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Defense

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## Mini-Warriors Microelectromechanical Systems: A Munitions Revolution

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in Defense Acquisition**  
*by the Under Secretary  
of Defense (AT&L)*

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Space System  
Acquisitions**

**Concepts  
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**A Program Master  
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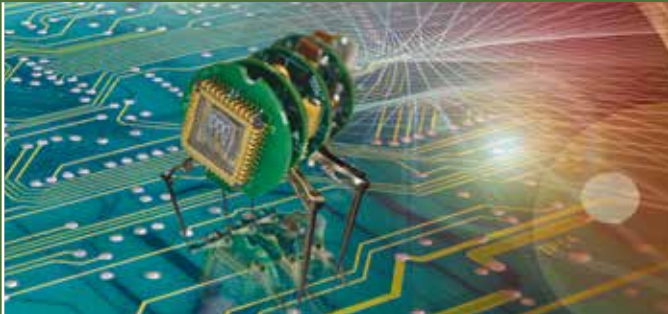
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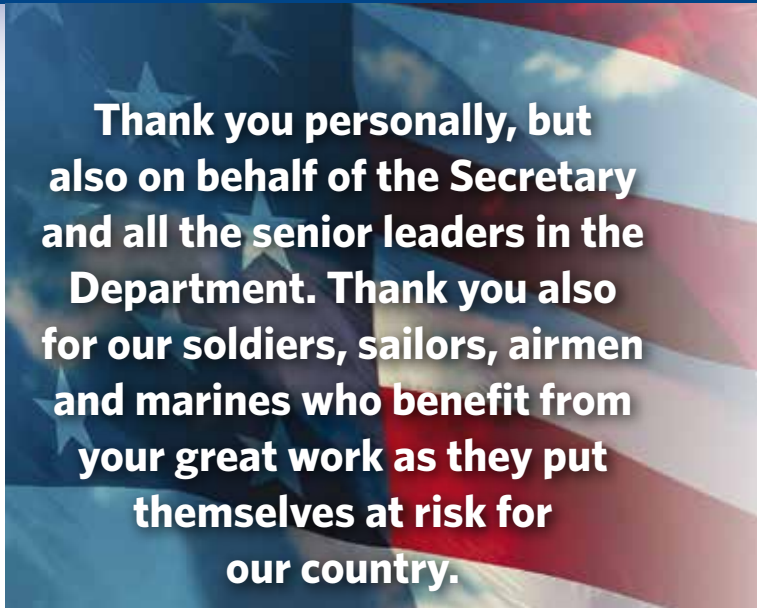
# What Really Matters in Defense Acquisition

*Frank Kendall*



**M**y first inclination for this issue's article was to discuss the newly released DoDI 5000.02. We recently implemented this new acquisition policy document as interim guidance. I provided a cover letter explaining why I had done a new version and outlined some of the features of this edition. I do recommend that you look at both the cover letter and the new document, but on reflection I decided to write about something else for this issue. An enormous amount of time and energy goes into designing our processes and implementing them, but at the end of the day it isn't those processes or policy documents like 5000.02 that really drive our results. What really matters in defense acquisition is our people and their professionalism and leadership—so I thought I would start the new year by writing about that.

This past year we've gone through a lot, and all of our acquisition professionals have been asked to put up with more than any workforce should have to endure. We've had continuing budget turmoil and uncertainty, furloughs, continuing resolutions, late-breaking sequestration, and most recently a government shutdown. We're also living under pay freezes and the prospect of further budget reductions and staff reductions. I want to thank the whole workforce for the way you have all coped with these challenges. While other senior leaders and I have been asking you to improve our productivity and achieve ever greater results for our warfighters and the taxpayer, you've also had to work in very challenging circumstances. You've come through, and it has inspired me and your other senior leaders to see the way you've dealt with all these challenges in stride. Thank you. Thank you personally, but also on behalf of the Secretary and all the senior leaders in the Department. Thank you also for our soldiers, sailors, airmen and marines who benefit from your great work as they put themselves at risk for our country.



**Thank you personally, but also on behalf of the Secretary and all the senior leaders in the Department. Thank you also for our soldiers, sailors, airmen and marines who benefit from your great work as they put themselves at risk for our country.**

Recently, I joined Dr. Carter in one of his last official acts as Deputy Secretary in presenting the Packard Awards to this year's recipients. As I write this, I'm looking forward to going out to the Defense Acquisition University to present the USD(AT&L) awards for professionalism and developing the work force to some of our outstanding performers. I'm sorry that we can't recognize more of our exceptional performers—there are so many of you, and you all deserve to be recognized for what you do. During the last few weeks, I also have had occasion to note the departure of some of our most capable people who are retiring or will soon retire from government service. We lose a lot of terrific people every year of course, and these individuals are just examples of the many fine professionals working in defense acquisition, technology and logistics. I decided that for this article I would note the contributions of some of these people with whom over the last few years I've had the chance to work. They are just examples, but they are especially powerful examples of what one can accomplish during a career in defense acquisition.


I'll start with Charlie Williams, the recently retired Director of the Defense Contract Management Agency (DCMA). Charlie led DCMA for the past several years. He started federal service in 1982 in Air Logistics Command in a Mid-Level Management Training Program. Charlie then rose through a series of contracting, program analysis and contract management positions with the Air Force both in the field and at Air Force Headquarters. He became Air Force Deputy Assistant Secretary for Contracting before taking the reins at DCMA. At DCMA, Charlie led the rebuilding of the organization after severe reductions in the 1990s. He kept his team together during the Base Realignment and Closure move from D.C. to Richmond, and he led the effort to ensure that our contracts in support of operations in Afghanistan and Iraq were executed properly.

Next I'll mention MajGen Tim Crosby, the soon-to-retire Army Program Executive Officer (PEO) for Aviation. Tim has led Army aviation programs since 2008. He was commissioned after graduating from the Citadel and started out as a field artillery officer. He moved quickly into aviation as a pilot before following his interest in research and development and flight testing. In acquisition, he worked in logistics, training and simulation, and test and evaluation before becoming a Product Manager, first for the CH-47 F and later Program Manager for the Army's Armed Scout. His long tenure at PEO Aviation is marked by strong leadership in support of our deployed forces and in building the capability of the Afghan Air Force. Tim embraced the Better Buying Power principles and was implementing them well before Dr. Carter and I gave them a name.

Rear Admiral Jim Murdoch retired recently after serving as the Navy's first PEO for Littoral Combat Ships (LCS). Jim en-

tered the Navy with an ROTC commission after graduating from Rensselaer Polytechnic Institute in mechanical engineering. He moved between surface combatant assignments and acquisition positions. His acquisition assignments included program management for surface weapons and launchers and responsibility for integrated warfare systems as well as program manager for the Littoral Combat Ships. In 2011, Jim was handpicked by Sean Stackley to lead the new Program Executive Office for LCS sea-frames and mission modules. He stabilized and fully integrated one of the Navy's most complex acquisition endeavors.

Finally Scott Correll, our retiring Air Force PEO for Space Launch, also started his career as an intern. From the Pacer Intern Contracting Program at Robbins Air Force Base, where he began as a cost analyst and contract negotiator on the F-4 and F-15, Scott rose through the contracting, supply chain management and program management fields. Scott's diverse positions include leadership positions at Military Sealift Command and TRANSCOM. I was able to take Scott in to meet Secretary Hagel recently so the Secretary could thank him personally for saving the Department billions of dollars in space launch costs—quite an achievement for our taxpayers and warfighters.


The people I mention above have accomplished a great deal for their country during their careers. They've also had the opportunity to do exciting and fulfilling work. People who achieve this sort of success over their careers are what give us the best equipped military in the world. All of these people have a lot to be proud of. All of you have a lot to be proud of. I'm looking forward to 2014 with the hope that things will improve—and there are some signs that they will. But mostly I'm just looking forward to another year of working with this terrific team. Thank you again for all that you do. 

# Mini-Warriors

Microelectromechanical Systems:  
A Munitions Revolution

*Dan Jean, Ph.D. ■ Dan Pines ■ Kevin Cochran*





In 1959, renowned physicist Dr. Richard Feynman proposed the idea of very tiny machines that could perform micro-level tasks with macro-level effects. Today such machines exist, measuring only millimeters, with gears and levers smaller than dust mites. In smart phones, they change display orientations as you move the phone, and in cars, they collect speed, acceleration and steering data, sending that data to an in-vehicle network.

These “microelectromechanical systems,” or MEMS, are increasingly found in systems we use daily, replacing larger, heavier, and less reliable components at lower costs. They are freeing up space in systems, enabling performance improvements and added functions, and they are performing previously unimaginable tasks at the micro level. Like their significant transformation of commercial systems, MEMS have the potential to transform munitions across defense systems, as found in MEMS development at the Naval Surface Warfare Center Indian Head Explosive Ordnance Disposal Technology Division (Indian Head EODTD).

### **Revolution in Commercial Products**

“MEMS promises to revolutionize every product category,” wrote manufacturing expert Dr. Xuan F. Zha of the National Institute of Standards and Technology. That revolution was indicated by the integration of the first commercially made MEMS sensor into automotive airbags in 1993. Measuring less than 1 cm<sup>2</sup>, this MEMS detected crashes and activated air bags, replacing sensors that were orders of magnitude larger.

MEMS, which vary in design and function, are produced by a process associated with making integrated circuits. Using micromachining, materials are deposited, molded and etched on silicon, which is harder than most metals and has semiconductor properties. The result is a micro system, with tiny moving parts and microelectronic circuits that sense and act.

The benefits of MEMS have been increasingly recognized. Not only are they smaller and lighter than the devices they replace, but they are cheaper because the cost of manufacturing and materials is smaller. At just \$5 apiece, the first commercial MEMS reduced air-bag systems’ costs from roughly \$500 to \$100. It also proved highly reliable. A decade later, the maker of that MEMS accelerometer had sold more than 100 million units for air bags and other systems, reporting “less than one failure per billion hours of operation.”

The integration of MEMS devices for other uses also increased system functionality. In less than a decade, the BMW 740i had more than 70 MEMS devices, enabling anti-lock

---

**Jean and Cochran** are mechanical engineers and **Pines** is a materials scientist in the Fuze and Initiation Systems Branch at the Naval Surface Warfare Center Indian Head Explosive Ordnance Disposal Technology Division.

braking, active suspension, appliance and navigation control, vibration monitoring, fuel sensing, noise reduction, rollover detection, seat-belt restraint and tensioning and more.

MEMS' debut in the automotive industry led to varied uses in other systems. By 2011, an estimated 3 billion MEMS were used to heat and apply ink in inkjet printers. Incorporated into cameras, these tiny machines stabilize optics and enable clear photos, even when held by unsteady hands. If you have played Nintendo Wii, a MEMS in the hand-held controller senses and transmits body movements to the video game—much like the Lycra suit with 85 MEMS, worn by actors, which aided computer-generated imagery in the movie "Iron Man 2."

In the biotech industry, MEMS have aided micro-level tasks. They sense blood pressure, monitor glaucoma-related eye pressure and pump insulin when needed. Additionally, researchers have developed MEMS that provide a high degree of control over stimuli that cells receive in lab environments.


According to a Yole Development report, *Status of the MEMS Industry 2013*, the MEMS market will double between 2012 and 2018, expanding from \$11 billion to \$22 billion. That expansion undoubtedly will include increased use of MEMS in munitions.

### **The Promise for Munitions**

In movies, the term "explosives expert" often describes someone with competence in this area. To some degree, that characterizes the Division at Indian Head. The Division does more, however. It researches and develops explosives, propellants and pyrotechnics, a field called "energetics" because the materials release chemical energy. The explosive cartridges activating car air bags are traceable to those in ejection seats, developed at Indian Head. The Division also develops counters to energetic threats, such as improvised explosive devices. Because of this work, the Division serves as a Department of Defense (DoD) Energetics Center.

Shortly after MEMS' introduction into the marketplace, the Division began investigating them for munitions. It did what MIT Professor Judy Hoyt advocated: "To innovate in products, one has to understand the processes by which these products are made." The Division set up a clean room to characterize and fabricate MEMS. While many such clean rooms exist, the one at Indian Head EODTD is the only one certified to handle and integrate explosives with MEMS, including firing small amounts in a test chamber.

The Division's investigation led to developing MEMS for possible use in underwater, sea surface, land and air-delivered munitions. It first characterized commercial MEMS for the torpedo U.S. Navy surface ships will use to kill enemy torpedoes. Within this 6.75-inch-diameter, anti-torpedo torpedo, eight MEMS sensors aid navigation by measuring acceleration, angular rate and flow, thus enabling detonation at a safe distance from the launching ship.



**At just \$5 apiece, the first commercial MEMS reduced air-bag systems' costs from roughly \$500 to \$100. It also proved highly reliable.**

The Division also developed MEMS fuzes. Fuzes have been called the brains of munitions. They keep a munition safe, arm it after firing and then detonate it at an opportune time relative to a target. How fuzes do this varies. Some are mechanical, detonating on impact. Some use timers, and some rely on a tiny radar to detect targets and then detonate. All are relatively big, however. For example, a torpedo fuze is about the size of a coffee can. Fuzes also take up a fair portion of a munition's weight. In the 10-pound, 81mm mortar round, the fuze weighs a half-pound.

The MEMS fuzes produced by Indian Head EODTD are about fingernail size, with mechanical and electronic features only a tenth of a hair's width. The first was for the anti-torpedo torpedo. Although it uses a macro-size fuze, significantly reduced in size by the Division, its experimental MEMS fuze informed development of such fuzes for more widely used munitions.

These MEMS fuzes work at the micro-level, interfacing with munitions at the macro-level, as exemplified by one developed for mortars. After launch, a "G" sensor measures acceleration and, when a given number of Gs is reached, removes a safety lock in the MEMS, the first step toward arming. Another sensor measures the round's spin rate and, at a set number, signals removal of a second lock, arming and readying the munition for a fire signal. This may come from a point-detonating switch, a delayed detonation setting, or another sensor detecting a target. The signal initiates a tiny explosive in MEMS' first unlocked section, setting off another explosive in the second unlocked section, which detonates the main explosive.

These MEMS fuzes do something else: harvest energy. They convert launch acceleration into electricity. Thus, MEMS fuzes can power not only their electronics but additional MEMS sensors. They can be power sources in munitions, which previously lacked them, thus allowing incorporation of additional functions. Energy-harvesting MEMS are also cheaper, safer, faster-activating and longer-lasting power sources than batteries.

MEMS fuzes also free up space in existing munitions. This extra space can be used for improved capabilities and additional functions.





MEMS clean room at Naval Surface Warfare Center Indian Head Explosive Ordnance Disposal Technology Division, the only one certified to handle and integrate explosives with MEMS.

**Improved Capabilities.** More room in munitions allows addition of more propellant, thus increasing range, which U.S. forces in Afghanistan needed for mortars and shoulder-launched munitions. Another option would be to add more explosive, thus increasing lethality. For example, the 81mm mortar round carries about a pound of explosive. Replacing its present, half-pound fuze with the dime-size MEMS could increase the explosive payload by almost 50 percent.

**Additional Functions.** MEMS fuzes and added sensors and technologies may provide the following new functions:

- *More fuzing functions.* For example, today's 40mm grenades detonate only on impact. However, MEMS fuzes could delay detonation until after impact. More sensors could be added, such as those with radar or radio frequency (RF) capabilities, making it possible to detect targets and detonate in close proximity.
- *Faster arming.* Warfighters need this for shoulder-launched munitions in close engagements. Their time between firing and impact is about a fifth of a second. That means fuzes must arm munitions in less time, which MEMS fuzes can.
- *Precision guidance.* These technologies are getting smaller and cheaper, making them increasingly available. A guidance system with a MEMS fuze soon will be demonstrated in 81mm and 120mm mortars, and could be incorporated similarly into the 2.75-inch-diameter Hydra rockets launched by helicopters, fixed-wing aircraft and possibly Navy surface ships.

MEMS fuzes also can endure tough environments. Electronics in fuzes for medium-caliber munitions, such as 30mm,

experience severe shock and vibration in gun barrels, with acceleration exceeding 60,000 Gs. Also, munitions for hard targets must have fuzes that function after penetration, which has been problematic. MEMS fuzes have sustained 100,000 Gs and high-velocity impacts on hard targets, making them suitable for missiles, artillery, naval gunfire rounds and future railgun projectiles. MEMS sensors already are in the Extended Range Guided Munition, Hellfire missile and Small Diameter Bomb.

Additionally, MEMS make new munitions possible. MEMS fuzes and sensors, along with advances in explosives and propellants, can lead to smaller, lighter and more powerful munitions, which is the trend in warfare. Such munitions are sought for U.S. ground warfighters, who carried more than 130 pounds each in Afghanistan. Attack aircraft have gone from carrying 2,000-pound bombs to the 250-pound Small Diameter Bomb, allowing more targets to be hit per sortie, and smaller munitions would enable even more. Furthermore, smaller and lighter munitions especially are needed for ever-smaller unmanned systems.

Just as MEMS do incredibly small tasks like manipulating cells in medical research, they can do the incredibly small tasks with respect to munitions and even micro-vehicles. Fuzes could further shrink for nano-energetics—nanometer-size explosive and propellant particles—releasing energy faster and enabling very powerful and very tiny munitions. MEMS also may be used in micro-thrusters for miniature munitions or aerial micro-vehicles. An autonomous, 4-by-7-millimeter micro-robot, using nano-energetics integrated with microchips, already has been demonstrated.

**"A \$30,000 missile typically contains \$1,000 worth of conventional accelerometers and gyroscopes. An equivalent MEMS device, costing \$20, can be directly substituted in this platform. This represents a 50x subsystem cost reduction."**

MEMS uses even go beyond detonating munitions. They could help reduce traumatic brain injuries, which more than 150,000 U.S. military personnel have suffered since 2000. Most of these injuries are caused by blasts, but newly developed MEMS sensors, which can be worn in warfighters' helmets, will detect the blast pressures that cause brain injuries. Such quick detection will alert medical personnel in time to arrest brain cell death with serums and other treatments.

