A View of Future APL Science and Technology: Guest Editor's Introduction

John C. Sommerer

Prediction is difficult, especially about the future.
Niels Bohr[1]

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, while a few have been research and development updates—anthologies, if you will, of essentially unrelated but noteworthy technical efforts. By contrast, this issue is an attempt to present a relatively comprehensive view of APL capabilities and activities in science and technology (S&T), in the future. Except for the last clause of the preceding sentence, the beginning of this paragraph is identical to the one with which I introduced the previous issue[2] of the *Technical Digest* that I had the privilege of serving as guest editor. In that issue, from 2003, the authors presented, for the first time, a coherent snapshot of the range of S&T contemporarily under way throughout the APL enterprise. A significant fraction of my introduction explained that this was a particularly difficult task, given the historical autonomy of APL's organizational units and the scarcity of APL staff with visibility into the practice of technical disciplines across the entirety of the Laboratory. Nevertheless, the issue was successfully received by our peer organizations and by our sponsors.

With this issue, however, we won't be able to determine the success of our efforts just by waiting for the reviews, so to speak. Why? Because this issue discusses an institutional vision for APL's *future* in S&T. No matter how well the articles herein are written (and I think they are very well written, as we expect from APL authors), no matter how many readers agree with them (or disagree, for that matter), the real measure of success for this issue, and more importantly, the underlying institutional vision, will be how well it measures up to the test of time. Will the areas where we're now technically preeminent continue to propel our contributions to critical national challenges? Will the new areas where APL is investing and working hard to establish new capabilities turn out to underpin future contributions? What will we have missed that we'll be kicking ourselves about 5 or 10 years hence? What will we have clung to out of comfort or familiarity that turns out to be the 21st century equivalent of the buggy whip? Only time will tell.

MOTIVATING AN APL S&T VISION

So, why do this at all? As Bohr pointed out, predicting the future is a bit of a fool's game. We at APL pride ourselves on our ability to apply S&T to operational problems of our national security and space exploration sponsors in ways that achieve practical solutions. We're not really in the business of speculation. Or are we?

Unfortunately, as the last couple of decades have shown, the world is changing very rapidly. The technology is changing at an ever-accelerating pace. When I rejoined APL after graduate school in 1991, a few dozen people here had connections to the ARPAnet, as it was then still known. Today, hundreds of APL staff (to say nothing of tens of thousands of government employees in our sponsors' organizations) carry around wireless devices so they don't even have to wait until returning to their offices to read their e-mail. In drafting this introduction, I initially refrained from naming the currently most popular brand of these wireless devices (Blackberry) because it wasn't clear that the brand would exist by the time the issue was published. That points to the second aspect of rapid change: The cast of leading characters in our world is changing at least as fast as the technology. Five years ago, few had heard of Al Qa'ida, and fewer still could imagine the kinds of operations in which U.S. forces, shaped by the cold war, would be engaged—from disaster relief, to nation building, to counterinsurgency against profoundly asymmetric and amorphous enemies. Five years ago we had just survived the Y2K jitters, and the developing economies that had helped the world do so were kicking into high gear, driving technology still faster and geographically dispersing its engine in ways that will make it very difficult for the United States to retain its current position of technological dominance.[3]

This pace of change means that any organization that "stands pat" in terms of its competencies will almost certainly lose whatever place it holds. As the technology APL needs to apply to our sponsors' problems changes, and our sponsors' problems also change in profound ways, we will be *forced* to constantly speculate about what will be important in the future, to conduct explorations in many areas, building capability in some, establishing hedging positions in others, and cutting our losses in still others.

DRAFTING AN APL S&T VISION

As noted in the 2003 S&T issue of the *Technical Digest*, Dr. Roca's appointment as APL Director marked a watershed in terms of the Laboratory's enterprise-level stewardship of its technical competencies. His creation of the APL Science & Technology Council, and its creation, in turn, of the APL S&T Advisory Panel (STAP), drove the vision discussed in this issue in important ways.

