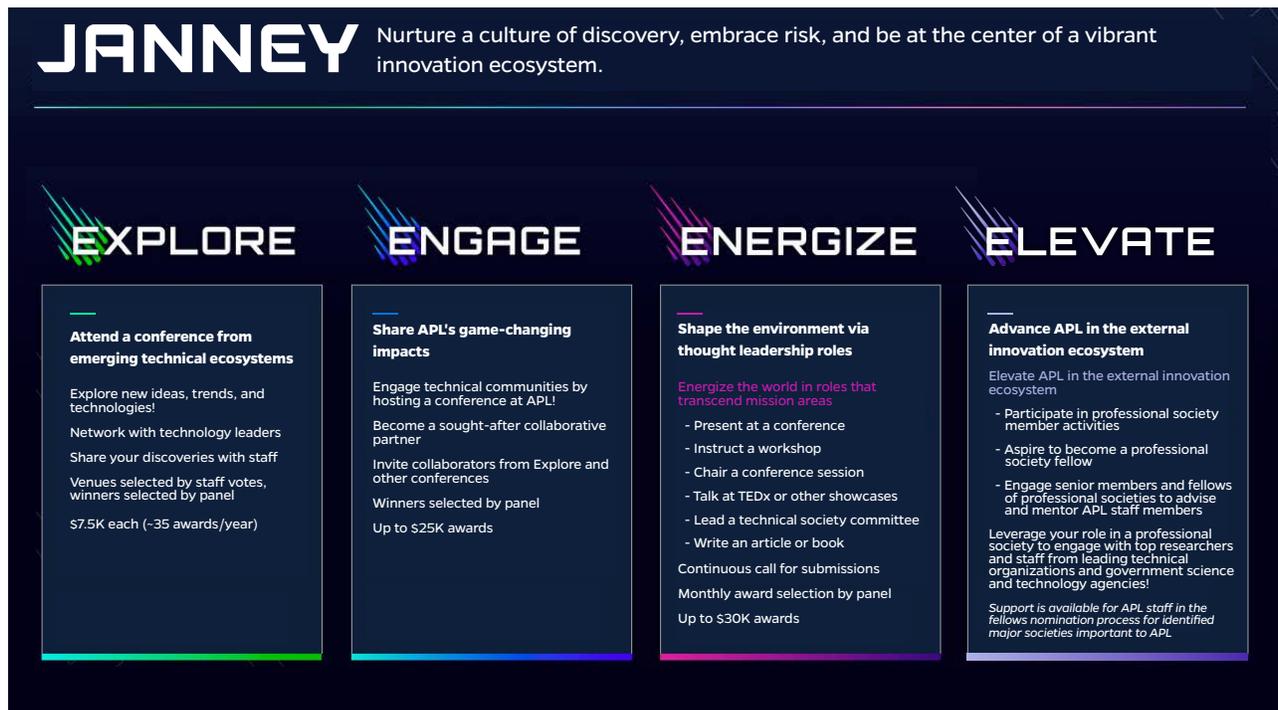


Figure 8. Janney program overview. Shown are the four tracks of the program, with their goals, selection processes, and award amounts.

of previous winners selects those they judge to have the most compelling expression of potential value, relevant expertise, or identified need. After attending the conference, each staff member gives a presentation, referred to as a Janney Talk, to share what they learned with other interested staff members.

The Engage track provides funds to selected APL staff members to host a conference at APL to share the Lab's game-changing impacts with the broader community and to become sought-after partners for important emerging technical areas. The conferences are selected on the basis of their potential impact and importance to APL's present or possible future missions.

Janney's Energize track asks staff members to propose giving a keynote, a TED talk, or some other high-level talk that would help them and APL to become better known as a leader in a particular area of the ecosystem. Selected staff members receive funding as well as coaching and assistance to prepare for the talk. This category also funds selected staff members interested in writing or finishing a book or book chapters, again based on potential impact and relevance to APL's present and possible future missions. This track provides funding beyond what APL's departments and sectors are able to provide, such as to travel to and attend meetings to perform duties as a society officer or session chair or to present an invited talk.

