APL's Asymmetric Operations Sector: Driven by Envisioned Futures

Donna M. Gregg, Robert A. Nichols, and William J. Blackert

ABSTRACT

As the Johns Hopkins University Applied Physics Laboratory (APL) looks toward its 100th anniversary in 2042, its leaders are undertaking strategic planning efforts to imagine the challenges the future Lab—and indeed the future nation and world—will face. APL's Asymmetric Operations Sector (AOS) created envisioned futures for 13 challenges spanning its four mission areas, Cyber Operations, Special Operations, Homeland Protection, and National Health, and is focusing its efforts on creating disruptive technical solutions to realize these envisioned futures. This article describes the envisioned futures and the strategic efforts involved in their formulation.

INTRODUCTION

APL's Asymmetric Operations Sector (AOS), in many ways, is a reflection of the fundamental shifts our nation has experienced over the past two decades. Staff members across the sector's four mission areas are focused on developing solutions to the challenges presented by these changes. The widespread deployment of the internet accelerated by the development of the smartphone fundamentally changed how we communicate, innovate, and interact while also introducing the nation to new vulnerabilities, motivating our focus on **Cyber Operations**. The events of 9/11 created a need for specialized tools and techniques to enable the Department of Defense and Intelligence Community to address terrorist threats through **Special Operations** and required an emphasis on new threats and **Homeland Protection**. And, with the nation's aging population and skyrocketing healthcare costs, bringing APL's results-oriented perspective together with expertise from the larger Johns Hopkins University enterprise to tackle the challenges of **National Health** was a compelling idea even before the COVID-19 pandemic made it an essential element of national security.

The innovation to solve these complex problems requires technical expertise in data science, cyber and cyber-physical systems, communications, and sensors. Experts come from traditional fields for APL staff members, such as mathematics, engineering, physics, and computer science, as well as from fields such as biology, chemistry, and cognitive science. Many AOS staff members also bring the operational expertise from military, intelligence, and health systems needed to frame solutions to these complex problems.

While this construct—readily available diverse expertise and perspectives along with opportunities for meaningful contributions—is powerful, it does present challenges. One of these challenges became apparent when we began to consider APL's Centennial Vision, discussed in the director's introductory letter and

shown on the inside back cover of this issue. While the diversity and newness of the sector had inspired plenty of fresh ideas, it also led to diverse and disjoint projects that, while valuable, were unlikely to have the impact of a defining innovation—a game-changing development that profoundly advances science, engineering, and military capabilities and transforms the world. We wondered how we could reframe the sector's strategy to ensure that it focused on creating defining innovations.

The problem we faced can be summarized with the following question: How do you motivate a diverse organization in a way that provides the focus necessary to seek defining innovations while still embracing the power of diverse perspectives and projects?

ENVISIONED FUTURES FOR STRATEGY

The Future Research Focus Area Advisory Panel

In 2017, APL's Research and Exploratory Development Department (REDD) was developing a strategic plan to align its R&D directions not only with future technology trends but also with APL's mission areas. The Future Research Focus Area Advisory Panel (FRFAAP) was conceived and led by APL staff members Andrew Merkle and David Blodgett and included representatives from each mission area at the Laboratory. As the FRFAAP sought to understand how REDD could better support the mission areas, the concept of envisioned futures arose. This notion was developed by Jim Collins and Jerry Porras,[1] experts in corporate strategy who describe the two components necessary to create a company's ideology: core values and an envisioned future. An envisioned future comprises two components, a big hairy audacious goal (BHAG) and a vivid description that "paint[s] a picture of what it will be like to achieve the BHAG."

The FRFAAP adopted this approach, and each mission area was tasked with envisioning its futures and then deriving the critical capability gaps that could not be solved with near-term technology. During this process, many aspects of the required R&D focus emerged. The envisioned futures revealed and motivated the hard problems, capability gaps, technical alternatives, and multiyear R&D paths that REDD could pursue jointly with the mission areas. The FRFAAP activities, which extended into 2018, were successful from multiple perspectives. For mission areas with clear envisioned futures, the initiative illuminated specific supporting R&D efforts. For mission areas without clarity on their envisioned futures, the FRFAAP activities catalyzed an effort to pursue clear envisioned futures going forward. AOS leadership recognized the enduring value of adopting this approach as a way to focus the organization, and we set out to craft a set of envisioned futures to use beyond the original purpose of the FRFAAP.

