"APL in the Twenty-First Century": A Retrospective on the 1983 Report to the Director

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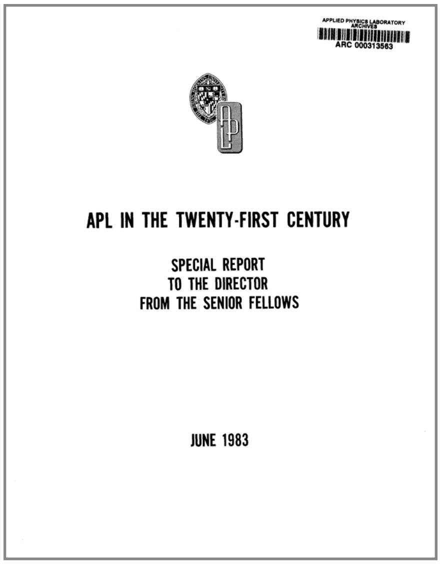
ABSTRACT

In 1983, at the behest of the Johns Hopkins University Applied Physics Laboratory (APL) director, an accomplished group called the APL senior fellows produced a report on the projected state of the Laboratory at the beginning of the 21st century. This article presents a retrospective on that report, which Identified key technologies, relationships, and environmental factors that would be important to APL at the dawn of the 21st century and beyond. In this article, these key items are identified, discussed, and assessed for their relevance (or not) to the current state of the Laboratory.

INTRODUCTION

In the early 1980s, Laboratory director Carl O. Bostrom[1] commissioned the APL senior fellows (H. C. Anderson, W. H. Avery, J. T. Massey, C. F. Meyer, R. C. Morton, and A. M. Stone; see Box 1 for biographical details) to project the state of the Laboratory in the twenty-first century. In their 1983 report,[2] the cover of which is shown in Figure 1, the senior fellows addressed several key areas:

1. The 21st-century environment
2. Long-range APL goals
3. APL's relationships with the military
4. Funding (research and development)
5. APL's relationships with other divisions of Johns Hopkins University (JHU)
6. Educational responsibilities and opportunities
7. Technology and new program opportunities



APL IN THE TWENTY-FIRST CENTURY

SPECIAL REPORT
TO THE DIRECTOR
FROM THE SENIOR FELLOWS

JUNE 1983

Figure 1. Image of the cover of the 1983 "APL in the Twenty-First Century" special report to the director from the senior fellows.

In addition, they devoted a significant number of pages in the document to describing (and presumably significant time to devising) their methods and models[3] for predicting long-term trends for things that were important in the early 1980s and would help shape the future after the turn of the 21st century, such as world population and gross national product (GNP). Table 1 illustrates some of their predictions for the year 2000, as well as actual statistical data for the years 2000 and 2020. As the table shows, their projections typically differed from the actual data. More will be said about this later in this article. In addition to the parameters shown in Table 1, the senior fellows speculated on raw material and food availability as well as war, space exploration, and deterrent weapons; again, more discussion of these projections will come later. They again detailed their methods of speculation, allocating a significant number of pages to discussing the theories of speculation that were prevalent at the time and why they would or would not work. The salient features related to APL's future, which can be distilled from these predictive models and forecasting (speculation) methods, are described in the sections that follow.

Table 1. Comparison of the 1983 senior fellows projections for the year 2000 with actual data collected in years 2000 and 2020

Parameter	Senior Fellow 2000 Prediction	2000 Actual	2020 Actual
Population[a]			
World	4.73×10^9	6.15×10^9	7.84×10^9
United States	4.92×10^6	2.82×10^6	3.35×10^6
GNP (US dollars)[b]			
World	10.76×10^{12}	33.8×10^{12}	86.4×10^{12}
United States	1.39×10^{12}	10.1×10^{12}	21.43×10^{12}
Energy Use (Btu)[c]			
World	5.71×10^{18}	3.79×10^{17}	6.25×10^{17}
United States	1.82×10^{18}	9.81×10^{15}	1.22×10^{16}
Pollution (ppm)[d]			
Atmospheric CO_2	3.9[e]	369.7	414.2

[a] *Date source for 2000 and 2020:* United Nations Department of Economic and Social Affairs World Population Prospects (2022).
[b] *Data source for 2000 and 2020:* World Bank.
[c] *Data source for 2000 and 2020:* Energy Institute Statistical Review of World Energy (2022).
[d] *Data source for 2000 and 2020:* NOAA Climate.gov.
[e] Although the senior fellows report listed 3.9 ppm, it seems safe to assume that some powers of 10 are missing in this entry since atmospheric CO_2 was already at 343.2 ppm in 1983.