### **Compelling Reasons: Reliability and Low Cost**

"Munitions system reliability must be addressed soon, otherwise a critical aspect of our warfighting capability will be jeopardized and held to even higher levels of scrutiny," stated a 2005 Defense Science Board report, *Munitions System Reliability*. It also stated, "Fuzes based on integrated circuits, Micro-Electro-Mechanical Systems and integrated fuzing, targeting and guidance systems can provide greater reliability."

On 1,400 identified sites alone, "Estimated clean-up cost of current unexploded ordnance is tens of billions of dollars," according to a 2003 Defense Science Board report. Of great concern is unexploded ordnance from cluster munitions in the battlespace. These constitute the vast majority of U.S. indirect tactical fires. Some manufacturers claim submunition failure rates of 2 percent to 5 percent, while mine clearance specialists report 10 percent to 30 percent failure rates, according to a Congressional Research Service report. In 2008, DoD policy mandated that U.S. forces after 2018 will employ only cluster munitions "that do not result in more than 1 percent unexploded ordnance (UXO)," further stating, "The 1 percent UXO limit will not be waived."

MEMS fuzes have long been seen as capable of reducing failure rates. "MEMS devices offer the opportunity for 5x to 10x greater reliability, performance, and service life through improved safe-arming/detonating functions and inherent quality,

which is currently lacking in smaller bomblet and submunition ordnance," stated a 1995 DoD assessment, *Microelectromechanical Systems Opportunities*.


MEMS also can aid reliability by helping monitor munitions' health. Ordnance is designed for a life averaging 5 to 8 years, but it is often stockpiled for about 25 years. Over time, ordnance reliability can be affected by chemical changes, accelerated by extreme temperature and poor handling. Making matters worse, it is hard to tell whether it is still good. In Operation Iraqi Freedom, one of eight Patriot missile containers was dropped, causing concern that propellant grains or guidance components may have been damaged. Yet, the dropped container could not be identified as it had no visible damage. Thus, all eight were sent to the United States for evaluation and possible repair—costing \$22 million.

In a demonstration in Germany and Indiana and aboard Navy ships, MEMS that could sense such drops were incorporated into munitions packages. Their data and other data were collected via RF tags by a system that monitored the health of munitions. A similar idea was recommended by the Defense Science Board's *Munitions System Reliability* report. In the future, such systems conceivably could communicate with MEMS inside munitions, assessing fuzes and other health aspects.

In a time of austere defense budgets, there is another compelling reason for munitions-related MEMS: low costs. After MEMS commercial debut, the DoD report *Microelectromechanical Systems Opportunities* assessed these devices for their potential cost savings: "A \$30,000 missile typically contains \$1,000 worth of conventional accelerometers and gyroscopes. An equivalent MEMS device, costing \$20, can be directly substituted in this platform. This represents a 50x subsystem cost reduction." Just as a \$10 MEMS blood pressure monitor replaced a \$600 macro-size one in the medical community, MEMS can provide similar savings in munitions across defense systems.

### **Looking Ahead**

Industry provides a model for MEMS implementation. "We are seeing a massive proliferation of MEMS devices across a broad range of applications: from mobile handsets, tablets and pico projectors, to health/medical monitors, automotive safety systems, the smart grid, gaming, and robotics," said Karen Lightman, managing director of the MEMS Industry Group.

That proliferation should occur in defense. MEMS devices, particularly fuzes, can help add functions and reliability to munitions and other defense systems at low costs. In doing so, they can help maintain technological advantage for U.S. warfighting in a time of tight budgets and growing challenges. Especially now, defense needs the MEMS revolution that's happening throughout commercial industry. 

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# Future Space System Acquisitions

Is the Key “What” or “When”?

*Lt. Gen. Aloysius G. Casey, USAF (Ret.)  
Col. Eugene J. DeNezza, USAF (Ret.)*

Illustration, Defense Meteorological Satellite Program orbiter. Source: U.S. Air Force Space and Missile Systems Center.

A serious discussion is under way within the defense community on the strategic direction of future space system acquisitions. Among the questions being addressed:  
Now that the difficulties with our major, large, aggregated space systems seem to have been overcome, should the United States simply continue and/or improve these systems over time? Or should we go quickly toward small-satellite, platform-focused, distributed-system architectures?

What seems to be missing in the discussion is a basic tenet of good acquisition management: Do not initiate a major acquisition program, either a revolutionary architecture change or an evolutionary one, until the key technologies are mature.

---

**Casey** is a technical and management consultant specializing in space systems, launch vehicles, aircraft, unmanned air vehicles and associate weapons systems. He capped his 34-year Air Force career as commander of the Space Division of the Air Force Systems Command, charged with managing design, development, delivery and operation of the Air Force space systems and launch vehicles. **DeNezza** is a senior associate with Burdeshaw Associates, Ltd. For more than 17 years, he served in top management at TASC (originally The Analytic Sciences Corporation). During his 23-year Air Force career, DeNezza held very responsible program management positions, including deputy program director, Strategic Systems Program; commander, European Office of Aerospace Research and Development; and program manager, Air Force Advanced Navigation Programs.

## What We Buy

Certainly, what we buy is very important. Successful space acquisitions depend on many factors. For a military space system to succeed, mission performance requirements must be met; costs must be affordable; the system must be available when needed (resilient); and it must be adaptable to new mission needs. All these factors influence what we decide to buy.

There is an ongoing, low-key debate within the space community on whether to move to proposed small-satellite, distributed architectures or to continue and/or evolve existing aggregated systems. In a recent *Strategic Studies Quarterly* article, "Disruptive Challenges, New Opportunities, and New Strategies," Lt. Gen. Ellen Pawlikowski, Doug Laverro, and Col. Tom Cristler argued that our current and near-future space systems lack the needed resiliency, affordability and adaptability demanded by new international realities. These new realities, or disruptive challenges, include:

- Widespread and growing operational dependence on U.S. space systems.
- Growing threats (e.g., anti-satellite weapons (ASATS), jamming, cyber attacks, etc.) to these systems.
- Poor resiliency of U.S. space systems (i.e., large, expensive satellites; few if any spares; small constellations and easy targets).
- Fragility of U.S. constellations. A loss or delay of a single satellite greatly degrades capabilities.
- Technological stagnation of our systems.
- The shrinking industrial base, especially suppliers in the second and third tier.

In formulating a response to these disruptive changes, the authors argued, "We found the most important elements were not the conditions surrounding what we build, but rather the architectures we choose to build."

They further concluded that many challenges are a direct result of building aggregated, highly integrated, long-lived satellites. The solution presented concentrates on small-satellite, platform-focused, distributed-system architectures. The potential advantages they advocated for this revolutionary architectural approach fall into four important areas:

- Cost and Schedule Improvement
  - Lower the cost of individual satellites.
  - Use less costly mission assurance and smaller, less-expensive launch vehicles.
  - Use executable baselines (cost and schedule).
  - Create hosting opportunities at reduced cost.
- Industrial Base Strengthening
  - Use smaller satellites in larger constellations that call for a continuous, multiyear production line, thereby strengthening the industrial base and lowering cost.
- Improved Resiliency
  - Lower-cost options for adding on orbit spare or redundant systems—and ground reserves for reconstitution.

- Increase constellation size, distribute capability and reduce the impact of losing a satellite to render more difficult an attack on the satellites.
- Ease of Technology Insertion
  - Use less complex satellites to allow for easier, new technology insertion and capability upgrades.

This concept, however, has its critics. We maintain that the transition from mission to architecture focus must be assessed and analyzed carefully. Once requirements are defined, architectural alternatives represent only one metric. Other needs that must be assessed to arrive at a best value program include acquisition strategy, sensor performance, satellite performance, total integrated system performance, launch vehicle requirements, ground station architecture and user equipment.

As to the proposed advantages of a small-satellite, platform-focused, disaggregated architecture, other considerations merit discussion.

### **Definitive Analysis**

There has not yet been a rigorous analytical comparison of using a proposed small-satellite, distributed architecture versus evolving an existing aggregated system for each mission.

### **Cost and Schedule**

Though the costs of the existing aggregated systems are very high, there is no reason to believe the small-satellite, distributed architectures will cost less.

The need for aggregation and complexity is driven by mission performance requirements. Disaggregation may reduce the cost of an individual satellite but not necessarily the cost of the composite architecture needed to fulfill the mission.

Many smaller satellites in an architecture have unique constellation management issues, possible constellation intercommunications requirements, transition considerations, ground infrastructure complexities and user costs that could greatly increase the composite architecture life-cycle costs.

When deciding whether to evolve from the existing aggregated systems (e.g., SBIRS, AEHF, etc.), the impressive technology and performance advances now available in those systems also must be considered and treated carefully.

Hosted payloads may have a role, but many unique challenges concerning weight, power, space, communications, and satellite support must be addressed.

### **Space System Industrial Base**

While a small-satellite production line may help, other current factors contribute to the industrial base problem. These include the reduced opportunities for space-related research and development; current fiscal downsizing; budget instability; the inability of primes (until Efficient Space Procurement) to

Right: National Polar-orbiting Operational Environmental Satellite System.  
 Source: National Oceanic and Atmospheric Administration.  
 Below: Advanced Extremely High Frequency satellite system.  
 Source: Lockheed Martin.



**Technology Insertion**

Disaggregation of a satellite system doesn't necessarily mean it is easy to insert new technologies. Complex transition management across several evolutionary generations and configurations of space payloads still could be costly and take considerable time to implement as evidenced by the recent Global Positioning System (GPS) program experience.

It is hoped that this brief treatment of the very complex architectural issues illustrates there are no easy, obvious architecture solutions and that architecture is only one of many space system acquisition issues. One of the most important is when to enter the Defense Acquisition System.

**When We Buy**

There are some very important lessons in our space history. When we interviewed industry and government executives and asked what space programs they considered successful models and which were troubled, the answers were very consistent. Successful programs included:

- Discoverer/Corona and its successors
- Transit
- Defense Support Program (DSP)
- Defense Satellite Communications System (DSCS)
- Defense Meteorological Satellite Program (DMSP)

Almost as many were considered "troubled" programs, including:

- Future Imagery Architecture (FIA)
- Military Strategic and Tactical Relay (MILSTAR)

block buying satellites; and the prohibition against part and subsystem purchases across a number of individual programs.

**Resiliency**

There seems to have been none of the needed, detailed studies to assess the relationship between constellation size and resilience and to demonstrate how much disaggregation is enough. Intuitively, more satellites may make it more difficult to attack the capability—but not necessarily by much.

Other space protection measures should factor into our strategy. Examples include international agreements and treaties; satellite self-defense; decoys; counterstrike capability; a clearly stated U.S. policy to retaliate for any such attack; space control capabilities; hardening; and augmentation capabilities from the aerial and ground levels. Proliferation of satellites may be the least cost-efficient path to resiliency.

- National Polar-orbiting Operational Environmental Satellite System (NPOESS)
- Space Based Infrared System (SBIRS)
- Advanced Extremely High Frequency (AEHF) satellites

We decided to look at these programs broadly to see if we could discern a consistent pattern that would point to the really important differences between successful and troubled programs in the context of our present situation.

## Lessons from Successful Programs

### *Discoverer/Corona*

The Discoverer/Corona (KH-1 through KH-5/6) programs produced a series of strategic reconnaissance satellites used from 1963 through 1972. The program, at inception, was truly revolutionary. This is demonstrated by the number of firsts Discoverer/Corona achieved. Among those were the first polar orbiting satellite (Discoverer 1); the first 3-axis stabilized satellite maneuverable from the ground; the first to send a re-entry vehicle back to Earth (Discoverer 2); the first successful recovery of a re-entry vehicle (Discoverer 13/KH-1);


But it wasn't easy at first. Transit went through five experimental satellites, three series of operational prototypes, and 11 short-lived "operational satellites" before the fully successful O-12 (Oscar 12). The design through this period evolved. Navigation accuracy went from 120 meters (1964) down to 3 meters (1980).

### *Defense Support Program (DSP)*

The DSP is one of the most successful U.S. programs. It is a survivable, reliable satellite constellation designed to detect missile and/or spacecraft launches and nuclear explosions. The DSP has undergone five technology upgrades that have taken its weight from 2,100 to 5,250 pounds; its power from 400 watts to over 1,250 watts; its detectors from 2,000 to more than 6,000; and its design life from 1.25 years to more than 5 years. Since its first launch in 1970, DSP has provided 40 years of uninterrupted space-based early warning.

### *Defense Satellite Communications System (DSCS)*

The DSCS program began in 1967 with the launch of three Initial DSCS I satellites. The DSCS I program launched 27 initial



**The mere fact that a satellite system is disaggregated doesn't necessarily mean it is easy to insert new technologies.**

and the first successful recovery of image intelligence from space (Discoverer 14/KH-1).

These "firsts" came at a price—11 of the first 12 launches were failures. But as the Corona satellites' technology evolved, performance improved, and, by the end of the program in 1972, the program had launched 144 satellites with 102 successful recoveries of usable photographs.

### *Transit (also known as NAVSAT)*

Transit was the first operational satellite navigation system. It started development in 1959, but the first Transit failed to reach orbit. Transit 1B was launched successfully in 1960. This was followed by 42 more launches, culminating in Transit Oscar-31 in 1988.

Following some difficult initial problems, the Transit proved very reliable. The first production run (Transit Oscar-12 through Oscar-32) of this indestructible satellite was able to keep the constellation operational for more than 32 years, and the constellation still is transmitting as the Navy Ionospheric Monitoring System.

DSCS satellites with one failure. The DSCS I satellites weighed 100 pounds and contained a single X-band transponder.

The DSCS II program was approved in 1968, with the first launch in 1971. The DSCS II satellites were a significant upgrade of DSCS I. This 1,150- to 1,350-pound satellite emphasized hardening, anti-jam protection and increased channel capacity. The communication payload included two 20-watt X-band channels. Fifteen DSCS II satellites were launched, with two failures.

The DSCS III, first launched in 1982, remains the workhorse of the U.S. military's super high-frequency communications system. It offers significantly greater capacity, longer life and better-protected communications than its predecessors. It is a 2,580-pound satellite with six channels of X-band communications. Fourteen DSCS III satellites have been launched successfully.

### *Defense Meteorological Satellite Program (DMSP)*

Another of the most successful U.S. space programs, the DMSP was initiated in 1961 at the National Reconnaissance

Office (NRO). Now in its fifth decade of service, the DMSP still provides valuable weather data to the military, civil and scientific communities. The DMSP-5D3 is the latest (11th) version of DMSP satellites. The DMSP has evolved from a 90-pound, spin-stabilized satellite with shutter-style TV cameras to the current 2,640-pound satellite with seven sophisticated instruments. Fifty-one DMSP satellites have been launched with nine failures during its 50-year lifetime.

### **Lessons from 'Troubled' Programs** **Future Imagery Architecture**

A book could probably be written about this program—called by the *New York Times* “perhaps the most spectacular and expensive failure in the 50-year history of American spy satellite programs.” In summary, NRO decided to develop optical and radar imagery satellites that were smaller, lighter and less expensive than the current satellites. Conceptual architectural studies began in 1996, but it wasn't until 1999 that Boeing was awarded the optical and radar-imaging satellite contracts. Boeing had underbid Lockheed Martin by a billion dollars. It was a very surprising selection since Lockheed Martin had supplied all the then-current imaging spacecraft—optical and radar—and Boeing had never built the kind of satellites the government was seeking. By 2005, an estimated \$10 billion had been spent, twice the original estimate of \$5 billion. Most analysts believe FIA was destined to fail because the technology needed to meet requirements wasn't mature, there wasn't enough funding, the schedule was unrealistic and the selection criteria and source selection process for the space element of FIA were flawed.

### **MILSTAR**

The MILSTAR program officially started in 1981 to develop a secure, jam-resistant, worldwide communication satellite system. The first launch was scheduled for 1987. Schedule slips and cost overruns started in 1984 and continued. In 1991, DoD restructured the program by reducing constellation size from eight to six, reducing ground stations from 25 to nine, cutting total terminal quantity from 1,721 to 1,467 and eliminating survivability features.

Six satellites were launched between 1994 and 2003, with one failure. These satellites provide jam-proof, UHF and high-data-rate communications. The cost of reaching the redirected capability has been estimated at \$22 billion (up from an estimated \$9 billion to \$10 billion), with each satellite costing about \$800 million. The schedule slipped more than 4 years.

The Government Accountability Office identified the following MILSTAR problems:

- Technology was insufficiently mature (concurrency).
- Software needs were poorly understood.
- Requirements were defined inadequately.
- There were myriad requirements and engineering changes.

### **National Polar-orbiting Operational Environmental Satellite System (NPOESS)**

NPOESS, a revolutionary, very complex, next-generation weather satellite system was designed to monitor the Earth's weather, atmosphere, oceans, land and near-space environment. The NPOESS program was managed jointly by the U.S. Air Force, the National Oceanic and Atmospheric Administration (NOAA) and NASA. The program was canceled Feb. 1, 2010, due to cost overruns, schedule slips and technology difficulties.

The NPOESS program was an effort to integrate the capabilities of the NOAA Polar-orbiting Environmental Satellite, the DoD DMSP, and NASA's continuous climate data collection satellite into one satellite. Some of the NPOESS problems centered on technically maturing its large suite of very sophisticated sensors.

This, coupled with many interagency management problems, killed the program.

### **Space-Based Infrared System (SBIRS)**

Like the NPOESS, the SBIRS was conceived in an era when the prevailing wisdom called for combining missions on a single satellite to reduce the number of satellites and launches, saving development and operational costs. The SBIRS satellites were built to satisfy four missions—missile warning, missile defense, technical intelligence and battle-space characterization.

The program encountered significant technical problems (both hardware and software), unclear requirements, unexpected software complexity and unstable funding. As a result, program costs ballooned and the schedule slipped dramatically. The program now faces parts and subsystem obsolescence challenges. If the government decides to purchase GEO 6 and 7, the focal plane array substrate will have to be replaced, as the only company that made the substrate material has gone out of business. This problem largely came about because of the multiyear schedule slippages but also because some of the parts are unique to SBIRS and have only a single supplier or no source.