While the FRFAAP initiative was a milestone in our decision, we had already had positive experiences with a similar type of framework. Over several years, the Cyber Operations Mission Area had been exploring the alignment of its strategy with a set of mission vectors. These mission vectors created clarity by aligning sponsored work and internal research investments with a series of bold concepts that drove the mission area's strategy. These concepts, such as the Cyber-Resilient Ship, which frames a disruptive approach to computing that can potentially negate hardware and software vulnerabilities, provided significant focus and clarity within the mission area. Audacious goals were set, internal strategy and investments were aligned to these goals, and sponsor engagements were prioritized and shaped as program managers sought to find sponsors aligned with the goals. Sponsors were ready and engaged with Cyber Operations Mission Area thought leaders, many eager for bold new ideas. These mission vectors were cast as Cyber Operations Mission Area contributions to the FRFAAP and served well as a foundation for strategy.

So, given the desire to focus all of AOS more deliberately on shared goals, the idea of framing the goals using the envisioned futures concept emerged, with AOS leadership wondering whether an envisioned futures–inspired construct could drive AOS to set its sights on creating defining innovations.

Forming the AOS Envisioned Futures

After much discussion about how best to focus the organization, in early 2019 AOS set out to form its envisioned futures. Given the expected longevity of the envisioned futures and their potentially profound impact on the sector's future, this process needed to be strategic and deliberate and required involvement of leadership at multiple levels. With the strategies of each mission area in mind, we crafted an initial baseline set of envisioned futures and deliberated for months. We knew that having too many envisioned futures would defeat the purpose of bringing focus but having too few would do the same. Also important in this formative stage was linkage between mission areas involved in common strategic pursuits. For example, APL has made longstanding contributions in nuclear command, control, and communications (C3) and associated senior leader decision-making, and these efforts straddle both the Cyber Operations and Homeland Protection Mission Areas. It was not only logical but beneficial to formulate shared envisioned futures, ensuring cohesion as a sector. Although the AOS Strategic Advisory Team led these strategy-setting activities, many levels of leadership, including line managers, program managers, and technical leaders like chief scientists and engineers, were involved in discussions and ultimately in creating the sector's envisioned futures.

The result, a set of 13 envisioned futures agreed on by sector leadership, is shown in Table 1. The leadership team undertook an extensive effort to form the BHAGs and vivid descriptions, the two components recommended by Collins and Porras. We wanted to create intentionally pithy and provocative BHAGs, aimed at challenging the sector with bold goals that are only asymptotically achievable, so it was not an easy task to develop them. The vivid descriptions were equally challenging to create because we wanted to mold their scope and highlight specific ideas in support of the BHAGs, but we did not want to overly constrain new ideas given that these envisioned futures would be in place for many years. The Cyber-Resilient Ship vivid description is a good example:

> APL will ensure the resilience of ship and submarine platforms to cyberattack by changing the defensive paradigm. Their mission-critical systems will operate through and recover from cyberattacks, despite reliance on compromised processors and networks. Architectures will isolate the need for high-security trusted hardware and software components to a bounded set usable in many mission applications. By intelligently distributing functionality, the ships' computing infrastructure will allow extraction of trusted mission results from adversary-compromised systems. Out-of-band restoration capabilities will outpace cyberattacks to provide a final safeguard. While this envisioned future focuses on ship and submarine platforms, the underlying technologies will be widely applicable to other critical mission systems.

To realize the vision, in fall 2019 sector leadership and the teams behind the envisioned futures conducted line-by-line reviews and selected leads for each of the envisioned futures to ensure that each had a champion to drive progress and maintain momentum. These leads make up a diverse set of program, line, and technical leaders who are empowered to work across organizational boundaries to achieve the sector's vision. The reviews and revisions continued into the summer.