The senior fellows assumed that APL would maintain its 1983 staffing level (2,800 APL staff members plus a few hundred resident subcontract employees). They had no idea of the growth that APL would experience during the first 20+ years of the new century. This assumption limited their thinking about the number and size of programs that APL could or should undertake.

KEY AREAS ADDRESSED IN THE REPORT

1. The 21st-Century Environment

As mentioned, Table 1 compares some of the fellows' numerical projections for the year 2000 with the actual data in the year 2000. Except for the atmospheric CO_2 projection, which seems anomalous, they overestimated the United States' population and underestimated the world's by factors ranging from about 1.5 to 2. The world's GNP and that of the United States were underestimated by factors of about 3 to 7. Clearly, the information age's dramatic impact on world economies was not fully understood or even considered in the 1983 time frame. Energy use was overestimated in all cases, but especially in the United States. In 1983, few people could foresee the energy conservation and energy technology developments that would occur over the next 20 years. Although the 1983 report recognized the need to control both automobile and factory emissions and to advance the use of alternative energy sources such as solar, geothermal, and nuclear, it did not discuss the impact of high atmospheric CO_2 levels and climate change. There was also no mention of technologies such as light-emitting diodes and hybrid and all-electric vehicles. While these technologies were known, their impact on energy and society was certainly unknown at the time of the report.

The fellows projected that raw materials would be adequate for 20–30 years, except maybe mercury and tin, but they felt that mining of ocean nodules may alleviate any shortages. They did not envision the rapid increase in the use of batteries, for example in portable electronics and hybrid and all-electric vehicles. Battery technology has put strains on supplies of lithium, graphite, and cobalt. Rare earth elements are being used in many applications, and today's supply is limited.

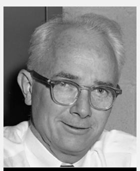
The 1983 team speculated that food supplies would be adequate far beyond the year 2000 except perhaps for a few small countries. This possibly stems from the fact that they underestimated the year 2000 world population by about 1.4 billion people, and climate change's environmental effects on food production were, of course, unknown at the time. It is estimated that early in the 21st century, almost 1 billion people have inadequate food supplies owing to a variety of factors such as poverty, disease, natural disasters (earthquakes, floods, and storms), climate change, and conflict. According to some reports, upward of 75% of the world's malnourished people live in conflict zones.

BOX 1. BRIEF BIOGRAPHIES OF SENIOR FELLOWS

Senior Fellow of the Applied Physics Laboratory was a professional appointment first announced by Dr. Steven Muller, president of the university in 1981. The title recognized those staff members who had distinguished themselves by making truly exceptional contributions to the accomplishments, reputation, and strength of the Laboratory throughout their careers.

1917–1992

Harry C. Anderson joined APL in 1949, working in the Bumblebee group as assistant supervisor of the Launching and Propulsion Group. Later he was supervisor of both the Personnel Group and the Solid and Liquid Propellant Information Agencies and chair of the Committee on Education. In 1952, he was named director of personnel and education and held that position until 1982, when he was appointed an APL senior fellow. From 1959 to 1969, he concurrently served as head of the JANNAF Solid and Liquid Propellant Information Agencies, later renamed the Chemical Propulsion Information Agency, which was part of APL. He retired from the Laboratory in 1983.



1912–2004

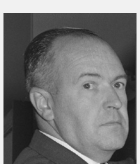
William H. Avery was the former assistant director for exploratory development and supervisor of APL's Aeronautics Division. He relinquished those posts in 1977 and was named director of ocean energy programs. A pioneer in rocket and ramjet research, he first joined the APL staff in 1947 as supervisor of the group developing launch rockets for guided missiles after having previously worked with Ralph Gibson (APL director from 1948 to 1969) and Alexander Kossiakoff (APL director from 1969 to 1980) at the National Defense Research Committee (NDRC). He retired from the Laboratory in 1998. For further details on Dr. Avery's career and life, see A. Kossiakoff.[4]

1917–2004

Joseph T. Massey came to APL in 1945. He was assistant supervisor of the Guidance and Control Group and supervisor of the Guidance Intelligence Group from 1946 to 1949, and then he joined the Research Center. In 1965, he participated in establishing a collaborative biomedical program between APL and the Johns Hopkins School of Medicine, and from 1973 until his retirement from APL in 1983, he was the director of biomedical programs. After his retirement from APL, he was engaged in research on primate motor physiology at the Johns Hopkins School of Medicine, where he had faculty appointments in biomedical engineering and neuroscience.

