

# Historical Aspects of Formal Education at APL

Harry K. Charles Jr. and Christine M. Morris



## ABSTRACT

*Education has been the cornerstone for developing the capabilities of Johns Hopkins University Applied Physics Laboratory (APL) staff. This article highlights APL's various formal educational programs, focusing on the graduate education program that started in the late 1950s and has blossomed into the Engineering for Professionals program—the largest professional graduate engineering program in the nation. Under the joint auspices of APL and the Johns Hopkins University Whiting School of Engineering, the Engineering for Professionals program continues to grow, with annual enrollments approaching the 10,000 mark. The program also tailors partnerships to meet the unique needs of industrial and governmental organizations. In addition to this degree-granting program, APL offers the Strategic Education Program, with noncredit advanced-level technical and scientific courses that are tailored to the specific needs of APL's staff. Details of this highly successful internal education program are presented, along with brief descriptions of several other educational initiatives at the Lab.*

## INTRODUCTION

From its beginning, the Johns Hopkins University Applied Physics Laboratory (APL) has valued education and has endeavored to keep its staff on the cutting edge of technology. At the end of World War II, with the university's decision to extend APL's contract with the Navy (keeping APL in existence),<sup>1</sup> the Laboratory's leaders took steps to ensure that APL would remain at the forefront of scientific and engineering developments.

APL leaders have long recognized that professional scientists and engineers need continuing education to gain or refine the knowledge and skills necessary to tackle the current and future critical problems the Laboratory seeks to address. As technology changes, this continuing education must also change to meet the needs of

the practicing engineer or scientist: courses must be convenient (scheduled at local facilities at a time that is outside of work hours or available asynchronously online), focused on job-related skills and techniques, and taught by academics and practicing professionals.

To meet these needs, in 1958 the JHU Evening College started sponsoring a few courses (no degree-granting programs) on the APL campus for APL staff members.<sup>2</sup> These courses were taught by APL senior scientists and engineers and were not open to the public. In 1963, APL's educational operation became an Evening College Center of the Johns Hopkins University, and by the fall of 1964 it began offering a master of science degree in electrical engineering that paralleled a similar degree

offering on JHU's Homewood Campus. The offerings at APL were also opened to the public in recognition that APL's needs for continuing technical education reflected those of nearby governmental and industrial organizations. The growth and evolution of the Evening College Center (later called the APL Education Center) and its partnership with the Johns Hopkins University Whiting School of Engineering is described in the next section. Today this collaborative educational partnership between APL and the Whiting School is known as the Engineering for Professionals program.

Over the years, APL's leaders noticed that many of the Lab's engineering professionals, after achieving successes in early assignments, remained in those domains until there was no longer a significant need for their particular specialties. Several years past their days as undergraduate or graduate students, many of these engineers, while intelligent and energetic, were reluctant to return to formal graduate programs. These engineers and scientists likely had families and financial responsibilities and may not have had time to embark on a multiyear degree program. What they wanted was to obtain the knowledge necessary to keep their skill sets current and to work at the leading edges of their fields.

Although many short courses and other education/training programs existed in the private sector, they rarely focused on the real-life situations that APL engineers and scientists encountered. To address this need for relevant, leading-edge noncredit education for its

staff, the Laboratory developed Career Enhancement courses in the late 1980s. Taught by APL staff members, these courses were designed to help technical staff members prepare for new career paths and learn tools and techniques for solving critical problems. While somewhat successful, the program lacked strategic APL oversight and focused mainly on grassroots requests from individual staff members.

In 2005–2006, the Career Enhancement Program was renamed the Strategic Education Program. Until 2011, the program typically offered several courses each semester, but enrollments were low, with less than 100 per year on average. In 2012, the Strategic Education Program began working with APL's Management Forum to identify more strategic courses for development. Key APL managers provided insight regarding the courses their staff members needed to be able to grow and succeed in current and future assignments. The modern-day Strategic Education Program has been a phenomenal success, growing from less than 50 enrollments in the 2006 academic year (fall 2005–spring 2006) to more than 500 in the 2017 academic year. Details on the current Strategic Education Program and its growth are at the end of this article.

To encourage staff members to continue their education, the Lab offers a part-time study program; some form of this program has been offered since 1948. At its start, the program enabled flexible work schedules for staff members whose studies took them away from the

### BOX 1. TALENT DEVELOPMENT PROGRAM

APL's Talent Development Office provides diverse non-credit educational opportunities for APL staff members, with courses taught on-site at APL as well as at local learning institutions. Courses generally fall into the following categories:

- **Leadership and management development:** This curriculum provides learning opportunities for Lab leaders looking to increase their skills in getting the most out of themselves and others. APL offers internal courses for leaders, as well as external opportunities through its relationship with the Institute for Management Studies. Example courses include New Supervisor Foundations, Leaders Workshop, Supervisory Feedback, Coaching Seminar, Group Supervisors Course, and Planning & Managing Projects at APL.
- **Technical training:** APL offers a wide variety of in-classroom technical training opportunities, including courses conveniently taught at APL as well as courses offered at institutions throughout the area. On-site short courses range from 1 to 5 days and are held during the business day on a variety of technical topics. Examples include DoD Acquisition Process; Security+ Certification Boot Camp; Satellite Communications Design and Engineering; Digital Signal Processing—An Introduc-

tion with Practical Applications in MATLAB; Missile Design, Development, and System Engineering; and Applied Python Programming.