In its very first report to Director Roca, the founding STAP Chair, Professor Daniel Hastings of MIT, noted that

> *"[Although] APL presented a clear strategic value statement,… the STAP did not hear a clear vision for where APL wanted to be in terms of Science and Technology (S&T) in the long-term future or on any timescale. While there was a good understanding of where APL was now in the use of S&T and a developing understanding of the core competencies in S&T, no vision was presented. The development of such a vision on a five and ten year timescale will provide guidance for investment of scarce S&T resources."*

The terms of engagement between the STAP and APL management, negotiated with Professor Hastings before he agreed to serve as Chair, required us to respond to any principal recommendation the STAP made (not necessarily to do what the STAP suggested, but if not, to explain why not). Drafting an APL S&T Vision thus became one of the early assignments of the APL S&T Council, though there were many necessary prerequisites that were needed before attacking the Vision itself.

It was no easy task. At that point in Dr. Roca's administration, we were just in the process of standing up Business Areas (BAs) as the external view of APL, defining the critical challenges of each and determining the critical contributions that APL wished to attempt. As a starting point for an APL S&T Vision that was actionable and relevant to our future enterprise strategy, we needed both business and technology plans for each BA. The first BA technology plans were submitted by the BA management teams in September 2002. Each was reviewed by the S&T Council, by me as APL Chief Technology Officer, and by Dr. Roca himself. Each was briefed to the STAP, which made many constructive comments on them. Subsequently, each BA has revised its technology plan about every 2 years. As this is written, a third round of BA technology plans has just been submitted to the S&T Council.

In a parallel effort, the Council was drafting a template for APL's as yet unwritten S&T Vision. We felt that this was extremely important, given past difficulties APL had had in setting enterprise-level priorities. For example, an effort to establish something like an S&T Vision in the early 1990s resulted in a declaration that something like a hundred different technical specialties were no less than "extremely important" at APL. That statement may well have been true, but it was hardly actionable, nor were any actions called for in the final report. The S&T Council was determined to avoid a repeat and so established a disciplined, parsimonious framework within which an S&T Vision could be articulated.

First, we recognized that an organization must focus its resources on a relatively small number of initiatives. One of the weaknesses APL had shown in the past was to set an equal priority on addressing a large number of issues, thus effectively setting a low priority on each. Therefore, the Council determined that we could usefully establish a hierarchy within our S&T Vision. We could set our sights on a relatively few areas where we expected to be true leaders in S&T; in perhaps a few more areas we could expect to be early adopters and fast followers, perhaps retaining an option to subsequently attain a leadership position should circumstances dictate. And, in any area where APL needed to perform on behalf of our sponsors, we would need to be no less than excellent practitioners, even if we did not aspire to set the technical agenda in the external community. The S&T Council defined each level in the hierarchy (see the boxed insert) in terms of the expected impact APL would have on the external technical community, the development of intellectual property, and the balance between discovery and application to be expected. Further, it established critical internal tests to be applied to any areas (and advocates) before a technical discipline would be slated for a leadership billing.

Criticality
- Critical to our envisioned future
- Underpins systems engineering and problem solving
- Underpins a strategic commitment

Significance
- Credibility: feasibility or demonstrated capability

Commitment to attaining stature
- Professional recognition
- Shaping the S&T landscape

Enterprise stewardship
- Investment of corporate resources
- Responsiveness to corporate review and guidance
- Time constant consistent with S&T Council investment of time and effort

Second, we recognized that one of the conundrums we needed to face was the tremendous technical diversity found at APL, especially for an organization our size. There *were* (and still are) hundreds of technical specialties important to carrying out the work of our sponsors. It was also clear that, the STAP's observations notwithstanding, APL had been successful in providing value to an increasing array of sponsors for over 65 years. The lesson seemed to be that existing management constructs were quite good at providing technical stewardship within sponsor communities. We may have missed some things during that time, and perhaps we weren't taking full advantage of potential synergies across the organization, but we maintained deep technical competence in areas that were important to our stakeholders. Thus, the S&T Council resolved to focus APL's attention on areas that warranted *enterprise-level* stewardship: areas where a leadership or early adopter position was essential to a strategic commitment of a BA (and where the BA was not able to maintain or establish the desired position with its own resources), areas that would provide a strategic advantage to multiple APL BAs, and areas that would underpin APL's ability to perform exemplary systems engineering. This also made clear a key factor that we felt would be critical in minimizing the number of technical areas proposed for leadership billing for "feel-good" or "game-theoretic" reasons: if advocates for a technical capability laid claim on Laboratory resources beyond those organic to a BA in order to establish or maintain a leadership position, they also would have to accept enterprise stewardship of those resources as well as enterprise definition and review of that capability.

