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SPACE ACQUISITION

HIGH FRONTIER

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Cover: *Air Force Space Command's mission is to provide an integrated constellation of space and cyberspace capabilities at the speed of need.*

Introduction

General C. Robert Kehler
Commander, Air Force Space Command

"This is about leadership. The success of all we do in the Air Force depends on superb leadership across our acquisition and sustainment portfolio." ~ General Norton Schwartz, chief of staff, USAF

Military acquisition processes are under revision after years of faltering practices and a litany of failed programs. There is a determined effort in the Air Force and in Air Force Space Command (AFSPC) to restore credibility to our acquisition process. Recapturing acquisition excellence is a leadership problem, not a resource problem. In an environment of declining resources and increased desire for capability, precise leadership through the acquisition process will allow programs to meet the needs of the joint warfighter. AFSPC's goal is to "reengineer acquisition to deliver capability at the speed of need." Our focus is to bring agility, speed, and discipline to acquisition. While we are beginning to turn the corner on acquisition problems, we must build upon victories to institutionalize successful practices.

This edition provides a frank and honest discussion of problems with the space acquisition process. The Senior Leader Perspective begins with an explanation of the Air Force acquisition strategy by Mr. Gary Payton, deputy under secretary of the Air Force for space programs. Maj Gen Ellen Pawlikowski, deputy director, National Reconnaissance Office (NRO), discusses how the NRO applies lessons learned from the acquisition reform initiatives in the 1990s for the Next Generation Electro-Optical system. Requirements generation begins the acquisition process for AFSPC, which is defined by Col Jay Moody based on his perspective as the deputy director of requirements at Headquarters AFSPC.

Once space and missile program requirements are defined, AFSPC turns to the Space and Missile Systems Center (SMC). As the only major command with its own acquisition arm, it is fitting for this edition to have an SMC Section, providing a look into SMC and the effort to improve space and missile acquisition.

As the only major command with its own acquisition arm, it is fitting for this edition to have a SMC section, providing a look into SMC and the effort to improve space and missile acquisition. Lt Gen Tom Sheridan, commander of SMC, discusses SMC's mission and long-term future. Mr. Doug Loverro, executive director, SMC, discusses the three phases of acquisition where proper application of lessons learned can yield desired outcomes. With mission assurance as the overarching goal for all programs, Col David Swanson, Dr. Sumner Matsunaga, and Ms. Rita Lollock discuss how SMC uses the results of 11 acquisition studies to deliver mission assurance for future programs. Col Mun Kwon calls for everyone to be a leader in combating acquisition problems and describes how the Program Management Assistance Group at SMC serves to improve the acquisition process. Rounding out the SMC section is an article by Ms. Catherine Steele, vice president of strategic space operations, The Aerospace Corporation. She discusses how Aerospace serves as a vital partner to SMC during the acquisition process.

There are many aspects to the acquisitions process and we are fortunate to have seven articles on space, cyberspace, and missile acquisition by authors providing broad and differing views. Dr. Robert Butterworth analyzes current acquisition reform in context of former Deputy Secretary of Defense David Packard's 1971 directives. Col James Fisher discusses the focus on nuclear sustainment as a part of the Air Force's goal to reinvigorate the nuclear enterprise. Education is an important component to restoring acquisition excellence and Dr. Brian Anderson provides a review of the many courses available regarding space acquisition. Dr. Owen Brown and Mr. Paul Eremenko discuss the value-centric acquisition model, which accounts for modern acquisition realities, as an alternative to the current process. A team from the Air Force Institute of Technology tackles the differences with cyberspace acquisitions and offers ideas on how to approach the process. Completing this section is Maj Nick Martin, who deconstructs the many facets of space systems acquisition problems and reviews potential strategies.

The industry perspective on this topic is provided by Maj Gen Thomas Taverney, USAF, retired and Colonel James Rendleman, USAF, retired. They discuss their experiences in context of ten rules for program managers to establish baselines and manage programs.

The Legislative Perspective focuses on national efforts to restore credibility and focus to all DoD programs. Maj Jung Ha details the Weapons Systems Reform Act signed into law in May 2009, reviews the Air Force Acquisition Improvement Plan, and discusses AFSPC application of these guidelines. Our journal comes to a close with Mr. Edward White's review of James Hasik's "Arms and Innovation: Entrepreneurship and Alliances in the Twenty-First Century Defense Industry." The author advocates strength in the defense industrial base through collaborative efforts among companies.

The acquisition process is complex, requiring precision leadership from all involved parties—military, civil, industry, and government. The joint warfighter relies on leaders to get this right, and we will not fail. I hope the articles in this edition ignite thought and inspire excellence in space acquisition. The next edition of the *High Frontier Journal* will focus on "International Space." I look forward to the thought-provoking dialogue this topic will encourage.

General C. Robert "Bob" Kehler (BS, Education, Pennsylvania State University; MS, Public Administration, University of Oklahoma; MA, National Security and Strategic Studies, Naval War College, Newport, Rhode Island) is commander, Air Force Space Command (AFSPC), Peterson AFB, Colorado. He is responsible for organizing, equipping, training and maintaining mission-ready space, cyberspace and missile forces and capabilities for North American Aerospace Defense Command, US Strategic Command (USSTRATCOM), and other combatant commands around the world. General Kehler oversees Air Force network operations; manages a global network of satellite command and control, communications, missile warning and launch facilities; ensures the combat readiness of America's intercontinental ballistic missile force; and is responsible for space system development and acquisition. He leads more than 43,000 professionals, assigned to 86 locations worldwide and deployed to an additional 35 global locations.

General Kehler has commanded at the squadron, group, and twice at the wing level, and has a broad range of operational and command tours in ICBM operations, space launch, space operations, missile warning, and space control. The general has served on the AFSPC staff, Air Staff, and Joint Staff and served as the director of the National Security Space Office. Prior to assuming his current position, General Kehler was the deputy commander, USSTRATCOM, where he helped provide the president and secretary of defense with a broad range of strategic capabilities and options for the joint warfighter through several diverse mission areas, including space operations, integrated missile defense, computer network operations, and global strike.

Air Force Space Acquisition

Mr. Gary E. Payton
Deputy Under Secretary
Air Force for Space Programs
Pentagon, Washington DC

Air Force weapon system acquisition over the past 15 years has been faced with exceptional challenges. Reeling from acquisition reform of the 1990s, the drawdown of our military, and the consolidation of the aerospace industrial base, we continue to adapt to the changing landscape, and work to deliver the best Air Force capability the world has ever known. Challenges unique to acquisition of space systems are further exacerbated by the harsh space environment where systems are expected to survive for a decade or more with no opportunity for routine maintenance or physical modifications. As a result, we must design, engineer, test, and launch even the first article as an operational asset. Additionally, unique management and cost control concerns arise because over 70 percent of the total life cycle cost for a space system occurs early during the development and build phase, as compared to 30 percent for non-space programs. Space systems never go beyond low rate initial production; therefore, costs must be allocated over a small number of systems with limited opportunity to apply a learning curve to improve subsequent builds. Over the past 40 years our space acquisition community has worked to navigate these challenges while providing continuity of mission for key capabilities in missile warning, communication, navigation, weather, and launch. Continuity of our key space missions is now as important as modernization. For example, we recently launched two Wideband Global SATCOM (WGS) satellites, with each WGS satellite providing the equivalent capacity of the entire legacy Defense Satellite Communications System constellation it is replenishing. However, even with a full complement of WGS satellites, we will continue to rely on commercial SATCOM to heavily supplement the need for wideband, long haul communications. In addition, over the next 18-24 months we will be delivering four "first of" satellites to maintain continuity of service in other mission areas with Space-Based Space Surveillance, GPS IIF, Advanced Extremely High Frequency (AEHF) SATCOM, and Space-Based Infrared System Geosynchronous. Finally, for our next generation of space capabilities, we have re-instituted a 'Back to Basics' space acquisition strategy.

Back to Basics

'Back to Basics' is a comprehensive strategy to address criticisms for "over-reaching" on space programs. By that I mean pursuing programs that are a giant leap in capability, and failing to deliver in a timely manner. Through 'Back to Basics' we have focused on fundamental areas: mission success through clear and achievable requirements, disciplined systems engineering, proven technology, and appropriate resourcing. Proper program execution depends on stable requirements, and realistic funding based on rigorous cost estimates.

One of the important practices we have embraced within 'Back to Basics' is a block approach to delivering satellites and their ground systems. This block approach is used to distribute risk across the entire life cycle of a program, and avoid the "all or nothing" scenario of a single delivery for an entire system after years of research and development investment. This approach permits more timely delivery of incremental capabilities to the warfighter. For example, we parsed the GPS III development into distinct blocks, and will deliver incrementally greater capability as key technologies are matured. The first block will baseline the bus configuration for all GPS III satellites, increase signal power, and add a civil signal. Future blocks will add cross-links to improve accuracy, integrity, and real-time communications with the constellation, and a high power spot beam to improve anti-jam and navigation warfare capabilities.

We are also applying the 'Back to Basics' philosophy by conducting technology maturation efforts ahead of the satellite full-scale development. The Third Generation Infrared Surveillance (3GIRS) program is developing wide field of view (WFOV) Infrared sensor technology to increase capability with reduced design complexity. 3GIRS employs competing prototypes and commercial ride share opportunities to mature technologies prior to initiating an acquisition program using WFOV technology. The 3GIRS commercially hosted infrared payload demonstration, launching in 2010, is an example where we take advantage of pre-existing weight and power margin on a commercial communications satellite in the timeframe we needed, at a fraction of the cost of a dedicated government satellite/booster.

While we have benefitted tremendously from our 'Back to Basics' strategy, we are committed to recapturing acquisition excellence by rebuilding the Air Force acquisition culture that delivers products and services as promised—on time, within budget, and in compliance with all laws, policies, and regulations. Earlier this year the Air Force developed an Acquisition Improvement Plan (AIP) to serve as our strategic framework to address many of the lessons learned from past shortfalls in our procurement processes. The plan focuses on revitalizing the acquisition workforce; improving the requirements generation process; instilling budget and financial discipline; improving major systems source selection; and establishing clear lines of authority and accountability within acquisition organizations. Recent legislation, the Weapons Systems Acquisition Reform Act of 2009, reinforces the Air Force AIP through added rigor in cost estimation; technology maturity assessments; appropriate alignment of milestone and technical reviews, ensuring trade-offs between cost, schedule, and performance are part of the requirements process; and instituting acquisition workforce recognition programs.

Operationally Responsive Space

In addition to our 'Back to Basics' strategy, we are seeking innovations to expedite the space acquisition process. One example is the operationally responsive space (ORS) office which is developing the enablers to allow delivery of space capability to our combatant commanders in significantly reduced timelines. ORS has adopted modular open system architecture with a specific purpose of lowering barriers to entry and thereby enabling small companies to effectively compete for building portions of space systems. Key tenants of the ORS program are to keep costs low, and deliver "good enough to win" capabilities to the warfighter rapidly. ORS systems can augment, surge, or reconstitute existing constellations of satellites. A clear example of these tenants, the first ORS operational satellite (ORS-1), is being built in 24 months to meet a US Central Command (USCENTCOM) urgent need to monitor denied areas, and will be tasked like other USCENTCOM organic intelligence, surveillance, and reconnaissance assets.

Space Protection

Space is no longer a sanctuary; our potential adversaries continue to advance technologies and evolve capabilities that can deny our use of space. The need for increased protection of our space assets in an increasingly contested environment is paramount, and requires enhanced space situational awareness capabilities—improved accuracy, responsiveness, timeliness, and data integration to support the warfighter. To do this we must combine various inputs into a single picture for our warfighters. Currently, operators must assemble an understanding of the global space picture from many disparate sources, including e-mails, telephone calls, classified chat rooms, intelligence Web sites, and imagery feeds. We have acknowledged this shortcoming, and recently consolidated the integrated space situational awareness, RAIDRS Block 20, and space command and control programs into a single program—the Joint Space Operation Center [JSpOC] Mission System (JMS). The JMS program will continue risk reduction engineering and focus on incremental deliveries to deploy a services-oriented architecture environment and tools to progressively advance operational capabilities toward an integrated JMS. This program will produce a net-centric collaborative environment, enhance and modernize space surveillance capabilities, create decision relevant views of the space environment, and enable efficient distribution of data across the space surveillance network.

Summary

Our space systems are the envy of the world. Our infrared surveillance satellites are able to detect missile launches anywhere in the world, at any time of day or night; no other nation can do that. Strategic communications systems allow the president precise and assured control over nuclear forces in any stage of conflict, and our wideband SATCOM systems rapidly transmit critical information between the continental US to our front line forces; no one else has global, secure, anti-jam communications. Our weather satellites allow us to accurately predict future conditions half a world away as well as in space. Our GPS constellation enables position knowledge down to centimeters and timing down to nanoseconds; no one else has deployed such a capability. All of our space systems rely on successful launch systems. Our current medium and heavy-lift launch systems are the most reliable this nation has ever seen. These sophisticated systems make each deployed Soldier, Sailor, Marine, and Airman safer, and more capable. Our accomplishments are the result of a world-class team of space professionals across our government and industry, all dedicated to the single purpose of providing essential capabilities to our joint warfighters and allies around the world. As a nation, we have cultivated, modernized, and integrated space capabilities for over a half century into our national instruments of power—diplomatic, information, military, and economic. The reward for this commitment is a space capability which tilts the geopolitical and military advantage to our nation and our allies.

Mr. Gary E. Payton (BS, Astronautical Engineering, US Air Force Academy, Colorado Springs, Colorado; MS, Aeronautical and Astronautical Engineering, Purdue University, Indiana) is the deputy under secretary of the Air Force for space programs, Washington, DC. He provides guidance, direction and oversight for the formulation, review, and execution of military space programs. This includes oversight of all space and space-related acquisition plans, strategies and assessments for research, development, test, evaluation, and space-related industrial base issues.

As an Air Force officer, he served as a pilot, instructor pilot, spacecraft operations director and space technology manager. In 1985, he flew as a payload specialist on board the Space Shuttle Discovery in the first military flight of the space shuttle program. He retired from the Air Force in the rank of colonel after more than 23 years of service, with his last duty in the Strategic Defense Initiative Organization. While there, he was responsible for directing the development of sensor and interceptor technologies for detecting, tracking, discriminating targets, and intercepting ballistic missiles in all phases of flight. He was instrumental in the initiation and management of the Midcourse Sensor Experiment, the Lightweight Exo-Atmospheric Projectile, Delta-183, Talon Shield, Clementine and the DC-X launch vehicle technology project.

Mr. Payton has also served as NASA's deputy associate administrator for space transportation technology where he initiated, planned and led the Reusable Launch Vehicle technology demonstration program, which included the X-33, X-34, X-37, and DC-XA flight test projects. His responsibilities included program formulation, budget preparation and program advocacy with Congress, the White House, the Department of Defense and the media. For two years he was the senior vice president of engineering and operations for ORBIMAGE, a leading global provider of Earth imagery products and services. Prior to his current position, Mr. Payton served as the deputy for advanced systems in the Missile Defense Agency. There he led the MDA technology program to enhance ballistic missile defense sensor, weapon and battle management capabilities.

Applying the Lessons of Acquisition Success in the Next Generation Electro-Optical Program

Maj Gen Ellen M. Pawlikowski, USAF
Deputy Director
National Reconnaissance Office
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In April 2009, after a four-year period of focused analysis and senior-leader deliberation, Director of National Intelligence Dennis C. Blair and Secretary of Defense Robert M. Gates announced a national strategy designed to modernize America's aging electro-optical satellite reconnaissance constellation. Since the first near real-time electro-optical imagery intelligence satellite was launched on 19 December 1976, electro-optical imagery has provided the US with a decisive information advantage. The US depends on space-based imagery to monitor potential adversaries and maintain critical worldwide situational awareness. National electro-optical systems are an intelligence community and Department of Defense (DoD) asset when addressing hard intelligence problems across multiple mission areas that include counterterrorism, support to military operations, counterproliferation, and indications-and-warnings. Analysts use electro-optical system data to detect activity, characterize content, identify objects, and monitor change. These systems also monitor the environment and support relief operations during national disasters and humanitarian aid efforts. National systems provide timely image resolution adequate to discriminate, measure, and locate objects, improving the analysis of targets.

The National Reconnaissance Office (NRO) is responsible for acquiring the Next Generation Electro-Optical (NGEO) system, the high-resolution segment of the nation's modernization strategy. With experience garnered over nearly five decades in complex satellite development, NRO is applying "lessons learned" in the areas of technical risk and recurring cost reduction, requirements stability, and realistic budgeting to ensure America's overhead electro-optical capabilities continue unhindered for the decades to come.

Acquisition reform of the mid-1990s was a well-intentioned attempt to reduce cost and delivery time of new space systems. However, these measures resulted in diminished oversight, weakened systems engineering, and ultimately declining performance in program execution. The NRO did not adopt acquisition reform across the board, and most of its programs continued making steady and predictable progress. However, for those programs where NRO did adopt the acquisition reform model, primarily the Future Imagery Architecture (FIA) program, results were disastrous. The NRO learned valuable lessons from its experience with acquisition reform, and consequently, the interim replacement for FIA's electro-optical component is among NRO's most successful programs. The NRO is applying the lessons learned from mistakes and current successes to the NGEO acquisition. Key lessons include the need for strong domain expertise in both the contractor and government teams; the need for proactive government management throughout the acquisition; stable requirements well defined early in the program; and the use of a realistic funding profile based on an independent cost estimate rather than a competitively-driven developer quote. Another critical lesson is the importance of up-front systems engineering to develop the system concept and fully characterize overall risks.

To provide a foundation for NGEO, the National Geospatial-Intelligence Agency (NGA), the geospatial intelligence functional manager, took aggressive steps to establish solid, stable requirements. The NGA worked through a new streamlined Intelligence Resources Board process to secure intelligence community and DoD buy-in on a much clearer and shorter statement of capabilities, which identifies a small prioritized list of "must do" requirements. It also gives the program managers authority to make necessary trade-offs on lesser requirements during the development. As NGA solidified the requirements, the NRO established a dedicated program office to focus resources on initiating the system development and acquisition. The NRO's efforts at this early stage reflect the same degree of urgency commensurate three months before a launch. The first priority was navigating through a June 2009 Milestone-A Joint Intelligence Acquisition Board to gain formal approval for entering into Phase A, Concept Refinement, and Technology Maturation Demonstration. Having successfully met this milestone, NRO is now concentrating on detailed development planning. Phase A activities include identifying space, ground, and end-to-end interface requirements, driving down spacecraft component risks, and generating a preliminary space system design.