- **Career development and critical success factors:** APL defines career development as growth in knowledge, skills, experience, and responsibilities that aligns with personal goals and results in increased impact and/or contribution to the organization. Critical success factors are APL's description of the knowledge, skills, and abilities that support the professional development of all APL employees. They include work practices/achievement of results, customer focus/initiative, teamwork/collaboration, communication, supervisory/leadership skills, and job knowledge. Courses cover a wide assortment of topics ranging from conflict management to presentation skills to time management.
- **Computer applications and programming:** APL offers access to low-cost short training courses designed to introduce or bring a user up to speed on a new or existing piece of software, programming language, or office tool. Courses are typically offered off-site at local training institutions or community colleges. Example courses include MS Word 2013 in a Day, Intro to Adobe Photoshop, HTML 5 and CSS Level 1, and Movie Maker Introduction.

## BOX 2. APL'S STEM PROGRAM

APL's STEM (Science, Technology, Engineering, and Math) Program Management Office focuses on outreach to middle school and high school students, educators, and parents to help students recognize their potential in STEM-related fields. The multifaceted program includes the following initiatives:

- The **APL STEM Corps** is a group of APL staff who give their time to support STEM outreach by participating in a variety of activities such as mentoring students, judging science fairs, or helping to develop curriculum.
- The **College Prep Program** helps students prepare for, apply to, and succeed in college. Any area high school student can apply for admission.
- APL hosts **Girl Power**, a STEM expo, with support from the Women's Giving Circle of Howard County, Maryland MESA, and the Maryland Space Business Roundtable. The event gives middle school and high school girls the opportunity to talk to professional women in STEM careers and features hands-on activities, cool demonstrations, and take-home material to encourage interest in STEM careers.
- The **ASPIRE High School Mentoring Program** matches high school juniors and seniors with APL staff who mentor the students through a technical project. Students receive academic credit(s) toward graduation or other formal recognition.
- **Maryland MESA** (Mathematics, Engineering, Science Achievement) is an after- or before-school enrichment program that engages students in hands-on applications of math, engineering, science, and technology concepts through projects and competitions. In addition, high school students participate in college preparation workshops and presentations, which include information about the college admission process.
- The **Education and Public Outreach** office in the APL Space Exploration Sector provides opportunities for students, educators, museums, science centers, and the public to learn about the missions that APL manages for NASA.
- APL partners with **FIRST Robotics** to host the **FIRST Tech Challenge**, in which teams of middle and high school students design, build, and program a robot and then play a game against other teams' creations.

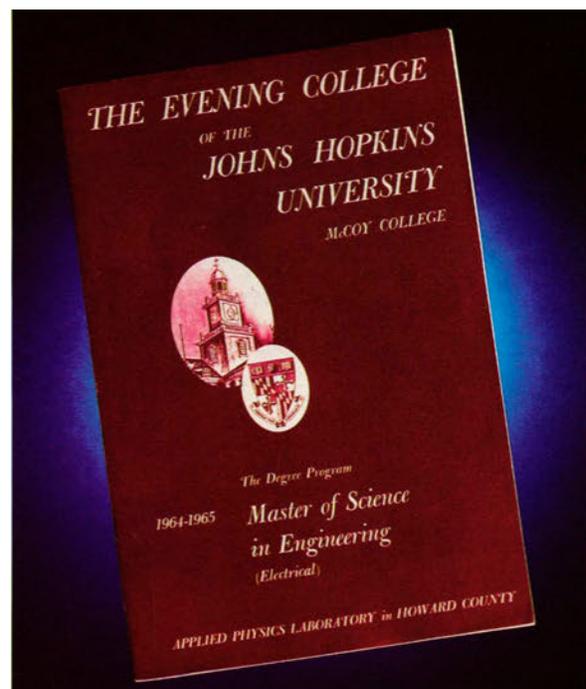
Lab during regular business hours. In 1957, the program expanded to include tuition payments and up to 6 hours of approved absence per week to take classes during the workday. Also at that time, the program began offering benefits for study at colleges and universities of choice, rather than only Johns Hopkins. Today the program includes payment of tuition and certain fees and allowance for flexible work schedules.

In addition to the formal graduate-level education programs that are the focus of this article, APL has a robust Talent Development Program (see Box 1) and is involved in many other educational activities for students of various ages, such as a robust STEM program for youth (see Box 2) and several summer intern programs for college students (see Box 3). APL's new educational partnership primarily with the JHU Whiting School of Engineering, called Strategic Partnership for University Research (SPUR), will be described in detail in a future issue.