Third, and critically, the Council recognized that a key component of a future vision was *aspiration*. We had to allow for the identification of technical capabilities that would be sufficiently important in the future that our current standing, if any, would need to be enhanced, and for which the full capabilities of the enterprise would be needed to do so. Although APL has in the past established technical leadership positions *ab initio* (the development of satellite navigation and the associated ability to engineer spacecraft, along with the enabling space science and geodesy, stand out as archetypal examples), recent forays of this type usually resulted from the critical influence of particular people (with access to Laboratory resources, or at least influence on those with such access), rather than as a result of systematic deliberation

THE APL S&T HIERARCHY FOR POSITION IN VARIOUS TECHNOLOGIES

Excellent Practitioner: Look to others to lead
- Proficiency in application
- Knowledge of other competent providers who serve as potential partners
- Ability to be aware of changes in the technology in a useful timeframe
- Production of solid results through application

Fast Follower/Early Adopter
- Ability to move to a leadership position when needed
- Ability to quickly follow changing technology and to insert key capabilities into APL programs when needed
- Ability to interact authoritatively with peer early adopters
- Ability to produce some publications, patents, and licensable results

Leader
- Creating and publishing original results
- Working at the leading edge of S&T
- Changing the direction of the technical community through discovery
- Recognition and consultation by peers
- Innovation, patents, licensing

by APL management. This was perhaps one of the most controversial aspects of the template, both within APL and in interacting with the STAP. The establishment of technical capabilities in advance of perceived business need offers many opportunities for embarrassment and disappointment. Indeed, several initiatives under consideration in the 1998 APL Strategic Planning effort were not acted upon because they were viewed as "hammers in search of a nail." Similarly, my determination to establish at APL a biological agent detection capability during the mid-to-late 1990s was viewed with great skepticism (to put it mildly), notwithstanding external funding for those efforts, until the events on and following 9/11.

Having reviewed the BA technology plans and prepared a template for the Vision, the Council held an intensive off-site meeting to (finally) actually draft a Vision for our future technical capabilities. Although that wasn't a pretty process (Otto von Bismark's quip about the making of both sausage and law comes to mind), it was a stimulating one.

In summarizing the S&T Vision for both the Executive Council and the STAP, we used a simple diagram, shown in Fig. 1.

Since the whole point of this issue of the *Technical Digest* is to discuss many of the entries in this figure, I won't attempt to do that here, but I will point out several features. First, the APL S&T Vision is hierarchical, with only a few items in the leadership category, one more item in the fast-follow category, and a rather larger number in the excellent practitioner category. Second, three of the elements are aspirational: information assurance, autonomous systems, and cognitive engineering. In those areas, the S&T Council felt that future capability well beyond our current competence would be extremely valuable, given APL's core purpose and our understanding of the changing nature of both national security and space exploration challenges. Third, one of the most surprising things to many who saw this for the first time is that systems engineering is not explicitly identified as a technical discipline. The Council's feeling was that systems engineering, though of overwhelming importance to APL and its sponsors, was not something that was an isolated technical discipline. Rather, it seemed to us that systems engineering is an approach that allows us to integrate many technical areas of competence to provide the practical solutions to sponsor problems for which we are known. Certainly, many APL staff teach systems engineering through JHU's Whiting School of Engineering, and the Laboratory's late Chief Scientist and former Director, Alexander Kossiakoff, co-authored a definitive treatise on the subject.[4] Yet even Kossy himself, a member of the Council up until his death last year, never advocated systems engineering for a role in the Vision other than as an integrating factor. Finally, there are two areas not found on the brief summary of the Vision where APL has had an unquestioned leadership position: confidence-based test and evaluation and hypersonic propulsion. In these areas, which *are* treated in articles in this issue, serious questions about their future viability and (market) value existed at the time of drafting. In the former case, it seemed then that few sponsors beyond the Strategic Systems Project Office were interested in the investment required to perform confidence-based evaluation; subsequently, technical developments potentially reducing the amount of flight testing needed (such as Bayesian hierarchical networks) have substantially removed such doubts. In the latter case, facilitization viewed by practitioners at APL has proven increasingly difficult for economic reasons; it now appears that future APL participation in the hypersonic propulsion arena will require an emphasis on systems engineering contributions and the use of testing facilities not owned by APL.