1913–1993

Charles F. Meyer joined APL in 1944. While working at APL, he was also a part-time assistant professor in the Institute for Cooperative Research at Johns Hopkins, teaching atomic physics from 1946 to 1948. In 1947, he helped form the Warhead Analysis Group and served on various government groups interested in that subject. From 1950 to 1981, he headed what was to become the Central Laboratory Assessment Division, which analyzed naval warfare and continental air defense in collaboration with various outside agencies. At the time of the report, he was senior fellow on special assignment with the Director's Office. He retired from the Laboratory in 1983.



1915–1984

Robert C. Morton joined the APL staff in 1948 as a Terrier guided missile engineer. He later headed the Strategic Systems Department from 1963 until July 1981, making major contributions in testing and analysis of the Navy's Fleet Ballistic Missile Submarine system. Prior to that, he supervised the Polaris Analysis and Evaluation Group and had formerly served as systems group supervisor of the Terrier/Tartar programs. At the time of the report, he was on special assignment as a senior fellow with the Director's Office. He was still a senior fellow at the time of his death. For more details of his life and career, see Potocki et al.[5]

1913–2012

Albert M. Stone came to APL in 1949 and held several important Laboratory positions, including technical assistant to the director from 1949 to 1974, supervisor of the Plasma Physics Group from 1960 to 1973, and head of the Technical Information Division from 1961 to 1979. He was a member of the former Program Review Board and the first editor in chief of the *APL Technical Digest*, the progenitor of this journal, and served in that role from 1961 until 1963. At the time of the report, he held the post of director of Advanced Research Programs, a position he had also held since 1974. He retired from the Laboratory in 1987.

In their general reflections on the 21st century, the senior fellows commented on war, deterrence, and space. They did not believe there would be a major war between the United States and the Soviet Union because of the fear that the world would be destroyed by nuclear weapons. They did not foresee the breakup of the Soviet Union and its worldwide impact on strategic forces and deterrence. Similarly, they did recognize that smaller wars between other nations would occur and that there may be need for US intervention. The events of September 11, 2001, and the subsequent war on terror were not on their radar.

When they addressed deterrence, they thought of strategic deterrence between the United States and the Soviet Union mainly involving the submarine forces. As mentioned, the eventual breakup of the Soviet Union was unknown, and China's rise as a world power requiring strategic deterrence was not mentioned.

When considering space, the fellows speculated that space exploration would continue, and they specifically felt that it was possible that humans would have made expeditions to Mars. While they did note that satellite communications would increase and they were aware of GPS, the senior fellows did not foresee the almost ubiquitous use of GPS smartphones by the worlds' population. However, they were extremely familiar with the Transit system (Figure 2) for global navigation of ships and submarines, which was invented at APL and later recognized as one of APL's defining innovations.[6] No mention was made of the low-cost uncrewed planetary exploration missions that have become another defining innovation of the Laboratory.

Figure 2. APL designed, built, tested, and operated several satellites for the Transit navigation system. Transit greatly improved the ability of US submarines around the world to accurately determine their positions. In 1967, APL released use of the system to private industry, and it became the reference system for many critical measurements, continuing to serve into the 2000s.

2. Long-Range APL Goals

The senior fellows reiterated the long-standing mission statement of the Laboratory: "to make a major contribution to the solution of important problems of National security in which the solution depends strongly on the application of new technology or new uses of existing technology." They stated that national security was to be understood in a broad sense to include the maintenance of a strong US base in advanced technology that will allow the nation to continue its industrial preeminence in the world. The report devoted no real attention to globalization and the specter of major outsourcing that continues to impact our industrial base.

Underlying this mission statement is the assumption that APL will have special competence in the projects it undertakes and will continue to recruit staff members with outstanding talents in science and engineering. In addition to acknowledging the need for scientists and engineers, the senior fellows also recognized the need for staff members with social science backgrounds (economists, political scientists, and policy specialists) to make effective contributions to the solution of important national problems in the non-defense, non-aerospace sectors of the government, while also solving bureaucratic, funding, and political entanglements standing in the way of the technical work in the defense arena.

