

Looking Back—and Looking Ahead: Guest Editor's Introduction

Jerry A. Krill



A SNAPSHOT FROM THE 1970s

I arrived at the Johns Hopkins University Applied Physics Laboratory (APL) fresh out of college in the early 1970s, when APL was just over 30 years old. I found APL to be a scintillating place—bristling with antennas and labs. We had a mainframe computer in Building 3 with 4 megabytes of available memory—a huge storage capacity at the time! I would load my box of computer punch cards into the mainframe peripherals and await output the next day, hoping there were no key punch errors in my PL-1 program changes, or frayed punch cards, to set me back a day or longer. Staff members talked about their work during coffee breaks at the coffee carts and over lunch. After lunch some walked around the APL pond in deep discussion. (Of course, this was before our resident Canadian geese!) Nearly everyone had bookshelves, called “hutches,” on their GSA-issued desks as well as heavy, black rotary telephones and fluorescent desk lights. The library was a bustling central place to seek information. There was no Google; the only googol was the large number with 100 zeros (10^{100}). No one had a personal calculator unless it was for simple arithmetic. An advanced calculator with trig functions was at least \$500 and was owned by the group. Most of us used our slide rules.

Dr. Kossiakoff, the director, was personally involved in the automatic integrated detection and tracking system known as SYS-1, a capability that fused radar returns of multiple radars on each Terrier and Tartar ship to speed up detection and ultimately missile engagements. However, the system that would succeed the Navy Terrier, Tartar, and Talos air defense systems, Aegis, was already in development. What would become the Aegis

SPY-1 radar had recently been prototyped. Called the Advanced Multi-Function Array Radar (AMFAR), it was used for experiments on the rooftop of APL's Building 6, aimed toward the concentrated air traffic of Baltimore's Friendship International Airport, now the Thurgood Marshall Baltimore–Washington International Airport. The concepts of what would become the Cooperative Engagement Capability (CEC) and Naval Integrated Fire Control – Counter Air (NIFC-CA) were already visions of the future, captured in plastic “vu-graphs” that APL showed to the Navy. Then-Captain Wayne Meyer, the future “Father of Aegis,” regularly visited APL during Aegis program reviews, and we looked forward to his motivational talks extolling us on realizing the Navy's future. With the completion of AMFAR, a couple phased-array radar engineers I knew transferred to other groups to explore how sonar arrays might be designed to revolutionize undersea acoustic detection.

During this time, APL was also working with sponsors to develop other visions for the future, some of which became operational in the succeeding decades. These visions included Aegis Ballistic Missile Defense; terrain-guided cruise missile guidance, eventually leading to the Tomahawk cruise missile; novel uses of space, leading to SATRACK; and interest in greater participation in interplanetary exploration, succeeding the SAS-A and SAS-B survey satellites. Regular Poseidon submarine-launched ballistic missile tests involved whole families going to Cape Canaveral, Florida, for a month at a time. APL was beginning to lead exploration of any and every phenomena that might expose our nation's submarines to detection while they are hiding

in the depths of the ocean. Bio-medical programs were under way, largely in the Research Center, as part of a formal collaboration agreement signed by APL and the Johns Hopkins University School of Medicine just a few years earlier. With the energy crisis of the 1970s and long gas lines in Maryland, APL was exploring new concepts for alternative energy, such as ocean thermal energy generation and methane extraction from landfills, while also exploring fuel-efficient mass transit systems, such as accelerating walkways (“people movers”) and automated trams.