From a technical perspective, the new space system is using a "state-of-the-industry" rather than "state-of-the-art" approach, using less complex, modular designs to provide more opportunities to exploit commonalities with other US space systems.

The NRO's overall acquisition approach for this effort differs from troubled programs. From a technical perspective, the new space system is using a "state-of-the-industry" rather than "state-of-the-art" approach, using less complex, modular designs to provide more opportunities to exploit commonalities with other US space systems. This approach also takes the nearly obsolete technology, developed over the last 30 years, and modernizes it to allow for future growth while still leveraging the evolution of NRO's past successful electro-optical systems. With multiple risk reduction paths, NRO is using only new technologies that have reached targeted maturity, or readiness levels, required at the appropriate phase of system acquisition. To reduce development challenges further, the new space system will "plug" into the evolving NRO ground architecture. This approach avoids development of a unique "stovepipe" ground segment, and supports continued improvements in cross-system integration to benefit users who can thoroughly exploit national system data.

From an acquisition perspective, NRO will employ a proven prime contractor with vast domain expertise in building this class of space system. The NRO is minimizing risk through increased emphasis on more robust systems engineering early in the acquisition. Systems engineering is focusing on providing thorough requirements development and allocation, as well as adequately funded technology development. In addition, the program is using effective engineering practices to define realistic program milestones that better account for development dependencies. To provide program stability, NRO is fully funding this acquisition to an independent cost estimate and is driving to meet the requirements with a "most affordable, best-value" approach. This approach applies targeted up-front funding of non-recurring engineering efforts to expel longer-term reductions to the system's recurring costs. Most importantly, NGEO is relying on broad government involvement throughout the entire process.

The NGEO effort resulted from an intense defense and intelligence community effort to determine the best architecture for replenishing America's aging electro-optical constellation. The NRO collaborated with NGA and other agencies to evaluate numerous constellations capable of meeting diverse performance requirements, while balancing schedule, cost, survivability, robustness, flexibility, and risk. During this period, competing priorities among imagery users (driven by each agency's mission) constantly confronted the community. Multiple-user utility studies evaluated mission satisfaction of key collection performance attributes. The community determined that high-resolution, space-based electro-optical imagery systems would remain a critical component of America's intelligence infrastructure, now and in the future.

The NRO will ensure that the nation can continue to rely on this vital form of intelligence. By employing acquisition practices honed over decades of experience with complex space systems and applying the lessons learned from the mistakes of acquisition reform, the NRO is embarking on this program to deliver the NGEO satellite system. These actions are ensuring civilian and military analysts, planners, and policy makers retain this critical tool in their arsenal to address difficult intelligence problems.

Maj Gen Ellen M. Pawlikowski (BS, Chemical Engineering, New Jersey Institute of Technology; PhD, Chemical Engineering, University of California at Berkeley) is the deputy director, National Reconnaissance Office (NRO), Chantilly, Virginia. She is responsible for mission-related acquisition and operations of overhead reconnaissance systems to meet the needs of the intelligence community and the Department of Defense. Also, as the commander, Air Force Space Command Element, she manages all Air Force personnel and resources assigned to the NRO and serves as the senior adviser to the NRO director on all military matters.

Major General Pawlikowski has served in a variety of technical management, leadership, and staff positions in the Air Force. Previous assignments include vice commander, Space and Missile Systems Center, Los Angeles AFB, California, and commander, Military Satellite Communications Systems Wing, Space and Missile Systems Center, Los Angeles AFB, California

The community determined that high-resolution, space-based electro-optical imagery systems would remain a critical component of America's intelligence infrastructure, now and in the future.

Requirements Generation: The Crucial First Step to Delivering Warfighter Capability

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Air Force Space Command (AFSPC) is responsible for providing our nation and its joint warfighting commands with critical space and cyber capabilities. With constantly increasing and changing threats, today's fielded systems will not deliver the capabilities needed tomorrow. New systems and new ways of conducting operations must be developed. With limited resources available, requirements must be valid and feasible. The requirements generation process is the mechanism by which AFSPC continually works with its stakeholders to discern user needs and articulate them into operational requirements. This is the crucial front end work to generate validated requirements that drive successful space and cyber acquisition programs. Generating clear, feasible requirements in a timely manner is one key to delivering capability at the speed of need, and AFSPC is working to meet the challenge.

Warfighter needs form the basis for the requirements generation process, but translating those needs is difficult. It is not as easy as simply asking what the warfighter wants. Space and cyber capabilities are global in nature and must serve many different customers simultaneously, and they must operate in context with terrestrial, maritime, and airborne forces within systems of systems. Sometimes, the warfighters do not know what they want or they lack a consistent voice regarding what needs must be fulfilled and when. Working with many customers to reconcile diverse and complex needs in a resource constrained environment to distinguish needs versus wants contributes to the lengthy process reflected in figure 1.

Combatant commanders (CCDR) seek to accomplish their mission sets in support of the president's overarching National Security Strategy (NSS). The NSS is further refined for the Department of Defense (DoD) in the form of policy and guidance contained in the National Military Strategy, National Defense Strategy, and Guidance for the Development of the Force. Policy documents are translated by the Joint Staff into a series of concept documents that which ultimately provide a "shopping list" of capabilities the joint force will need in the future.

Given the list of desired capabilities, combatant commands, services, and major commands (MAJCOM) analyze the "shopping list" and identify current and projected gaps and shortfalls in each capability area. The overall process for this analysis, called the capability-based assessment (CBA), is defined in Chairman Joint Chief of Staff Instruction (CJCSI) 3170.01. Typically, a CCDR will initiate a CBA to look at a particular capability or mission area. The Air Force uses a similar methodology in its capabilities review and risk assessment (CRRA) process, but looks at a much broader set of capabilities across the entire Air Force portfolio, based on capabilities articulated in the seven Air Force operating concepts. AFSPC likewise uses the methodology in its integrated planning process (IPP) to analyze capabilities it can provide, which are documented in the AFSPC functional concepts. Each set of concept documents show linkage to the next level, that is AFSPC to Air Force, Air Force to joint. The key is to maintain the logical thread from the desired joint capability to all Air Force and AFSPC processes.

The CBA is comprised of three basic steps: (1) Define specific tasks needed to be performed, (2) identify gaps/shortfalls, and (3) define solution recommendation. For CBAs conducted by the CCDR, the result is documentation of the analysis and recommendation for action by the services—either to pursue a materiel solution (i.e., a new system) or a non-materiel solution (i.e., changes in doctrine, organization, training, leadership, personnel, or facilities). This constitutes a validated warfighter gap/shortfall to be addressed. If the Air Force or AFSPC is conducting the CBA process (via the CRRA or IPP), the solution recommendation may be a bit more specific. The Air Force may task AFSPC to further explore space and/or cyber solutions. This task informs the IPP, and the capability solution analysis conducted by AFSPC will actually recommend potential systems for further analysis. AFSPC commander's (CC) priorities are delivered as a product of the IPP in the Long Range Recapitalization Plan. In any case, the desired outcome is to have a set of clearly articulated, validated, warfighter needs. The expectation for the CBA process,

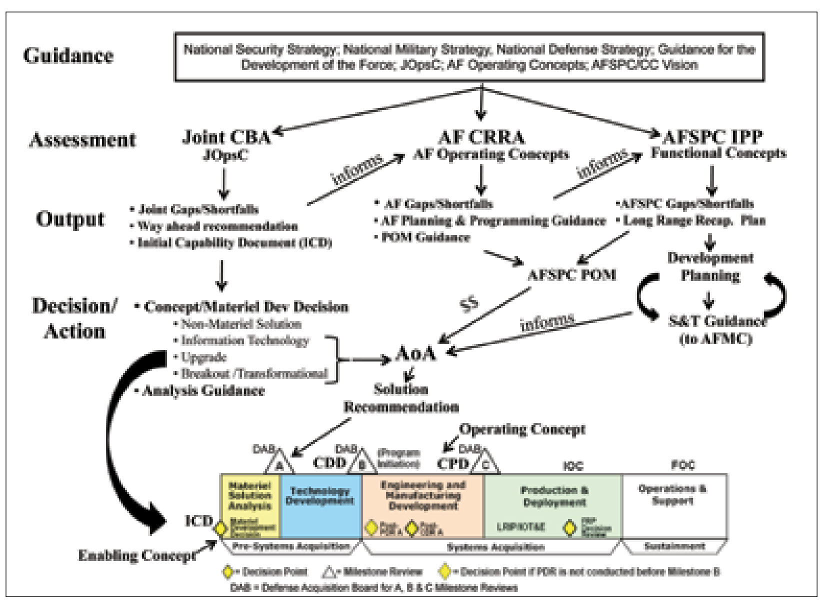

Figure 1. Requirements Generation and Connection to Acquisition.

per CJCSI 3170.01, is no more than 180 days from start to finish.

A CBA is not the only source for such needs, however. CCDRs annually publish integrated priority lists that identify the gaps and shortfalls the CCDR believes are hindering his ability to accomplish his missions. Gaps can be identified in top-down direction, where the Air Force Chief of Staff (CSAF) (or above) directs pursuit of a solution to an identified need. Joint Commanders involved in ongoing operations can identify an immediate need in the form of a joint urgent operational need (JUON), which may serve as a validated requirement in and of itself, and therefore does not require a lengthy review and validation process. JUONs may only be used in situations that require a "quick fix" to prevent loss of life or mission failure. AFSPC responds to JUONs.

Once gaps are identified, the process begins in earnest. The first product in the requirements generation process is the initial capabilities document (ICD). The ICD is a concise document that captures the steps of the CBA, and it is essentially the mission need statement for the identified gap/shortfall. An ICD can be generated by a CCDR or by the services. In AFSPC, the directorate of requirements (A5) is responsible for producing the ICD, following the processes outlined in AFSPC Instruction 10-103, Capabilities-Based Operational Requirements Guidance. AFSPC uses an Integrated Concept Team (ICT) to bring together the requisite expertise to generate requirements documentation. The ICT must have membership from across the enterprise for the capability being pursued. This includes not only the Headquarters (HQ) AFSPC staff, but also product centers (e.g., Space and Missile Systems Center, Electronic Systems Center), test organizations (e.g., Air Force Operational Test and Evaluation Center), other services, CCDR representatives, other governmental agencies, and so forth. An action officer from AFSPC/A5, called the requirements lead (RL), will lead this diverse group to formulate the final products in support of the capability area command lead.

As stated earlier, the process cannot begin without identified gaps, and the steps towards solution should not proceed without giving the gap some disciplined thought with respect to operational context. This is where enabling concepts come into play. Imagine building a car for a customer who has said he needs transportation without really delving into what the customer wants. You know he needs transportation, but do you know how he intends to use it? Do you know who will use it, who has authority to say who can use it, what it will carry, and so forth? This is the role of the enabling concept … to flesh out the need into some operational context and take a hard look at how the needed capability will be used, by whom, and what effects it will ultimately produce when used in conjunction with other existing capabilities. Articulating these ideas at some level of detail is absolutely essential to producing good requirements.

The Air Staff provides oversight of all Air Force requirements activities to ensure gaps and shortfalls are being addressed appropriately, and to limit duplication of effort between MAJCOMs. To this end, AFSPC must present its strategy for developing any requirements document in the form of a Requirements Strategy Review briefing to the director of operational capability requirements (AF/A5R). Once approved, AF/A5R will provide a venue and the needed support from the Pentagon to draft the actual ICD in a small group known as a high performance team (HPT). The HPT usually meets in the Washington, D.C. area with the sole purpose of producing a staffing-ready document. In keeping with the objectives of the Joint Capability Integration and Development System defined in CJCSI 3170.01, a post-HPT requirements document receives the widest possible review from all MAJCOMs, services, staffs, CCDRs and other agencies as required. This process ensures all joint equities are considered prior to final validation and approval of the document.

The RL will also initiate internal coordination with all AFSPC organizations, and gain AFSPC/A5 approval (as a minimum), to proceed to Air Force validation. Air Force validation takes place at the Air Force Requirements Oversight Council (AFROC), which is chaired by AF/A5R and is the CSAF's governing body for all Air Force requirements. But even after Air Staff validation, we are not done. Every requirements document will undergo Joint Staff review, and those that could lead to large acquisition programs require approval by the Joint Requirements Oversight Council (JROC), chaired by the vice chairman of the Joint Chiefs of Staff.

A JROC-validated ICD allows the Air Force to formally engage the acquisition community in a forum called the Materiel Development Decision (MDD). This meeting is chaired by the probable acquisition executive, called the Milestone Decision Authority (MDA). For large military space activities, the MDA is the under secretary of defense for acquisition, technology, and logistics. The MDA, with the advice and consent of the JROC representative, will decide if the validated ICD is worthy of entering the acquisition cycle, and at what step it should enter. The MDD is mandatory for all new potential acquisition programs.

With MDA guidance, more analysis follows, usually in the form of an analysis of alternatives (AoA). An AoA takes inputs from a variety of sources, including development planning and science and technology efforts. The MDA reconvenes for a decision to either proceed with the effort or do more analysis at meetings called Defense Acquisition Boards (DAB). From this point on, the requirements and acquisition processes become intertwined in a series of DABs, each supported by a matured set of requirements. Time between DABs can be many months or even years.

The next iteration of the requirements document is the Capability Development Document (CDD). This results from work done during the AoA and subsequent development planning efforts to define and prioritize the most critical requirements, known as key performance parameters. It also articulates the next level of requirements, called key system attributes as well as other system attributes desired. All defined requirements will be stated in terms of a threshold value (what is good enough to satisfy the warfighter need) and an objective value (the value beyond which there is limited operational value, and it doesn't make sense to further expend resources). The acquisition community takes the CDD and translates the requirements into engineering terms. Prioritizing requirements through identifying KPPs and KSAs and providing thresholds and objectives provides the acquisition community with the needed trade space to execute successful programs.

The CDD must undergo the same approval process as did the ICD described above. This may seem repetitive, but it ensures the warfighter need still exists, and that the requirements are indeed being developed in a manner that will satisfy the need in an affordable increment of capability.

The final requirements document is the capability production document (CPD). As the name implies, the CPD is the final set of operational requirements that will influence system requirements to begin production of the chosen weapon system.

Although the process is well documented, not every projected space gap and shortfall results in requirements with the same level of maturity in the same timeline. The processes and their execution are not perfect, and they need continuous evaluation and modification. However, recent changes at the Office of the Secretary of Defense (OSD) and Air Force-level have resulted in improvements. The 2007 National Defense Authorization Act mandated the Requirements Management Certification Training for all personnel involved in the requirements generation process, either through writing, reviewing, or approving requirements documents. Those individuals are required to complete two requirements courses developed by Defense Acquisition University within six months of filling the position. AFSPC has been pursuing this aggressively. Then on 4 May 2009, the Secretary of the Air Force and CSAF signed the Acquisition Improvement Plan (AIP). The AIP lists five initiatives for improving how the Air Force obtains new capabilities—one of them covers requirements generation (Initiative 2). One major change directs the AFSPC/CC to certify CDDs in conjunction with the AFROC. Certification means the required capabilities can be translated in a clear and unambiguous way for evaluation in a source selection, are prioritized if appropriate, and organized into feasible increments of capability. AFSPC/CC certification forces greater dialogue between the AFSPC requirements and acquisition communities, ensuring greater requirements feasibility and reduced development risk.

Such changes in OSD and Air Force-level policies complement AFSPC-level initiatives to improve the front end requirements process. In 2008, HQ AFSPC organized capability teams and placed an O-6 or civilian equivalent command lead in charge of each mission capability area—thereby establishing a single point of responsibility and accountability across the entire command for defining requirements in each capability area. This has improved communication between HQ AFSPC and outside organizations. HQ AFSPC also instituted the Space Operations Weapon System Management (SOWSM) process to help command leads manage their programs. Essentially, SOWSM monitors over 20 operational (critical path elements [CPE]) every program must go through as it moves along the development timeline from a concept through deactivation of the operational system. Confirming each program successfully meets every CPE (requirement) helps ensure a timely, affordable, and relevant end product for the warfighter. We are also developing requirements roadmaps to better plan and track requirements activities over the coming two-year horizon. In addition, we are investigating the systematic application of architecting and portfolio management tools to improve requirements process execution. And finally, we are looking at how our various capability teams organize their ICTs for requirements definition to make sure the right organizations are involved and the needed teaming is taking place. My experience on the Transformational Satellite Communications System program showed me the tremendous value of a very robust collaborative partnership among HQ AFSPC, program offices, Air Force operators, and combatant commands.

Recent changes to the AFSPC mission and scope of responsibility have made the command even more forward thinking to provide capabilities at the "speed of need." As AFSPC assumed the role of lead command for the cyberspace domain, many objectives have been set to ensure mission success. Among these objectives, and arguably one of the most crucial is 'reengineering acquisitions' for cyber. With the acceleration of technology, in which many products are rendered obsolete after 2 years (*Moore's Law*), the current requirements process is struggling to keep up with the cyber warfighter's needs. Therefore, the development of a streamlined process is essential in order to adapt to real-time situations and meet the rapid timeline demands of our customers.

Due to the inherent lengthy timelines that are associated with traditional requirements processes, AFSPC has teamed with Air Force Materiel Command and others to examine existing methods, as well as new, innovative techniques to rapidly acquire and support urgent cyber needs. Understanding the blazing tempo of changing cyber threats and the varying degrees of operational needs has been the means for establishing a new 'three-tiered' approach for cyber requirements. This new approach will provide the ability to triage new requirements as they come in; categorizing them appropriately into real-time, rapid, or foundational channels, ultimately allowing capability deliveries much more quickly.

The requirements generation process is evolving and improving at DoD, Air Force, and AFSPC levels. Accountability and increased communication among all players, whether they are at the HQ AFSPC, program offices, or HQ Air Force, must result from these modifications. This changing environment has caused us to rethink our processes and our culture in order to meet the AFSPC mission to "provide an integrated constellation of space and cyberspace capabilities at the speed of need" and vision of being, "the leading source of emerging and integrated space and cyberspace capabilities."