The recently launched SBIRS GEO and HEO satellites are performing very well and provide significantly improved performance and utility to their users.

### **Advanced Extremely High Frequency (AEHF) Satellite System**

The AEHF is a planned six-satellite constellation to be used to relay service communications for U.S., British, Canadian and Dutch military forces worldwide. Two of the six have been launched and are undergoing tests. AEHF will provide 10 to 12 times the bandwidth and 6 times the data rates and it will support twice as many tactical networks as the MILSTAR II satellites. This means the AEHF will deliver 10 to 12 times the data throughput of MILSTAR so that “for every one link of the



Illustration of a disaggregated satellite system. Source: Defense Advanced Research Projects Agency.

old MILSTAR, the Air Force now has 12 links operating at 4 (to 6) times the speed.”

The AEHF had its share of technical problems, including interface control redesigns, delayed delivery of signal-encryption products, disqualified parts, and unplanned component testing. But the program suffered as much, if not more, from as many as six changes in the requirements and number of satellites, from budget fluctuations and from constant program replanning and rebaselining. Two successful AEHF launches have occurred, and testing is under way. The satellites have displayed very impressive performance in these early tests.

## Summary

Lessons we might justifiably draw from this brief and broad recap of past satellite programs include:

(1) Virtually all the programs, successful or troubled, that were revolutionary in technology and/or design had significant initial cost, schedule and technical problems (see Discoverer/Corona, Transit, NPOESS, SBIRS and AEHF).

(2) Once the technology matures (e.g., Discoverer/Corona, Transit, MILSTAR, SBIRS, and AEHF), revolutionary systems can further evolve and improve with significantly fewer problems as long as the inserted technology is mature and has a continuing industrial base. For example, to go from the Discoverer/Corona re-entry capsules to the first real-time imaging satellite, the risk reduction/maturation process took about

5 years and more than \$1 billion (in today's dollars).

(3) Technical maturity must be matched by a significant production base for the parts and subsystems used on the satellites. As SBIRS is demonstrating, if there is no production base and no commercial adjunct, the Service would not only bear the cost of developing the system but as sole customer would have to support the manufacturing base at enormous cost over the many years of a typical system life cycle or develop new technology to replace the parts or subsystems.

The most successful programs (DSP, DSCS and DMSP) really were evolutionary programs. That

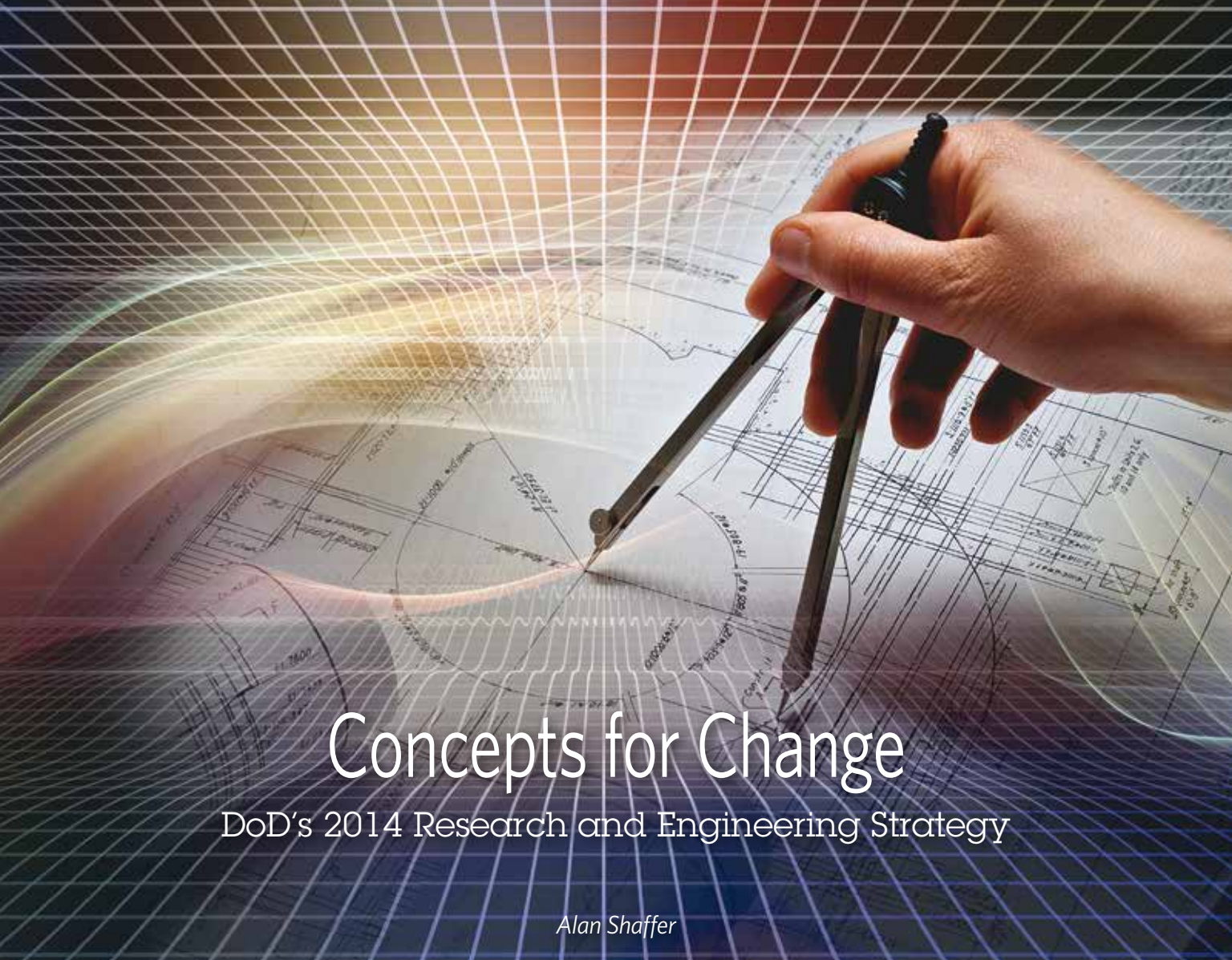
is, the initial versions were challenging technically but didn't require major technological leaps. These programs had some initial problems but these were much less significant than those seen in the more revolutionary programs. Significant upgrades were made, with few major problems, in subsequent versions—when the technology was mature.

It is clear that evolution of a mature technology (be it from the beginning of the full-scale development effort or after the painful maturing of a revolutionary development effort) is the best approach for successful space system acquisition.

One key to successful space system development is to initiate acquisition of the operational space system after the research-and-development effort has matured the technology to be utilized. Maturity can be defined as follows: The technology has been developed, tested on the ground and in orbit; production sources have been identified and costs verified; and performance ranges (i.e., marginal performance vs. cost) have been established. Our bottom line is that the United States should evolve its present systems carefully. Evolutionary changes should be made as the technology matures, and revolutionary architecture changes should be deferred until small-satellite, distributed-system technology has been thoroughly analyzed, developed and tested; costs have been verified; performance ranges established and production sources identified. &

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# Concepts for Change

DoD's 2014 Research and Engineering Strategy

*Alan Shaffer*

For more than 50 years, the Department of Defense (DoD) has relied on Research and Engineering (R&E) to provide the nation with the technology-based operational capability superiority that protects U.S. forces and helps to ensure national security. DoD's scientists and engineers work daily with industry and academia to conceive, develop and mature concepts into capabilities that provide an operational advantage to our warfighters.

The Office of the Assistant Secretary of Defense for Research and Engineering (OASD[R&E]) is responsible for the department's current and future technical and engineering capabilities and for helping to define the technical boundaries and expand the realm of the possible early in the department's acquisition process. The office includes the roles of chief technology officer, chief engineer, and chief of developmental testing, and is responsible for leading the rapid transition of new technologies to the warfighter.

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**Shaffer**, *Acting Assistant Secretary of Defense for Research and Engineering (ASD[R&E])*, is responsible for formulating, planning, and reviewing the Department of Defense (DoD) Research, Development, Test, and Evaluation (RDT&E) programs, plans, strategy, priorities and execution of the DoD RDT&E budget.

The security of our nation and the capabilities of our warfighters depend on a robust partnership of research and development (R&D) and acquisition efforts. In the past decade, examples of fielded capabilities delivered to the warfighter in part due to the efforts of the OASD(R&E) include: the first Mine Resistant Ambush Protected vehicle system, which provides dramatically greater protection for its passengers; aerostat systems that deliver 24/7 surveillance around our forward operating bases; a laser radar system that maps topography at a very high resolution and identifies objects under canopy; sensors and platforms that enable use of full-motion video in support of operational and intelligence needs; portable hybrid photovoltaic/battery systems supplying needed power at much lower weight; and wound repair and tissue regeneration capability.

Simply put, the job of the OASD(R&E) is to address the current and future needs of the DoD and its warfighters. As our warfighters move off the frontline in Iraq and Afghanistan, and the department rebalances to the Asia-Pacific region, continued investment is needed in innovative and adaptable capabilities to meet the challenges of emerging global threats.

In his foreword to the Defense Department's January 2012 strategy report, "Sustaining Global Leadership: Priorities for 21st Century Defense," President Obama wrote: "As we end today's wars and reshape our Armed Forces, we will ensure that our military is agile, flexible, and ready for the

- Mitigate new and emerging adversary threats that could degrade U.S. (and allied) capabilities.
- Affordably enable new or extended capabilities in existing military systems.
- Develop technology surprise through science and engineering applications to military problems.

These objectives complement the seven science and technology (S&T) priorities approved in 2011 by then-Secretary of Defense Robert Gates. The focus to meet these objectives is provided by the collective effort of the Services and defense agencies in cyber, electronic warfare, countering weapons of mass destruction, engineered resilient systems, autonomy, data to decisions, and human systems.

### **Mitigate Emerging Threats**

The Defense Department must be prepared to meet its current and future missions against a backdrop of increasing types and complexities of foreign systems and capabilities. The following is an overview of threat areas and how the R&E community is addressing these challenges to maintain and advance our military's capabilities.

**Cyber:** We are integrating our efforts in cyber defense across the department and have prioritized our R&D investments in several focus areas: the hardening and expansion of cyber test ranges; developing metrics for cyber events; resilience under attack; improving network agility to reduce the available target; and the modeling and simulation of cyber nets.



**“ . . . we will continue to invest in the capabilities critical to future success, including intelligence, surveillance, and reconnaissance; counterterrorism; countering weapons of mass destruction; operating in anti-access environments; and prevailing in all domains, including cyber.”**

**—President Barack Obama, January 2012**

full range of contingencies. In particular, we will continue to invest in the capabilities critical to future success, including intelligence, surveillance, and reconnaissance; counterterrorism; countering weapons of mass destruction; operating in anti-access environments; and prevailing in all domains, including cyber.”

### **Research & Engineering Objectives**

The guidance is clear: The president and the secretary of defense rely on the R&E community to make key contributions to the defense of our nation. This guidance is summarized in three strategic objectives:


**Advanced Electronic Warfare Systems:** The proliferation and global availability of advanced digital electronics coupled with high-speed processing and advanced algorithms are enabling adversaries to develop effective countermeasures to our sensor and communications capabilities. We are working to ensure that the technology capabilities we see around the world will not undercut the effectiveness of some of our most promising and sophisticated sensors and weapons systems. The department's emphasis in countering these threats is focused on maturing and testing the next generation of electronic and photonic components as well as expanding the operating capabilities of existing and new

electronic systems, to maintain and increase our advantage in the electromagnetic spectrum.

**Space:** The U.S. military relies on dependable global positioning systems, communications and intelligence, surveillance and reconnaissance. A focus of our efforts is protection of these critical capabilities against emerging threats, such as

effectiveness of fielded systems and provide life-cycle costs for decision making.

The tools and procedures of ERS will produce more comprehensive and robust requirements suitable for many more alternative mission scenarios very early in the design process or pre-Milestone A. The reuse of data and models, distrib-



**We are developing robust tools to stress systems against new mission contexts, tactics, techniques and procedures or emerging requirements, to permit precise measurement and understanding of their impact on all design and production factors.**

electronic jammers and dazzlers, and kinetic kill vehicles, which present a challenge to future operations. We must be able to operate freely even in austere or compromised environments. The chip-scale atomic clock provides precision navigation and timing so that every dismount can know its position. We also are developing alternative communications networks that do not rely on satellites.

***Affordably Enable New or Extended Capabilities***

The second strategic objective emphasizes maximizing our investment dollars by improving the design and transition of technologies to acquisition programs in a more affordable and timely manner. Our focus is on both new and existing systems and their life-cycle upgrades, interoperability between existing platforms, and design and prototyping of new systems. Our Engineering Resilient Systems program, the enhanced use of prototypes, and our “Shift Left” initiative all help guide our efforts.

**Engineered Resilient Systems (ERS):** Our focus in ERS is to develop engineering concepts, science, and design tools to protect against malicious compromise of weapon systems and to greatly enhance the manufacturability of trusted and assured defense systems across the acquisition life cycle. Through the ERS initiative, the department is developing an integrated suite of computational modeling and simulation capabilities and systems engineering tools, complete with an open-reference architecture, directly aligned to acquisition and operational business processes. The R&D investment in ERS focuses on infrastructure, information, design support, highly robust tradespace analytics, decision support tools and knowledge environments to increase the speed and efficiency of system development, improve the

uted databases that are searched jointly, virtual collaboration environments and open architectures that encourage partnering will lead to better-informed acquisition decisions. The engineering design process is streamlined, and the manufacturability of a proposed design is explicitly investigated from both engineering and cost perspectives before design commitment. Finally, we are developing robust tools to stress systems against new mission contexts, tactics, techniques and procedures or emerging requirements, to permit precise measurement and understanding of their impact on all design and production factors.

**Capability Prototyping:** Operational prototyping is a flexible and robust tool we intend to use to a greater extent in evaluating new systems and technologies, stimulating design teams and exploring the realm of the possible without needing an early commitment to procurement. Capability prototyping allows us to develop and demonstrate concepts and technologies at varying degrees of maturity as a hedge against the technical uncertainty of an unanticipated threat, to enhance the interoperability or extend the utility of existing systems and to enable the introduction of more capability and affordability. It is our intent to employ capability prototyping more for subsystems and force multipliers, but we expect to do some platform prototyping as well.

**Shift-Left Initiative:** Affordability also can be addressed by engaging with an acquisition program earlier in the life cycle to ensure a better understanding of program technical risks and opportunities before major milestone decisions. Early systems engineering and Developmental Test and Evaluation (DT&E) will better identify and correct deficiencies, thereby avoiding the high cost of late-cycle repairs.

The Shift-Left initiative is about improving the effectiveness of DT&E, so programs can find and fix problems before entering production. Effective DT&E also requires using a robust DT&E framework to ensure a program conducts the right testing at the right time to gather the required information before milestone decisions. There are three essential elements of the initiative:

- **Mission Context:** Bringing mission context into DT&E takes the new system out of the lab to see how it will be used. It does not, however, mean program managers have to conduct developmental testing with large-scale deployment of troops to the field.
- **Interoperability:** Throughout the last decade of combat operations, we did not find interoperability issues early enough to correct them before system deployment.
- **Cybersecurity:** Ten years of data from Director of Operational Testing and Evaluation field tests assessing cybersecurity indicate that fielded systems must be protected in the cyber domain. Vulnerabilities should be discovered in testing and corrected before deployment.

### ***Technology Surprise: Develop New Capabilities***

While we will need to react, we must focus on leading change. Thus, our third strategic objective, and a critical component in the department's ability to develop new capabilities, is to invest in a wide range of potentially game-changing basic and applied research. Autonomy is one of three emphasis areas that include data to decisions and human systems priority areas, where our integrated efforts across the Services will provide new capabilities.

**Autonomy Research Pilot Initiative:** Autonomous technology is just one of the new capability areas that will enable technology surprise. Our activities focus on the ability to enable DoD warfighting systems to be more adaptable and more self-governing, to function with greater independence from human interaction and with reduced response times in stressed environments.

To complement our contracted research with industry and academia, we established the Autonomy Research Pilot Initiative, a new process to evaluate internal innovative ideas. This effort is a coordinated program among DoD laboratories, encouraging cross-Service collaboration by bench-level scientists and engineers on autonomy-related applied research topics.

Guided by feedback from operational experience and evolving mission requirements, seven proposals were selected out of 54 submissions to be a part of this multiyear funded activity. Advancement of technologies will result in autonomous systems that provide more capability to warfighters, lessen the cognitive load on operator/supervisors and lower overall operational cost. In addition, the investment in this cross-Service collaboration will strengthen mission effectiveness while maintaining fiscal responsibility and optimizing interoperability across all domains.

### **The Future: R&E's Coordinated Approach**


A key strength of our R&E enterprise is its substantial emphasis on coordinated planning. Especially in these challenging budgetary times, it is important to strengthen the department's efforts to ensure that we receive the most value from our investment. As part of this coordinated approach, we have taken steps to provide new tools to communicate our efforts both internally and with industry and academia.

**Horizon Scanning:** To conduct effective technology horizon scanning, we are developing a low-cost effort to apply advanced analytics, leveraging a range of algorithms and data streams, to isolate and identify emerging science and technology areas.

**DoDTechipedia:** The ability to bring together performers and operational and acquisition communities is a challenge. DoDTechipedia ([www.dtic.mil](http://www.dtic.mil)) hosts an online electronic encyclopedia and provides a platform where organizations can share information on challenges and needs.

**Defense Innovation Marketplace:** A critical source of innovation technology comes from outside the department. The key to this innovation source is communication, thus we deployed the Defense Innovation Marketplace ([www.DefenseInnovationMarketplace.mil](http://www.DefenseInnovationMarketplace.mil)) to enable better connections between industry and the DoD. The Marketplace provides S&T/R&D technology needs, investment priorities and roadmaps to help industry members better support the warfighter through their independent research and development (IR&D) projects. In addition, the site contains a secure portal for industry to share its R&D projects and for DoD personnel to learn about these industry IR&D projects to better inform current and future program planning.