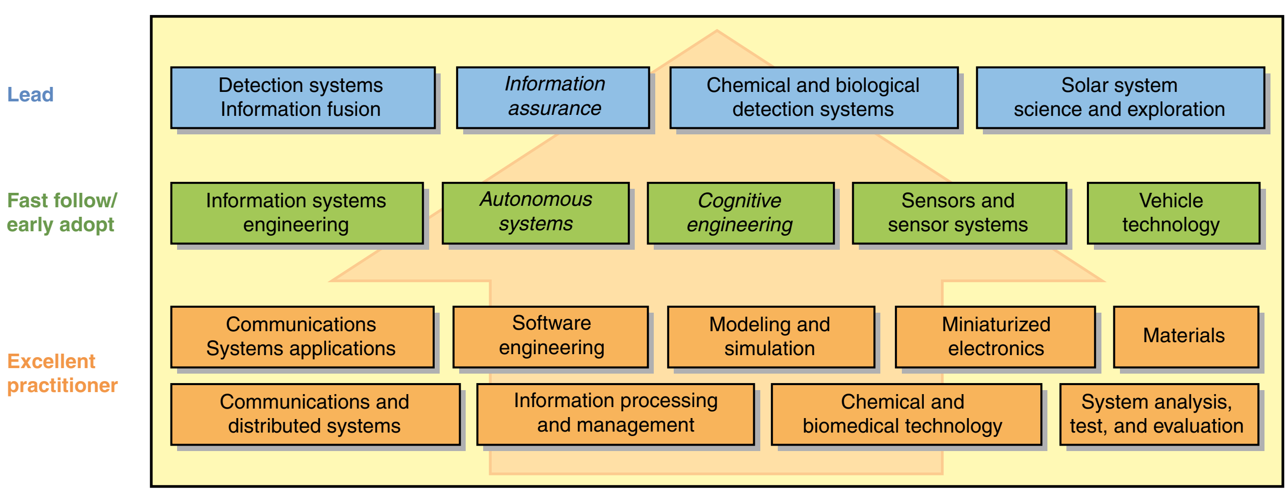

Figure 1. Representation of APL's S&T Vision for enabling critical contributions to critical challenges. Systems engineering is the glue that makes the contributions possible.

TESTING THE VISION

As noted earlier, the only true test of this Vision will be over the course of time, but there are some early indicators that it isn't a completely botched job, at least.

Although both the Executive Council and the STAP suggested some changes, they were by and large in agreement with the draft as it emerged from the S&T Council. APL sponsors and government officials uniformly praised the approach to developing the Vision (and some now refer to the "APL approach" in discussing development of a technical strategy) and seemed pleased with the content.

More probative is APL's progress in developing the aspirational areas. In all three areas, APL is more prominent than before (though probably not at the end state we desire). The technical competency we have been able to develop and demonstrate in the relatively short time since the Vision was drafted has played an important role in acquiring some tens of millions of dollars of program funding (much of it competitively awarded through S&T funding agencies like DARPA), in recruiting nationally recognized thought leaders, and in establishing the precedent that APL *can* strategically initiate new technical capabilities. This was the area where the STAP expressed its greatest concern, and they have been very pleased with our progress.