Coming out of our so-called summer of envisioned futures, we had established initial BHAGs and vivid descriptions, which set the baseline for our pursuits. The next step was to ensure that all of the sector's staff members understood this shift in strategy. Activities ranged from presenting the approach at the annual sector all-hands update; holding a showcase where staff could engage with the envisioned futures leads; establishing an internal web page featuring the BHAGs, vivid descriptions, and (eventually) podcast discussions for each envisioned future; and holding group-level meetings where leaders provided background and groups discussed the envisioned futures.

Table 1. AOS envisioned futures

Envisioned Future		BHAG	Relevant Mission Area(s)
	AI-Driven Counter WMD	Move from data to WMD defeat at machine speed	Homeland Protection
	Assured Care	Healthcare anytime, anywhere	National Health
	Continuous Cyber Advantage	Stop the cyber adversary before they can make their move	Cyber Operations
	Cyber-Resilient Ship	Don't let cyber sink the ship	Cyber Operations
	Exploit Factory	Just-in-time offensive cyber capabilities	Cyber Operations
	Global Health Security	Sense infectious disease in people who are asymptomatic	National Health
	Influence Superiority	Winning below the threshold of war	Homeland Protection, Special Operations
	Predictive Health	Discover a comprehensive measure of health	National Health
	Pushing Out the Border	Denying threats at the source	Homeland Protection
	Secure and Resilient Infrastructure	Resilient infrastructure in the face of any threat	Homeland Protection
	Spectrum Supremacy	Dictate the spectrum, win the battle	Cyber Operations
	Undeniable Access	The right information at the right time for the right decision—every time, every place	Special Operations
	Unquestionable National Strategic C3	Seamlessly connected strategic missions	Cyber Operations, Homeland Protection

In addition to these outreach activities, we continued to refine the envisioned futures themselves, primarily focused on further shaping them by distilling the futures described in the vivid descriptions into descriptions of the technical capabilities required to achieve the envisioned futures. These technical capabilities, which we refer to as systems concepts, provide a more tangible example of what is being sought, shaping investments, framing discussions, and supporting activities such as R&D roadmap development.

EARLY INDICATORS OF ENVISIONED FUTURES DRIVING INNOVATION

Though we are still early in our pursuits, as of this writing we see indicators that the envisioned futures are guiding us and having an impact on strategy, R&D, and unity of effort.

Impact on Strategy

The Laboratory has used the vision, strategy, and execution (VSE) concept to guide its strategic planning since 2012, having completed several full cycles at the time of this writing in 2020. Every 3 years, the Lab and each sector and department develop full VSE plans, and AOS leadership intends to use envisioned futures to provide continuity across these epochs. As we planned for fiscal year (FY) 2021, the envisioned futures provided a framework that helped us shape the sector's strategy more quickly and effectively than before. AOS mission area leaders generally framed their strategic focus development by considering the envisioned futures as 10-year goals. The initial epoch for each envisioned future framed the FY2021–2023 activities and helped set the strategic foci. Although identifying strategic focus areas is inherent in the VSE approach, the envisioned futures provided a deliberate and enduring framework for our pursuits.

Impact on R&D

We have started to see indicators of R&D focus through the use of the envisioned futures and their associated systems concepts. For example, the Cyber-Resilient Ship envisioned future has framed the call for proposals for independent R&D in one research area in the Cyber Operations Mission Area. Staff proposals align with three major areas of work in this concept: trusted endpoints, untrusted mission processing environment, and out-of-band monitoring and recovery. With the envisioned future systems concept driving a research agenda, staff members better understand what to expect over several years because each year's R&D call emphasizes tackling a new piece of the challenge. While staff members have proposed solid near-term R&D efforts, they have also proposed more longer-term science and technology advances that they may not have pursued without the far-reaching target in the envisioned future. For example we have been conducting R&D on the use of homomorphic encryption, a technology that enables functional operations on encrypted data, as a potential breakthrough for the Cyber-Resilient Ship. In APL's typical mode of operation, staff members are deep in the application space, implementing prototypes and trying to understand the feasibility in computational run-time perspectives. Similarly, the AI-Driven Counter WMD envisioned future led to a systems concept involving autonomy and AI to efficiently perform sensitive site exploitation. By considering the lack of operator at the site, staff members created new concepts from the autonomy of robotic systems that can infer their next move based on the observables to new sensors that reveal compounds for automated processing. APL is activity developing hyperspectral imaging, which can identify chemical compounds from standoff distances, opening up entirely new deployment concepts. Placing the smarts at the edge through compact AI implementations on specialized hardware not only minimizes the harms humans would face but also imparts additional advantages, such as more efficient information transfer out of the site. It is readily apparent that staff members understand the concepts and propose ideas that are integral pieces of the overall solutions. While these observations are not quantitative evidence, they are a positive sign that staff members are internalizing the envisioned futures, developing an understanding of the relevant problems, and proposing solutions.

