The Origin and History of the Global Engagement Department

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The Global Engagement Department and its two business areas (BAs), Strategic Systems and Precision Engagement, stem from the very beginning of APL. The two BAs followed separate evolutionary paths, which reflected the DoD's separation of conventional and nuclear forces. Recently, in a move that reflects the DoD's recent consolidated definition of Global Strike, the two BAs were brought together to form the Global Engagement Department, a new APL department. The common theme of both BAs has been offensive warfare and the common functions needed to make it work. This article describes the histories of the programs in these BAs, the divergence of the BAs from a common heritage, and their recent rejoining to form the Global Engagement Department.

HISTORIC OVERVIEW

In the beginning, APL dedicated itself to the development of the proximity, or VT (variable time), artillery fuze that led to increased protection of Navy ships and the city of London against aircraft attack and of Army ground forces in the Battle of the Bulge. For the first 10 years after the war, the Laboratory focused primarily on the development of long-range rockets and guided missiles for the same purposes. The work of today's Precision Engagement (PE) and Strategic Systems (SS) business areas (BAs), within the Global Engagement Department (GED), began in APL's original Bumblebee organization. The Bumblebee organization was the single technical unit at APL that carried out the bulk of the Laboratory's efforts for the U.S. Navy in the 1940s and 1950s and produced the Terrier, Tartar, and Talos missile systems.

In 1955, when the Navy began development of a long-range, nuclear, sea-launched ballistic missile and submarine, the Navy requested APL's assistance. In 1958, this relationship was formalized with the creation of APL's Polaris Division. This Fleet Ballistic Missile (FBM) effort and its follow-on strategic systems activities evolved through a series of organizational changes, leading to today's SSBA organization in the GED. This evolution is depicted on the left side of Fig. 1.

Similarly, today's precision engagement activities evolved through a more complex series of organizational changes influenced by a series of technological advances

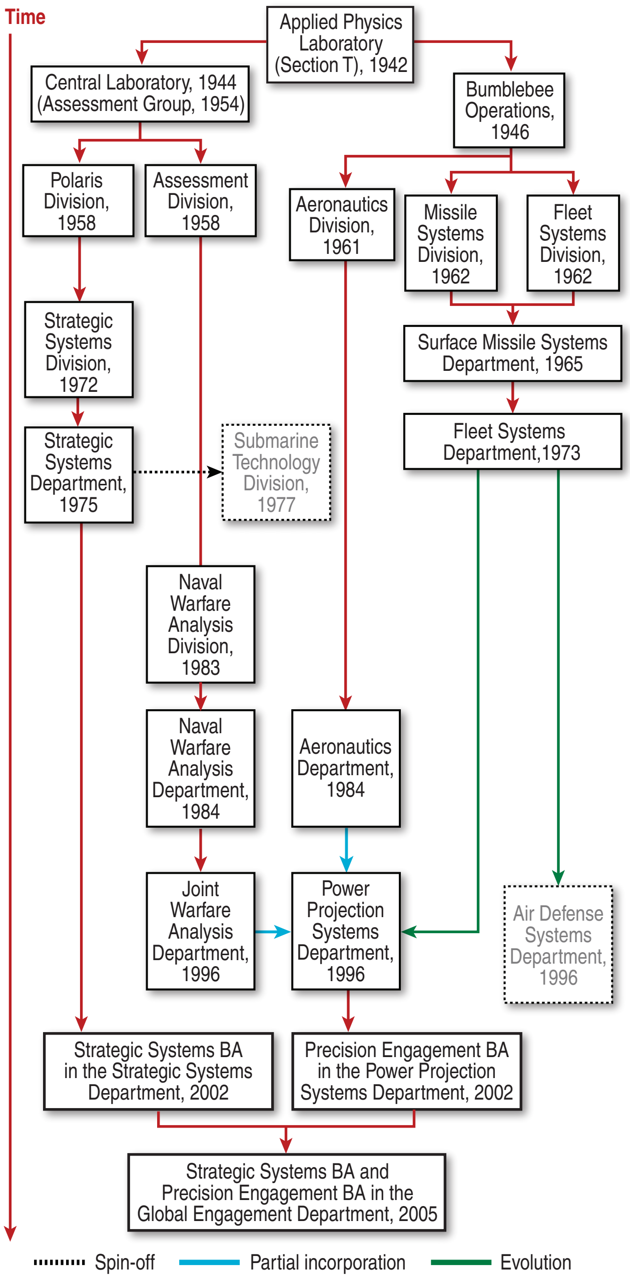

Figure 1. Organizational evolution of the GED.

and broader Laboratory involvement in the Navy's conventional fleet defensive and offensive missile systems. The organizational evolution of these efforts, leading to the current PEBA organization in the GED, is depicted in the center and on the right side of Fig. 1.

What separated, and ultimately drew together, the programs in SS and PE at APL was the treatment of these areas within the DoD and the U.S. Navy. Strategic nuclear systems and conventional tactical systems were very separate, organizationally and operationally, for many years. Recently, however, these two areas have become more common as capabilities and potential employment differences have become less distinct. Thus, APL's efforts in both areas became increasingly synergistic. In October 2005, the two BAs were brought together by APL management to form a new department, the GED. The APL administrative memorandum from Director Rich Roca announcing the change stated that "this new, combined team will be focused on strike, be it conventional or strategic."[1] The intent of the merger was to establish APL as a nationally recognized center of excellence for systems that achieve end-to-end offensive effects-on-demand. The areas of interest include gathering actionable information about potential targets, making command and control (C2) decisions, and conducting strikes—either kinetic or nonkinetic, conventional or nuclear.

Many of the efforts noted below are described in more detail in the accompanying articles in this issue of the *Johns Hopkins APL Technical Digest*.

STRATEGIC SYSTEMS BUSINESS AREA

The SSBA has a long history within APL, starting in the mid-1950s. In November 1955, the Navy created the Special Projects Office (SPO) to oversee the development of a submarine-launched, nuclear ballistic missile program.[2] In early 1957, because of the Laboratory's long involvement with the Navy's fleet missile systems and the personal and professional relationships between Laboratory staff (Ralph Gibson, Alexander Kossiakoff, William Avery, and Richard Kershner) and Captain Levering Smith, the newly appointed technical director of SPO, the Laboratory began its formal relationship with the Navy's FBM program. Captain Smith specifically requested that APL provide part-time technical assistance in the person of Richard Kershner because of his systems evaluation expertise.[3] As the pace of activity accelerated in subsequent months, the Laboratory was requested to bring more of its known technical and systems expertise to bear through a series of studies and technical consultations. By the fall of 1957, the Navy and Laboratory leaders determined that a significant effort by the Laboratory was needed, and a formal task, Task P, was established with the Navy. In addition, a new central laboratory group was designated: CLS (Special Project). The group was led by Kershner and was composed of senior APL staff who also reported to the Laboratory's Bumblebee organization, because the Laboratory had ongoing commitments to other Bureau of Ordnance projects. As the pace of activity continued to increase, in August 1958, a formal Polaris Division, initially under the leadership of Kershner and later under Robert Morton, was designated as a Laboratory entity and drew on staff from the Bumblebee organization.