Let me mention two other tests that the Vision has weathered well. Under APL Director of Strategic Planning Ira Blatstein's leadership, the APL Executive and S&T Councils, assisted by an external board of advisors chaired by former DARPA Director Frank Fernandez, conducted an "alternative futures" exercise[5] in 2004, where APL's capabilities and strategy were tested in four plausible (if not probable) alternative futures meant to be so distinct that they would likely bracket the actual future's unfolding. All of these futures would be extremely challenging for APL to continue to succeed in. However, in general the S&T Vision did well (or at least included capabilities that did well) in all the futures. Most of the threat to APL success in these alternative futures had to do with the Laboratory's business model, the relative importance of our current portfolio of sponsors, economic conditions, etc., *not* with our technology choices.

One factor that has changed most measurably since the initial drafting of the Vision has been APL's senior leadership team. As a result of retirements and a few promotions (and one presidential appointment), the APL Executive Council's membership has changed by about half since the Vision was first issued. This fresh set of eyes reviewed the S&T Vision in some depth during the September 2005 Executive Council retreat and found that it seems quite sound. In fact, the Executive Council tasked Assistant Director for Programs Jerry Krill and me to ensure that there is sufficient responsibility and accountability in the APL BAs to ensure execution of the Vision; this has become an explicit element in APL's integrated investment planning and allocation process.

Finally, of course, the APL S&T Vision isn't meant to be an ideological doctrine or creed. As circumstances, insight, and the test of time suggest that it should change, we will change it. After all, this is meant to be a vision, not a hallucination. In fact, as a result of discussion of APL's S&T position and future needs at the September 2005 Executive Council retreat, the S&T Council is considering a few relatively minor changes to the Vision.

THE ARTICLES

As outlined earlier, speculation about the future is something that APL scientists and engineers may well be comfortable doing around the lunch table, but they typically don't do it in writing for a wide audience. The authors of this issue's articles were asked to go beyond describing what APL is doing today in the areas discussed and to address why they might be important in the future and in what directions the work may evolve. And, of course, the authors didn't have the freedom to speculate on a strictly personal basis, because the S&T Vision is meant to be institutional in nature and they were left to articulate parts of a vision drafted by a committee.

To be candid, some found the task more agreeable than others. In some cases, author teams grew or changed from the initial assignments, precisely because of the discomfort involved. Whether you agree with the authors' and the S&T Council's views of the future or not, we need to recognize their courage in confronting the difficulty of predicting, especially about the future.

All of the "Lead" and "Fast Follow" categories in the Vision are covered in this issue, together with a number of "Excellent Practitioner" topics where we felt we had something particularly important to convey, or where there was an author eager to stake out territory on behalf of APL.

Lead

Jerry Bath, Chris Boswell, Suzette Sommerer, and I-Jeng Wang lead off with an article about Detection System Information Fusion, a term we coined at APL to indicate the sort of "upstream" fusion characterizing the Cooperative Engagement Capability (one of the chief exhibits in support of our claim of leadership in this area) and the Global Network-Centric Surveillance and Targeting effort. We see this as a bread-and-butter area for APL, given the ubiquitous need to make sense of the ever-increasing torrent of data our sensors and information systems collect. "Information overload" now seems to be one of the chief ingredients in Von Clausewitz's fog of war.

Paul Spudis, a member of the President's Commission on Implementation of United States Space Exploration Policy, discusses another element of the APL S&T Vision where we are acknowledged leaders: Solar System Science and Exploration. With the launch of the New Horizons spacecraft this winter, APL now has NASA missions under way, truly spanning the solar system, from Mercury to Pluto and beyond; with the launch of STEREO in 2006, we'll be keeping an eye on the Sun as well. It now remains for us to forge a key role in President Bush's new vision, where robotic exploration serves as a precursor to human exploration, an area where APL has not traditionally been a major player.

Plamen Demirev, Andy Feldman, and Jeffrey Lin outline a vision for APL in the area of Detection Systems for Chemical and Biological Weapons. This may be, for many observers, one of the most surprising entries in the APL S&T Vision. Technology developed at APL since the mid-1990s, some of which turned out to be among the most potentially useful in the nation's post-9/11 inventory, stakes our claim in this area. This technology underpins only one APL BA, Homeland Protection, which is seeking a greater proportion of systems engineering and less S&T-type effort in its portfolio. However, this technology area is APL's primary practical contact with modern biology, probably the most rapidly developing frontier in current science. Moreover, given the potentially catastrophic consequences resulting from an asymmetrically inclined adversary's use of biological weapons, together with the apparently increasing probability of new natural disease outbreaks from pandemic flu to antibiotic-resistant bacteria, this element in APL's Vision should not be retired quite yet.