The DoD will always rely on R&D to provide the nation with technical superiority. Our investment over the last 50 years has enabled many breakthroughs including stealth, GPS, unmanned technology, Web protocols, advanced robotics and data mining.

As we move into this new year, with the current budget pressures and a new security landscape, we must continue to balance our investments across the department as well as with our acquisition partners. Moreover, the last two major budget contractions (post-Vietnam and the ending of the Cold War) showed that strategic efforts by the department's leadership protected R&D and allowed us to make important advances in maintaining our technological edge. The value of our research and development investments, and focus on new tools that improve affordability and communication, strengthen our overall competencies so we can continue to provide capabilities and value to the warfighter. 

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# A Program Master Schedule Can Improve Results

Patrick K. Barker

**“There cannot be a crisis today; my schedule is already full.”**

**—Henry Kissinger**

## Scheduling from a Government Perspective

Schedules are important. As government acquisition officials, we want things delivered at the time we agreed they would be delivered and for what we agreed to pay. We want to know whether something is going to be late or over cost. Contractor-delivered schedules can help the government program manager (PM) answer some of these important questions. However, a contractor schedule rightly focuses only on contract scope and not on the entire program picture.

A successful government PM must maintain and share situational awareness (SA) across the entire program and its environment. This requires visibility beyond contract scope, from budget drills to congressional inquiries to warfighter requirement changes and everything in between. Government acquisition programs are complex systems highly sensitive to emerging conditions and dependencies among multiple elements. It is an exceptionally challenging, but not impossible, task for a government PM to maintain SA. In other words, it is awfully hard to keep track of everything, let alone predict what might happen at any point in time.


A well-built and believable dynamic model that is of practical use provides a powerful tool to support PM decision making. To enable this, the government program management office (PMO) can employ its own program-level schedule. To distinguish this from the contractor's schedule, let's call this a "PMO Integrated Master Schedule (IMS)" or "PMO IMS." A PMO IMS helps the government PM to maintain SA and make informed

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**"I am not sure where we are, but we are making good progress."**





## Inattention to best practices... puts the schedule on the fast track to irrelevance, at best out of date before the ink dries.

decisions. While this article won't be the "final word" on a PMO IMS, it will highlight desirable PMO IMS characteristics and important PMO considerations.

### **Desired Characteristics**

#### ***A dynamic model reflective of best scheduling practices***

We build models to represent reality in ways we can understand and use for making decisions. Typical acquisition models are used to depict aircraft flight, radar propagation, heat signatures, reliability, cost relationships and so on. A schedule models a program by depicting the duration of and relationship among the program-specific tasks that constitute the required work. Since actual performance will differ from parts of the initial model, this schedule must also be dynamic or changeable in order to characterize the program accurately over time.

Thus a PMO IMS must be built in such a way that it reasonably represents the program and can keep pace with its evolution. Use of proper schedule construction mechanics—like those described in references such as the *National Defense Industrial Association Planning and Scheduling Excellence Guide*, the Defense Contract Management Agency's "Fourteen-Point Assessment," and the draft *Government Accountability Office Schedule Assessment Guide*—lays the groundwork for effective dynamic modeling of programs. These are frameworks forged by subject matter experts who successfully applied scheduling to project management. Inattention to best practices like these puts the schedule on the fast track to irrelevance, at best out of date before the ink dries. Poorly constructed schedules become little more than "to do" lists or expensive calendars incapable of providing SA.

Well-built schedules can depict more than program status. They are also predictive. Schedules help the government PM anticipate changes and consider "what-if" scenarios on demand, because dynamic modeling allows individual task dependencies, current status and individual forecasts to be overlaid and projected in a program context. Commercial scheduling software is uniquely capable of doing this in repeatable and reliable fashion. However, scheduling software

doesn't always produce the "pretty" pictures preferred for briefings, so PMOs often rely on static pictures and Gantt charts available on presentation software such as Microsoft PowerPoint. That's fine—and often necessary—for clear communication. However, over-reliance on eye-pleasing graphics risks projecting a false impression of SA over a dynamic process.

### ***Believability***

Robust dynamic modeling lays the groundwork for an effective PMO IMS, but there is more work to do, and it takes more than the scheduler to make it happen. Program team members and stakeholders most familiar with the work and program-unique environment are best suited to judge how accurately an IMS depicts the program. These same individuals also need to assess external information affecting the PMO IMS, such as that coming from the contractor.

A scheduler should sit down and talk with other team members; the scheduler's initiative and interpersonal skills go a long way toward ensuring the PMO IMS remains accurate and relevant over time. However, team interaction is a two-way street. The other PMO members must help create, scrub and continually update the schedule in order to trust the information it provides. A team-built and team-operated PMO IMS replaces a program picture characterized by multiple individual snapshots with a single picture composited from various contributors. Team ownership paves the way for "buy-in" of schedule information.

### ***Practicality***

The schedule ought to provide actionable answers to questions like these:

- What work must be done, and when?
- Who is doing the work, and when?
- What is happening right now?
- Where are we going?
- What risks/opportunities do we face ahead?
- When will we be done, and how do we know?

Answering the above questions requires inputs from and integration of a variety of sources in order to ensure that schedule information provides robust SA. These include requirements documents, statements of work, product work breakdown structures, organizational breakdown structures, risk register inputs, integrated master plans and technical performance measures, to name a few. Schedulers with a strong project management background are critical because they grasp the individual contributions of these sources, recognize when information from a given source is missing or of questionable value, and take action to correct the situation without prompting.

The PMO IMS does not need to be huge, but it should "pull" information that enhances the government PM's SA at any given time. A contractor might produce a 15,000-line



schedule in order to cover its contract scope and associated tasks, but the associated government PMO IMS might only be 200 to 300 lines. A PMO IMS might expand in some sections to provide detailed insight into high risks but remain more general for low risk areas. It will also expand and contract in size over time as the program evolves. External events or inputs that might influence the program are always included, along with key risk-handling efforts and decision points. Getting a usable PMO IMS off the ground takes thought and hard work, but it should not take weeks of effort at inordinate expense.

### **PMO Considerations**

#### ***Integrating schedules is complex but rewarding.***

A lead PMO scheduler typically faces integrating schedule information from multiple sources, including contractors and stakeholders. If a PMO integrates related but different schedules produced by different people, then it creates a scheduling system. Integration—especially automated integration—is easier said than done. Therefore, a PM should consider the following:

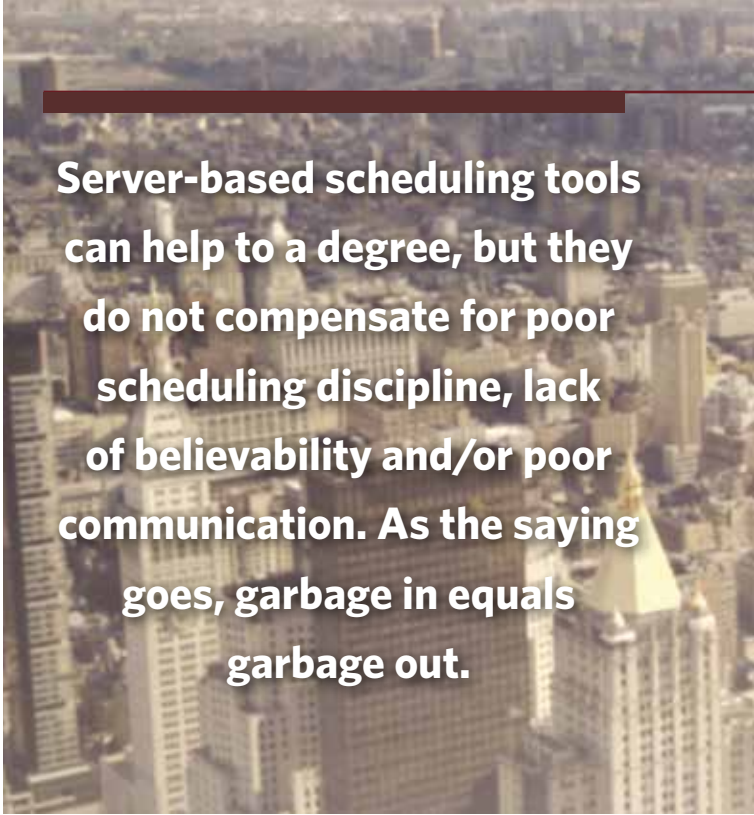
- A common program and scheduling language
- Shared desktop procedures (how an individual creates and maintains a schedule)
- Compatible data used in the various “fields” within scheduling software
- Identical scheduling software (Project, Primavera, Open Plan, etc.)
- Shared ideas of what constitutes healthy schedules (e.g., practical, believable, dynamic models)

Unsuccessful scheduling systems drive schedulers to spend much of their time diagnosing and fixing schedules, which means little attention is spent analyzing and evaluating program execution. This, in turn, jeopardizes the PMO IMS ability to support the PM.

Schedule integration is a systemic challenge, and it therefore requires a systemic response. Paying attention to the individual considerations shown above is one thing. Enforcing all of them across a diverse set of organizations and schedulers is another matter entirely. Server-based scheduling tools can help to a degree, but they do not compensate for poor scheduling discipline, lack of believability and/or poor communication. As the saying goes, garbage in equals garbage out. On the other hand, successful multi-schedule integration is a powerful “force multiplier” for program SA. It frees valuable time for analysis, synthesis and evaluation of schedule information. As a result, effective PMO IMS information can be made available in time for a PM to make proactive decisions.

#### ***Knowledge of a commercial scheduling tool does not solely define the PMO IMS scheduler.***

True, a scheduler should be familiar with the nuances of the scheduling software used by the program and have a firm grasp of scheduling-discipline fundamentals. It takes time to develop a skilled, professional scheduler based on published



**Server-based scheduling tools can help to a degree, but they do not compensate for poor scheduling discipline, lack of believability and/or poor communication. As the saying goes, garbage in equals garbage out.**

professional guidelines: There simply is no way around that. Expectations for professional schedulers are best defined within the context of industry certifications such as the American Association of Cost Engineers Planning and Scheduling Professional and the Project Management Institute Scheduling Professional. However, schedulers are not simply “tool jockeys.” Schedulers also must have a firm command of project management theory and practice, because the PMO IMS must be both believable and of practical use to the government PM. Leadership and interpersonal and communication skills in the lead scheduler also are critically important.

A good PMO IMS scheduler has his/her “finger on the pulse” of the program at all times, and doing so requires an individual with a balanced set of skills. It is important for a scheduler to be adept with scheduling software and discipline, but not entirely at the expense of the other demands of the job. At times, it is far more important to have the PMO team sitting around a table engaged in thoughtful and facilitated discussion on schedule risk than having the scheduler spending those hours figuring out how to resource load the PMO IMS. The PM should not think of the scheduling position as something that can be filled only by an experienced, certified scheduling professional. There is more to scheduling than running software. The PM should consider filling the scheduling position with a talented individual as soon as possible and “growing” that individual over time in scheduling, project management and/or leadership as required.

#### ***The effectiveness of the PMO IMS ultimately hinges on the government PM’s leadership.***

The government PM must lead the PMO team to use and maintain a PMO IMS effectively. This requires the following:


- The PM must ensure that the lead scheduling position is staffed by a high-quality individual who either already has the requisite skill or in whom the PM is willing to invest time, resources, and mentoring to develop the necessary skills.
- The PM should know what key questions need asking to ensure that best scheduling practice is employed. This requires the PM to be conversant (not a subject matter expert) in salient aspects of schedule construction and discipline.
- The PM must lead the team and ensure the schedule is built and maintained in a joint, multifunctional fashion. This might involve guiding team members outside their comfort zones.
- The PM must proactively shape the schedule as a decision support tool, rather than be a passive observer and/or recipient of scheduling information. The PM should work with the scheduler to “pull” the information needed to make informed decisions.
- The PM must also empower the scheduler to create an effective scheduling system. The scheduler does not have a single “swim lane.” The scheduler swims in every lane. Building a scheduling system often requires crossing boundaries, and a lead scheduler needs the trust and authority of the PM to make that happen.

No matter how believable and practical the PMO IMS might be, it has little value if the government program team does not use it. The PMO IMS must be “owned” by the government PM because the program team will typically take their cue from the PM. For example, consider a PMO IMS schedule risk analysis (SRA). An SRA should never be performed alone by the scheduler. An effective SRA requires the scheduler, team leads, subject matter experts and risk owners to work in concert; the PM should set the tone for that effort. The PMO

IMS needs to be a prominent fixture within the PM’s decision process and part of the language used by the PMO teams to convey status, predictions, strategies, risks and opportunities.

### So What?

A government PM needs a mechanism to collect and sift through important tactical information in order to remain focused on the big picture. To borrow from aviation parlance, you cannot maintain effective SA if your head remains buried inside the cockpit. If the PMO IMS provides robust and actionable answers to key performance questions—How are we doing? When are we done? What lies ahead?—the PM does not have to spend an inordinate amount of time trying to investigate and answer those questions. This frees time for the PM to think and act strategically, “pulling” PMO IMS information as needed to support SA and decision making.

The PMO IMS is a communication tool that helps the PM make informed decisions and enables the government PMO to maintain a proactive stance. While this article offered a set of considerations, rarely will all be achieved at once in a PMO. It takes effort to develop, and keep, talented schedulers who create and maintain robust schedules, but that’s not a reason to delay investment of time and energy into a PMO IMS. It must be kept in mind that building and sustaining a PMO IMS is not an end in itself. Ultimately, a schedule must help the PM make decisions about the program. Thus, a simple but useful schedule today is better than the detailed and perfect schedule next month. Time is money. Make the PMO IMS a critical contributor to decision making in your program office. 

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## MDAP/MAIS Program Manager Changes

With the assistance of the Office of the Secretary of Defense, *Defense AT&L* magazine publishes the names of incoming and outgoing program managers for major defense acquisition programs (MDAPs) and major automated information system (MAIS) programs. This announcement lists all such changes of leadership, for both civilian and military program managers for the months of September and October 2013. (Some program managers listed took the position earlier than September but were missed by the Service in their previous input.)

### Navy/Marine Corps

**Capt. Michael N. Abreu** assumed the position of program manager for the Naval Enterprise Networks Program (PMW 205) on Oct. 7.

**Karen Davis** relieved **Capt. Patricia Gill** as program manager of Advanced Technology (PEO [IWS]) on June 10.

**John M. Garner** relieved **Col. John K. Buckles** as program manager of Advanced Amphibious Assault (PEO [LS]) on July 10.

### Air Force

**Col. Christopher Coombs** relieved **Col. Shaun Morris** as the ACAT ID systems program manager for the KC-46 Tanker Modernization Program on Oct. 1.

**Col. William Leister** relieved **Col. Christopher Coombs** as the ACAT IC systems program manager for the MQ-1 & MQ-9 Unmanned Aircraft Systems Programs on Oct. 1.

**Lt. Col. Kevin Sellers** relieved **Lt. Col. Brian McDonald** as the ACAT ID program manager for the Three-Dimensional Expeditionary Long-Range Radar (3DELRR) Program on Aug. 2.

**Col. Gregg Kline** relieved **Col. Margaret Larezos** as the ACAT IA systems program manager for the Air and Space Operations Center Weapon System (AOC WS) Increment 10.2 Program on July 31.

# Scorecard Reviews

for Improved Software Reliability

Timothy Pohland ■ David Bernreuther



Software reliability poses a significant challenge for the Army as software is increasingly important in a broad range of applications. The safety, welfare and effectiveness of our Soldiers directly depend on the ability of software to perform as intended and operate reliably in adverse and austere conditions. The ability of the Defense Department (DoD) to provide a high level of Soldier services while minimizing overhead and other sustainment costs is tied directly to the reliability of large and complex software systems.

Software is a key enabler in compiling intelligence, conducting analysis, and performing command-and-control functions. For example, the Army must support numerous command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) systems at a cost in excess of \$200 million annually. Furthermore, embedded software has become an essential feature of virtually all hardware systems. This necessitates assessing system reliability through a holistic accounting of hardware, software, operator and their interdependencies.

**Pohland** is a computer engineer and a member of the U.S. Army Materiel Systems Analysis Agency (AMSAA) Reliability Branch with 5 years of reliability analysis, software development, and process improvement experience. **Bernreuther** is an operations research analyst at AMSAA Reliability Branch at Aberdeen Proving Ground, Md., and has 30 years of software development, technical analysis and process improvement experience.

**Figure 1. Sample Element Description (Low Risk)**

Design for Reliability
Developmental Testing
<ul style="list-style-type: none"> <li>• All modules of software are covered by unit testing and all are included in integration testing.</li> <li>• All external systems are included (or surrogated) in integration testing.</li> <li>• Multiple sets of test data are available to support both unit testing and integration testing during development. The test data adequately represents the scale of operations that the software will encounter when used operationally.</li> </ul>

Issues with the performance and reliability of software throughout the DoD led to development of the Capability Maturity Model (now Capability Maturity Model Integration or CMMI) in the late 1980s. Similarly, industry standards such as the IEEE/ISO 12207 also have emerged to address sound software practices. Additionally, a plethora of tools and techniques, from requirements management tools to dynamic code analyzers, are available to support the engineering of reliable software. Yet, as mature as software reliability practices and standards have become, reliability remains a significant issue for government and industry. A recent sample of combined hardware-software systems tested by the Army illustrates the significance of the issue. It found software failures pervasive throughout the sampled systems, constituting 52 percent of the overall failures (worst case: 82 percent).

**Benefits of a Scorecard Approach**

Software development often is complex and expensive, while available resources and time are generally limited. This exacerbates the challenges of ensuring appropriate and effective practices are followed. To facilitate development of more reliable software, the Army Materiel Systems Analysis Agency (AMSAA) has developed a software reliability scorecard. This instrument extends and complements an existing scorecard on general reliability practices. It also complements organization-centric approaches, such as CMMI, by assessing the level of risk associated with reliability-specific practices within an individual software project.

