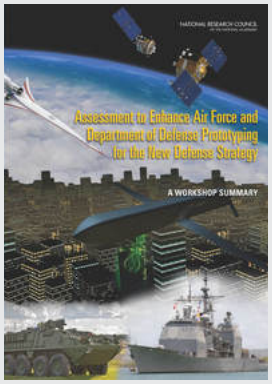

Assessment to Enhance Air Force and Department of Defense Prototyping for the New Defense Strategy: A Workshop Summary

DETAILS

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Assessment to Enhance Air Force and Department of Defense Prototyping for the New Defense Strategy

A WORKSHOP SUMMARY

Norman M. Haller, *Rapporteur*

Air Force Studies Board

Division on Engineering and Physical Sciences

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PLANNING COMMITTEE FOR A WORKSHOP ON ASSESSMENT TO ENHANCE AIR FORCE AND DEPARTMENT OF DEFENSE PROTOTYPING FOR THE NEW DEFENSE STRATEGY

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Preface

The committee was honored that so many expert speakers from the U.S. government, government-related entities, industry, and academia were available to discuss in detail their views regarding the very important subject of this 3-day workshop. In addition, the committee was especially pleased that Robert Whalen, a retired industry executive with several decades of experience in advanced technology endeavors, shared his perspectives as our emeritus speaker. The committee also thanks the many guests who contributed immensely to this workshop. Finally, this report has been prepared by the workshop rapporteur as a factual summary of what occurred at the workshop. The planning committee's role was limited to planning and convening the workshop. The views contained in the report are those of individual workshop participants and do not necessarily represent the views of all workshop participants, the planning committee, or the National Research Council.

Lester L. Lyles, *Chair*
Planning Committee for a Workshop on Assessment to Enhance Air Force and Department of Defense Prototyping for the New Defense Strategy

Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Jill P. Dahlburg, Naval Research Laboratory,
Paul G. Kaminski, Technovation, Inc.,
Gregory S. Martin, GS Martin Consulting, and
Paul D. Nielsen, Software Engineering Institute.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the views presented at the workshop, nor did they see the final draft of the workshop summary before its release. The review of this workshop summary was overseen by Stephen M. Robinson, University of Wisconsin-Madison. Appointed by the NRC, he was responsible for making certain that an independent examination of this workshop summary was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this summary rests entirely with the author and the institution.

Contents

Acronyms

ACTD	Advanced Concept Technology Demonstration
ADP	Advanced Development Programs
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
CWMD	counter weapons of mass destruction
D2D	data to decisions
DoD	Department of Defense
ERS	engineered resilient systems
EW/EP	electronic warfare/electronic protection
LM	Lockheed Martin
OMB	Office of Management and Budget
R&D	research and development
S&T	science and technology
STEM	science, technology, engineering, and mathematics
TLAR	“that looks about right”
TOR	terms of reference
TRL	technology readiness level

1

Introduction

Prototyping has historically been of great benefit to the Air Force and Department of Defense (DoD) in terms of risk reduction and concept demonstration prior to system development, both during austere budget environments and at other times. Specifically, prototyping has advanced new technologies, enhanced industry workforce skills between major acquisitions, and dissuaded adversaries by demonstrating new capabilities. Importantly, prototyping enabled U.S. technological surprise through classified technologies.[1] Over the last two decades, however, many issues with prototyping have arisen. As examples, the definitions and terminology associated with prototyping have been convoluted, and budgets for prototyping have been used as offsets to remedy budget shortfalls. Additionally, at times, prototyping has been done with little strategic intent or context.[2]

It is against this backdrop that the Air Force requested the Air Force Studies Board of the National Research Council to plan and moderate this workshop to enhance Air Force and DoD prototyping for the new defense strategy. The terms of reference (TOR) for this workshop (see Appendix B) called for examination of a wide range of prototyping issues, individual recommendations for a renewed prototype program, addressing particular program elements, attention to the application of prototyping as a tool for technology/system development and sustainment

[1] David Walker, Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering, personal communication to Terry Jaggers, National Research Council. April 9, 2013.
[2] Ibid.

(including annual funding), positive and negative effects of a renewed program, and consideration of additional topics.

To help focus the very broad range of topics covered at the workshop on September 24-26, 2013, in Washington, D.C., several questions involving a description of prototyping, as well as its value and best practices, were posed to the workshop participants (see Appendix C, "Workshop Agenda"). Given the vast amount of prototyping expertise of the presenters and other participants, the scope of the presentations and discussions was necessarily comprehensive (see Appendix D, "Workshop Participants." and Appendix E, "Speaker Abstracts"). The remainder of this workshop summary is organized primarily around eight major themes, specifically (1) prototyping and its many definitions; (2) the value of prototyping; (3) tying prototyping to strategy; (4) prototyping as an agent for change; (5) prototyping as a versatile tool; (6) prototyping as a means to empower people; (7) funds and incentives for prototyping; and (8) a technology development strategy.

2

Overview

This overview addresses the major themes that arose during the presentations and discussions—sometimes across two or all three of the daily sessions—and were articulated explicitly by the participants during the last session. The thematic summaries include individual views of committee members, speakers, and other participants. Different opinions have been included to both inform particular themes and illustrate the range of views expressed; however, a lack of different opinions in the summaries of particular points does not imply there were none. Additionally, all views from the workshop, including any suggestions for future actions by the Air Force or others, expressed in this workshop summary are solely the views of individual participants as understood and interpreted by the rapporteur. Although the chair and other members of the planning committee participated in the workshop, they did so as individuals, and nothing in this report should be construed as a "committee position."

THEME 1. PROTOTYPING AND ITS MANY DEFINITIONS

Several workshop participants noted that prototyping has many definitions and involves concept, developmental, and operational definitions at a minimum.

Prototyping was defined very broadly but in different ways by several participants and speakers. For example, prototyping is an important tool to demonstrate the art of the possible, to expand the realm of the possible, to learn by doing, to free up enormous creativity in government, industry, and academia, to "uncover truth;"[1] and "a concerted effort to mature…, stabilize…, and define/quantify…"[2] Throughout the 3 days presenters and participants established that prototyping has many meanings that range across the full spectrum of defense S&T (science and technology) and major programs of record. At the front end—for example, during applied research—prototyping can mean relatively small and low-cost experiments to prove a concept or demonstrate feasibility. At the other extreme, prototypes can involve very large and expensive demonstrations, perhaps of experimental aircraft or space vehicles, prototype aircraft in competition with each other for acquisition, or the integration of two or more operational or nearly operational systems (e.g., radars, missiles, satellites, and communications).

Earl Wyatt, Deputy Assistant Secretary of Defense for Rapid Fielding, associated prototype classifications with various levels of technology maturity—specifically, concept prototypes for the early stages (e.g., feasibility), development prototypes for the middle stages (e.g., advanced concepts and integrated capabilities), and operational/fieldable prototypes that look toward the production and deployment stage and satisfying operational needs. The following collection of descriptors associated by various attendees with prototypes or prototyping illustrates the very broad nature of prototyping in the technical community: component prototypes, S&T prototypes, acquisition prototypes, production prototypes, total-system prototypes,[3] software prototypes, virtual prototypes, program-life-extension prototypes, policy/procedure prototypes, collaborative prototyping, emerging-capabilities prototyping, competitive prototyping, rapid prototyping, and prototyping on demand. Nevertheless, many attendees believed that the linkage of prototyping to a specific purpose, a strategy, and a strategic process is much more important than the term and its associated modifier; this linkage is addressed under other themes.

Such broad use of the term prototype caused one participant to suggest that perhaps the term is too broad because it already occurs as a best practice at lower subsystem levels and all along the S&T process. To some participants, however, the term may primarily suggest a very expensive fly-off between two or more companies competing for an aircraft development and production contract. During the workshop, other terms, like experiment, demonstration, or ACTD (advanced concept technology demonstration), which was previously used in DoD, were suggested for possible use at various points in the S&T and acquisition process.

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[1]William Melvin, Director, Sensors and Electromagnetic Applications Laboratory, Georgia Tech Research Institute.

[2]Brian Hershberger, Senior Aeronautical Engineer, Advanced Development Programs, Lockheed Martin Aeronautics.

[3]Total system prototypes could include prototypes both at advanced levels and also at the early-applied level, particularly for distributed systems.

