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Sustaining a Competitive Advantage for the Nation's Defense:

Education, Technology, Acquisition, and the Defense Industrial Base

BY

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NORTHROP GRUMMAN

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Preface

BY

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In a then top-secret 1953 memorandum to the Chairman of the Joint Chiefs of Staff, President Dwight Eisenhower wrote:

> *"Permeating all of our hard problems in security, including force levels and budget allocations, is the question of the mobilization base. The base must at once be economical enough to be bearable in the long pull—the lean years and the boom years—but at the same time, it must be quickly and fully responsive to the complicated and ever-changing requirements of modern war."*

President Eisenhower oversaw the nexus of two ages in national security: the Pre-World War II age when the fates of nations at war were determined by the weight of their heavy industries, and the subsequent age – and our current age – wherein national security is determined by the commodity of intellectual capital.

During the first age, the United States reigned supreme. In the three-and-a-half years of America's participation in WWII our industry amazed the world. Automakers turned to the construction of aircraft and tanks. Small boat builders turned their skills to the construction of landing craft and "PT" boats. Even the Steinway piano company temporarily remade itself, re-training its craftsmen to build wooden components for army assault gliders. In the aggregate, the result was astounding. On December 7, 1941, the Japanese navy had ten aircraft carriers to our seven. Three and a half years later, on "V-J Day," they had four carriers still afloat. We had just under one hundred.

The Cold War was different. The Soviet Union, with its vast natural resources and command economy, could devote itself continuously to war-time levels of military industrial output. The only way America could compete with such a foe without bankrupting our nation was to combine our two greatest strengths – intellectual capital and a vibrant free market economy – into the awesome force that eventually won the Cold War. This was the combination that gave us aerospace dominance, a nuclear navy, advanced reconnaissance satellites, information technologies, micro-processing, composite materials, and stealth. And all this was accomplished while reducing our defense expenditures from

50% of our GDP by the end of World War II, to about 4% today. Eisenhower was among the first to understand just how the Cold War had changed our national security: from the need to improvise our nation's defenses on an emergency basis to the redefinition of war as a "come as you are" proposition; from our dependence on the factory worker to our reliance on the scientist and engineer; and, from wielding our heavy industry to leveraging our intellectual capital.

And so it remains today. In this "post-Cold War" world, we are once again faced with the task of sustaining a competitive advantage for national security over the long haul.

It is this topic that the authors of the latest Northrop Grumman Analysis Center paper turn to, and I am pleased to offer a preface to their work. The real value of this paper by Messrs. Fowler, Haffa, Patton, and Welch is in demonstrating that the imperatives called for by President Eisenhower for a robust and competitive industrial base—and the educational, scientific and organizational enterprises in its support—are with us still. For today, the challenges to our security are not just military but economic, political, social, and technological. Surely we are engaged in such a long-term competition with elements of radical Islam. It presents a cruel combination of medieval theology and modern technology: using the internet to spread barbarous dogma and to recruit new members; using cell phones to detonate roadside bombs. With an ideological foot planted in the 12th century and a terrorist arm acting in the 21st, those who would destroy our way of life impose upon us a war of ideas and unrestricted violence that we must counter with our own industry and intellectual capital.

But this proximate terrorist threat is not our only competition over the long-term. The U.S. Department of Defense (DoD) 2006 Quadrennial Defense Review directed our attention to disruptive and catastrophic scenarios and offered the challenge of "shaping the choices of countries facing strategic crossroads." As the United States seeks to encourage international actors to become integrated into a peaceful and prosperous international political system, it will also seek to dissuade disruptive capabilities and deter aggression and coercion. The ability of the United States and its allies to successfully meet these challenges while preserving our own security and liberty will depend on our ability to sustain a competitive advantage across a range of capabilities for the foreseeable future.

The authors of these papers focus our attention on four key elements of this long-term competition: the overall U.S. educational system, our investment in technology, our defense acquisition system, and the health of the defense industrial base. These are issues that frequently occupy the thoughts of the nation's defense and industrial leaders, and deserve widespread attention and action.

In the first of this series of four papers, Jasper Welch examines America's Overall Educational System and finds it lacking from several perspectives. As General Welch explains, study after study reveals that we are falling far behind other countries in the numbers of scientists and engineers we graduate from college annually, while more and more American students are avoiding studying math and science in high school and college. He provides us some incisive observations, precise analysis, and solid recommendations for sustaining a competitive advantage in our educational system. The only point I would add to his excellent paper is the role of inspiration. Just as my generation was inspired to the study of science by *Sputnik* and the ensuing space race, so must we find a way to inspire future generations of American youth. America would be well served by the pursuit of a future noble, national science-driven quest—whether it is the prospect of human exploration of the solar system, or a remarkable bio-medical breakthrough which could fundamentally improve the quality of human life, or some other yet unimagined game-changing objective.

Captain Jim Patton turns his—and our—attention to technological competitions. As a submarine captain during the Cold War, Jim learned first-hand the advantage that technology can bring when facing a very capable adversary in a contest decided by degrees of stealth. In previous work for Northrop Grumman, Jim extended his knowledge of stealthy underwater competitions to those our air forces will face in the future. In this paper, he develops the concept of the "value of cost," arguing that America's competitive edge can be maintained by leveraging our vast resources and investing them in the right technologies. He was right about stealth, and he's probably right about the other technologies he suggests will provide a significant competitive advantage in the future: unmanned systems, directed energy applications, and space-based capabilities. Certainly those are strategic arenas that Northrop Grumman and its customers have high on their investment agendas.

Bert Fowler is concerned that we aren't investing enough in the research and development accounts needed to bring these technologies to fruition, and fears that budgetary pressures will continue to limit the amounts allocated to basic science and engineering research. As a long-time participant and observer of the weapons acquisition process, he also knows where lots of dollars could be saved and diverted to basic research. Toward that end, Bert reprises for us his recommendations for fixing the DoD acquisition system, with the acknowledgement that acquisition reform is always on everyone's agenda, and always, for reasons he explains, very hard to accomplish. We agree with Bert that another study of acquisition reform is not needed: government and industry are well aware of the problems that exist. Tying this paper back to Jim Patton's, we can conclude that a long-term sustainable technological advantage will not derive from a weapons

acquisition system that is bureaucratically hidebound and risk averse. So, in addition to some of the recommendations that Bert Fowler makes, I suggest that we need to swing the contracting needle away from the "risk containment" peg, and more towards the "risk tolerance" post—particularly in key technologies and capabilities recommended by Patton, such as unmanned and space-based systems.

The Director of our Corporate Analysis Center, Bob Haffa, focuses on the defense industrial base in the final paper of this series. He wonders, "Do we need to 'transform' the defense industrial base to ensure it is capable of sustaining America's competitive advantage?" He concludes that we do not, that the "sustaining" type of innovation required by the nation's armed services can well be met by the existing and evolving industrial base. But to hearken back to the Eisenhower quote at the beginning of this introduction, that industrial base must *be quickly and fully responsive to the complicated and ever-changing requirements of modern war*. Bob develops an argument that without emphasis on the dual thrusts of global cooperation and internal innovation, the U.S. industrial base is at risk of falling behind in underwriting our competitive military advantage. Globalization, he points out, was rapidly reconfiguring the defense industrial base until the 9/11 attacks changed the equation and resulted in greater scrutiny of international defense trade. But in a global war on terrorism, he concludes correctly, it is essential that we collaborate with our international friends and allies to harvest technologies, improve interoperability and enable capacity building. Bob posits that it will take "continued, proactive cooperation among political, military and industrial leaders to ensure that the funds directed toward military transformation are allocated in the proper direction and amounts." We couldn't agree more, and work daily with our customer towards those ends.

As I conclude, let me just say a word about the Northrop Grumman Analysis Center, the papers they produce, and this specific effort. This paper series has been underway now for more than five years (the Analysis Center dates back to 1977) and has made significant contributions to helping Northrop Grumman and its customers "define the future." As consultants to the Analysis Center, each for more than twenty years, Jasper Welch, Bert Fowler and Jim Patton have taken time from their distinguished military, scientific and technology-intensive careers to help the Analysis Center work "on the leading edge in shaping U.S. strategy and defining operational requirements." In this paper they used their highly-regarded talents to help us not only think about the future, but also to ensure we will be in a position to enjoy it when we get there. As in their long and distinguished careers, the service they have provided us in these papers is relevant, timely, and important. We owe them our thanks.

Sustaining a Competitive Advantage for the Nation's Defense

Part 1: Improving the Overall Educational System

BY JASPER WELCH

The United States is now engaged in what is likely to be a long-term cultural, ideological, economic and military competition with elements of radical Islam. In addition, we face enduring global security challenges referred to in the Department of Defense (DoD) 2006 *Quadrennial Defense Review* (QDR) as "shaping the choices of countries at strategic crossroads."[1] In the past, national efforts to address long-term complex challenges to national security have involved bold activities within the educational system of this country. Current circumstances similarly call for bold actions across the Overall Educational System, starting with children's education in grades K-12 and continuing through college, graduate school and life-long learning.

A strategy for sustaining a competitive advantage across the Overall Educational System must also be a long-term commitment. This commitment can start with formal schooling of children, as well as summer and after-school programs. Contributions ought to include parental and community support to shape attitudes and aspirations of students as they face their many choices. They also should include continual learning through corporate and post-graduate programs to cope with a faster-than-ever evolution of technology and sociology. Industry will further be called upon to address employment migration issues such as keeping technically educated persons engaged in research and engineering, as well as concerns about outsourcing of technical services to foreign firms and employing non-U.S. citizens in sensitive positions.

There are specific areas within the Overall Educational System that directly support a long-term, sustainable competitive advantage for national security. The obvious areas are science, technology, engineering and mathematics (STEM), including professional military education.[2] But for many good reasons, appropriate subject matter also includes cultural, linguistic, political and geographical studies pertinent to our friends, allies, trading partners, sources of raw materials and relevant non-governmental organizations, as well as threatening states and states that support and harbor threatening non-state actors. Action within these areas is critical for two principal reasons: 1) all of the activities outlined can play a substantial role in sustaining our competitive advantage, particularly in consideration of the downside risks of taking no action, and 2) there are deeply troubling situations or trends in many areas of the Overall Educational System.

Recent History: Competition During the Cold War

It is useful to revisit U.S. initiatives in education during the most recent long-term, complex competition for national security, known as the Cold War. Beginning right after World War II, and with

[1] *Quadrennial Defense Review Report*, Washington, D.C.: U.S. Department of Defense, February 6, 2006, p. 27.

[2] See Susan W. Pollack, "Human Capital Strategy and the Future of our Nation's Space Industry Workforce" in Lynne C. Thompson and Sheila R. Ranis (eds.) *U.S. Defense Industrial Base: National Security Implications of a Globalized World*. Washington, D.C.: National Defense University Press, 2006.

a renewed effort after the Soviet Union's launching of the *Sputnik* satellite, the United States undertook a number of fairly successful initiatives to promote university education in fields then deemed important to the nation's strategic advantage in its competition with communism. They involved activities at many educational levels and through a number of avenues, and included focused study of the culture and society of our nation's adversaries. The initiatives also are notable for being a part of a concerted effort by government agencies and educational institutions to support goals for national defense.

The initiatives included at least four distinct components:

- Scholarships and research fellowships for students, primarily under the provisions of the National Defense Education Act (NDEA).[3]
- Research grants to universities and other research institutions, many of which were funded and administered by the Department of Defense, the Atomic Energy Commission and later the National Aeronautics and Space Administration (NASA).
- New and novel institutions such as the Government-owned, commercially-operated (GOCO) National Laboratories; government agencies like ARPA (Advanced Research Projects Agency, later DARPA), Navy Special Projects, Air Force Ballistic Missile Office and National Reconnaissance Office; long-term support for research organizations like RAND, JASON and Lincoln Laboratories; and broad underwriting of international science projects such as the International Geophysical Year.[4] Most of these institutions were established with explicit ties to universities.
- Major public relations initiatives by every branch and level of government to inform and sensitize the public and the legislative branch as to the long-term value of these initiatives and their necessity in prevailing in the competition with the Soviet Union and communism.

This continued support for education diverges from its Cold War aims in that it is not associated with a greater strategy for sustaining a competitive advantage for the nation's defense.

All of these components were key to the success of the national strategy. The scholarships allowed promising students to go on to graduate school, an activity then considered a luxury. The grants enabled universities to establish research programs in the selected fields. The new institutions, generously funded, provided post-graduate employment and research facilities. The research output sustained our competitive position. The public relations program kept the overall initiative well funded, even during difficult budget years.

One part of the initiative, often overlooked, was support for Russian (or Soviet) Studies. It provided two whole generations of journalists, linguists, political scientists, intelligence analysts and diplomats who served the country well in delivering to the public and the government a significant understanding of the Soviet Union, in spite of that nation's efforts at secrecy. Similarly, there was an important, albeit smaller, effort to support the study of economics, at least as it informed the competition with Russia.

As the Cold War wound down, these initiatives faded in perceived need and had mostly disappeared from the scene by the 1990s. But federal support for education, particularly technical education, continued apace. There are federally subsidized student loan programs and a number of scholarship programs of which the Pell grants[5] to financially needy students are the best known.

[3] The NDEA was enacted in 1958 and provided a wide range of assistance at all education levels.

[4] All of these institutions were established with research charters, and other operating principles, that were at variance with established "norms" of government procedures; the variances were justified on the basis that the unusual arrangements were necessary to sustain the U.S. competitive advantage in the Cold War.

[5] The Pell Grant program is a post-secondary education subsidy run by the U.S. Government. The basic premise is that such grants will help only those students who actually need help to pay for their studies. See Wikipedia, the on-line encyclopedia at http://en.wikipedia.org.

Today, more than half of all university research in the physical sciences is supported by the federal government: some from the Defense Department, but mostly from other cabinet departments, NASA and the National Science Foundation.

But this continued support for education diverges from its Cold War aims in that it is not associated with a greater strategy for sustaining a competitive advantage for the nation's defense. Indeed, at the national level, the term "competitive advantage" is widely viewed in only its economic dimension. For example, President Bush announced "The American Competitiveness Initiative" in February 2006 to boost business and government investment in research and support of math and science education in the schools. But while the White House describes the program as a path to economic competitiveness, it does not link it to national security, nor does it include the Department of Defense or the Intelligence Community as participants. This is unfortunate due to the fact that our nation's global economic and national security interests are broader than ever before, and clearly intersect.

Meeting Today's Challenges

Today we have a new long-term competition, arising from new adversaries and waged against us with asymmetric means. In one sense, the competition is similar to the Cold War—we and our competitors hold radically distinct views on governance and social values. The competition is utterly serious, having already led to vicious and determined hostile actions by our adversaries and curtailment of precious civil rights of Americans. In many ways, these outcomes have exceeded what was experienced in the Cold War and there is genuine fear that worse is yet to come on both scores.

