A Synoptic View of APL Science and Technology

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> *For a successful technology, reality must take precedence over public relations, for Nature cannot be fooled.*
>
> *—Richard Feynman*

This is a unique edition of the *Johns Hopkins APL Technical Digest*. Most issues over the past decade or so have focused on themes relating to specific APL organizations, programs, or mission areas, and a few have been research and development updates—anthologies, if you will, of essentially unrelated but noteworthy technical efforts. By contrast, this issue presents a synoptic but relatively comprehensive view of the Laboratory's capabilities and activities in science and technology (S&T). This is, in some sense, the first time that the *Digest* has explicitly tried to represent some aspect of the whole APL enterprise in a single issue. Candidly, the task has been quite problematic.

Basically, three factors have contributed to the difficulty, and it seems reasonable to focus this introduction on those issues, because their exploration illuminates important questions about APL's role, its internal environment, and its external environment. We should start with the most basic question: "What is the significance of S&T to APL?"

THE ROLE OF S&T IN A PROBLEM-SOLVING ORGANIZATION

At a somewhat trivial level, most of the staff time billed to our government sponsors is for scientific and engineering talent; APL is an organization created and managed to apply science and develop technology. But although we are part of a great research university, the Laboratory does not, in general, do science for science's sake (or engineering for *its* own sake). We are not driven by curiosity, but rather represent ourselves as a problem-solving organization. "We take pride in achieving practical, operationally sound solutions to complex problems."[1] And let there be no doubt—we are contributing to the solutions of some mighty complex problems: defense of our nation and its military forces against threats ranging from ballistic missiles to terrorist attacks with biological weapons; exploration of the solar system, from Mercury to Pluto; helping the Navy to formulate its desired balance of mission capabilities; and helping our colleagues within the Johns Hopkins Medical Institutions to address problems ranging from individual patient care to regional crises with the potential for mass casualties.

So at a substantially less trivial level, the significance of S&T to APL is characterized by Feynman's quotation at the beginning of this editorial. If we are going to contribute to the solutions of complex operational problems, we had better be extremely well grounded in the S&T being applied. This is true not just because the problems are complex, but because there are tremendous national security, political, and economic implications to these problems and the implementation of proposed solutions. Only the highest levels of technical competence and professional integrity will allow APL to meet its mission in serving the national interest.

Feynman's statement concludes Appendix F of the Challenger disaster report[2] because it was considered too controversial to be included in the main text of that document. Ironically, it may be the best-remembered sentence in the whole report. Appendix F noted that there was a factor of 1000 difference between the system reliability estimates of the Shuttle engineering team and the Shuttle management team, which prompted Feynman to question, "What is the cause of management's fantastic faith in the machinery?" Of course, 17 years later, a second Shuttle was lost, and the current members of the accident investigation board must be wondering if Feynman's insights were understood and addressed.

Such questions can also be found closer to home. The American Physical Society recently released a report[3] that is highly skeptical of the prospects for the success of "boost-phase intercept" systems in the context of ballistic missile defense, a high-priority initiative within the current administration and an area in which APL does a significant amount of work. It is important to the Laboratory's reputation, and to the country's future, that we give technically authoritative answers when asked about the likely performance of such systems. Those answers can only come from a deep and fundamental understanding of the underlying technical issues.

The importance of our ability to supply those authoritative answers underlies the origin of this issue of the *Digest* in fundamental ways. When Richard T. Roca became the eighth Director of the Laboratory in January 2000, he met with government policy makers and APL sponsors, the University administration, and APL senior management and staff to learn about the issues and challenges facing the organization for which he was now responsible. Within a few months, he made significant changes in the governance of the Laboratory, creating three councils to guide our future from an enterprise perspective. The Executive Council was charged with setting APL's policy and strategy. The Operations Council was given responsibility for managing APL's costs and infrastructure. Finally, a completely new construct for the Laboratory emerged: an S&T Council charged with the responsibility "to ensure that APL always has the technical capability required to meet its mission." Although the application of S&T was central to APL's purpose for being, there had been no enterprise-level stewardship of that capability. The current membership of the S&T Council is shown in Table 1.