Finally, Susan Lee and Donna Gregg discuss Information Assurance as an aspirational element of the S&T Vision to lead. As this article makes clear, when APL determines that it needs to claim a leading position in a technology area where we have little previous experience, the choice of niche and the approach to entering it are critical. Given the tremendous power of the global commercial sector in information technology, it's extremely important to understand that our leadership in this area must be narrowly focused and carefully aligned with our national security sponsors' most urgent needs. We won't be competing with Microsoft Research! On the other hand, our sponsors can't easily count on such commercial providers to secure their most sensitive and critical information infrastructure.

Early Adopter

David Silberberg and Glenn Mitzel discuss APL's desired role as a fast follower in the area of Information Systems Engineering. APL has always prided itself on being more than a "paper mill." Despite our long and continuing tradition of hardware prototypes, an ever-increasing proportion of the Laboratory's innovation will be instantiated in software. Thus, application of systems engineering principles in the context of tightly coupled, interoperable information systems will necessarily be central to our technical work in the future.

Joe Suter discusses a continuing mainstay of APL technology, Sensors and Sensor Systems. It's perhaps obvious, but information systems can only move information that's valuable if that information has been transduced in some way from the physical world—and that means sensors. In addition, the whole point of the spacecraft that APL builds on behalf of NASA and the DoD is to place sensors. The trend toward smaller, lower-power sensors with more on-site processing is well aligned with both space exploration and network-centric warfare; this is clearly an area where the Laboratory will need to be close to the leading edge.

John Wozniak, Pat Stadter, and Bill Kujawa discuss "Vehicle Technology," an APL coinage that we use to cover a wide range of technologies required to engineer state-of-the-art vehicles—from aircraft, to missiles, to spacecraft, to uninhabited underwater vehicles. Areas such as guidance, control, navigation, propulsion, and power distribution are essential to the creation of our own systems, as well as to the "trusted agent" evaluation and troubleshooting of vehicles produced by others.

Dave Watson and Dave Scheidt discuss APL's position in Autonomous Systems, an area where we aspire to be a fast follower. Of course, our history in spacecraft development and guided missile technology gives us a firm foundation, but currently envisioned military operations and space exploration will require a great deal more "intelligence" and independence for autonomous systems. Watson and Scheidt played a key role in establishing a cross-enterprise initiative in autonomy which has drawn prominent collaborators from across the nation and has already significantly increased APL's involvement in externally funded work in this area.

John Gersh, Jennifer McKneely, and Roger Remington discuss APL's aspirations in an area we call Cognitive Engineering, basically the intersection of cognitive science, human factors, systems engineering, and human-computer interface design. Given the degree to which information overload complicates almost all domains of management and control today, we believe that deep insight in this area will critically underpin APL's ability to do meaningful systems engineering in the 21st century. Candidly, this was an area over which the STAP expressed significant skepticism about APL's ability to mount a credible effort from a standing start. At this point, however, it looks like we are off to an excellent start, indeed. Gersh and McKneely have done a very significant amount of concept development and evangelism within APL, as well as having secured a sound initial externally funded program base. Remington, an internationally recognized researcher in this area, was sufficiently captivated by our vision and initial progress that he left NASA Ames and joined APL just about a year ago. The STAP's Chief Advisor to APL in this area, Judith Olson (who just won the Association for Computing Machinery Special Interest Group on Computer-Human Interaction Lifetime Achievement Award in Computer-Human Interaction), recently encouraged one of her postdocs, Nathan Bos, to join the APL team. Further, the *majority* of APL's BA technology plans now cite cognitive engineering as one of their strategically differentiating technology needs for the next 5 years.

Excellent Practitioner

Bharat Doshi, newly appointed as the Head of APL's Research and Technology Development Center (RTDC), discusses Communications Systems Engineering in the context of the challenges presented by the need for secure global communications.