The scope of this paper is long-term, so it will not comment on current diplomatic and military operations. But a plethora of books and articles recently published deal with the irregular nature of current conflicts and their roots in profound cultural and religious animosities[6] and support the judgment that a sustainable (that is, long-term) competitive strategy to meet this challenge is needed. The current Administration has recognized the same in a number of top-level documents.[7] However, these documents focus on the construction of and justification for the federal budget for national security activities. As such, they dwell on education only in passing and for several narrow issues. They contain no discussion of the Overall Educational System as an important entity in its own right—its value, its complexity or its relationship to the budget matters that are the proper focus of these documents. As such, they fall short of prescribing an effective national strategy.

Similarly, corresponding documents promulgated by the Department of Education fail to connect education to sustaining national security. There is, however, a large body of relevant research and analyses by institutions such as the National Academies, the National Research Council and the National Science Board on the effectiveness of the Overall Educational System. Their reports cover many important aspects relevant to supporting a national effort to focus and enhance education, complete with data and recommendations for near-term action.[8] However, there is little discussion of education's role in supporting a strategic goal of sustaining our competitive advantage for national defense.

So we are on our own. One obvious line of attack is to explore what might be the proper parallel, for this competition, to the successful federal initiatives in education that served us so well in the past response to the Cold War.

First, one should retain the principles of four components outlined above, which together can make education a key contributor to national defense. To many, the NDEA Act of 1958 was a stand-alone program, and a success at that. But, as explained above, the other three components were essential. There is a fair initiative now underway to have a

[6] A good reference is "Complex Irregular Warfare: The Face of Contemporary Conflict," in *The Military Balance 2005-2006*, London IISS, pp. 411-420.

[7] See the 2006 Quadrennial Defense Review Report (QDR) and National Defense Strategy (NDS) at www.defenselink.mil/qdr/ and www.defenselink.mil/news/March2005/d20050318nds1.pdf.

[8] Augustine, Norm, et al., *Rising Above the Gathering Storm*, Washington, D.C.: National Academy Press, 2006. See also http://newton.nap.edu/catalog/11463.html. These documents provide plans for improving education and research at all levels to foster national competitive advantage in economic terms.

new NDEA to deal with the current situation.[9] One important goal of the new NDEA is to provide a source of graduate scientists and engineers that are U.S. citizens who can fill the depleting ranks of U.S. government and defense industry personnel now retiring in ever larger numbers. Citizenship is deemed essential for positions of trust in the national security workforce.[10] As such, some versions of the new NDEA would require a period of government service in return for financial assistance at the college or graduate school level. The new National Defense Educational Program's modest budget is set at $20 million in 2007.[11]

Secondly, our leaders should support relevant subjects selected on the basis of an objective evaluation of the current circumstances. They do not have to be chosen for all time; adjustments should be made downstream. But if the initiative is to have tangible payoffs and enduring financial support, the subject matter must have direct and plausible connection to the evident problems that need solutions. After WWII, most technical progress and solutions rested on better machinery and better control of energy—read vehicles, engines and weapons. Today, the most critical fields are generally found in biology, information handling technology, sensors and computational devices. During the Cold War the industry supporting the nation's defense developed to a fine art two professional skills: Project Management and Systems Engineering. For reasons associated with creeping bureaucratic control, workforce attrition and retirement, these skills are being lost. These are very powerful and important skills. They should be respected and nurtured. They can be taught: a growing number of engineering schools are now offering degrees in Systems Engineering.

The challenges facing our nation in national security should be addressed with a coordinated effort to prepare students, academics, and professionals for the problems at hand.

Third, our educational focus should include relevant non-technical fields such as Islamic studies, the languages of the Middle-East and Asia, economics of globalization, integration of Non-Governmental Organizations (NGOs) into U.S. Government activities, nation-building, and refugee and relief support and management. These latter subjects are not normally covered in the portfolio. Indeed, there was a concerted effort within the current administration to remove all such activities from the Defense budget. But the argument was for budget clarity—hardly a top-drawer cause. The U.S. military will always have to interact with these types of activities, even if in a supporting role. As recent events suggest, the military's role may at times be extensive.

Fourth, there is a need to invent and establish new institutions appropriate to supporting a national strategy. In the Post-WWII years, the Atomic Energy Commission was established with unusual attributes to deal with a very new situation. ARPA and NASA were established to respond to *Sputnik*; again with new and unusual attributes. In some sense the Department of Homeland Security (DHS) is such an institution, but its size and omnibus extent becloud the few truly relevant and focused activities within it—such as the development of inspection devices to find special materials for weapons of mass destruction.

Fifth, public support and participation will be critical to such a campaign. To gain that support, the appropriate agencies should implement a coherent marketing strategy and establish a public face. National-level spokespersons with significant prestige and recognition (e.g., astronauts) could spark interest, and celebrities who routinely champion health and humanitarian issues could certainly

[9] See Association of American Universities at www.aau.edu/education/NDSEOP.

[10] See Department of Defense briefing "National Security Workforce: Challenges and Solutions" at www.DoD.mil/ddre/doc/NDEA_BRIEFING.pdf.

[11] "Technology Forecast," *National Defense*, November 2006, p. 31.

be brought aboard to urge their teenage fans to stay in school and pursue skills relevant to national security.

The United States has a powerful resource in its public and private education systems, especially when these systems are focused on shared values and goals. The challenges facing our nation in national security should be addressed with a coordinated effort to prepare students, academics and professionals for the problems at hand. Unfortunately, there are widely recognized shortcomings in education that will hinder progress.

Education In Trouble

Over the past decades there has been a great deal of concern and research into the shortcoming of technical education. The National Academy of Engineering has attacked the problem head on with a formal program.[12] The National Science Foundation has been active for two decades.[13] Numerous professional associations also have raised their independent voices. The following highlights some of the worrisome matters raised in contemporary accounts.

Quality of Technical Education in Grades K-12

A number of studies and initiatives document America's technical education shortfalls. A recent National Academies study concluded that our K-12 students lack sufficient knowledge of science and mathematics to live in the current technical age, are unprepared to enter technical programs in college,[14] and would benefit from programs providing assistance to classroom teachers deficient in technical domain knowledge.[15] The article also noted the prevailing social attitudes discouraging smart young students, especially women and minorities, from preparing themselves for technical work in college.[16] As noted in Table 1, there has been improvement in advanced science and mathematics coursework, but the absolute levels remain too low, especially in mathematics. Although some universities have started outreach programs showcasing the value of technical education to high school students,[17] these programs often suffer from a lack of interest of senior faculty members who view their principal duty as research, not teaching or recruiting. President Bush's American Competitiveness Initiative also acknowledges the need for improving public education in these areas,

Table 1. Percent of U.S. high school graduates who completed advanced mathematics and science courses in high school, by sex and year of graduation: Selected years, 1990-2000.

Subject	1990		1994		1998		2000	
	Male	Female	Male	Female	Male	Female	Male	Female
Mathematics								
Trigonometry/Algebra III	20.6	20.9	23.0	24.9	19.4	22.5	17.9	21.1
Precalculus/Analysis	14.4	13.0	16.3	18.4	23.1	22.9	25.4	27.9
Statistics and Probability	1.2	0.8	2.0	2.1	3.4	4.0	5.8	5.6
Calculus	8.3	6.2	10.3	10.1	12.0	11.6	13.3	12.0
Science								
Advanced Biology	25.7	29.2	31.5	37.8	33.8	40.8	31.5	40.5
Chemistry	43.8	46.1	47.5	53.3	53.3	59.2	58.1	66.8
Physics	24.9	18.3	26.7	22.5	31.0	26.6	35.6	31.5

SOURCES: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 1990, 1994, 1998, and 2000 High School Transcript Studies.

National Science Foundation *Science and Engineering Indicators 2006*.

http://www.nsf.gov/statistics/seind06/c1/tt01-08.htm

[12] Clough, G.W., et al., *Educating the Engineer of 2020*, Washington, D.C.: National Academy Press, 2005, available through www.nap.edu., provides a summary of recommendations and monographs.

[13] National Science Foundation, *Imperatives in Undergraduate Engineering Education*, 1989.

[14] Sullivan, J.F., A Call for K-16 Engineering Education, in *The Bridge*, Vol. 36, #2, Summer 2006.

[15] The American Society for Engineering Education offers on-line assistance at www.engineeringk12.org.

[16] Harris Interactive, "American Perspectives on Engineers and Engineering." Conducted for the American Association of Engineering Societies, 2004. Also at www.aaes.org/harris_2004files/frame.htm.

[17] Kadanoff, Leo, *Physics Today*, Sep 2006, p. 8-9 reports on a number of successful, ongoing programs.

calling for a broad set of actions at the federal level intended to improve the nation's competitiveness. Although the initiative supports math and science programs in K-12 education, with substantial funding goals, it views "competitiveness" primarily in economic terms rather than as a means of assuring national security.[18]

Retention of Technical Students Through College Graduation

Even at good schools, with strong engineering departments, there is considerable attrition of students during the four year undergraduate programs, with 50% completion rates not uncommon. Moreover, many schools do not routinely evaluate themselves on graduation rates. Nor do many schools have formal programs aimed at retention of students through graduation—the *de facto* policy is to sink or swim. In terms of technical degree completion, the numbers are worrisome. As Table 2 notes, the percent of U.S. science and engineering graduates is quite low—ranking last among the G8 nations. Some schools have attacked this issue. For example, one college offered a freshman course in which students worked all year to complete the design of a fairly complex engineering project. Those students who elected the rigorous design course had a much higher graduation rate.[19] Indications are that retention is significantly lower among women and minority students, but the reasons why are murky, since we generally don't know what happens to students who leave the technical curricula. But the raw attrition of women and minorities is so large that there must be real issues at play that unfortunately have been met by a weak overall response from schools.

Quality of Teaching at the College Level

During the last decade significant advances have been made in the understanding of how best to teach technical material to college-level students.[20] For example, students reach college with well-formed, but often erroneous "personal views" as to how things work in the physical world. Educators now understand that students hang onto those "personal views" with tenacity, even in the face of contrary instruction until someone explains to them the fault in their understanding. Rarely does the college instructional regimen provide such opportunities for correcting faulty perceptions. Many other "best practices" are not yet incorporated widely into college instruction. Nor are there robust mechanisms for incorporating improved educational practices into college curricula, or supporting engineering faculty members in improving their skills as educators.[21]

Table 2. Natural Science and Engineering degrees per 100 24-year-olds, by country/economy: Most recent year.

Country/Economy (Year)	Degrees/100 24-Year-Olds
Taiwan (2003)	16.43
Finland (2002)	14.82
Lithuania (2002)	12.52
South Korea (2002)	12.51
Australia (2002)	12.47
France (2002)	11.40
United Kingdom (2003)	10.23
Russia (1999)	8.56
European Union (2002)	8.09
Japan (2004)	7.82
Poland (2002)	7.59
Canada (2001)	7.13
Singapore (1995)	6.75
Italy (2002)	6.72
Germany (2002)	5.88
United States (2002)	**5.69**
China (2001)	1.64
India (1990)	0.99

SOURCES: Organisation for Economic Co-operation and Development, Center for Education Research and Innovation, Education database, www1.oecd.org/scripts/cde/members/ edu_uoeauthenticate.asp; United Nations Educational, Scientific, and Cultural Organization (UNESCO), Institute for Statistics database, http://www.unesco.org/statistics, and national sources.

National Science Foundation *Science and Engineering Indicators 2006*.

http://www.nsf.gov/statistics/seind06/c1/tt01-08.htm

Accreditation of College Curricula

Over the last few years there has been a major three-way tussle between the accreditation agency for engineering curricula, critics of existing engineering education, and the engineering departments as a

[18] See Department of Education summary at www.ed.gov/about/inits/ed/competitiveness/challenge.html.

[19] Clough, Op. cit., pp. 40-41.

[20] Bransford, J.D., et al., "How People Learn," Washington, D.C.: National Academy Press, 2000, provides an extensive summation of research results based on studies by the Commission on Behavioral and Social Sciences and Education of the National Research Council.

[21] Ambrose, S.A., and Norman, M., "Preparing Engineering Faculty as Educators," in "*The Bridge*," Vol. 36, #2, Summer 2006, pp. 25-32. Also available at http://www.nae.edu/TheBridge.

whole.[22] It would appear that the new policies of the Accreditation Board for Engineering and Technology (ABET) are an adequate basis upon which to proceed. In particular, the new policies promote goals long advocated by industry to include instruction in teamwork and presentation skills as well as analysis of economic and environmental considerations in design. But tradition reigns strong in academe, so substantial implementation may be painfully slow.

Innovation, Product Development and Life-long Learning

We expect our engineers to be able to convert raw technology into useful products and services. Traditionally, engineering curricula have not included explicit instruction in entrepreneurial activities such as searching for a business model concomitant with searching for a product—all based on a new technology. We need that in our schools; some are starting to offer it.

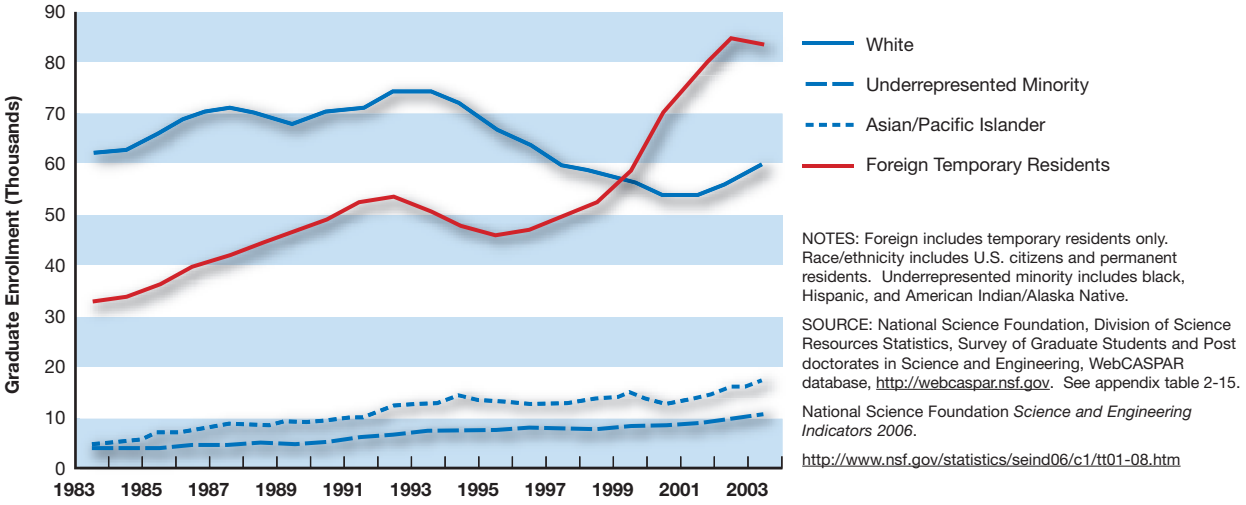
As we look at today's technology of economic importance, it is easy to see that much of it is less than ten years old, and we expect the same assessment ten years hence.[23] And so we need to train our engineers to "know how to learn." It is a special skill. It can be taught. To promote these skills, some have pushed for a professional degree similar to an MBA, to include the "case study" instructional technique so powerfully used in the Harvard Business School.[24]

Retaining Graduate Engineers and Scientists

In most of the technical fields, we find that about one-half of all persons holding a technical degree are no longer practicing in their field. Many are in closely supporting fields such as management, sales, distribution and repair services where their technical training is important to the quality of their performance, though not essential. Others have left their fields entirely, generally for personal reasons or economic opportunity. Women and minorities are underrepresented in most practicing technical professions, have higher drop-out rates and are underrepresented as a fraction of their cohort groups. Such is the strength of cultural and societal norms.[25]

At the same time, about half of all graduate students in technical fields today are citizens of countries outside of the United States. As Figure 1 demonstrates for example, the rise of foreign graduate student enrollment in U.S. computer science and engineering programs has been dramatic compared to that of U.S. citizens and residents.