The senior fellows went on to say that APL is a unique national resource. The key word is *unique*, indicating that no other type of institution produces an environment in which independence of thought, depth of scientific understanding, freedom of imagination, and flexibility of approach can flourish to the same degree. The senior fellows felt so strongly about APL's uniqueness (as defined above) that they made preserving this characteristic their first and foremost goal for the 21st century. Fortunately for the nation, JHU, and the Laboratory's sponsors, APL continues to maintain world-class resources and facilities in a number of areas.

Aside from the first and foremost goal mentioned above, the senior fellows declined to set goals looking out more than 20 years, recognizing that APL would accomplish such goals with an almost entirely new staff in a world driven by new, unforeseeable technologies against a backdrop of not even vaguely defined national (and international) goals. They did, however, set down some tangible attributes and requirements of a unique resource, and these are reproduced verbatim in Box 2. It is easily recognized that these attributes apply to APL today, as APL is truly world-class in many of its activities.

In fact, the thinking of the senior fellows on maintaining the existence of the Laboratory in the future closely aligns with the strategic systems approach articulated by today's leaders (see the article by Luman, Galpin, and Krill, in this issue):

1. A consensus among key policymakers on the basic, long-range mission of the Laboratory
2. A clear statement of goals that can be expected to strengthen the Laboratory's ability to maintain the role defined by its mission
3. Definition of criteria that can be used to judge whether new or ongoing projects or programs are contributing significantly, holding the line, or either wasting resources or preventing work on more significant topics

The senior fellows did set some intermediate goals (nominally 15 years out) that would involve

1. the exploration of research and development activities leading to funded APL programs in
   - ocean science and engineering;
   - biomedical engineering (molecular engineering);
   - computer system applications to scientific and engineering research and development (such as artificial intelligence, computer graphics, and computer-aided design);
   - space science;
   - high-energy beam transmission; and
   - targeted solid-state research;
2. fleet systems integrated defense; and
3. submarine security science and tactics.

BOX 2. ATTRIBUTES AND REQUIREMENTS OF A UNIQUE RESOURCE

- To develop in-house scientific and technological expertise in areas even remotely thought to have application to solutions of major national problems.
- To use effectively, that is, flexibly and with imagination, these resources as needed to evaluate technically, economically and socially contemporary national needs.
- To foster new endeavors for which evaluation indicates need and for which APL has particular capabilities to bring to the endeavor.
- To assess clearly and without bias the status of any program at any time and submit recommendations for its realistic future course.
- To oppose vehemently any endeavor to reduce the Laboratory's hands-on capability in its mission (i.e. laboratory experimentation to the point of a prototype if necessary).
- To foster and enhance closer ties to other divisions of The Johns Hopkins University through collaborative endeavors and other intellectual involvements.
- To maximize advantages of the University-APL relationship rather than to emphasize differences.

Except for some of the research topics, these intermediate goals reflected extensions of APL business at that time, and they ultimately came to fruition.

3. APL's Relationships with the Military

In this section, the senior fellows mainly focused on the Navy and the size of its fleet and the weapon systems that would exist in the year 2000. The backdrop was the Cold War conflict with the Soviet Union. No one on the team foresaw the fall of the Soviet Union, but they made several subtle mentions of a "peace dividend" and what impact it might have on the nature of the Laboratory's business. This impact was characterized as shifting a portion of APL program interest from military to more civilian activities such as biomedicine, transportation, and space exploration. The senior fellows took the projections in the Navy's year 2000 report, prepared in 1978,[7] as a basis for discussion. This report predicted a 500-ship Navy in the year 2000 and talked about the strengths of missiles and bombers on both the US and Soviet sides. The senior fellows offered insights about the military environment (both hardware and "software") to be expected at the turn of the century. They foresaw the outer air battle being fought at distances greater than 1,000 nautical miles requiring more advanced development in missiles as well as improved surveillance and targeting capabilities. They forewarned of advanced anti-ship missiles and the greater need to protect the fleet. They were aware of the work APL was doing on multi-target tracking and fleet sensor integration that led to the Cooperative Engagement Capability (CEC), an APL defining innovation, in the 1990s (Figure 3). They mentioned the ballistic missile threat but did not envision APL's defining innovation of Ballistic Missile

Figure 3. CEC being operated aboard USS *Cape St. George*. APL conceived and provided technical leadership with collaborating partners in industry and warfare centers on behalf of the sponsor to develop CEC. CEC networks multiple radars to provide fire control–quality composite tracking of aircraft and missiles.