Paul Biermann, Jennifer Sample, and Dave Drewry write of the importance of Materials Science for APL in the future. This is a particularly interesting area from an APL political perspective. We essentially left this area (institutionally, at least) based on perceptions of previous investment disappointments. A number of materials scientists left APL, some explicitly noting that "APL has many materials issues impeding its progress, but it refuses to recognize them as materials issues." As Head of the RTDC during the late 1990s, I made certain that any materials work we had under way went by some other name. More recently, materials science has been more welcome at APL, especially with the emergence of truly enabling capabilities resulting from composites, functionally graded materials, and the emerging area of nanotechnology.

Harry Charles, a member of the S&T Council during the whole period since the S&T Vision was first conceived, discusses the importance of APL's ability to be an excellent practitioner in the area of Miniaturized Electronics. This is, at once, an obvious fact and a great challenge, as the capital investments required to fabricate devices on modern scales goes ever higher and more and more of the activity in this field occurs offshore.

Jim Coolahan looks at Modeling and Simulation, an area in which many APL staff (based on roughly annual technical capability surveys that have been undertaken by the S&T Council since 2001) note that they spend a considerable amount of their time, and an area where Coolahan has had significant Laboratory responsibility for over a decade.

Paul Hanke, Hilary Hershey, and Pam Smith discuss APL's perspective on Software Development. They have a unique perspective on this issue, having both led a Laboratory-level initiative on disciplined software development that preceded APL's more recent institutional and multidisciplinary focus on quality assurance. I find their perspective on the future of this field particularly fascinating. There is no doubt that software development will be important in APL's future. The question is more about whether *people* will be the software developers or whether people will serve a more limited, higher-level architectural role.

Other Existing Leadership Positions

Dave Van Wie, Steve D'Alessio, and Mike White present a vision for APL's continued leadership in Hypersonic Airbreathing Propulsion. This is an area where APL played an absolutely pivotal role when Navy air defense systems were based on air-breathers, and where the Laboratory maintained an international reputation in the technology (even when the Navy abandoned air-breathing propulsion in favor of rockets) through support of the National Aerospace Plane program, and later through advanced technology programs for NASA, DARPA, ONR, and the Air Force. The authors all played an important role in demonstrating a 1970s-era APL invention, the dual-combustion ramjet, through the joint DARPA-ONR HyFly program, scheduled to have its first dual-combustion ramjet–powered test flight within the coming year. An important ingredient in APL's technical preeminence in this area was the William A. Avery Propulsion Research Laboratory, built at APL's Howard County campus in the early 1960s. In one of the more painful decisions in recent memory, it was recently decided to close that aging facility because associated revenue streams, together with government and APL cost-accounting policies, made it impossible to operate and recapitalize it. Further, retirements, deaths, and career changes by key technologists have thinned the ranks of the human capital behind this technology area, making it less likely that APL will continue to maintain its preeminent role in the future.

Larry Levy, another S&T Council "plank owner," discusses the confidence-based Systems Analysis, Test, and Evaluation techniques that APL developed in the context of ensuring the deterrent value of the U.S. submarine-based strategic missile system. When APL's S&T Vision was first drafted, the future of this technical capability seemed certain *only* in the context of the SSBNs, and even there concerns about the cost of the attendant flight testing raised doubts about whether this "Cadillac" version of test and evaluation had a future. More recently, the importance of the confidence-based techniques, augmented by new methodologies, has been embraced by a broader community, and it seems safe to say that it will be an important part of APL's future.

CONCLUSION

As we've noted, predicting the future is difficult but necessary in any forward-looking technological institution that plans on being around for the long term. Of course, we aren't really trying to predict the future in terms of a sequence of events. We seek to understand what technical capabilities will enable APL to make critical contributions to the future's critical challenges, no matter what they may be. We can't possibly get this right 100% of the time. But not trying would guarantee that we'd eventually be wrong 100% of the time. One of the key tests for APL's future success is not the scorecard for the current version of the S&T Vision, but whether we have the fortitude and intellectual honesty to continue to reexamine and revise the Vision, augmenting it as needed and pruning the unproductive branches, no matter how painful. I congratulate my S&T Council partners, past and present, for making a good start.