The scorecard is a structured and transparent instrument for assessing the health of an individual software development effort and is invaluable in isolating weak areas for further analysis and work. It enables scarce resources

to be prioritized and, subsequently, more reliable software to be developed. The research, discussion and reflection undertaken while applying the instrument can be as valuable as the resultant score(s). It provides a common structure for multiple disciplines to see the interrelationship and importance of various reliability issues and practices outside their own domain.

The scorecard focuses on areas that warrant additional research and analysis. It highlights areas of weakness and, through the evaluator’s recommendations, gives insight on how to address those weaknesses. However, it is not prescriptive as to specific actions that should be taken. AMSAA recommends that the areas of concern, once discovered, be investigated further to identify the best software and reliability practices and tools to be applied at those areas.

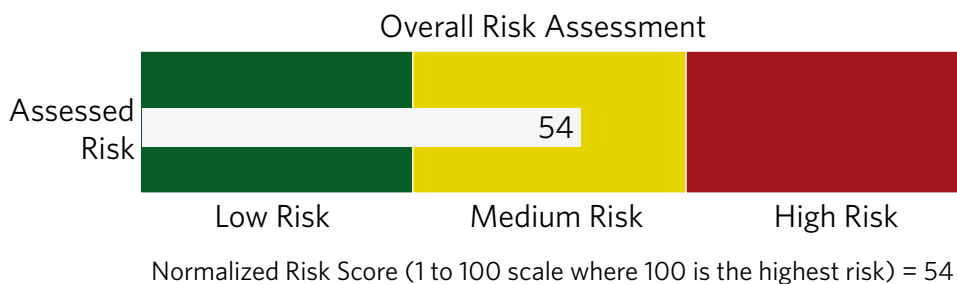
**How It Works**

The software reliability scorecard adheres to conventions similar to the existing General Reliability Scorecard, which is used by numerous DoD organizations. It is self-contained in an Excel spreadsheet with 57 specific elements to be evaluated and rated. All the elements are grouped into seven categories, along with definitions for each rating level, and laid out in a single input sheet. Each element is rated red, yellow or green to represent high, medium or low risk, respectively. An example of a rating definition of Low Risk for Developmental Testing appears in Figure 1. Additionally, cells are provided for the rater to enter a rationale and recommendations for each element. These offer important insights for the feedback process, helping turn the scorecard ratings into focused and effective actions.

The scorecard processes the individual ratings and derives a total score assessing how much the program is at risk. The ratings are adjusted by weighting factors assigned to each individual element. The overall risk assessment is normalized to a value between 1 and 100, where 1 is low risk and 100 is high risk. A top-level quantitative assessment is illustrated in Figure 2.

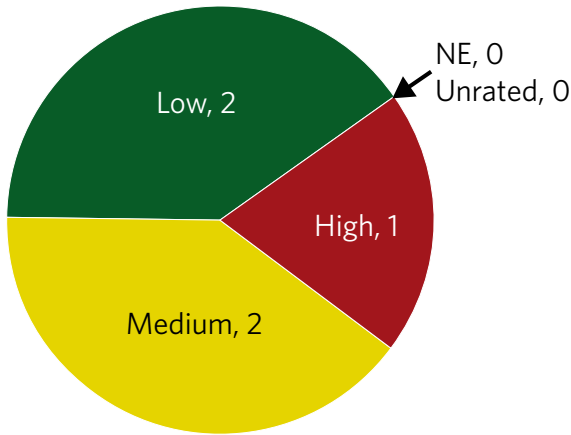
The scorecard also generates summaries of each of the seven categories to help focus on strengths and weaknesses. These pictorially represent the number of high-, medium- and low-risk elements in each category, as shown in Figure 3.

**Figure 2. Sample Overall Rating**



### Figure 3. Sample Category-Level Summary

Design for Reliability  
Number of Ratings by Risk Level



Normalized Risk Score (1 to 100 scale where 100 is the highest risk) = 40

It is highly recommended that a multidisciplinary team apply the scorecard to a project. Initially, each member should assess the project from his or her perspective and knowledge. The team then should compare and discuss its members' ratings of each element to achieve consensus. These deliberations usually are as insightful and valuable as the rating scores. The team should use the Rationale and Recommendation fields to help record the key points of its deliberations and draft recommended actions.

The instrument is designed to be of value at any stage of software development. Although many of the elements lend themselves to specific stages of the software life cycle, the results are most insightful when all elements have been assessed regardless of the project's current status. If the instrument is being applied later in a project's life cycle, assessment of the earlier activities provides valuable insight about the character of the existing design and code. Conversely, activities that are usually a priority later in a project (preparations for Fielding and Sustainment, for example) are "leading indicators" of the quality and thoroughness of the reliability tests being conducted. These later elements are not weighted as highly as earlier activities but still reduce risk. A project that proactively starts them early is reducing the overall risk of the project.

There may be cases where an element simply does not apply to a given project. For these circumstances, there is a "not evaluated" option for reviewers; the scorecard will drop these elements from its calculations and provide a normalized risk score from the remaining elements. In the summary chart for each category, a count of the "NE" elements is provided.

### Categories and Elements

The software reliability scorecard addresses seven key categories of reliability practices most applicable to software development: program management, requirements management, design capabilities, system design, design for reliability, (customer) test and acceptance, and fielding and sustainment. Each category then covers a number of specific elements focusing on key reliability practices. A detailed examination of every element within the scorecard is beyond the scope of this article. However, a discussion of each of the categories and some of their key features should provide an understanding of the breadth and depth of the examination of good reliability practices.

#### Program Management

Development of reliable software requires that limited resources and time be well managed; that the customer and team work collaboratively; and that reliability-enhancing activities receive the necessary resources, visibility and priority. The Program Management category addresses these needs by looking at 12 elements:


- Developer's Experience
- Process Maturity
- Program Planning
- Currency of Plans
- Progress Reviews
- Readiness
- Reliability Engineering
- Reliability Growth Management
- Verification and Validation (V&V)
- Supporting Disciplines
- Risk Management
- Commercial Off-the-Shelf (COTS) Management

CMMI, or similar organization maturity levels, is considered part of the developer's experience. As organizational maturity does not guarantee success, this element also considers the developer's experience with applications of the domain, size and complexity under consideration. Supporting Disciplines include human factors, technical writing, and others—essential to the software, but not necessarily involved with a project's core design and coding activities.

#### Requirements Management

Any successful development project relies on complete and clearly understood requirements. These should include well-considered and -defined reliability goal(s). A good system for recording requirements and linking them to the design capabilities that will provide them is also essential. The elements in Requirements Management are:

- System Requirements
- Currency
- Reliability Goals
- Requirements Allocation
- Quality of Requirements



**Ideally, the requirements of a software project are defined completely and well understood when design begins. They remain static thereafter. Realistically, this rarely happens because requirements evolve while the project progresses.**

- Use Cases
- Interoperability
- Dependency
- Other Characteristics

Ideally, the requirements of a software project are defined completely and well understood when design begins. They remain static thereafter. Realistically, this rarely happens because requirements evolve while the project progresses. Accordingly, Requirements Management also assesses how well the project realizes requirements have changed and adapts its plans and activities. A mature developer will seek to discover and accommodate the changes. This not only reduces risk but minimizes costs and time, as resources are more wisely allocated to accommodate the newest requirements.

Use Cases is a notable element, because these cases provide a powerful method to enhance understanding between the customer and developer and among the various involved disciplines. They also facilitate requirements definition, development, testing and documentation such as users guides. Their use greatly aids the development of reliable and effective software.

### ***Design Capabilities***

By assessing the developer's Design Capabilities, the scorecard seeks to ensure that sufficient capabilities to design reliable software are in place and implemented effectively. The seven elements of Design Capabilities are:

- Development Process
- Process Implementation

- Documentation and Repository
- Configuration Management
- Collaboration Capabilities
- Development Samples
- Analysis of Alternatives

The Development Samples element is particularly relevant to the DoD, where the applications/systems to be supported are often unique or highly specialized.

### ***System Design***

The software scorecard is intended to examine the enabling practices and capabilities being applied to a software development effort. It is not intended to make a detailed software engineering assessment of the code and design itself. However, the following key elements of the design can be assessed to ensure that the design addresses reliability drivers:

- System Architecture
- Modular Design
- Data Architecture
- Interface Design
- Fault Tolerance
- Usability
- COTS Selection

The scorecard treats Usability as an element integral to the software's reliability. This is particularly true for DoD applications, where a misunderstanding by the user or a series of small disruptions can endanger Soldiers in combat. Similarly, Soldiers rely on software prepared to handle Faults (internal and with other interfaced systems) with minimal disruption. The physically dispersed and austere locations in which the Army operates require that a well-designed Data Architecture consider the physical location of data and users and the realistic levels of communication between them.

### ***Design for Reliability (DFR)***

The category of DFR elements endeavors to ensure that practices crucial to the design of any reliable product are integral to the development effort. These practices need to be applied from the very start of development; program risk should be assessed higher if they are not. The DFR elements consist of:

- Failure Management
- Developmental Testing
- Reliability Monitoring
- System Reliability Analysis
- Independent Reviews

It is significant to note that Developmental Testing is called out as a separate element. Solid DFR requires that most reliability be "baked in" the software and design before customer testing. This means that the developer must expose failure modes as early as possible. Each mode cannot be resolved immediately. However, a general characterization of the failure

mode enables the developer to plan when and how it should be addressed. Mature developers will reduce risk and costs by conducting developmental testing to expose, characterize and prioritize failure modes as soon as possible. The subsequent customer test then becomes, as appropriate, a refinement stage to iron out a minimum of issues.

### ***(Customer) Testing and Acceptance***

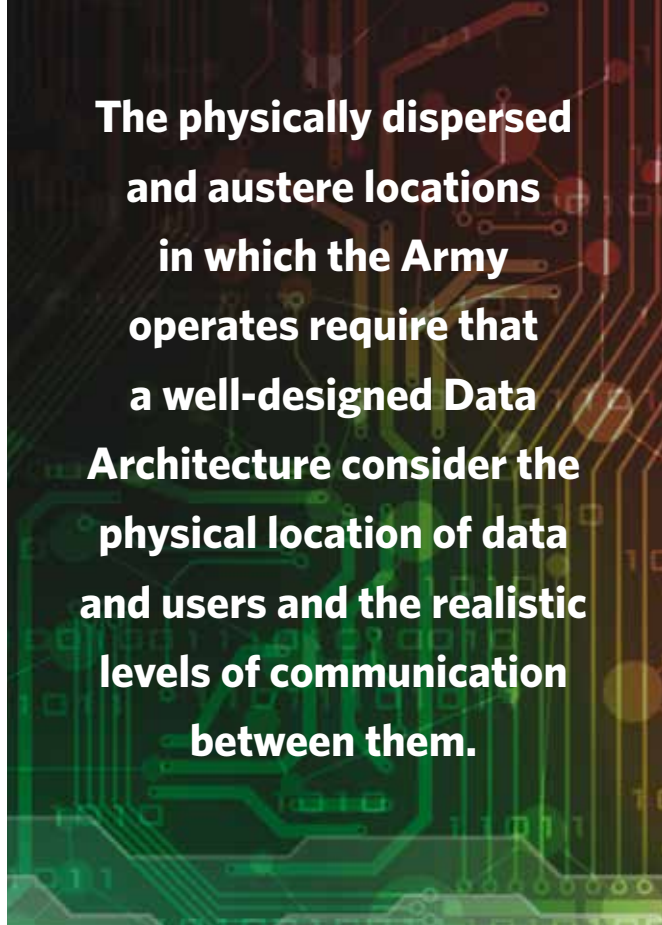
It is preferable that a developer bring a highly reliable product to customer testing—one that requires minimal corrections. The reality is that many software systems are provided to the customer with a low level of reliability. This has been particularly true of many DoD applications that call for a level of sophistication, fault tolerance and size that are hard to simulate in a development environment. Generally, new DoD systems experience new failure modes and a subsequent decline in reliability when they are fielded. Correcting these failures is extremely expensive and difficult. Accordingly, it is vital that customer acceptance-testing expose and resolve as many remaining failure modes and problems as possible. Further, the developer must have the capabilities and tools in place to handle the new issues as they arise. The numerous elements of (Customer) Testing and Acceptance seek to address these issues. The elements are:

- Test Coverage
- Companion Test Systems
- Test Depth
- Usability and Suitability
- Scalability
- Non-functional Characteristics
- Embedded Systems Testing
- Failure Analysis
- Software Code Analysis Tools

### ***Fielding and Sustainment***

The utility of a software reliability scorecard is less apparent when a project has reached the Fielding or Sustainment stage. However, the fielding and maintenance of existing software requires significant resources. For large applications, the financial cost is substantial. The elements of this category assess how well a project has prepared for these stages of the life cycle. It is recommended that the prior elements of the scorecard also be assessed at this time. They provide insight into the quality and character of the software on hand. A mature developer will, for example, know what issues (e.g., failure modes) remain unresolved. The elements addressed regarding Fielding and Sustainment are:

- Software Maintenance
- Field Support
- Documentation for Sustainment
- Dependencies and Interoperability
- Sustainment Testing
- Training
- Distribution
- Continuity of Operations Plan (COOP)




**The physically dispersed and austere locations in which the Army operates require that a well-designed Data Architecture consider the physical location of data and users and the realistic levels of communication between them.**

In the earlier stages of software development, scorecard users are encouraged to consider and assess the Fielding and Sustainment elements. Though these activities may not be due yet, a proactive developer will start working on them in parallel with earlier activities. They can serve as “leading indicators” of a low-risk project.

### **Summary and Conclusion**

AMSAA developed the software scorecard to complement its existing hardware reliability portfolio and facilitate an increasing software reliability workload. Its primary use is to assess the reliability practices of individual software projects and to focus more detailed analysis and work on the areas of most concern. It is a particularly useful approach when “triaging” ongoing software projects to identify where to focus analysis and support. AMSAA applies the scorecard methodology to provide Army and other DoD programs an independent assessment of the project’s level of risk. However, the instrument can be applied by the customer or as a self-assessment tool by the developer. Valuable ideas and feedback from industry partners and other DoD organizations have been used to improve this tool for more general use.

The software scorecard is available at no cost to any U.S. government agency and its contractors. Information to request a copy is available at [www.amsaa.army.mil/ReliabilityTechnology/RelTools.html](http://www.amsaa.army.mil/ReliabilityTechnology/RelTools.html). 

The authors can be contacted at [timothy.g.pohland.civ@mail.mil](mailto:timothy.g.pohland.civ@mail.mil) and [david.g.bernreuther.civ@mail.mil](mailto:david.g.bernreuther.civ@mail.mil).

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## The Original Director for Test and Evaluation

*Steven J. Hutchison, Ph.D.*

In the May-June 2013 issue of *Defense AT&L* magazine, Under Secretary of Defense for Acquisition, Technology and Logistics Frank Kendall authored an article titled “The Original Better Buying Power—David Packard Acquisition Rules 1971.” Packard’s fifth acquisition rule was “fly before you buy”—the underpinnings of test and evaluation (T&E). I thought it might be interesting to look at another challenge that then Deputy Secretary of Defense David Packard confronted in 1971: what to do about test and evaluation in the Department of Defense (DoD). The original Director for Test and Evaluation created by David Packard was a DT&E with broad responsibilities for all T&E matters in the DoD. Today’s DT&E is focused only on

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**Hutchison** is the principal deputy for developmental test and evaluation in the Office of the Secretary of Defense.



Developmental Test and Evaluation. This article provides a brief snapshot into the challenges involved in forming the first DT&E office in the Pentagon and its evolution into the DT&E office today.

In July 1970, President Nixon's Blue Ribbon Defense Panel (BRDP) reported its findings. The "Fitzhugh Commission," as it is sometimes called, in recognition of its chairman, Gilbert W. Fitzhugh, had been appointed 1 year earlier with the broad charter to report and make recommendations on the organization and management of the DoD, its research and development efforts, and its procurement policies and practices. The final report prominently featured a discussion of operational test and evaluation, and the panel's recommendations had significant influence on how David Packard would shape the role of T&E to support defense acquisition. (The BRDP is available at <http://www.dtic.mil/dtic/tr/fulltext/u2/a013261.pdf>.)

The BRDP had three main findings relative to the conduct of T&E: "functional testing" (we use the term "developmental testing" today) is fundamentally sound; operational testing is generally inadequate, and the Services do not conduct enough joint test and evaluation. Regarding "functional" testing, the BRDP wrote:

By and large, functional testing in and for the Department of Defense appears to be well understood and faithfully executed. Serious policy deficiencies are not apparent, and such failures in functional testing as occur can be primarily attributed to lack of technical competence, oversight, or procedural breakdowns. Functional testing is not considered to be a major problem area.

Pertaining to operational test and evaluation, however, the BRDP found that "Operational test and evaluation has been too infrequent, poorly designed and executed, and generally

responsibilities for any evaluation function must be exercised independently. When they are subordinated to or combined with responsibilities for the development of the item or subject being evaluated, the requisite objectivity is seriously jeopardized." The BRDP also considered evaluation within a much broader construct and recommended that the Secretary create a position of "Deputy Secretary of Defense for Evaluation" supported by three Assistant Secretaries: Comptroller, Program and Force Analysis, and Test and Evaluation. The BRDP further recommended that the Secretary create a Defense Test Agency "to perform the functions of overview of all Defense test and evaluation, designing or reviewing of designs for test, monitoring and evaluation of the entire Defense test program, and conducting tests and evaluations as required, with particular emphasis on operational testing, and on systems and equipments which span Service lines."

Packard promptly began acting on the BRDP recommendations. In the first 8 months of 1971, he signed three memoranda that made sweeping changes to the role of test and evaluation in support of defense acquisition.