Elevate is the newest track of the Janney program. It assists staff members in participating in technical professional societies of key relevance to APL, such as IEEE (a professional association for engineering disciplines) and AIAA (the American Institute of Aeronautics and Astronautics). The goal of this track is to increase the number of APL staff members inducted as fellows of their respective professional societies. Achieving the status of fellow is a reflection not only of the technical expertise and reputation of the staff member but also of APL, enhancing APL's footprint in the innovation ecosystem. In 2019, during the first of what will be an annual formal reception, existing APL fellows and associate fellows of several premier societies came together to recognize APL staff members newly elected to associate fellows or fellows.

## INNOVATION CULTURE AT APL REACHES A TIPPING POINT

The continuing introduction of Labwide innovation initiatives seems to have reached a tipping point, with all APL sectors and departments establishing new initiatives or expanding their existing innovation initiatives. As has been the case previously, some of these home-grown programs have transitioned into Labwide initiatives. Local and Labwide innovation initiatives and enablers take the form of seedling IRAD funding; idea generation processes; collaboration experiments and

competitions; buildings and spaces designed to foster collaboration; educational opportunities; and hiring, performance management processes, and team building practices that emphasize inclusion and diversity.

### Mission Area Efforts

#### *Challenge after Next*

APL's mission areas began incorporating additional measures to enhance their innovation. One initiative, to identify the "challenge after next" during regular IRAD cycles, aims to anticipate longer-term challenges beyond those that sponsors are thinking about and working on in the near term. Dedicated funding is allocated for these projects, enabling research that otherwise would not have been initiated so early.

#### *Evolutionary, Expansionary, Revolutionary Continuum*

Mission area leaders also began to assess the percentage of their areas' IRAD and sponsored work in terms of the Evolutionary, Expansionary, Revolutionary (EER) continuum.<sup>27</sup> The continuum categorizes innovative solutions from evolutionary (like going from an iPhone 10 to an iPhone 11) to expansionary (such as modifying an iPhone for 3-D VR visualization) to revolutionary (e.g., going from a flip phone to an iPhone).<sup>27</sup> The creators of this construct worked with the EC to explore how the concept could be applied at APL. After this exercise, mission area leaders endeavored to increase the portion of revolutionary work in their areas. As a first step, they defined at least one "mission impossible" future vision based on a national challenge consistent with their respective mission. These practices have begun to pay off, with fresh ideas and new developments toward future sponsor needs.

### Diversity and Inclusion Initiatives

#### *BLAST*

BLAST, short for Building Leaders, Accelerating Science and Technology, is one example of a long-standing sector innovation project that has transitioned into a Labwide initiative. When Dr. Semmel was head of what is now the Asymmetric Operations Sector (AOS) before becoming director in 2010, he acted on staff interests and established what was called the Innovation Challenge for teams of early-career staff members. Although the program was managed by AOS, staff members from across the Lab were invited to participate. Each year AOS management posed a seemingly impossible challenge, such as hacking a secure room or device or developing a revolutionary new capability for special operations forces. The teams usually achieved surprising successes, some of which went on to become operational.

When reviewing data for the Project Catalyst grants, the 2018 winning AOS Innovation Challenge team

observed that teams led by early-career staff members were underrepresented in selected Propulsion Grants. Surmising that more training in proposal writing, project management, and technical risk reduction would give early-career teams a better chance of winning, they proposed that the AOS Innovation Challenge be extended to a Labwide program and they named it BLAST. Not only was their proposal accepted by the EC, but it became an APL 2020 strategic execution priority, with the Management Forum providing support for implementation. The first year for the Labwide program was 2020.

### Mosaic

Continuing its efforts to promote diversity and inclusion and recognizing that inclusive teams often produce better results,<sup>28–30</sup> APL launched Project Mosaic in late 2018 to transform the Lab's approach to building and maintaining thriving teams. The premise underlying Project Mosaic is that each team member's unique perspective and experiences inform and enhance the team's ability to solve problems and innovate.