THEME 2. THE VALUE OF PROTOTYPING

Many participants noted that the prototyping ethos can benefit innovation, develop and maintain workforce skills/retention, reduce time to development, improve knowledge management, support a national security strategy, and provide a hedge against technical uncertainty or unanticipated threats.

Prototyping was clearly recognized by many workshop participants to be a valuable tool for the Air Force and DoD. Among its many benefits that were discussed are the following: demonstrating new technologies or capabilities, maturing technology, reducing risk and increasing confidence, transferring technology to industry, hedging against possible threats, enabling rapid responses to emerging threats, exploring design trade-space, informing the establishment of requirements,[4] testing and understanding concepts of operation, improving or preserving skilled technical workforces and related infrastructure, promoting innovation, offering opportunities for collaboration, and creating a sense of excitement to attract young engineers and scientists.

Robie Samanta Roy, Professional Staff Member, Senate Armed Services Committee, emphasized the importance of prototyping to keep design and integration teams together as DoD funding declines; he advocated "agile prototyping" as a way of having teams understand what it takes to meet certain requirements and quickly move a capability into the field. At various times other speakers and participants returned to the importance of prototyping as a way of continuing to attract, retain, and exercise perishable skills, such as engineering, to maintain the highly motivated and capable technical workforce needed by the Air Force and DoD. For example, Patricia Falcone, Associate Director, Office of Science and Technology Policy, advocated enhancing DoD's prototyping competency by defining targeted prototyping efforts, which will not only deliver value but attract and connect innovators, thereby strengthening talent, competency, and capabilities. In addition, Brian Hershberger, Senior Aeronautical Engineer, Advanced Development Programs, Lockheed Martin Aeronautics, proclaimed "Prototypes are high value enablers to grow the workforce experience base."

A substantial number of examples of prototyping successes described during the workshop involved past experiments and demonstrations, such as X-planes, that greatly advanced U.S. technological superiority. Mr. Hershberger provided a graphic illustrating the changing nature of prototyping over the decades (see Figure 2-1). Figure 2-1 shows the early emphasis on platforms, such as the XFs and YFs, shifting toward emphasis on integrated systems. A glimpse into future possibilities

[4] A participant suggested that this thought could be more broadly captured as providing strategy inputs covering everything from elucidating needs and opportunities to concepts of operation, among other things.

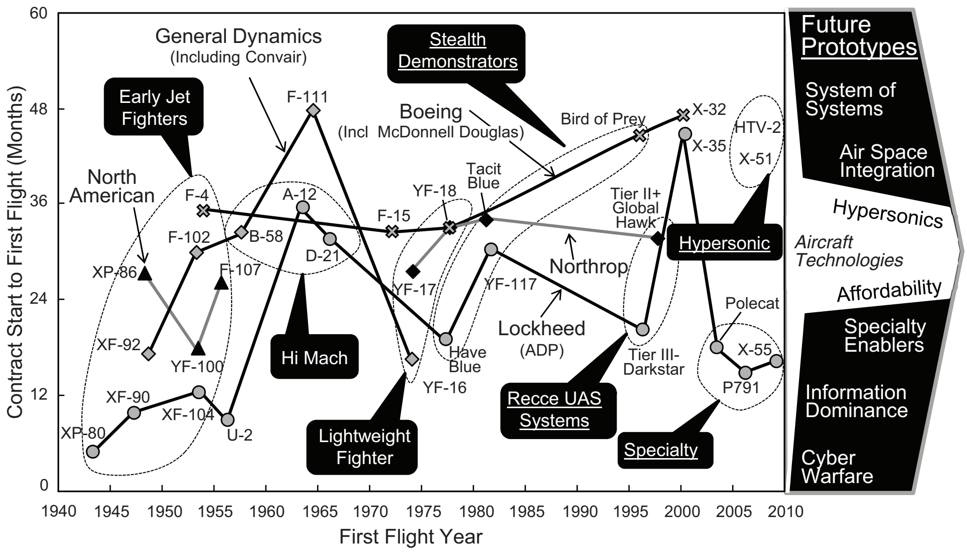

FIGURE 2-1 Historical development programs, including demonstrators, prototypes, and operational systems. NOTE: The horizontal axis shows the year the labeled vehicle achieved first flight; the vertical axis shows how long it took (each line is 12 months) to achieve first flight from program go-ahead (not counting studies leading up to go-ahead). The histogram lines capture trends and link programs to companies that developed the aircraft. The shaded groupings capture like types to draw commonality between the classes of systems. NOTE: LM ADP, Lockheed Martin Advanced Development Programs. SOURCE: Brian Hershberger, Senior Aeronautical Engineer, Advanced Development Programs, Lockheed Martin Aeronautics. "Lockheed Martin Perspectives," presentation to the workshop on September 25, 2013. Figure reprinted courtesy of Lockheed Martin Aeronautics.

emphasizing capabilities like air-space integration and hypersonics is depicted at the right side.

Given the value of past prototyping activities, many attendees expressed concern that the Air Force and DoD no longer appear to be enthusiastic about prototyping. Given this concern, it was interesting that multiple speakers explained how the values of prototyping place it at the root of what is accomplished daily in their S&T projects. But these projects are mostly at levels lower than the expensive high-visibility prototypes associated with recent programs of record (e.g., F-22, F-35). One participant urged the Air Force representatives to "educate" members of Congress on the value of prototyping. Nevertheless, some discussions during the workshop indicated that the benefits of prototyping, such as reduced time to develop, are not always clear because they are outweighed by other key factors that drive programs (e.g., changing requirements).

THEME 3. TYING PROTOTYPING TO STRATEGY

A number of participants pointed out that prototyping is best tied to corporate strategy at the DoD and Service level and resourced appropriately to support the strategy.

Although many best practices for prototyping were described during the workshop, one stood out so strongly that it was a theme of itself. During the workshop many participants agreed strongly with the need for tying prototyping to a clearly understood purpose and linking that purpose to a strategic plan.[5] In fact, prototyping was described by some as both a tool and a strategy. For example, William Melvin, Director, Sensors and Electromagnetic Applications Laboratory, Georgia Tech Research Institute, said "Prototyping is both a tool and a strategy." Daryl Pelc, Vice President for Engineering, Phantom Works, The Boeing Company, stated his organization's approach is "Prototype to win." Jim Shields, President and CEO, Charles Stark Draper Laboratory, discussed "Prototyping as a strategy rather than a program." Dr. Melvin explained it this way: "As a strategy, we use prototyping to further our customer's objectives, …to build credibility in all we do, to create a culture of excellence in applied R&D [research and development], to create new research opportunities…, to recruit like-minded researchers and engineers."[6]

In spite of the rather obvious need to tie prototyping to a strategy, several participants lamented the fact that, as stated in Chapter 1, "…at times, prototyping has been done with little strategic intent or context." For example, a participant reminded the attendees that F-22 prototyping was done for political, not technical reasons. As a result, he indicated that the expensive F-22 prototyping effort did not examine the fighter's critical technologies and did not reduce the risk. In this regard, a general discussion topic was the prototyping requirement put in place by the Weapon Systems Acquisition Reform Act of 2009, as amended, which—unless waived—requires competitive prototypes before a major acquisition program can enter system development.[7] It was pointed out by some participants that, unfortunately, this requirement could make it possible to justify expenditures for some prototyping not on the basis of any technical or strategic purpose but just because the law requires it.

[5]One element of the strategic plan could be to develop critical enabling science and technology.

[6]Later themes address resources needed to support prototyping.

[7]For additional information on the Weapon Systems Acquisition Reform Act, see http://thomas.loc.gov/cgi-bin/query/z?c111:S.454, accessed October 4, 2013.

THEME 4. PROTOTYPING AS AN AGENT FOR CHANGE

Many participants noted that prototyping is a change agent involving technology, culture, people, concepts, and processes; it is best managed actively to enable change and promote an entrepreneurial attitude.