AOS also focused its FY2021 Propulsion Grant challenge (an internal funding opportunity) on the envisioned futures, consistent with the focus of the conventional independent R&D cycle for the mission areas. (For more details on the Propulsion Grant program, see the article by Kedia and Krill, in this issue.) With the Disrupt Our Futures challenge, AOS encouraged Laboratory staff to develop game-changing, disruptive ideas that could accelerate one or more envisioned futures. As of this writing, we just selected our FY2021 Propulsion Grants and received a number of bold concepts that are well aligned with the envisioned futures.

Ultimately the envisioned futures are starting to point toward longer-term technical challenges that require disruptive science and technology advances and are often cross-cutting. Autonomy is not only important for the AI-Driven Counter WMD envisioned future but will also be key in multiple envisioned futures, such as the Continuous Cyber Advantage envisioned future where machines and algorithms will need to complement humans because of the speed and scale of cyber operations. Additionally, in the Undeniable Access envisioned future we anticipate the need for autonomous unmanned systems to support intelligence collection.

An envisioned future like Pushing Out the Border, with a multitude of sensors that need to be orchestrated and heterogeneous data that need to be fused, is a physically broad use case around the borders of our country. But these sensors and fusion techniques could potentially be leveraged in the smaller confines of a mobile site exploitation environment or even other envisioned futures such as Assured Care, where we seek to assess casualties using a range of sensors, fused information, and decision aids for a nonexpert medic. As part of Assured Care we are also investigating novel sensors such as noninvasive optical imaging, which has the potential for extremely precise assessments of traumatic brain injuries given optical wavelengths and a small form factor that could be useful for the battlefield. Many medical imaging techniques are in development, but the envisioned future has pushed us to consider advancements much farther out on the time horizon. Finally, multiple envisioned futures have clearly pointed us toward diversity and ensembles of solutions. There is not one single sensor that will "solve" WMD detection and border intrusions or enable diagnoses. The key to many of our envisioned futures is diversity of solutions that are orchestrated and fused to achieve an objective.

This notion of diversity extends beyond sensing. Based on our history with nuclear C3, we do not believe that there is a single robust path that will deliver our critical messages, but rather an ensemble of communication modalities that will create the overall performance we need for Unquestionable National Strategic C3. We are looking at nontraditional communication techniques that on their own may be marginally useful but, in concert with other techniques and secure, federated network control, can contribute to an unquestionable capability. While the mission and metrics vary, these same technical principles can apply to reaching our special operators in denied areas as part of the Undeniable Access envisioned future. A diverse set of communication pathways not only ensures that special operators can communicate but could even confuse others who may try to detect and observe their communications. The envisioned futures are resulting in the creation of R&D concepts with much longer time horizons than those proposed in the past, and we see common science and technology themes emerging.