The primary focus of the Laboratory's efforts was to coordinate analysis of the Polaris subsystems with operational concepts to define performance requirements and to produce a test concept for the integrated weapon system, i.e., an operational test and evaluation program. Additionally, the Laboratory carried out engineering development work, experimental work, and other studies during these early days of the FBM program. These efforts included seminal development of an artificial satellite system for precise navigation position fixes, which were essential to the FBM program. These navigation satellite efforts almost immediately evolved into a distinct activity that eventually became the APL Space Department. The Navy's Polaris program office head, Rear Admiral Raborn, also was in need of a technical organization that could provide objectivity, independence, and expertise in an area that few organizations had experience with at that time: he was looking for a "systems approach."[4] Admiral Raborn also recognized the importance of testing to the success of a deployed weapons system. He assigned the task of developing a comprehensive test program, the SPO Technical and Operational Test Program, to the Laboratory. This continuing test program, originally conceived of and developed by APL, still provides the basis of testing conducted by FBM weapon systems today (see Fig. 2).

APL's role in the FBM program was originally to be temporary and terminate after the first several nuclear ballistic submarines (SSBNs) were deployed. However, after the FBM fleet began deployed operations in late 1960, problems began to emerge that required solutions, and the Navy requested that APL expand its weapon-system evaluation activities beyond the original test programs to a continuing Patrol Evaluation Program. In November 1962, APL conducted its first tactical patrol evaluation.[5] As part of its patrol evaluation effort, and to gain continuing deployed system performance information, APL devised a new test concept called a Weapon-System Readiness Test. For each Weapon-System Readiness Test, a message is sent to the submarine by using the tactical communications system, and the crew conducts a simulated launch operation while on operational patrol. The hallmarks of these evaluations, as well as of the earlier test programs, were the inclusion of embedded system instrumentation and the logging of all weapon-system evolutions. This approach proved to be invaluable over the several generations of FBM weapon systems and has led to significant understanding of system performance and to subsequent improvements in follow-on systems.

In 1965, an additional APL effort in the expanded and continuing support of the FBM weapon systems

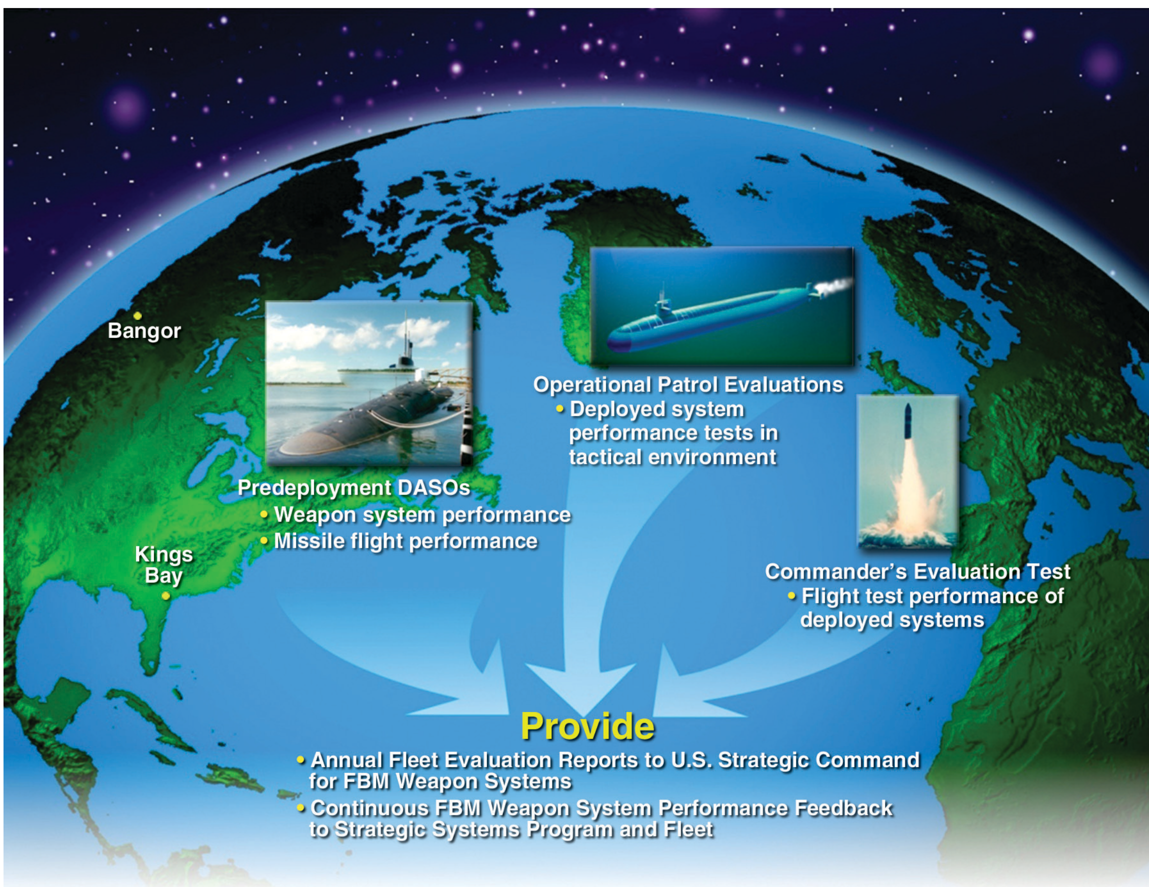

Figure 2. FBM strategic weapon systems continuing test programs.

commenced. Because of the high national importance of strategic nuclear weapon systems, the Joint Chiefs of Staff required annual performance estimates for all such systems. Before 1965, these evaluations were done by the Weapons System Evaluation Group in the DoD and not by the services. In 1965, the services were directed to provide these evaluations, and the Navy designated APL as its independent evaluation agent for the Polaris FBM systems. The Laboratory continues in this role currently, providing the annual performance estimates to U.S. Strategic Command (USSTRATCOM) for the FBM weapon systems.