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Space and Missile Systems Center "Building the Future of Military Space Today"

Lt Gen John T. "Tom" Sheridan, USAF
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As the Air Force's product center for the development, acquisition, and sustainment of space and missile systems, the Space and Missile Systems Center (SMC) at Los Angeles AFB, California, is building the future of military space today. Established in 1954, the center has a rich history dating back to the earliest days of the space age. Today, SMC leads in the development, acquisition, fielding, and sustainment of the world's best military space and missile systems. SMC enables Air Force Space Command (AFSPC) to deliver unparalleled capabilities to national decision makers, asymmetric operational advantages to joint warfighters, and game-changing economic and technological benefits to our nation.

The center is responsible for a comprehensive set of military space capabilities across all space mission areas, including force enhancement, space superiority, force projection and space support. The center also develops and maintains a full range of systems and technical expertise including satellites, payloads, launch vehicles, future missile systems, ground control systems, user equipment, and ground sensors. These systems provide capabilities such as communications, precision navigation and timing, spacelift, space situational awareness, space control, missile warning, weather monitoring, satellite command and control, supporting missile defense, and land-based strategic deterrence.

Comprised of over 6,000 employees, the workforce at SMC includes active duty military members, government civilians, Federally Funded Research and Development Center (FFRDC) personnel, and systems engineering and technical assistance contractors. In 2009, for the first time in the center's history, the government civilian workforce outnumbers active-duty service members. This shift resulted from several factors to include the 2006 Air Force reduction in force and a continual decrease in military billets assigned to SMC. While personnel numbers decreased, the center has seen growth of its total obligation authority by close to fifty percent when compared to that executed just four years ago—to nearly 10 billion dollars in fiscal year (FY) 2009. The reduction in government manpower and increase in programs resulted in a greater reliance on FFRDCs to accomplish SMC's mission. Co-located in Los Angeles, The Aerospace Corporation provides the bulk of FFRDC support to SMC programs. Sharing a unique partnership dating back to 1960, SMC programs heavily rely on the vast technical expertise of our FFRDC personnel to achieve mission success.

I concurrently serve as the commander (CC) of SMC and the Air Force program executive officer for space (AFPEO/SP). As SMC/CC, I have responsibility for organizing, training, and equipping the SMC team to conduct the Air Force's space and missile acquisition and sustainment missions. As the AFPEO/SP, I have oversight responsibility for 73 Air Force space programs, including 17 ACAT 1D level major defense acquisition programs. Another key role I perform as SMC/CC is to certify the flight readiness of SMC-built spacecraft and rockets through the flight readiness review process prior to launch. To support this dual role, SMC is organized into line program management organizations and functional management organizations.

The line program management organizations—systems wings and groups—plan and execute major space development and acquisition programs. The wings and groups translate operational requirements provided by Headquarters AFSPC into system's level requirements and, along with industry partners, design, formulate, develop, and acquire programs to satisfy those needs. The functional directorates—engineering, program management and integration, developmental planning, finance, contracting, logistics, and manpower and personnel—develop and maintain the expertise, processes, and workforce necessary to plan and execute the programs of today, as well as lead acquisition into the future.

In 2001, as a result of the Space Commission, SMC was realigned under AFSPC. This organization affords unique responsibilities and opportunities within a single major command to organize, train and equip space and certain missile systems in the Air Force from "cradle to grave." SMC's responsibilities begin by working with Headquarters AFSPC and the user community to refine operational concepts and requirements; continue with systems definition and program formulation; extend through execution and fielding of systems in concert with industry partners; and ultimately sustain systems over their operational lives. By managing these cutting-edge space systems throughout the entire acquisition life cycle, SMC provides AFSPC, the joint warfighter, and the nation with unrivaled capabilities.

The Department of Defense integrates and employs space in virtually every aspect of military planning and operations. Space critically enables warfare at all levels—strategic, operational, and tactical—and has become integrated into all land, sea, air, and special operations missions. The future will place a greater demand on space to successfully execute military and national security objectives, and SMC will continue to deliver and sustain dominant space and missile capabilities.

Recent events demonstrate that space is no longer an uncontested domain. Just as gaining air superiority is a first priority in any joint operation, maintaining space superiority must remain a top priority in peace, crisis, or conflict. SMC must design future systems to be both survivable in the face of increased threats and responsive to operational needs. When delivering these future systems, SMC must maintain focus on its unshakable goal: 100 percent mission success. The center has a critical role in aiding current and future military commanders and operators in understanding what systems and capabilities to develop in order to meet operational needs. To achieve this role, SMC maintains continuous interaction with the supported warfighters and customers, understands the principles of war and the applications of space in joint warfighting, and develops the people and processes that are capable of delivering responsive and effective operational systems.

The center's near-term focus is to achieve mission success one mission, one launch at a time. In the next 24 months, we will deliver to orbit five major new systems/mission capabilities:

- *Space-Based Infrared System (SBIRS)* will continue the ever-vigilant missile-warning mission. Two SBIRS highly elliptical orbit sensors are operationally certified and flying now, and the first geosynchronous spacecraft is scheduled to launch in FY 2011.
- *Advanced Extremely High Frequency (AEHF)* communication satellite will deliver ten-times the communication bandwidth that is available today for protected communications to our forces and our National Command Authority. The first AEHF spacecraft is on-track to launch in FY 2010.
- *Wideband Global Satellite Communications (WGS)* provides in one satellite the communications equivalent of today's entire operational Defense Satellite Communications System. The first and second WGS satellites are now on station, certified for operations, and providing service to the Pacific Command and Central Command areas of responsibility. WGS-3 is moving forward toward an FY 2010 launch and operations.
- *Global Positioning System (GPS) II-F*, which will upgrade timing, navigation accuracy, and add a new civilian "L5" signal to the system, is scheduled to launch in FY 2010.
- *The Space-Based Space Surveillance System* will provide greatly improved space situational awareness to help better understand location and mission capabilities of all satellites and other objects in space.

SMC's long-term future is even more exciting. GPS III will provide a ten-fold increase in signal power so that GPS signals reach into valleys, canyons, and cities with skyscrapers. In addition, GPS III will include a new civil navigational signal compatible with the European Union's Galileo system. Prompt Global Strike is a demonstration program in development. It will integrate conventional munitions inside an aeroshell on components of a retired intercontinental ballistic missile rocket to demonstrate global targeting capability in a matter of minutes with no ambiguity between conventional and nuclear missions.

This year also ushered in opportunities for changes to enhance our space acquisition enterprise. SMC continues to rebuild the space development and acquisition workforce, expertise, processes, and culture while strengthening cooperation across government space and industry. Long-standing partnerships with the National Reconnaissance Office, National Security Space (NSS) Office, and Missile Defense Agency will continue to expand the relationships between the US civilian and military space programs.

In this journal, you will find four articles written by fellow SMC members that describe how our partnerships are contributing to the NSS enterprise. In them, you will see how lessons from our rich heritage have influenced the way we do business, how we have incorporated these lessons in our programs, and the direction we are headed as we develop the next generation of space capabilities while maintaining our space superiority.

First, successful space development is dependent on how well we learn from and incorporate our past experiences. Mr. Douglas Loverro, SMC executive director, describes some valuable lessons learned during his 30+ years of program management across many NSS programs. His insight serves as a guidepost for current and future program managers, and SMC is very fortunate to benefit from it. Capitalizing on these lessons learned, Col David Swanson from the Directorate of Engineering and Architectures and Col Mun H. Kwon from our new Program Management Assistance Group will describe how their respective efforts are reshaping the way we do business for the better at the center. Both articles hold examples of the functional-wing interdependencies from their own perspective. Their work exemplifies our back-to-basic approach with an emphasis on mission assurance.

Finally, our partners at the Aerospace Corporation have penned a synopsis of how together we provide 100 percent mission success for the warfighter. The article "Keys to Acquisition Success" stresses the importance of building an integrated, high performance team from multiple government organizations. Given the high stakes, Ms. Catherine J. Steele, vice president of strategic space operations for The Aerospace Corporation, outlines the tools that can help guide teams to successfully execute programs throughout the system life cycle.

As the people of AFSPC continue to expand the development and evolution of military space capabilities, doctrine, and tactics, they must learn how to integrate space with air, land, and maritime forces and operations. Just as the pioneers who established SMC over 50 years ago had a strong vision for where their efforts would lead, but had little idea just how pervasive and critical their systems would become, the men and women of SMC today, their industry partners and the operational users continue to build on the vision and discover new untapped capabilities which can be provided by space access. SMC and our mission partners know efforts must be synergized in order to continually evolve strategic advantages the nation has gained in space and sustain it for decades to come.

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General Sheridan's experience includes acquisition leadership of aircraft, simulator and classified space programs; requirements development across all Air Force space programs; and operational leadership in four different national space programs. He has served as military assistant to the assistant secretary of the Air Force for space, commandant of Air Command and Staff College, director of requirements at Headquarters AFSPC, and most recently as the deputy director of the National Reconnaissance Office.

Getting it Right: Lessons from Failed Space Acquisitions

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It is almost inevitable—major system development programs will get into trouble sometime during the engineering, manufacturing and development phase (EMD)! This is not a disease endemic to only space programs; it occurs for ships, aircraft, tanks, and trainers. It happens in every sector of the US government. But what makes it particularly tough for those of us in the space business is that first, unlike most other systems, the majority of our costs are spent during EMD; and second, due to the real physical limitations on space system life, we are almost always in development in any one of our mission areas. This dynamic led to the statement several years ago by a former secretary of the Air Force who asked, "Why are all my space programs in trouble?" Part of the answer, although not one we gave him, was, "because they were all in development."

But is it really inevitable? It sure seems so. The names are legend; Military Strategic and Tactical Relay System (MILSTAR), GPS IIF, Space Based Infrared Systems, National Polar-orbiting Operational Environmental Satellite System, Future Imagery Architecture, Space Based Space Surveillance, and Advanced Extremely High Frequency just to name a few. Nearly everyone has gone through a Nunn-McCurdy certification process, or the equivalent. The issues were so widespread that in National Security Presidential Directive-49 (NSPD-49), US National Space Policy, signed by President George W. Bush on 31 August 2006, a focus was placed on space systems development costs. The Office of Management and Budget was asked to craft rules to monitor the space acquisition process across the federal government. When the president has to jump in to fix things, you know we are doing poorly.

So what's the answer? What's a space program manager (PM) to do? In just the last 10 years we have had numerous defense science board studies, congressional commissions, National Academy of Science findings, and Department of Defense (DoD) Executive Agent Independent Reviews. All prescribed a menu of fixes from making sure everything is 80 percent funded, to confirming all up front system engineering is completed before starting a development, and focusing our efforts on removing all technology risks prior to Milestone B. Unfortunately, they never said whose job these things were… the program executive officer, the headquarters, the Air Staff, or the Office of the Secretary of Defense? Ultimately though, only one person can be accountable—the PM. Yet he or she does not control all the levers all those studies told us to pull. This article outlines some levers or guidelines that I believe the PM actually ***does*** control.

Most of these guidelines focus on processes early in the program's life because that's the key timeframe to put a program on the right track. A program that's broken heading out of Critical Design Review or even Preliminary Design Review (PDR) is probably going to stay broken through development. It will suffer from, as the 2008 Young Panel Report put it, "congenital defects" throughout its life presuming it is allowed to live. There is no such thing as an acquisition panacea so the steps prescribed below are not program cure-alls; but they are also not just palliatives. In my 30-plus years of acquisition experience, I have observed that these seemingly common-sense changes can have a huge impact on the eventual outcome. I have divided these lessons into three distinct phases: failures in source selection, failures in program initiation, and failures in program execution.

Starting Right: Lessons From Flawed Source Selections

How Bad Do You Want It?

It sure seems simple. You have a firm requirement that includes numerous key performance parameters (KPP) signed by the Joint Requirements Oversight Council. The Pentagon has told you how much money you have by fiscal year. The combatant command has told you when they want initial operational capability. All you need to do is get it on contract. So you go out for bids and you put all that information in the request for proposal. As a savvy manager, you hold some time and money back in management reserve and ask for a bit more than the threshold requirements to make sure the contractor does not "under-deliver." You explain that unless the contractor can meet your schedule for the dollars laid out and with the minimum requirements satisfied, they can't win. Of course, every contractor who responds says they can do it for exactly that amount of money (or less) and exactly to your schedule (or sooner). In fact, they can actually beat your minimum requirements. Your alarm bells should be ringing!

Either you are uncannily omniscient, or the contractors simply told you what they thought you wanted to hear. Good programs begin with an achievable set of requirements bid at a realistic cost and a realistic schedule. Given the freedom, a contractor will try to bring you an aggressive, but doable program. But if put in a position of either losing or having to promise an unachievable program, he will promise the unachievable. It may not be in his self interest to do so, but it will happen nonetheless.

Lesson 1 – An overly constrained source selection can and will force an offerer to bid to an unachievable baseline.

Am I Being Clear?

Have you ever been asked by a friend to help them shop for a car? I have. Several years ago, a relative asked me for help buying a car. When I asked what kind, the answer was, "a Mercedes." When I asked what kind of Mercedes, their clear answer was, "Well, a Mercedes—you know!" Actually, I didn't; and neither did they (by the way, they bought a Lexus). Several years ago, it became fashionable to stop writing statements of work (SOW) and to start writing statements of objectives (SOO). The theory was to tell the contractor in broad terms what the government needed (a Mercedes) and let the contractor figure out how to deliver. This strategy was often paired with concepts like commercial parts and test standards, total system performance responsibility, or other questionable premises all presuming the contractor knew better than the government what the government needed.

Unfortunately, it does not work for cars and it does not work for satellites. If you go to the library (or Wikipedia) and search for "commercial test standards for national security satellites," you will not find it, because it does not exist. Rather, such statements become "county option." And trying to evaluate a proposal against standards that do not exist is a prescription for disaster. No one understands the government's requirements better than the government. Being forced to write them down in the form of a SOW affirms in clear, unambiguous terms what those requirements are ... you understand them, the contractor understands them and so do your teams. Who knows, you might even get the Mercedes you asked for!

Lesson 2 – To be a smart buyer, the government needs to know what it wants, needs to state it clearly, and needs to evaluate against those needs.

Getting Underway: Lessons in Program Initiation

The Race to Failure!

There is a famous software development aphorism that goes, "There's no time to stop for gas, we're already late!"[1] So too for major space systems; by the time we get on contract we are already well behind schedule: the Joint Capabilities Integration and Development system took too long, funding got cut, acquisition approvals were delayed, and source selection did not go quite as planned. Often, the program team has been working the program for many years prior to getting a contractor hired. The urge now is to speed toward PDR to make up for lost time.

Well not yet. Writing clear SOWs (Lesson 2) does a great job of heading both you and the contractor in the same direction, but planning the decade-long journey you are about to undertake together is still critical to your joint success. This is the role of an Initial Baseline Review (IBR). As described in an article by Col Mun H. Kwon (also in this issue), getting the IBR right is the reason Space and Missile Systems Center (SMC) created the Program Management Assistance Group. A good IBR takes a committed effort for three months; a great IBR might even take longer. To many program teams who have worked for years to leave the starting gate, this looks like a wasteful pit stop—"There's no time to stop for gas, we're already late!" In the end though, it is well worth the extra effort. It is especially important during those early phases when most of what you are producing is paper and not hardware. The IBR creates a clear plan for program execution that becomes the PM's roadmap for judging if he's on track. The clearer and more detailed the map, the easier it is to tell when you are headed off course. Programs need to resist the urge to "get up and head out" before that course is well known and understood.

Lesson 3 – Staying on course is only possible once you have plotted the journey.

Cutting the "Fat"?

I had the unenviable task several years ago to be a member of an Independent Review Team (IRT) for a multi-billion dollar space development effort that had run into massive problems. We were supposed to figure out why. As is often my habit in such circumstances, I first went to the contract, the SOW, the contractor's proposal, and the last year of cost performance reports (CPR) so I could understand what was happening. Error number one for this particular effort was that there was no SOW, only a SOO (again, refer to lesson 2). But what struck me most in reviewing these documents was the statement by the company president on the transmittal letter for the final proposal. It proudly proclaimed that they had reduced their final offer by, "eliminating $800 million of unnecessary system engineering and delegating that to our subs." Well, to adapt another software proverb, "If you think good system engineering is expensive, try bad system engineering!"[2]

When faced with too little money and too little time (see lesson 1), and where the government has not spelled out clear compliance standards for design activities (lesson 2), a contractor will often cut things that appear secondary to making clear progress. That almost always means starving the system engineering effort. System engineering costs a lot, at least in the early phases. In fact, it becomes one of the primary expenses in the first few years. However, early system engineering is the foundation that will support the program through the years that follow. The danger of building a foundation that is too extensive is far less than that of building a rickety infrastructure that collapses at the start of integration and test.

Lesson 4 – When costs are constrained, the contractor will shortchange those aspects of the program that seem to be indirect to program execution.

Staying on Track: Lessons in Program Execution

Tools of the Trade—They Only Work if You Know How to Use Them.

During the course of a development effort, a PM has many sources of information about what is going on. Some are clearly understood: if the integrated master schedule indicates the program is behind, it probably is. If the test fails, then the system probably needs to be fixed. But some of the products a PM gets are less clear and more confusing. One of the most notorious is the CPR.

CPRs are probably the most misunderstood elements of program data that the government receives. However, it can be one of the most powerful when used correctly. As mentioned earlier, when new to a program, one of the tools I always turn to is the CPR. For one of my programs, the CPRs told me the secondary payload for the system was years from delivery (at least two years late to need). It was also on course to cost over twice as much as the vendor had been given to deliver it (turns out I actually guessed low). Within a month of taking over, we terminated that part of the effort for the first satellite.

Mind you, we had not had a review with this contractor yet and no hardware had failed in test. In fact, I could barely tell you how it worked. But a careful reading of the CPR, data that had been available to the program team for well over a year, quickly revealed the issues and drove a rapid decision. A nearly identical picture emerged in two other IRTs in which I was involved. The point here is not to suggest that all program issues can be determined by reading a CPR—they can't. The PM, and the program team, has many sources of information, but they only work if everyone knows how to use them. In an operational system, there are many telemetry points. Some have set limits that flash red when exceeded. Some just tell you what the value is and you have to know what that means. Skilled operators understand more than just the flashing reds. So do skilled PMs and the people who work for them. If they don't, then teach them.

Lesson 5 – Ensure your entire team understands all the tools in their toolkit and uses them on a regular basis to track program performance.

Never Let Them See You Sweat.

There is nothing as uncertain or tenuous as starting something new. This is especially true for new space development programs. The most dangerous time for a new space effort is in the very beginning; the time before PDR. At this time, it is still not too late (at least in theory) to go back and buy one more of the old design before the new system gets too far down the road. So many PMs "learn" not to cast doubt against the system's ability to meet the validated KPPs. Missing a KPP means having to re-justify a program and risk cancellation.