In preparation for building the Mosaic framework, the Mosaic team reviewed the available research and lessons learned from organizations around the country and met with supervisors, managers, chief engineers, and scientists at all levels of the Lab. The framework centers on eight key areas: leadership, hiring, messaging, training, tools and techniques, recognition, career advancement, and iterative design. Before the program was officially rolled out to the entire Lab, the Mosaic team conducted a pilot to introduce staff members to the project's concepts and new team-building tools, such as a web-based tool with techniques for creating and managing more inclusive teams and a platform where team leaders can search for potential team members.

The Project Mosaic team collaborated with APL's Talent Services team to develop strategies to ensure a diverse applicant pool, inclusive hiring, and positive candidate experiences. The teams also partnered to update APL's staff classification practices to emphasize diversity and inclusion as important considerations for staff advancement. The Mosaic team reviewed APL's recog-

nitition programs, and with input from the Mosaic team, Lab leaders updated programs to formally recognize inclusive behaviors. Training sessions on diversity, inclusion, and nonconscious bias reinforce these actions and are open to and encouraged for all APL staff members.

### Educational Opportunities

With the increasing pace of scientific discoveries and new technologies (and their subsequent obsolescence), APL staff members must find ways to keep up with trends in their respective fields. APL has long partnered with the Johns Hopkins Whiting School of Engineering, with 12 of the 23 part-time graduate programs currently chaired by APL staff members and many APL staff members earning their master's degrees through the program. APL and the Whiting School recently expanded their partnership in a new doctor of engineering program that enables doctoral candidates to conduct their research at APL while offering APL staff members increased flexibility while they work toward their doctorates. In addition, the Lab's Strategic Education courses are specifically tailored to APL staff needs, some of which are classified. Example course topics include cyber for Navy tactical systems, quantum engineering, and artificial intelligence. These educational opportunities are described in detail by Harry Charles in this issue. APL's Talent Services Department also offers short courses and classes on various topics, both technical and nontechnical. This spectrum of educational programs available to staff members, combined with the leading-edge research and development (R&D) tasks that staff members work on, ensures the continued expansion of expertise required to carry out the Lab's work.

### Continued Experimentation with Collaborative Work Spaces

APL has leveraged several small-scale, low-cost experiments in its projects with progressively larger scales and costs. Central Spark gave APL leadership experience with an open collaboration space at a relatively low cost, and they applied the lessons learned to design of the next collaboration space, the REDD



**Figure 9.** Evolution of experiments and lessons learned in the design of innovation-promoting work spaces at APL. Left, Central Spark, the Lab's first major collaboration space. Middle, the ISC, designed to promote collaboration among robotics, neuroscience, autonomy, and information systems researchers. Right, Building 201, which will house advanced labs and work spaces for REDD.

Intelligent Systems Center, or ISC. The ISC was designed to encourage its researchers in robotics, neuroscience, autonomy, and information systems to cross paths and collaborate on projects and ideas at the seams between the disciplines. The ISC cost about 10 times more than Central Spark cost. The ISC's success and the lessons learned from its design and use then motivated the design of a new building to house most of REDD's staff and labs. The cost of this building, known as Building 201, is expected to be 20 times the cost of the ISC when it is completed in 2021. The building will accommodate advanced labs and work spaces conducive to collaboration. Figure 9 illustrates the evolution of these spaces. Today every new building and refurbishment on APL's campus carries with it an adaptation of innovation and collaboration principles tailored to those buildings' functions. The application of innovation principles is discussed in Brian Cornell's article describing the concept for the APL campus.