Impact on Unity of Effort

Another overall aspect of envisioned futures is the unity of effort, and we have seen progress in this area as well. Although this is again a qualitative perspective, we see anecdotal evidence through R&D, sponsor engagements, and competencies. Envisioned future leads have created teams cutting across line and program roles, enabling clarity of roles, empowerment, and accountability. This approach also has begun to

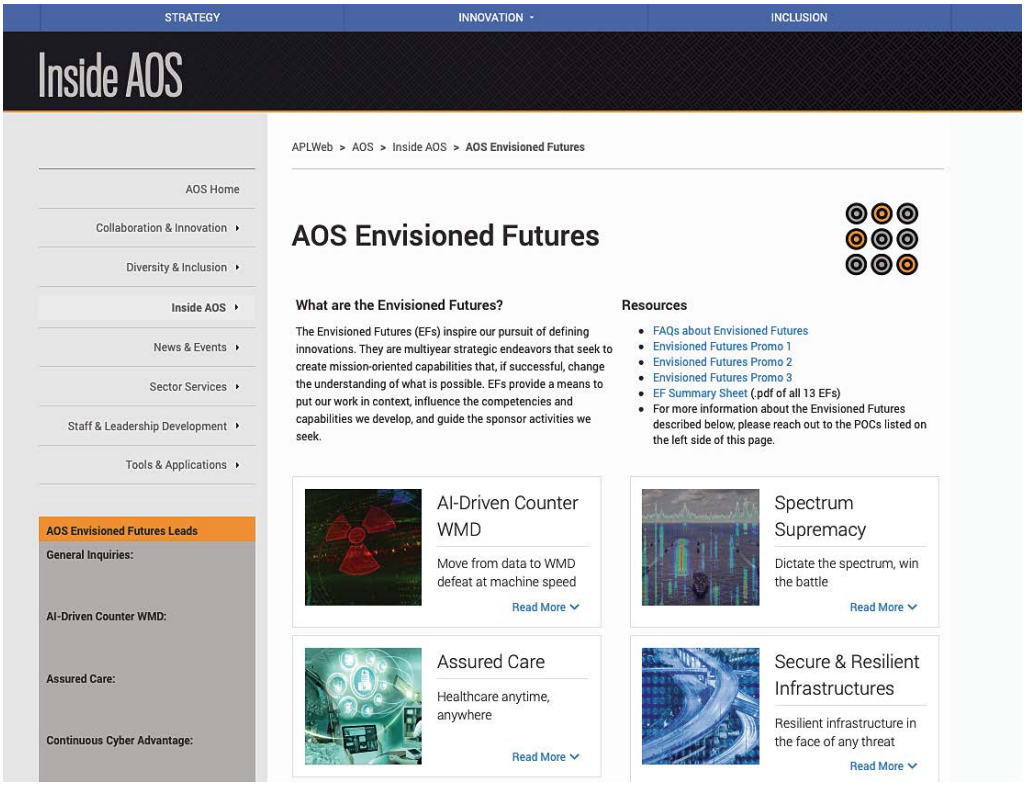

Figure 1. AOS envisioned futures web presence. The web page is one avenue for sharing information with all AOS staff members.

synchronize our messaging and resource decisions, ultimately focusing our efforts.

Part of the unity of effort comes through communications, a major consideration as the envisioned futures were created. During the formulation phase, we shared draft material on informal AOS websites to allow staff members to see what was being considered. Once the 13 envisioned futures were solidified with BHAGs and vivid descriptions, we developed a more substantial web presence to share information, as depicted in Figure 1.

One of our milestones was the January 2020 all-hands meeting where we not only discussed the use of envisioned futures but also showcased them in APL's Kossiakoff Center where staff could talk to the envisioned future leads to gain fuller understanding of the envisioned futures (Figure 2). Videos from this event are posted on the AOS internal website. Additionally several podcasts developed as part of the Propulsion Grant program have also proven useful for increasing staff awareness.

We believe the envisioned futures concept has the potential to unify efforts beyond even the Laboratory. The problems we are seeking to solve are significant, and we need partnerships to enable broad and comprehensive results. In that light, we have shared some of our concepts with sponsors and other collaborators and requested their feedback. Those exchanges have been fruitful and have presented us with perspectives that helped us refine our thoughts and directions. There are signs that APL is building ecosystems to cooperatively determine solutions. While we will not describe specifics because of sensitivities, in some cases we are helping sponsors set the stage for their future plans, and in other cases sharing our envisioned futures prompted vigorous debate about technical approaches, which is equally valuable for both parties as we imagine the future.