From its initial involvement with the Polaris Program in 1957 through the mid-1960s, APL's efforts in FBM systems were almost exclusively sponsored by the U.S. Navy Ballistic Missile Program Office. However, starting in the mid-1960s, several additional related efforts were undertaken by APL's Polaris Division. In 1965, the U.S. Army, which had the Pershing tactical nuclear missile system deployed, required similar performance estimates for their system, and they asked APL and the Polaris Division to undertake this activity. APL developed similar testing scenarios and instrumentation systems for the Army, and the Laboratory continued as the independent evaluator for these systems until Pershing's retirement in 1979 in compliance with the Intermediate-Range Nuclear Forces (INF) Treaty. In 1966, the Laboratory and Polaris Division were tasked to assist the U.K. Royal Navy in testing and evaluation of its Polaris weapon system, which it had acquired from the United States. APL assisted the United Kingdom in developing its weapon-system evaluation programs and in conducting the weapon-system evaluations during U.K. Demonstration and Shakedown Operations (DASOs). Later, when the United Kingdom acquired the much more advanced Trident II (D5) system from the United States, APL was tasked by the U.S. and U.K. navies to expand its support by providing weapon-system performance estimates, analysis, and data-processing support.

The Strategic Systems Division/Department (SSD)/SSBA program activities have evolved and expanded over the years, as illustrated in Fig. 3. However, in each case, these changes have stemmed from the system-level testing and evaluation expertise developed and demonstrated by the Laboratory in support of the FBM weapon systems. In the early 1970s, the Navy's Strategic Systems Program Office (SSPO), renamed from SPO, asked APL to undertake an evaluation program for its range-tracking systems used in support of its FBM test missile flights. The system was required to track multiple long-range submarine-launched ballistic missiles (SLBMs) in flight at one time, and the Navy was concerned about its ability to do this. That evaluation and additional range system evaluation responsibilities con-

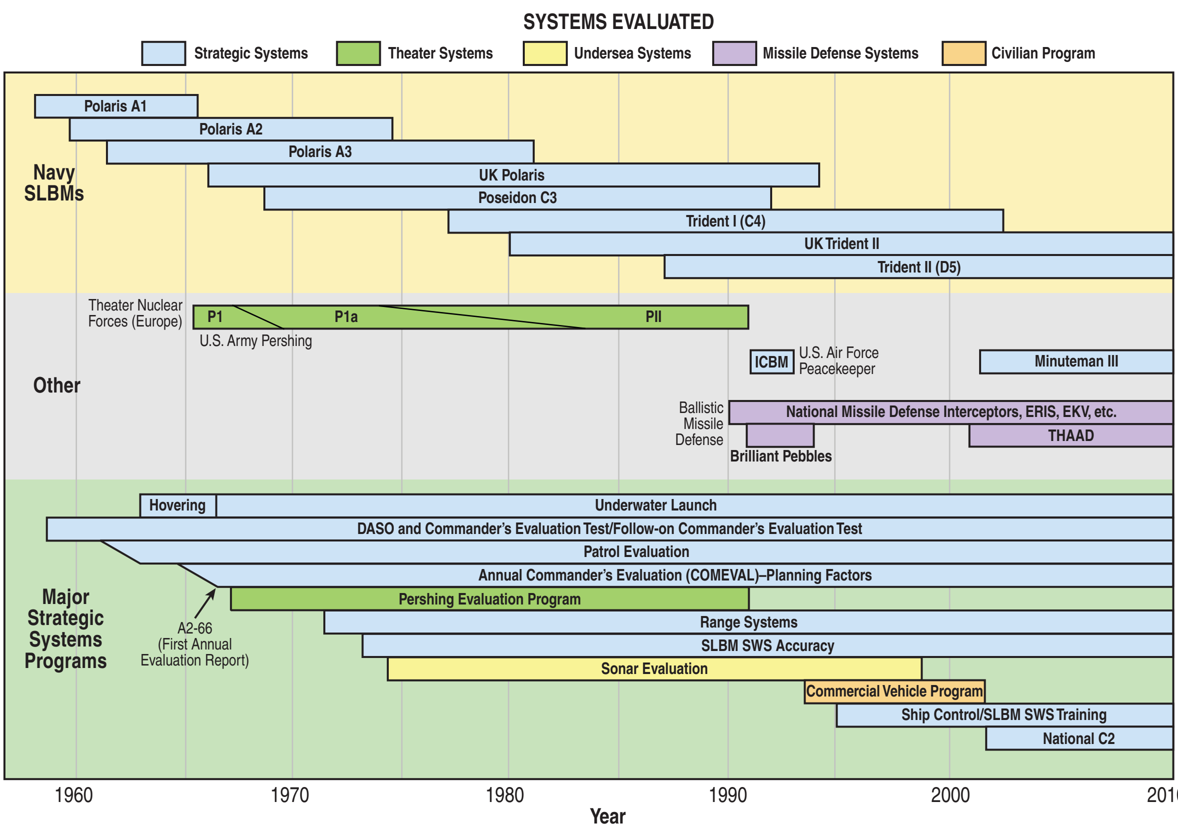

Figure 3. Evolution and expansion of SSBA programs. ICBM, intercontinental ballistic missile.

tinue today as the Range Systems Program. Again, in the early 1970s, the Navy was concerned about the performance of its unique SSBN sonars; APL was asked by SSPO to develop a program and the instrumentation to assess SSBN sonar performance while deployed, by using principles similar to those of the FBM evaluation efforts. That program, developed and initially led by Lou Montanaro and known as the Sonar Evaluation Program, continued through 2000.

In the early 1970s, the initial efforts of what would become a major technical challenge and activity at APL in support of the FBM program began within SSD as SSPO began to develop a highly accurate SLBM weapon system. APL's involvement began with a series of studies led by Larry Levy to understand the sources of inaccuracy in the SLBM weapon system. In 1974, these efforts were consolidated into a formal accuracy technology effort called the Improved Accuracy Program. The program's objective was to establish technical accuracy options for the next-generation SLBM weapon system, Trident II (D5), and to define the infrastructure needed to validate, through "precise tests and measurements," that the system could achieve its high-accuracy goals. This effort ultimately led to development and implementation of the accuracy instrumentation systems depicted in Fig. 4.

The Laboratory made several significant contributions to this effort. Arguably the most important one was the development of a novel satellite tracking system, named SATRACK, led by Levy, Edwin Westerfield, and Tommy Thompson. It enabled precision missile-trajectory-error analysis by using GPS satellites, and it was initially a collaborative development effort between the Space and SS departments. This complex technical development included an APL-developed, missile-borne translator that received GPS signals and relayed that information to ground receiving stations (see Fig. 4) and an APL-conceived and -implemented postflight analysis and processing approach that permitted determination of individual guidance and other weapon-system-accuracy error sources. (Some of the accuracy-assessment techniques developed for the FBM program were eventually spun off and applied to the Tomahawk program, which is discussed later in this article.)