This theme has two elements: change agent and management. Much of the workshop consisted of various speakers providing examples of the change-agent nature of prototyping, both in the past and in their current work. Past examples typically emphasized the tremendous U.S. technological advances brought about by one or more particular prototype programs, such as X-planes, missiles, missile-guidance systems, and stealth. When it came to discussing management of such programs to enable change and promote innovation and risk taking, numerous best practices were described.[8]

The X-planes of the 1940s and 1960s (e.g., the X-1 broke the sound barrier in 1947; the X-15 was flown in 1959 and became the world's first space-plane in the early 1960s) illustrate proven approaches for innovation in aeronautics.[9] The Titan family of missiles, originally part of the U.S. nuclear deterrent, also lifted other military and civil payloads into space.[10] Marvelous advances in ballistic missile guidance systems resulted from prototype inertial systems first designed at MIT's Draper Laboratory in the 1950s.[11] The HAVE BLUE conceptual and program successes of the 1970s led to a 1979 decision to implement stealth by building the F-117A fighter. These stealth advances, which were truly game-changing, foreshadowed the B-2 bomber and other stealth developments.[12]

In addition to demonstrating new technological capabilities and U.S. technological prowess, ventures like these created excitement with their spectacular achievements and novel designs—excitement for engineers and scientists as well as for an admiring population when the results were made public. These prototyping efforts helped nurture a culture of technological innovation and developed processes for later programs. Current prototype programs, though not as newsworthy, are developing improved processes for technical advancement. One example is strategic teaming, which Sonya Sepahban, Senior Vice President, Engineering and

[8]A participant noted that active management could also mean enabling flexibility in program development, stalwartly blocking requirements creep, and concertedly minimizing expensive and unnecessary documentation.

[9]Innovations in aeronautics were discussed during presentations by Brian Hershberger and Jaiwon Shin.

[10]The Titan IIIC launch in 1965 was described by news media as "a triumph for the Air Force" http://archive.org/details/1965-06-21_Missile_Passes_Test, accessed October 4, 2013. Titan developments were discussed during the presentation by Robert Whalen.

[11]Advances in guidance systems were discussed during the presentation by Jim Shields.

[12]Stealth advances were discussed during the presentations by Brian Hershberger and Richard Van Atta.

Technology, General Dynamics Land Systems, described as a way to design, build, and test a fully integrated prototype in record time. This process is enabled by collaboration across a broad spectrum of stakeholders—engineers, warfighters, academia, suppliers, customers, and industry—to focus on challenges and develop consensus. Another process improvement discussed by the workshop participants is called Sidecar, which consists of pluggable interfaces where different experimental algorithms can be fed into a real system to check their capabilities and enable other contractors to experiment with the prototype system.

A somewhat unique push for conceptual change was tabled when Robert Whalen, President and CEO, International Systems, LLC, concerned that the United States needs a "numbers response" to possible adversaries, recommended a program focused on "cost technology." He believed "the most 'Disruptive Technology' would be the one that provides system(s) with current/improved effectiveness, at 1/2 to 1/10 current costs." Prototyping cost-reduction technologies with the same functional capabilities could be a central element of that kind of program.

To manage such change, various prototyping approaches and best practices were discussed by the participants at length. For example, Earl Wyatt, Deputy Assistant Secretary of Defense for Rapid Fielding, indicated movement from a "responsive model" of prototyping driven mostly by user pull toward more of an "emerging capabilities" model, which reflects a desire to return to more forward-leaning prototypes of the past. This approach would develop options for future threats and anticipated capability shortfalls; it would also consider increased needs to reduce sustainment costs. Some key management best practices offered by various participants included (1) willingness to identify new game-changing technologies; (2) a leadership champion; (3) ensuring that the right people are at all levels of the effort—"right people" meaning "those who are educated, trained, and have the mentored experience to do the work;" (4) use of the Air Force Institute of Technology to instill a prototyping culture; (5) collaboration among industry, government, and academia; (6) good social interaction in the contracting process; and (7) learning how to ask the "Otis question" (referring to a speaker's story that the Otis Elevator Company, looking to improve elevators, broke 110 years of tradition and assembled a diverse team that led to a flat and thin cable design, which enabled elimination of the large wheel room and increased usable space for building owners).[13]

[13]Jaiwon Shin, Associate Administrator for Aeronautics, Headquarters, National Aeronautics and Space Administration.

THEME 5. PROTOTYPING AS A VERSATILE TOOL

Several participants noted that prototyping is a tool and is best leveraged in all areas, at all levels, and in all phases of the enterprise.

Near the end of the workshop, and after many examples illustrating extensive use of prototyping, Gen Lyles emphasized that prototyping is a valuable tool and worth almost a mandate to require every program director across the board to consider.[14] In other words, directors should be told to either use it or state why they are not using it. Many participants agreed. But the Air Force representative was concerned that some in DoD believe prototyping should not occur until it is part of a program of record. Interestingly, Jim Shields, President and CEO, Charles Stark Draper Laboratory, made the point that "requirements-based acquisition is often too reactive to embrace prototyping," suggesting there is also opposition to prototyping in the program-of-record phase.

Opposing prototyping before or after a program of record is contrary to Mr. Wyatt's presentation, which clearly showed prototyping across the board and covering at least TRL 4 to TRLs 7 or 8 (technology readiness levels, a widely used gauge of nine levels of technological maturity starting at TRL 1, which applies to principles observed and reported in basic research).[15] The Air Force representative's issue was that, to transition technologies from S&T efforts into programs of record, normally a TRL of 6 is necessary. However, it is hard to fund prototypes in the S&T phase to get them to TRL 6; thus, it is difficult to move promising technologies beyond the S&T phase. More is said about this Air Force dilemma later, but it did bring to mind Mr. Whalen's earlier admonition to not let TRLs determine where you want to go; he believed that some old, successful programs would not have gone forward under the current TRL regimen. He urged "No TRL gate;" allow "high-risk/high-payoff" technologies to proceed; for risk, use "engineering 'bottoms up'/ margin analysis versus TRL."

THEME 6. PROTOTYPING AS A MEANS TO EMPOWER PEOPLE

A number of participants noted that people could be empowered to accomplish prototyping with knowledge, skills, resources, and incentives.

[14] At least one participant interpreted this suggestion to be quite broad, with prototyping accepted at all levels of the ecosystem, scientists and engineers empowered to use prototyping, and processes established to take advantage of prototyping outcomes.

[15] Definitions of all nine TRLs can be found in DoD's Technology Readiness Assessment Guidance, April 2011. For example, TRL 4 means component or breadboard validation in laboratory environment, TRL 6 means system/subsystem model or prototype demonstration in relevant environment, and TRL 7 means system prototype demonstration in operational environment.

Many participants pointed out that the many values of prototyping cannot be fully realized unless people are empowered. Best practices for empowering that arose during the workshop include those listed below. First of all, state-of-the-art facilities, laboratories as well as associated equipment, design tools, and modeling and simulation capabilities are required. Next, repeating from an earlier theme, would be encouraging collaboration across a broad spectrum of stakeholders, not only technical people but the contract specialists and other necessary administrative personnel; the infrastructures affiliated with various types of "centers" to facilitate such collaboration are vital.[16] Independent R&D and modernization resources should be invested wisely with the above needs in mind.

The right knowledge and skills are critical, especially those gleaned from lessons learned and skills transferred after past successes and failures; more than one speaker emphasized this point. For example, one speaker touted "leveraging a history of developing prototypes,"[17] and another speaker used the phrase "that looks about right (TLAR)" to indicate the type of knowledge and skill sets that are so important (TLAR means the judgment to estimate, based on experience, whether what is happening is approximately correct;[18] prototyping gives scientists and engineers that ability). The ability to say "TLAR" is further enabled when management allows—in fact, offers incentives for—people to use time and resources to increase their knowledge and skills (e.g., benefit from schools; training; cross-discipline assignments to form a mobile science, technology, engineering, and math workforce; mentoring). One participant mentioned prizes and "grand challenges" as possibilities.

THEME 7. FUNDS AND INCENTIVES FOR PROTOTYPING

Several participants noted that prototyping programs appear to work best when they include adequate funds. They also asserted that such actions could incentivize the DoD, industry, and academia to take risk and collaborate to meet the enterprise's strategy.

Gen Lyles was concerned that the Air Force no longer seems to be opening the aperture for program managers to realize the richness and value offered by prototyping tools, and he welcomed suggested ways to get the Air Force back to what it used to be with respect to prototyping. What funding it would take to do that was discussed in the context of possible approaches to permit the Air Force to

[16]A participant believed this approach would be particularly true for disruptive technologies that need disruptive methods of insertion.