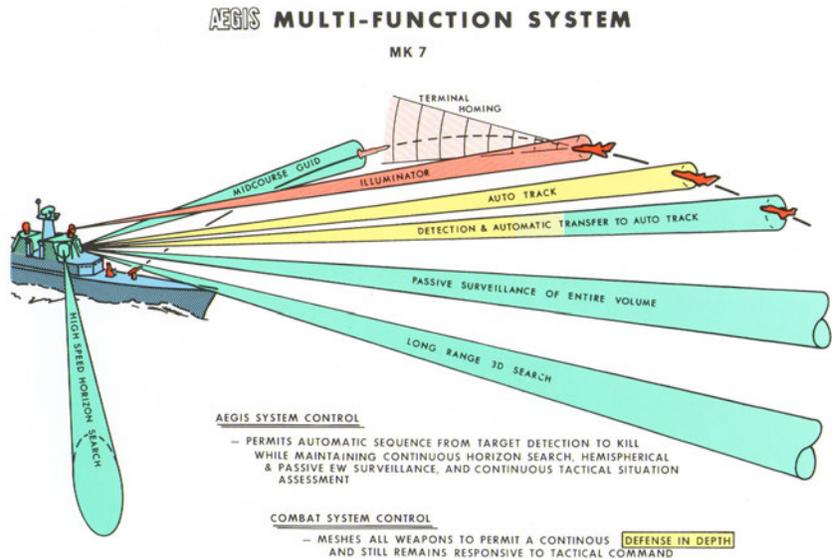
FAST-FORWARD TO TODAY

Much has happened since the 1970s: the end of the Cold War, Operation Enduring Freedom, 9/11, Operation Iraqi Freedom, and the global war on terrorism. Much has also happened technologically. Following Moore’s law, the performance of the most powerful APL computer in the 1970s is now exceeded in a cheap watch, and computing devices are everywhere in daily life. The Doppler signal-oriented Transit system was succeeded by the digital GPS constellation supporting the age of precision weapons in national security as well as ubiquitous commercial personal devices using tiny GPS receivers. The birth of the Internet and then cellular services and social media have changed society as well as our national security posture, with capabilities once available only at national

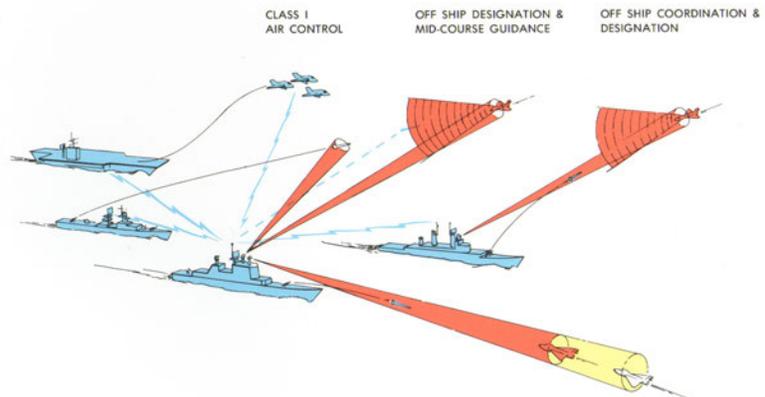
Right, The concept for Aegis was prepared by APL in 1973 and affectionately known as the Aegis Coloring Book. Top, Coloring Book cover. Middle, Functions of the SPY-1 multifunction array radar. Bottom, Concept showing Aegis in a force that anticipated CEC in coordinating missile engagements among ships and enabling the radar from one ship to support engagement of missiles fired from another ship.



COMBAT SYSTEM CONTROL



AEGIS AAW FORCE COORDINATION & CONTROL



and corporate levels now accessible to the individual. We have learned to exploit the nuances of acoustic propagation in the oceans and of radio frequency propagation on Earth and in space. We can simulate in some detail to predict how systems will work and whether they will be effective well before they are built. Autonomous interplanetary spacecraft have become feasible, affordable, and, therefore, a reality.

Yet, even with the profound changes in the world and the dramatic increase in human knowledge and technology, the key attributes of APL's culture and heritage are the same as they were in the Lab's early days. A few years ago, several of us talked with Al Eaton about what life was like during APL's early days. Mr. Eaton had arrived at the Lab in 1945. He had invented reverse tail control for supersonic missiles, a key part of one of APL's defining innovations, rising to become head of the Fleet Systems Department and then associate APL director. He also established APL's ability to perform highly classified work. Al, still employed at APL in 2012, described what the early Lab was like during the 1950s, with the challenges of the Cold War and opportunities in rocketry and space exploration. He told us that the can-do spirit, the creative energy, the call to service, and the ability to respond quickly with a total-system perspective were alive and well at APL. Our competition of ideas, inherent curiosity, national service perspective, need to "build and try," vibrant technical debates, team orientation, and world-class staff and facilities are as relevant now as they were in earlier times.

Several of us became well acquainted with Dr. Kosciakoff, who became the APL chief scientist after serving as director and led the establishment of the systems engineering master's degree program for Johns Hopkins. A compelling personality, "Kossy" would recruit us to teach systems engineering courses, would continually inquire about the latest systems engineering practices, especially in the era of real-time computing and networks, and pondered a future of online courses. He was considered a foremost leader in systems engineering, having "written the book"¹ based on his extensive experiences performing, leading, and, finally, as director, overseeing extraordinary system developments. To his final days, he especially encouraged us to continue to run experiments, collect and analyze data, and be creative yet methodical and thorough, taking risks to introduce first-ever capabilities. These activities and characteristics are evident at APL today.