## APL EDUCATION CENTER

In the fall of 1964, the APL Evening College Center (now the APL Education Center) began formal operation with a single master's degree offered in electrical engineering.<sup>3</sup> The cover of the first catalog featuring the electrical engineering master's is shown in Fig. 1. A master's degree in numerical science soon followed in 1966, and two more programs—Applied Physics and Space Technology—began operations in 1967. In 1971, a master's degree program in computer science was added. Technical Management followed in 1981, and in the ensuing years operations have expanded to include

11 APL-based programs, including Systems Engineering, Cybersecurity, Information Systems Engineering, Engineering Management, Space Systems Engineering, and Data Science. During the period from 1951 to the present, the Space Technology program was absorbed into Applied Physics, and Numerical Science morphed



**Figure 1.** The cover of the first catalog listing the electrical engineering graduate courses offered at APL.

**Table 1.** A list of the current Engineering for Professionals part-time graduate degree programs and their key leadership personnel

Program	Chair (C); Vice-Chair (VC); Program Coordinator (PC); Program Manager (PM)
Applied Biomedical Engineering	Dr. Eileen Haase (C); Dr. Brock Wester (VC)
Applied and Computational Mathematics	Dr. James Spall (C)
Applied Physics	Dr. Harry K. Charles Jr. (C); Dr. William E. Torruellas (VC)
Chemical and Biomedical Engineering	Dr. Michael Betenbaugh (C)
Civil Engineering	Dr. Rachel Sangree (C)
Computer Science/Cybersecurity/ Information Systems Engineering	Dr. Thomas Longstaff (C); Dr. John Piorowski (VC); Dr. Eleanor Chlan (PM)
Data Science	Dr. Thomas Longstaff (C); Dr. James Spall (C); Dr. Eleanor Chlan (PM)
Electrical and Computer Engineering	Dr. Brian Jennison (C); Dr. Cleon Davis (VC); Dr. Ramsey Hourani (PC)
Engineering Management/ Technical Management	Dr. Timothy Collins (C); Mr. Richard Blank (PC)
Environmental Engineering/Environmental Science/Environmental Management	Dr. Hedy Alavi (C)
Financial Mathematics	Dr. David Audley (C)
Materials Science and Engineering	Dr. James Spicer (C)
Mechanical Engineering	Dr. Gregory Chirikjian (C)
Space Systems Engineering	Dr. Patrick Binning (C); Dr. Clinton Edwards (PC)
Systems Engineering	Dr. Ron Luman (C); Dr. David Flanigan (VC); Mr. Christian Utara and Dr. Larry Strawser (PC); Dr. James Coolahan (PM)

APL-led programs are highlighted. The Applied Biomedical Engineering program was established as part of the APL-based program set, but it is now jointly managed by the Whiting School of Engineering and APL.

into Applied and Computational Mathematics. Table 1 lists the current Engineering for Professionals degree programs. The APL-led Engineering for Professionals programs (highlighted in Table 1) are in areas of strategic importance to APL, and they are led by program chairs and vice chairs who are established APL professionals holding doctoral degrees. The Applied Biomedical Engineering program was established as part of the APL-based program set, but it is now jointly managed by the Whiting School of Engineering and APL.

Figure 2 presents fall-semester enrollments from 1964 through 2016. Initial enrollments in 1964 were 145, and by 1980 they had increased to almost 1300. In 2016, fall-semester enrollments were slightly over 3700. The fall semester, the bellwether for the entire academic year, usually has the greatest number of enrollments of the three semesters (fall, spring, and summer) of the academic year. Spring enrollment numbers are typically