Such a circumstance confronted the PM on a major space reconnaissance effort soon after it began. He had been the person who "sold" the program, and had shepherded it through the byzantine approval process that accompanies multi-billion dollar developments. Approaching PDR, it became apparent that the system design was going to fall short of one of his many (too many it turned out) KPPs. He had a choice: (A) go back to the combined DoD and intelligence requirements boards and ask for relief, or, (B) direct the contractor to change their design and find another way. He chose (B) because choosing (A) would have reopened the debate of whether this system was the right one to build.

The contractor complied. They redesigned the spacecraft to meet the requirement. But the weight of the satellite increased by 50 percent in the process as did the cost. By the time they were done (nearly a year later) the program was hopelessly behind schedule, over cost, and on a nearly unrecoverable downward spiral. As it turned out though, the requirements community had been prepared to provide relief. The calculation was that the system would have missed the KPP by less than 5 percent. In fact, the calculated value was still better than any prior system had ever delivered. But, because the PM was unwilling to risk possible cancellation by asking for relief, he had doomed the program by forcing a compliant design. The program was cancelled four years later after billions more had been spent.

Lesson 6 – Never get so close to a program that you can't make objective trade-offs, even those that might call the program into question.

Is That All It Takes?

Behind these six lessons are hundreds more. There are obstacles at every turn and it takes skill and persistence to overcome them one by one. But these lessons, these six easy steps, are some of the most important in "getting it right." Space Acquisition is a tough business. I hope current and future PMs will take to heart these lessons from past space acquisitions. Having personally experienced the ramifications from each and every one, I assure you the mistakes are not worth repeating!

The recent GPS III acquisition at SMC instituted most of the above steps, and they appear, so far, to be working. Our joint challenge is to replicate that model throughout the enterprise. Doing so provides the space community the best chance of emerging from the "space acquisition battle" unscathed. Getting it wrong, beginning with too little money and time, with uncertain needs along an undefined path, with a program team not armed with rigorous system engineering and program tools, and a program leadership chain unwilling to make tough decisions on the program itself, dooms us to failure.

Notes:

[1] Ms. Karin Donker, proverbs and quotations, Cornell University, http://instruct1.cit.cornell.edu/courses/ee476/Proverbs.html.

[2] Adapted from the saying, "If you think good architecture is expensive, try bad architecture," Brian Foote and Joseph Yoder, *Big Ball of Mud*, Department of Computer Science, University of Illinois at Urbana-Champaign, 1999.

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Mr. Loverro has served in a variety of technical management, leadership and staff positions in the Air Force. Previous assignments include director of Advanced Systems, Space and Missile Systems Center; system program director, Navigation Satellite Timing and Ranging Global Positioning System Joint Program Office, Space and Missile Systems Center; commander, Future Imagery Architecture Materiel Wing, National Reconnaissance Office, Chantilly, Virginia; and associate director, Imagery Systems Acquisition and Operations, National Reconnaissance Office.

Mission Assurance: "Baking In" Mission Success

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It is generally accepted that the period of acquisition reform has had a significant negative impact on current space system development. The trigger events that jolted the National Security Space (NSS) community out of the total system performance responsibility (TSPR) mindset was a sequence of five failures of the Delta III and Titan IV launch vehicles in a 10-month period starting in 1998. What followed was a series of 11 studies starting with the Space Launch Broad Area Review in November 1999 and ending with the 2003 Congressional Hearings on Space. Each study found there is a need to revitalize America's ability to successfully design, develop and launch spacelift vehicles and spacecraft. These studies collectively highlighted that the NSS acquisition community had lost its discipline for solid systems engineering (SE).

In 2003, Space and Missile Systems Center (SMC) stepped out with an aggressive program to revitalize systems engineering for its space programs. Today, after six years, SMC has brought back specifications and standards, mission assurance (MA) processes, and a full array of command media supporting the development of space systems. Although SMC's acquisition programs initiated over the last six years have benefited from this renewed emphasis on MA, GPS IIIA is the first new program to fully implement or "bake in" the lessons learned from a decade of relearning. This article uses the findings of the 11 studies to support the need for "baking in" MA into SMC's future programs. It covers SMC's current MA baseline process and addresses the corporate actions taken to avert future problems with TSPR programs. Most importantly, the article describes how GPS IIIA was "born" with robust programmatic and technical MA features.

The findings of the 11 studies can be categorized into two broad areas of MA: programmatic assurance and technical assurance. Listed here are the relevant findings of those studies.

Programmatic Assurance

- Systems suffer from inadequate resourcing.
- Lack of disciplined SE processes.
- Poor requirement analysis and stability.
- Inappropriate acquisition strategies.
- No block evolutionary plans.
- Low technology readiness levels (TRL).
- Lack of independent assessments.
- Source selections with providers of unknown capabilities.
- Lacked program baseline discipline.
- Inadequate incentive structures.
- Low realism in costing.

Technical Assurance

- Lacked consistent specification and standards.
- Designs were not verified.
- Limited control of parts and materials.
- Did not use simulators or prototypes.
- Lacked software independent verification and validation.
- Heritage that was not evaluated fully.
- Did not implement solid command media.
- Were not tested as they were intended to be operated.
- Did not validate the MA processes.

Standing at the end of the TSPR era, SMC leadership was faced with a dual problem. First and foremost, how to affect change in programs already well into development. The second was how to reinvigorate a workforce whose mode of operations was to remain hands-off. The answer was to book-end the life cycle acquisition process. At the end of the process, just before launch, the Air Force program executive officer (PEO) for space received three views of performance risk—one from the program technical management; one from The Aerospace Corporation's engineering team; and the final was from the center's technical authority, the Independent Readiness Review Team (IRRT). Collectively these teams informed the PEO prior to shipment, integration, and launch of the risks involved with a given mission. Admittedly these assessments held some degree of redundancy, but without the alternate perspectives, the PEO could not make the critical decision to *go* or *not go* to launch.

The second solution was to revitalize SE efforts that would start early and carry throughout the program. This effort focused on recreating critical command media—policies, standards, technical specifications, best practices, hand-books, guides, and deliverable data. It took significant effort to reestablish this media since most of the people and documentation had been lost during the TSPR era. Figure 1 illustrates SMC MA baseline of activities.

Today the baseline has stabilized. SMC maintains 65 revitalize specifications and standards which are applied to all new developments by SMC commander policy. The IRRT continues to uncover hidden issues that are vetted and resolved prior to launch. SMC's Acquisition Center of Excellence (ACE), supported by the Engineering Acquisition Support Team (EAST), acquisition strategy panels, and solicitation review boards were reinvigorated and ensure that mission assurance command media are applied to all new contracts. SMC's Program Management Assistance Group (PMAG) enhances the systems planning and systems executability of all SMC acquisition programs. "Graybeard" independent program assessments were initiated and executed for all SMC Acquisition Category I programs at major milestones. An industry consortium was formed, such as the Space Quality Improvement Council, consisting of primes and major subcontractors, and the Space Supplier Council, consisting of lower-tiered suppliers. This approach defined an effective, consistent, repeatable, single, enterprise-wide MA baseline process to apply to all programs. Resource and schedule constraints require that a program define an overall MA process that is tailored to program-specific needs and places emphasis on those aspects of MA that the program considers most important for its success. The targeted breadth and depth of applied MA processes will depend on several factors, including budget, schedule, state of maturity of the underlying technology, nature of the program (e.g., demonstration versus operational), and more importantly, the criticality of the mission.

As SMC's MA baseline matured, programs continued to reach milestones ripe for inclusion of these concepts, yet the baseline was evolving. Today, the baseline is stable and the first program to fully reap the benefit is GPS IIIA. Disciplined GPS IIIA program management began with approved and well understood system requirements along with senior leadership advocacy and Joint Requirements Oversight Council stabilization. For GPS IIIA, it took six years in understanding and decomposing requirements with numerous Department of Defense, Department of Transportation, and secretary of the Air Force executive-level reviews. The next step was the development and approval of a well-thought out acquisition strategy that was thoroughly vetted with multiple reviews such as independent program assessments and a five-month long Initial Baseline Review (IBR). There was an independent advisory team throughout along with significant assistance from the EAST, ACE, and PMAG. Significant risk mitigation was achieved by thorough concept exploration, ensuring that critical technology elements would be at TRL 6/7 at KDP-B for all blocks. The program maintained two prime contractors from requirements definition through system design review. In addition, key risk mitigators, such as a pathfinder and GPS satellite simulator, were built into the integrated master schedule (IMS) baseline. A quality workforce was groomed that is providing capable and consistent government oversight and system integration. Extensive training was provided to organic, Federally Funded Research Development Center (FFRDC), systems engineering and integration, and systems engineering technical assistance assets. The GPS IIIA baseline is very thorough with a robust IMS and IBR process. Extensive use of the PMAG filled critical program office gaps and joint training and execution was held with contractor cost accounting models. Lastly, business execution was held on par with technical execution. Cost estimates were realistic resulting in a low-risk schedule and 80 percent confidence (includes all requirements). The sound schedule was based on government schedule estimates with mature technologies. The single integrated performance baseline provides visibility of cost and schedule impacts, and the critical path analysis allows for proper allocation of resources and early intervention.

Disciplined engineering for GPS IIIA is also of paramount importance. The integration of program segments: space, control and user, required a strong configuration control board (chaired by the wing commander). Wing and contractor processes were standardized or integrated and includes integrated change management, wing-level system engineering plans and test and evaluation master plans in concert with prime contractor contracts, and industrial base and manufacturing readiness assessments. Emphasis is placed on subcontractor management (e.g., supplier audits)—a one team approach. The FFRDCs are fully leveraged, for example, The Aerospace Corporation serves as the squadron's chief engineer. Early compliance with mandatory efforts, such as environmental, the Clinger-Cohen

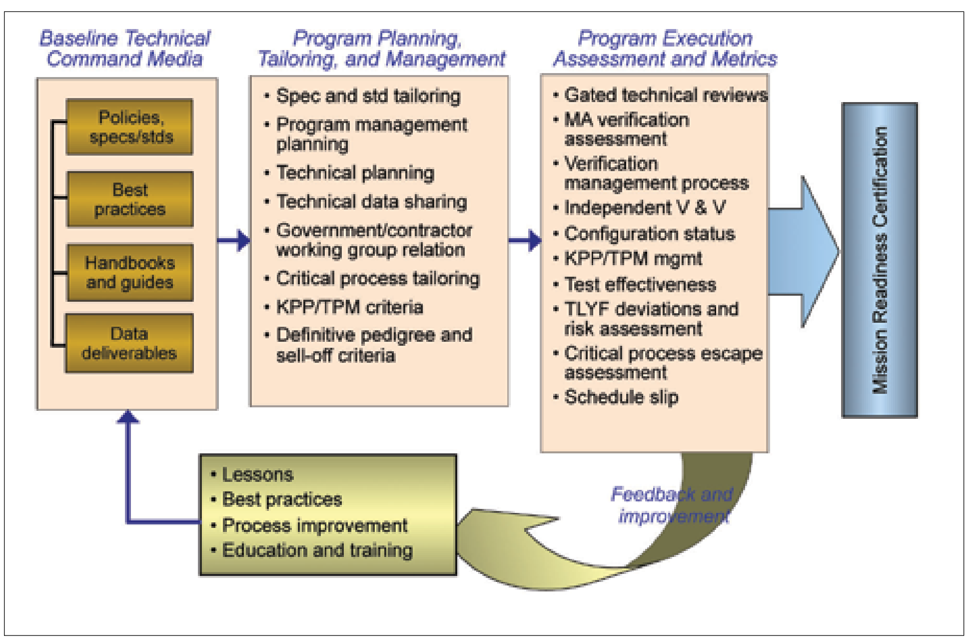

Figure 1. Baseline Mission Assurance Process Model.

Act, and information assurance, was performed. Special attention was given to software development (full independent verification and validation), design verification and satellite modeling. Additionally, fully tailored specifications and standards and lessons learned are on contract.

In summary, SMC has recorded and applied extensive lessons-learned findings in both corporate and individual program processes. Our work is not done and there is still much to do at all levels. However, Air Force Space Command and our mission partners have significant confidence that SMC has established the right track for future programs, and we will continue to deliver outstanding products to the warfighters.

Col David E. Swanson (BS, Electrical Engineering, Southern Illinois University; MS, Space Operations, Air Force Institute of Technology, Wright-Patterson AFB, Ohio; MS, Electrical Engineering, University of Colorado) is the director of engineering and architectures, Space and Missile Systems Center, Air Force Space Command, Los Angeles AFB, California, and also the center's chief engineer. In this capacity, he leads a team of 140-plus military, government civilian and contractors who are responsible to the SMC commander for the quality of all engineering, architecting, test/evaluation and mission assurance activities for military space and missile programs.

Colonel Swanson's experience includes an assignment as an analyst in Phillips Laboratory's Satellite Assessment Center, a project manager in SMC's Test Program, a programmer in the National Reconnaissance Office's Plans and Programs Directorate and the executive officer to the NRO's deputy director. He has held the position of deputy division chief in the National Security Space Architect, was an orbital analyst and the chief of the special operations vault in Cheyenne Mountain Operations Center's Satellite Control Center, and served as a speech writer to the commander in chief of USSPACECOM, General Ralph E. Eberhart.

Dr. Sumner S. Matsunaga (BA, Electrical Engineering, University of Hawaii; MA and PhD in Electrical Engineering, University of Southern California) is the general manager for a new division supporting the Space and Missile Systems Center (SMC) in engineering and architectures and program management and integration.

He is also the acting senior technical director for the SMC chief engineer. His organization focuses on successful program initiation, execution and mission assurance for all SMC programs. He previously was the corporate chief architect/engineer. In this capacity, he and his division worked with multiple government customers in developing or improving acquisition, mission assurance, systems and software engineering, and information assurance processes in order to enhance mission success and overall program execution. His organization also oversaw corporate efforts in new concept developments and special projects in space and launch systems. He led several corporate enterprise activities such as the Space Quality Improvement Council whose members include senior space industry contractors and government sponsors. He initiated and facilitated the SMC Chief Executive Officer Council, a collaboration forum for the four major Federally Funded Research and Development Centers supporting SMC. He initiated and led corporate "Lean/Six-Sigma" activities in concert with the Air Force Smart Operations for the 21st century initiative.

Dr. Sumner S. Matsunaga has served in increasingly more responsible positions with The Aerospace Corporation since 1989. Dr. Matsunaga's other positions included general manager of the Electronic Systems Division and principal director of the Technology Development and Applications Directorate. He is a graduate of the Defense Acquisition University (systems acquisition) and Center for Creative Leadership (leadership development).

He is an American Institute of Aeronautics and Astronautics Associate Fellow, Institute of Electrical and Electronics Engineers senior member, and Eta Kappa Nu EE Honor Society Member.

Ms. Rita M. Lollock (BSME, System Engineering, University of Texas at Arlington; MSME, System Engineering, University of Texas at Arlington) is the general manager of the navigation division at The Aerospace Corporation, which provides Aerospace support to the Space and Missile Systems Center's Global Positioning Systems Wing.

Ms. Lollock joined The Aerospace Corporation in April 1989 working in the Engineering and Technology Group and then the GPS Program Office.

Ms. Lollock joined the GPS Program Office as a project engineer in March 1992 and was promoted to systems director for military user equipment in July 1993. She chaired the Technology Assessment Panel of the Navigation Warfare Evaluation Team (NET) from February 1996 until the NET completed its work in December 1999.

In January 2000, Ms. Lollock assumed the responsibilities of systems director for GPS modernization, leading Aerospace efforts for modernizing the Block IIR satellites, the Block IIF satellites, the corresponding operational control segment, and the initiation of the new GPS III space and control program. By October 2000, the IIR, IIF, and OCS modernization efforts were on contract and responsibility was transferred to the Space and Control Directorate.

In April 2001, Ms. Lollock was promoted to principal director for GPS III and military applications. In November 2003, Ms. Lollock assumed responsibilities as principal director for system engineering in the GPS Program Office. In October 2005, Ms. Lollock was promoted to her current position as general manager of the navigation division.

PMAG: The Relentless Pursuit of Program Management Excellence

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Program Management and Integration Directorate
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We Can Say "YES" To Combating Complacency

How many people truly understand what it is to be on a "high-performance" team? When asked if someone is a high-performance team player, how often do they stand up and say, "Yes"? Do they believe it? Can they say it with certainty? Do they slam their hands on the desk, kick the trash can, and with a fire in their eyes to match the intensity in their hearts, do they look up and say with truth and conviction, "I am a team leader!"?

Reading this, you may get a good laugh. But it is a knowing and cynical laugh. You know as well as I do that the phrase "high-performance team" is a marketing tool bandied about far too often in our industry. This is a phrase which should mean everything in our business, yet has been so politicized and caught up in the paradigms of the day that it is unclear what it really means, if anything.

We must take up a sense of urgency to improve our acquisition performance. Now more than ever, we must relentlessly pursue excellence in developing and deploying our weapons systems to support the joint warfighter. In these lean years, what are the real challenges organizations must recognize when developing a winning model for acquisitions processes and personnel? What must be cultivated in our employees that will have meaning and drive behavior and action? Is it leadership, judgment, the flexibility to respond to a new kind of crisis, disciplined execution, the ability to lead one's team or still rise above it to get a sense of the big picture? Yes, it is all of these, time-honored and tested attributes. But as they say in Missouri, show me. Prove it. Be content-based, not just process-based. Know what to look for and why—pay attention to details. Develop and demonstrate program management acumen, do not just repeat the buzz-words or check the boxes.

There is still a lot of foot-dragging in the acquisitions community, and we need to come to grips with current acquisition problems and their far-flung, scattered, non-integrated nature in our business. To combat these problems at their core, real leadership has to come from within every one of us.

The new Program Management Assistance Group (PMAG), Space and Missile Systems Center (SMC), Los Angeles AFB, California, is living this leadership model. The PMAG is a true "high-performance" team which seeks to force-multiply not only its team members, but the entirety of Air Force acquisitions. It is the expectation of Air Force Space Command and SMC commanders that PMAG strive to improve acquisitions processes toward acquisition excellence. Because of this, we are eliminating the box-check mentality and courageously combating acquisitions complacency.

How is this possible, you ask?