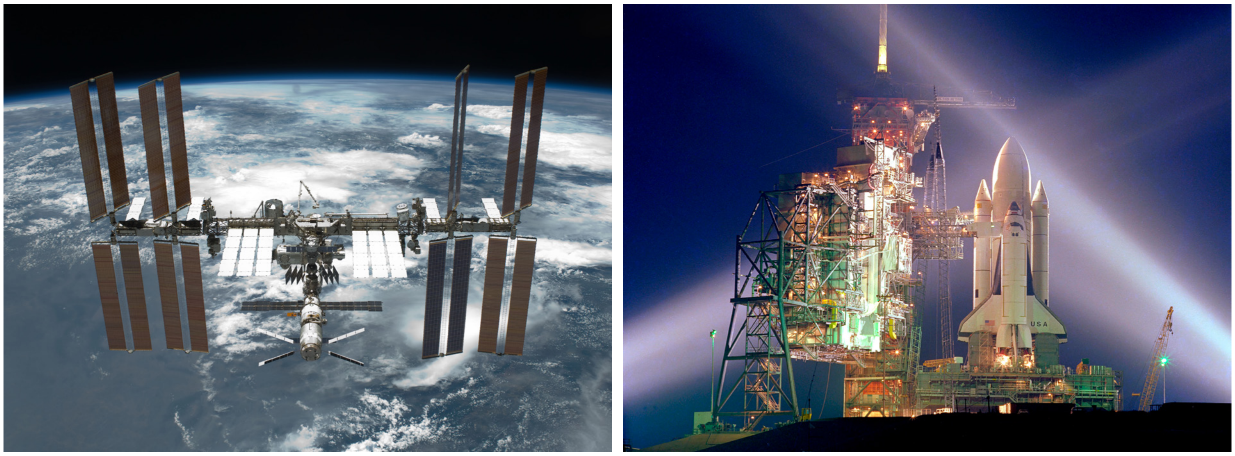


Figure 4. The senior fellows predicted space stations and greater human presence in space. Left, the International Space Station photographed by an STS-134 crew member on the space shuttle Endeavour after the station and shuttle began their post-undocking relative separation on May 29, 2011. Right, a timed exposure of the first Space Shuttle mission, STS-1, taken at Launch Pad A, Complex 39, on March 5, 1981. (NASA photos.)

Defense from the sea.[8] They felt there would be extensive use of stealth technology in aircraft and even suggested that vertical or short takeoff and landing aircraft would become the mainstay of the fleet. They made no mention of uncrewed autonomous vehicles (UAVs) for air, surface, and undersea applications, and the word *drone* never appeared.

The senior fellows did mention that space provides many of the significant tools of war and alluded to the possibility that it could become the battleground of the future. This is a real concern in 2023. They did not address the threat of our planet's destruction or devastation by an asteroid collision and, thus, never discussed planetary defense, which APL has since pioneered with the Double Asteroid Redirection Test (DART) mission.[9] They did predict things like space stations and greater human presence in space (Figure 4).

Submarines, both ballistic missile and attack, would provide a major strategic deterrent as the senior fellows predicted. They expressed concern about nonconventional weapons, such as laser and charged-particle beams, as well as the use of chemical and biological weapons. They also believed, for the most part, that the hardware trends of the early 1980s would continue through the year 2000. New technologies (such as advances in integrated circuits) would have a significant ultimate impact but would not change the general direction until after the year 2000, since the then-current hardware time constant was greater than 15 years. While such time constants may still be experienced for major hardware acquisitions, modularity of design in later systems is beginning to allow much more timely updates of functional capabilities.

The senior fellows introduced the term *software* as a means to discuss the political side of the Cold War and the general trend to support human rights and settle conflicts by negotiations. This "software" part of the environment could change the hardware picture greatly with ongoing arms control negotiations. The senior fellows feared that, if successful, these negotiations could reduce our deterrent arms significantly and hence affect our total defense posture. Such reduction in arms would reduce the total defense budget, both strategic and tactical. In turn, there would be a reduced Navy budget, which would directly affect APL funding and the percentage of funds for defense. Such a "software" event downturn happened to APL during the early to mid-1990s when defense budgets were reduced as a result of the end of the Cold War with the Soviet Union.