In the first memorandum, "Conduct of Operational Test and Evaluation," dated Feb. 11, 1971, Packard wrote, "... a number of specific actions must be taken to put our house in order in this very important aspect of the weapon system acquisition process." Packard directed three specific actions:

- Services will restructure their organizations for OT&E to be "separate and distinct from the developing command" and report the results of its test and evaluation efforts "directly to the Chief of the Service."
- OSD will establish "a Deputy Director for Test and Evaluation within the Office of Director of Defense Research and Engineering (ODDR&E) with across-the-board



**Prior to 1976, the fiscal year began on July 1 and ended on June 30; in other words, Packard gave the DoD just 4 months to put its house in order!**

inadequate." The panel's recommendations regarding T&E, and thus the actions taken by DoD to implement those recommendations, essentially focused on correcting deficiencies in operational test and evaluation (OT&E), and have driven the primary focus in defense acquisition for the past 40 years.

The BRDP also highlighted the lack of OT&E oversight in OSD as a "glaring deficiency" and reported that "In connection with test and evaluation, it should be emphasized that

responsibilities for OSD in test and evaluation matters. This office will review and approve test and evaluation plans prepared by the Services and will provide an assessment of results obtained."

- Services will conduct more joint operational test and evaluation.

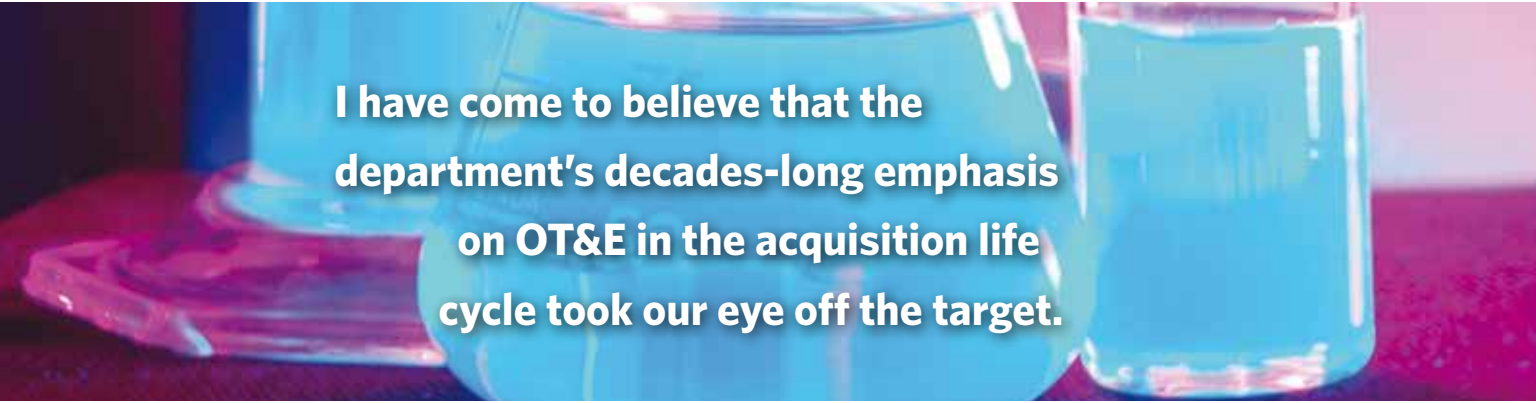
In the Feb. 11, 1971, memo, Packard asked the Service Secretaries to advise him of their plans before March 31, and to "be

prepared to have the new structure in effect by the end of this fiscal year." Prior to 1976, the fiscal year began on July 1 and ended on June 30; in other words, Packard gave the DoD just 4 months to put its house in order! Clearly, this was a high priority for the Deputy Secretary.

The second of Packard's memoranda, dated April 21, 1971, cemented the role of the Deputy Director for T&E in the Defense System Acquisition Review Council (DSARC) (the DSARC was the forerunner of the modern Defense Acquisition Board).

Evaluation would be responsible for "initiating and coordinating appropriate joint testing; overseeing the test and evaluation of foreign systems for possible DoD use; and administering for OSD its responsibilities for the national and major Service test ranges."

Packard needed someone to lead the new organization and make his vision reality. On June 7, 1971, Packard appointed retired Lt. Gen. Alfred Dodd Starbird to be the first Deputy Director for Test and Evaluation. Lt. Gen. Starbird set out to



**I have come to believe that the department's decades-long emphasis on OT&E in the acquisition life cycle took our eye off the target.**

Packard directed the Military Departments to provide their assessment of test results to the DDR&E prior to the DSARC Milestone III production decision. The Deputy Director for Test and Evaluation (DDT&E) would review those results and provide his independent recommendations at the Milestone III meeting.

Packard also quickly began honing the new processes as they were implemented. On Aug. 3, 1971, Packard wrote, "Based on experience to date resulting from [the previous two memos], I consider certain further clarification and instruction is required." In this third memorandum, "Test and Evaluation in System Acquisition Process," Packard described in more detail requirements for conduct of adequate OT&E. Additionally, Packard assigned these additional responsibilities to the Deputy Director for Test and Evaluation:

- "be responsible within OSD for reviewing test and evaluation policies and procedures and recommending to me changes as appropriate;
- "monitor closely test and evaluation conducted by the Services for DSARC programs, and such other programs as he believes necessary, throughout the entire testing cycle;
- "report to the DSARC and directly to me at DSARC Milestones I and II his assessment as to the adequacy of the list of critical issues and problems to be attacked by test and evaluation and the schedule of test milestones;
- and "report at Milestone III to the DSARC and directly to me his independent recommendation."

The Deputy Secretary went on to require that "Service test plans and test results be made available at his request as early as developed." Additionally, the Deputy Director for Test and

build the new DDT&E organization. He had three assistant directors with responsibilities for Tactical Systems T&E, Strategic and Support Systems T&E, and Test Resources. During his tenure, Starbird recommended the Defense Science Board (DSB) examine test and evaluation in the department. The DSB published the first report on T&E in April 1974; it would be the first of six reports the DSB would issue on T&E over the next 40 years. Starbird also initiated the publication of the first DoD Directive on test and evaluation: DoD Directive 5000.3, Test and Evaluation, was published on Jan. 19, 1973. The 5000.3 continued in effect, with four updates, until 1991, when the February 1991 issuance of DoD Directive 5000.1 canceled the 5000.3 and T&E became Part 8 of DoD Instruction 5000.2. Starbird also was able to insert into the defense budget a new appropriation for the deputy director of T&E. The Department of Defense Appropriation Act for FY 1973, Public Law 92-570, dated Oct. 26, 1972, included the following language:

***DIRECTOR OF TEST AND EVALUATION, DEFENSE***


For expenses, not otherwise provided for, of independent activities of the Director of Defense Test and Evaluation in the direction and supervision of test and evaluation, including initial operational testing and evaluation; and performance of joint testing and evaluation; and administrative expenses in connection therewith, \$27,000,000, to remain available for obligation until June 30, 1974.

Thus did David Packard implement the recommendations of the BRDP. Although there would not be a Deputy Secretary for Evaluation, or an Assistant Secretary for T&E, he did create the "defense test agency" in the form of the Office of the Deputy Director for Test and Evaluation in the Office of the Director of Defense Research and Engineering. The Deputy Director

for T&E was responsible for all matters involving T&E almost exactly as the BRDP recommended. Importantly, Packard also ensured the Deputy Director for T&E provided his independent assessment at the DSARC. However, independence came to be another issue entirely, and the T&E organization Packard put in place would not endure.

Concerns about OT&E continued to consume attention in the Pentagon and especially on the Hill. Likewise, there was an overwhelming sense that assignment of the Deputy Director for Test and Evaluation under the DDR&E posed a conflict of interest. The DDR&E was the DoD's chief acquisition official at the time, which violated the BRDP's premise that when responsibilities for evaluation "are subordinated to or combined with responsibilities for the development of the item or subject being evaluated, the requisite objectivity is seriously jeopardized." I doubt that Starbird, or any of the deputies after him, felt that way, but regardless, in September 1983, Congress established a presidentially appointed, Senate-confirmed position of Director, Operational Test and Evaluation, independent of the acquisition authority and reporting directly to the Secretary of Defense. The position of Deputy Director for Test and Evaluation was renamed Deputy Director for Developmental Test and Evaluation. Another 16 years later, on June 7, 1999—or 28 years after Packard created it—Secretary of Defense William Cohen disestablished the test office within what had become the Office of the Undersecretary of Defense for Acquisition and Technology. During those nearly 3 decades, all

emphasis in T&E in the department continued to be on operational testing, and Cohen's decision was intended specifically to strengthen the Office of the DOT&E; however, it virtually eliminated oversight of developmental test and evaluation. Congress would reverse this 10 years later. How that came to pass is another story.

As a member of the DT&E organization in OSD today, my view of test and evaluation is obviously biased. But with 15 years' experience in the T&E community, most of which has involved operational testing in some capacity, I have come to believe that the department's decades-long emphasis on OT&E in the acquisition life cycle took our eye off the target. Acquisition success is not about passing OT&E and getting that full-rate production decision; success occurs when we have properly set the conditions to begin production. The key to improving acquisition outcomes is to get the development right, and verify it through rigorous developmental test and evaluation. We have to do a better job helping programs get to Milestone C; that's the target we must aim for. In T&E, we have to shift left if we are going to "fly before you buy." Packard had a good plan back in 1971, but we lost track of the target. Given his unprecedented (and unmatched) level of involvement in shaping the course for T&E in the department, I think one could make a convincing argument that David Packard was, himself, the original DT&E. 

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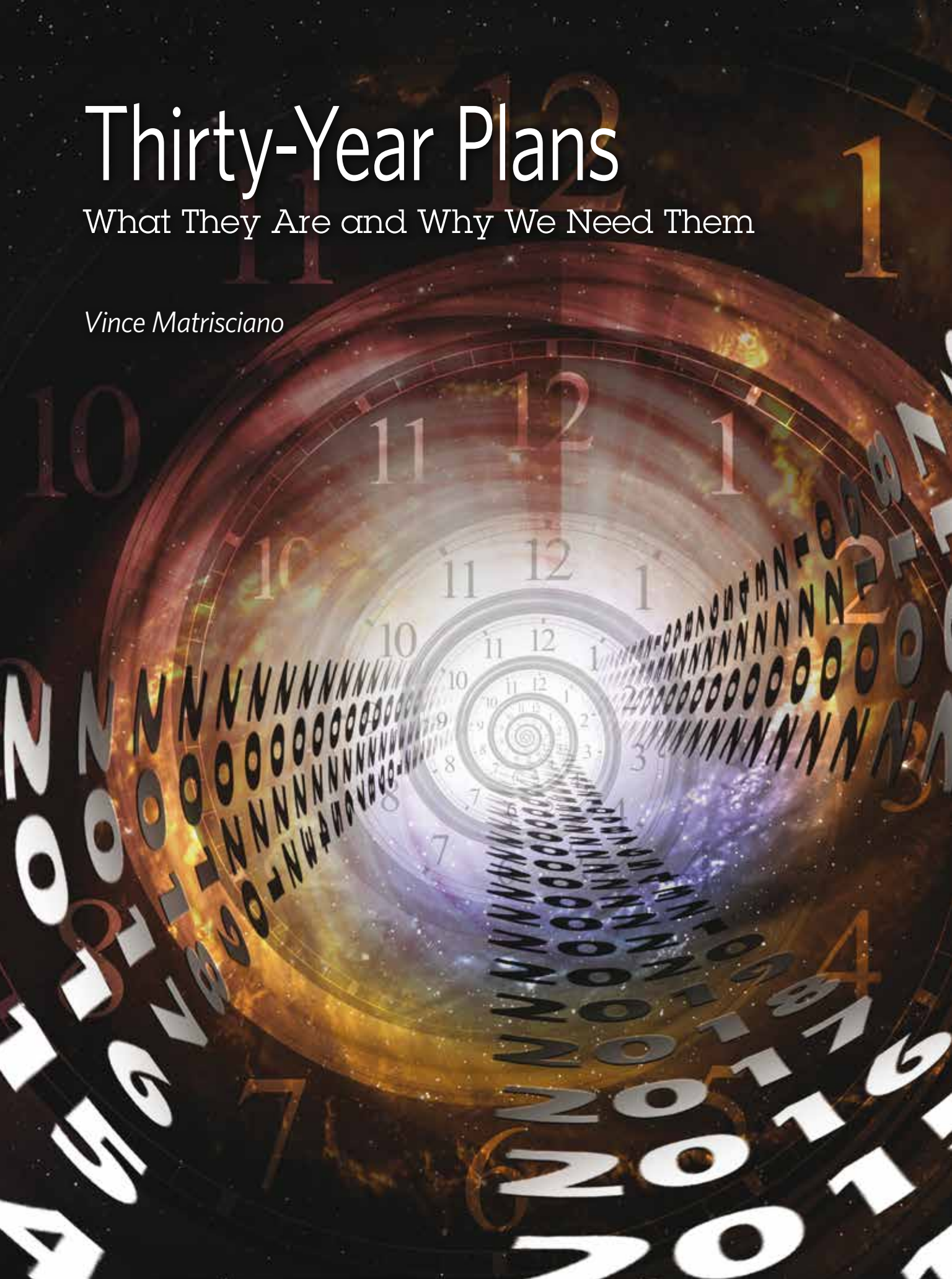
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# Thirty-Year Plans

What They Are and Why We Need Them

*Vince Matrisciano*





In the summer of 2012, Heidi Shyu, the recently confirmed Army Acquisition Executive, directed each Program Executive Office (PEO) to develop a 30-year strategic plan. The plan was to focus on linking science and technology (S&T) projects to programs of record, as well as modernization of existing fielded equipment. Each Army PEO developed its own plan, which mapped its programs of record to capability gaps and known S&T efforts meant to close those gaps. These plans were to address challenges leadership faced in obtaining in-depth information to support fact-based decision making.

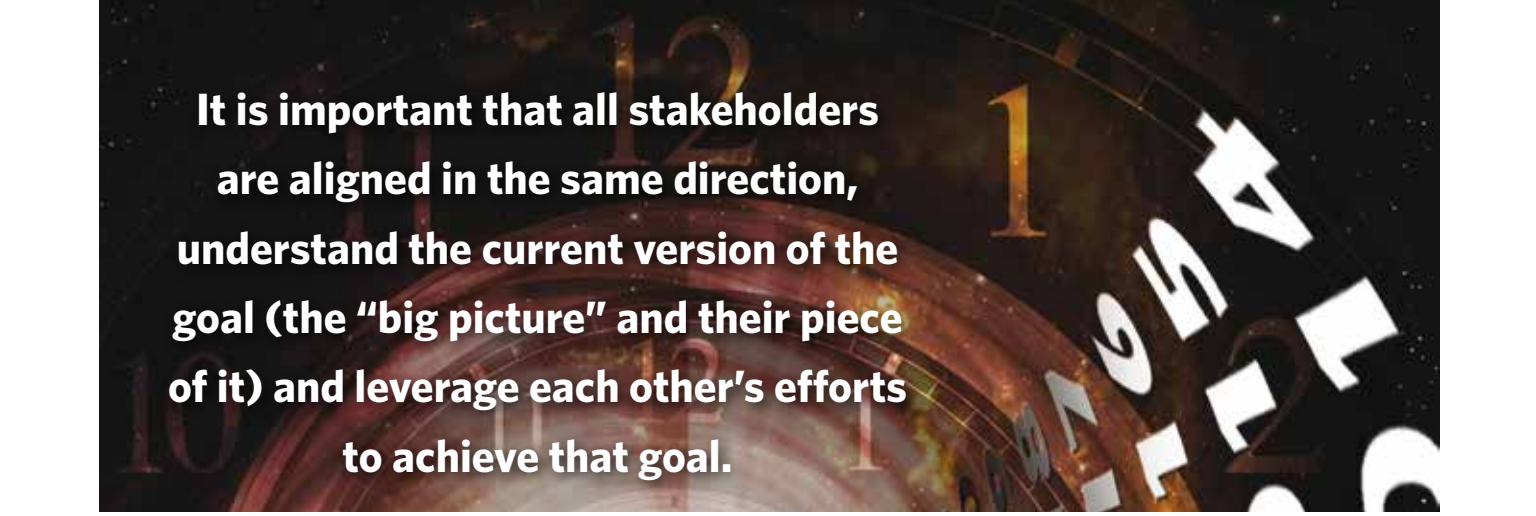
Army leadership constantly must make decisions related to prioritizing funding, scheduling and materiel acquisition; and these decisions are becoming more complex given the current and projected fiscal challenges. Second- and third-order effects of decisions become increasingly important, and these plans were intended to provide insight into those effects.

In parallel, Deputy Chief of Staff of the Army G8 initiated development of the modernization plans for existing equipment known as LIRA, or Long-Range Investment Requirements Analysis. These plans were meant to answer the question “how much of tomorrow’s dollars are we committing by spending dollars today?”

Subsequently, the Research, Development and Engineering Command (RDECOM) and its subordinate centers and laboratories, under direction of the Deputy Assistant Secretary of the Army for Research and Technology, developed 30-year roadmaps linking their technology initiatives to capability gaps and known programs of record. Again, the purpose of these plans was to support fact-based decisions by providing a longer range look at the consequences and effects of those decisions.

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**Matrisciano** has more than 20 years of research and development program experience within the Army and is currently the Research & Development Program Coordinator at the Program Executive Office for Ammunition, Picatinny Arsenal, N.J. He is responsible for defining the PEO’s near-, mid- and far-term research and development priorities, including the 30-year strategy. He is collaborating with counterparts in other PEOs and R&D organizations in developing an integrated strategy.



**It is important that all stakeholders are aligned in the same direction, understand the current version of the goal (the “big picture” and their piece of it) and leverage each other’s efforts to achieve that goal.**

Although diligent and fervent work went into each of the plans, they were all developed semi-independently. Limited coordination among plan authors provided some synergy among the plans, but they remained largely independent. And currently there is no clear path to integrate these plans.

During the development of these plans, the predominant questions from participants were, “Why are we doing this, especially given current funding limitations?” and “How can we know what life will be like 30 years from now?”

Both are valid questions. After all, who 30 years ago could have imagined all the products we use today? Regardless, there are significant benefits to developing a 30-year strategic plan, even if we cannot accurately forecast life in 2044. It all begins with the value of planning.