[17]Daryl Pelc, Vice President for Engineering, Phantom Works, The Boeing Company.

[18]Brian Hershberger, Senior Aeronautical Engineer, Advanced Development Programs, Lockheed Martin Aeronautics.

do prototyping during the S&T advanced development phase. Several participants offered various opinions of how much funding would be needed to handle two or three prototypes, which could help the Air Force transition useful technologies into programs of record.

The immediate issue raised, of course, was where the funds would come from.[19] A couple of participants suggested that these dollars could come from finding efficiencies in the acquisition programs—some efficiencies could result because of the prototyping, which would make the prototyping costs well worthwhile. An alternative approach suggested by some participants for the Air Force would be to just cancel advanced development funding under the assumption there is no need for what the advanced developments are producing. The Air Force representative said these issues applied mostly to the aircraft side, however, because the space side does a pretty good job of transitioning technology.

There were many related comments by individual participants: (1) the Navy has ways of accommodating both technology push and requirements pull in its activities; (2) the Air Force problem may be one of labeling technology demonstrations as prototypes, conjuring up a big competition between companies to win a production contract; (3) if industry can see a funding line, then the Air Force and DoD may get back more because industry will put in its own funds; (4) the Air Force and DoD could rely on Congress to fund the really big ideas, but that requires a zealot to really push such things; (5) prototyping occurs at all levels and will continue regardless of what may occur at the top levels of the Air Force and DoD, so why not just stick with that model; and (6) the Air Force and DoD should examine some creative contracting processes with some sort of payback to invigorate industry's participation in a prototyping activity.

With respect to risk, a sub-theme that recurred during discussions at the workshop was that some prototyping is no longer done because failure has become unacceptable. At early levels in the technology maturation process, where expenses are relatively small, some participants acknowledged that failures are expected as part of the learning process. But when one considers big, expensive, possibly spectacular prototypes that could have high payoff, it is just too risky in today's budget-cutting environment to fail; thus, some high-payoff technologies will not get prototyped. Discussions like these led to many suggestions from various participants. For example, (1) failure should be expected during prototyping, particularly in the S&T phases; (2) prototypes must be allowed to fail without repercussions; (3) tolerance for technical risk is needed, although there is significant difference between pre-acquisition technical failures that can be beneficial and technical failures during acquisition, which should not occur; (4) failing early should be recognized as an

[19] Also, see current lack of systems advanced development (6.3B) funding, which is addressed under Theme 8.

affordable path to later success;[20] and (5) capturing and documenting both failures and successes , in a collaborative way across many S&T entities, is key.

How to incentivize the S&T community at large to take risks and not fear failure was another matter. For example, one participant believed that Congressional flexibility will be required to better enable innovative prototyping by the military laboratories, which should have the ability to fail. Stated another way, S&T prototyping of the kind described during this workshop could lead Congress to accept failures more readily than in a program of record.

Finally, with respect to incentivizing collaboration, which many participants praised during the workshop, a participant suggested that one possible approach could be a program, perhaps led by DR&E and using appropriate funding mechanisms, to compete non-profit institutions to establish prototyping teams (with representation from government, industry, and academia). These teams would address difficult defense technical areas, such as hypersonics or electronic warfare. Winning teams, incentivized by prizes, would conduct prototyping activities to address challenges and develop products for use by the Defense Advanced Research Projects Agency and the military services.

THEME 8. A TECHNOLOGY DEVELOPMENT STRATEGY

Some participants suggested that the Air Force and the DoD could benefit from a technology development strategy that balances technology push and requirements pull to support the grand strategy.

Theme 4 identified Mr. Wyatt's proposed strategy, which is to shift to the new model called emerging capabilities prototyping—thereby achieving better balance between technology push and requirements pull by engaging prototypes across the TRL spectrum. Funding suggestions for adding dollars to the Air Force advanced technology line were discussed under Theme 7 as a way to increase the ability to transition promising technologies into programs of record.

A workshop participant volunteered an approach with some elements similar to DoD's plan. His strategy would have prototypes, where appropriate, all along the S&T and acquisition line. Specifically, a prototype related to definition of needs; another related to refinement of needs and requirements; another—this time a competitive prototype—at the beginning of acquisition; a pre-production prototype; and, although not explicit, maybe even more—perhaps to examine sustainment issues in depth or improvements to operational or yet-to-be-produced systems. The overall goal would be to enable the application of prototyping to a diverse range of opportunities that would benefit from prototyping. In summary, the design, imple-

[20] To add quantification, a participant noted that when approximately 10 percent of a program's budget is spent, almost all of the engineering decisions have been made.

mentation, practices, and funding would take account of the many prototyping values and best practices discussed during this workshop, with emphasis on diverse and agile application of this tool. For implementation, a government-sponsored, open, virtual, scalable, and adaptable environment was suggested, with utilization of government data bases and collaboration space for government, industry, other laboratories, and academia. Flexible contracting mechanisms would be among necessary policy changes.

The prior discussion can next be elevated to the "Grand Strategy" level, elements of which were in Mr. Wyatt's presentation. He noted that Frank Kendall, the Undersecretary of Defense for Acquisition, Technology, and Logistics, said the following:

> I expect that the Department will be stretched significantly as we attempt to retain the force structure needed to execute our national security strategy while simultaneously maintaining readiness, sustaining infrastructure, recapitalizing or modernizing aging equipment, introducing innovative technologies, preserving our industrial base, and ensuring the continuing technological superiority that our forces have every right to expect.[21]

Mr. Wyatt's presentation ended with the statement "Prototyping offers the potential to assist the Department in addressing those expectations . . ." Figure 2-2 depicts the essence of the new operating model for prototyping and shows the direct linkage between the new approach and DoD's overarching guidance.

On the last day of the workshop, Richard Van Atta, Institute for Defense Analyses, closed his talk with the phrase "prototyping must be seen in the context of an overall innovation strategy." DoD's top-level strategy document (Sustaining U.S. Global Leadership: Priorities for 21st Century Defense, January 2012) lays out several key principles for the Joint Force of 2020. The final principle, which encourages and provides a framework for innovation as well as a culture of change, appears below.

> Finally, in adjusting our strategy and attendant force size, the Department will make every effort to maintain an adequate industrial base and our investment in science and technology. We will also encourage innovation in concepts of operation. Over the past ten years, the United States and its coalition allies and partners have learned hard lessons and applied new operational approaches in the counter terrorism, counterinsurgency, and security force assistance arenas, most often operating in uncontested sea and air environments. Accordingly, similar work needs to be done to ensure the United States, its allies, and partners are capable of operating in A2/AD, cyber, and other contested operating environments. To that end, the Department will both encourage a culture of change and be prudent with its "seed corn," balancing reductions necessitated by resource pressures with the imperative to sustain key streams of innovation that may provide significant long-term payoffs.

[21] Frank Kendall, USD(AT&L), Defense AT&L Magazine, Jan-Feb 2013.