Table 1. APL Science and Technology Council, 2003.

"Statutory" members	Technical department representatives
John Sommerer (Chair) APL Chief Technology Officer	**Harry Charles** Head, Technical Services Department
Dick Garritson (Deputy Chair) Director of S&T Planning	**Joe Frank** Chief Scientist, Air Defense Systems Department
Alexander Kossiakoff APL Chief Scientist	**Don Hartman** Chief Scientist, Applied Maritime Technology Branch, National Security Technology Department
Ira Blatstein Director of Strategic Planning	**Larry Levy** Chief Scientist, Strategic Systems Department
Wayne Swann Director of Technology Transfer	**Victor McCrary** Assistant Head, Research and Technology Development Center
Jim Teesdale Director of the APL Education Center	**Ralph McNutt** Chief Scientist, Space Department
Ilene Busch-Vishniac* Dean, Whiting School of Engineering	**Dan Phillips** Associate Head, Power Projection Systems Department

*Prof. Busch-Vishniac served on the council from its inception until stepping down in 2003 as Dean of the Whiting School. A search is under way for her successor. APL will seek continued Whiting School representation on the S&T Council when a new dean is appointed.

Historically, APL departments cultivated the capabilities that were needed to meet the challenges faced by their sponsors. They did a good job, too, given that the Laboratory had been a national resource for nearly 60 years by 2000. However, changes in the national security environment and observations by significant sponsors suggested that we would need to more flexibly deploy our overall organizational capabilities in the future. Ballistic missile defense is again an excellent example. Our participation in the Navy's air and (later) missile defense programs was well grounded in the capabilities of the Air Defense Systems Department, but clearly the capabilities of the Space Department, Strategic Systems Department, and Research and Technology Development Center were also relevant. (These changes in our operating environment led to a host of other changes in APL governance, such as the creation of enterprise-level "business areas," but many of these issues are well beyond the scope of this introduction.)

BOOTSTRAPPING AN ENTERPRISE PERSPECTIVE

One challenge facing the three new APL councils was the development of an enterprise-wide perspective on Laboratory activities and capabilities (in January 2000, for example, only one member of the Executive Council had served in more than one APL sponsored department). As a result, one of the earliest requests from the Executive Council to the S&T Council was to orchestrate a set of technology reviews for the APL Senior Leadership Team that would comprehensively showcase the technical capabilities of the entire Laboratory. As a sort of footnote (*always* read the fine print!), Director Roca suggested that this overview be presented from a crosscutting perspective, *not* organized according to organizational units or program areas. This constituted a significant bootstrapping problem, i.e., to provide significant visibility across organizational boundaries that unintentionally had developed into barriers to the flow of information.

To accomplish the task, the S&T Council first developed a taxonomy (see the facing page) of APL technological activity, encompassing the vast majority of current and anticipated technical work. Although not a perfect partition into thematically coherent technical domains with no overlapping, this taxonomy has subsequently proven useful in the analysis of the skill base of the Laboratory's technical staff, the subsequent development of departmental staff development plans to ensure that the necessary skills are available in sufficient supply to support the activities of the APL business areas, the comparison of intellectual property generated by APL technologists to that at peer organizations, and the development of a draft APL Science and Technology Vision to guide the nucleation of new technical competencies.

The S&T Council organized the requested Senior Leadership Team Technology Reviews around this taxonomy, covering each of the 10 technology "bins" with a plenary presentation and a poster session. The poster sessions gave Laboratory management the opportunity to meet and interact with technical staff outside their own organizations, and to learn about specific technical projects at some level of detail (a sort of interactive *Technical Digest* article).

The plenary sessions presented a special challenge since the council asked technical experts in each technology area to represent the *entire spectrum of activities across the Laboratory* in their remarks. In an organization that had not, for at least the previous decade, actively fostered communications across departments, this was an extremely difficult assignment. Each plenary speaker faced the same ordeal: not just to assimilate a vast amount of new material, organize it effectively, and articulate it clearly, but to find out *where* to get the information in the first place. Nevertheless, the 10 presenters met the challenge and provided an unprecedented view of APL technical activity over a relatively short period of about 18 months. The S&T Council hoped that the networks built in this process would pay off far beyond the technology reviews, and fortunately there are some successes along those lines that continue to emerge.