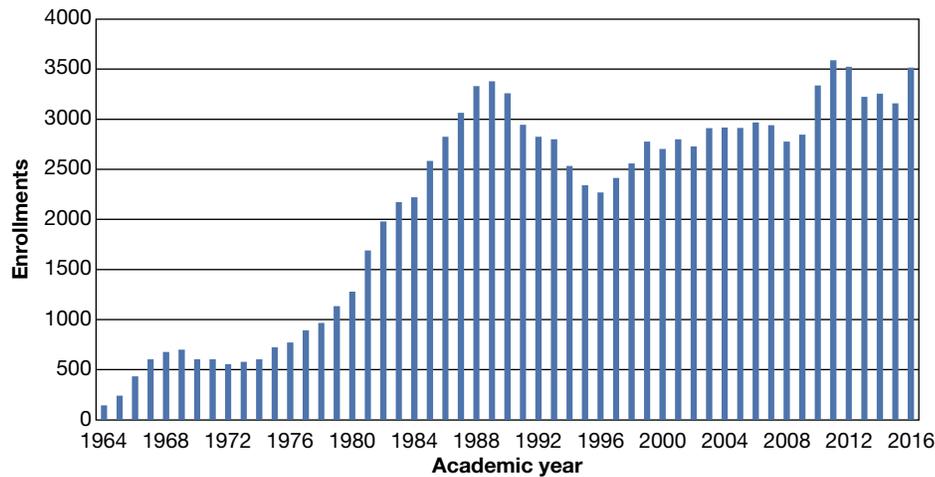
slightly lower, with summer enrollments reflecting about 50% of the spring numbers due to the reduced number of available courses. For the 2016 academic year (which includes the summer and fall of 2015 and the spring of 2016), total enrollments were 8256. A major boost to the program's scope, offerings, and visibility (as well as enrollments) occurred in 1983–1984 when APL's educational operation was incorporated into the Johns Hopkins University G. W. C. Whiting School of Engineering. This incorporation emphasized the value of the APL Education Center as well as the scope and quality of APL's instructional and program development efforts. The rapid rise during the 1980s reflects the expansion of the electronics and computer markets as well as the defensive military buildup during the Reagan administration. The dip from 1990 through 1996 reflects the end of the Cold War as well as the offshore transition of electronics and computer hardware industries.

This growth signified the importance of the educational component that APL provided the university, and in 1988 the Johns Hopkins University board of trustees approved a change to

APL's mission statement to explicitly include its educational charge:<sup>4</sup>

The general purpose of The Johns Hopkins University can be stated as public service through education, research, and the application of knowledge to human affairs. As part of the University, the Applied Physics Laboratory shares this purpose through the application of advanced science and technology to the enhancement of the security of the United States of America and through basic research and participation in the educational programs of the academic divisions of the University to which its staff and facilities can make an especially favorable contribution.

While enrollments grew rapidly during the 1980s, classroom space was at a premium. Classes were originally held in classrooms under what was once APL's Gibson Library, but the space was so limited that classes had to be held in dual sessions on weekday nights (Monday through Friday) as well as on Saturday mornings. In 1984, the Laboratory opened the Kossiakoff Center, containing



**Figure 2.** Fall enrollments in the Engineering for Professionals program since its inception in 1964 until the fall of 2016.

eight classrooms on the first floor and five laboratory and computer facilities on the second floor. Although the new space offered some temporary relief, by 1988 all of the classrooms in both the Kossiakoff Center and the library were home to dual class sessions every weekday night plus classes on Saturday morning. Satellite campuses opened (including one in Montgomery County and later the Dorsey Center in Elkrige, Maryland, mainly for electrical and computer engineering laboratories and overall program administration). Although enrollments declined in the early to mid-1990s, the demand for and introduction of new classes continued to grow. Enrollments began

to recover in the late 1990s and have grown slowly ever since, with slight dips due to the recession in 2008 and sequestration in 2013.

Hidden in the enrollment numbers (see Fig. 3) from about 2002 onward are two key elements that have dramatically changed the demographics of the student body during the last 15 years. The first element is the introduction of industrial partnerships, which tailor master's programs (primarily in systems engineering) to the specific needs of corporate clients.

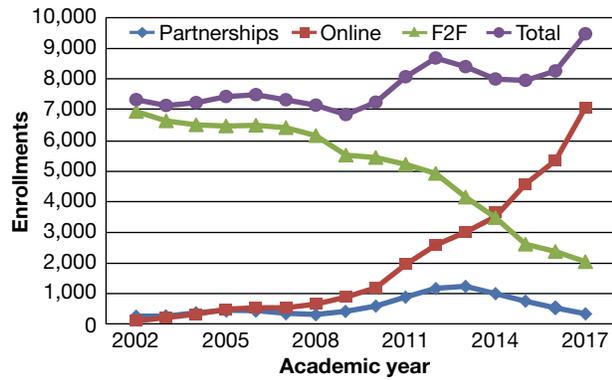
While the partnership numbers peaked in 2012–2013 with over 1200 enrollments, they have declined to around 300 enrollments in the current academic year. See the Partnership section for details on the APL-based Systems Engineering Partnership Program.

The second element is online education. The development and exploitation of online learning has had a dramatic effect on the Engineering for Professionals student demographics and has contributed significantly to the number of enrollments, more than offsetting the decline in partnerships. The 2002 academic year saw slightly over 100 enrollments in online courses (about

### BOX 3. COLLEGE INTERNSHIP PROGRAMS

APL offers a number of internship programs for college students.