The success of the SATRACK system, the flight-borne translator, and the postflight analysis regime led

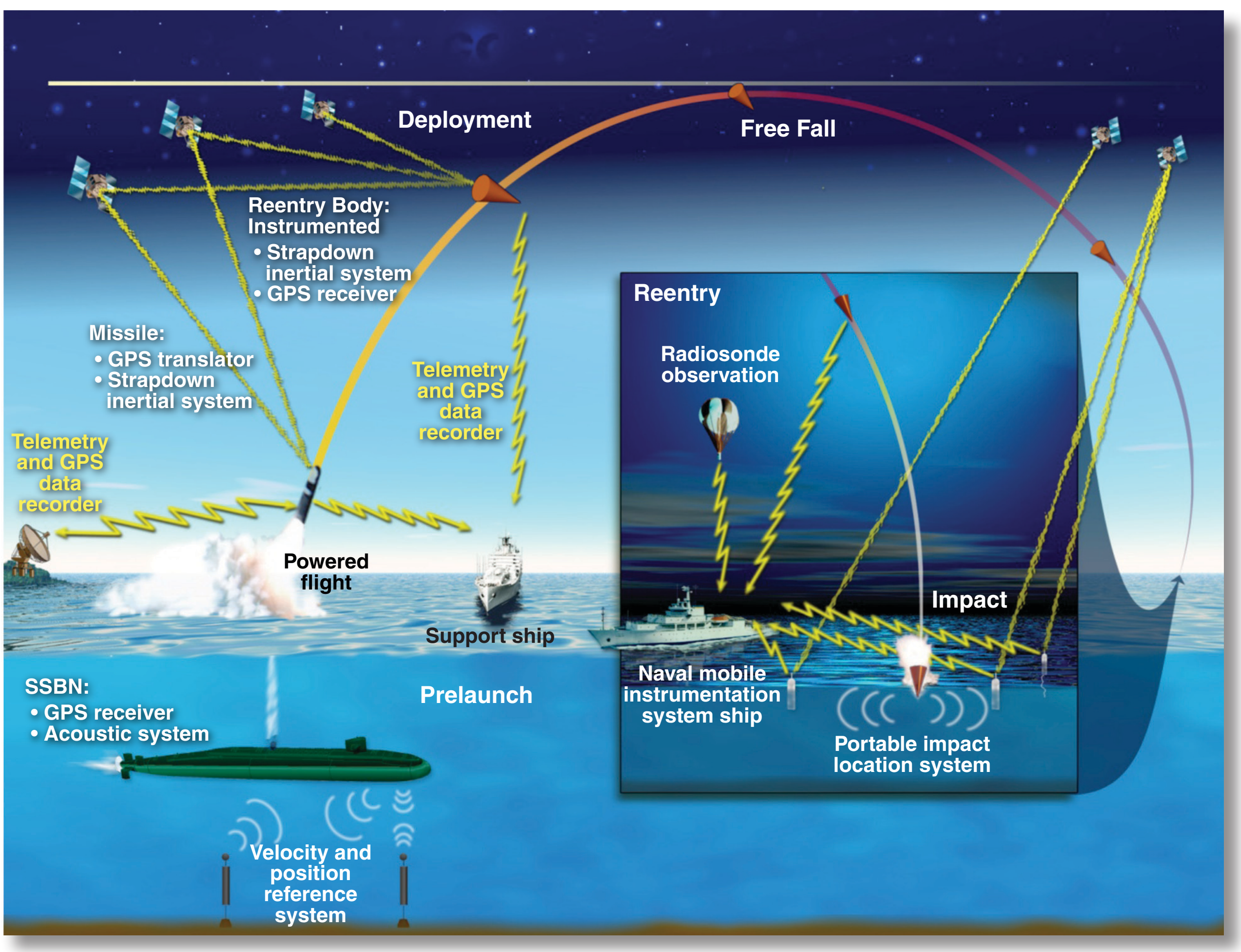

Figure 4. Trident II flight-test-accuracy instrumentation.

to expanded implementation as the Navy and other services sought not only higher accuracy for their weapons but also the necessary understanding of the error sources. APL's unique understanding in this area led to several additional efforts. In 1992, the Air Force's Peacekeeper missile system implemented the APL SATRACK approach for two specially configured flight tests to gain accuracy understanding. A similar effort was again undertaken by APL for the Air Force in 2002 for Minuteman III. Also in the 1990s, APL became involved in applications of SATRACK for several missile defense systems—the Army's Exoatmospheric Reentry Interceptor Subsystem (ERIS), the Strategic Defense Initiative Organization Brilliant Pebbles effort, the National Missile Defense Exoatmospheric Kinetic Energy Kill Vehicle (EKV) Program, and the Terminal High-Altitude Area Defense (THAAD) Program. Since the initial development of the SATRACK system, the Laboratory has miniaturized its translator hardware to enable it to fly on individual reentry vehicles. These translators and the postflight evaluation of their data are being used by the FBM program to evaluate the in-flight performance of reentry vehicles and to evaluate and quantify guidance-system errors during development testing. Today the SATRACK technology is being applied to ever-more-precise strategic weapons, such as conventional strategic applications.

In the early 1990s, as the Cold War was coming to an end, there was an effort at the Laboratory to diversify its support base beyond traditional military sponsors. SSD, looking to leverage its expertise in large-scale system testing and evaluation developed in support of the Navy's FBM evaluation effort, undertook a series of tasks for the U.S. Department of Transportation. The goal was to develop a set of common standards and a testing and evaluation regime for commercial vehicles across the nation. This series of programs lasted for several years, through early 2001. They were transitioned to other external organizations as the Laboratory's strategic direction was again re-oriented to focus more on national security activities. However, several of the system-architecture tasks accomplished for these programs have been applied to more recent strategic C2 efforts described below.

As SSD entered the new century, it was challenged by its principal sponsor, Strategic Systems Programs, to expand its contributions by assuming more far-ranging support in the systems-integration areas. Whereas APL's previous support was almost exclusively in the testing and evaluation of the SLBM weapons systems, APL was being asked to apply its unique system knowledge to SLBM-system integration and engineering tasks.

Also at this time, the defense establishment was redefining the attributes of what was considered "strategic." These attributes were expanding to include not only nuclear systems but also conventional systems, missile defense, information systems, and C2 systems. SSD and Laboratory leadership recognized that the relationship with USSTRATCOM had a greater impact on Laboratory activities than just the traditional FBM weapon system test and evaluation. Within SSD, a new liaison office with USSTRATCOM was established to coordinate Laboratory activities with that command. Additionally, a new strategic effort, consistent with the expanded strategic landscape, was identified—National C2. Efforts to support this component of strategic activity were initiated in 2002 and continue today.