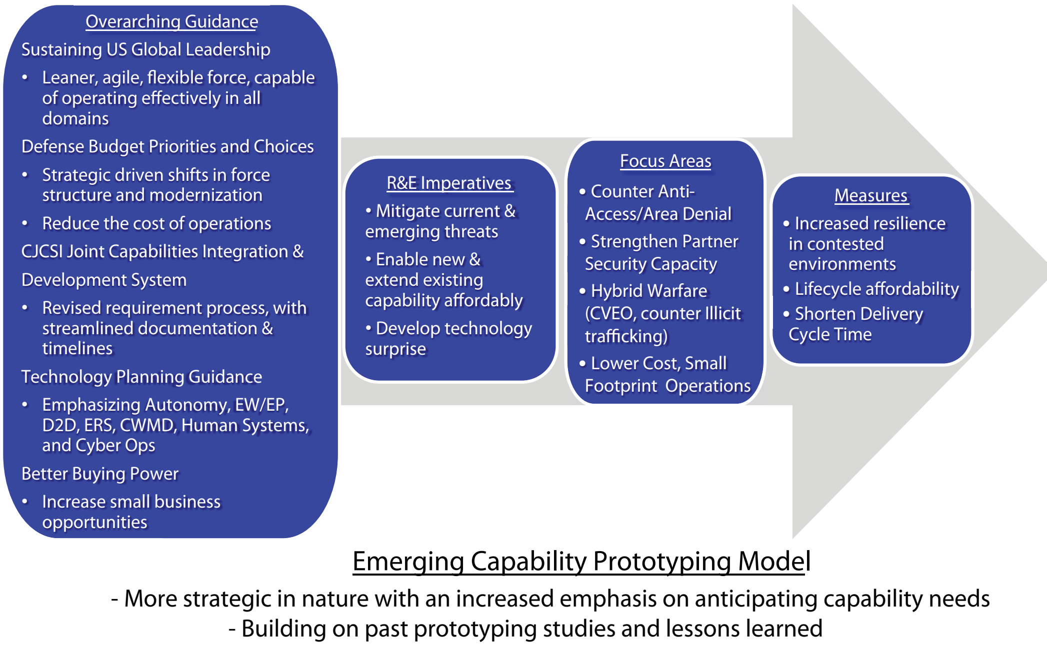

FIGURE 2-2 A new operating model for prototyping in the Department of Defense. SOURCE: Earl Wyatt, Deputy Assistant Secretary of Defense for Rapid Fielding, “OSD Perspective,” presentation to the workshop on September 24, 2013. NOTE: CJCSI, Chairman of the Joint Chiefs of Staff Instruction; CWMD; counter weapons of mass destruction; D2D, data to decisions; ERS, engineered resilient systems; EW/EP, electronic warfare/electronic protection.

The themes of this workshop, which reflect the views of many participants, acknowledge prototyping as a powerful tool for the Air Force and DoD to use in complying with the above principle.

Another element of grand strategy came from Patricia Falcone, Associate Director, Office of Science and Technology Policy. Her presentation referred to an action plan for the national security S&T enterprise. The plan, which offers a strategy for American innovation, involves people and the workforce, facilities and infrastructure, and roles and responsibilities.[22,23] The DoD is a part of this plan in several contexts, such as developing breakthroughs in space capabilities and applications; innovation clusters for robotics, energy, light-weight materials,

[22]See http://www.whitehouse.gov/sites/default/files/uploads/InnovationStrategy.pdf.

[23]A participant offered the following additional thoughts: “prototyping is broadly important for STEM (science, technology, engineering, and mathematics), and we cannot have a healthy democracy if citizens are not able to make S&T decisions.”

and cyber-security; and advanced learning technologies. She ended with a call for enhanced prototyping competency in the DoD. The first challenge was to expand the definition of prototyping to include software, integration, and other "soft power" elements. The other challenge to DoD was "Resources must be identified."

Dr. Falcone's final statement about resources was accompanied by the factual comment that, "Until 1998, the DoD budget included '6.3B' for systems advanced development that supported rapid prototyping programs; this no longer exists."[24,25] Dr. Falcone's factual comment and related discussions during the workshop suggested to many participants that returning to the past, a funded program element in S&T for prototyping, offers a way to enhance Air Force and DoD prototyping for the new defense strategy.

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[24]Air Force advanced development formerly contained two program elements known as 6.3A and 6.3B, the latter for technology demonstration and validation. Now there is just one program element, 6.3, advanced technology development. In this regard, and reflecting key elements of this workshop, the following recommendations on prototyping were in the Packard Commission's report: "A high priority should be given to building and testing prototype systems and subsystems before proceeding with full-scale development. This early phase of R&D should employ extensive informal competition and use streamlined procurement processes. It should demonstrate that the new technology under test can substantially improve military capability, and should as well provide a basis for making realistic cost estimates prior to a full-scale development decision. This increased emphasis on prototyping should allow us to 'fly and know how much it will cost before we buy.' The proper use of operational testing is critical to improving the operations performance of new weapons. *We recommend that operational testing begin early in advanced development and continue through full-scale development, using prototype hardware. . . .*" See President's Blue Ribbon Commission on Defense Management, June 30, 1986. pp. XXV-XXVI.

[25]Funds for prototyping and the Air Force's inability to transition promising technologies were addressed under Theme 7.

Appendixes

A

Biographical Sketches of Committee Members

Lester L. Lyles (NAE) is an independent consultant. He retired as Commander of the Air Force Materiel Command, Wright-Patterson Air Force Base, Ohio. General Lyles entered the Air Force in 1968 as a distinguished graduate of the Air Force ROTC program. He has served in various command assignments, including director of the Medium-Launch Vehicles Program and Space-Launch Systems offices; Vice Commander of Ogden Air Logistics Center, Hill AFB, Utah. He served as Commander of the center until 1994, then was assigned to command the Space and Missile Systems Center at Los Angeles AFB, California, until 1996. General Lyles became the director of the Ballistic Missile Defense Organization in 1996. In May 1999, he was assigned as Vice Chief of Staff at USAF/HQ and Commander of the Air Force Materiel Command in 2000. General Lyles received a B.S. in mechanical engineering from Howard University and an M.S. in mechanical/nuclear engineering from New Mexico State University. He has received honorary doctors of law from New Mexico State University and Urbana University. He is chair of the National Research Council's (NRC's) Aeronautics and Space Engineering Board and a member of the Air Force Studies Board. He also serves as a member of the Secretary of State's International Security Advisory Board and previously served on the President's Intelligence Advisory Board in the White House.

Claude M. Bolton, Jr., is the executive-in-residence for the Defense Acquisition University (DAU) since January 2008. Mr. Bolton's primary focus is assisting the DAU president achieve the Congressional direction to recruit, retain, train and educate the DoD acquisition workforce. Mr. Bolton is also a management consultant to defense and commercial companies and is a board member for several companies. Prior to becoming the DAU executive-in-residence, Mr. Bolton served as the assistant secretary of the Army for Acquisition, Logistics and Technology (ASAALT). As the ASA (ALT), Mr. Bolton served as the Army Acquisition Executive, the Senior Procurement Executive, and the Science Advisor to the Secretary. Mr. Bolton oversaw the Elimination of Chemical Weapons Program, and had oversight and executive authority over the Project and Contracting Office charged with Iraq reconstruction. He was responsible for appointing, managing, and evaluating program executive officers as well as managing the Army Acquisition Corps and Army Acquisition Workforce. Mr. Bolton retired as a Major General in the U.S. Air Force following a highly decorated career. Some highlights of his Air Force service include serving as the Commander, Air Force Security Assistance Center, where he managed foreign military sales programs with totals exceeding $90 billion that supported more than 80 foreign countries; serving as a test pilot for the F-4, F-111, and F-16; program executive officer for the Air Force Fighter and Bomber programs; and the first program manager for the Advance Tactical Fighter Technologies program, which evolved into the F-22 System Program Office. His is an experienced command pilot, flying more than 40 different aircraft, including Army helicopters. During the Vietnam War, he flew 232 combat missions, 40 over North Vietnam. Mr. Bolton served as commandant of the Defense Systems Management College and as Inspector General and director of requirements at Air Force Materiel Command headquarters. Mr. Bolton holds an M.S. in management from Troy State University and an M.A. in national security and strategic studies from the Naval War College. In 2006, he was awarded a D.Sc. (honoris causa) from Cranfield University. In 2007, he was awarded an honorary doctor of science degree from the University of Nebraska, Lincoln, his alma mater. Mr. Bolton is a member of the NRC's Air Force Studies Board.

Keith A. Coleman is a program manager in the Boeing Special Pursuits Cell within Boeing Phantom Works. This organization has a charter to design, build, and test prototype ground and airborne systems specific to special application customers with 1 year. He is currently managing a Boeing-developed Tier 2 Class Unmanned Air Vehicle (UAV) design, build, and fly effort within a very aggressive 10-month time span. Mr. Coleman has worked in the Phantom Works advanced design organization for over 25 years working prototype fighter aircraft and weapons. Mr. Coleman's last assignment was in the Advanced Weapons division working as the Program Manager for the successful Counter Electronics High Powered Microwave Advanced Missile Project (CHAMP) JCTD resulting in the world's first successful air launched HPM cruise missile in Oct 2012. Before the CHAMP program, Mr. Coleman led DTRA's UAV based Beyond Line-Of-Site Biological Combat Assessment System (BCAS) prototype Advanced Technology Demonstration. This shipboard system successfully intercepted a biological cloud (using harmless soil bacteria as a simulant), captured it autonomously and returned it for analysis. Keith has led and worked on numerous other aircraft and missile proprietary design efforts. Mr. Coleman's other prototype efforts were, in chronological order from the latest: the Boeing X-45A DARPA/Air Force Unmanned Combat Air Vehicle (UCAV); the Boeing X-32 Joint Strike Fighter (JSF); numerous Proprietary efforts, and the Northrop/McDonnell Douglas YF-23A Advanced Tactical Fighter. Mr. Coleman has worked in configuration design, prototype build and test, and management for over 28 years and is well versed in advanced composite, 3D printing, and prototype design and build practices. Mr. Coleman holds an MS in engineering from the University of Missouri at Rolla.