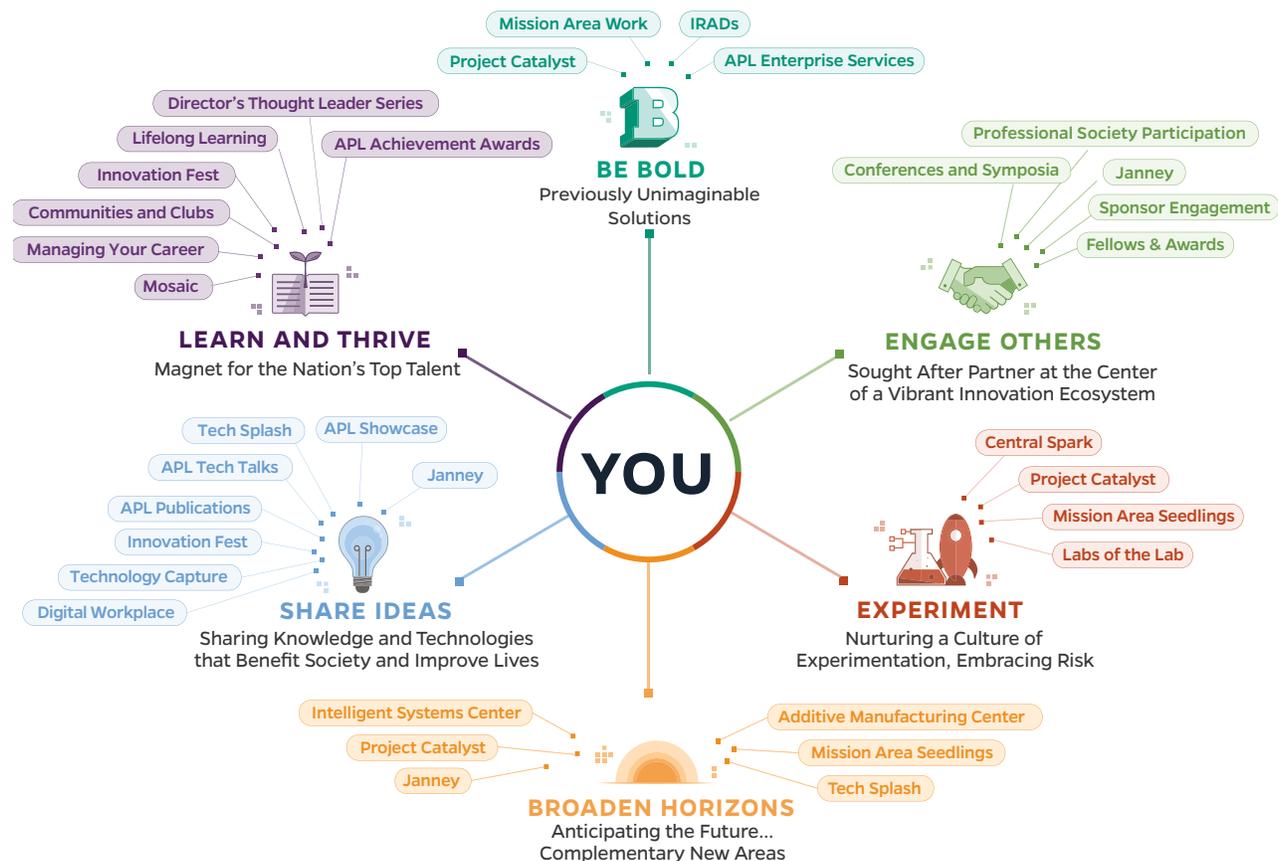
supervisors undertaking a time-consuming end-of-year retrospective evaluation of every professional staff member. Recent research<sup>31</sup> shows that the value gained from this traditional process is not necessarily commensurate with the amount of effort required. Some of APL's peer organizations had abandoned this kind of process with little change in staff performance. Dr. Semmel wondered whether excellence and innovation would suffer if the Lab replaced the document-heavy PMP with a zero-documentation staff and supervisor coaching approach. The Management Forum, with support from Talent Services Department staff, studied the question, concluding that replacing the PMP with coaching should be tried as an experiment. The experiment led to full adoption, and in the half decade since revamping the process, staff performance has not faltered and satisfaction with reviews and coaching has increased according to staff surveys.

### Staff Performance Evaluation

Another offshoot of the innovation strategy was a renewed look at the Lab's performance management process (PMP). The traditional PMP involved

### Enabling Innovation by Enabling You

With the proliferation of innovation initiatives and programs, both Labwide and local to departments and sectors, staff members needed to better understand the options available to them. Working with the Lab's



**Figure 10.** Enabling Innovation by Enabling You, APL's framework and online interface for all of its innovation initiatives. The graphic depicts the various opportunities to contribute, grow, and learn; it aligns with the key phrases of APL's Centennial Vision.

communications professionals, the Management Forum developed a framework, aligned with APL's Centennial Vision, and a simple online interface that allows staff to locate a program or a combination of programs of interest. The framework, Enabling Innovation by Enabling You, is shown in Figure 10.