- **APL–NASA Intern Program:** Participants in his program, open to rising sophomores through Ph.D. students, contribute to NASA missions and space-related research work at APL. The 10-week summer program includes talks by key mission engineers and scientists, along with tours of APL and other activities. Selected students receive stipends based on college level.
- **ATLAS:** ATLAS (APL Technology Leadership Scholars) is a summer internship program for undergraduate and graduate STEM students attending historically black colleges and universities (HBCUs), Hispanic-serving institutions (HSIs), and other minority-serving institutions (MSIs). Interns participate in professional development activities, engage with APL's executive leadership and ATLAS alumni, and attend panel discussions to gain insight on APL culture and possible pathways following their current academic studies.
- **GEM:** The National Consortium for Graduate Degrees for Minorities in Engineering and Science, Inc. (GEM), is a nonprofit organization that assists students from underrepresented minority groups who want to pursue graduate education. GEM was founded by Ted Habarth of APL, and APL continues to encourage its minority staff members to pursue educational opportunities, including paid summer internships, stipends, and tuition waivers, through the organization.
- **RISE@APL:** Open to full-time Johns Hopkins University (JHU) students majoring in engineering, computer science, applied mathematics, or physics, this highly competitive summer internship program focuses on professional development. Each participant works at APL, partnering with a staff scientist or engineer who is conducting research and development in a field consistent with the intern's academic major.
- **Summer Internship Program:** Each summer, hundreds of paid interns work with APL's scientists and engineers, conducting research, developing leadership skills, and growing professionally. Interns contribute to important projects and work with mentors to become acclimated to APL's social and professional cultures and to develop skills that may not be directly related to their summer tasks.



**Figure 3.** Engineering for Professionals enrollments by mode of delivery. Online courses are delivered in an asynchronous mode with scheduled instructor office hours. The partnerships follow a hybrid model of online and on-site face-to-face (F2F) instruction. The face-to-face numbers include independent study and Virtual Live, a format in which remote students can participate synchronously with face-to-face students.

1.5% of total enrollments), and the 2017 academic year boasted over 7000 online enrollments (about 75% of total enrollments). Some programs are offered totally online, and others offer an online degree while still maintaining a strong face-to-face presence. All programs offer some courses online and are seeking to increase the number. Figure 3 illustrates the course delivery demographics over the last 15 years. The online delivery model has allowed Engineering for Professionals to stretch beyond the region to have a national presence and even a small international footprint. Current statistics indicate that 62% of students are regional (from Maryland, DC, Delaware, Pennsylvania, and Virginia), 35% are from other U.S. regions (primarily from the Northeast and the West Coast), and 2% are international. Engineering for Professionals has significant growth potential in both the national and international markets, but it also faces greater competition and reduced brand recognition in these markets.

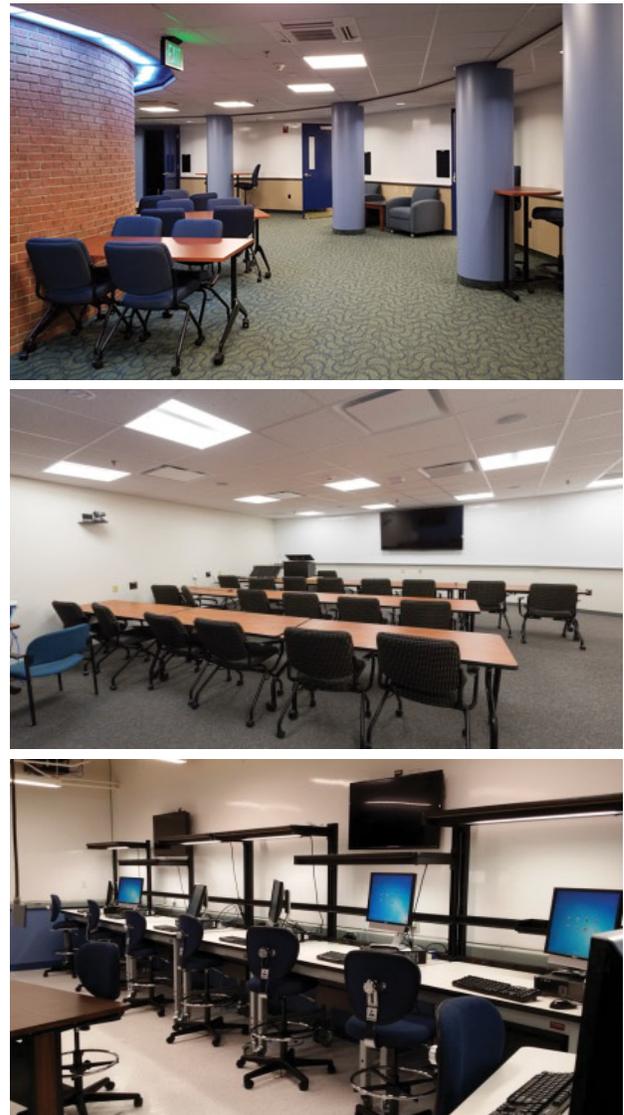
In 2013, the APL Education Center vacated the basement of the old library building, relocating all of its operations to the newly renovated second floor of the Kossiakoff Center. The move resulted in a loss of about 40% of the operation’s overall space. Because of declining face-to-face enrollments due to the rapid growth of online offerings, the loss of physical space was manageable. The renovations went smoothly, and the APL Education Center now has five modern, flexible classrooms and three new or refurbished laboratories on the second floor of the Kossiakoff Center, along with new student support facilities. In addition, the six classrooms on the first floor are still in use. Pictures of the newly renovated Kossiakoff Center are shown in Fig. 4.