Jill P. Dahlburg is superintendent of the Space Science Division (SSD) at the Naval Research Laboratory (NRL) and a member of the Department of the Navy (DON) Senior Executive Service since December 2007. In this position she serves as S&T expert on a broad-spectrum RDT&E program in solar-terrestrial physics, astrophysics, upper/middle atmospheric science, and astronomy. She leads conception, planning and execution of scientific research and development programs on instruments to be flown on satellites, sounding rockets and balloons, ground-based facilities and mathematical models, to study the atmospheres of the Sun and Earth, solar activity and its effects on the Earth's atmosphere, and physics and properties of celestial sources, and transitions capabilities to operational use. She is fully accountable for the overall financial, personnel, programmatic and facilities management of the SSD, including obtaining funding to support program execution within the Navy Working Capital Fund, and implementing plans for major scientific facilities to meet DON/DoD extended operational environment predictive needs. Dr. Dahlburg served as NRL Senior Scientist for Science Applications from June 2003 to December 2007, with duties that included: reviewing the NRL S&T program directions; evaluating NRL and NRL-relevant S&T for application to DoD mission needs; and facilitating/expediting the accomplishments of the scientific missions of organizations within NRL, with emphasis on interdisciplinary areas of opportunity and distributed autonomous systems. In 2000, Dr. Dahlburg served as head of the NRL Tactical Electronic Warfare Division Distributed Sensor Technology Office, where she co-proposed and was co-principal investigator for the first year of development of the small, expendable unmanned aerial vehicle Dragon Eye that saw active duty in Iraq. Her honors include six NRL Allan Berman Awards for scientific publication excellence, and a DOE Appreciation Award presented by DOE Under Secretary for Science Raymond L. Orbach for outstanding service as the Chair of the DOE ASCAC. Dr. Dahlburg is a Fellow of the APS and holds a Ph.D. in theoretical physics from the College of William and Mary.

Lawrence J. Delaney is an independent consultant. He retired as the executive vice president of operations, and president of the Advanced Systems Development Sector of Titan Corporation. Previously, he has held distinguished positions with Arete Associates, Inc.; Delaney Group, Inc.; BDM Europe; and the Environmental and Management Systems Group at IABG. He was also the acting secretary of the Air Force and served as the assistant secretary of the Air Force for acquisition, as well as the Air Force's service acquisition executive, responsible for all Air Force research, development and acquisition activities. He provided direction, guidance and supervision of all matters pertaining to the formulation, review, approval and execution of acquisition plans, policies and programs. Dr. Delaney has more than 41 years of international experience in high technology program acquisition, management and engineering, focusing on space and missile systems, information systems, propulsion systems and environmental technology. He served as chair of the NRC's Air Force Studies Board; co-chair of the Committee on the Air Force Intelligence, Surveillance, and Reconnaissance Capability Planning and Analysis Process; and as a member of the Board on Army Science and Technology. He also chaired the Army Science Board. Dr. Delaney holds a Ph.D. in chemical engineering from the University of Pennsylvania.

Brian K. Hershberger is a senior aeronautical engineer within Advanced Systems Development for Lockheed Martin's Advanced Development Projects (ADP) Skunk Works operation. He currently serves as the Mission Systems Lead for the Navy's UCLASS (Unmanned Carrier Launched Airborne Surveillance and Strike) System. He is a 1995 graduate of Wichita State University with a bachelor's degree in aerospace engineering and a 2001 graduate of California Polytechnic, Pomona, with a master's degree in aerospace engineering. Mr. Hershberger began his career in aerospace as a flight test engineer with Learjet while studying for his bachelor's degree. During this time he obtained his multi-engine, commercial pilot ratings. After graduation, he began his defense career by joining Lockheed Martin's Skunk Works in 1995. Within the Skunk Works, Mr. Hershberger has been a member of the configuration development team on multiple unmanned flight test and operational programs. These include JASSM, both the PDRR and EMD variants, the Polecat high altitude UAS and multiple classified programs. His responsibilities included aircraft conceptual design, multi-disciplinary integration and prototype development. Mr. Hershberger's aeronautical experience bridges from operations analysis-based requirements derivation through system flight test, specializing in multi-disciplinary design and integration. This engineering breadth is complimented by leadership roles as configuration lead, chief engineer, program manager and proposal capture team lead. Mr. Hershberger has been awarded 3 patents resulting from his multiple configuration development efforts. He is an instructor for the Lockheed Martin Technical Institute for Aircraft Configuration Development, Structural Design and Systems Design, and developed and instructed an Advanced Lofting Skills Course. Mr. Hershberger is an active pilot with over 600 hours who flies a 1972 CITABRIA 7KCAB. He maintains his Certified Flight Instructor certificate and has Instrument, Commercial and Multi-Engine ratings.

William L. Melvin is director of the Sensors and Electromagnetic Applications Laboratory at the Georgia Tech Research Institute, a University System of Georgia (USG) regents' researcher, and an adjunct professor in Georgia Tech's Electrical and Computer Engineering Department. His research interests include all aspects of RF and acoustic sensor development. He has authored over 180 publications in his areas of research interest and holds three US patents on sensor technology. Among his distinctions, Dr. Melvin is the recipient of the 2006 IEEE AESS Young Engineer of the Year Award, the 2003 US Air Force Research Laboratory Reservist of the Year Award, and the 2002 US Air Force Materiel Command Engineering and Technical Management Reservist of the Year Award. He was chosen as an IEEE Fellow for his contributions to adaptive radar technology, and is also a Fellow of the Military Sensing Symposium. Also, he is a member of the Board on Army Science and Technology through the National Academies. Dr. Melvin received the Ph.D. in electrical engineering from Lehigh University.

Paul D. Nielsen (NAE) is director and chief executive officer of the Software Engineering Institute (SEI), a federally funded research and development center operated by Carnegie Mellon University. The SEI advances software engineering and cyber security principles and practices through focused research and development, which is transitioned to the broad software engineering community. Prior to his arrival as SEI director, Dr. Nielsen served in the U.S. Air Force, retiring as a major general after 32 years of distinguished service. As commander of the Air Force Research Laboratory at Wright-Patterson Air Force Base for more than four years, he managed the Air Force's science and technology budget of more than $3 billion annually. He also served as the Air Force's technology executive officer, determining the investment strategy for the full spectrum of Air Force science and technology activities. Dr. Nielsen is a member of the National Academy of Engineering; a fellow of the American Institute of Aeronautics and Astronautics; and a fellow of the Institute of Electrical and Electronic Engineers. Dr. Nielsen received a Ph.D. in applied science from the University of California at Davis.

B

Terms of Reference

An ad hoc committee will plan and convene one 3-day public workshop, which will bring together national and international experts, to examine a wide range of prototyping issues in government, industry and academia and provide individual recommendations for a renewed prototype program. Specific program elements that will be addressed during the workshop include: (1) program goals; (2) program design, implementation, practices, and funding levels; and (3) changes to existing policy, as necessary, to ensure the program's effectiveness and efficiency. Special attention will be given to the appropriate application of prototyping as a tool for technology/system development and sustainment, including recommended annual funding. The workshop will examine the positive and negative effects of a renewed Air Force prototype program on the government and industry workforce.

The committee will develop the agenda for the workshop, select and invite speakers and discussants, and moderate the discussions.

In organizing the workshop, the committee might also consider additional topics close to and in line with those mentioned above. The workshop will use a mix of individual presentations, panels, breakout discussions, and question-and-answer sessions to develop an understanding of the relevant issues. Key stakeholders would be identified and invited to participate. One individually-authored Workshop Summary document will be prepared by a designated rapporteur.