NEXT STEPS

While efforts to realize our envisioned futures are well underway, our thinking is still evolving as of late 2020. We need to tackle two near-term challenges to continue to move the envisioned futures forward: we need to determine (1) how to measure our progress and (2) how to increase our momentum.

Metrics

We are considering two types of metrics to assess our progress. The first are enduring metrics that guide the envisioned future during its pursuit. For example, the Pushing Out the Border envisioned future seeks to improve the ability to preempt a threat by enabling us to detect it sooner and farther from the border. These metrics provide a North Star, a way to both measure progress against the envisioned future over time and to explain how an activity contributes to progress. The second type of metric supports these overarching metrics by driving systems concepts. For example, communications throughput would be a secondary metric for a sensor fusion systems concept within Pushing Out the Border since high throughput could enable platforms to share rich sensor data. However, other Pushing Out the Border systems concepts might not rely on communications between platforms to improve time/distance performance. Therefore, these metrics are similar to the higher-level metrics as they will guide activities for particular systems concept's activities but are expected to be more transient; these metrics would cease to be necessary once the systems concept is sufficiently realized, pointing back to the primary North Star metrics.

The Flywheel

In 1942, Merle Tuve, APL's first director, established a set of APL operating rules that included the following: "The final result is the only thing that counts; the only criterion is, does it work then." Reflecting on this statement in the context of envisioned futures, it becomes clear that although solving a technical problem is probably necessary to achieve a defining innovation, it is not sufficient to achieve a "final result"—creating a defining innovation will also depend on operationalizing the solution, relationships with many external communities (i.e., funding sponsors, operational users, etc.), and ensuring we have a deep understanding of the underlying operational challenges.

Figure 2. The envisioned futures showcase during the 2020 all-hands event. This showcase was another part of the coordinated effort to share the envisioned futures approach and the output of the process with the entire sector.

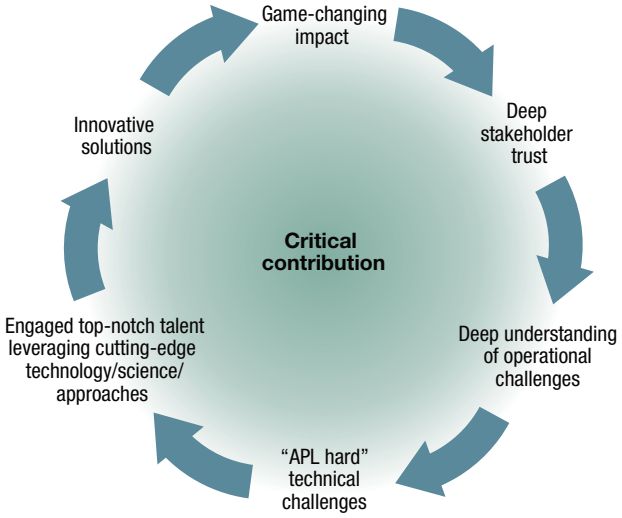

Figure 3. Collins's flywheel concept adapted to APL. This construct reinforces that achieving game-changing impact requires developing stakeholder trust, deep understanding of the operational and technical challenges, and engaging the right skills and capabilities to realize innovative solutions.

In *Good to Great*, Collins[2] introduces the concept of a flywheel as a way to frame activities that feed each other, allowing an organization to build momentum over time. Implicit in this concept is a systematic approach to considering all the factors necessary to achieve a meaningful result.

To ensure that our envisioned future teams maintain this broad perspective, we are exploring adopting the flywheel construct to the envisioned futures as a way to systematically think about the elements that have to be in place to realize an envisioned future. Figure 3 shows our initial adaption of the flywheel construct to APL's model. This construct reinforces that realizing the game-changing impact we desire from envisioned futures requires focus not only on the innovative technical solutions but also on developing stakeholder trust, ensuring we deeply understand the operational and technical challenges and possess the right skills and capabilities to innovate.

Endurance

During development of the envisioned futures, a commonly raised question related to the time horizon. AOS leadership viewed the envisioned futures as decade-long pursuits, with capabilities being realized incrementally of course. As we mature our thinking we will no doubt be spurred to modify a vivid description or BHAG. Perhaps after some sufficient amount of time working toward an envisioned future, we will find that it fails to be on a productive path, or perhaps something will change in the world, with our sponsors, or with technology. We would not blindly continue down an unfruitful path; however, we all want to stay the course when possible so that we truly bring all the capabilities of APL to bear in solving these important national and global problems.