The increase in online course offerings has also changed the number of centers required. At present, only the APL Education Center, the Dorsey Center, and

the Whiting School of Engineering home on the main Johns Hopkins University campus (Homewood) have significant student loads. Plans are to move the electrical and computer engineering laboratories at the Dorsey Center to the APL campus over the next couple of years, leaving only two major operation points for Engineering for Professionals—the APL Education Center and the Homewood Campus.

## PARTNERSHIPS

For over 15 years, the Engineering for Professionals Systems Engineering program has responded to the needs of companies by providing high-quality graduate programs tailored for their unique cohorts of employees.



**Figure 4.** Renovations to the Kossiakoff Center. Top, The redecorated and enlarged student lounge and study area. Middle, One of the new classrooms equipped with plasma displays and videoteleconferencing capabilities. Bottom, The new computer laboratory.

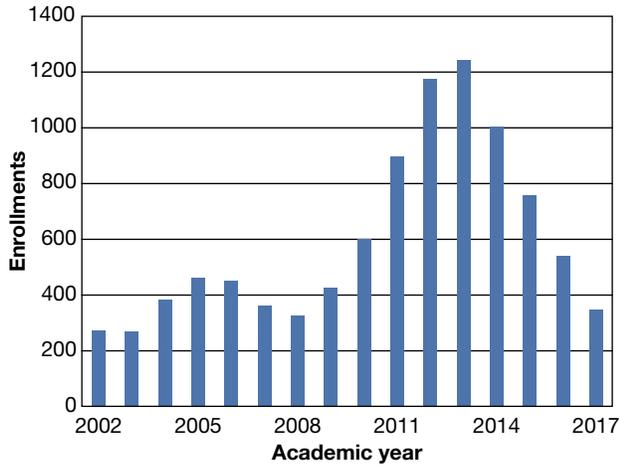
With its flexible, innovative course and program delivery model, the partnership program preserves the high quality of a Hopkins degree while offering partnership students a customized experience. Table 2 presents some of the features of the Engineering for Professionals corporate partnership model.

Since 2002, over 1,150 students (representing over 11,500 enrollments) have graduated from Systems Engineering partnership programs. From 2009 through 2013, the Systems Engineering corporate partnership programs were the primary driver for increased enrollments in the Engineering for Professionals program. Although requests for partnership programs have declined in the last few years, Engineering for Professionals' rapidly expanding online presence has more than compensated for the partnership reductions. Figure 5 illustrates the partnership enrollments by academic year.

Raytheon first approached APL in 2007 with a request for a customized master's degree program in systems engineering. After identifying a corporate-wide gap in critical knowledge and skill in systems engineering, Raytheon conducted an extensive nationwide search for master's degree programs in this area. The company selected the Johns Hopkins University Systems Engineering program offered by Engineering for Professionals as the best educational partner to offer a cohort-based master's degree program to Raytheon employees at locations across the country. With this selection, Raytheon recognized the program's close relationship with APL, which has a world-renowned reputation for systems engineering. The goal of the partnership was to offer a systems engineering master's degree program to accelerate the development of early- and mid-career engineers. In 2009, the program launched at Raytheon Missile Systems in Tucson, Ari-

**Table 2.** Summary of the most important features of the Engineering for Professionals corporate partnership model

Process	Key Factors	Comments
Student selection	Corporate management involvement	Most companies require candidates to submit résumés, managerial recommendations, and performance evaluations as part of the company selection process. Many companies encourage their corporate leadership to stay engaged with cohort students by attending student presentations, participating in panels, etc.
Schedule	Four 9-week semesters per year	Engineering for Professionals created an accelerated format that allows students to graduate in 2.5 years. Instead of regular 14-week fall and spring semesters, the program offers four 9-week semesters each year (starting in September, October, January, and March). Students have a week or two between semesters with a longer summer break.
Instructors	Team approach	The partnership programs include a team of instructors. Each course has a lead Engineering for Professionals instructor, a second Engineering for Professionals instructor, and a company co-instructor (nominated by the corporate partner). The Engineering for Professionals instructors are primarily responsible for the course format and content, and the company instructor's role is to ensure that the content is made relevant for the students through the use of company-specific examples, case studies, artifacts, etc.
Curriculum	Customized	One of the advantages of offering a corporate partnership program is that companies have the chance to customize the program content. The Systems Engineering program has six core courses and four electives. A company's leadership has the opportunity to select valuable electives from a wide array of disciplines. Popular electives come from fields such as applied physics, electrical and computer engineering, and cybersecurity.
Capstone project	Real-world problem	One of the unique features of the Systems Engineering program is the capstone project course. This course involves team-based learning in which students synthesize and apply all their previous learning to the design of a real-world system.
Delivery options	Flexible and multimodal	The Engineering for Professionals team works with each partner individually to determine the most effective delivery option. For the Raytheon partnership, courses are conducted using a combination of face-to-face and videoteleconferencing of classes. The newest partnership model involves asynchronous online cohorts.
Software	Blackboard	Every partnership course uses the JHU Blackboard course management tool and has a Blackboard course site that may be accessed online from anywhere in the world. These sites include all course materials, slides, homework, and project assignments.
Feedback	Required	In addition to regular feedback collected through student course evaluations, Engineering for Professionals hosts an annual steering committee meeting that involves important stakeholders (students, faculty, and administrators). The purpose of the meeting is to solicit feedback on how things are going and to identify areas for improvement.