C

Workshop Agenda

SEPTEMBER 24-26, 2013
NATIONAL ACADEMY OF SCIENCES BUILDING
WASHINGTON, D.C.

Questions for Speakers

1. What is prototyping? In what areas/phases is prototyping best applied (innovation, maturation, risk reduction, workforce, others or all)?
2. Why is prototyping important? Has its importance and value changed over time? Will its importance and value increase or decrease in the future and why?
3. What characteristics are important to an effective an efficient prototyping program (resources applied, processes used, stability, others or all)? What partnerships or programs might you recommend to the government to adopt for an effective and efficient prototyping program, based on best practices in academia, industry or other parts of the government?

September 24, 2013

0730 **Welcome and Introductions** *with Breakfast Available*

0830 **Vision for the Workshop**
Gen Lester Lyles (USAF, Ret.), Workshop Committee Chair

0930 **Congressional Perspectives**
Robie Samanta Roy, Professional Staff Member, SASC

1030 Break

1045 **White House Perspectives**
Patricia Falcone, Associate Director, National Security and International Affairs, Office of Science and Technology Policy
Reed Skaggs, Assistant Director, Defense Programs, National Security and International Affairs, Office of Science and Technology Policy

1145 **Continue Discussions** *with Lunch Available*

1215 **OSD Perspectives**
Earl Wyatt (SES), Deputy Assistant Secretary of Defense for Rapid Fielding

1315 **NASA Perspectives**
Jaiwon Shin, Associate Administrator for Aeronautics Research Mission Directorate, NASA HQ

1415 Break

1430 **Charles Stark Draper Laboratory Perspectives**
Jim Shields, President

1530 **General Dynamics Perspectives**
Sonya Sepahban, Senior Vice President for Land Systems

1630 **Workshop Feedback to Day 1 Presentations**
All

1700 Adjourn

September 25, 2013

0730 **Welcome and Introductions** *with Breakfast Available*
Gen Lester Lyles (USAF, Ret.), Workshop Committee Chair

0800 **Workshop Feedback to Day 1 Presentations (continued)**
All

0900 **Lockheed Martin Perspectives**
Brian Hershberger, Senior Aeronautical Engineer, Advanced Development Programs

1000 Break

1015 **Boeing Perspectives**
Daryl Pelc, Vice President for Engineering, Phantom Works

1115 **Emeritus Perspectives**
Robert Whalen, International Systems, LLC

1215 **Continue Discussions** *with Lunch Available*

1300 **MIT Lincoln Laboratory Perspectives**
Eric Evans, Director

1400 Break

1415 **Workshop Feedback to Day 2 Presentations**
All

1700 Adjourn

September 26, 2013

0730 **Welcome and Introductions** *with Breakfast Available*
Gen Lester Lyles (USAF, Ret.), Workshop Committee Chair

0830 **National Defense University Perspectives**
Linton Wells, Director, Center for Technology and National Security Policy

0930 **Georgia Tech Research Institute Perspectives**
William Melvin, Director of Research, Sensors and Electromagnetic Applications Laboratory

1030 Break

1045 **Institute for Defense Analyses Perspectives**
Richard Van Atta

1145 **Continue Discussions** *with Lunch Available*

1245 **General Discussion with Participants to Include Next Steps**
Gen Lester Lyles (USAF, Ret.), Workshop Committee Chair
Earl Wyatt (SES), Deputy Assistant Secretary of Defense for Rapid Fielding
David Walker (SES), Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering

1500 Adjourn

D

Workshop Participants

WORKSHOP PLANNING COMMITTEE

Lester L. Lyles, *Chair*
Claude M. Bolton, Jr.
Keith A. Coleman
Jill P. Dahlburg
Lawrence J. Delaney
Brian K. Hershberger
William Melvin
Paul D. Nielsen

NATIONAL RESEARCH COUNCIL STAFF

Terry J. Jaggers, AFSB Director
Carter W. Ford, Program Officer
Norman M. Haller, Rapporteur
Dionna Ali, Research Assistant

SPEAKERS

Eric Evans, Director, Massachusetts Institute of Technology, Lincoln Laboratory
Patricia Falcone, Associate Director, National Security and International Affairs, Office of Science and Technology Policy

Brian Hershberger, Senior Aeronautical Engineer, Advanced Development Programs, Lockheed Aeronautics Company
William Melvin, Director of Research, Sensors and Electromagnetic Applications Laboratory, Georgia Tech Research Institute
Daryl Pelc, Vice President for Engineering, Phantom Works, The Boeing Company
Robie Samanta Roy, Professional Staff Member, Senate Armed Services Committee
Sonya Sepahban, Senior Vice President, Engineering, Development & Technology, General Dynamics Land Systems
Jim Shields, President and CEO, Charles Stark Draper Laboratory
Jaiwon Shin, Associate Administrator for Aeronautics Research Mission Directorate, NASA HQ
Richard Van Atta, Institute for Defense Analyses
Linton Wells, Director, Center for Technology and National Security Policy, National Defense University
Robert Whalen, President, International Systems, LLC
Earl C. Wyatt, Deputy Assistant Secretary of Defense for Rapid Fielding, Office of the Secretary of Defense

GUESTS

Paul Decker, Deputy Chief Scientist, DoD
Maj Michael Dunlavy, Materials and Manufacturing Program Element Monitor, U.S. Air Force (SAF/AQR)
CAPT Richard Hencke, Military Assistant to Deputy Assistant Secretary of Defense for Rapid Fielding, Office of the Secretary of Defense
Col Ralph Sandfry, Military Deputy, Office of the Deputy Assistant Secretary of the Air Force for Science, Technology and Engineering
Reed Skaggs, Assistant Director, Defense Programs, National Security and International Affairs, Office of Science and Technology Policy
David E. Walker, Deputy Assistant Secretary of the Air Force for Science, Technology and Engineering, U.S. Air Force

E

Speaker Abstracts

SCIENCE, TECHNOLOGY, AND INNOVATION FOR AMERICA'S NATIONAL SECURITY: ENHANCING PROTOTYPING COMPETENCY IN THE DEPARTMENT OF DEFENSE

Patricia Falcone, Associate Director, Office of Science and Technology Policy

A set of policy actions are being developed to enable a more cost-effective and agile national security science and technology enterprise. This enterprise includes universities, private research institutions, small and large businesses, and federal laboratories. Actions are needed to enable our nation to meet rapidly evolving threats, employ swiftly changing technologies, cope with diminishing resources, and benefit from accelerating globalization. The success of the United States' defense, intelligence, and national- and homeland-security missions has long been enabled by a range of capabilities in space, sensors, energetics, new materials, and other key domains. Investments in national security science and technology have contributed to civilian advancements in the Internet, global positioning systems, jet engine technologies, weather forecasting, voice recognition, and translation software, as well as more recently to wideband networks, solid state radar, and advanced robotics. The Office of Science and Technology Policy (OSTP) and partner agencies are prioritizing actions that improve recruitment and retention of the best and brightest scientists and engineers to work on hard national-security problems; increase investment in modern labs and facilities; and streamline rules and regulations that stifle innovation and performance.

OSTP seeks to develop a specific pilot action for enhancing prototyping competency in the DOD. Creating a prototyping competency, at this difficult time to attract and connect innovators from among the primary performers of U.S. national security science and technology as well as from non-traditional disciplines will: stimulate innovation; reduce technical risk in acquisition programs; decrease product delivery time; support technology maturation; and with rotational assignments, enhance the workforce with a flow of people and ideas.

DRAPER LABORATORY PERSPECTIVES ON PROTOTYPING

James Shields, President and Chief Executive Officer
The Charles Stark Draper Laboratory

This presentation discussed the role of not-for-profit R&D laboratories in prototyping. Specifically, it identified five different objectives for prototyping, namely: reducing risks in the early stages of development programs, demonstrating technology to create alternative development program options, raising technology readiness levels to put capability on the shelf for rapid adoption when future needs demand it, transferring technology from the not-for-profit laboratory to industry to ensure that it is widely adopted and creating new capabilities that explore concepts of operations for how technology may be used effectively. Each role for prototyping was illustrated with specific projects at Draper Laboratory. Finally, the presentation presented some observations related to improving the DoD and the Air Force's approaches to prototyping. The key observations were that prototyping should be a strategy rather than a program and that the current focus on requirements-based acquisition is often too reactive to embrace the benefits of prototyping. It also was observed that the ending of the urgency of war and the impact of diminished budgets should create an environment that can be exploited to effect changes that can increase the role of prototyping. A specific recommendation was to set an expectation that prototyping strategies be created for all key capability areas and that, even in a declining budget environment, the percentage of funds allocated to advanced development projects be increased as a hedge against breakout threats, with the focus of these resources being directed for prototyping efforts.