Figure 1. Graduate enrollment in computer sciences and engineering, by citizenship, race/ethnicity: 1983-2003. U.S. Citizens and permanent visa holders represented in blue; Temporary visa holders represented in red; In thousands.



NOTES: Foreign includes temporary residents only. Race/ethnicity includes U.S. citizens and permanent residents. Underrepresented minority includes black, Hispanic, and American Indian/Alaska Native.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Post doctorates in Science and Engineering, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-15.

National Science Foundation *Science and Engineering Indicators 2006*.

http://www.nsf.gov/statistics/seind06/c1/tt01-08.htm

[22] Lattuca, et al., "The Changing Face of Engineering Education," in *The Bridge*, Vol. 36, #2, p. 5ff, describes the matter from the perspective of the Accreditation Board for Engineering and Technology (ABET). Also available at http://www.nae.edu/TheBridge.

[23] Director, S.W., et al., *The Engineer of 2020*, Washington, D.C.: The National Academies Press. See www.nap.edu.

[24] Clough, op. cit., p. 55.

[25] Harris Interactive, Op. cit.

Our educational institutions have welcomed this group because they are serious students of high quality and because their sponsors are willing and able to pay the full tuition. The previously referenced Augustine Report explicitly supports the education of foreign students as helpful to American competitiveness.[26] But there is friction between these students and the educational community owing to the understanding that many students will return to their homelands. Table 3 offers a breakdown of the origin of foreign students earning U.S. science and engineering doctorates, and thus an indication of where they may be likely to apply their expertise. Further, the U.S. export control regime purposefully restricts the degree of access of non-citizens to certain technical documents and equipment. New approaches are required to smooth both issues if we are to benefit fully from the scientific and engineering talents of foreign nationals over the longer term.[27]

Outsourcing of Engineering Work to Foreigners

There is growing concern in some quarters over the increasing amount of engineering work, paid for by U.S. firms, that is being performed by foreigners. There are two forms of this work: 1) work performed within the United States by immigrants on special visas that are justified on the basis that suitable U.S. technical personnel are not available to do the work; and, 2) work performed outside the United States by foreign firms or out-of-country subsidiaries of U.S. firms. In both cases the cost to the U.S. firm is lower and the quality of the work product is more than adequate. Given that there is an acknowledged and growing shortage of U.S. technical personnel, what is the concern?

Table 3. Origin of foreigners earning U.S. Science and Engineering doctorates: 1983-2003: Stated as a percent.

Foreign Student Origin	Percent
China	20.1
Taiwan	11.2
India	10.0
South Korea	9.7
Other Asia	17.6
All Others	13.3
Canada	3.3
Mexico	1.7
Central/Eastern Europe	3.5
Western Europe	9.6

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2005).

National Science Foundation *Science and Engineering Indicators 2006*.

http://www.nsf.gov/statistics/seind06/c1/tt01-08.htm

There are three general classes of concern, although they come in many variants. First, there is a long-term concern that these options may work so well that the U.S. internal capability will erode to an inadequate size and quality to serve our national needs in the event of geopolitical shifts that curtail access to foreign employees. Second, there is a shorter-term concern that U.S. students, already not so keen on technical careers, will see a diminished job market for their future careers and be further turned away, thus exacerbating the first concern. Third, there is worry that intellectual property and national security information will be inadvertently transferred outside of this country in the course of normal business, as well as the potential for increased opportunities for dedicated espionage. International engineering and scientific commercial firms are generally relaxed about the situation,[28] but firms that serve the defense and intelligence establishments, government personnel charged with national security programs, and their legislative supporters are much more concerned.

Quality of Data and Analysis of the Overall Educational System

The basic statistical source for data on scientific and engineering jobs and education is a publication of the National Science Board.[29] It compiles data from a large number of sources and is usually published every two years. The data are aggregated at the national level in most cases. Such an aggregation can obscure some subtle but important aspects of a deep understanding of the Overall Educational System that is needed to formulate policy initiatives. As to quantitative analysis at the Overall Educational System level, there simply has not been any. Nor, since the scope is so broad, is it really the

[26] Augustine, Norm, Op. cit.

[27] See Robert L. Paarlberg, "Knowledge as Power: Science, Military Dominance, and U.S. Security," *International Security*, Vol. 29, No. 1 (Summer, 2004), pp. 122-151.

[28] Kennedy, T.C., "The 'Value-Added' Approach to Engineering Education: An Industry Perspective," in *The Bridge*, Vol. 36, #2, Summer 2006, National Academy Press.

[29] See National Science Foundation at www.nsf.gov/statistics/seind04/.

province of any existing organization to perform such analysis.

For example, it would be very difficult to decide, on analytic grounds, how best to allocate financial resources among alternatives such as: 1) providing technical education throughout grades K-12; 2) encouraging promising young students to enter technical college programs; 3) retaining college students in technical fields through graduation; 4) subsidizing graduate students through scholarships; and, 5) supporting research in universities.

Similarly, it would be difficult to support a policy analysis on the preferred mix of quantity and quality of technical graduates. For example, is out-sourcing so inevitable that the U.S. should abandon the competition for routine engineering and focus on high-end innovative design and top-level program management? Such a decision would be a radical change from the current situation and should be made on the basis of sound analysis.

The nation needs a permanent organization, with seed money, entrepreneurial spirit and procedures for raising much larger funds for projects seeking to improve the Overall Educational System.

Observations: Sustaining a Competitive Advantage In Education

Among the more worrisome aspects of the path forward is the fairly weak set of cultural and economic forces that are naturally present to drive implementation of fixes to the Overall Educational System. Many of the pilot programs that do exist—and there are many promising ones—have come not from large or well-heeled institutions, but from inspired individuals and non-profit organizations. Such pilot programs can only last so long. They need to have their innovations taken up by the mainstream education community as a whole to assure widespread adoption. In a word, there are major opportunities for excellence, but leadership is required at the national level.

To support such efforts, the nation needs a permanent organization, with seed money, entrepreneurial spirit and procedures for raising much larger funds for promising projects. The purpose of this organization is to "incubate" pilot projects seeking to improve the Overall Educational System and to develop programs of continued promise into broadly incorporated practices. The evidence to date clearly shows that far too many promising ideas get proven in pilot projects only to die away for lack of a viable mechanism for developing them into broadly accepted practice.

Moreover, the nation needs a permanent, standing research and analysis organization that is empowered to collect, analyze and interpret performance data on the Overall Educational System; as well as evaluate the organizational, educational and cultural effectiveness and efficiency of traditional and innovative approaches to improving the Overall Educational System. The new entity also would publish papers intended to promulgate the results of its research and evaluation for all to see.

We would envision this permanent organization as modeled along the lines of a Federally Funded Research and Development Center (FFRDC) as widely and successfully used in the Department of Defense. It would require support from a wide range of government and non-government organizations. It is inevitable that the published products of the organization, though merely expository opinion based on open research and analysis, will from time to time be controversial. Processes for resolving such controversies should be established at the outset.

Existing governmental and non-governmental organizations, particularly those whose publications are referenced in this paper, are important players and will continue to be significant in supporting

the improvement of the Overall Educational System. Those organizations have carried the burden of this effort for many years. Nothing in the two initiatives identified above should be interpreted as demeaning the efforts of these existing institutions. The two new institutions set forth above are action agencies, with fairly narrow action charters but with broad purviews. They need the continuing support of the existing institutions to do their job.

The nation needs the continuing support of its professional educational institutions to build the best possible Overall Educational System. This paper has been pointedly critical of some actions and attitudes within the professional educational institutions. Clearly, this criticism reflects the perspective of the paper—how to sustain the national competitive advantage over the long term through the technical educational system. Those engaged in education have a wide range of perspectives, some of which might not resonate with the national security perspective presented here. From time to time such conflicts, when allowed to grow unbridled, have injured both the nation's security and its educational institutions.

Improvements to the Overall Educational System also require the continued support of the nation's industrial base in terms of public relations, participation in local, state and federal level programs, both tax-supported and collaborative, and with innovative and enlightened programs of in-service continuing education. The industrial base needs to develop and maintain steady and wise policies with regard to out-sourcing, employment of non-citizens and export of intellectual property. Mere adherence to existing Federal regulations is unlikely to constitute the very finest contribution to national security in this difficult area. The industrial base could do a lot more.

Sustaining a Competitive Advantage for the Nation's Defense

Part 2: Focused Technology Investments

by James H. Patton, Jr.

"Scientific knowledge and innovation are going to occur. It's just a question of whether it will occur in the United States" [30]

Newt Gingrich
Former Speaker of U.S. House of Representatives

Where should the United States invest its marginal dollar in technology to assure a competitive advantage for the future? It is a question that carries enormous weight, potentially informing budget decisions at various levels within public and private organizations. The answer depends upon a number of variables, including who might we be competing against and for how long; and whether the competition takes the form of a traditional conventional military rivalry, or a contest against adversaries armed with irregular, disruptive and possibly catastrophic technologies. Other pertinent questions are how much should we be investing in our traditional areas of strength, and what are the technological "white spaces" that deserve added resources? We cannot answer all of these questions with absolute certainty for the future, and can only make decisions based on our knowledge of historical lessons and existing trends. What we do know prompts a range of plausible investment streams. But I argue that we should not shy away from substantial investments in key capabilities to sustain a competitive advantage. How affordable (or costly) a technology is may be central to whether (and for how long) it can sustain a competitive advantage.

The driving concern of my colleagues in this collection of papers is to assure that the United States maintains its competitive superiority in regards to national security in the future. Already, the proliferation and increased affordability of military-applicable technology is diminishing the U.S. technological advantage on several fronts. But in the high-cost areas of nuclear power and stealth, the U.S. military remains far ahead of its adversaries. The high costs can be viewed as being as much a blessing as a curse in that, at least for now, they keep all but the high rollers out of the game. These technologies have offered tremendous advantages in the naval sector, where technological dominance is critical due to lengthy development timeframes. Investments in these cutting-edge and costly technologies have made the U.S. naval fleet the dominant maritime power on the globe.

For the future, the United States would be wise to continue to focus investments on areas that offer huge potential payoffs, not so much in spite of their cost, but, perhaps as a barrier to entry, *because* of it. I shall use as a case in point the long-term U.S. development and deployment of a robust nuclear-powered submarine fleet, and draw implications

[30] As quoted by Mark A. Kellner in "Group Urges Increase in Spending on Basic Research", *Defense News*, 20 November 2006.

for future technological and financial options from that case study.

We profited from technological superiority because we chose to afford it.

Affordable and Disruptive Technologies

Because victory has many fathers, there are several claimants to the technology that served to contribute to the fall of the Soviet Union or, at least, to the realization of its leaders that they could no longer afford to compete militarily in the Cold War. The information revolution, the Strategic Defense Initiative to develop ballistic missile defenses, and the stealthiness of our submarines and long-range bombers all share some of that credit. Just as Jasper Welch noted in the previous essay that the United States was willing to make major investments in the Overall Educational System to meet the challenge of the Cold War, so were we willing to spend generously to build and sustain a competitive advantage in military technology. We profited from technological superiority because we chose to afford it.

For the coming decades, we will continue to see competitions in military technology. As that competition unfolds, the perception will prevail that increased value implies increased cost. Consider that a Cold War West German BMW cost more than did an East German Trabant and the value was apparent. In modern times weapons and weapon platforms may be the most dramatic examples of "disruptive technologies" that render everything that came before obsolete. When export versions of Russian "double-digit" surface-to-air missile (SAM) systems, capable of engaging conventional aircraft more than a hundred miles away, proliferate, they make very low observable (VLO) aircraft, such as the B-2 bomber, much more than just expensive technological curiosities. Those answers to SAM proliferation become sources of continued competitive advantage.

Some technologies start off as seemingly cost prohibitive, but grow affordable as commercial industry adopts them. As recently as the first Gulf War in 1990-91, the military version of a Global Positioning System (GPS) receiver was a fifteen-pound backpack costing about $15,000. Soon commercial hand-held variants were hitting the market at a few hundred dollars apiece. Today, the heart and soul of such a receiver – the "chipset" – is priced well under $10, and the predominant factor driving the cost of a personal GPS is the aesthetics of its packaging and other software frills that get bundled with its navigational capability.

While we all enjoy a drop in price in the latest gadget that improves our quality of life, the proliferation of cheap GPS guidance systems is not all good news. Such gadgetry has now landed within the discretionary budgets of potentially adversarial third world states and even non-state entities who wish the industrialized democracies ill. Precision weaponry, once the "gold standard" of highly developed and technologically advanced states, is now (thanks to GPS) on the cusp of being standard issue for all. To put all this in perspective, an operations analyst can show mathematically that it would require the firing of some 3000+ SCUD Theater Ballistic Missiles (TBM) to achieve a high probability of destroying a fixed soft target at the maximum range (~200 miles). SCUD missiles have become ubiquitous and standard weapons among U.S. adversaries, and are available on the black market from North Korea for $100,000 or so. However, if the navigation accuracy of that missile were improved by one order of magnitude, the same kill probability could be achieved by launching two or three SCUDs. Such improvements are not yet available through the purchase of about $20 worth of parts from a local Radio Shack, but the indicators are that they might soon be. Thus, break-through technologies, as they become affordable, can threaten U.S. national security.

The Value of Cost: The Case of the Nuclear-Powered Submarine

Nuclear weaponry is an area that has, thus far, remained out of reach of many smaller states and entities. We may consider it "fortunate" that nuclear weapons haven't proliferated more in the 60-plus years since the *Trinity* blast. More to the

point, it was prohibitively expensive to enrich natural uranium to weapons-grade levels. During the height of the World War II "Manhattan Project," the enrichment projects at Oak Ridge and other sites consumed about a sixth of the total U.S. electric generating capacity, and the cost of developing a sovereign nuclear weapons production facility remains a significant barrier to entry to the nuclear club. Had the production of nuclear weapons been more affordable, the last half of the 20th century might have been characterized by multi-polar nuclear exchanges rather than bi-polar nuclear deterrence.