At the very least, this issue of the *Technical Digest* documents an APL experiment in speculating about the future. I hope that you enjoy reading it and will help us collect the data and analyze the results.

ACKNOWLEDGMENTS: First, I would like to thank my colleagues on the APL S&T Council for their creative and disciplined efforts in confronting the discomfort of looking into an uncertain future, and not blinking. As mentioned previously, the authors of the articles in this issue also deserve thanks and admiration for trying to articulate our institutional vision for future technology. Finally, thanks must go to the editorial and production staff of the *Digest*, for both their patience and determination to see this issue published.

REFERENCES AND NOTES

[1]This epigraph (together with many variations) has been attributed to a number of authors, most often Nobel prize–winning Danish physicist Niels Bohr. Unfortunately, I have been unable to connect this useful saying to Bohr through any authoritative written source. The phrase has also been ascribed to Yogi Berra (easy to dismiss, since Berra himself noted that "I didn't really say everything I said"), to Danish 17th century naval hero Piet Hein, and occasionally to 20th century Danish cartoonist and social commentator Robert Storm Peterson. The strength of the Denmark connection is marked, and provides a good clue to perhaps the most definitive attribution. The Danish quotation dictionary *Bevingede Ord* (*Winged Words*, T. Vogel-Jørgensen, Gads Forlag, Copenhagen, 1979) notes that in the 1948 memoirs of Danish statesman K. K. Steincke, *Goodbye and Thanks*, the phrase was attributed to an otherwise unidentified member of the Folketing (Danish Parliament) during the period 1935–1939. It is, of course, completely plausible that Bohr read this phrase in a newspaper and subsequently adopted it conversationally.

[2]*Science and Technology in Service to the Nation*, special issue, *Johns Hopkins APL Tech. Dig.* **24**(1) (2003).

[3]The influence of Y2K in extending the information technology revolution to developing economies, particularly India's, is one of "ten forces that flattened the world," as described in Thomas L. Friedman's fascinating and sobering book, *The World is Flat: A Brief History of the Twenty-first Century* (Farrar, Straus, and Giroux, NY, 2005). Any American technologist who hasn't read this book needs to, quickly.

[4]Kossiakoff, A., and Sweet, W. N., *Systems Engineering Principles and Practice*, John Wiley and Sons, Hoboken, NJ (2003).

[5]So-called scenario-based planning, where corporate strategies and portfolios are tested in highly stressing postulated alternative futures, has developed as an alternative to more traditional planning methodologies which tend to consider parametric variations around a "momentum" projection of the future. Such an approach is now felt to provide more robust strategies against highly disruptive, but difficult-to-predict eventualities (9/11 would be a singular example). This approach is described by one of the earliest practitioners of such planning, Peter Schwarz, in his book *The Art of the Long View: Planning for the Future in an Uncertain World* (Currency Doubleday, 1991).

THE AUTHOR

John C. Sommerer

John C. Sommerer has been APL's Director of Science and Technology since October 2005, its Chief Technology Officer since October 2001, and Chair of the APL Science and Technology Council since April 2000. Prior to his most recent assignment, he was Director of the Milton S. Eisenhower Research and Technology Development Center for 9 years. He is an internationally recognized expert in nonlinear dynamics and was named Maryland's Distinguished Young Scientist in 1994 for his experimental and theoretical contributions to that field. Dr. Sommerer has B.S. (*summa cum laude*) and M.S. (with honors) degrees in systems science and mathematics from Washington University in St. Louis, an M.S. (with honors) in applied physics from The Johns Hopkins University, and a Ph.D. in physics from the University of Maryland. Starting at APL in 1978, Dr. Sommerer worked in the Fleet Systems and Submarine Technology departments, where he contributed to the solution of image processing, search and screening, optimization, stochastic analysis, optics, and threat assessment problems. Currently, Dr. Sommerer also serves as Vice Chair of the U.S. Naval Research Advisory Committee, the senior scientific advisory body to the Secretary of the Navy, the Chief of Naval Operations, the Commandant of the Marine Corps, and the Chief of Naval Research. His e-mail address is john.sommerer@jhuapl.edu.