An overarching ingredient established by our founders that is just as important today is APL's continued strategic relationships with our sponsors and stakeholders. Entering into a dialogue with the sponsor community was one of the first things I learned as a young engineer. Our sponsors fund and partner with APL to tackle the major challenges as a team. APL staff members have

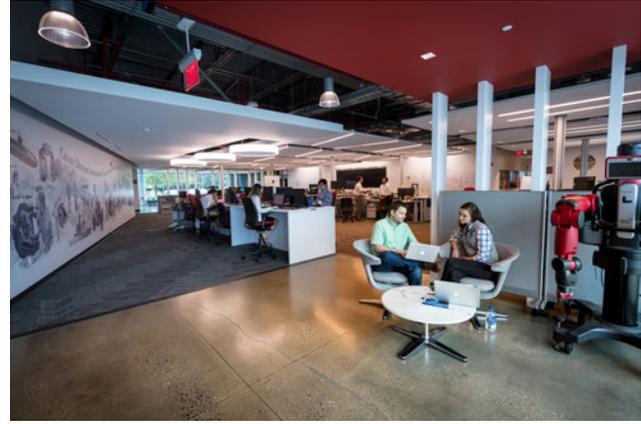
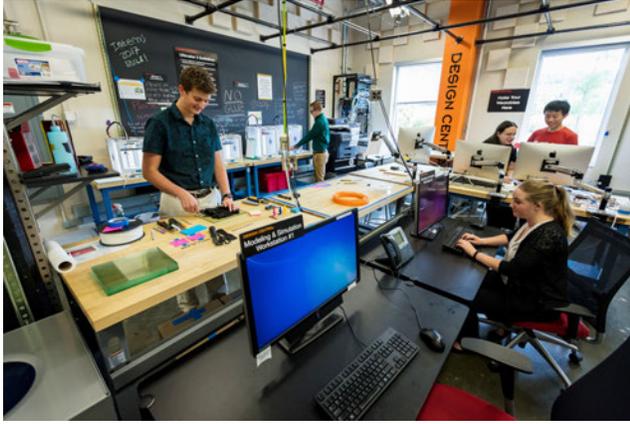
always felt a strong sense of collaboration with leaders from a wide variety of U.S. government programs.

LOOKING AHEAD

As an early-career engineer in the 1970s, I observed developments that eventually led to some of our defining innovations. Today, I am excited about the new technical developments percolating around the Lab that might become defining innovations in the coming decades. Will the brain-computer interface lead to a new communication path for humans? Will our renewed focus in hypersonics lead to a new generation of weapons? Will we introduce the technical approach for trusted, cyber-resilient autonomous vehicles and robotics that can complement our sailors and soldiers in maintaining a national security posture second to none? Perhaps APL and Johns Hopkins Medicine will develop the pathfinding data analytics to identify potential treatments for long-standing maladies. APL's partnership in the Europa mission may lead to exciting new discoveries about the origin of our solar system and perhaps life itself. What tiny spark of an idea being bounced around in a collaboration or project team might become just the solution to a national challenge?

With the accelerating pace of new, widely accessible technologies and with an increasingly complex spectrum of national security challenges, beginning in 2010 our director, Ralph Semmel, led development of a strategy to enhance innovation at APL. Building on the Lab's culture that has served us so well over the decades, we embarked on a methodical series of experimental initiatives to infuse new innovation practices and staff empowerment into the organization.² For example, we introduced Project Catalyst to provide various levels of funding, from small grants to backing for large projects, giving all staff members the opportunity to propose and collaborate on potentially game-changing innovations aimed at solving critical future challenges. This program enables staff members to go well beyond contributing only to their assigned tasks. Project Catalyst seeks revolutionary approaches, typically beyond the time horizons of our sponsors' programs. To date, a number of highly innovative concepts are being developed as part of the program, with the commensurate risks to their success that come with working at the edge of knowledge. Two examples are a means to detect and attribute genetically engineered organisms and a means for autonomous patrol vehicles to detect and identify adversaries' mines quickly and over a large area of ocean.