This counterweight to the proliferation of affordable, weapons-related technologies may be termed the "value of cost."[31] It is also apparent in the non-proliferation of nuclear-powered submarines. The U.S. nuclear submarine was far from perfect when first deployed and even, as some critics of the time argued, bordered on the impractical. Because of the limits on nuclear physics knowledge at that time, coupled with manufacturing limitations, the *USS Nautilus* first sailed with an amount of fuel in the core sufficient to support only one or two ballistic missile patrols—a year or so of operations—before requiring a costly and time-consuming refueling process. But as the Cold War played out, and the advantages of both strategic nuclear and attack submarines became apparent, significant U.S. investments in reactor core technologies preserved a competitive edge. The newly-commissioned *Virginia*-class submarine (SSN-774) and her sisters are fitted with reactors that will never require refueling during the ship's 30-year serviceable life.

Building, maintaining and improving stealth platforms is a good example of the value of cost. A fleet of modern nuclear-powered submarines is so expensive that few countries in the world can afford one.

However, sustaining a competitive advantage in stealthy submarines carries certain recurring costs. For example, for a half-century the United States and Soviet submarine forces were in a "quieting" race regarding their platforms' radiated noise. U.S. submarines won this race owing to the insistence that not only the next class of ships be built quieter, but also that subsequent ships within the same class would be stealthier and the quieting process would continue for the life of the platform. Thus, when submarines were retired after 25-30 years of hard service, they went to the "boneyard" stealthier than when they were built, due to uncompromisingly thorough maintenance and constant costly improvements. Building, maintaining and improving such stealth platforms is a good example of the value of cost. A fleet of modern nuclear-powered submarines is so expensive that few countries in the world can afford one.

In addition to the five countries (all members of the UN Security Council) that presently have nuclear-powered submarines, India is reported to be in the process of constructing them, and Brazil is believed to have extended developmental efforts several times because of an inability to achieve the level of uranium enrichment needed for a naval pressurized light water reactor. In fact, the indigenous construction of nuclear submarines is more difficult, and represents a higher degree of nuclear sophistication, than does the production of a nuclear weapon. That same submarine is also far more useful than an atomic bomb in protecting and furthering a nation's interests across the entire conflict spectrum.[32]

[31] This is not a new phenomenon. As Max Boot explains in his recent examination of the role of technology in warfare through the ages, the winning forces in the "gunpowder revolution" were those rich states that "could afford large, well-trained, well-equipped, well supplied armies and navies." See *War Made New*, New York: Gotham, 2006. In a more recent application, Barry Watts argues that the annual infrastructure costs of maintaining the Global Positioning System (GPS) satellites are so expensive that "only the United States has had the wherewithal to sustain the availability of GPS-quality navigation worldwide." Thus, "only the U.S. military has been able to field the guided munitions and battle networks for prompt precision strike on a global basis." Barry D. Watts, *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects*. Washington, D.C., CSBA, March 2007.

[32] Since the submarine's principal defensive weapon system is its stealth and its principal deterrent value is the ubiquitous nature provided by contiguous waters deeper than 20 fathoms, even as a single platform, a submarine represents a credible "presence" to many widely separated potential adversaries once at sea for only a few days. A nuclear submarine, out of home port for as little as about two weeks, is literally capable of being anywhere in the world, and an appropriately dispersed force of as few as 13-14 could always be within *Tomahawk* Submarine-Launched Cruise Missile (SLCM) range of all the world's littorals.

As proof of this claim, in the little more than a half-century of its existence, we have seen essentially the same nuclear submarine serve as the ultimate strategic nuclear deterrent, the premier anti-submarine warfare (ASW) platform during the Cold War, a "one shot" terminator of a naval confrontation off the Falkland Islands, a preeminent and manpower risk-free land attack platform in Afghanistan and the Persian Gulf, the quintessential Special Operating Forces (SOF)[33] insertion and extraction vehicle, and a persistent and covert collector of intelligence.[34] The ability to cover all of these diverse missions during the lifetime of a single platform and the career of an officer that commands it has to capture the very essence of the word "transformational."[35]

Perhaps the greatest competitive advantage of a nuclear submarine has yet to be realized and depends on certain technological developments. Since most other naval platforms (especially non-nuclear powered submarines) have stored energy and power constraints, few will be able to fully exploit deployable directed energy offensive and defensive (i.e., anti-missile) weapon systems. Nuclear submarines and nuclear-powered surface combatants such as aircraft carriers have the inherent potential to provide all or any portion of the reactor plant's output in the form of electrical energy to drive these exotic and devastatingly effective devices. When combined with the submarine's stealth and insensitivity to an adversary's anti-access/area denial measures, such systems could drive another "Revolution in Military Affairs" as did the machine gun and nuclear weapons.

If a nation aspires to maintain a competitive edge in pursuit of maritime domain awareness and superiority, it must have a force of modern, quiet and well-armed nuclear attack submarines, if for no other reason than to protect its access to the "maritime commons."[36] In tracking this kind of technological proliferation, Professor Owen Cote of the Massachusetts Institute of Technology stated:[37]

> Fast, quiet nuclear submarines will remain the least vulnerable of all basing modes because antisubmarine warfare is least affected by the technical trends that will potentially transform other warfare areas. Thus, ASW against modern nuclear submarines will remain both extremely demanding technically, very expensive, and still a largely fruitless endeavor.

Beyond the clear advantages provided by the covertness and assured access of submarines, it is likely that stealth will continue to provide a capability edge to surface warships and aircraft of all types owing to inherent enhanced survivability. Like nuclear submarines, stealthy aircraft were also very costly to design and procure – a factor suggesting why these weapon systems have not been used against U.S. or coalition forces. The very success of these transformational weapons, however, assures us that determined potential adversaries will seek the resources and expend effort to attempt to emulate these effective platforms or, more likely, seek ways to counter them.

Sustaining a Competitive Technological Advantage

In an uncertain and challenging security environment, this technical dominance will continue to be more, rather than less, important. In the previous paper, Jasper Welch argued convincingly that the nation's Overall Educational System is inadequate to ensure a competitive advantage in science and engineering, and Bert Fowler and Bob Haffa will subsequently discuss their concerns for the defense industry, particularly in the realm of innovation. Is the U.S. also losing its technological edge?[38] A recent

[33] There has long been a symbiotic relationship between submariners and SOF, which has gotten only stronger as the submarine proves to be the delivery and extraction platform of choice along troubled littorals. With increased emphasis on SOF to achieve operational objectives without the huge footprint, political baggage and logistics tail associated with conventional ground forces, this relationship continues to grow. See James H. Patton, Jr., "Subs and SOF: The Odd Couple," forthcoming.

[34] Those who would say that manned or unmanned aircraft and space-based sensors can better provide these same services don't understand either the physics or the realities of the problem. Any *overt* monitoring of an action significantly affects what is observed, and additional artificialities and unknowns are injected when such monitoring is only periodic and transitory, such as is the case with orbiting satellites. Real information and intent is *only* obtained when such monitoring is covert and persistent. One should not be surprised that these benefits extend into engagements conducted in the "War on Drugs" as well as the Global War on Terror.

[35] With a demonstrated ability to quickly transform in order to execute several different most-important missions during its 3-decade plus lifetime, the modern nuclear submarine could almost be viewed as a "Battle Group of One", to alter a recruiting phrase from the Army.

[36] See Barry Posen, "Command of the Commons," *International Security*, Volume 28, Issue 1, Summer 2003. Professor Posen's basic theme is that it is incumbent on the United States to guarantee the unfettered use of the sea, air, and space "commons."

[37] Dr. Owen R. Cote, Jr., "The Future of Naval Aviation," Massachusetts Institute of Technology Security Studies Program report, 2005.

[38] See Robert Kavetsky and Christopher McCook, "The Technological Perfect Storm." U.S. Naval Institute *Proceedings*, October 2006, pp. 48-52.

report from the Task Force on the Future of American Innovation advised President Bush that "The United States is investing too little for the new global strategic environment. Research in physics, mathematics, computer sciences and engineering is the basis of military transformation. A robust research portfolio is a necessary part of a national security strategy."[39] To be the dominant military power, a state must lead in military technology. To lead in military technology a state must be its developer – meaning, it must fund development and employ the intellectual capital that produces innovation, either directly or indirectly through contracting. Purchasing technology, no matter how cutting-edge, is not enough to make a state the technological leader.

There is no area of military expertise where the need for a competitive military advantage is more pronounced than in the naval sector, since concept-to-hardware for ships is longer than in fielding other military capabilities.[40] There is a historical and powerful correlation indicating that the dominant naval power has also been the dominant economic power.[41] Every reason exists for the current primary economic power to maintain its position of primacy by investing in the resources that will keep its fleet beyond challenge by other "island nations"[42] depending on open sea lanes of communication (SLOCs). A robust fleet of nuclear-powered attack submarines and the investment to maintain it are the *sine qua non* of any dominant maritime strategy.[43] The submarine as a case study can also lead us in the direction for future investments in other areas of military power. Some of my previous work has established the analogies between stealthy submarines and stealthy aircraft,[44] and it is useful to consider the properties that make the stealthy submarine so valuable in a range of potential military scenarios in considering whether they are worth the cost of sustaining that advantage.

For example, four times during the 20th century submarines and the people that operated them managed to quickly and effectively transition from an existing "most important mission" to entirely different one. These include the shifts from coastal defense to fleet scouting in the 1930s, from fleet scouting to commerce interdiction in the 1940s, from commerce interdiction to Anti-Submarine Warfare in the 1950s, and from ASW to land attack in the 1980/90s. Most submarines and submariners accomplished these transitions through relatively minor adjustments in training and equipment. In the last analysis, these adaptations were enabled by the inherent stealth of the platforms along with superb engineering and attention to "space and weight reserved" considerations early in their design phase. As we invest in new technologies, platforms, and architectures, we would be wise to keep in mind the need to reserve a place for unseen requirements and capabilities.

When considering the value of cost combined with the value of unsurpassable capability, a number of technologies stand out as warranting considerable investment. Advancements in these areas show the most promise for achieving new technological heights, while their cost likely will prohibit proliferation among adversaries. Some of these technologies include:

Unmanned Ground, Air and Sea (Including Undersea) Systems

A major thrust within the submarine community is to further leverage the inherent mobility and endurance of a nuclear submarine by employing it as a platform from which to operate any number of autonomous vehicles thereby exploiting another of the United States' "long suits" – that of robotics. There is no reason why this approach can't be adopted for other purposes, with long-range

[39] Task Force on the Future of American Innovation, "Measuring the Moment: Innovation, National Security, and Economic Competitiveness," http://futureofinnovation.org/2006report/.

[40] See RADM William J. Holland, Jr. USN (ret), "The Fleet: Low Profile Today, Vital Tomorrow", Naval Institute *Proceedings*, May 2006, pp. 52-57.

[41] As noted in a presentation by VADM J. Guy Reynolds, USN (ret), the President of the Naval Submarine League during the 2006 Submarine Technology Symposium at the Johns Hopkins Applied Physics Laboratory, Laurel, MD.

[42] A workable definition of an "island nation" in today's world, Clausewitz and Mahan aside, is one who is or has become economically *dependent* on the broad oceans for either a source of raw materials or access to markets for its manufactured goods. By both of these measures, China has become an island nation, and has every strategic reason for building a powerful navy.

[43] Air-Independent-Propulsion (AIP) non-nuclear submarines might initially appear to the uninitiated to be a less costly way to obtain a "good enough" capability in this area. However, since their AIP capability is rapidly consumed at anything but very slow speeds, they represent in fact a marvelous regional and defensive capability, but not one providing global maritime influence – a conclusion equally reached by the United Kingdom and France, both of which have "cashiered" their non-nuclear submarines.

[44] See, for example, Robert P. Haffa Jr. and James H. Patton Jr., "Analogues of Stealth," Northrop Grumman Analysis Center Papers, June 2002.

bombers acting as "mother ships" for a fleet of unmanned combat air vehicles. These vehicles can be distributed among land, sea and space areas.

Directed Energy

Extending nuclear and new electrical power systems to the U.S. fleet will provide the opportunity for electrical power production that can support directed energy applications. New aircraft propulsion systems, such as the "lift-fan" engine in the F-35 Joint Strike Fighter may offer similar capabilities. A "Manhattan Project" level of effort may be needed to ensure that the United States is the first to develop and deploy workable directed energy (DE) weapons for, first defensive, then offensive employment across the battlespace. There has been recent interest in the application of DE technologies to precision attack, missile defense, homeland security and non-lethal weapons.[45]

Space-based Systems

The recently published U.S. National Space Policy (NSP) provides the guidelines for increasing investment to maintain a competitive advantage in space-based systems.[46] If the U.S. is to pursue the goal of space superiority as vigorously as it does air or maritime superiority, the key lies first in space situational awareness as a critical enabling capability for space control. According to the NSP, the United States "must take those actions necessary to protect its space capabilities, respond to interference, and deny... space capabilities hostile to U.S. national interests."[47]

The difficulty in prescribing funding priorities for the long-term maintenance of our military's competitive advantage in the world lies in our inability to predict precisely what threats our forces will face in the future or what unimaginable technologies may emerge. The costs of certain high-end capabilities will attract scrutiny by our leaders, as rightly they should. As one looks across a range of future security scenarios, however, a few key technologies emerge with cross-cutting capabilities and applications essential to sustaining a competitive advantage for the nation's defense. It behooves the nation to start leveraging the principle of the "value of cost" within these strategic arenas.

[45] See Memorandum for Chairman, Defense Science Board, subject: Terms of Reference, Task Force on DE Weapons Systems and Technology Applications. Washington, D.C., The Undersecretary of Defense for Acquisition, Technology and Logistics, October 30, 2006. Also see Richard J. Dunn, III. "Operational Implications of Laser Weapons," Northrop Grumman Analysis Center Papers, September 205

[46] The National Space Policy was declared in a Presidential Memorandum on August 31, 2006. See www.ostp.gov.

[47] Ibid.

Sustaining a Competitive Advantage for the Nation's Defense

Part 3: Defense Acquisition Reform, or "Getting More for Our Money"

by Charles A. "Bert" Fowler

It is clearly desirable that the United States maintains a competitive advantage in this uncertain security environment. And if sustaining our competitive edge depends significantly on advanced technology, as Jim Patton argues in the previous paper, then it is crucial that our nation continue to lead in basic science and maintain a strong engineering capability.

To maintain its technological edge, the U.S. military draws on engineering advances derived from basic science. Ideally this would be supported by strong federal support of basic research, an education system with a strong emphasis on mathematics, the sciences and engineering, and an environment that encourages scholarship, innovation and appropriate relevant investments.[48] Jasper Welch addressed the problems with education in the first paper. In the area of basic scientific research, U.S. funding has fallen behind other spending priorities. Even DoD has focused more heavily on engineering design and prototype testing than on basic science. Further, as documented in the previously referenced Augustine report, there has been an alarming decline in the number of people entering the sciences and engineering.[49] This is worrisome because a strong technical foundation is necessary for achieving a highly capable military force.[50]

Unfortunately, the U.S. investment in basic science has not kept up with the growth of our GDP and, as a consequence, the threat of being overtaken in education, technology and innovation has grown substantially.[51] As Figure 2 highlights, the once prominent role the federal government held in research and development has diminished considerably over the years. To make up for these shortfalls, one might hope that the Department of Defense would grant a higher priority to funding for Research & Development (R&D). But current budget realities make it unlikely that there will be a significant increase sufficient to sustain and advance our competitive edge. Therefore, the defense community must find the money from within a flattening DoD budget.