PRECISION ENGAGEMENT BUSINESS AREA

Much of the work in today's PEBA originated with efforts in the original Bumblebee programs that began soon after World War II. Early work at APL was dedicated to defending U.S. forces during World War II. During the postwar years, the Laboratory led Navy efforts in experimentation with and development of long-range rockets and missiles, which initially were to be used for defensive purposes. Soon, APL began using these new technologies to build offensive weapons.

Perhaps the first offensive missile was Cannonball, designed to destroy enemy tanks. Conceived by APL, the missile was spherical and was successfully tested in the late 1950s. The Triton missile was another early development effort initially proposed by APL. An outgrowth of the anti-air Talos missile program, Triton was designed as a long-range (several thousand miles), supersonic (Mach 2–3) missile to be used for naval bombardment. Neither Cannonball nor Triton ever became operational, but Triton guidance work used map-matching for midcourse corrections. This technology prepared the way for the Terrain Contour Matching (TERCOM) system that was incorporated into Tomahawk two decades later. More broadly, the work that James Follin, James Hansen, and Richard Bucy performed in determining how to use Triton's map-matcher position updates to correct errors in its inertial navigator's estimates of orientation, velocity, and position provided the fundamental knowledge that enabled Bucy and Rudolph Kalman (of the Research Institute for Advanced Study) to introduce in 1961 a revolutionary advance in adaptive estimation initially known as the Kalman–Bucy filter.

In the mid-1960s, APL's initial entry into what is now known as PE was in electronic attack, a nonkinetic offensive capability. In the late 1960s and 1970s, APL got into the offensive missile (kinetic) business with Harpoon and Tomahawk. All of these programs still exist today. The 1980s saw the advent of tactical aircraft and air-launched missiles at APL. Other aircraft programs started in the 1990s, and new ship platforms came along in the 2000s.

With the establishment of APL BAs in 2002, PE programs became organized and managed by the three functions of a simplified "kill chain": detect, control, and engage. In operational order, detection and targeting (finding and locating the target) is first, C2 (deciding on and coordinating the desired effects on the target) is second, and engagement (carrying out the decision to destroy, disable, or otherwise affect the target) is third. PE activities changed, diversified, and expanded over the years, as illustrated in Fig. 5. As also can be seen in Fig. 5, the first function that APL worked on was engage. Work was recently started in detect and, as this is being written, work has also begun in control.

The following paragraphs describe the history of the major efforts in PE in these three functional areas.

Engage

There are two means of engaging a target—nonkinetic and kinetic. Nonkinetic effects are those usually intended to temporarily deny an enemy's capabilities. For example, a radar jammer produces a nonkinetic, electronic attack on an enemy's radar system that denies its effective use, usually for only as long as the jammer is operating. Kinetic effects are those intended to physically damage a target. Most bombs and missiles have warheads that explode.

Nonkinetic Engagement

Electronic Attack. As indicated above, some of the earliest efforts in the engage function were in electronic attack. Just as APL's development of the VT fuze in World War II was in response to severe threats to U.S. Navy ships in the Pacific (leading to APL's role in developing defensive and offensive missile systems), APL's entrée to electronic warfare (EW) came as a response to threats to U.S. aircraft in Vietnam. On 24 July 1965, the United States lost its first aircraft to a Soviet-built surface-to-air missile system. The next day, the Director of Defense Research and Engineering asked that APL study the situation and recommend how to best counter this threat.

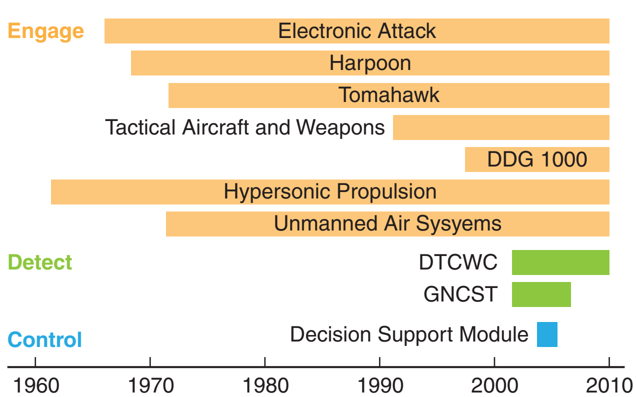

Figure 5. Evolution of PE programs.

The APL team was led by Al Eaton and completed the initial study by 10 August, just 2 weeks later.

APL recommended changing tactics and developing electronic countermeasures. The recommendations worked, and they led to efforts to formally test the recommendations and the corresponding need to create a test range with facilities to adequately conduct these tests. The APL team, led by Don Staake and Art Williamson, worked with the Navy's primary operational testing organization to conduct and analyze the tests and to develop such a range, which became known as ECHO Range at China Lake, California. According to Leonard Sullivan Jr., Deputy Director of Defense Research and Engineering, "The capability of APL to perform work of this nature is considerably enhanced by the 'hardware' orientation of the Laboratory and its responsibility in the design of our own air-defense systems."[6]

These efforts ultimately expanded into work that continues today to address both sides of the countermeasures issue: U.S. countermeasures against enemy weapon systems and counter-countermeasures to prevent enemy systems from defeating U.S. systems. APL had a large role in the design and development of the EA-6B, the Navy's primary jamming aircraft. The EA-6B is used to suppress enemy defenses in support of U.S. and allied offensive operations. APL played a large role in the first tests of the EA-6B and in subsequent tactics and systems development, mission planning, communications countermeasures, and the integration of antijamming weapons. In addition, APL has analyzed day-to-day use of the EA-6B in real-world operations and passed recommendations directly to operational forces.

The EA-6B originally supported both Navy and Air Force operations. When the Air Force decided to build its own jamming capability in the EF-111A in 1983, APL did similar tasks for that aircraft. This work also led to related self-protection jamming and decoy work. The Marine Corps more recently has asked APL to help build a jamming capability to defeat the use of improvised explosive devices in Iraq. At present, APL continues to support the Navy, Air Force, and Marines in developing and operating countermeasure systems. Figure 6 shows platforms for which APL has provided significant electronic attack expertise.

Kinetic Engagement

Harpoon. The sinking of the Israeli destroyer *Elath* in 1967 by a Soviet-built Egyptian Styx cruise missile led the U.S. Navy to reconsider the Soviet navy's capabilities. The U.S. Navy developed its own all-weather, antiship missile, called Harpoon, and it entered the Fleet in 1977. Still in service, Harpoon can be launched from aircraft, surface ships, and submarines and flies a low-altitude cruise trajectory to search for, acquire, and attack enemy ships. Initially, APL used its missile expertise in

Figure 6. Samples of electronic attack platforms.

all areas of the Harpoon design but, particularly in the later years, focused primarily on the design, testing, and evaluation of radar homing and countermeasures technologies. APL's Harpoon efforts were led initially and for many years into the program by Marty Barylski and Jim Walker.