### **Benefits of Planning**

As acquisition professionals, we all are taught that a good plan (or any plan for that matter) is a valuable tool. It provides a barometer from which to measure our progress and success, helping us maintain control of our activity. Project managers typically plan their programs before they start to execute them. As most of us have experienced, however, forecasting the next few years of a program is difficult, and some programs fail or do not meet their goals fully despite a well-thought-out plan.

As a result, many of us have learned that the plan is not the panacea, not the end-all and be-all, but only the first step in the program management process. Strict diligence in monitoring performance and risk, and adjusting as necessary, are keys to success. And so it is with our 30-year strategic plans. They are a best guess based on what we know today, but probably are not very accurate. Nevertheless, they provide an orientation from which to proceed, and a rationale for why we are going that way. This allows all stakeholders to “be on the same page” and work toward a common goal.

When completed and integrated, the 30-year plan should show the “big picture,” linking all capability gaps to S&T activity, all S&T activity to fielding of materiel, and every fielding

to operations, support and eventual disposal and/or replacement. An important benefit is minimization of the Army’s demilitarization stockpile through greater emphasis on strategic planning at the materiel level. The finished product not only shows what needs to be done throughout the life cycle, but how much it will cost and when it should happen. Any breaks in the linkage are highlighted and addressed by informed leadership decisions, either by strengthening the links or eliminating them altogether.

### **Integrated Planning**

To be effective, these 30-year strategic plans must be integrated and include the same diligent monitoring that is applied to acquisition programs. To achieve integration, the individual PEO and RDECOM plans must be combined to become the cohesive 30-year strategic plan. This will ensure that all interfaces and relationships among systems and programs are considered. Integration of the individual plans is currently evolving at the “grass roots” level. PEOs and Research Development and Engineering Centers (RDECs) are coordinating with each other on mutual touch points to ensure that their efforts are useful and efficient. However, this process is not fully effective. While there is some integration in some areas, other areas are being missed. In other words, integration is “ad hoc.” To streamline this process, the standard acquisition Integrated Product Team, or IPT, model should be used. As applied here, the members of the IPT represent each of the PEOs, RDECOM, TRADOC, and Army headquarters staff (and others as appropriate). An IPT Lead would manage the integrated planning effort to ensure that roles and responsibilities are defined and the common goal of an integrated plan is achieved.

### **Maintaining the Integrated Plan**

Once the plan is completed and baselined, adequate monitoring is vital to avoid having it become “shelf ware.” The process for monitoring the plans also should mirror the IPT model described above, with the IPT Lead running regularly scheduled formal discussions (i.e., quarterly, semi-annually, etc.) to ensure the entire team remains aligned, manages risk, communicates status and updates the plan as needed. When assumptions become reality, the plan is updated. When “near term” planned activities come to fruition, “out years” are added

so it is a rolling 30-year plan. It is important that all stakeholders are aligned in the same direction, understand the current version of the goal (the “big picture” and their piece of it) and leverage each other’s efforts to achieve that goal.

Maintenance of the plan also includes regular interaction with senior leadership to communicate plan contents and status, as well as obtain feedback on any required adjustments based on changing priorities and/or updated strategy. Since its overall purpose is to inform leadership decisions, the plan must become a standard “front and center” fixture in the decision-making process. For the plan to be useful, senior leaders must routinely consider the information it provides.

### Why Now?

Another common question is, “The Army has been around a long time and we’ve never had a 30-year plan, so why do we need one now?”

One could also ask why—though the Army continues to field some of the best equipment in the world—programs still encounter roadblocks or dead ends. How many of those fielded items could have been fielded sooner and at a lower life-cycle cost? How many overlapping capabilities exist? How many technologies did not get fielded even though they achieved technical success? Why are there so many items in our demilitarization account? Now more than ever, the answers to these

questions have strategic relevance, but they remain elusive without an integrated long-term plan from which to acquire this knowledge.

No doubt we can collectively work more efficiently while remaining effective, and the integrated long-term plan—and ongoing maintenance of the plan—is essential for that to happen. It provides a mechanism to ensure that our efforts are complementary and neither duplicative nor wasted by showing how they fit into the long-term strategy while highlighting second- and third-order effects. In other words, it provides more and better information to feed fact-based leadership decisions.

Although long-term plans like this 30-year strategic plan are far from perfect, they provide the required baseline from which to operate and support informed decisions. In the current climate of fiscal uncertainties, long-term planning will help provide more “bang for the buck” by guiding informed investment decisions and identifying the second- and third-order effects. The key to effective and efficient fielding of equipment to the warfighter is active leadership in developing, monitoring and maintaining the collective plan. With budgets declining, and no sign of recovering, we owe our ultimate customers—the warfighter and the taxpayer—the best we can deliver in the most efficient manner possible. &

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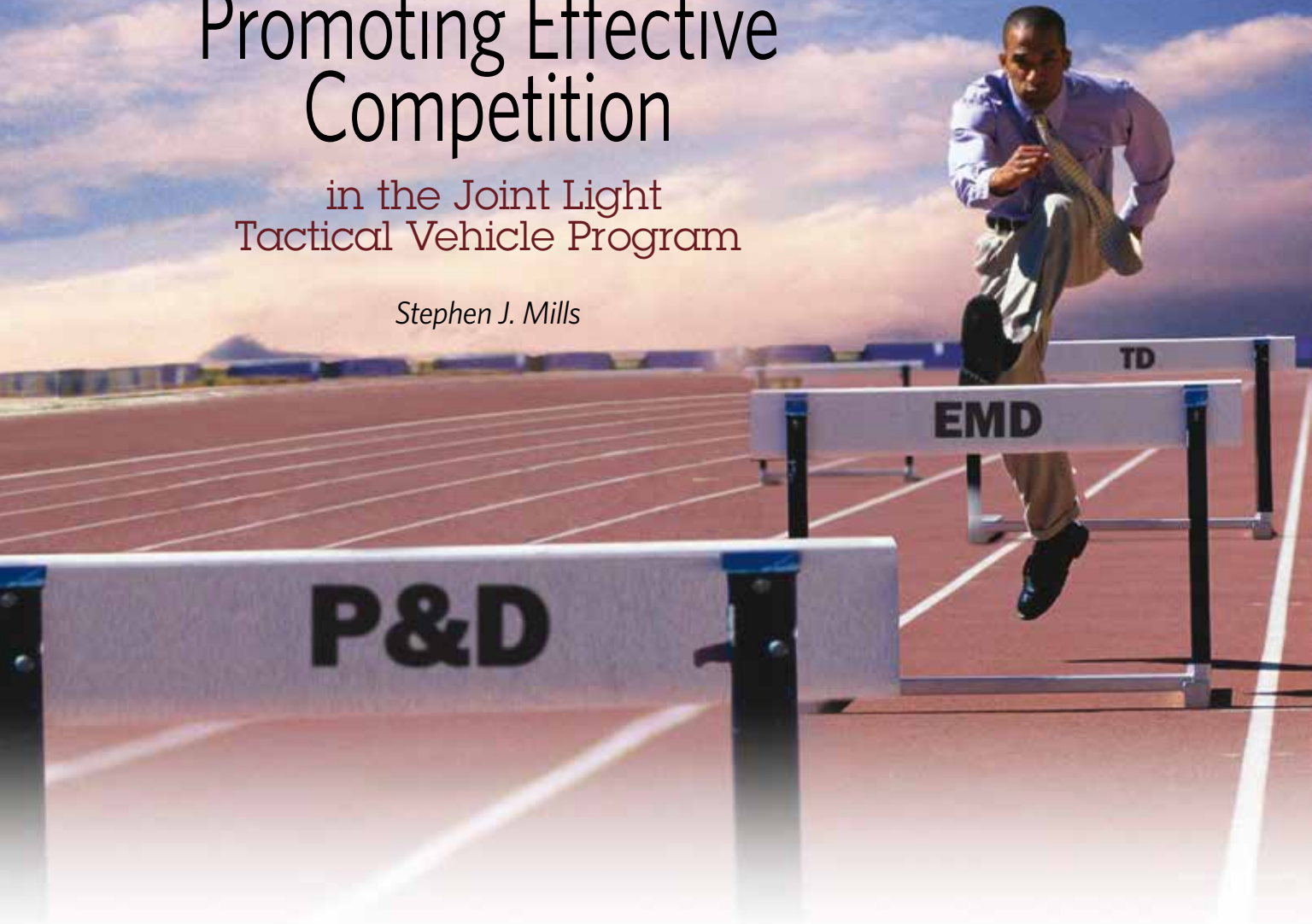
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# Promoting Effective Competition

## in the Joint Light Tactical Vehicle Program

*Stephen J. Mills*



Competition throughout the life cycle of an acquisition program not only is possible, it is alive and well in the Joint Light Tactical Vehicle (JLTV) program. This article focuses on the JLTV program and the Better Buying Power 2.0 (BBP 2.0) effort to “Promote Effective Competition.” Although the JLTV program began before BBP 2.0, the overarching concept of competition throughout the life cycle of an acquisition program is not new and remains a key component of the Federal Acquisition Regulation.

### **Program Overview**

Development of the JLTV is a joint program to augment the High Mobility Multipurpose Wheeled Vehicle (HMMWV) fleet currently in service with the U.S. Army and U.S. Marine Corps. For the Marine Corps, it is designed to replace HMMWVs only for the most demanding mission profiles, and for the Army, to replace “approximately 1/3 of the light wheeled vehicle fleet by 2040.” The JLTV family of vehicles will provide additional survivability, a greater payload, and responsive, well-integrated command and control. Changes in contemporary threats, coupled with the inability of the HMMWV platform to accommodate the magnitude of change needed to meet the new requirements, made the JLTV program necessary.

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## **“Do I spend precious time and resources to compete for the EMD phase of the JLTV program even though I just lost the TD-phase competition?” The conclusion many outside observers would come to is “No!”**

The JLTV program requirements were approved by the Joint Requirements Oversight Council in November 2006 and designated an Acquisition Category ID program with the Army as the lead. This program has experienced some significant challenges, including Technology Development (TD) phase protests from two offerors and a threatened program termination at the end of the phase. In September 2011, the Senate Appropriations Defense Subcommittee recommended canceling the JLTV due to rising program costs and continuous changes in requirements. The subcommittee endorsed the idea of changing the Modernized Expanded Capacity Vehicle (MECV) program (HMMWV Recapitalization) from a stop-gap effort to a full solution to meet the vehicle requirements of the Army and Marine Corps in place of the JLTV.

As a full solution, MECV funding would have had to increase significantly. Once the subcommittee recommendation was released, the Army and Marine Corps finalized the JLTV requirements and established a cost cap of \$250,000 per vehicle. These new program requirements were codified in the Engineering, Manufacturing and Development (EMD) Phase Request for Proposal (RFP) and proved effective in reversing the recommendation of the subcommittee. The MECV program was canceled in January 2012. The restructured JLTV program is in the EMD phase with three competing industry partners (Lockheed Martin, Oshkosh Corporation and AM General). Low-rate initial production is planned for 2015, with full-rate production scheduled for 2018. The Army intends to purchase 49,909 vehicles, and the Marine Corps, 5,500.

As noted above, BBP 2.0 clearly focuses on the importance and value to the government of both creating and maintaining a competitive environment. The JLTV Joint Program Office used requests for information, industry days, and draft RFPs to communicate program requirements effectively to industry and to demonstrate the government’s commitment to the viability of the JLTV program.

In the case of the JLTV, the use of these tools provided clear commitment to the JLTV program and motivated the three industry teams—Lockheed Martin, BAE and General Tactical Vehicles—each to have completed a working JLTV prototype before release of the final RFP during the TD phase. This type of response from the offerors has the potential to reduce overall program technical risk as well as program cost.

Government acquisition programs’ overall risk is reduced when the government provides industry with a clear

understanding of future needs. The JLTV acquisition strategy and source selection plan served as a framework for industry to conduct effective strategic planning and enabled industry to compete for both TD and EMD contracts. The EMD-phase RFP focused on “full and open” competition and contained language that specifically allowed offerors who were rejected in the TD phase to compete for EMD-phase contracts.

This component of the JLTV acquisition/source selection strategy created an interesting opportunity for industry teams to ponder: “Do I spend precious time and resources to compete for the EMD phase of the JLTV program even though I just lost the TD-phase competition?” The conclusion many outside observers would come to is “No!” Significant time and money would be required, and convincing senior industry leaders to assume that level of risk would be difficult. Yet, in the case of the JLTV, two of the three teams selected for the EMD phase were teams that had been rejected in the TD phase.

This occurrence generates many questions. What motivated these industry teams to compete for the EMD phase? What is the real story behind the firm’s success in the EMD phase competition? Is this a David and Goliath story? One of the industry partners rejected for the TD phase, but selected for the EMD phase was Oshkosh Corporation. Part of their story revolves around leveraging other opportunities:

“Finally, Oshkosh, which had its eye on the JLTV program since it lost out on a technology development contract in 2008, is offering a variant of its Light Combat Tactical All-Terrain Vehicle (L-ATV),” wrote Kate Brannen (“Competition upended in JLTV program”) in the March 31, 2012, *Marine Corps Times*. “Oshkosh said it has been able to build off of lessons learned from its MRAP-ATV (M-ATV) effort, which was designed to meet an urgent need in Afghanistan for a lighter mine-resistant, ambush-protected vehicle.” Brannen added.

Oshkosh’s efforts on the M-ATV provided significant value for their EMD-phase offering. They not only leveraged lessons learned in Afghanistan, but could claim recent and relevant past performance in fielding tactical, wheeled vehicles. A quick review of the Oshkosh EMD-phase proposal reveals that past performance was the second-highest rated factor after technical. This is a major change to relative importance when compared with the TD-phase request; in the TD phase, past performance was much less important when compared with the other factors.

The other team that did not win a TD-phase contract, but was successful in the EMD-phase competition was AM General, manufacturer of the HMMWV. With diminishing HMMWV work, AM General remained motivated to continue to compete for the JLTV production effort.

In the end, a key contributor that motivated both Oshkosh and AM General to compete in the EMD-phase competition was the major change in user requirements driven by the Senate subcommittee's threat of program cancellation. The new user requirements changed the overall technical focus of the program from an expensive, high-risk approach to an approach with less technical risk and a significantly lower cost in production. This change reduced the relevance of the competitive prototyping strategy employed in the TD phase, which was based on much different JLTV user requirements.

The JLTV program is currently in the EMD phase. The source selection strategy for the program's next phase, Production and Deployment (P&D), has not been finalized at this time. Will the JLTV program simply choose to employ a single industry partner based on the results of the EMD-phase efforts, or will competition continue?


It appears that "ensuring competition throughout the program life cycle" remains a focus of the JLTV program office. On March 13, 2013, the JLTV office released a P&D-phase

Deployment Phase Market Research (non-EMD vendors) paragraph in the executive summary: 'Non-EMD vendors will be expected to perform, at a minimum, all of the same testing in the same manner with the same hardware quantities as the EMD vendors.'

The conditions for continued competition into the next phase appear to be in place. Do these conditions represent a viable opportunity for a non-EMD vendor to win a production contract for the JLTV?

The JLTV program's acquisition strategy includes a competitive focus well into the P&D phase through the optional purchase of the JLTV Technical Data Package (TDP). Ownership of the JLTV TDP provides the capability of competing for follow-on production efforts with other industry partners. This competitive component of the JLTV program was briefly mentioned in the JLTV Selective Acquisition Report Executive Summary dated Dec. 31, 2012.

In conclusion, the JLTV program has had significant competition to date and clearly supports the concept of maintaining competitive environments. The decision to continue competition into the EMD phase with three offerors is costly, but it clearly ensures the continuation of competition through the P&D phase. The unusual occurrence of two of three TD-phase losers winning EMD-phase contracts is an event worthy of



**This 12-page document outlines in-depth requirements for any interested industry partner that desires to compete for the final production contract. It leaves the door open for continued competition into the production phase of the program.**

market survey for the following reason: "The purpose of this market survey is to determine whether there are any viable non-EMD vendors able to compete on a full and open basis in accordance with the acquisition strategy of the JLTV program."

This 12-page document outlines in-depth requirements for any interested industry partner that desires to compete for the final production contract. It leaves the door open for continued competition into the production phase of the program. This market survey also clearly states what potential, non-EMD vendors must do to be competitive in the event they submit a bid for the upcoming JLTV production effort:

The JLTV EMD solicitation (W56HZV-11-R-0329) offered non-EMD vendors the opportunity to participate in the JLTV EMD program at their own risk and expense. Per the Production and

examination. For this to occur, those teams (Oshkosh and AM General) had to use significant internal funding to be competitive. What was their motivation for doing so? I believe part of the answer lies in the changes to user requirements, which made these teams more competitive. The recent release of the market survey and the option to purchase the TDP for possible competition for additional production contracts are positive developments from a competition perspective. The big question is whether any non-EMD offeror could meet the rigorous requirements outlined in the market survey. A critical question yet to be answered is whether the JLTV acquisition strategy, which maximizes competition, will result in a fielded product that meets user requirements and the established cost cap per vehicle of \$250,000. Only time will tell. &

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# Your PM Personality —and Why It Matters

*Owen Gadeken, DSci., Eng. Mgt.*

Personality type doesn't sound like a topic with much relevance to program management. Most of my DAU students in the program management (PM) career path don't think a lot about the impact of their personality or management style until they begin to have problems on the job. Then it slowly dawns on them that their personality may be part of the problem as well as the way forward to a solution.

Effectiveness in the acquisition workplace requires much more than just knowing what to do. You have to be able to apply your knowledge in a variety of complex situations where "by the book" solutions often fail. This gives rise to the "knowing-doing gap" or the inability to translate subject-matter expertise into workplace results.

As a manager, your results depend much less on what you know and do, and much more on what your team knows and can do. Therein lies the link between personality and results. Your personality impacts your management style, and your management style impacts how you interact with your team to achieve results.