Forecasts for DoD investment in R&D are not encouraging, as they fail to show adequate growth to sustain new basic science expenditures. Moreover, there is no evidence to suggest that the forward-looking science and technology (S&T) investments —basic and applied research as well as technology development—will receive any increased focus.

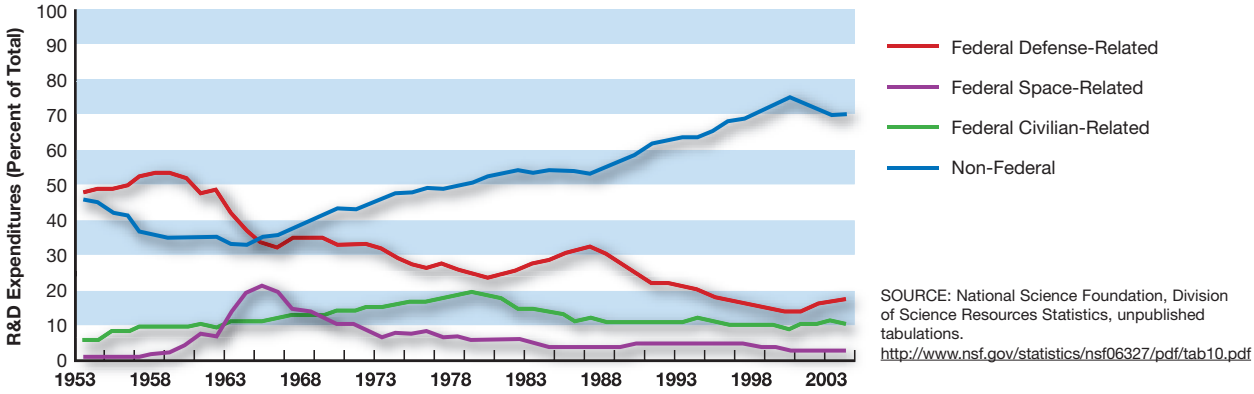
[48] It is important to note that the bulk of the DoD RDT&E budget is devoted to engineering design and test of prototypes in new systems. With the exception of DARPA, that budget contains little basic science, which remains dependent on non-DoD funding.

[49] National Academy of Sciences, "Rising Above the Gathering Storm," www.national-academies.org.

[50] See Robert Paarlberg, "Knowledge as Power," *International Security*, Summer 2004, pp. 122-151.

[51] See President of the National Academy of Engineering Dr. Bill Wulf's letter to the Academy's members in his July 2006 newsletter warning of China's commitment to engineering education and innovation.

Figure 2. Federal and Non-federal Research and Development Expenditures as a Percentage of Total Research and Development: 1953-2004.



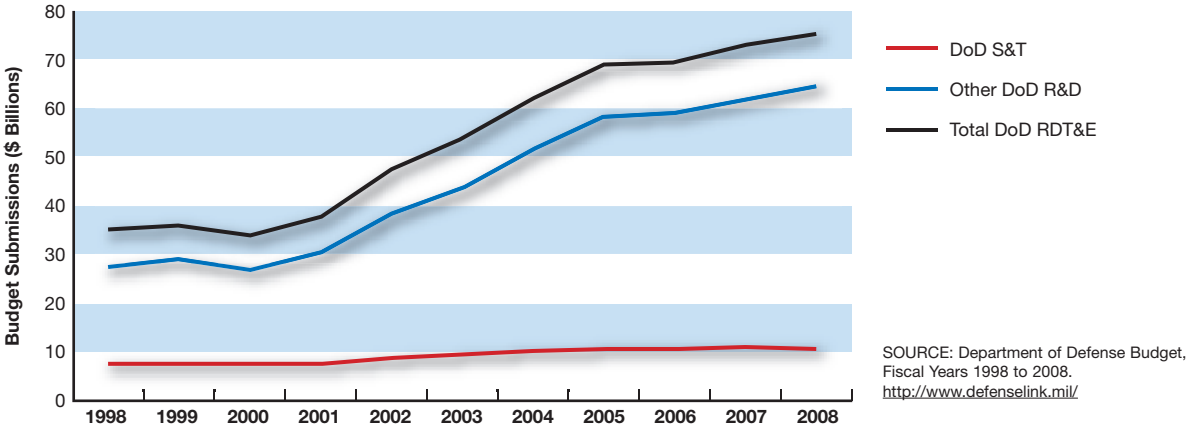
SOURCE: National Science Foundation, Division of Science Resources Statistics, unpublished tabulations.
http://www.nsf.gov/statistics/nsf06327/pdf/tab10.pdf

As noted in Figure 3, a decadal review of annual DoD R&D budgets illustrates that S&T funding levels have remained static while remaining R&D has been granted an equal pace with whatever modest growth in budget there has been.

We can also expect to see continued pressures weighing against defense budget growth given public concerns over the longer-term budget and balance-of-trade deficits, as well as the many non-military claims on the discretionary federal budget. There also are questions about whether a focus on near-term counterinsurgency operations will drain funds from the longer, high-technology competition that lies ahead. And while the 2006 *Quadrennial Defense Review* emphasizes capabilities to counter terrorists and insurgents in complex irregular warfare that might spin off into longer-term advantages, the voting public seems to realize that dealing with this threat requires political, social, economic and cultural change to win "hearts and minds"—involving, but not depending solely on, military operations.[52]

These budgetary realities leave the Defense Department with a substantial problem, but not a hopeless one. It must make science and engineering a priority, and it must fund these areas appropriately. The situation may prove fortuitous, as it may provide the impetus the defense community needs to implement reforms to its muddled program

Figure 3. Comparison of DOD S&T and other R&D Budget Submissions: Fiscal Years 1998-2008. DOD Research, Development, Test, and Evaluation (RDT&E) sub-divisions consist of seven activity areas, the first three being "science and technology" (S&T) spending—6.1 Basic Research, 6.2 Applied Research, and 6.3 Advanced Technology Development—and the last four being 6.4 Demonstration and Validation, 6.5 Engineering and Manufacturing, 6.6 Management and Support, and 6.7 Operational Systems Deployment. In billions of dollars.



SOURCE: Department of Defense Budget, Fiscal Years 1998 to 2008.
http://www.defenselink.mil/

[52] "Asymmetric Warfare: A Primer," by: C.A. "Bert" Fowler - IEEE Spectrum-On-Line http://www.spectrum.ieee.org/print/3091

selection and acquisition systems. More efficient processes and cost-effective programs will make more money available for basic research.

If the goal is to get more for our Defense acquisition dollar, there are two principal places to look: The first is deciding what to buy and the second is how to go about buying it.

Over my many years of dealing with the Defense Department from a number of perspectives, I have become convinced that if the goal is to get more for our Defense acquisition dollar, there are two principal places to look: The first is deciding what to buy and the second is how to go about buying it. Deciding what to buy is heavily influenced by budget "turf" battles among the individual armed services. Once that is sorted out— far too often in favor of redundancy—the antiquated defense acquisition system too frequently results in programs that cost more than they should, are inefficiently managed, and fail to deliver the best bang for the buck. That leaves plenty of room for improvement.

Deciding What To Buy

The problem of deciding what to buy starts with a "requirements" process that leads to over-specification and an overly rigid approach to system development followed by an illogical decision process for determining what to acquire. But the DoD acquisition system has not always been so cumbersome. When Robert McNamara became Secretary of Defense in 1961, he created a "Systems Analysis" (SA) office with the purpose of analyzing each requirement from a systems perspective, examining the military capability provided for the estimated cost, and comparing it with other approaches supporting similar missions. In addition, the stature of the relatively new Defense Director of Research and Engineering (DDR&E) was then elevated to promote relevant technologies and review the technology required by service proposals. In those early days SA under Alain Enthoven and DDR&E under Harold Brown reviewed each proposed program to avoid needless duplication and to promote cost-effective solutions. And the system worked—for a while.[53]

Before long, SA started inventing its own programs and, instead of acting as detached analyzers, those in the Systems Analysis shop became as ardent in promoting SA proposals as the armed services were in promoting theirs. Even so, SA continued to challenge each program and DDR&E worked with the Services to assure the soundness of programs with generally good results throughout the 1960s and 1970s. Although far from perfect (SA was probably the most reviled organization in DoD history because it challenged service roles, missions, budgets and autonomy), the operation was sufficiently effective that not-needed and poorly-conceived programs (the B-70, Skybolt and the Nuclear Powered Aircraft) were cancelled.

However, over time, Systems Analysis lost its clout as well as its objectivity and devolved into Program Analysis and Evaluation (PA&E), which looked primarily at force structure. Over a longer period, both the capabilities and the influence of DDR&E declined. As a consequence, for many years DoD has lacked both the objective SA-like challenges to service requirements, as well as the DDR&E-like reviews and scrubbings of service programs. Whatever has been proposed has pretty much been approved. One can readily think of recent efforts in each service that would not in their current form have passed the challenges and reviews of the 1960s and 1970s. These days, you have to look very hard to find a cancelled program.

There's another acquisition disconnect that needs to be addressed. The 1986 Goldwater-Nichols reorganization bill assigned combat responsibility to the regional Combat Commanders (COCOMs, formerly regional Commanders-in Chief or CINCs) while the acquisition and training roles remained with the separate services. Ultimately, the DoD buys what the services desire, not necessarily what the COCOMs want and need. The Defense

[53] The best reference of those years remains Alain C. Enthoven and K. Wayne Smith, *How Much is Enough?*, New York: Harper Colophon Books, 1971.

Science Board (DSB, an advisory body for the Secretary of Defense) produced a series of efforts over many years chaired by Dr. Bob Hermann and General Larry Welch (USAF, Retired) addressing this issue and recommending a strengthened role for the COCOMs in determining where to invest.[54] However, few of the DSB recommendations have been implemented and the COCOMs (with the exception of SOCOM, granted by Congress its own acquisition budget) play relatively minor roles in prioritizing future major military investments—a serious barrier to matching resources with objectives.

Deciding How To Buy It

After approval, each program enters the DoD acquisition system where significant cost overruns and schedule delays are, unfortunately, the norm. For example, a recent Government Accountability Office (GAO) report noted cost overruns on 23 programs came to $23 billion and delays ranged from one to four years.[55] Another study documented that the Pentagon's acquisition budget has doubled since the "9/11" terrorist attacks, even though its major weapons development efforts expanded only from 71 to 80 programs during that same period.[56]

In the past, such major flaps have resulted in investigations and panels to delve into the cause of the problems. Internal DoD and/or Congressional reviews ensued. Almost every one of these reviews added another acquisition wicket to get through, another set of generally unneeded peripheral tasks, another layer of checks, meetings, and reports. Each addition was an intended improvement that in the long run generally just made things worse.[57] Each time one of these items is added to a contract, program cost and schedule increase and the number of people on the government and contractor sides increases. Many of us unwittingly "helped" in this process. Whoever said, "Today's problems were yesterday's solutions," had it right.

The result of all this is a system that has "grown like Topsy"—resulting in an incredibly complex and grossly inefficient acquisition process. A typical contract contains a few items relating to the capability and delivery of the end item. But far more items, called CDRLs (Contract Data Requirements Lists), are also required as a result of past attempts to fix the system.[58] Often when a new "fix," such as Reliability, Maintainability, Availability criteria (the old "RMA" acronym better known as the "ilities"); or Operational Test and Evaluation (OT&E) requirements, among others, is added, a cult is born. Before long a national organization is established, officers are elected, conferences are held, a magazine is published, awards are given, and, over time, the original purpose fades and the "fix" becomes an end unto itself. By the way, these cults can endure: The RMA society held its 50th Anniversary conference last year. The attention paid to these new requirements, not surprisingly, raises the cost of acquisitions and takes much longer to deliver than originally intended. A major disadvantage of lengthening the acquisition schedule is that some of the early designs, especially electronic portions, become obsolete during this period and must be redesigned, thus adding to total program costs. For example, the Air Force top fighter aircraft, the F-22, was fielded in 2005 with the equivalent of a 1980s-vintage "386" computer processor because the electronic design for the aircraft was frozen early in its two-decade long development. Now the Air Force faces a problem of "diminished manufacturer supply" because no one makes those chips anymore.

Here's another outrageous example of the impact these peripheral specifications can have on a program. The Joint STARS system (a modified 707 aircraft) is made up of airborne radar that can detect and track moving ground targets, and appropriate displays providing U.S. air and ground forces a

[54] 2003 DSB Report on "Enabling Joint Force Capabilities" and the DSB 2005 Summer Study on "Transformation: A Progress Assessment" (Volumes I & II).

[55] "Pentagon Struggles with Cost Overruns and Delays," *The New York Times*, July 11, 2006, http://www.nytimes.com/2006/07/11/business/11overruns.html?ex=1183867200&en=c15393ecfa49249e&ei=5070.

[56] "Defense Buying Costs Doubled Since 9/11, with few new weapons added," *Inside the Pentagon*, August 17, 2006, p. 1.

[57] The classic argument that such added bureaucratic layers are counterproductive is contained in Ed Luttwak's "Why we need more Fraud, Waste and Mismanagement in the Pentagon," *Commentary* 73 (February 1982), pp. 17-30. But, those battling the system are still at it. Senate Democrats recently unveiled a bill targeting alleged defense contracting waste, fraud and abuse, and the DoD responded with a Defense Acquisition Transformation Report. See "House passes contracting reform bill," *Aerospace Daily*, March 16, 2007, p. 3.

[58] The CDRL defines the data to be delivered to the government by the contractor tailored to the offeror's proposed design solution. Its purpose is to provide a standardized method of delineating the government's minimum essential data needs. See the Acquisition Community Connection website at https://acc.dau.mil.

picture of the enemy force disposition and actions. It is a truly transformational capability.[59]

On January 12, 1991, the two developmental Joint STARS aircraft—that is, the aircraft had not yet reached official initial operational capability (IOC)—arrived in Saudi Arabia and two days later began flying combat sorties in *Desert Storm*. Time and again Joint STARS provided essential timely and reliable enemy ground order of battle and targeting information to *Desert Storm* coalition forces. The aircraft flew every day during the war, flying 49 combat sorties and logging over 535 hours between the two aircraft.[60]

At the conclusion of *Desert Storm* General Schwarzkopf and his staff described Joint STARS as an "unqualified success" and the Air Force Chief of Staff announced that the United States Air Force would never go to war again without Joint STARS. Now that's the good news. The bad news is Joint STARS then went back into our standard acquisition system in pursuit of reaching IOC. As part of the process, Joint STARS reentered that Serbonian bog otherwise known as OT&E, where several hundred government and support contractors pored over the system for several years, apparently to convert it from an "unqualified" success to a "qualified" success! After considerable added effort and expense, Joint STARS reached that milestone six years later when IOC was officially declared.