Simply put, there are too many programs with baseline execution problems. There is only marginal program stability. Acquisition Category I Department of Defense Component acquisitions are slow, built on cumbersome processes which are infamous for cost overruns, schedule slips, and performance problems. We have too many acquisition-certified program managers who are not adequately trained or sufficiently skilled to craft executable baselines capable of reaching program stability. We have a workforce that needs to be revitalized to be content-based through application-oriented training. The SMC PMAG has found that there are numerous times where we have good processes in place but have lacked disciplined execution due to inadequate understanding of the content. As a result, we fail to comply with proven processes from our own program command media.

Space-based acquisition demands a complex, high order of intelligence, knowledge, and experience. Intelligence is seldom an issue, but touch-time, know-how, and experience are hard to come by: government military and civilian personnel rotate out of their positions as soon as they become subject matter experts. The PMAG mitigates the impact of rotation requirements by filling in the holes these rotations inevitably cause. We provide additional program management capabilities thus ensuring continuity in multidisciplinary capabilities and, ultimately, program success.

The PMAG assists and supplements wing commanders and program offices in fixing these common problems, raising core competencies and providing a consistent culture that sweeps across programs.

How PMAG Captures Lightning in a Bottle

The PMAG was created, first in 1975 at Headquarters Air Force Systems Command and dissolved in 1987, and resurrected in July 2007 at SMC. A relatively small cadre of professionals, the PMAG was created to help mitigate program management, system integration, and program control deficiencies within specific ongoing programs. In doing so, the PMAG strengthens government organic capabilities by establishing a high-performance and content-based culture. The PMAG institutionalizes the Air Force's drive for change, creating a new corporate culture which has integrated itself across programs and across locations, starting at SMC and propagating across the Air Force.

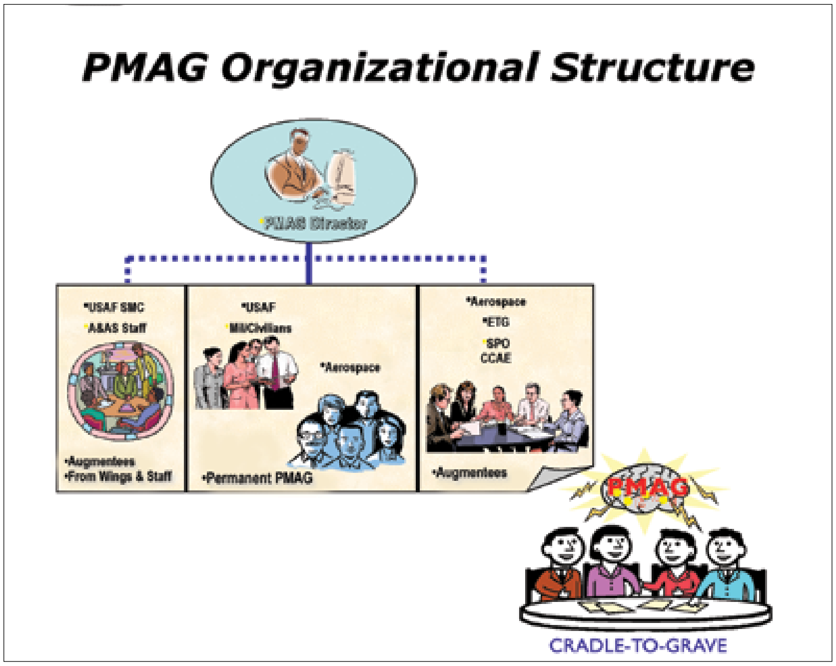

Figure 1. PMAG Organizational Structure.

The PMAG is not just an organization; it is a way of thinking, a way of performing, and a commitment to the relentless pursuit of excellence. The PMAG is a way of doing business, of being passionate about acquisitions, of coming to work and enjoying it. It is working hard, not for personal glory but to further center-wide acquisitions, to further the mission, to feel in your pulse the pride of working in the service of your country and the joint warfighter. We can do better than people think we can in Air Force acquisitions; we are striving toward the best, we know best practices, and through proper team-building we can bring out these high-performance organic capabilities.

It is no surprise that PMAG has been so successful that the center's commander believes this PMAG initiative will help strengthen SMC's program performance.

The PMAG has become SMC's leading program management "firefighting team" to provide program management, system integration, and program control expert assistance to our line program managers. We have earned this credibility through both our expertise and close collaborative relationships with our integrated staffs, industry partners, as well as Federally Funded Research Development Center (FFRDC), Defense Contract Management Agency, systems engineering technology assistance (SETA), and customers. Our primary customers include six wings and two direct report groups. This spirit of collaboration has resulted in many program milestone successes (including, but not limited to, Space-Based Space Surveillance integrated baseline review (IBR), Space-Based Infrared System (SBIRS) engineering manufacturing development design review and IBR, SBIRS follow-on production system requirement review and preliminary design review, and GPS IIIA program start-up assistance).

A PMAG project can be initiated by the center's commander, vice commander, executive director, wing commander, acquisition commander, and directors from the staff. The PMAG director works with the appropriate leadership to determine program needs and assign team members. To achieve program success, the current PMAG seeks to maintain a lean operation of only 10 to 15 permanent members. This core team is supplemented by "augmentees" as needed. These augmentees may be selected by the PMAG director on an as-needed basis to assist with project teams and provide extra capabilities. Selected augmentees may be from government civilian, military, aerospace, and contractor personnel. Interns, graduates on presidential management fellowships, and even second lieutenants have been given project management leadership opportunities, mentored by the experienced PMAG core, developing competencies and knowledge for program management execution that they will take with them throughout their careers. This is a win-win situation for the wings as these individuals, who have received valuable touch-time experience, are later hired into their organizations; the PMAG augmentee becomes a valuable team member in the wing.

This unique and varied team composition allows for a flexible group of subject matter experts who can learn from different programs and provide lessons learned and best practices from

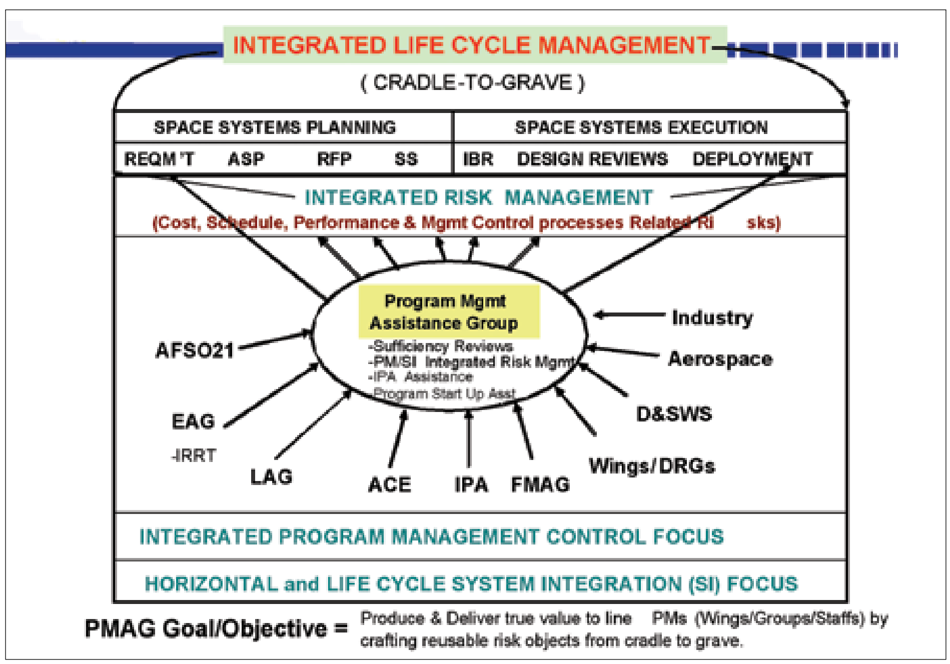

Figure 2. Program Management Assistance Group Framework.

By relentlessly pursuing continuous improvements in all areas of our SMC business cases, we have learned to not merely exchange ideas but to jointly mitigate program deficiencies with our customers.

one program to another. Most importantly, PMAG members are not simply consultants, but participants who roll up their sleeves and provide true value to our customers. By rotating core and augmentee staff across programs, a life cycle system integration focus is developed and applied.

Everybody in PMAG brings their own unique expertise. The keystone of PMAG's success is this multi-disciplinary team approach. Each member is holistically focused, enthusiastic to apply integrated program management capabilities with a strong technical background. It is this passionate teamwork that pushes each PMAG member to exceed their own expectations and results in creation of valuable group products (i.e., integrated program risks). The success of the PMAG is not due to any individual accomplishment but to the nature and quality of the teamwork. It is this dedicated collaboration that enables PMAG to successfully execute multiple programs simultaneously. This commitment to excellence earned the learning opportunities, touch-time, and unprecedented collaboration with PMAG partners and customers.

By relentlessly pursuing continuous improvements in all areas of our SMC business cases, we have learned to not merely exchange ideas but to jointly mitigate program deficiencies with our customers. These business cases include development of requirements definitions, acquisition strategies, requests for proposal, source selections, integrated baseline reviews, design reviews, and deployment processes. These passionate collaborative relationships are at the core of innovation. Successful creative relationships spark further collaborations creating a cycle of more and more successes—and this passion for success is contagious.

While the PMAG continues to provide assistance to many military space programs, it is the intention of senior Air Force acquisition leadership at the secretary of the Air Force for acquisition and Air Force Materiel Command (AFMC), that the PMAG concept be propagated throughout the US Air Force. As a first step in spreading these new methodologies outside of SMC, the PMAG is to propagate its methods, culture, and lessons learned to the Defense Acquisition University and AFMC. This is a key step in changing current development acquisition culture and training new acquisition professionals, but it is hardly enough. True knowledge in acquisitions comes not in a classroom, but in on-the-job training, in seeing, in doing and in experiencing passionate mentoring and coaching efforts. To just read about PMAG's implementation of integrated program management does not compare with experiencing it personally; there is nothing like an acquisitions team operating at its highest level of performance.

PMAG Support of GPS IIIA Program Startup

From 13 November 2007 to 31 October 2008, PMAG distinguished itself by supporting the SMC's $1.4 billion GPS Block IIIA IBR Team. As GPS Commander Col David W. Madden stated to *Aerotech News and Review*, "The PMAG, SMC's program management [expert assistance team], were an integral part of the overall process providing application oriented training, templates, analyses, and assessments vital to IBR success."[1]

PMAG's three-phased risk formulation, CAM Notebook evaluation training, program planning, best baseline review practice, and collaboration with the contractor's program start-up assistance team succeeded in building a strong organic integrated program management capability within the wing and the prime contractor. This three-phased startup IBR verified and validated technical, schedule, and cost performance aspects of the baseline, encompassing over 600 control accounts in total. The PMAG conducted close to 180 critical and near-critical path control account assessments to ensure this crucial $1.4 billion performance measurement baseline is executable.

This program startup assistance in IBR was accomplished through unheralded cooperation with the wing, integrated staff, FFRDC, SETA, and industry partners to provide integrated program management, program control, and system integration expertise. PMAG worked to develop new methodologies and incorporate lessons learned from other successful programs, providing detailed instruction to the wing to ensure further program success. PMAG methodologies for various program startup activities will be detailed in a later article.

Re-Focusing Our Organic Capability

The success of any high-performance team is dependent on each team member as an individual. We are all team members, every one of us; with responsibilities to ourselves, to each other, our industry, our community, and our country. We have the responsibility and accountability as individual team members to be the best, to push the envelope at all times and in all directions. We can accept no less if SMC is to maintain itself as the nation's center of acquisition excellence for 21st century space systems development. So as individuals, what must we do to become the best of the best? We must:

- Combat complacency and passivity.
- Connect with anyone in the workplace.
- Make ourselves multilingual, multicultural, multidisciplinary acquisition experts.
- Develop a better understanding of ourselves and the people around us.
- Have respect for all individuals.
- Be a life-long learner.
- Be adaptable.
- Demonstrate agility.
- Embrace disciplined execution.
- Become active listeners.
- Proceed with optimism and a can-do spirit.

- Constantly strive to be the best we can be.
- Have unconditional passion.

The world is changing faster than ever. To manage change in lean years and become high performance team players, we must continue to learn to:

- Apply the tools, ideas, and inspiration to be success-oriented in the midst of continually changing environments.
- Emphasize education and training to overcome barriers to career and personal success while going beyond personal and organizational limits.
- Be active leaders in lean management processes.
- Foster a collaborative environment.
- Recruit, retain, educate, and produce a highly-motivated and accountable workforce.
- Develop effective communicators and high-performance team players in managing change.
- Cultivate and encourage future leaders.

We Can Do Better; We Must Do Better

So what about you, the reader? Does the joy of service ignite a flame within you? Do you have that passion? If so, enjoy it. Enjoy it because you are a vital leader in the world's best acquisition force. Not only will you be a valuable asset to the PMAG and the Air Force acquisitions community, but it will also benefit your personal life. Live your personal passions, develop your acumen as a spouse, as a father or mother, as a neighbor, a civic member—your passion of excellence will be absolutely contagious to everyone around you throughout your life.

For the acquisitions community to be a part of the world's most respected Air and Space Force, we must innovatively and collaboratively develop ourselves to be valuable and knowledgeable workers. Learn the PMAG methodology, and live it! We simply have to invest in our future generation through relentless mentoring and coaching with a content-based, and not just process-based, focus. We can not merely say the right things, but we need to do the right things, and understand why it is that we are doing them.

Words are nice; they tell good stories and paint vivid pictures. But they are worthless if they do not connect somehow with their audience or inspire them to action or make a change in some small way. The PMAG brings substance through disciplined execution and focuses on content while de-emphasizing automatic delegation. A fundamental aspect of the PMAG is the integrated team's approach to producing compounded products and services. We must do the innovative work necessary to make Air Force acquisitions better.

If you take nothing else with you from this article, take this: We CAN do better; we MUST do better. If we all pick ourselves up, reinvigorate ourselves and remember what it is that truly inspires us—about service, about development acquisitions, about our country—we can reinvigorate this acquisitions community! You say you are already a true leader, a team player, you do everything right and you know everything? I tell you now that even I am not so perfect; even I continue to improve after 29 years of service. We can all do better. We all must do better! Complacency and passivity cannot permeate our culture. Competency, collaboration, and content-based performance—these are the tools, these are the keys to our success.

Feel the buzz and the change in the world around you. Stand up, commit, execute! We absolutely need every one of us to put in that extra contribution toward improving, toward acquisition excellence. All of us can improve, all of us can be more passionate, and all of us can do better. This is a commitment all of us—in every organization and under every command—can make right now. This is a commitment all of us NEED to execute right now.

We will all have to step up to this; real leadership has to come from within every one of us. Be a high-performance team player, live the PMAG model, and be a team leader. Be the best in everything you do, and push yourself to be even better than that. We can do better; we must do better. We shall be the ultimate program managers in the world's premier acquisition work force!

Notes:

1 *Aerotech News and Review* 2, no. 17 (14 November 2008).

Col Mun H. Kwon (BS, Chemistry, University of Maryland; MS, Systems Management, USC; MS, Strategic Studies, Air War College; PhD, Business Administration, US International University) is deputy for program management and system integration directorate, Space and Missile Systems Center (SMC), Los Angeles AFB, California. He leads the center's Program Execution and Analysis Group, Acquisition Center of Excellence Group, and Program Management Assistance Group to Support the SMC's mission

Colonel Kwon entered the Air Force as a ROTC graduate from University Maryland, College Park in 1980. His career has spanned a wide variety of acquisition program management, education, air staff, and materiel leader assignments including Solid Rocket Motors budget analyst, launch vehicles acquisition manager, Titan 34D Solid Rocket Motors Production and Launch Services project manager, Space Shuttle Payload Integrator, Precision Lightweight GPS Receivers program manager, Advanced Space Technology (XR) program manager, AF/XP chief scientist, professor of systems and acquisition management, National Missile Defense program control chief, dean of education and technology, National Defense University, ACAT I national space systems program manager, and commander of materiel acquisition group.

Among his many awards, Colonel Kwon has been awarded the Defense Meritorious Service Medal with two oak leaf cluster, Air Force Meritorious Service Medal with two oak leaf cluster, Joint Service Commendation Medal with one oak leaf cluster, Air Force Commendation Medal with one oak leaf cluster, Joint Service Achievement Medal, Air Force Achievement Medal, National Defense Service Medal, and Global War on Terrorism Service Medal.

Keys to Acquisition Success

Ms. Catherine J. Steele
Vice President, Strategic Space Operations
The Aerospace Corporation

INTRODUCTION/BACKGROUND

Acquisition success is the result of effective and efficient operation of the combined government/contractor team. Specifically, success lies in creating the conditions that allow the prime contractor to deliver a product that is responsive to the operational need and within the cost and schedule targets. Keys to creating those conditions are the following:

- Creation of stable, achievable operational requirements and concepts of operation (CONOPS).
- Conduct of concept definition and alternative selection driven by realistic technology maturity and risk appraisals.
- Extensive, thorough systems engineering preparation that continues throughout the program's life cycle.
- Effective program execution driven by maintenance and control of cost, schedule, performance, and risk baselines.
- Definition and management of key external factors, including system of systems impacts.
- Continuous, proactive identification, mitigation, and retirement of risks during the life of the system.
- Perceptive, aggressive testing characterized by stressful testing at the lowest possible level of assemblage.
- An objective, rigorous mission assurance process driven by lessons learned on other programs.

The Aerospace Corporation operates the Federally Funded Research and Development Center (FFRDC) for space. Aerospace shares the characteristics of all FFRDCs: a not-for-profit company, prohibited from competition with for-profit entities (and, therefore, free of most conflict of interest issues), that is predominately, but not exclusively, under contract to the US government. Unique among the FFRDCs, Aerospace specializes in the engineering disciplines associated with on-orbit spacecraft (both hardware and software components) and any ground-based command and control, communications, security, or cyber issues related to them.

Aerospace program office teams support the entire National Security Space (NSS) community, including the Air Force, Navy, National Oceanic and Atmospheric Administration, and intelligence community. Aerospace engineers and scientists are split equally between generalists in functional or program offices colocated with a government team and specialists in a centralized organization who are matrixed to the program offices when and as needed. This combination allows both breadth and depth of support. Breadth comes from the corporation's participation in all NSS programs, with the attendant ability to provide lessons learned and experience across the entire community. Depth comes from Aerospace's world-class, on-call cadre of specialists in all facets of spacecraft technology who provide specific, targeted expertise to our government customer's hardest problems.