Tomahawk. APL applied its experience with Harpoon and other technologies to help with the Navy's Tomahawk program, starting in 1971. Then Navy Captain Walter Locke conceived of a long-range cruise missile that would come in several variants: an anti-ship missile with a conventional warhead and three land-attack missiles (two with conventional warheads and one with a tactical nuclear warhead). The first two operational missiles in the Tomahawk program were the conventional Tomahawk anti-ship missile (TASM) and the nuclear Tomahawk land-attack missile (TLAM-N). Jim Walker and Dave Kalbaugh led the APL team in supporting the initial development of all of these variants and worked closely with Captain (later Admiral) Locke's team. TASM combined radar seeker and guidance technology from the Harpoon program with a significantly longer range and a larger warhead. TLAM-N was a very-long-range missile that was developed by using technologies that APL helped select and develop. Later, a conventional land-attack missile, with either a unitary warhead (TLAM-C) or distributed bomblets (TLAM-D), was also developed.

In December 1982, in two Joint Cruise Missiles Project Office letters, one to the Chief of Naval Material and another to Al Eaton, Rear Admiral Stephen Hostettler, then in charge of the Tomahawk program, designated APL as the program's Technical Direction Agent (TDA) and specifically defined APL's roles and responsibilities as TDA.[7, 8] Subsequently, Marion Oliver was named as APL's Tomahawk program manager.[9] APL remains the Tomahawk TDA to this day (see Fig. 7).

To support TASM, APL conducted studies and Fleet experiments to demonstrate and improve the concept of targeting ships at sea. This work led APL to designing missile- and radar-seeker search patterns and assisting in the development of an electronic system to passively detect, identify, and select Soviet warships for attack. TASM was operational as a surface-ship- and submarine-launched missile for a number of years before the end of the Cold War caused this variant to be removed from service.

To support TLAM, APL led the development of several techniques to ensure that the missile would strike near enough to the target to achieve the desired damage. Chief among these were the Terrain Contour Matching (TERCOM) system and the Digital Scene Matching Area Correlator (DSMAC), both used to obtain position fixes for the missile's inertial navigation system as it flies toward the target. To enable both systems to work, great strides had to be made in map accuracies and in the algorithms used to compare the measurements made during flight with those expected in that area. APL worked with contractors and the Defense Mapping Agency, now the National Geospatial-Intelligence Agency, to make the required improvements. Perhaps most significantly, APL invented algorithms that predicted the flight performance and accuracy of TLAM missions, thus making Tomahawk the first weapon system to be able to make such predictions. TLAM-N was eventually removed from active service, but, of course, TLAM-C has been used extensively by both the U.S. and U.K. navies, starting with Operation Desert Storm in 1991.

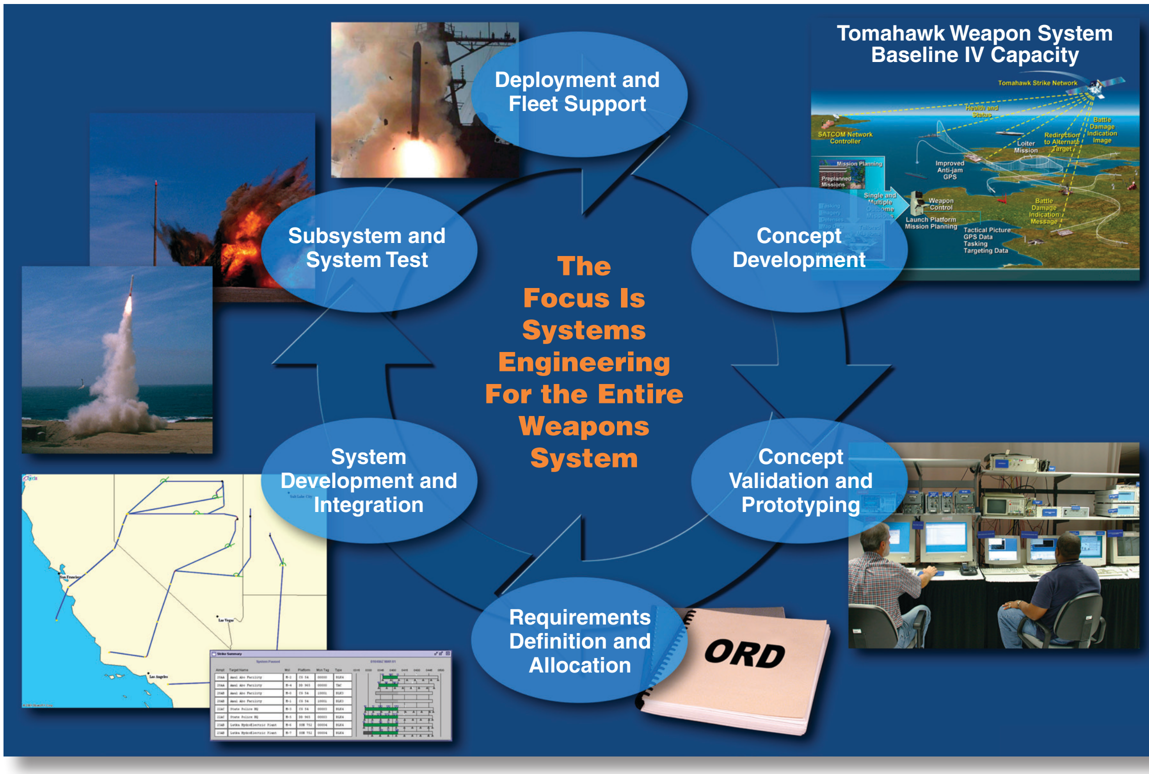

Figure 7. APL's scope of effort as the TDA for the Tomahawk program.

For each of these missiles, pre-launch planning involved designing what the missiles would do after launch (i.e., how they would fly and how they would act), and systems had to be built to launch the missiles. APL played a large role in developing the following subsystems: the shore- and carrier-based systems responsible for the mission planning and C2 for TLAMs and the surface-ship- and submarine-based weapon control systems responsible for planning TASM missions and for preparing and launching all Tomahawk missiles. From the program's inception, APL also played key roles in testing and evaluating the Tomahawk program. APL has conducted rigorous assessments of the system reliability and accuracy (work that continues today) and provides annual performance estimates to USSTRATCOM for the Tomahawk Weapon System.