Once in a great while, a program is carried out very efficiently delivering an important new capability in a reasonable time. Examples include the early spy satellites, the Polaris ballistic missile submarine, and the F-117 stealth fighter.[61] These were done outside the formal acquisition system, were heavily classified and, therefore, the program costs were not always transparent. Nevertheless, they are appropriately looked upon as models for achieving important new capabilities in a timely way at a reasonable cost. When "black" programs like the B-2 advanced technology bomber and F-22 advanced tactical fighter were saddled with the standard DoD procurement model, complete with bureaucratic red tape and high security costs, however, the resulting "sticker shock," led to criticism and cuts.

The current acquisition process is outmoded, too expensive, too lengthy, and should be replaced.

There have been efforts aimed at making fundamental changes to the acquisition system. Several DSB studies[62] in the mid-1990s contained such recommendations, but few were implemented. Occasionally some individual gets sufficiently upset with a system that seems to deliver so little capability for so much money and so much time that he offers his own solution. There have been many such efforts, but the one I am most familiar with is my own: "The Defense Acquisition System: Too Late for the Scalpel; Bring out the Meataxe!"[63] As the title indicates, the system has grown in complexity and inefficiency to the point that it can't be fixed by modification. The 1996 Phase III DSB Report supported this view: "The current acquisition process is outmoded, too expensive, too lengthy, and should be replaced." I have learned in some 40 years of advisory committee service that polite recommendations, if read at all, are reinterpreted and watered down by the group receiving the advice. Consequently, my recommendations are blunt and unambiguous. Here they are again:

Recommendations for Fixing the DoD Acquisition System

- Adopt the "Fieldable Brassboard/Prototype" approach as the standard approach for most weapon system developments. This will help offset much of

[59] See Richard Dunn, Price Bingham and C.A. Fowler, "Ground Moving Target Indicator Radar and the Transformation of U.S. Warfighting," Northrop Grumman Analysis Center Papers, February 2004.

[60] Ibid.

[61] For a reminder of the Polaris program see Norman Polmar, "Polaris—A True Revolution," Naval Institute *Proceedings*, June 2006. On the F-117 see Ben Rich and Leo Janos, *Skunk Works*, New York, Little Brown, 1994.

[62] DSB Task Force on Defense Acquisition Reform – Phase I, July 1993; Phase II, August 1994; Phase III, May1996; Phase IV, July 1999.

[63] "The Defense Acquisition System: Too Late for the Scalpel; Bring out the Meataxe!", *IEEE SPECTRUM*, October, 1994.

the problems with "concurrency"—developing technology while both the platform and the technology are maturing—and the tendency to "buy before fly."

- Continue the close interaction of the technical and operational communities. This will come about in part as a result of the point above, but must be expanded to include technical cadres in each Combatant Command.
- Outlaw "BAFO" as a technique used to achieve the lowest (and most unattainable) price-to-win. Many years ago, some naïve program manager or contracting officer decided program costs could be reduced by having a bidding war at the end of the competitive period. After the bids were received, each bidder was asked for his "Best And Final Offer" or BAFO. I once described the BAFO process this way: "Now comes the time when grown men gather in a room in each company and spend their time not trying to decide on what the cost would really be, but trying to guess what the grown men in the other rooms are going to do." Sometimes an overly ambitious program manager or contracting officer will find reasons to do this more than once and end up with a request for a "Best And Really Final Offer" or BARFO!
- Eliminate all the peripheral items (the "ilities"—maintainability, reliability and the detailed cost data in their support) and their specifications (specs) from DOD Requests for Proposal (RFPs) and contracts and abolish the groups that wrote them. Deputy Defense Secretary Dave Packard pointed out when dealing with this issue in 1970 that if one didn't abolish the writers the specs would be back in some other form before you knew it. There needs to be an edict banning such from all new RFPs, and Special Project Offices (SPOs, the organizations chartered to lead a system acquisition within the services) should be given three months to negotiate them out of ongoing contracts.
- Reduce the size of the SPOs and their support contractors by a factor of at least five. The large majority of these people deal with the peripherals and with the peripherals gone they are not needed.

The impact of my paper was accurately predicted by Norm Augustine: "Watching the DoD respond to Fowler's suggestions is like watching a python swallow a pig." I presume Norm meant it was slow and painful—much like the acquisition reform process itself. Despite the waving of red flags by many experienced defense experts, the system has remained largely resistant to reform.

Why Is Reforming Defense Acquisition So Hard To Do?

Essentially, the weapons acquisition system has been structured to try to eliminate all risk. Layers of procedures must be followed, checked by another group, then rechecked by yet another. In most cases the program director doesn't have control over what happens, but by following all the rules he is fairly isolated from criticism. Furthermore, these serial actions taking years to accomplish almost guarantee that he'll be reassigned before any real problem created on his watch shows up. And who can blame him (or her) for being cautious what with the Inspector General, the Government Accountability Office (GAO), the media, and the losing contractors all waiting in the wings to criticize, protest, or recommend prosecution. So there is no incentive for the services to change the way they acquire things. These endless procedures reduce the risk to the program directors but not to the programs.[64]

Might the defense industry help? A quick and unofficial survey of top-level executives in the defense industry finds a generally shared opinion that the system is far too risk-averse, and that incentives for innovation are in short supply. Unfortunately, despite a wealth of opportunity, talent, and good ideas in the American defense industry, neither the customer nor Wall Street offers much incentive for innovation or risk taking. Of course, all those specifications also protect the contractor, and getting out front on this issue would risk offending the customer. And, owing to the way contracts are structured, engineering change proposals, more time, and more people all add something to the bottom line, to keeping the competition off the field, and to the ability to compete for additional work.[65]

[64] There has been a great deal of work done on cost risk analysis. For an excellent overview of general risk analysis see Mark V. Arena, et al., *Impossible Certainty: Cost Risk Analysis for Air Force Systems*, Santa Monica: RAND 2006, pp. 1-15. This area has also proved strong in the field of institution building, as evidenced by the DoD Cost Analysis Symposium, the Society of Cost Estimation and Analysis, the International Society for Parametric Analysts and, of course, the Defense Acquisition University.

[65] The move toward "Firm, fixed-price" contracts probably won't help owing to the nature of the thousands of design changes in the production of a weapons system that cannot be anticipated by customer or contractor. For example, in the design and production of the LHD amphibious assault ship program for the U.S. Marine Corps, the contractor experienced over 5700 customer requested design changes between the first and second ships, and an average of 3500 changes per hull after that.

One might think that the warfighting community would demand change. After all, they are the ones who are being shortchanged. One reason they don't is that the money keeps flowing to the services and they dare not stand in the way. Another reason is that serving officers in the Office of the Secretary of Defense, on the Joint Staff, or out there with the COCOMs know they will likely go back to their parent service and they don't want to be seen as unpromotable pariahs because they opposed a Service priority. Until the major regional Combat Commanders are empowered with budget authority, this is unlikely to change.

But we continue to try. One recent effort has been the establishment of the "joint capabilities integration and development system"—JCIDS, for short.[66] The purpose of this effort is to encourage joint thinking and action in the acquisition of weapons systems, and to eliminate the redundancies that exist when separate Services pursue similar objectives in different ways. In other words, JCIDS is another attempt at installing some top-down "Systems Analysis" rationality over Pentagon programs. The Pentagon has also claimed that it is reasserting its lead role in acquisition through the Joint Requirements Oversight Council (JROC) meant to ensure that programs meet more than single-Service priorities. The rationale is valid and the effort laudable, but the power of the Services remains pretty much untouched. Without the "power of the purse," any new organization will lack clout.

In the meantime, for the United States to take advantage of its educational advantage and technological prowess, it needs to focus on implementation, rapid fielding of needed capabilities to the field, and prudent design and development of weapons systems preserving a competitive edge in the long term. Time is of the essence, and the nation needs leadership at the highest levels in our federal government and military to overcome the cultural obstacles and practical difficulties to making institutional changes. There are several key steps that could go far in making this happen:

The United States needs to focus on implementation, rapid fielding of needed capabilities to the field, and prudent design and development of weapons systems preserving a competitive edge.

- The Combat Commanders should be given a key role in the decisions regarding major acquisitions. This may call for Title 10 authority in the COCOMs—particularly to aid in a quick reaction capability that gets needed technology to the field on time and circumvents the service-centric acquisition bureaucracy. Another way to effect this change would be for OSD to withhold some percentage of each service budget and allocate those funds to meet programs underwriting the COCOM's integrated priority lists.
- The Office of the Secretary of Defense should be reorganized to restore a "Systems Analysis" type office and to improve the capabilities and increase the authority of DDR&E.
- The DoD acquisition system should be totally redesigned along the lines of the suggestions made in the previous section. DoD should draw upon the nation's proven systems engineering capabilities to design a much more efficient and responsive system. A blue ribbon team should be established to do just that.

It will take a unified effort on the part of DoD, the armed forces, the Congress and defense industry to make these changes. But drastic improvements to the selection process and the acquisition system are DoD's most important needs. With such improvements the US can have a capable, affordable, high technology force that will build a formidable and sustainable competitive advantage for the future.

[66] See the unclassified Joint Staff J-7 briefing, "JCIDS Overview" 18 October 2004 and Sandra Erwin, "Pentagon Takes another Shot at Enforcing Joint Thinking," *National Defense*, August 2004, and the definition of JCIDS in Wikipedia, the free on-line encyclopedia.

Sustaining a Competitive Advantage for the Nation's Defense

Part 4: The Defense Industrial Base

by Robert P. Haffa, Jr.

To what degree does sustaining a competitive advantage for the nation's defense require some form of "transformation?" Had that word not become a bit overused by too frequent reference and ubiquitous application within the U.S. Department of Defense, it might have appeared more often in this set of papers. Surely Jasper Welch is arguing for a transformation of sorts in the Overall Education System to assure a skilled populace whose intellectual capital can be tapped to keep our nation on the leading edge of science and technology. Jim Patton emphasized the importance of technology—one of the essential components of transformation or a "revolution in military affairs"—in the long-term competition ahead of us. Bert Fowler turned his attention to another aspect of the RMA—organization—when he argued for a transformation in the way the Department of Defense chooses and acquires its assets and capabilities. What about the defense industrial base? Is some form of transformation required here as well, or is the post-Cold War structure of industry well suited to meet the demands of an uncertain security environment?

This paper argues that the U.S. defense industrial base need not be "transformed," but it certainly deserves some attention from its government customer to assure it remains competitive. Specifically, I focus on two factors that often enter this debate: the globalization of the defense industrial base, and the ability of those industries to innovate at rates that sustain a competitive advantage over the long haul, while meeting the challenges of supporting the war on terrorism in the near term. Without the dual thrusts of global cooperation and internal innovation, the United States defense industrial base is at risk of falling behind in its efforts to assist our military forces in sustaining their competitive advantage. Where shortfalls exist, the U.S. government and defense industry must take steps to strengthen international cooperation and encourage innovation. To what degree are incentives required, or which policy levers might be pulled to ensure a level of innovation needed to meet the challenge of terrorism fueled by radical religious zeal, and also to dissuade, deter and defend against a more traditional and symmetric military threat?

This paper describes how the pace of globalization slowed after the terrorist attacks on the United States in 2001 and the subsequently declared "war on terrorism." It also offers commentary on the current state of innovation in the U.S. defense industry, with a specific focus on meeting the new challenges of conducting "complex irregular warfare" in an uncertain security environment.[67] Finally, I will suggest some steps toward achieving and sustaining a competitive advantage into the future for both traditional and irregular warfare. Those steps are based upon the premise that broadening globalization and encouraging innovation are prudent policy goals for that future.

[67] The best description of "complex irregular warfare" may be found in London: IISS, *The Military Balance*, 2005-2006, pp. 411-420.

Sustaining An Industrial Advantage: Globalization

It may come as a surprise to some readers that the 9/11 terrorist attacks on the United States and the subsequent declared war on terrorism slowed the pace of defense globalization that had swept through the post-Cold War defense industry. Despite generating new issues and arenas for cooperation, the war on terrorism created a climate of suspicion of all things "foreign." That climate stalled, rather than furthered, the movement toward a globalized defense industry. If the politico-military response to this global terrorist threat is to be multilateral in scope and innovative in approach, then this inhibition of defense globalization should be overcome.

My working definition of defense globalization has three aspects: a) government-sponsored and/or firm-led initiatives and activities; b) that are intended to encourage and exploit transnational production links and inputs of foreign resources; c) into the process of designing, developing, manufacturing and marketing military equipment.

"Globalization" as a concept is broadly defined as "an increasing international interdependence in all forms of social interaction" and has been bandied about in intellectual circles since the mid-1960s.[68] But it has achieved prominence as a factor in the U.S. defense industry only since the end of the Cold War. As a 1999 U.S. Defense Science Board (DSB) Task Force on Globalization and Security pointed out, that is principally because of four factors:[69]

- Deep cuts in the U.S. defense budget leading the U.S. defense industry to look overseas for new customers and markets;
- Commercial sector investment in high-technology R&D exceeding the DoD investment leading to new practices and products available to DoD;
- DoD acquisition reform allowing increased international licensing and defense trade; and,
- A shift in procurement emphasis from platforms to information technologies provided by a range of global suppliers.

The prevailing image of the U.S. defense industry in the late 1990s was that of an industry transforming itself into a more commercially oriented, globally involved enterprise. Facing a declining domestic customer base, a growing dependence on commercial information technologies to leverage its legacy platforms and systems, and diminished concern about weapons proliferation in what was perceived to be a less hostile world, U.S. defense firms began to consolidate domestically and integrate internationally. The potential benefits of such consolidation and integration included new markets and suppliers, shorter acquisition cycle times, enhanced competition spawning innovation, and lower costs. The prevailing thinking was that, not only would international defense links result in greater allied interoperability through technology transfer, but also they would strengthen political and economic cohesion across the globe.

As Keith Hayward has pointed out, globalization was a significant departure from the defense complexes that the industrial nations of the world had developed and sustained during the Cold War.[70] During that era defense industry capabilities were protected as national proprietary interests and seen as important guarantors of sovereignty. Compared to the imperatives for providing the best military capabilities, implementing commercial competencies or practices into defense acquisition and production was rarely a serious consideration. Indeed, large, diversified American companies kept their sectors conducting defense business with the government separate from their commercial enterprises. And, through most of the Cold War, the government provided the majority of technological research

[68] Held, McGrew, Goldblatt and Perraton, *Global Transformations*, Stanford University Press, 1999, p.1. See also Christopher Coker, "Globalisation and Insecurity in the Twenty-first Century: NATO and the Management of Risk," London: IISS, Adelphi Paper 345, 2002 and Pierre Chao, "The Future of the U.S. Industrial Base: National Security Implications of a Globalized World," in Thompson and Ronis, Op. cit.

[69] Office of the Undersecretary of Defense for Acquisition and Technology: *Final Report of the Defense Science Board Task Force on Globalization and Security*, Washington, D.C.: December 1999, p.i.