PROTOTYPING FOR THE NEW DEFENSE STRATEGY

Sonya Sepahban, Senior Vice President, Engineering and Technology
General Dynamics Land Systems (GDLS)

Prototyping has been used throughout history to reduce uncertainty. Given the New Defense Strategy of a smaller more agile force, and the hybrid threat environment that requires agility to maintain asymmetric advantage, the value of prototyping is increasing. Other key factors, such as requirements stability and technology maturity, however, may outweigh benefits of prototyping. Since early program decisions drive majority of costs, prototyping can be more important in these phases. Specifically, key technologies should be matured and requirements need to be stabilized in an agreed upon operational context prior to the Materiel Development Decision (MDD). In the Systems Acquisition Phase, key System architecture decisions, cost estimates, and programs risk management will benefit from prototyping. A comprehensive study is recommended to develop lessons learned regarding recent prototyping programs. Examples of GDLS success with prototyping, and the institutional capability GDLS has recently developed for *"Collaborative Prototyping on Demand"* point to three key success factors: Focus on challenges driven by priorities and program phase, broad collaboration, and agility.

PROTOTYPING: LOCKHEED MARTIN PERSPECTIVES

Brian Hershberger, Senior Aeronautical Engineer
Advanced Development Programs

As a single word, prototyping conveys multiple different meanings. Production contract competition (YF-22, YF-23), technology exploration demonstrators (X-1, X-15) and rapid fielding (Gnat750/MQ-1, Tier II+/MQ-4) are all forms of prototypes. Independent of naming, successful prototypes exhibit common key elements: a clear understanding of the problem, a minimum number of clear objectives and an acceptance of risk combined with a tolerance for failure. The Air Force has a distinguished history of successful flight demonstrator projects capturing these elements and expanding the boundary of the known. Future prototypes will likely depart from an aircraft centric approach into adjacent domains addressing a range of challenges. The targeted application of prototypes, in their appropriate form, within a relevant environment is a necessary tool for innovation and the development of affordable solutions meeting DoD capability needs.

PROTOTYPING: A BOEING PERSPECTIVE

Daryl Pelc, Vice President for Engineering, Phantom Works

In an environment of tight budgets that drive difficult funding decisions, prototyping offers customers the opportunity to see technologies tested before committing to new programs. Boeing boasts a long history of developing prototypes, and continues that legacy today with such current products as Phantom Eye, Phantom Badger, Phantom Fusion and more. By engaging with our customers to identify needs, innovating ways to address those needs, and building prototypes to prove proposed solutions, Boeing is successfully demonstrating solutions to a host of challenges faced by today's warfighter. Despite the difficult environment the defense faces, Boeing has held steady its research & development funding to ensure continued responsiveness to and collaboration with customers.

40 YEARS OF DEVELOPMENT TO PRODUCTION PROGRAM(S) OBSERVATIONS

Robert Whalen, President and Chief Executive Officer
International Systems, LLC

Prototyping questions are addressed by examining the history, lessons learned, and recommendations of 40 years of the speaker's development-to-production experience. The 8 programs discussed—i.e, space launch vehicles, tactical missiles, helicopter and fixed wing target acquisition systems, ship vertical launch system, nuclear missile, and high speed ship—are diverse as to size, technology, contracting type, policies, and procedures. Lessons learned and recommendations are made based on this experience. Finally, a "prototyping program" is recommended.

MIT LINCOLN LABORATORY OVERVIEW AND TECHNOLOGY DIRECTIONS

Eric D. Evans, Director, MIT Lincoln Laboratory

MIT Lincoln Lincoln Laboratory is a Federally Funded Research and Development Center (FFRDC), developing new technology in support of national security. The core areas of research include advanced sensors, information extraction (signal processing and embedded computing), and communications. Laboratory programs focus on high-risk, high-payoff technology and prototypes which, if successful, transition to industry for production. Nearly all of the Lincoln Laboratory facilities are located in Lexington, Massachusetts. This talk will describe some of Lincoln

Laboratory's current research, development and prototyping programs. Technology challenges for some future defense systems will be highlighted.

PERSPECTIVES ON PROTOTYPING

William L. Melvin, Director
Sensors and Electromagnetics Applications Laboratory
Georgia Tech Research Institute
Regent's Researcher, University System of Georgia

Prototyping is a critical element of technology development, application, and fielding. There are three common prototype classes of interest to the US Air Force: conceptual; developmental; and, operational. The conceptual prototype is used to validate an idea and collect experimental data in support of further development. Developmental prototypes provide a mechanism to mature the technology readiness level (TRL) of systems or subsystems. An operational prototype is a deployed system under scrutiny for sustained mission suitability. From the perspective of a not-for-profit, university-affiliated research institute, prototyping is both a tool and a strategy. As a tool, prototyping provides a means to validate ideas and collect essential data; to refine a system or subsystem concept; or, to put into service a unique, one-of-a-kind system. As a strategy, prototyping is used to further customer objectives, oftentimes supporting the creation of a program of record; to save time and money; to reduce system risk; to build technical credibility; to create a culture of excellence in applied R&D; to generate new research opportunities based on observations, lessons, and a firm grasp on the problem at hand; and, to recruit like-minded researchers and engineers.

This presentation reviews several prototyping examples at the Georgia Tech Research Institute (GTRI), including the design and development of a real-time radar signal processing system leading to new capabilities in air-to-ground surveillance (conceptual, developmental, and operational prototypes); the design, fabrication, and testing of a low probability of intercept MASINT radar (conceptual, developmental, and operational prototypes); the enhancement of a commercially-available radar system modified to meet specific performance objectives (operational prototype); the design and development of a specialized weapons location radar in support of a program new start (developmental prototype); and, the development of a cognitively controlled digital RF memory jammer tied to an advanced electronic support capability and cognitive decision support (conceptual prototype). Some perspectives on prototyping best practices are given: strong top-down design work is critical; building and validating modeling and simulation capability is essential; being rigorous and benchmarking performance supports "high/low" trades; scrutinizing design choices with respect to potential requirements creep can lead to a more robust design; the use of open, modular designs from the onset is necessary; working closely with Government and industry partners maximizes transition probability; leveraging COTS hardware wherever possible keeps cost down; and, being smart about software reduces development timeline.

PERSPECTIVES ON PROTOTYPING: THE ROLE OF PROTOTYPING IN FOSTERING INNOVATION

Richard Van Atta, Institute for Defense Analyses

My perspective on prototyping aims to provide a broader perspective to view the prototyping issue—that of innovation within and for DOD. I focus on some clear examples of what prototyping did in different circumstances—i.e., Stealth: Have Blue and the F-117A; Assault Breaker and Stand-off precision strike; and UAVs, such as Predator and Global Hawk. I note that these were highly exceptional and focused on breakthrough concepts. However I think they illustrate what might be considered the "good, bad, and ugly" of prototyping, recognizing that there is a range of other possible prototyping uses that this perspective may address. I place this in a broader "innovation strategy" context raising some issues regarding risk and cycle time and prospect of a more "adaptive" innovation system that uses a combination of approaches including modeling & simulation and iterative prototypes as part of way of doing real Analyses of Alternatives. My message is that just doing prototypes is not enough. The question is how to conceive and implement an innovation strategy aimed at responsiveness, adaptability and flexibility and what is the role of different types of prototyping in this? In this context prototyping is not the same as being able to start serial production of a prototype that gets products out the door. The rate at which we are building things of consequence today suggests that actually manufacturing a product may be as perishable a skill as the design/development piece. My basic entreaty is not to treat prototyping in isolation or as a "cure-all". Prototyping must be seen in the context of an overall innovation strategy that links concept and technology development to assessment of alternatives to effective implementation through production. In today's world, that's a big challenge.