**Figure 5.** Total enrollments in partnerships by academic year (2002–2017).

zona, with 234 students from all engineering departments organized into nine cohorts of 24 students each.

After Raytheon Missile Systems started its partnership, other Raytheon business units launched comparable systems engineering cohorts, and in August 2017, Engineering for Professionals will launch its 21st cohort with Raytheon. Current locations for Raytheon cohorts include California, Texas, Utah, and Massachusetts. In 2013, Raytheon Missile Systems developed a rigorous program assessment designed to measure their partnership programs’ return on investment. In addition to administering a survey to approximately 100 program graduates, the assessment team interviewed the managers of graduates. The program assessment confirmed the value of the partnership program, with 89% of survey respondents (program graduates) saying that they would highly recommend the Hopkins program to others.

As the corporate workforce becomes increasingly global and mobile, online partnerships are becoming more popular. Engineering for Professionals has an online partnership with one corporate client already, and another government client

has requested to start an online cohort in the coming year. In a world where online educational options abound, Engineering for Professionals Systems Engineering partnerships will continue to offer a customized, high-quality option for companies interested in investing in the leadership potential of their best and brightest.

**STRATEGIC EDUCATION**

Developed and taught by APL experts, Strategic Education courses fill in subject-matter gaps that are not covered by graduate courses or by noncredit, short-term training and development courses. In some cases, the subject matter for Strategic Education courses is so new that the content has not been included yet in standard graduate curriculum. In other cases, Strategic Education courses make specialized, APL-focused content available to students with backgrounds in a wide variety of disciplines. Many courses are offered at the secret or higher level of security.

The goal of Strategic Education is to strengthen the science and technology base of APL staff through the delivery of high-quality technical courses tailored to strategic APL needs.

—Dr. Jerry Krill, Assistant Director for Science & Technology, APL

**Table 3.** Most popular Strategic Education courses, 2012–2017

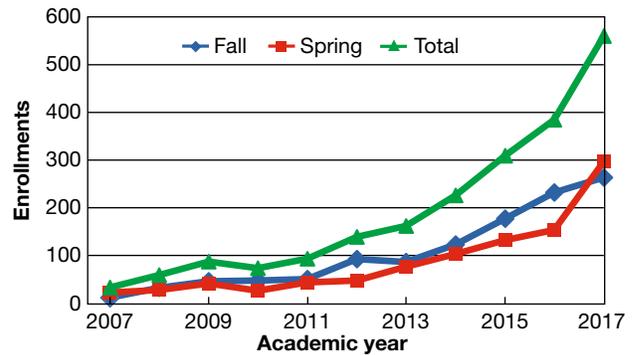
Course	Developer/Instructor(s)
Additive Manufacturing	John Slotwinski
Affordability Seminar	Chuck Alexander, Jeff Hamman, Rodney Yerger
Agile Methods for Innovative Solutions	Bob Cameron
APL Systems Engineering Competency Advancement (ASECA)	Matt Montoya et al.
Cloud Computer & Big Data Analytics	David Silberberg, Sandy Hider
Combat Systems Engineering	Robert Fry
Cyber Systems Engineering Foundations	Tom Llanso, Julie Tarr, Mike Smeltzer
Cyber and Threat Intelligence	Mark Munoz, Anthony Talamantes
Cyber Test and Evaluation	Paul Dailey
Electronic Warfare	Glenn Gealy et al.
Fundamentals of Ocean Optics	Jeff Smart
Game Theory and Agent-Based Modeling	Ariel Greenberg, Matt Henry
Graph Analytics	Cetin Savkli
Introduction to Autonomous Systems	Bob Chalmers, Adam Watkins
Introduction to Missile Defense	Andreas Chrysostomou et al.
Introduction to Model-Based Systems Engineering	Sean McGervey
MBSE Using SysML	Sean McGervey, Joseph Wolfrom
NTM Systems and Missions	Chung-Fu Chang
Space Environment and Weather	Betsey Mitchell, Ethan Miller
Survey of Human Language Technologies	Paul McNamee, Jim Mayfield
Undersea Warfare	Michael Nord et al.
Virtual Reality	Blake Schreurs

Semester courses are offered once per week (usually from 4:00 p.m. to 6:00 p.m.) for 10–12 weeks. These courses include some homework, reading, projects, or lab work to reinforce learning in between classes. Course tuition is \$800 and includes textbooks when applicable. Most course instructors make materials available on a class Blackboard site. Short courses are offered once a week for 4–6 weeks. Some short courses meet conveniently during the lunch hour, and others start near the end of the workday. Courses do not offer graduate credit, but students receive certificates of completion. All courses are conveniently taught in conference rooms on APL's main campus. Table 3 presents a list of popular Strategic Education Courses offered from 2012 to 2017.