4. Funding (Research and Development)

Just as it is today, funding was critical to the future of the Laboratory in 1983. The senior fellows recognized that only a large source of funding could support a laboratory of APL's size; thus, they believed that the bulk of APL's funding in the 21st century would still need to come from the federal government—notably, the Department of Defense and its agencies. Historically, APL was (and still is) dependent on annual funding of its various programs. The senior fellows looked at this fact in two ways. On one hand, they considered this predominantly annual funding of programs an advantage in that it ensured abandonment of weakly funded programs; but on the other hand they believed it was also a disadvantage because it emphasized short-term projects, prevented rejection of routine sponsor tasks (best done by other organizations), and discouraged work on high-risk and potentially high-payoff ideas that were vital to APL's future ability to contribute to national goals. Some of the same issues and concerns exist today, but APL has made significant strides in investing in facilities and technology development that are necessary for its future.[10]

The senior fellows believed that it was imperative for the Laboratory to develop new sources of discretionary funding, apart from the discretionary funds that can be gleaned from program tasks (Independent Research and Development, or IRAD; and bid and proposal, or B&P). They thought that while IRAD and B&P funding was insufficient, it was essential for APL's survival. In addition to these sources of discretionary funding, they also thought there was a need for another source of discretionary funding, what they proposed as an "endowment" fund. They envisioned the endowment fund as a source of funding "to incubate new technologies and programs, and to provide for a flow of fresh talent through expanded pre-doctoral and post-doctoral fellows programs, as well as staff re-education [continuing education] programs."

They discussed many ways to finance the endowment fund: using patent and licensing revenue, launching an endowment-fund campaign, using the income from the Stabilization and Contingency fund, tapping the net revenue from graduate education program, and raising and restructuring the fee from the omnibus Navy contract. At the time, they concluded that raising the fee was the only viable solution, and they expended some effort on justifying this recommendation.

Fortunately, today APL's IRAD funding is much higher, at 3% of revenue. Also, as a university-affiliated research center (UARC) (APL was established as a UARC in the 1990s), the Laboratory can compete for science and technology (S&T) funds, which now amount to hundreds of millions of dollars. So, it is clear that raising the fee was not the answer.

5. APL's Relationships with Other Divisions of JHU

The senior fellows predicted no radical changes in APL's 21st-century relationship with the rest of the university. APL became a Limited Liability Corporation in 2009. This change did not deter APL from doing what the fellows predicted: strengthening collaborative relationships with the medical institutions and the Homewood faculties both in engineering and the physical sciences.

The senior fellows did envision expanded opportunities for graduate students to work at APL with the Laboratory's extensive advanced facilities and research and engineering experts. They also envisioned a greater flux of postdoctoral assignments. Both these ideas now have APL institutional roots with the joint research assistantship agreement with the Whiting School of Engineering and the Laboratory pool of central IRAD funding to support resident postdoctoral research studies.

Two additional ideas surfaced in the fellows' report: (1) a joint "Division of Research and Engineering Services," which would contract with industry to solve its problems; and (2) a "JHU Associates Program" in which industrial organizations would pay an annual subscription for special briefings and/or training in a specific area. These programs were not pursued, probably because of potential conflicts of interest and concerns about working for industry.

6. Educational Responsibilities and Opportunities

The educational ties with the university were of paramount importance in 1983, just as they are today. Recognizing the ever-growing complexity of science and technology, the senior fellows foresaw the need for a "considerably more structured" educational program at APL. They discussed two aspects of this program: (1) the external aspect relating to the Laboratory's educational function as part of the university as a whole; and (2) the internal requirement to educate and support the APL staff.

The senior fellows foresaw an advanced engineering degree as part of the external activities—"a step beyond the Master's degree" as they called it. It would have the basic quality of a doctoral degree, but without the research dissertation requirement. Instead, there would be a practical project requirement. In 2018, some 35 years after the senior fellows' recommendation, APL and the Whiting School launched the Doctor of Engineering program, a portfolio-oriented degree program for working professionals.[11] The senior fellows also felt that APL should be the focus for the instruction and should provide the facilities and supervision for the portfolio. As of this writing in 2023, this exact scenario has not come to fruition, although 19 APL staff members have received their doctor of engineering degree by leveraging aspects of their daily work assignments for their portfolio. Another 21 APL staff members are enrolled in the program as of 2023.