The articles in this issue of the *Digest* are the written versions of the Senior Leadership Team Technology Review plenary presentations. There is one article for each of the 10 major categories of the S&T taxonomy. In each case, the technical activities and capabilities discussed come from across APL's program spectrum, and provide some indication of our standing relative to current trends and the state of the art.

Given the effort involved in developing this material and the unique perspective it provided about the Laboratory, the S&T Council made maximum use of the information presented. A second area of focus for the S&T Council was the formation of APL's first enterprise-level advisory body (aside from the JHU Trustees' Committee on APL) to advise the director on three fundamental questions: (1) What technologies are important for the Laboratory's future? (2) What is APL's standing in those technologies? and (3) What should APL do about any mismatch between where we are and where we need to be?

The S&T Council, after much preparation, empanelled and chartered the APL S&T Advisory Panel (STAP) in October 2001. The distinguished people on the panel are listed on the facing page. Members were chosen for their insight into critical technology areas for APL, their experience in managing technology, and their familiarity with the national security, space exploration, and biomedical arenas. They were not, *a priori*, intimately familiar with the Laboratory. The plenary

APL SCIENCE AND TECHNOLOGY TAXONOMY

1. Sensors and Sensor Systems
   - Radar and lidar technology
   - Acoustic sensors
   - Electro-optical sensors
   - Chemical and biological sensors
   - Space sensing instruments
   - Other sensors and sensor systems technology
2. Communications and Distributed Systems
   - Antenna technology
   - Distributed control technology
   - Communication link technology
   - Network control technology
   - Interoperability systems engineering
   - Other communications and distributed systems
3. Information Processing and Management
   - Decision support systems
   - Software engineering
   - Information retrieval and fusion
   - Information systems engineering
   - Information security
   - Other information processing and management
4. Materials and Structures
   - Composites and advanced structures
   - Manufacturing and fabrication technology
   - Nanotechnology
   - Materials and structures evaluation
   - Other materials and structures
5. Electronics Technology
   - Microelectronics and advanced packaging
   - Micro electric mechanical systems (MEMS)
   - RF electronics
   - Microcontroller devices
   - Opto-electronics and photonics
   - Other electronics technology
6. Modeling and Simulation
   - Dynamical simulation
   - Operational effectiveness simulation
   - System performance modeling and simulation
   - Distributed system simulation
   - Environmental modeling and simulation
   - Other modeling and simulation
7. Vehicle Technology
   - Navigation technology
   - Guidance and control
   - Aerodynamics and hydrodynamics
   - Propulsion and power
   - Vehicle systems
   - Other vehicle technology
8. Space and Environmental Physics
   - Magnetics, space composition, and imaging
   - Electromagnetic propagation
   - Ocean physics
   - Environmental characterization
   - Other space and environmental physics
9. System Analysis, Test and Evaluation
   - Operations analysis
   - System architectural analysis
   - Test environment and instrumentation
   - Test data acquisition and evaluation
   - System performance and readiness evaluation
   - Other system analysis, test and evaluation
10. Biomedical/Biochemical Technology
    - Biomedical instrumentation
    - Medical information systems
    - Bio-informatics
    - Pathogen identification
    - Chemical/biological defense
    - Other biomedical/biochemical technology

APL S&T ADVISORY PANEL, 2001–2003

Daniel Hastings (Chair)
Professor of Aeronautics and Astronautics and Engineering Systems
Director, MIT Technology and Policy Program
Former Chief Scientist, USAF (1997–1999)

Duane A. Adams
Vice Provost for Research, Carnegie Mellon University
Former Deputy Director of DARPA (1992–1996)
Member of many NRC and DSB study panels

Otis Brown
Dean, Rosenstiel School of Marine and Atmospheric Science, University of Miami
Charter member of MEDEA

Kevin G. Coleman
Private consultant
Former Chief Strategist for Netscape

Robert S. Cooper
President, Titan Atlantic Aerospace
Former Director, NASA/GSFC (1975–1979)
Former Asst. SECDEF (res. and technol.; 1984–1985)