Another APL innovation initiative recognizes that the preponderance of emerging science and technology originates in the global commercial community, outside traditional U.S. government programs. The initiative is called Janney 2.75, a major revision (the "2") of a long-standing publication grant program that honors the late



The evolution of APL innovation spaces. The left photo depicts part of the Central Spark innovation center, a facility available to all staff members for use in design thinking, modeling and simulation, and 3-D printing. The right photo shows a neighborhood within APL's Intelligent Systems Center (ISC), which supports experts from the multiple disciplines of robotics, neuroscience, autonomy, and information science. The lessons learned from Central Spark and the ISC are informing the design of APL's newest major building, which will house the Research and Exploratory Development Department.

Stuart S. Janney Jr. and his son, Stuart S. Janney III, who each served as chair of APL's board of trustees and managers for a total of over half of APL's history. The new name also honors APL's 75th anniversary (the "75"). The Janney program competitively provides grants for staff to attend and present papers at conferences on technical topics that are unfamiliar to APL but seem especially important for the future. This collaboration allows APL to gain access to and strategically exhibit leadership in emergent technical societies, possibly leading to important contributions to future innovations.

We believe that our founding leaders would have applauded these and other strategic initiatives to position APL at the center of key innovation ecosystems and to include all staff in solving the greatest technical challenges of our time.

THIS ISSUE

As you read the histories in this 75th anniversary issue, I hope you will agree that the culture that marked APL's early days is alive and well today. And the Lab's recent innovation initiatives provide new opportunities for staff members to contribute ideas to solve critical challenges more than ever before.

The historic highlights of the mission areas in APL's four current sectors, Air and Missile Defense, Force Projection, Space Exploration, and Asymmetric Operations, capture the can-do spirit and operational perspective in describing the nine historic defining innovations discussed by APL director Ralph Semmel in his introductory article. A number of these articles also introduce recent and ongoing critical contributions that might be considered defining innovations when APL looks back from its 100th anniversary in 25 years. Air and Missile

Defense and Force Projection have direct legacies to the proximity fuze that was used by the Navy for air defense and by the Army for power projection. The Space Exploration Sector traces its history to the dawn of the Space Age when APL's first experimental navigation satellites were launched. The Lab's newest sector, Asymmetric Operations, grew rapidly after 9/11 but has roots that go back to ensuring the integrity of communications for critical national systems in the 1970s.

From the beginning, research, analysis, and assessment have been key to APL's ability to explore emerging technologies and to analyze perceived threats years in advance of their manifestation. These activities, which help position the mission-oriented programs for the future, are now embodied in the Research and Exploratory Development Department (REDD) and National Security Analysis Department (NSAD), respectively. APL's role with Johns Hopkins Medicine, centered in REDD, has recently expanded well beyond the Lab's early biomedical research as medical professionals have increasingly recognized the importance of technology and systems engineering in improving the quality of care and exploring sophisticated interventions. Taken together, REDD and NSAD have been described as the "headlights of APL," peering out at possible future technological and global conditions decades beyond today. APL chief engineer Conrad Grant discusses the Lab's systems engineering approach as well as other key ingredients enabling APL staff to meet critical challenges in the wide expanse from the deep ocean to deep space.

Additional articles capture important elements of APL's history and culture: highlights from our long-standing Colloquium series, the history of the *Technical Digest* itself, the Lab's commitment to awarding staff members' achievements, APL's ever-evolving facilities and capabilities, and our directors.

Another article describes APL's history of offering diverse educational opportunities to its staff members. APL's partnership with the Johns Hopkins University Whiting School of Engineering has expanded over the years to become the largest part-time engineering graduate program in the nation.

Having begun as a few hundred staff members working covertly in a used car garage to meet one of the greatest critical challenges of the 20th century, APL is now a highly complex multi-mission-oriented laboratory of over 6000 staff members on a nearly 460-acre campus. It is still addressing the critical challenges of our time, the 21st century, from the depths of the oceans to the edge of the solar system, from the nanoscale structures of the human body to the macrostructures of national health care, and through the ubiquitous cyberspace. The storied history of APL continues.

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- ²Garrison Darrin, M. A., and Krill, J. A., *Infusing Innovation into Organizations: A Systems Engineering Approach*, CRC Press, Boca Raton, FL (2016).



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

Dr. Krill earned bachelor's and master's degrees from Michigan State University and a Ph.D. from the University of Maryland, all in electrical engineering. Previously he was the 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. Dr. Krill holds 22 patents, has authored over 100 papers and documents, 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, co-authored the book *Infusing Innovation into Organizations*, and co-led the Naval Studies Board study entitled *Responding to Capability Surprise: A Strategy for U.S. Naval Forces*. His e-mail address is jerry.krill@jhuapl.edu.