During the more than 30 years that APL has worked for the Navy in developing these Tomahawk capabilities, the system has undergone several upgrades. These have culminated in the recent Fleet introduction of the Tactical Tomahawk Weapon System. This system includes a number of revolutionary capabilities, including planning TLAM missions on the launch platform and communicating with in-flight missiles to modify their mission and assess their health and status. APL had a large role in all of these development activities. APL also works with the Fleet and the Office of the Chief of Naval Operations (OPNAV) to develop and document top-level requirements—with the sponsors on program planning and funding issues, with the system developers and DoD laboratories in developing the systems, with the Navy in testing the capabilities, and with the Fleet in helping to employ the systems. APL also provides extensive technical descriptions of Tomahawk capabilities and limitations and has worked with the Navy's tactics communities to develop the tactical documentation for Tomahawk employment. Currently, APL is participating in the integration of the Tomahawk Weapon System on new U.S. Navy ships, notably the DDG 1000 and the SSGN, and on U.K. submarines.

In 2000, APL received the Precision Strike Association's prestigious William J. Perry Award (named after the former Secretary of Defense). The award was given in recognition of the Laboratory's more than four decades of technical leadership and contributions to the development, introduction, and support of precision strike systems, in particular, the Tomahawk Weapon System.

Tactical Aircraft and Their Weapons. APL has had more than half a century of distinguished history in technology development for the Navy's surface and submarine communities. For a variety of reasons, analogous comprehensive involvement with the aviation community had not developed until relatively recently.

In the late 1980s and early 1990s, there were a number of small, independent, aviation programs extant in multiple APL departments: E-2C Hawkeye, F-14 Tomcat, Joint Direct Attack Munitions (JDAM), and Advanced

Medium-Range Air-to-Air Missiles (AMRAAM) in Fleet Systems; F/A-18 Hornet and Joint Strike Fighter in Aeronautics; and EA-6B Prowler, EF-111 Raven, and Self-Protection Countermeasures in Naval Warfare Analysis. Recognition of the potential for organizational synergy was one impetus for the formation of the Power Projection Systems Department in 1996, which was initially established under the leadership of Dave Kalbaugh and led later by Jerry Krill.

Under unified leadership in the new Power Projection Systems Department and with Roger Burnett as program manager and Ken Plesser as group supervisor, the Laboratory set out to establish itself as a technical and intellectual resource for the Naval Aviation (and Air Force) community. In 1997, a field office was established at Naval Air Station Patuxent River, Maryland, the site of Naval Air Systems Command headquarters, program offices, and aircraft engineering facilities. Field offices at Eglin Air Force Base, Florida, and Naval Air Station, Fallon, Nevada, soon followed. These sites provide visibility for the ~10 APL staff members permanently located there, as well as a conduit for Laurel-based staff members to understand and appreciate the programmatic and operational constraints of their customers. Acknowledging Naval Air Systems Command's unified team approach to system development, APL emphasized collaboration over competition in the conduct of its work and in its relationships with other organizations. In the following years, new programs such as the Multi-Mission Aircraft (a follow-on to the Navy's venerable P-3C Orion) and a number of unmanned air systems were added to the business portfolio. By the time that the GED was formed in 2005, there were three program managers and two group supervisors, whereas previously there had been but one of each.

APL presented itself, and continues to present itself, to the aviation community not only as an organization fully capable of contributing to the solution of a sponsor's immediate technical problems but also as uniquely suited to address large-scale system engineering issues (i.e., the interface and interoperability of multiple platforms and weapons in the battlespace). This is the grand challenge in the precision engagement arena: to develop seamless connectivity among sensors, delivery platforms, and weapons to ensure rapid precision engagement.

In this area, APL has had a role that encompasses a number of aircraft and a number of weapons deployable from those aircraft. Most of these are Navy systems, but the largest at present is the joint Air Force and Navy aircraft called Joint Strike Fighter (JSF). Starting with an independent one-engine versus two-engines analysis for JSF in 1994, APL developed a special relationship similar to that of a trusted agent and was designated by the DoD's JSF Program Office as its only nongovernmental field site. As such, APL provides independent modeling, simulation, and analysis capabilities to the government, and many assessments and studies have been completed.

Since the late 1990s, APL has also worked on a number of Navy and Air Force air-launched bombs and missiles. Early on, APL provided analyses and studies to the JDAM and Joint Standoff Weapon (JSOW) programs, and presently APL provides concepts of operations and studies on mission effectiveness and moving targets for the Navy's follow-on small-diameter bomb (SDB) program. APL also has a small but important role in the AMRAAM program. Figure 8 shows one of the largest and one of the smallest of these weapons: JSF and SDB.

APL is also leading a number of analyses of alternatives, studies, and other analyses for EW self-protection systems, guided rockets, and upgrades for EW range capabilities—all of which are Navy programs.

DDG 1000. The DDG 1000 is a new destroyer being developed by the U.S. Navy. This ship features many new technologies and will be capable of performing land, air, and sea missions in the littoral. In June 1997, APL convinced the Navy's program office (PMS 500, then led by Captain Tom Bush) that its systems expertise could be used to help industry develop what is now known as DDG 1000. Initially led by Tom Sleight and later by Dan Peletier, the APL team developed the Design Reference Mission, a set of tactical warfare situations used to design, analyze, and test the operational concepts. The Design Reference Mission was written by warfare experts from APL in cooperation with several Navy laboratories and was used by the industry teams to develop DDG 1000 concepts and by APL and the government team to assess the proposals and select a winning team. In addition, APL personnel resident at PMS 500 assisted in the development of the ship's requirements, specifications, and manning documents.

The requirements seek to reduce operating costs by reducing crew, employing significant automation, and using existing systems. APL provides expertise for the creation of approaches to crew operations and for workload and software development. In addition, APL's unique understanding of requirements, based on its experience with Navy operational forces, provides insight into the resolution of issues associated with using legacy systems.

Figure 8. A JSF and an SDB.

Finally, APL brings a multi-mission analysis capability to the effort, including the integrated use of crew and systems in all operational areas.

Hypersonic Missiles. APL has a long history in the area of very fast (supersonic and hypersonic) missiles. In 1961, several APL groups were combined to form the Aeronautics Division. Its work was divided between practical support to programs ongoing in other parts of the Laboratory and performing forward-looking research in a number of areas. One area of research was the development and tests of ramjet engines. This research was a continuation of work done for the development of the Mach 2.7 Talos missile (fielded for a number of years) and then for the Mach 4 Typhon missile programs (successfully flight-tested but subsequently cancelled). The Propulsion Research Laboratory was established and could test ramjet and scramjet engines in flight conditions simulating speeds up to Mach 7. Many of these capabilities were unmatched anywhere else in the nation. These propulsion efforts continued with advanced missile designs and work for the National Aerospace Plane. APL-based dual-combustion ramjet technology formed the basis of a hypersonic (Mach 6) strike missile flight demonstration program called HyFly; the first missile test flight was in 2007. The goal of the program is to demonstrate the feasibility of using hypersonic missiles to help reduce the response time and increase missile effectiveness against time-critical, heavily defended, hardened, and deeply buried targets.