Aerospace contributes to each of the eight key acquisition success activities listed above through:

- *Requirements/CONOPS:* Aerospace provides engineering support to operational users to help define realistic and complete operational requirements early in a program so that an executable development plan can be built on stable requirements.
- *Concepts/Alternatives:* Aerospace provides engineering support to Development Plans organizations to monitor and evaluate contractor concept development activities. Aerospace created and operates the Concept Design Center, where competing concepts can be modeled and compared in an unbiased setting.
- *Systems Engineering:* Systems engineering is the Aerospace core competency; the corporation provides and maintains the systems engineering cadre for most NSS programs throughout their life cycle.
- *Program Execution:* Aerospace provides the core technical capability to create, maintain, and assess the program technical baseline and the technical inputs to the cost and schedule baselines. Determination of the absolute program risk level and selection of relative risk levels posed by alternative courses of action is a government function. By providing the government with the technical and schedule risk assessments needed to make an informed decision, Aerospace plays a critical role in risk baseline activities.
- *Management of External Factors:* By virtue of its wide participation in NSS programs, Aerospace identifies cross-program issues within NSS and facilitates their solution. Aerospace, working with its sister FFRDCs, also participates in efforts to identify and resolve cross-program issues with non-NSS programs.
- *Risk:* Critical operational capability, high unit costs, and low production rates drive the NSS community to be risk-adverse. Aerospace combines a systems engineering core competency with an experienced workforce. This combination is absolutely essential in evaluating risk and providing the appropriate, timely information in the government risk decision process.
- *Testing:* Aerospace authored the military standard on space systems testing and is an integral part of the test planning and execution for NSS programs. Aerospace not only provides assessments of test program adequacy and in-plant monitoring of contractor test activities, but also has a world-class in-house laboratory capability, not available elsewhere in the contractor community, to conduct detailed failure investigations and independent testing.

- *Mission Assurance:* Aerospace is tasked with being the "technical conscience" of the NSS community. The corporation has structured its participation in NSS programs to address the issues key to mission success, which Aerospace determines jointly with the government customer. Aerospace provides assessments of NSS programs to senior leadership ranging from formal watch lists to independent program assessments (IPAs) at major milestones.

TOOLS AND PRACTICES TO ENSURE MISSION SUCCESS

Some key recent Aerospace initiatives to support acquisition success are:

- The Aerospace Institute's "Smarter Buyer" courses.
- Codification of core mission assurance processes and supporting disciplines in the Aerospace *Mission Assurance Guide*.
- Space and Missile Systems Center's (SMC) Acquisition Center of Excellence, Program Management and Assistance Group, and Independent Readiness Review Team.

"Smarter Buyer" Courses for the Government Space Workforce

The space program workforce has steadily decreased due to retirements, industry consolidation, and downsizing, and the ability to document lessons learned was lost quickly with the elimination of specifications and standards during the era of acquisition reform in the 1990s. Space system complexity has increased; there are more powerful multi-mission systems, requiring complex acquisition approaches and organizational, system, contractual, operational, and maintenance interfaces from sensor through end-user system. All of these pressures necessitate that the workforce keeps pace and becomes more productive and flexible.

To respond to these needs, the educational arm of Aerospace, The Aerospace Institute, developed two "Smarter Buyer" courses for the space acquisition workforce, designed for center commanders down to their acquisition staff. *Smarter Buyer 1: Industry Perspectives* has been delivered over 35 times since 2005; *Smarter Buyer 2: Knowledge-Based Technical Management* has been delivered twice in 2009. Both are available to Aerospace's employees as well as to its customers, at no charge, on a space-available basis. Figure 1 illustrates the build-up of typical space industry financial metrics that are used in the course, which has been given to well over 2000 participants, including SMC, National Reconnaissance Office (NRO), Missile Defense Agency (MDA) and Air Force Space Command (AFSPC) personnel, as well as other members of the intelligence community.

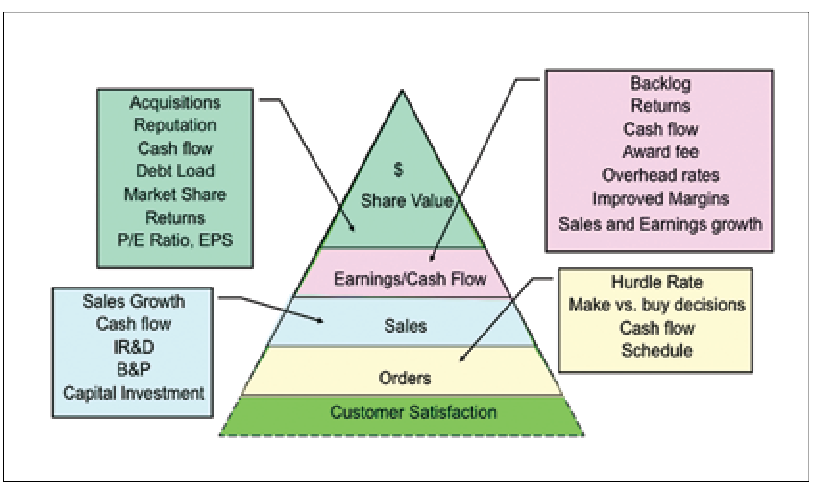

Figure 1. Industry financial measures.

Smarter Buyer 1: Industry Perspectives

This course was requested by the under secretary of the Air Force for acquisition in 2004 to improve the way government space acquisition organizations effectively partner with industry to improve space acquisitions. Aerospace served in the role of "honest broker" between the government and industry. Aerospace personnel interviewed many senior government acquisition officials, recognized outstanding program managers, key industry leaders, and well-known Wall Street analysts to determine which methods typically lead to success. They then examined corporate financial information, Wall Street trending of risks/rewards, and how typical corporate business development decision processes are defined. Combining the information gleaned from these sources resulted in a one-day course that focuses on industry accountabilities of the chief executive officer, space segment portfolio manager, business developer, and program manager. The course reviews financial health, cash flow, and variables that must be handled at each level and how these factors can be influenced by government contracting and program execution.

Smarter Buyer 2: Knowledge-Based Technical Management

Knowledge-based technical management was the next topic chosen in the Smarter Buyer series because so many space acquisition programs have had difficulty staying on their acquisition program baseline. Again, Aerospace interviewed government and acquisition officials to confirm the issues and target the problem. Aerospace adopted a knowledge-based focus after review of the Defense Acquisition Guide, General Accounting Office reports on the topic, and MDA successes in applying it along with leading-edge systems engineering research and the IPA technique used to assess program executability. Aerospace used the systems engineering and mission assurance process life cycle components, together with the nominal space acquisition milestones, to extract knowledge points—each with a detailed and supportable set of evaluation criteria, requisite inputs, and expected outcomes—to be used for program go, recovery, contingency, or no-go decisions. Figure 2 shows the knowledge points that are recommended for most programs. For simplicity, a single system view is shown instead of a system-of-systems.

This one-day course provides both an assessment approach for existing programs and the planning ap-

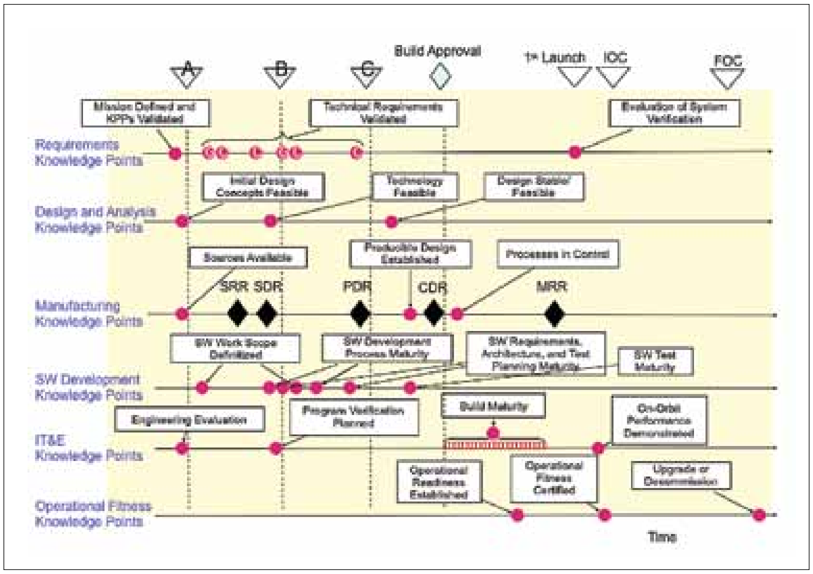

Figure 2. Template knowledge points.

proach for the formation of new programs and acquisitions. A detailed set of appendices provides a "desk reference." Aerospace is working to integrate course materials into acquisition guidance, systems engineering plans, mission assurance products, and IPA guidance materials.

Developing a Consistent, Credible Acquisition Risk Strategy

Aerospace has codified a set of core processes and supporting disciplines to ensure successful development, deployment, and operation of space systems ranging in type and complexity.

In the context of a major engineering endeavor such as the acquisition of a space system, mission assurance is that part of the systems engineering and integration activities that, by means of a combination of design validation and product verification, provide both the designer and the user with a high degree of confidence in the successful execution of the required system functions.

Consistent with this perspective, mission assurance is at the core of the Aerospace charter and represents one of the primary technical functions that Aerospace performs for its NSS customers. Accordingly, Aerospace has prioritized a series of development initiatives that better document and facilitate the application of mission assurance processes. One of these initiatives led to the publication of the *Mission Assurance Guide*.

The *Mission Assurance Guide* addresses mission assurance from a systems engineering perspective. It introduces the fundamental principles and objectives, and then further defines them in practical terms as a hierarchically organized set of standard processes and methodologies. These processes cover the complete life cycle of space, launch, and ground system programs, from concept to disposal, and are systematically interwoven in their application to achieve a successful and repeatable mission outcome.

Mission assurance objectives complement key acquisition tasks. For example, in the early conceptual phases of a program, the primary objective is to ensure that the architecture and system requirements are aligned with user needs and expectations. A parallel and equally important goal is to lay the contractual groundwork for staffing, generation of design-relevant data, and open communications necessary for successful program execution. As the program moves from design through fabrication to checkout and operation, the mission assurance focus moves accordingly to ensure that the integrity of the system design is maintained throughout.

The guide defines mission assurance in terms of a reference set of core mission assurance processes, supporting mission assurance disciplines and associated tasks. This definition draws from a foundation of systems engineering principles and from Aerospace experience in applying engineering best practices to the procurement and launch-readiness certification of space systems. This experience has established that a judiciously combined application of the mission assurance processes and disciplines maximizes the likelihood that a system will not only meet its basic, specified performance requirements, but also user expectations regarding safety, operability, suitability, and supportability.

Core mission assurance processes identify and organize—in a standard systems engineering execution flow that naturally lends itself to actual programmatic implementation—tasks that focus on the validation and verification of system acquisition activities.

The core processes can actually be executed through a combination of tasks and technical approaches that can vary in nature and depth. A degree of flexibility is in fact necessary to accommodate the scope and constraints of each specific space program implementation. Such flexibility is achieved through a tailoring process, which is an essential element in defining the program mission assurance plan (see figure 3).

The implementation of mission assurance cannot succeed without a solid foundation of baseline activities executed by space program contractors and suppliers. Beyond that, however, mission assurance requires detailed technical insight into each program by a truly independent organization to measure the effectiveness and outcome of core processes and tasks. Through the disciplined application of mission assurance practices, Aerospace has contributed to the current string of successful launches and their associated missions on orbit.

Besides the definition of reference processes and disciplines, successful programmatic implementation of mission assurance methodologies relies on the application of risk criteria to tailor processes and tasks onto a specific program based on resource and schedule constraints and system priorities. Thus, the breadth and depth of mission assurance processes for a given program will depend on several factors, including budget, schedule, technology maturity, purpose, and mission criticality.

An essential extension of the guide is a database of the mission assurance tasks that it references. These tasks—grouped according to execution timelines, hierarchy, and functional organization—are selected and tracked using a software tool associated with an extensive database. This combination of data-

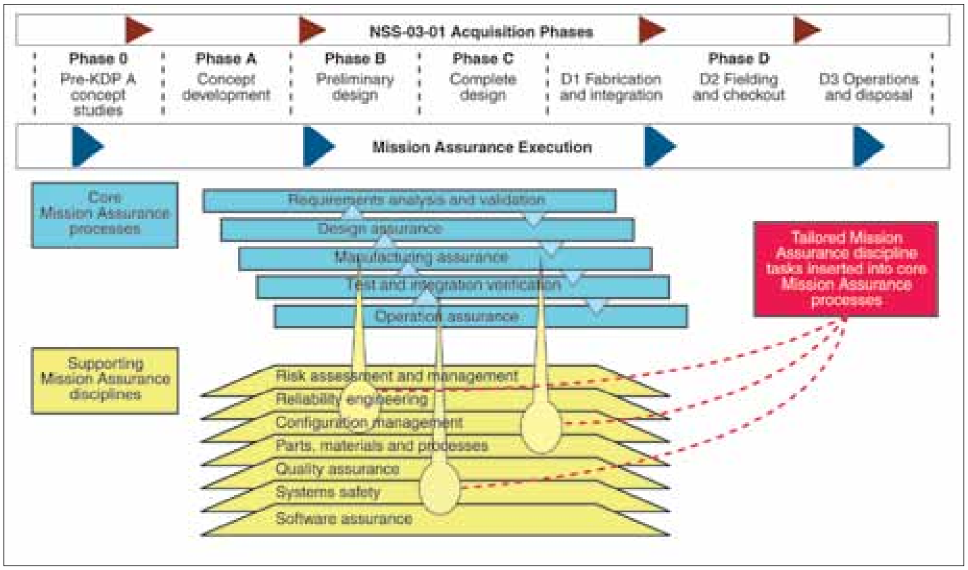

Figure 3. Core mission assurance processes are supported by tailored tasks and technical approaches.

base and software is known as the integrated mission assurance tool. In addition to facilitating task management and tailoring, this matrix enables a number of other user functions—most notably, the various types of assessments defined in the guide—to gauge the quality of planning and execution of mission assurance activities by individual programs.

As programs transition to their operational phase or achieve legacy status, attention shifts to those programs that are still in the formative and production stages; mission assurance continues for the life of the program. Technologies advance, acquisition policies change, the industrial base reorganizes … all of this creates a challenge for critical program management, but it also underscores the importance of comprehensive and consistent mission assurance support.

Examples of Successful Mission Assurance Process Activities

Some noteworthy examples of successful space mission assurance process activities include the work of integrated teams at the SMC Acquisition Center of Excellence (ACE), Program Management Advisory Group (PMAG), and the Independent Readiness Review Team (IRRT). The ACE and PMAG leverage multiple functional organizations in formulating integrated process teams. Examples include engineering support from the Engineering Acquisition Support Team (EAST) and Wing Execution Acquisition Support Team out of the SMC Chief Engineer's Division. Each functional team has primary expertise in some part of the acquisition life cycle, such as the pre-award process, post-award process, requirements, acquisition strategy, request for proposal (RFP) development, source selection, IPAs, acquisition program baseline, design reviews, technical requirements, specifications and standards, launch readiness reviews, test, and so forth. When viewed together, the teams' expertise is applied across the entire program life cycle. Each team utilizes technical and programmatic experts from the government staff, program offices, Aerospace, and Defense Contract Management Agency, as well as support contractors. The impacts of the ACE, PMAG, and IRRT are most beneficial when they are involved early and often in their respective mission assurance process activities.

SMC Acquisition Center of Excellence (ACE)

The SMC ACE provides advice, counsel, and leadership for strategic program formulation, solicitation, and execution. Unlike most other Air Force ACE offices, the SMC ACE includes a technical arm populated by Aerospace engineers with many years of program office experience. The ACE relies on documented core processes that create a discipline for programs to follow during the system acquisition life cycle, thus leading to program life cycle success. The ACE ensures there are no "congenital defects" in any SMC new acquisition in terms of the strategy, solicitation, and source selection in matching contractor capability to warfighter needs. The ACE is not a new organization within SMC or the Air Force, but its re-invigoration derives from the many ill-fated acquisition reform experiments that demonstrated how problematic decisions early in a program's formation can evolve into expensive failures and repairs months or even years later. A cross-flow of ACE personnel with recent program office experience, some with industrial backgrounds, and seasoned staff personnel is creating a stronger team to ensure consistent pre-milestone activities and documentation to lay the foundation on which a prime contractor will eventually build. The stable Aerospace component provides years of lessons-learned continuity for the ACE.

The EAST is a relatively new initiative that provides engineering expertise to support the ACE. While the ACE is focused on the programmatic and executability aspects of burgeoning programs, the EAST focuses on the technical foundation of the program. This includes the establishment of the program technical baseline, implementation of specifications and standards, and the creation of effective systems engineering processes. Core team members and subject matter experts from Aerospace supporting the EAST also review program documentation to ensure technical content is aligned with Air Force and SMC instructions and process directives.

The ACE works in close cooperation with staff at the secretary of the Air Force, Office of the Secretary of Defense/Acquisition, Technology and Logistics (OSD/AT&L), and the various milestone decision authorities to define and plan the acquisitions for all Air Force space programs. The ACE analyzes acquisition decisions as well as findings from IPAs, and distills them for release to the acquisition wings and senior leadership to ensure decisions are grounded in policy, regulation, and guidance from preceding programs. The ACE engages program offices 12 to 18 months in advance of milestone decision points

The primary focus will be to leverage cross-program experience and lessons learned so that program offices can benefit from previous work and not be required to "re-invent the wheel" in executing the program.

to provide (1) the benefit of clear direction and lessons learned from programs that have just completed the decision process, and (2) a resource for technical and programmatic expertise.

A milestone decision authority charters an IPA to assess a program's maturity, risk, and readiness to proceed to the next phase of development. Aerospace provides the core elements of the IPA process definition, management, and implementation. The IPA assesses a program along 17 different dimensions, highlighting issues for the program office and providing suggestions (including mentorship) to the program director for opportunities to improve their posture with regard to milestone decisions and successful program execution. The IPA integrates the independent cost assessment findings and ultimately advises the milestone decision authority on unresolved issues with recommendations for action and redirection. The National Research Council of the National Academies survey of system program directors recognized the IPA as the most effective mechanism for assessing the execution status of programs. Highlights of their report, *Optimizing US Air Force and Department of Defense Review of Air Force Acquisition Programs*, include the following: greatest impact on program performance; involvement of subject matter experts and senior leaders to resolve problems; providing useful information to senior Air Force and OSD leadership; and appropriateness of the information required to support the assessment.