Each of the major categories, Be Bold, Engage Others, Experiment, Broaden Horizons, Share Ideas, and Learn and Thrive, corresponds to a phrase from the Lab's Centennial Vision vivid description. By selecting one of these areas, a staff member can connect with opportunities aligned with the principles of the Centennial Vision.

## MOVING FORWARD TOWARD THE CENTENNIAL

APL has accomplished a great deal with its innovation strategy, including creating a culture where staff members say yes to exploring ideas and taking risks, encouraging and realizing revolutionary new ideas, expanding educational opportunities for its staff, and increasing its footprint in the innovation ecosystem. Although there is more to do, the foundation is set and the momentum is strong. As evidence, in 2019 and again in 2020, Fast Company named APL one of the 50 most innovative companies in its inaugural rating in that category.<sup>32,33</sup> In 2020 APL was named the third-best workplace for innovators of over 800 entries worldwide.<sup>33</sup> In addition, APL's ratings on Glassdoor, a website collecting anonymous reviews from current and former employees, have continued to climb. In the past 6 years, APL's rating on Glassdoor rose from 3.6 to 4.4 (of 5.0), with 95% of all respondents positively recommending the organization to others.

However, no one can say where in the global innovation ecosystem the next big breakthrough will occur and in what technical area, much less whether it represents an opportunity or a threat. Therefore, APL must be ever vigilant in its discovery of science and early-stage technologies in the ecosystem. Staff members will need to be increasingly engaged in technical societies, and APL will need to be increasingly connected with global R&D organizations to increase awareness. The Lab will need to partner with organizations with complementary expertise and facilities, because technologies will change too quickly for APL to develop expertise in all of them.

With its portfolio of innovation initiatives, APL is on a strong path to meet its Centennial Vision. It will be interesting for APL staff members in 2042 to look back and consider the impact that the innovation strategy of the 2010 decade has had on APL and the nation. The full story has yet to be written, but the first chapter has already been exciting.

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**Ann E. Kedia**, Communications Department, Johns Hopkins University Applied Physics Laboratory, Laurel, MD

Ann E. Kedia is the managing executive of APL's Communications Department. She holds a BS in chemical engineering from Cornell University and an MS in technical management from Johns Hopkins University. Ann has a combination of business and engineering management skills and champions change and organizational agility. She has significant staff and program leadership experience using a collaborative style to engage teams and deliver results; communications and partnering skills to achieve strategic visions; and extensive experience in innovation management, technology solutions implementation, program management, staff management, budget management, and leadership development. Her email address is [ann.kedia@jhuapl.edu](mailto:ann.kedia@jhuapl.edu).



**Jerry A. Krill**, Assistant Director for Science and Technology and Chief Technology Officer, Johns Hopkins University Applied Physics Laboratory, Laurel, MD

Jerry A. Krill is APL's assistant director for science and technology and chief technology officer. He earned bachelor's and master's degrees from Michigan State University and a PhD from the University of Maryland, all in electrical engineering. Previously he was APL's assistant director for programs, head of the Power Projection Systems Department, and executive for air defense programs. He was a co-conceiver and APL's systems engineer for the Cooperative Engagement Capability, meeting its accelerated, congressionally directed fleet introduction in 1996. He was APL's systems engineer for the Mountain Top advanced concept technology demonstration leading to today's Naval Integrated Fire Control – Counter Air capability. He led the Navy/Ballistic Missile Defense Organization Concept Formulation Working Group in a study of the Navy's role in ballistic missile defense. He holds 22 patents; has authored over 100 papers and documents, including co-authoring the book *Infusing Innovation into Organizations* and co-leading the Naval Studies Board study entitled *Responding to Capability Surprise: A Strategy for U.S. Naval Forces*; and serves on the Whiting School of Engineering's advisory board. He was inducted into the University of Maryland Clark School Innovation Hall of Fame. His email address is [jerry.krill@jhuapl.edu](mailto:jerry.krill@jhuapl.edu).