Every manager seeks to provide direction and motivation to his or her team, but management style can often get in the way. Every team member is different. Each one has different experiences, skill levels, motivation and different ways (styles) by which they like to be managed. So, effective managers take time to analyze their style

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and the style of each of their team members, and often adapt their style with different team members to get better results.

One tool that has proven quite useful in analyzing people's styles at work is the Myers-Briggs (personality) Type Indicator (MBTI). This assessment can be done in a few minutes online or with a self-score instrument in class and is quite easy to understand when presented by a trained facilitator. In many of our classes, most students have already taken the MBTI but have not had enough training or practice in how to use it.

**Figure 1. MBTI® Type Table of PM Attributes**

ISTJ responsible structured consistent	ISFJ gracious dependable low-key	INFJ insightful caring inner-drive	INTJ thoughtful independent focused
ISTP practical immediate calm in crisis	ISFP easy going supportive quiet action	INFP idealistic value-driven facilitative	INTP conceptual adaptive challenger
ESTP action oriented risk taker negotiator	ESFP engaging resourceful spontaneous	ENFP energetic inclusive idea oriented	ENTP freethinker theoretical natural debater
ESTJ decisive systematic accountable	ESFJ debonair organized traditional	ENFJ enthusiastic persuasive team builder	ENTJ strategic commanding results focused

Note: Myers-Briggs Type Indicator and MBTI are registered trademarks of the Myers-Briggs Type Indicator Trust in the United States and other countries.

MBTI is composed of four basic personality preferences that relate well to workplace activities. The first two preferences, called the core functions, deal with how we gather information and then make decisions based on this information. Sensors (S) prefer to take their information from what they see in the present with their five "senses"—information they often capture in great detail. Those who are iNtuitors (N) look more at how the information fits into a "big picture" or what future possibilities it suggests. With the data gathered, thinkers (T) analyze it logically to make the most objective decision, while feelers (F) include the impact on the people involved to achieve a more harmonious and subjective decision.

The remaining two preferences, the first and last letters in your four-letter personality Type, are called the "attitudes" since they amplify the two core functions discussed above. The first letter of your MBTI Type has to do with where you get your energy. Extroverts (E) get their energy from being in the external world of people and activities, while Introverts (I) are more comfortable reflecting in their inner world of thoughts and ideas. The fourth and last letter of your MBTI Type indicates which of the core functions you display to the outside world. If your last letter is J, your Judging or decision-making function is what you show to the world. You appear to others as structured and decisive. If on the other hand, your last letter is P, your Perceiving or data gathering function is what you show to others. You appear open and flexible since as a perceiver you always are looking for new information.

With MBTI, it is important to understand the concept of preference. While Type theory says we are born with a preference for one letter in each of these pairs (S-N, T-F, E-I & J-P), our day-to-day behavior reflects a balancing act that includes all

eight letters. We choose our behavior, so even the most introverted type still must engage with the outside world and talk to people, and the off-the-wall extrovert still needs some time alone to reflect. The key here is to find the right balance between your individual preferences and the demands created by the situations you face each day.

The other key concept in Type theory is self-validation. The results of your MBTI assessment are really just a working hypothesis, which you must validate. In other words, you decide which of the four-letter Types (see Figure 1 Type Table) is the best fit for you. This is often the Type from your assessment report, but you still must decide and validate ("take ownership" of) your Type.

Many potential insights can come from MBTI, but they all require spending some time reflecting on the Type you validate and how that Type has helped and hindered you in your current and past assignments. For example, as an ENFJ, I was great at putting together a people-centered vision as a DAU department chair, a role I played in two departments for more than 10 years. I wasn't so great at keeping track of the details such as spell checking my slides and following up on action items I had assigned to subordinates. I was very strong on empowering my faculty across the board, until I discovered that many of them didn't want to be empowered ("just tell me what to do"). I was always interested in talking with my team to the point where my two administrative assistants actually asked me to stop coming into their office every 15 minutes with a different task (both were introverts). They took our MBTI team-building off-site session to heart and actually learned how to manage their boss (me). The point here is that MBTI really helped me and my team work more effectively. Reflecting on my MBTI Type eventually convinced me that my best role at DAU was

not as a department chair but back in the classroom interacting with our customers (students).

So, what does MBTI mean to you? You actually can explore that question after you have completed an MBTI assessment and reflect on your four-letter type. Here a few questions which may prove helpful. How does my type play out in my current job environment? What type or behaviors do I need to demonstrate on my current program to maximize our probability of success? What are the implications of my type for future career opportunities? How does my type play out at home with my family and friends? This list of questions can go on from here.


Let's take the type we most frequently find in our DAU PM courses, namely ISTJ. This Type derives from and is ideally suited for the Department of Defense, military, program management, and science and engineering cultures which make up defense acquisition. But this type also has (as do all types) some rather glaring weaknesses, especially as you move up in the organization from doing program management to leading a program or organization. Building on the ISTJ baseline of being responsible, structured and consistent, an ISTJ PM also needs the flexibility to behave at the opposite end of each of these preferences as illustrated in Figure 2 and discussed below.

While the "I" program managers think and reflect carefully (often in the comfort of their closed-door offices) before taking action, they need E behavior to be the visible spokespersons for their program and get out and "manage by walking around" their office environments. While Ss take in and sort

vast amounts of project data, Ns help us see where that data take us in the future. While Ts make clear and well-organized decisions, Fs make sure the people can "buy in" to these decision and are not lost in the process. While Js make sure the program runs on schedule and key deliverable dates are met, Ps stay open to new and possibly better ways of meeting or exceeding these requirements.

**Figure 2. Type Development Challenge**

<b>I</b> think and reflect, then act	→	<b>E</b> visible spokesperson for the team
<b>S</b> gather the real-world data	→	<b>N</b> look to the future (plan & vision)
<b>T</b> make fact-based decisions	→	<b>F</b> stand up for the people you lead
<b>J</b> Be decisive, reach closure	→	<b>P</b> stay open to new ideas

It has become apparent to me that the more you can integrate across each of the preferences, the better program manager and leader you will be. Instead of someone who is "locked in" to your box on the Type Table, you can be more of a situational leader, not with your preferences but with the behaviors you choose to employ. Your better self-management and adaptive behaviors can end up being a gift to you, your people and your program. 

The author may be contacted at [owen.gadeken@dau.mil](mailto:owen.gadeken@dau.mil).

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# Predicting Program Success— Not Child's Play

*Debra E. Hahn*

**W**henever I deal with stakeholders, I am reminded of the game “Rock, Paper, Scissors” that I played as a child. If you're not familiar with the game, two players, on the count of three, put forth a hand in a symbol representing a rock, paper or scissors. The winner of the round is determined by the relationship between the two factors: Paper covers rock, so paper wins; rock breaks scissors, so rock wins; or scissors cut paper, so scissors win. When I was young, the winner got to punch the loser in the arm or give a two-finger wet slap. Both consequences were harmless but somewhat painful.

One could argue that there is a forecasting aspect of the game based on the player's last three to five throws—i.e., past performance. To win continuously, a player has to guess what symbol the other player will throw and then throw the appropriate winning symbol. It is difficult to predict because every throw has a winner or loser based solely on the situation at the time, and the situation is dynamic.

This is very similar to the program management and acquisition environment where predicting the currently acceptable set of decision factors is critical to program success. When developing an acquisition strategy or determining a course

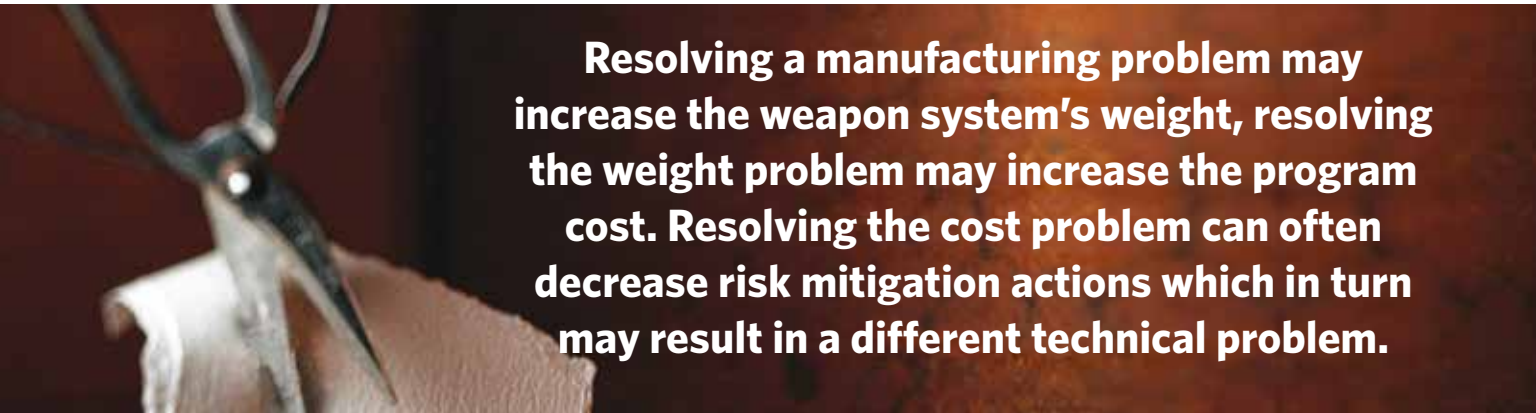
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**Hahn** has 41 years of financial and program management experience as a military officer, DoD civilian and as the deputy director of Lockheed-Martin's Center of Performance Excellence. At Defense Acquisition University, she served as the PMT 401 course manager for 7 years and currently is a professor of financial management and BCF 301 course manager.

of action, the hot or driving influence or focus today likely will change in the next 12 to 18 months as political and budgetary considerations change. Another complicating aspect is that each headquarter's directorates (functional areas) have different perspectives with associated desired outcomes. The various multiple perspectives can cloud the context of the issue or decision at hand. The decision process becomes more complicated when you consider the obviously inconsistent objectives of the contractor, user, different Services, the Office of the Secretary of Defense, the whole Executive Branch

because of the dynamic, contradictory, interrelated, piecemeal decision factors within an environment with inconsistent requirements—and within DoD—sometimes unspoken requirements. Obviously, there is no one set of approved properties of wicked problems; each author has his or her own “bookworthy” set.

A quick review of a recognized set of wicked problem factors will demonstrate how the DoD acquisition environment clearly fosters wicked problems.



**Resolving a manufacturing problem may increase the weapon system's weight, resolving the weight problem may increase the program cost. Resolving the cost problem can often decrease risk mitigation actions which in turn may result in a different technical problem.**

and Congress. Trying to find a solution or make a decision that satisfactorily appeases each of these stakeholders with their conflicting objectives can be mind-numbing. Yes, conflicting! The result is that many times the outcome is not the optimal or even the best decision but the decision that placates the majority of the stakeholders. In other words, the most sellable solution/decision is made.

As an instructor who spent more than 11 years teaching critical thinking and decision making using “real” program scenarios/case studies in both government and contractor program management training courses, I’ve witnessed this phenomenon firsthand. Each student’s experiences, functional perspective and current assignment set the boundaries of an acceptable solution. The ensuing emotional discussions center on the assumptions each student has made based on unique backgrounds, viewpoints and biases.

Considering there are myriad stakeholders and decision makers within the Department of Defense (DoD) acquisition process, each with unique boundaries, the result is innumerable, diverse decision factors. Therefore, I can unequivocally state that, regardless of your perspective (government or contractor) determining the appropriate set of decision factors is crucial to determining a sellable solution. Unfortunately, the four- or five-step decision-making process typically taught is not adequate to handle this multifaceted and overly complex environment, as it assumes an agreed upon set of decision factors. Therefore, a more dynamic process is required.

The term generally associated with a problem with dynamic decision factors in a multistakeholder environment is “wicked.” A wicked problem is almost impossible to solve

There are multiple stakeholders with multiple unique requirements and decision factors. In addition, based on their perspective, each stakeholder may envision a different problem or acceptable solution.

Every problem is unique. Similar problem may exist, but in reality each similar problem has a unique situation and impacting factors. For example, both the Joint Strike Fighter and the MQ-4C Triton programs have technical and cost issues, but the factors driving those issues are uniquely different.

The problems are not discrete; rather the solution to one problem tends to cause another problem. Resolving a manufacturing problem may increase the weapon system’s weight, resolving the weight problem may increase the program cost. Resolving the cost problem can often decrease risk mitigation actions, which in turn may result in a different technical problem.

It is difficult to fully comprehend the problem without an in-depth analysis of the choices, and when each option is analyzed the problem evolves or morphs into a different problem. As a team considers the implications or circumstances surrounding various choices, either the team identifies secondary or tertiary impacts that are unacceptable or the review in itself changes the situation. In either case, the original problem or the range of acceptable outcomes is redefined.

There are multiple reasonable solutions to a wicked problem. There is not one right solution. Multiple solutions will provide a wide range of acceptable outcomes. And unfortunately, a good decision does not guarantee a good outcome, because of the dynamic nature of the environment.



There are no “do overs.” The implementation of the decision significantly changes the environment/situation, thereby altering the problem. Because the program environment and resources have been modified, previously considered alternatives no longer are viable and a new wicked problem emerges.

In summary, wicked problems tend to be one-of-a-kind situations without a “right” solution; a number of possible, reasonable solutions exist. Because of the complexity of a wicked problem, its resolution typically creates another problem; which is typically wicked. It is this never-ending cycle of wicked problem after wicked problem that explains why the DoD acquisition process is inconsistent and why years of acquisition reform changes have improved overall individual program performance very little.


As I said earlier, selecting the right decision factors is critical to making the best decision; this is especially true in the “wicked” DoD acquisition process. As a longtime instructor, I’ve studied the brain and how it functions. A human brain cannot simultaneously process more than four or five decision-factors. The human brain cannot assimilate and evaluate more than four or five interrelated factors and consider more than four to five possible consequences. Yet, the DoD program manager (and milestone decision authority) often has 10 to 15 “critical” factors and multiple objectives to consider in making a decision. I contend that it isn’t the acquisition process that needs to be improved, but rather the acquisition environment. Key decision makers must accept the fact that the DoD acquisition environment inherently generates wicked problems. Solving

between past and present situations and cautiously apply lessons learned.

Second, whenever possible, break the problem or decision down into more discrete pieces. In order to solve any problem, the problem definition must be clear and agreed upon by all stakeholders. Because wicked problems are pervasive and extremely difficult to delimit, thus allowing for different perceptions, it is easier to get agreement on smaller aspects of the problem or desired outcomes. The “bite-size” pieces then can be prioritized. There is a risk that defining the problem in “bite-size” pieces makes it easy to fall into the trap of solving the smaller pieces and ignoring the dynamic, interrelated aspects of the problem. Beware of simplistic solutions to complex problems. The slogan should be: Define small and resolve big.

Third, focus on understanding the problem’s interdependencies and multidimensional aspects. This action is extremely difficult to effectively employ, as we often are completely unaware of the interdependencies until we implement our solution—and days, weeks or months later the secondary or tertiary impacts unexpectedly reveal themselves. It is the multidimensional aspect and requirements of the acquisition environment that muddles the process. Multidimensional problems require multidimensional solutions, and most of us are novices in multidimensional thinking.


Finally, I believe the easiest way to tame wicked problems is to simplify the environment by agreeing on four or five prioritized



**Beware of simplistic solutions to complex problems. The slogan should be: Define small and resolve big.**

wicked problems requires a multifaceted, dynamic decision-making process and the typical DoD 6-month decision-making cycle/process just doesn’t “cut the mustard.” The acquisition environment must be simplified.

So the million-dollar question is: How do you solve a wicked problem? The answer is simple to state and very difficult to implement. First and foremost, accept that this is a unique problem within a distinctive environment with an exclusive set of decision factors. What worked 5 years ago in a similar situation on another program probably won’t work in this situation; it is a different problem in a different environment. Beware of the Lessons Learned trap. I strongly believe we should learn from our mistakes, but be cognizant of the differences

key decision factors. Unfortunately, it isn’t easy because not only must they be “agreed upon” by all stakeholders/decision makers, but they must be adhered to regardless of the stakeholder’s functional area or level within the DoD, Executive Branch or Congress. Alignment of decision factors is critical to improvement of overall program performance. The non-selected decision factors favored by various “rice bowl constituents” must truly be set aside. In an overall context, better decisions can be made only when the acquisition environment becomes less wicked and acquisition decision factors and requirements become less complex and more definitive. Until that happens, program managers will continue to play Rock, Paper, Scissors when making decisions. 

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# Defense AT&L

## Writers' Guidelines in Brief

### Purpose

*Defense AT&L* is a bimonthly magazine published by DAU Press, Defense Acquisition University, for senior military personnel, civilians, defense contractors, and defense industry professionals in program management and the acquisition, technology, and logistics workforce.

### Submission Procedures

Submit articles by e-mail to [datl@dau.mil](mailto:datl@dau.mil). Submissions must include each author's name, mailing address, office phone number, e-mail address, and brief biographical statement. Each must also be accompanied by a copyright release.

Receipt of your submission will be acknowledged in 5 working days. You will be notified of our publication decision in 2 to 3 weeks. All decisions are final.

### Deadlines

Note: If the magazine fills up before the author deadline, submissions are considered for the following issue.

Issue	Author Deadline
January-February	1 October
March-April	1 December
May-June	1 February
July-August	1 April
September-October	1 June
November-December	1 August

### Audience

*Defense AT&L* readers are mainly acquisition professionals serving in career positions covered by the Defense Acquisition Workforce Improvement Act (DAWIA) or industry equivalent.

### Style

*Defense AT&L* prints feature stories focusing on real people and events. The magazine seeks articles that reflect author experiences in and thoughts about acquisition rather than pages of researched information. Articles should discuss the individual's experience with problems and solutions in acquisition, contracting, logistics, or program management, or with emerging trends.

The magazine does not print academic papers; fact sheets; technical papers; white papers; or articles with footnotes, endnotes, or references. Manuscripts meeting any of those criteria are more suitable for DAU's journal, *Defense Acquisition Research Journal (ARJ)*.

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### Length

Articles should be 1,500-2,500 words.

### Format

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