Unmanned Air Systems. Work on unmanned air systems at APL began with the avocations of several APL personnel, including Walt Good and Maynard Hill. On the basis of that experience, DARPA asked APL in 1972 to develop some small, remotely piloted vehicles (RPVs) for military use. Hill invented a simple method to automatically stabilize such vehicles and went on to set a number of world records for RPVs.

The RPV work and APL's experience in missile programs ultimately led to APL's present efforts in unmanned air systems, including the Joint Unmanned Combat Air System (J-UCAS) program. A distinctive attribute of this program was the development of a common operating system (COS). APL won the competition to serve as the integrator/broker for a government/industry consortium to develop the COS in collaboration with the two prime contractors and DARPA. This unique business arrangement also permitted other technology contributors to provide advanced software applications and "best of breed" algorithms. The Articles of Collaboration establishing the COS Consortium were approved in late 2004.

In late 2005, the J-UCAS program transitioned to a new joint U.S. Air Force/Navy office, but a few months later, the *Quadrennial Defense Review* terminated J-UCAS. Fortunately, the Navy continued its interest in a carrier-based, persistent intelligence, surveillance, and reconnaissance (ISR) asset with some strike capability, and APL's efforts were transferred to the Navy in 2006 with two primary analysis tasks: develop a technology development strategy and a functional needs analysis to support a Milestone B decision for a future acquisition program.

In addition, APL is exploring the use of commercially available parts to build and deploy "swarms" of very small, light, and inexpensive, yet capable, unmanned air systems. These unmanned air systems can add to the sources of ISR information on the battlefield and the generation of a common operational picture for the warfighter.

Detect

The start of APL's efforts in the detect function of the kill chain is fairly recent in the history of the PEBA. Toward the end of 1999, APL's Bill Walker and Glenn Mitzel began a relationship with two retired U.S. Air Force officers to try to make the best use of all intelligence data and information to detect and target enemy defensive surface-to-air missile sites, which had been used with devastating effect in Vietnam and were likely to be similarly used in the future. In 2000, APL hosted a mini-conference that was attended by several outside organizations. The conclusion was that this was a worthy goal and that APL should lead a team effort to develop such a capability. (Some people said it would be impossible to establish a program of record because no single organization really was responsible for this problem.)

APL developed the concepts and architectures and engaged many acquisition, research, and operational commands in the DoD. Later that year, the National Reconnaissance Office agreed to fund a feasibility study; this was the first direct funding received. The result was Dynamic Time-Critical Warfighter Capability (DTCWC). APL continued to flesh out the concepts and plans for critical improvements and enabling technologies by using a systems engineering approach and continued to conduct briefings on a near-weekly basis. In 2002, the National Imagery and Mapping Agency (NIMA) requested and ultimately funded an APL proposal. This was the beginning of the Global Net-Centric Surveillance and Targeting (GNCST) effort, which was under a National Reconnaissance Office contract with NIMA management. In 2003, APL established a contract with the National Geospatial-Intelligence Agency (formerly NIMA), and GNCST became one element of the Horizontal Fusion Portfolio. Several successful GNCST demonstrations were completed during exercises in 2003 and 2004, but APL was directed to stop the effort—officially because of the perception that

GNCST was neither ready for nor relevant to a specific upcoming Iraqi deployment.

In 2005, USSTRATCOM became interested in funding another GNCST demonstration, and the deputy commander of the Pacific Air Force saw its relevance to his responsibilities. APL's effort now reverted to the DTCWC name because, in the summer of 2006, the National Geospatial-Intelligence Agency established GNCST as a program of record. (The National Geospatial-Intelligence Agency's action proved that a program of record for this type of activity could be established, and it was done largely because of APL's efforts at shaping the environment.) APL is working with the Air Force to continue, expand, and integrate the DTCWC work into the Distributed Common Ground System and to make the new capabilities available for integration into other programs of record (e.g., GNCST).

Control

When the PEBA was organized into the three functional areas of detect, control, and engage, it was recognized that APL had little work in control, i.e., military C2. Work in this area was initiated in 2004, when the PEBA was asked by the Secretary of the Air Force to review a development effort, already underway, called the Decision Support Module. APL was funded by the Air Force's C2 Battle Laboratory at Langley Air Force Base, and, when Decision Support Module intellectual property issues could not be resolved, the Air Force asked APL to use the remaining funds to look at improving their Combined Air Operations Center (CAOC). This led to APL developing the CAOC Performance Assessment System, which automatically records and analyzes CAOC operations. More recently, APL has completed an initial task to help the Navy develop a Maritime Headquarters with Maritime Operations Center capability, to be similar in nature to a CAOC.

INTO THE FUTURE

The preceding paragraphs have provided a brief history of GED and its SSBA and PEBA and each effort's historic association with APL's beginnings. As the direction of U.S. naval warfare diverged and the technologies and evaluation activities became more complex and diverse, the supporting efforts within APL mirrored those changes. This led to the establishment of the SSD and the Power Projection Department as separate entities.

Now, as the Navy looks to the future and the new strategic and tactical worlds, the technologies and programs supporting precision strategic nuclear and conventional strike and strategic C2 are implementing many common elements. With the Laboratory supporting many of these diverse programs, and with so much technology application becoming common in the new global strike world, it made sense to join these efforts in a single organizational entity within APL; thus, GED was created. As the commonality of technologies and approaches between the strategic and tactical offensive military worlds increases, efforts are continuing within GED to maximize the synergy of efforts common to the department's tactical and strategic activities. The challenges posed by the Conventional Prompt Global Strike (CPGS) mission require capabilities and solutions from both precision strike and strategic nuclear systems. CPGS will require time-critical and adaptive collaborative training, drawing on C2 and ISR assets and capabilities traditionally employed in the execution of tactical strike missions. At the same time, the employment of this new class of system will demand a level of performance and understanding of system performance previously applied only to the nation's nuclear deterrent systems. This new CPGS activity will need to build on the attributes of both tactical and strategic strike systems as well as respond to some CPGS-unique challenges.

It is interesting to note that very different disciplines and cultures have evolved over the course of the separation of the nuclear strategic and precision tactical conventional missile programs within the Laboratory. The melding of these different cultures into a common organization in GED mirrors similar situations in the Navy itself as it addresses the differences in the risk-avoidance approaches that have dominated strategic-nuclear-systems acquisition and employment and the less stringent risk-mitigation approaches that have been applied to conventional weapon systems. As the GED addresses these differences and as the envisioned future of precision strike across the Navy battlespace becomes a reality, the Laboratory is well positioned to make significant contributions through the combined technical capabilities of the SSBA and PEBA.

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