Other independent reviews may be requested by senior leadership and may focus on either the government program office or on the contractor. The Program Executive Office/Space charters a Senior Executability Assurance Team (SEAT) to address specific elements of a program such as acquisition strategy, solicitation, source selection, or execution. Interim Program Review is a focused SEAT review occurring between program milestones to assess a program's adherence to plans. Interim Contractor Review is a focused SEAT review to assess the contractor's ability to achieve deliverables as planned, typically triggered by an indicator of an impending problem. Aerospace provides the core elements of the SEAT management and implementation.

Program Management and Assistance Group (PMAG)

The PMAG concept was first established in 1975 at Headquarters, Air Force Systems Command. Because of reorganizations and downsizing that occurred in the early 1990s, the initiative dissolved. In response to exigent programmatic needs, the PMAG concept was redesigned and re-institutionalized at SMC in July 2007. The SMC PMAG was established to help mitigate program management, system integration, and program control deficiencies in all phases of the acquisition program life cycle. In doing so, the PMAG strengthens government organic capabilities by establishing a high-performance, content-based culture that provides significant benefits throughout SMC and has the potential of benefiting the entire US Air Force. The PMAG consists of a highly experienced core Aerospace team complemented by Aerospace subject matter experts from the Engineering and Technology Group (ETG), and led by hand-selected Air Force officers and senior civilians with a demonstrated history of success in program management. Aerospace provides key technical expertise to the PMAG for integrated program risk assessment at key program events (e.g., baseline reviews, design reviews, sell-off activities, etc.), and provides key inputs to the SMC PMAG on program baseline executability assessment.

The SMC PMAG is chartered by the SMC commander to implement an integrated methodology to enhance systems planning and executability of all SMC acquisition programs. The purpose of the group is to enhance and supplement capabilities of acquisition wings and functional organizations by executing, coaching, mentoring, and advising on issues related to the management of SMC acquisition programs, including technical requirements documents, acquisition strategies, RFPs, source selections, integrated baseline reviews, design reviews, sell-off activities, and deployment/sustainment acquisition activities. Members of the PMAG also support IPAs as core members or subject matter experts.

The PMAG has a horizontal integration function for sharing and integrating lessons learned, best practices, and exemplary program management approaches across SMC. The PMAG has the ability to reach back into the government and FFRDC in the areas of program management, systems engineering, systems integration, software engineering, logistics, systems hardware and software interfaces, production, procurement, financial operations, and integrated risk management. The primary focus will be to leverage cross-program experience and lessons learned so that program offices can benefit from previous work and not be required to "re-invent the wheel" in executing the program.

Independent Readiness Review Team (IRRT)

The IRRT performs risk assessments of space launches and reports its findings in prelaunch reviews to the SMC commander and the Aerospace president. Since 2001, SMC and NRO have experienced an unprecedented string of successful launches; this trend has been sustained through their commitment to mission success. Aerospace provides technical leadership and the "corporate memory" for the team, augmented (as necessary) by systems engineering and technical assistance contractors. Primary objectives include identifying technical risks, making recommendations for risk mitigation, and providing independent assessments of launch readiness. The team participates in space program development, including technical interchange meetings, integrated product team meetings, hardware acceptance, and pedigree and design reviews; it also examines selected parts, components, subsystems, and compliance documentation. The reviews usually start two years before a satellite launch and one year before a booster launch.

The IRRT also evaluates each mission-specific space program office and contractor processes, and, as necessary, offers assessments and recommendations for improvement. The team formally presents its results at periodic program reviews with SMC leadership, at the Aerospace president's review, and at the SMC commander's Flight Readiness Review. The IRRT, as a matter of practice, starts with checklists and questions that may be tailored, modified, and updated with each new review. As problems and issues are identified in the course of a review, the IRRT is chartered to conduct a cross-program investigation across the SMC portfolio to ensure that similar situations are addressed appropriately and resolved as early as possible in their respective program life cycles.

Continuity through Mission Life Cycle

The Technical Underpinnings of Acquisition Success

The Military Strategic and Tactical Relay System (MILSTAR) II program provides a good example of acquisition success. With a contract award in 1992, four satellites were successfully developed under budget, with launches occurring on schedule between 1999 and 2003. Unlike most programs since, MILSTAR II received stable and adequate funding, providing the government, the contractor, and Aerospace teams with the resources needed for successful execution. Keys to this success included:

- An adequately scoped system definition phase preceding contract award. This included systems engineering studies sufficient to analyze operational requirements and define a system, a schedule and cost profile capable of meeting them, and prototyping of key payload and satellite subsystems.
- Successful definition of an RFP and award of a contract that emphasized government satisfaction, but also allowed the contractor team to make a fair profit.
- Capitalizing on lessons learned from predecessor programs, notably MILSTAR I, re-using established processes, designs, and requirements, while replacing others as necessary.
- Development of good working relationships among the Aerospace, government, and contractor teams. Conspicuous efforts were made in the early portion of the development phase, including a number of off-sites, to share perspectives and establish communications and coordination processes.
- Adherence to pre-acquisition reform military standards and SMC commander's policies.

The stable government support provided to Aerospace in terms of staff years of technical effort levels and funding that enabled Aerospace participation in all of these activities was essential to program success.

As MILSTAR II transitioned to operations and sustainment, a national communications architecture study led to the initiation of the Transformational Satellite Communications System (TSAT) program in 2004. Though subject to intense political scrutiny and funding variations, TSAT was nonetheless given substantial latitude in executing a $3 billion+ multi-year system definition phase that followed many elements of the MILSTAR II program model. In 2007, the program completed a system design review, an IPA, an independent cost estimate, and a technology readiness assessment. Based on these events, an RFP for the space segment development contract was released and source selection was begun. Though ultimately cancelled in 2009 due to lack of funding support, all reviews judged the program ready to enter the development phase, and in fact, as being singularly well prepared to do so. Achieving this state of preparation required not only adequate funding and time, but reliance on lessons learned from MILSTAR II, and leveraging the Aerospace backplane of experience, capabilities, and personnel.

Small Satellite Acquisition – Space Test Program's Standard Interface Vehicle (SIV)

Aerospace not only supports the acquisition of large, high-performance systems, but also small satellite systems that are conceived, developed, launched, and operated in a very short timeframe. These small satellite systems typically have short mission durations (approximately 1 year) and historically support science and technology objectives. Most recently, Aerospace supported the Space Development and Test Wing's (SDTW) design, build, and test of the space test program (STP) SIV. SIV is an indefinite delivery, indefinite quantity contract for up to six small (less than 120 kg) spacecraft that can accommodate up to 60 kg of experiments. The contract was awarded in April 2006 and the first build was completed in 41 months in September 2009.

Aerospace's Space Innovation Directorate personnel, co-located with SDTW at Kirtland AFB, New Mexico, were engaged from the very beginning of the SIV effort. The directorate's personnel provided systems engineering and mission assurance support to the program. Given the fast pace of the program, they tailored those processes consistent with the mission objectives and associated risk tolerance.

Aerospace ETG personnel also played a critical role in this successful program. After the first experiment was chosen to

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be hosted on the SIV, now referred to as STPSat-2, the Aerospace Vehicle Concepts Department was engaged to complete a trade study to choose another experiment that could make use of the remaining mass, volume, and power margin. A second experiment was selected and an independent experiment accommodations study was completed. This study was then used in conjunction with the spacecraft contractor's study to confirm the low-risk approach to adding another experiment to the bus.

One feature of SIV is its compatibility with multiple launch vehicles, including the small launch vehicles Minotaur I, Minotaur IV, and Pegasus; and the larger launch vehicles Delta IV and Atlas V in the evolved expendable launch vehicle secondary payload adapter configuration. Since all of these launch vehicles impart a different random vibration environment on a space vehicle, a comprehensive design and test environment had to be developed for the SIV. Once again, Aerospace ETG personnel from the Environments, Test, and Assessment Department reviewed the random vibration environments from all the target launch vehicles and developed a comprehensive random vibration environment that became part of the SIV technical requirements. The random vibration environment has now become a standard requirement that all STP small (less than 180 kg) payloads must meet.

As an example of the Aerospace "backplane" in action, just as the space vehicle had completed bus integration and was preparing to begin experiment integration and the space vehicle system test campaign, the transponder subcontractor informed the SIV prime contractor that there was a suspect part in the transponder. It turns out this transponder issue was shared by many different programs. Aerospace personnel from the Parts, Materials, and Processes Department were brought in and, working closely with the parts supplier and the transponder subcontractor, performed a trade study to determine different solution approaches. The trade study considered the risk, schedule, and cost impacts of each path. Different options were adopted by the various program offices depending on the phase of their program and associated risk tolerance. The path eventually chosen by the SIV limited the schedule impact to three months of rework effort.

SIV is just one example of a rapid acquisition activity that is enhanced by the partnership between the Aerospace program offices and the Aerospace "backplane," as demonstrated by ETG's expertise. ETG represents a unique resource within the NSS community and is an important part of the answer to the question: "Why Aerospace?"

SUMMARY/CONCLUSION

Aerospace plays three roles in support of acquisition success. By virtue of its standing as the only FFRDC specifically tasked with space systems, the corporation is a core member of all NSS program teams. Because of the unique way Aerospace is organized, the corporation is able to provide the engineers and scientists—both generalists and specialists—required to staff these programs. Lastly, Aerospace has the objectivity required to serve as the "technical conscience" and independent assessor of NSS programs. These roles tie directly to the corporation's core values of:

- *Dedication to Mission Success:* Aerospace is committed to ensuring that our customers and industry achieve 100 percent space mission success.
- *Technical Excellence:* As the technical conscience of NSS, Aerospace tackles the tough questions and delivers the tough answers.
- *Commitment to Aerospace Personnel:* Aerospace has a rare collection of the smartest people in the field; Aerospace employees are fully empowered to do their best thinking and their best work.
- *Objectivity:* Aerospace is a truly independent and unbiased nonprofit organization, with no competing agendas or incentives.
- *Integrity:* Aerospace always delivers the technical truth, no matter what.

Next year will be an important milestone in Aerospace history—it marks the 50th year the corporation has supported the US government in making America's NSS program the envy of the rest of the world.

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At Aerospace, Ms. Steele served as general manager of National Space Systems Engineering, where she was responsible for national space systems engineering and architectures for customers in the Defense Department and within the intelligence community. Previously she was the principal director of Communications Systems and Information Engineering within the National Systems Group, assigned to the Communications Directorate of the National Reconnaissance Office. As principal director she was instrumental in establishing the Transformational Communications Office and developing the Transformational Communications Architecture.

Before joining Aerospace, Ms. Steele worked at Hughes Aircraft in the Radar Systems Division, for the MITRE Corporation in signal processing and navigation, and at Advent Systems in signal processing and communications.

Firth Principles

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"Painting the Forth" refers to painting and upkeep on the bridge over the Firth of Forth and is a British analog to the American expression, "painting the Golden Gate bridge;" both refer to jobs that are always continuing and never completed. For national security space, the analog is "acquisition reform," a lag function of difficulties in performance, budget, and schedule arising from specific concatenations of budgets, programs, politics, technology, and people. Because these circumstances change from program to program, reform efforts, while essential, can never completely anticipate the difficulties of current and future programs, and in practice they recur, on average, about every two and a half years.

The classic analysis is the 1971 directive from David Packard, which offered a deceptively simple recipe for success: good people properly organized to achieve smart priorities, with three major decision points: program initiation, beginning of full-scale development, and production and deployment.[1] Packard, of course, well knew the complex second-order relationships underlying this recipe: Industry does the heavy lifting, and government policy, particularly through acquisition, shapes industry, frequently in unanticipated and unintended ways. Instances where yesterday's reforms created today's difficulties are not unknown.

Proper Organization

National security space programs were spared many of these complexities until about twenty years ago. Some twenty years before that, the National Reconnaissance Office (NRO), shielded by special security barriers from programmatic competition and intrusive oversight, had evolved from its troubled infancy into a system of managed competition that produced the important "National Technical Means" (though not without failures, delays, and overruns of roughly twenty to thirty percent). The difficult part, of course, was management of the competition. It was done well initially, first by Dr. Alexander H. Flax and then by Dr. John L. McLucas. But over time, the competition ineluctably involved less the industrial base and more the program headquarters staffs, with acquisition decisions turning less on engineering judgments about design and fabrication and more on programmatic and budgetary politics. The approach finally cratered in the mid-1980s, triggering a flight to bureaucratize management and the first of several attempts to improve acquisition by restructuring work along centralized "functional" lines. A few years later (1991) saw the first protest of an NRO acquisition award (the protest was sustained), and soon thereafter revelations about NRO finances brought sharply increased legislative oversight. By the mid-1990s, despite continuing special authorities, national security space programs were fully enmeshed in the acquisition challenges entangling many other defense programs.

Those challenges were greatly magnified by the end of the Cold War and resulting expectations that national security budgets would shrink. Acquisition reform then focused on ways to preserve capability in the face of lower budgets, emphasizing an industrial policy whereby the government sought to use defense investments to foster research and development activities that would find commercial applications and so help the defense budget buy more with less. The challenge of the day, as described by the head of General Dynamics, was to achieve the "realignment of public and private sector roles in the production and support of our nation's weapon systems."[2] The hope was that defense goods and services in general and space activities in particular would no longer be entirely separate from the rest of the economy at large.[3] Defense needs would therefore be underwritten in several ways by commercial operations. Unit prices would be lower, overhead cost allocations would be lower, and modernization could take advantage of market-driven and market-financed innovations. Commercial markets and defense programs could be bound ever more tightly together.[4]

The effort was pursued vigorously and it fell flat, the results serving principally as reminders of the differences between government and commercial entities and confirming that the defense department rarely understands its commercial partners. The industrial base for national security space effectively consists of an oligopoly serving a monopsonistic purchaser, selling products that have not previously been designed and/or for which there is no production experience, at prices for which there is little precedent. Typically the seller must meet an intense initial demand, following which the market virtually disappears. Sellers are funded by programs that change unpredictably and can be canceled suddenly. Their ultimate profitability might not be known for a decade. They grow apart from commercial companies (or from commercial elements of their own companies) in dozens of ways, resulting from several influences:

- Acquisition laws, regulations, and culture.
- The culture of public sector acquisition organizations.
- The ways in which standards and specifications are developed and maintained.
- The aspects of military technologies, products, and services for which there is no commercial counterpart.
- The need to produce orders in commercially uneconomical quantities.
- The emphasis on performance and quality over cost.
- The need to protect classified information.
- The requirement to implement a variety of public policies (buy American, equal employment, depressed area assistance, prevailing wage, environmental, etc.).
- The lack of market-derived information for decisions about design, cost, and performance.

There is no doubt that governmental policy can make a big difference: public policy created the space industrial base and strongly influences its development. But it cannot make all the difference that was desired, and evidently it made some differences that were not desired. As reported by the Young panel in 2003, space acquisition suffered from systemic pathologies:

- "Cost has replaced mission success as the primary driver in management acquisition processes, resulting in excessive technical and schedule risk."
- "The space acquisition system is strongly biased to produce unrealistically low cost estimates throughout the acquisition process. These estimates lead to unrealistic budgets and unexecutable programs."
- "Government capabilities to lead and manage the acquisition process have seriously eroded."
- "While the space industrial base is adequate to support current programs, long-term concerns exist. A continuous flow of new programs—cautiously selected—is required to maintain a robust space industry. Without such a flow, we risk not only our workforce, but also critical national capabilities in the payload and sensor areas."[5]

By then, Mr. Peter B. Teets, undersecretary of the Air Force and director of the NRO, was preparing a revised acquisition process for national security space (figure 1). The new process was a recognizable modification of the three major decision points recommended by Packard (program initiation, beginning of full-scale development, and production and deployment). But these new procedures could only help with one of the primary ingredients in Packard's recipe—clearly defined responsibilities.

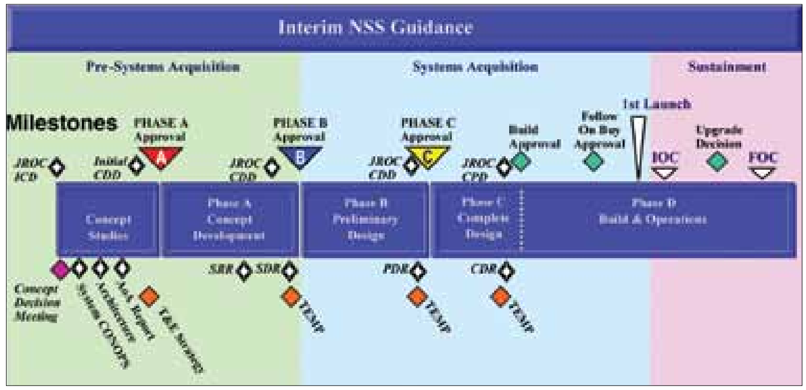


Figure 1. NSS Acquisition Policy 03-01, currently in force as Interim National Security Space Guidance.