When considering internal activities, the senior fellows recognized the need for lifelong learning and recommended increased emphasis on staff "re-training" considering rapidly changing technology. A specific management function would be to continually identify those technical disciplines vital to APL's future and provide access to a myriad of options to achieve the necessary re-education or re-training. These options would include:

1. an expanded education center program
2. sabbatical leave and fellowship programs
3. greater use of student interns and postdoctoral fellows
4. in-house experts to train other APL staff members

The Engineering for Professionals (EP) program now offers 23 degrees in engineering and scientific disciplines, compared with only 6 in 1982–1983. Despite the senior fellows calling for it in the 1980s, the in-house training of staff by APL's own subject-matter experts did not gain traction until the first decade of the 21st century. Given the name Strategic Education, the annual program offers about 50 courses per year, as of 2023, in new and technology-relevant fields. With annual enrollments above 800, this program has made an impact on several thousand APL staff members.[11] APL also has made strong commitments to a sabbatical fellows and professors program with JHU, an intern hiring program, a central postdoc support program, and a fellowship program for Hopkins PhD students.

The senior fellows went on to make strong statements about the need for lifelong learning and the development of programs allowing staff members to continue to learn and grow throughout their careers. They were particularly concerned with the professional development of engineers (and scientists) and the collective national technological capability, particularly in areas of "high technology." The fellows recommended collaboration between engineering schools and industry to develop "a new pattern of engineering education" to meet the needs of a world characterized by rapid technology change and engineering systems of rapidly growing complexity. This new educational approach would be distinguished from those of the past by three attributes: (1) engineers' uninterrupted commitment to formal (and informal) education; (2) employers' wholehearted support of the notion that study and teaching are necessary and valuable components of productive work; and (3) university faculties' increased attention to the educational needs of working engineers of all ages.

The senior fellows believed that APL and the university were in a strong position to support these lifelong learning needs of the working professional. Although perhaps not as rapidly as the fellows would have liked, JHU and APL have responded to these recommendations with the continuing growth of the EP program, the Doctor of Engineering program, the Lifelong Learning[12] program; and the APL Strategic Education program. APL also encourages its staff to attend short courses and technical conferences as well as to become active members of professional societies.

Although the senior fellows mentioned distance learning through remote TV–microwave links, they did not anticipate the information age and the impact that the internet would have on all aspects of education. They had no notion that 99% of all EP courses would be online and that face-to-face courses would be taught via video communications platforms. They were still of the mindset that brick and mortar was the prevailing model and that the market for EP was regional. This is realistic for the time frame since we are talking about the era when the personal computer had just been introduced.

7. Technology and New Program Opportunities

In the chapter devoted to technological and program opportunities, the senior fellows identified several new technologies of the time and justified why they believed they would be important (or not) to APL in the future. The technologies identified included

1. short-wavelength lasers (directed-energy weapons, nonexplosive triggering of a nuclear weapon, and perhaps containment and triggering of a fusion reaction);
2. large space structures such as space stations and laboratories (scientific research, weapons platforms, or even a "spacecraft carrier" concept);
3. high-power microwave generators (communications and radar);
4. space nuclear power (not to be practiced at APL; APL uses radioisotope thermoelectric generators as power sources for deep-space exploration missions);
5. particle beams (directed-energy weapons in all theaters of war including space);
6. electromagnetic pulse, from weapons to protection; optoelectronics, such as fiber optics surveillance, tracking, etc.;
7. artificial intelligence (nonmilitary versus military, robotics; they did not go as far as autonomous vehicles, etc.);
8. thermonuclear fusion (power, materials synthesis; they thought this would be too expensive for APL and noted the lack of critical staff);
9. near-theoretical-strength materials (they noted the lack of critical mass despite some early successes);
10. bioengineering (they mentioned the university-wide effort looking for an APL role); and
11. crewed lunar and planetary expeditions (they saw a role for APL, but because of costs and technology limitations, such activities have been delayed and will perhaps occur in the third and fourth decades of the 21st century)

The senior fellows ended their extensive report with a list of desirable directions for the Laboratory to explore or be engaged in 30 years hence. Their choices were tempered by the following assumptions:

1. There would be no radical changes in APL's relationship to the rest of the university.
2. The Laboratory would undergo no substantial growth in terms of its staff or facilities, although the fellows did expect a constant re-education of the staff and a steady modernization of the facilities.
3. The United States Navy would be the principal Laboratory sponsor and would support 65–70% of the work.