John A. Hildebrand
Professor, Scripps Institution of Oceanography and Department of Electrical and Computer Engineering, University of California at San Diego

Deborah Joseph
Computer Sciences Department, University of Wisconsin
Member, NAS Computer Science and Telecommunications Board
NSF Presidential Young Investigator (1985–1990)

Sharon L. Nunes
Director, Life Sciences Solution Development, IBM Corporation

Edward K. Reedy
Vice President, Georgia Institute of Technology
Director, Georgia Tech Research Institute

Steve Walker
Steve Walker & Associates
Founder and CEO, Trusted Information Systems
Member of DARPA team that established ARPAnet

presentations from the Senior Leadership Team Technology Reviews were used to familiarize the STAP with APL's technical capabilities. This proved an effective approach, for soon the STAP was able to make significant recommendations that have been beneficial to our technology strategy.

INFORMATION SHARING IN AN ERA OF HEIGHTENED INSECURITY

The observant reader may wonder why this material, developed over the course of 2001–2002, is just now appearing in the *Digest*. The simple answer has to do with clearance of the information for public release. It is a simple answer, but not a simple issue. Just as the development of the material presented a special challenge for APL, despite our internal organizational boundaries, clearance was a complicated matter for the government to address. Typical *Digest* articles concern one or a few Laboratory programs and are submitted for clearance to the appropriate government sponsor for review. In this case, *each* article contained information on perhaps dozens of APL programs with different sponsoring agencies. No single program sponsor was in a position to judge the impact of the public release of the totality of the information.

It is also worth noting that this clearance process was undertaken in the aftermath of the terrible events of 11 September 2001; the administration significantly increased its awareness to the possibility of "sensitive but unclassified" information after that date, making the clearance review of the material in this issue even more complicated, although ultimately possible.

I raise this point not to make excuses for the timing of this edition, nor to complain about the bureaucracy associated with control of information to protect our national security and economy. However, this issue does bear on the importance of S&T to a trusted advisor to the government such as APL as addressed earlier.

S&T develops most rapidly in an environment that fosters the free exchange of ideas and information. To quote Vannevar Bush, one of the primary architects of the United States' network of government and quasi-government defense R&D laboratories throughout and after World War II, "Scientific progress on a broad front results from the free play of free intellects."[4]

For an organization like APL to provide the best advice, ideas, and results to the government, its staff must be fully engaged in the technical community. The government has a profound responsibility to restrict information whose dissemination could undermine national security, but it must be careful not to create an environment that reduces its ability to recruit and retain the technical talent required to maintain our security. In addition, the engineers and scientists in the national security community need to interact with those in academia and industry to maintain contact with the state of the art in their fields.

Efforts by the government to control sensitive but unclassified information have created serious concern among universities (see, e.g., Refs. 5 and 6). Universities have refused subcontracts from APL that flow down prepublication review requirements under which the Laboratory routinely operates; this problem has impeded our access to some of the best talent available to address some national security–related problems. Given that thousands of talented APL scientists and engineers have dedicated their careers to enhancing the security of the United States, it is essential that our government carefully weigh the various factors that affect the overall long-term impact of an information control policy.

CONCLUDING THOUGHTS

In summary, APL must cultivate a deep understanding of the S&T underlying the operational and technical problems we address on behalf of our sponsors, not just to provide good solutions to those problems, but so that the solutions warrant the public trust accorded institutions such as ours. That cultivation can be impeded by our internal as well as external environments, even when the shapers of both have nothing but the noblest intentions and deepest commitment to supporting our organization's and nation's goals. It is a tough job, but the Laboratory has always relished challenge.

In any case, this issue of the *Technical Digest* provides, for the first time ever, a comprehensive summary of what APL technical staff are doing across the spectrum of S&T. I hope you enjoy reading it.

REFERENCES

[1] *APL, Looking to the Future*, JHU/APL, Laurel, MD (2001).
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[3] *Report of the APS Study Group on Boost-Phase Intercept Systems for National Missile Defense*, American Physical Society, Washington, DC (15 Jul 2003).
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