[70] Keith Hayward, "The Globalization of Defense Industries," *Survival*, Vol. 43, No. 2 (Summer, 2001) p. 117. Others have characterized the Cold War as an historic anomaly during which political decisions, rather than commercial market forces, drove the global defense industry. Thus, post-Cold War defense globalization can be seen as a return to normalcy. See http://www.cia.gov/nic/pubs/research_supported_by_nic/battilega/transformations_summary.htm. Another perspective was offered by Joseph Nye, who argued that the post-Cold War period might be characterized as "military de-globalization," but Nye was referring to a lack of international consensus on the use of force, not to growing international defense cooperation and trade. See "Military Deglobalization," *Foreign Policy*, January/February 2001, pp. 82-83.

and development funding in defense-related areas. Thus, across the American economy, the majority of technologies that were transferred between the two sectors took the form of defense technologies being spun-off to civilian uses and markets.

Owing to the factors identified by the DSB, much of that changed in the post-Cold War world. The pace of consolidation, integration and globalization of the defense industry accelerated its pursuit of more affordable and effective products. Compressed defense budgets were another impetus for seeking streamlined business processes and economies of scale. The defense industry principally led this acceleration of globalization, resulting in considerable mergers and acquisitions of defense firms within national boundaries at the prime level, coupled with greater participation of multinational companies and the commercial sector further down the supply chain.[71] Although the DSB noted that the concept of direct foreign investment in the U.S. defense industry was "antithetical to traditional defense industrial base concepts,"[72] the U.S. government appeared willing to accept globalized supply chains and the use of commercially developed technology as inevitable and necessary supplements to a contracting defense industry.

The emergence of a globalized defense industry altered the paradigm of a captive U.S. defense industry and provided challenges and opportunities for sustaining a competitive military advantage. The 1999 DSB found that, from a U.S. military standpoint, globalization's most profound effect was the worldwide proliferation of militarily useful technologies and capabilities. Of particular concern were those that would enable U.S. adversaries to deny American and allied forces ready access to a region of conflict. To be sure, this challenge arose more from the globalization of non-U.S. firms in the international defense market rather than from the business done by U.S. defense companies, primarily owing to U.S. export restrictions on the initial and secondary transfer of military wares and know-how. Regardless, the challenge posed by proliferation, the DSB argued, would require a fundamentally different approach to maintaining military superiority. Instead of protecting individual military technologies— judged infeasible on a large scale in a globalized information-rich environment—the DSB concluded that DoD should focus instead on developing and preserving those capabilities that would provide the U.S. military with an enduring advantage in the face of proliferating technologies and the resulting operational challenges.[73]

Globalization of the U.S. defense industry also helped make a virtue out of necessity. For example, coupled with the sheer economic advantages of new markets and new partners were the geopolitical changes affecting NATO. The alliance's focus was shifting from a singular concentration on Europe's territorial defense to broader security strategies encompassing out-of-area crisis response and peacetime engagement. This alteration in strategic attention called for greater reliance on coalition operations and a "network-centric" approach to the command and control of joint and combined military forces. Both trends increasingly depended on a "transformation" composed of new technology, agile organizations and force structure, and innovative concepts of operations. Specifically, these shifts have, over the last several years, generated renewed allied interest in U.S. capabilities in communication, command and control, intelligence, surveillance and reconnaissance.[74]

This common strategic vision among NATO members also promised increased international cooperation in defense. Therefore, U.S. defense companies busied themselves pursuing strategic alliances, mergers and acquisitions to ensure the necessary resources, technologies and competencies to compete for first-tier development and production contracts supporting the U.S. DoD. The emerging "system-of-systems" concept and demands for interoperability have partly driven the ability to move these skills and competencies from one capability area to another. Only the perceived inevitability of globalization surpassed the implications of globalization for American defense industries. Then came September 11.

[71] *Hayward*, p.118.

[72] DSB Task Force on Globalization and Security, p. 11

[73] *Final Report of the Defense Science Board*, pp. vi-vii.

[74] See Paul T. Mitchell, "Network-Centric Warfare: Coalition Operations in the age of US military primacy," London: IISS, Adelphi Paper 385, 2006.

Scholarly security studies papers once began with that obligatory phrase "the Cold War is over." No longer. They now start from the premise that a new war, the war on terrorism (or on its causes and radical religious perpetrators) has begun. This war, as Kurt Campbell states, is "the first major conflict to occur in the age of globalization."[75] Campbell asked, "What will happen when the logic of globalization collides with the consuming passions of a global conflict?" A quick answer is that globalization has slowed down. If "trade follows the flag," we might expect that trade would slow when the flag is retrenched and, in some cases, reviled.

Initial arguments advanced the proposition that terrorist attacks would slow the global economy. Outlining the economic costs of business anxieties caused by the threat of terrorism, former Federal Reserve Chairman Alan Greenspan noted "that the cost of capital is rising as investors demand higher returns to account for bigger risks."[76] The economic benefits of globalization—lowered prices, enhanced productivity, enlarged markets and widening pools of technical talent— diminished considerably as governments and firms imposed costly security measures and hedged their cross-border connectivity. Speculation also had the American economy, dependent for growth on global trade, suffering from slowdowns and protectionist measures in Europe and Japan.[77] It seemed reasonable to assume that if defense firms had profited from the rising tide of a globalized economy, a receding global economic tide would lower all boats, even those dedicated principally to supplying the military forces charged with combating terrorism.

To appreciate how globalization in the defense industry has changed post 9/11, it is worth revisiting the four factors the 1999 DSB task force presented as those most responsible for the internationalization of the U.S. defense industrial base. The first factor, the post-Cold War cuts in the U.S. defense budget, is the most telling. After September 11 the U.S. defense budget began a sustained rise matching the buildups of the Vietnam and Reagan eras.[78] Accordingly, defense spending trends shifted away from globalization as the U.S. defense market returned to a period of dominance.[79] Jumps in U.S. procurement and R&D spending dampened the need for U.S. defense firms to look for overseas customers, and the size and strength of U.S. defense spending caught the interest of European and other international defense firms seeking their share of the expanding budgetary pie.[80]

The three additional factors listed by the DSB as prompting defense globalization also retreated in effect. Commercial sector high-tech R&D investment was already declining after the "new economy" bubble burst, and fears of terrorism and war further weakened that sector while emphasizing the importance of secure, rather than open information architectures. Movement toward liberalizing export controls to allow an increased flow of defense goods and technologies also slowed as licenses were subjected to greater scrutiny. Placing proposed export control reforms on hold within the State Department's Office of Defense Trade Controls owing to a concern over the 9/11 attacks and the anthrax-tainted letters sent to U.S. government facilities was another example of this concern.[81] A longer-lasting trend seems to be the general tightening of export controls to strengthen anti-proliferation measures controlling the flow of advanced militarily applicable technologies. Even the fourth factor, a spending shift from weapons and platforms to information technologies encountered a reversal, as DoD asked lawmakers for added procurement dollars to plus-up platforms, replenish munitions supplies, and reset a force badly in need of repair. Although it can be expected that defense will continue to fund information technologies, it

[75] Kurt M. Campbell, "Globalization at War," *The Washington Post*, October 22, 2001, p. A19.

[76] "What's at Stake: How Terrorism Threatens the Global Economy," *Business Week*, October 22, 2001, p. 34.

[77] "Attacks had hefty economic toll," *The New York Times*, November 3, 2001.

[78] The FY08 Defense budget submitted on February 5, 2007 was described as the highest level of spending since the height of the Korean War. "Record $622 billion budget requested for the Pentagon," *The New York Times*, February 4, 2007.

[79] Tom Enders, director of EADS' defense systems division was quoted as observing, "The United States will be the biggest [defense] market for the next 50 years." *The Economist*, October 6, 2001, p. 57.

[80] Here a test case may be the future of the European Military Aircraft Company (EMAC) given the apparent collapse of the proposed alliance between EADS and Italy's Finmeccanica SpA. See "Alliance Plan Fades," *Defense News*, November 5-11, 2001, p. 1, and "Italian Backtrack," *Aviation Week and Space Technology*, November 5, 2001, p. 17.

[81] See Harold Kennedy, "Export Control Reforms Stall in Aftermath of Terrorist Attacks," *National Defense*, December 2001.

is likely that arena will be far more American-centric and controlled, and much less international and commercial-off-the-shelf, than projected by the DSB in December 1999.[82]

As the United States, its global partners and defense industries adapt to heightened security measures and to the disruptions to global integration, trade and communication, the pace of defense globalization has clearly slowed. Kurt Campbell has suggested that one outcome might be some fundamental structural adjustments, similar to the response of the U.S. economy to the 1973 oil shocks, allowing globalization to recover its previous momentum. But Campbell also notes that "the advances of globalization"—free trade, rising productivity, ease of travel, and global consumer confidence—once lost, are very difficult to regain.[83]

Ironically, the prosecution of a war on terrorism that demands global cooperation is hampered by the call for stronger export controls.

Thus, the danger is that these shifts in the defense marketplace are delaying the advantages promised by greater defense cooperation and interdependence precisely when that leverage is badly needed. The rationale, strategic implications and benefits of defense globalization go well beyond economics. Indeed, it can be argued that the international political and military challenges of conducting a war on terrorism demand even greater cooperative measures—fostering cooperation on tracking and targeting terrorists, building capacity for countering terrorism, sharing technology and practice—than those driven primarily by economic forces before September 11.

While every major U.S. national security government agency acknowledges the need for allies and friends in support of conducting the global war on terrorism, a strict system of export licensing persists that exacerbates the slowing of globalization documented earlier. It leans so much toward containing risk that it inhibits opportunities for international defense cooperation. Ironically, the prosecution of a war on terrorism that demands global cooperation is hampered by the call for stronger export controls to keep sensitive military-use technologies out of the hands of radical terrorist groups. The road to reconciliation of these two opposing forces will require a close working partnership between government and industry.

Most would agree that U.S. arms export policies ought to be geared to the profoundly different security environment that characterizes today's threats and requirements for international cooperation when compared with the Cold War, when the issue was protecting technology transfer to a single great power. Today the challenge is to collaborate in technology projects with friends and allies who can advance security capabilities against a range of regular and irregular threats, stretch national defense budgets by leveraging others' capabilities and investments, and improve interoperability with allies and coalition partners. Such cooperation and competition fosters innovation as well—innovation that is lost when we fail to take advantage of international partnerships in pursuit of common security goals. Civil space cooperation provides a good example of the military applications that await: the James Webb space telescope relies on European partners for two of the four principal scientific instruments as well as the launch vehicle. The Cassini-Huygens mission to Saturn, a joint effort of NASA, the European Space Agency and the Italian Space Agency, involves the U.S. Air Force, the Department of Energy and academic and industrial participation from nineteen other countries.

[82] Contravening arguments can be made. For example, the anti-terrorism campaign has led to the removal of trade barriers and restrictions previously placed on several nations in exchange for their support.

[83] Campbell is referring to new lines of business innovation springing up around security services and technologies, much as the U.S. looked to greater fuel efficiencies and alternative fuel supply sources after the oil embargo. See Campbell, "Globalization's First War," *The Washington Quarterly*, 25:1, pp. 7-14, Winter 2002.

So what stands in the way of greater international cooperation in defense? One of the biggest obstacles surely is the U.S. State Department's administration as part of the International Traffic in Arms Regulations, or ITAR. Commercial space provides a reference. Since the State Department placed satellites of all types on its munitions list for export control in 1999, the U.S. share of the commercial spacecraft market declined from 83 to 50 percent, a decline largely attributed to a strict export control policy.[84] Many would-be international customers simply give up on attempting to do business with the U.S. because ITAR poses such a formidable barrier to defense trade. Clearly, the U.S. and its partners must pursue the all-important objective of keeping useful military technology out of the grasp of adversaries. But we must do this with rule sets that also allow and encourage collaboration with our friends and allies in joint developmental plans, joint economic ventures and bilateral and multilateral negotiated programs and agreements. A government-industry team must work together to drive new policies to facilitate, rather than inhibit, such endeavors.[85]

The tension existing between the push for globalization of defense capabilities to underwrite a global war on terrorism and the need to protect technologies and capabilities from landing in the arsenal of the enemy is reflected in the debate over reforming ITAR. From the U.S. government's perspective, the purpose of technology transfer restrictions is to sustain the global security regime. If there were a broader international consensus on the terrorist threat and the means needed to combat it, then some of those impediments to defense trade could be easily removed. Voices in the European defense industry, however, which do not necessarily share that threat perception, claim that ITAR is all about keeping technology in the United States for U.S. advantage.[86] The American defense industry is often caught in the middle of this debate; it well understands the need for technology export controls, but sees areas where loosening those controls could benefit all concerned.

That tension is unlikely to be easily resolved. However, a number of steps could be taken through U.S. government-defense industry cooperation to smooth arms trade restrictions and broaden globalization.

- Leverage the U.S.-UK "special relationship" and the shared perception of the threat to construct a strong bilateral technology exchange. This might form a model for future bilateral or multilateral agreements but, most importantly, it would create synergies through the sharing of defense-related information, systems and technologies. It also would lower the risk that friction over arms trade issues could undermine the broader bilateral security relationship.[87]
- Better differentiate between sensitive technology transfers and common, industry-standard components. While the government must maintain controls over critical technologies, it could lower or eliminate restrictions on standard components readily available in foreign markets. For example, differentiation could easily be made between military/civil space hardware and commercial space hardware, enabling U.S. companies to compete for foreign commercial satellite programs.
- Pursue incremental improvements in ITAR that would streamline the process. For example, the threshold for Congressional review of defense exports could be raised, speeding the approval process for relatively routine transfers that Congress traditionally has not opposed. The system for third-party transfers could also be revisited allowing for the more rapid changing of hands of defense technologies to our friends and coalition partners when the urgency of prosecuting the war on terrorism demands it.

Sustaining An Industrial Advantage: Innovation

The globalization of the defense industry was well underway before the attacks of September 11. So was "defense transformation." Evolving from the

[84] The Satellite Industry Association says U.S. market share dropped five points to 41% in 2005, and sank again in 2006. Some European competitors, taking advantage of U.S.-imposed trade restrictions, have adopted "ITAR-free" satellite bus lines. See "Lean Pickings," *Aviation Week and Space Technology*, February 19, 2007, p. 56.

[85] In this regard, the willingness of DoD to support transatlantic cooperative teams, such as the selection of the Augusta Westland-Lockheed Martin/Bell team to provide the latest Presidential helicopter, is encouraging. See Michael T. Brewer, "An Aerospace Business Case for Transatlantic Cooperation" in Thompson and Ronis, Op. cit.

[86] See Security and Defence Agenda, "Is a Transatlantic defence industry increasingly in the cards?" 30 January 2006, at www.securitydefenceagenda.org.

[87] See Pierre Chao and Robin Niblett, "Trusted Partners: Sharing Technology within the U.S.-UK Security Relationship," Washington, D.C.: CSIS, May 26, 2006. See also "Bush to Back Deal on Arms Sales to UK," *Financial Times*, June 15, 2007 and "Bush, Blair signing treaty to obviate some US-UK export licenses," *Aerospace Daily*, June 25, 2007.