We conclude by noting that at the time of this writing we are experiencing an event that has disrupted the world in unprecedented ways. We have no idea how it will turn out. Given the nature of COVID-19 and our discussion about endurance, we reviewed our envisioned futures to try to grasp, even at this potentially early stage of the pandemic, what its implications could be. Many of our envisioned futures seem as prescient as if we had written them after the outbreak. Our BHAG in Global Health Security is to "sense infectious disease in people who are asymptomatic." This is as critical a goal as any we could imagine at this stage of the pandemic as the COVID-19 disease has spread across the globe. Many other envisioned futures also suggest highly relevant capabilities that should continue to be our targets. While we are encouraged, we also recognize that the world is rapidly changing in many dimensions and these changes could require us to modify some of our envisioned futures.

SUMMARY

The AOS envisioned futures have set in motion a strategic focus in the sector that we believe will propel the organization toward achieving defining innovations consistent with the Laboratory's role for the nation. These envisioned futures will define our contribution priorities, sponsors, R&D agenda, competencies, and partnerships, and our initial steps toward realizing these futures have been promising. By the time APL celebrates its 100th anniversary in 2042, we hope that a defining innovation has been achieved based on one or more of these envisioned futures, bringing with it a wake of additional disruptive capabilities against the asymmetric threats to our nation and world.

ACKNOWLEDGMENTS: We acknowledge that the AOS envisioned futures strategy has been the work of a team. First we acknowledge the strategic work of Andrew Merkle and David Blodgett in the FRFAAP, which served as a foundation for AOS's evolution toward envisioned futures. We also thank the AOS staff members, in particular the envisioned futures leads, who collectively created and are now realizing the goals of these envisioned futures in a multitude of ways.

REFERENCES

[1] J. Collins and J. Porras, "Building your company's vision," *Harvard Bus. Rev.*, Sep.–Oct. 1996.
[2] J. Collins, *Good to Great: Why Some Companies Make the Leap and Others Don't*. New York: HarperCollins, 2001.

Donna M. Gregg, Asymmetric Operations Sector, Johns Hopkins University Applied Physics Laboratory, Laurel, MD

Donna M. Gregg is the head of APL's Asymmetric Operations Sector. She has a BS in mathematics/applied mathematics from the University of Maryland, College Park and an MS in applied mathematics from Johns Hopkins University. She is responsible for approximately 1,400 staff members and the work of four mission areas focused on defeating asymmetric threats, whether human-made or naturally occurring. Specific areas of focus include countering weapons of mass destruction, influence, offensive cyber, and biological threats. A major thrust of the sector is the advancement and use of data science to find and combat these threats. Her email address is donna.gregg@jhuapl.edu.

Robert A. Nichols, Asymmetric Operations Sector, Johns Hopkins University Applied Physics Laboratory, Laurel, MD

Robert A. Nichols is the chief scientist of APL's Asymmetric Operations Sector (AOS). He holds a BS and an MSE in electrical engineering from Johns Hopkins University. He joined APL in 1992, initially working in satellite communications and then in numerous other areas in wireless communications and cyber operations. In his role as chief scientist, he helps AOS cultivate and realize innovative ideas across a span of multidisciplinary areas of science and technology. His email address is robert.nichols@jhuapl.edu.

William J. Blackert, Asymmetric Operations Sector, Johns Hopkins University Applied Physics Laboratory, Laurel, MD

William J. Blackert is a Principal Professional Staff member of APL's Asymmetric Operations Sector. He has a BS in electrical engineering from the Rose-Hulman Institute of Technology and an MS in electrical engineering from the University of Virginia. His expertise includes leading the analysis and development of asymmetric tools and techniques in the cyber and influence domains. He is currently responsible for assisting the Asymmetric Operations Sector head with the development, communication, and implementation of strategic initiatives. His email address is william.blackert@jhuapl.edu.