To ensure that courses are relevant for the needs of the Lab and that development resources are used wisely, the Strategic Education management team takes a three-pronged approach to identifying the need for new courses:

1. **Management forum input:** Once a year, Strategic Education leadership confers with the Mission Area Executives who serve on the Science and Technology subgroup of the Management Forum led by Jerry Krill. The Mission Area Executives in attendance review a draft schedule of courses and recommend new courses that would be of interest to multiple APL sectors and departments.
2. **APL's sector/departmental leadership:** The Strategic Education Program managers can and do work with managers of individual sectors and departments to help them leverage their training dollars. For example, the program worked with one APL sector to offer several cybersecurity courses with modified schedules, limiting enrollment to only that sector's staff members. In other cases, courses have been developed at the request of sector or departmental leadership.
3. **Grassroots requests from individual staff members:** If possible, Strategic Education management tries to accommodate course requests from individual staff members or small groups. In these cases, the program does not provide development funds to the instructors, but new classes can proceed with five to seven students (necessary to cover the cost of instruction).

Strategic Education enrollments have increased dramatically over the last few years because of this top-down, collaborative approach to identifying new courses for development. (Enrollment in Strategic Education courses for the 2016–2017 academic year was 560; see Fig. 6.)



**Figure 6.** Strategic Education Program enrollments from program inception through the 2016–2017 academic year.

## SUMMARY

Education has been a priority for APL since its beginnings, and it is alive and well today. APL's management has continued to assess and refine the Lab's educational programs to meet the changing needs of its staff, as well as the needs of its industry partners.

Enrollments are rapidly increasing in the Engineering for Professionals program as new courses and degree programs are brought online. The APL-based programs account for about 90% of all Engineering for Professionals enrollments. The newly renovated Education Center on the second floor of the Kossiakoff Center is the nucleus of the Engineering for Professionals program on APL's campus. Within the next year, additional Engineering for Professionals facilities currently at the Dorsey Center will move to APL.

While traditional partnership activities have declined, the APL-based program managers are exploring new partnership opportunities in areas such as cybersecurity and health systems, which promise to again increase enrollments, especially as the modalities for distance learning evolve further.

The Strategic Education Program has been a success story from the beginning, with increasing enrollments every year—especially with program guidance from APL's top management during the last 5 years. The fact that these courses are taught by APL staff and focus on the actual work of the Laboratory, incorporating real APL experiences, has contributed to the success of the program.

## REFERENCES

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**Harry K. Charles Jr.**, Research and Exploratory Development Department, Johns Hopkins University Applied Physics Laboratory, Laurel, MD

Harry K. Charles Jr. is a member of the APL Principal Professional Staff and the program manager and group supervisor for the APL Education Center in the Research and Exploratory Development Department. He has a B.S. from Drexel University and a Ph.D. from the Johns Hopkins University, both in electrical engineering. Dr. Charles has over 40 years of experience in the microelectronics field and is a specialist in electronic packaging. He has over 210 major technical publications, holds 17 U.S. patents, and is a life fellow of both the Institute of Electrical and Electronics Engineers (IEEE) and the International Microelectronics and Packaging Society (IMAPS). He has been internationally recognized for his research and teaching activities on several occasions. As a teacher, he has developed courses and taught in the Engineering for Professionals program since 1979 and is currently a student advisor and the program chair for Applied Physics. Dr. Charles is also the editor-in-chief of APL's *Technical Digest*. His e-mail address is [harry.charles@jhuapl.edu](mailto:harry.charles@jhuapl.edu).



**Christine M. Morris**, Research and Exploratory Development Department, Johns Hopkins University Applied Physics Laboratory, Laurel, MD

Christine M. Morris, a professional staff member in the Research and Exploratory Development Department, manages the APL Strategic Education Program. She holds a Ph.D. in English Literature from the University of North Carolina at Chapel Hill. She has over 20 years of experience developing, managing, and evaluating successful academic programs. She has worked at a variety of educational institutions, including Texas Tech University, Howard Community College, the University of Maryland, and the University of Maryland, Baltimore County. Her e-mail address is [christine.morris@jhuapl.edu](mailto:christine.morris@jhuapl.edu).