Based on these assumptions and their collective experience, the senior fellows projected the following new areas to be a significant focal point of APL activities in the 21st century.

1. Information networks, including optical fibers
2. Optoelectronics development (in light of electromagnetic pulse)
3. Military space systems
4. Particle and laser-beam weapons systems
5. Military bioengineering
6. Artificial intelligence
7. Microbiology and genetic engineering
8. Oceanography from space platforms

DISCUSSION: WERE THE SENIOR FELLOWS RIGHT OR WRONG?

Just as with any set of predictions made by intelligent people based on the facts available to them at the time, the results of the senior fellows' projections are mixed. Their education predictions were truly on target, aligning with the growth of EP program and the advent of the Doctor of Engineering, Lifelong Learning, and Strategic Education programs, although the realization of these items took much longer than expected. However, they did not account for the information age and the invention and use of the internet, which has revolutionized education. They still embraced regional education manifested by brick-and-mortar classrooms and did not envision the 99% online education practiced by EP, but they did feel that the clever use of the video media was bound to have a strong impact on the methodology of updating professional competencies. The worldwide shift to online education at colleges and universities was accelerated by COVID-19.

In their projections on future APL technical directions, the fellows hit many of the key components of the Laboratory's current technology base, such as artificial intelligence, military space, information technology, and aspects of biotechnology and engineering. They envisioned longer-range missiles and the use of hypersonic vehicles, both areas of active work in the Laboratory's Air and Missile Defense and Force Projection Sectors. They saw the need for increased research and the maintenance of in-house facilities to enable the physical realization of prototype hardware. The United States was still in the midst of the Cold War, and the strategic deterrent was of prime concern. The ocean threat was the ballistic missile submarine, and little thought was given to the control of the seabed. Robotics was mentioned, but UAVs and the drone population explosion were not.

A lot of the predictions were influenced by underlying assumptions (e.g., little or no staff and facilities growth and the Navy being primary contractor accounting for 65–70% of the work) that had been overturned as APL entered the 21st century. In the 21st century, the Laboratory's staff has grown significantly (its technical staff has almost tripled), its facilities have expanded by almost a million square feet, and the Navy and the Missile Defense Agency (MDA) represent less than 50% of APL's work.

Also, one has to remember that the senior fellows were not privy to many events that helped shape the world environment in the late 20th and early 21st centuries—the rise of the internet and email and the ubiquitous use of portable electronics equipment (computers to smartphones); the end of the Cold War; the events of 9/11; the artificial intelligence revolution; and the COVID-19 pandemic, to name a few. All these events have had a strong impact on the scale and nature of APL's work today and were unforeseen by the senior fellows. As we know, hindsight is 20-20, but foresight is rarely clear and is usually clouded by the underlying assumptions of the day. Obviously, it was no different for the senior fellows.

SUMMARY

This article is a brief retrospective of the senior fellows report to the director in 1983. It highlights some of the projections in the ~90-page report and provides some insights on how they apply (or do not apply) to APL today. The report is an interesting read, not only for its projections but also for its use of language and phraseology by great APL technical leaders nearing the end of their careers.

REFERENCES AND NOTES

[1]Carl O. Bostrom is a retired APL director, having served in that position from 1980 to 1992. In 1960, he joined APL as a senior staff physicist and helped start a group to research the space environment. Between 1960 and 1980, he had a variety of responsibilities ranging from instrument design and data analysis to management of satellite development and space systems. From 1974 to 1978, he was the chief scientist of the Space Department and served as department head from 1979 to 1980. He served on many advisory boards, committees, and panels and received numerous awards and honors. Since retiring in 1992, he has worked as a consultant in research and development management and space systems. For more details on his career, see H. E. Worth, "The visionary directors of APL: Creating and nurturing a national resource," *Johns Hopkins APL Tech. Dig.*, vol. 34, no. 2, pp. 333–348, 2018, https://secwww.jhuapl.edu/techdigest/Content/techdigest/pdf/V34-N02/34-02-Worth-Directors.pdf.

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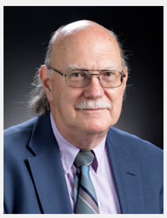
[12]While the JHU Lifelong Learning Program is aimed at providing continuing education for the general populace, it has provided significant teaching opportunities for the APL staff, thus enhancing their skills and technical reach in the world community.



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