Soviet concept of a "military-technical revolution;" and the more widespread understanding of a "revolution in military affairs" encompassing technological, organizational and doctrinal components, "transformation" implied that the American military needed to reinvent itself for the post-Cold War world. Many of the elements of this military revolution—air-launched precision weapons and rapidly moving ground forces enabled by satellite-based navigation, intelligence and communication—had been previewed in the 1991 Gulf War. Yet some defense analysts wondered if the U.S. industrial base was prepared for this transformation, or if it required new suppliers to enter an age of "net-centric warfare" that might rely more heavily on the adoption of commercial communications technologies. Because the implications and processes of transformation within the U.S. military were unclear, it also remained uncertain as to what degree the industrial base might have to change to achieve the new standards of innovation implied.[88]

My working definition of innovation, borrowed from James Q. Wilson and others, includes the components of invention, proposal and implementation. How well has the defense industry supported military innovations in the past? Here, Clayton Christensen's distinction between "sustaining" technologies that maintain and improve existing processes and products, and "disruptive" innovation that alters paradigms and demands new metrics provides a useful device for framing the discussion.[89] The U.S. defense industry might be judged as very effective in furthering the customer's demand for capabilities that sustain its roles, missions, budgets and service autonomy. But when the customer demanded disruptive types of innovation to meet and define the new requirements of military transformation on an irregular battlefield, many observers questioned how well those established and successful customer relationships and past performance would perform.

Fueling this issue was a growing sense among government officials and analysts that a hidebound defense industry—tied to its armed service customer by tradition and habit— was ill-suited to outfit a transformed military. The more likely candidates here, some presumed, were the entrepreneurial start-up firms or leaders in new commercial information technology capabilities that would apply "new economy" thinking to develop a network-centric military. That hypothesis was strengthened by a number of additional factors:

- The direction, methods and objectives of military transformation were unclear. In many cases, transformation, like beauty, was in the eye of the beholder. There was little direction from the government customer on how the industry could transform itself.
- As the Cold War ended, defense budgets were cut, "conversion" loomed, and other economic sectors prospered, and talented and skilled people departed government and industry for the fields of biotechnology, telecommunications, finance and information technology where innovation flourished.
- Without the Cold War—and with a "last supper" attended by defense industry CEOs and chaired by the Secretary of Defense warning that many of the defense firms composing the industry in previous fat years would not survive the impending lean ones—the capital markets began to drive the defense industry to focus more on "return on capital" than on innovation and new investment. One result of this perspective was that the defense industry and its customers tended to focus more on reducing cost and risk.
- Despite the significant reductions in the defense budget and the consolidation of the industry, little was done to shape the post-Cold War model of government-industry relationships, particularly with regard to spurring innovation. As transformation blossomed, the government-industry relationship remained status quo.

Such a relationship might not have turned deleterious had the defense needs of the country remained unchanged as well. After September 11, however, this was not the case. Since then, there has been an accelerated need to get new military capabilities into the hands of the warfighter facing an asymmetric threat. But the general consensus is that the U.S. government-industry team has not been as

[88] See the "Defense Industrial Base Capabilities Studies" conducted by the Office of the Deputy Undersecretary of Defense for Industrial Policy and, specifically, "Transforming the Defense Industrial Base: A Roadmap," February 2003 at www.acq.osd.mil.

[89] See Peter Dombrowski, Eugene Gholz and Andrew Ross, "Military Transformation and the Defense Industry after Next," Newport RI: US Naval War College Papers 18, 2002. Christiansen's work is *The Innovator's Dilemma* (Boston: Harvard Business School Press, 1997).

successful in getting these capabilities—advanced body/vehicle armor, counter-improvised explosive devices (IEDs) systems, tagging and tracking of individuals, infra-red countermeasures on helicopters, precise conventional munitions integrated with information systems, directed energy weapons applied to force protection—developed and deployed to the field with the same speed and innovation as during the Cold War.

The broad conclusion of defense industry analysts is that sustaining a competitive advantage does not require a new cast of industry players.

Was this because the defense industry had become good at sustaining innovation but was ill-equipped to make disruptive changes? The broad conclusion of defense industry analysts is that sustaining a competitive advantage does not require a new cast of industry players, although new suppliers will likely appear to meet certain technological needs. Peter Dombrowski and Eugene Gholz concluded that the existing defense industry has the size and scope to successfully underwrite future military transformation and innovation.[90] In particular, improved platforms and performance frequently seen as "transformational"—unmanned vehicles, secure telecommunications, system integration—suggest that established suppliers can well meet the improvements specified by their traditional customers. For the most part, these are examples of "sustaining" innovation rather than the "disruptive" sort. The authors conclude that the established industry, "expertly responsive to the military's unique language for describing operations, complex culture, and rule-laden acquisition environment," is well prepared and positioned to meet these needs.

The problem, therefore, may lie in internal DoD processes and external market pressures that unintentionally dampen innovation. One area to approach in addressing this issue is the appropriate balance between innovation and risk, a problem that Bert Fowler identifies in his paper. As the nation looks to the future challenges of homeland defense, irregular warfare, and conventional conflict it will require some dramatically different capabilities and technologies. Some of these, such as high-altitude, long endurance unmanned air vehicles, will have application across a range of scenarios, while others, such as robots to disarm IEDs, may have a very specific task to accomplish. In either case, we need to forthrightly face the risk involved in developing and fielding such capabilities, and not allow a risk-averse acquisition approach to limit investment in innovation. If we reference the views of those who lead the defense industry as well as those who study it, we find that executives in the defense industry are concerned that in managing the risk inherent in military innovation the U.S. government customer is leaning too far towards risk containment and not far enough toward risk tolerance. Those industry leaders further believe that a long-term competitive technological advantage cannot be sustained based on a climate slanted toward containing risk: the products will be less than state-of-the art and the innovators will migrate to more challenging fields and endeavors.

Accepting greater risk does not require a loosening of fiscal controls or a lessening of oversight across defense contracts. However, in encouraging innovation, some unique solutions may be required. Indeed, when considering issues regarding government-industry relationships, it is important to differentiate among sectors that provide different types of military capabilities, and therefore require different approaches to spur innovation. Let's briefly consider two sectors—shipbuilding and space—and how risk might be better tolerated in each.

Shipbuilding

As Dombrowski and Gholz have argued, the continued reliance on traditional naval capabilities—firepower, stealth, size and battlegroup synergy—will drive a sustaining brand of innovation to meet

[90] Peter Dombrowski and Eugene Gholz, *Buying Military Transformation*, (New York: Columbia University Press, 2006).

future naval requirements.[91] Unfortunately the nation's shipyards have experienced volatile and declining demand from the military customers over recent years, they remain well below their physical and labor capacity—despite the implementation of significant measures to mitigate the heavy toll taken by Hurricane Katrina on Gulf shipyards[92]—and a needed physical consolidation of the yards remains unlikely owing to particular skills inherent in certain yards as well as the regional political and labor factors that keep yards operating inefficiently. The result is that profitability has dropped dramatically owing to reduced and unstable demand coupled with expensive, non-recurring "first-in-class" work that overshadows the total ownership savings that might accrue over longer production runs. In turn, declining profitability constrains investment in innovation.

But transforming the shipbuilding industrial base by encouraging innovation is not a straightforward proposition. Attempts by the shipyards to enter commercial markets to spread cost over a larger base have not proved successful. Broadening ship contracts to combine hull, mechanical and electrical manufacture with weapons system integration has failed to achieve cost efficiencies. Further, reviews of ship complexity indicate that the work content of typical U.S. ship designs is substantially higher than similar international designs, and that government acquisition rules and practices create an additional financial burden—perhaps ten to fifteen percent, higher for nuclear-powered vessels—on shipbuilders.[93]

All of these issues are well recognized by the government-industry team, as is the need for increased cooperation. Navy officials are committed to getting the acquisition work force better balanced under the assumption that too much oversight has been removed from the Navy's responsibility.[94]

One of the problems, acknowledged by Navy Secretary Donald Winter, is that the Navy has lost its "domain knowledge and understanding." Given the diminished competition in the shipbuilding industry, it is incumbent on the service customer to structure the program and encourage innovation. Without that guidance, the "push on the industry" from both the investment and the regulatory communities, "has been to further focus industry on the financials."[95] Of course, industry has ideas to enhance innovation as well, including greater commonality of design and in components across classes of ships and greater industry participation in long-term shipbuilding plans.[96]

Tracking with these initiatives, among the more promising recommendations found in studies to enhance innovation and productivity improvements in the U.S. shipbuilding industrial base are:

- Government contracting agencies should develop and maintain stable acquisition budgets and schedules
- The industry should establish a Shipbuilding Industrial Base Investment Fund to focus on and encourage innovative design, engineering and production improvements to improve performance while reducing costs
- The government should limit regulatory requirements to remove financial burdens on the shipbuilding industry
- Shipbuilding design should balance requirements and producibility
- Commonality should be pursued in hull design, mission systems and manufacturing and electrical equipment across ship classes
- Efforts should be made to limit and control engineering changes during production
- Include in anticipated and managed shipbuilding costs the combat/mission systems of the ship, as well as its production costs.

[91] *Buying Military Transformation*, p. 140. The authors note the more disruptive innovation qualities of the Littoral Combat Ship, but suspect that these ships will represent a relatively small percentage of the surface fleet, and that the smaller ship producers brought in to develop these ships will still team with the larger shipyards who will remain the system integrators and program prime manufacturers.

[92] For example, in Katrina's aftermath, Northrop Grumman Ship Systems streamlined processes and took manufacturing initiatives saving more than $200 million.

[93] See "Global Shipbuilding Industrial Base Benchmarking Study, Part 1: Major Shipyards," Washington, D.C.: ODUSD(IP), January 2006 at www.acq.osd.mil. Three "best-in-class" lessons from international shipbuilding include: design for production, greater production per design on shorter intervals, and minimal design changes through production.

[94] "Navy-Industry Partnership Critical to Building Future Fleet, CNO Says," *Defense Daily,* May 2, 2007.

[95] "Navy Needs to Define its Needs, Examine Contract Options, SECNAV Says," *Defense Daily*, April 3, 2007.

[96] "Shipbuilders Provide Ideas for Helping Industry Survive," *Defense Daily*, April 30, 2007.

Space-based Systems

Where ships are often considered the "nodes" in the transformation from "platform-centric" to "network-centric" warfare called for in transformation, space-based systems contribute to the networks allowing the nodes to share data and information. Despite the marked differences in the way that ships and satellites are designed, manufactured, launched and maintained, however, there are some similarities in the way they are acquired that suggest parallel paths toward innovation and risk reduction.

Clearly there is room for improvement in the acquisition of space-based systems that could make room for continued innovation. A 2003 report of a Defense Science Board task force on space program acquisition found a devastating combination of factors contributing to cost overruns and schedule slips including unrealistic budget estimates, undisciplined requirements definition, and the erosion of government management capabilities.[97] The report expressed concern over the longer term for the aging of the industrial work force, and noted the need to develop recruit and retain top-level engineers and managers for the nation's space enterprise. Recommendations including focusing on mission success rather than cost and encouraging competition to push innovation will be familiar to those who have read Bert Fowler's paper earlier in this collection.

Acquisition issues that plague other DoD programs seem particularly acute in space-based systems, perhaps owing to the need for cutting-edge technological innovation. The Government Accountability Office (GAO) noted that space program acquisition programs were often started before the technology was understood or mature because "acquisition programs tend to attract more funding than science and technology efforts."[98] A related (and familiar) issue documented by the GAO was because requirements were not adequately designed up front, new requirements continued to be added (at additional time and expense) well into the acquisition phase. This was particularly true for programs such as Space Radar and the Transformational Satellite Communications System (TSAT) which were being counted on by the DoD to enable ambitious transformation efforts.

Such studies suggest that it's not just the push for technology advancement and innovation that results in sliding schedules and rising costs. Often as not, it's a problem of clashing cultures and disagreement among vendor and customer on how best to get the job done that has the counter-productive results. Yet there are as many success stories in space as there are troubled programs—the "GeoLITE" satellite launched in 2001 composed of lightweight composite materials allowing for increased instrument weight and reduced launch cost is a good example of the former. Other space-based systems might prove successful by replacing the "requirements-creep" spiral development approach with a "cookie-cutter" model that pushes sustaining, rather than disruptive innovation. This incremental approach to space acquisition deploys modules as part of the space-based security network and upgrades those components through a fixed production system.[99]

The Department of Defense recognizes the need to find innovative approaches for developing and employing space assets in order to obtain a "broadened portfolio of capabilities" including "larger numbers of relatively low cost, risk tolerant, quick reaction systems."[100] One of the initiatives launched toward achieving this objective termed "operationally responsive space" is focused on developing the satellites and support systems that would enable the rapid deployment of space assets. One recent example of industry response to this approach was the teaming of Northrop Grumman with Israel Aerospace Industries "to build and launch operational surveillance satellites in a responsive production cycle to provide U.S. government users unique, all-weather, day/night imaging capabilities."[101]

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[97] Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on "Acquisition of National Security Space Programs," Washington, D.C.: Office of the Undersecretary of Defense (AT&L), May 2003.

[98] GAO letter to the U.S. Senate Committee on Armed Services, Subject: Space System Acquisition Risks and Keys to Addressing them," Washington, D.C.: USGAO, June 1, 2006.

[99] Robbin Laird, "Fixing Space Acquisition: From spiral development to cookie-cutter production," *Space News Business Report*, February 13, 2006. http://www.space.com/spacenews.

[100] "DoD Needs New Business Approaches for Buying Space Systems," *Inside the Air Force*, May 4, 2007.

[101] "Northrop Grumman, Israel Aerospace Industries to offer Rapid Response, Operational Surveillance Satellites," Los Angles: Northrop Grumman Corporation News Release, April 11, 2007.

In this case, as in others, the solution lies in not only reforming the acquisition process to spur innovation in space-based systems, but in:

- Strong program and technical teams that understand and are committed to the user's mission
- Constant interchange among co-located government and industry teammates; and,
- An accepted sense of urgency shared by a commitment to a reasonable but fixed schedule.

Conclusion: Globalization and Innovation

The tragic terrorist attacks of September 11 slowed globalization and altered the trend toward international defense cooperation and collaboration. Yet global industrial security cooperation is exactly what is needed for success in prosecuting the Global War on Terrorism. Similarly, concerns regarding weapons proliferation have further constrained the arms and technology transfer processes, but wider sharing of defense systems and know-how is essential to facilitating the interoperability and capacity building necessary to deter and defend against future adversaries. A competitive advantage for the future also must be sustained through the acquisition of technologically innovative weapons systems. The defense industrial base appears up to the task of supplying those capabilities, but it will take continued, proactive cooperation among political, military and industrial leaders to ensure that the funds directed toward military transformation are allocated in the proper direction and amounts. Broadening globalization and spurring innovation will take a concerted effort on the part of the U.S. government, its allies, and the defense industry.

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