Rational Priorities

A second Packard ingredient—establishing rational priorities—would be supplied by implementing commercial best practices, according to some reformers, notably the General Accountability Office (GAO). In this view, acquisition should be undertaken only with proven technologies,[6] should be separated from technology development,[7] and should reflect an "enterprise-wide portfolio management approach … that integrates the assessment and determination of warfighting needs with available resources and cuts across the services by functional or capability area."[8]

Here again, the consequences of the salient differences between Department of Defense (DoD) and commercial entities appear heavily understated (and some of GAO's central contentions might be more accounting tricks than the results of analysis). For several reasons, the metrics and methods appropriate to commercial activities seem ill-suited to the national security space enterprise, in which:

- Innovation can be encouraged—but not well managed. The acquisition of national security space systems primarily concerns the development of applied innovations, which cannot be assigned to a separate work group and which require unique evaluation methods.
- There is no "return on investment" for the government, or at least none comparable to the concept used in businesses: many of the measures used to evaluate alternatives courses of action for commercially (profit, amortization, earnings per share) are not meaningful in governmental operations.
- There is no penalty for being late and over budget, if the satellite is launched and works well. Mission success trumps all shortcomings, and so the promise of performance overweighs objective cost estimates.
- We have never flown unused capability; innovation and unanticipated applications continue long after launch.
- We are analytically deficient. The integration of space across full-spectrum military capabilities presents analytic complexities that the standard conceptual tools for evaluation cannot capture (figure 2).[9]

Yet even though commercial investment logics are not applicable, the underlying theme is right on the mark: successful acquisition hangs on the decision about what to acquire. Recently reform attention has turned to procedures that could help make better decisions. Initiatives by the undersecretary for acquisition, technology, and logistics have aimed to improve the process by mandating a careful canvassing of needs, resources, and options at an early stage, and, once the decision is made, to prohibit

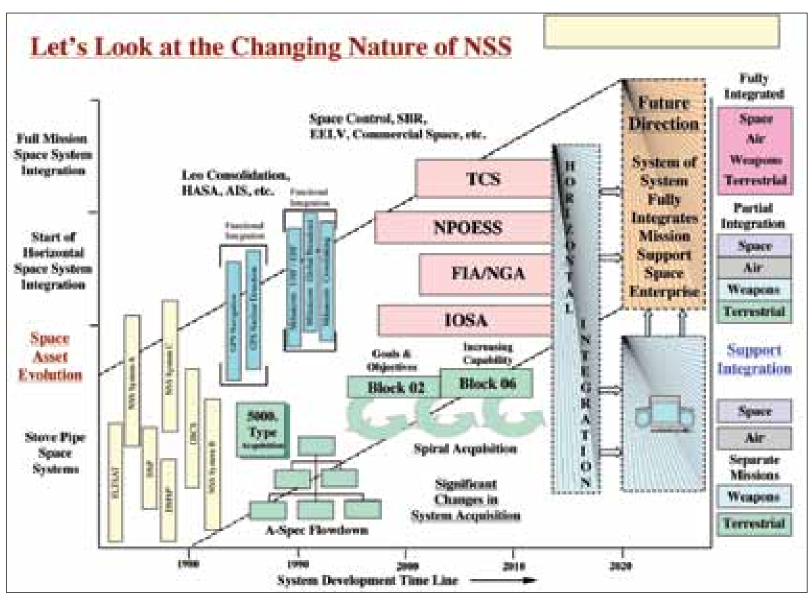


Figure 2. The Changing Nature of National Security Space.

changes to the requirements.[10] Yet the innovation sought in space programs entails uncertainties and unknowns in the development effort that no amount of pre-development consultation can reduce, and early freezing of requirements can prematurely limit the capability being developed. Systems engineering can also help,[11] but if not handled carefully can become counterproductive[12] and even when done well cannot eliminate the uncertainties endemic to any space development program.[13]

Competent People

And so, not surprisingly, two of Packard's essential elements really depend on the third: competent people are needed not only to manage programs but to organize the effort and set sound priorities as well. Undoubtedly we will continue to see new processes for setting requirements, arranging priorities, and monitoring programs, but procedures cannot substitute for judgment. The problems are too complex, and we cannot dependably assess alternative development options. The good news is that judgment generally improves with expertise and experience.[14] The defense department and the NRO have both recognized the imperative of strengthening the people component of their acquisition resources, and DoD seems to be returning to practices that will nurture career development in this field. Recent personnel initiatives by the Office of the Director of National Intelligence are hampering NRO's efforts in this regard, but perhaps those policies should be modified by a waiver for acquisition operations. As a seasoned program manager noted, "even well-designed processes work better with better people."[15]

Notes:

1 As Deputy Secretary of Defense, David Packard directed the first DoDD 5000.1, stating "Successful development, production, and deployment of major defense systems are primarily dependent upon competent people, rational priorities, and clearly defined responsibilities." For development of the 5000.1 directives, see "The Evolution of DoD Directive 5000.1 Acquisition Management Policy 1971 to 2003," Defense Acquisition History Project Working Paper no. 3, http://www.history.army.mil/acquisition/research/working3.html.

2 William R. Anders, "Revisiting the Rationalization of America's Defense Industrial Base—Ensuring Public and Private Sector Efficiency and Adequacy for Future National Security," address to the Aerospace Industries Association Human Resources Council, 27 October 1992, 4.

3 "First, we can no longer afford the extra cost of maintaining a defense-unique technology and industrial base. Second, we find in many fields vital to defense that commercial demand—not defense demand—is driving technological innovation." John Deutsch, "Future Technology May Work, But That's Not Enough," remarks prepared for delivery at Northeastern University commencement, Boston, 18 June 1994, printed in *Defense Issues* 9, no. 54 (Washington, DC: DoD, 1994), 3.

4 "A 'hothouse' industry will fail. America's defense companies [must] focus on becoming competitors on the world stage. The DoD is therefore … working to remove the rules, regulations, and accounting restrictions that inhibit innovation, efficiency, and competition . . . increasingly turning to off-the-shelf technologies and a commercial-like acquisition approach." John J. Hamre, "A 'Hothouse' Defense Industry Will Fail," *Aviation Week and Space Technology*, 10 January 2000, 66.

5 Final Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs, A. Thomas Young, chairman, May 2003, iii-iv.

6 "Before committing to the development and production of a weapon system … [the secretary of defense should] require that technologies needed to meet a weapon's requirements reach a high readiness level (analogous to TRL [Technology Readiness Level] 7 …" General Accountability Office, "Better Management of Technology Development Can Improve Weapon System Outcomes," GAO/NSIAD-99-162, 30 July 1999, 7.

7 DoD should "separate technology from acquisition, follow an incremental path toward meeting user needs, match resources and requirements at program start, and use quantifiable data and demonstratable knowledge to make decisions to move to next phases." Cristina T. Chaplain, "Space Acquisitions: Improvements Needed in Space Systems Acquisitions and Keys to Achieving Them," statement before the Subcommittee on Strategic Forces, Senate Committee on Armed Services (General Accountability Office, GAO-06-626T, 6 April 2006), 8.

8 "DoD still needs to guide its overall space portfolio with an investment strategy that makes high-level trade-offs before beginning programs." General Accountability Office, "Defense Acquisitions: Incentives and Pressures That Drive Problems Affecting Satellite and Related Acquisitions," GAO-05-570R Space System Acquisitions, 23 June 2005, 6; see also General Accountability Office, "Best Practices: An Integrated Potfolio Management Approach to Weapon System Investments Could Improve DoD's Acquisition Outcomes," GAO-07-388, March 2007.

9 Graphic courtesy of Dr. A. N. Sorenson, retired, Aerospace Corporation.

10 Material Development Decision and Acquisition Decision Memoranda.

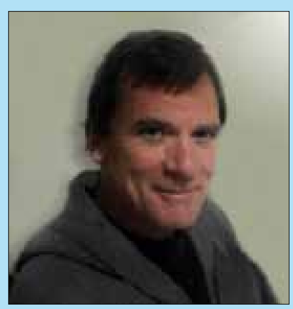
11 "Knowledge gaps are largely the result of a lack of disciplined systems engineering anlaysis prior to beginning system development," General Accountability Office, "Defense Acquisitions: Better Weapon Program Outcomes Require Discipline, Accountability, and Fundamental Changes in the Acquisition Environment," GAO-08-782T, 3 June 2008, 7.

12 "It would be a repeat of past failures to invent a series of SE reforms and mandate them in a 'one size fits all' fashion without assessment and tailoring to the situation." Air Force Studies Board, National Research Council, Pre-Milestone A and Early-Phase Systems Engineering: A Retrospective Review and Benefits for Future Air Force Systems Acquisition (Washington, DC: National Academies Press, 2008), 32.

13 "Even when the early systems engineering process is done well, the acquisition process is fraught with peril because of the unknowns and complications that arise in any program." *Pre-Milestone A*, 49.

14 "Previous experience among team members was one of the most valuable resources in the success of the [fighter jet] engine development program;" and "It is clear that program offices and industry teams staffed with domain experts equipped to handle technical and programmatic difficulties are best suited to respond quickly and effectively to the problems when they arise." *Pre-Milestone A*, 40.

15 Thanks to Col Jon Bryson, USAF, retired.



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During his government service, he worked on national security programs in the White House, the US Senate, and the Department of Defense. He is a former tenured associate professor at Pennsylvania State University and is the author of several contributions to basic and applied research in international affairs and national security studies. In the past few years, he has provided Congressional testimony on space policy issues, taught courses in space policy at the Air War College and at George Washington University and written histories of some classified programs.

Regaining Credibility: Making Nuclear Sustainment a Model of Excellence

Col James D. Fisher, USAF
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MainStream GS
Hill AFB, Utah

Reinvigorating the Air Force Nuclear Enterprise is the service's highest priority. As global stewards of the nuclear mission, the US Air Force is responsible for maintaining mission capability, nuclear surety, and nuclear safety to defend and protect America and our allies. It is a massive effort of global scale that requires a solemn commitment to the highest standards of excellence. Maintaining a safe, secure, and reliable nuclear system is the chief duty of the thousands of Airmen who support our nation's nuclear enterprise. The development, acquisition, and sustainment of the nuclear deterrent is both a requirement and validation of the principle that was laid down in the Atomic Energy Act of 1953.

Today, in a post 9/11 era, as the nation's adversaries seek to arm themselves with nuclear capabilities, it is more important than ever that we maintain our adherence to our core values and recommit to this critical mission with laser focus. We are returning to excellence in acquisition, supply, and sustainment with more emphasis than ever before on zero-defect due to high consequence. We have made great strides and restored single technical authority, while responding to the well-documented challenges of our recent history.

The development of a strategic Air Force Nuclear Roadmap was the first step in this commitment to change. It is focused on five major areas, including restoring the culture of compliance; rebuilding our nuclear expertise; investing in our nuclear capabilities; organizing and enabling clear lines of authority providing sustained institutional focus; and finally, reinvigorating the Air Force's nuclear stewardship role.

In the past year, the US Air Force has demonstrated its commitment to reinvigorating the nuclear enterprise in all of these focus areas—including the appointment of new leadership in both civilian and military positions. We still have many more steps to take in this cause, and we are proud to share the strides that we have made throughout the past year—just a small part of our long history delivering safe, secure, and reliable nuclear deterrence capabilities.

History of the Intercontinental Ballistic Missile

That long history began in the 1940s, when the US' shield of security provided by nuclear superiority was shattered by the revelation that the Soviet Union had detonated its own atomic bomb in 1949. A race began to develop the Intercontinental Ballistic Missile (ICBM), which was essential to the security and future of the US. The Air Force mapped out a development plan for the new weapon by spring of that year. In June, Vice Chief of Staff General Thomas D. White ordered the Air Research and Development Command to "proceed with the development of an ICBM at the highest speed possible, limited only by the advancement of technology in the various fields concerned." By July, the Air Force established a special project office to administer the program called the Western Development Division run by then Maj Gen Bernard A. Schriever with the expectation of having a fully operational ICBM weapon system delivered into the hands of the Strategic Air Command within six years.

On 7 January 1954, during his first State of the Union address, President Dwight D. Eisenhower declared that "American freedom is threatened so long as the communist conspiracy exists in its present scope, power, and hostility" and outlined his plans for defending the US against that threat. His stance was the foundation for much of the strategic defense plan that is still in place today. The ICBM became the key to the nation's defense. It was available to strike anywhere at any time—providing a global advantage that was impossible for ground forces to match in scope and scale. On 5 August 1954, General Schriever and a small selection of qualified military officers began their top secret mission in the effort to build an ICBM.

The Soviet Union's launch of Sputnik, the world's first artificial satellite in 1957, added another threat to US security. In response, the US' space research and development budget was grown from a half billion dollars annually to more than $10.5 billion in less than six months time—with most of the funding directed toward the development of the Minuteman missile. By 1958, under the authority of President Eisenhower, Congress had increased the appropriation for the Minuteman from $50 million to $140 million dollars and had added $2 billion dollars to the Minuteman budget the following year to be spread throughout the next half decade.

Following the successful flight of the Minuteman in 1961, the first Minuteman I was put on alert in 1962, adding the first "pushbutton" missile system to the Nation's nuclear arsenal that provided instant launch capabilities. The Air Force organized its nuclear weapons program into "wings" that would oversee 50 missiles each, and production ensued at a furious pace. Silos were built to house the weapons and staff oversaw the equipment necessary to support and fire each weapon. President John F. Kennedy had taken office and had begun to make strategic improvements to the effort—abandoning the idea of releasing the entire nuclear arsenal at one time and planning for a more selective deployment strategy. Engineering adjustments were made in support of the retooling efforts and the complex launch program provided a more flexible defense strategy.

The Minuteman Force Modernization Program initiated in

1966 to replace all Minuteman I's with either Minuteman II's or Minuteman III's. This process continued through the latter 1960s and into the mid-70s and was deployed broadly across the continental US at F. E. Warren AFB, Wyoming; Minot AFB, and Grand Forks AFB, North Dakota; and Malmstrom AFB, Montana. Engineering modifications were made that brought new suspension systems into the silos to maintain the security of each missile that would render them motionless during the aftershocks of a nuclear attack.

In July 1975, the last of the 550 Minuteman III missiles was lowered into its silo at Malmstrom AFB. At that time, only 450 Minutemen II remained in the American arsenal—at Malmstrom AFB, Ellsworth AFB, South Dakota, and Whiteman AFB, Missouri. This force structure remained intact for nearly two more decades.

The fall of the Berlin Wall in November 1989 marked the beginning of the end of the Cold War. On 31 July 1991, President George H. W. Bush signed the Strategic Arms Reduction Treaty with Soviet leader Mikhail Gorbachev—effectively limiting the worldwide number of ICBMs and outlining a process for demilitarization of additional weapons. The Air Force was faced with increasing costs surrounding maintenance of the Minuteman II system and all 450 were "withdrawn from alert" at the order of President Bush in September 1991 as part of his Plan for Peace.

When the Minuteman II deactivation was completed in the mid-1990s, the program experienced another decline in funding and attention along with relevantly skilled Airmen to adequately support it that generally lasted for the next two decades. With less threat came less attention to the nuclear arsenal that played out over time. The deterioration was brought back into the nation's spotlight after a series of events made it impossible to ignore the impact of weakened values and fragmented focus surrounding our most important deterrent capability. Several severe breaches of discipline were discovered in the 2007 to 2008 timeframe. These onerous events set in motion new attentions to rebuild, refocus, and reinvigorate the nuclear enterprise. This turning point has led to positive change in standing up more centralized oversight of this important asset and supporting it with proper personnel, funding, and focus.

Reinvigoration Actions

Consolidating all nuclear functions under one umbrella organization was essential to establishing clear lines of command. In the spring and summer of 2008, a realignment of organizational responsibilities from Air Force Space Command (AFSPC) to Air Force Nuclear Weapons Center (AFNWC) at Kirtland AFB, New Mexico, took place followed by the standup of a new Air Force Global Strike Command (AFGSC) at Barksdale AFB, Louisiana, in August 2009. Once operations are fully transitioned, AFGSC will oversee the ICBM function, along with nuclear-capable B-52 and B-2 bombers—putting them in a higher priority category, which is central to the overall nuclear mission.

ICBMs in the 20th Air Force, part of AFSPC, are expected to shift to AFGSC in early December 2009 and will be led by Lt Gen Frank Klotz. The 23,000 Airmen-strong command will contain an elaborate inspections regime with more demanding and rigorous schedules in addition to regular outside oversight. The goal of the command is to ensure the nuclear forces receive equal status with other missions in the Air Force and to support the development of skilled Airmen in the nuclear area.

Additionally, Air Force Secretary Michael Donley and Chief of Staff General Norman Schwartz directed the transfer of the weapons storage area logistics operations to AFNWC in order to provide streamlined sustainment and positive control of nuclear weapons systems with the goal to continually emphasize rigor and standardization in this critical function.

To accomplish this goal, four munitions maintenance units were stood up under the AFNWC in the summer of 2009, significantly advancing the force's reinvigoration efforts. They included the 798th Munitions Maintenance Group at Minot AFB, North Dakota, which joined the 15th Munitions Squadron at F. E. Warren AFB, and the 16th Munitions Squadron at Malmstrom AFB. Additionally, a Detachment 1 unit was stood up at Vandenberg AFB, California, to support test flights.

Furthermore, the Air Force embarked on an annual assessment to map its progress through the Air Force comprehensive assessment of nuclear sustainment (AFCANS) process. The AFCANS process includes an internal investigation geared toward identifying solutions and finding the needed resources to fix the challenges surrounding nuclear surety. Brig Gen Everett H. Thomas, AFNWC commander, led this effort under the direction of General Schwartz. The AFCANS II report was released in April 2009, providing recommendations for requirements and necessary funding to continue sustaining and reinvigorating the enterprise.

The Role of the Air Force Nuclear Weapons Center

The AFNWC plays a critical role in shaping the lines of command and providing structure. Following its establishment in March 2006, it continues to develop and expand to fulfill its goal of becoming the Air Force's center of excellence for all nuclear weapons systems activities. As the center commander, General Everett H. Thomas is responsible for the entire scope of stewardship and sustainment of Air Force nuclear weapon systems and support equipment in the US. Consolidating nuclear sustainment activities in the Air Force under a single commander provides an effective mechanism for improved nuclear sustainment force management and development, focused advocacy for nuclear sustainment programs, and clear lines of authority and accountability to ensure compliance with nuclear surety standards.

Reporting directly into the AFNWC commander are the 498th Nuclear Systems Wing (NSW), 377th Air Base Wing (ABW), and 526th ICBM Systems Group (ICBMSG). These organizations are the key to sustaining the nuclear enterprise in the long term as they handle much of the oversight, quality control, and sustainment activities. The 498 NSW oversees nuclear munitions and cruise missiles, as well as munitions maintenance and storage complexes. The 377 ABW provides world-class nuclear surety, expeditionary forces, and support to base operations. The 526 ICBMSG provides single program management for the entire lifecycle of the Minuteman III weapon system. In summary, these organizations encompass the scope of nuclear weapon system support functions that include sustainment, modernization and acquisition support activities for the Department of Defense and Department of Energy.

The Role of the 526 ICBM Systems Group

The 526 ICBMSG is responsible for inception-to-retirement weapons system management of the nation's land based strategic deterrent. The group began in July 1954 to develop the Titan I ICBM and intermediate range ballistic missiles and was later re-designated as the Air Force Ballistic Systems Division and then the Ballistic Missile Office responsible for developing and fielding the nation's ICBM fleets of Atlas, Titan, Minuteman I, II, III, and Peacekeeper weapons systems from 1962 to 1987. In 1993, the organization merged with the ICBM Product Directorate to form the ICBM Systems Program Office. The ICBM system program office (SPO) was responsible for completing the deployment of Peacekeeper, long-term sustainment of the ICBM fleets, as well as planning the next generation missile system. When the decision was made to extend the life of the Minuteman III fleet in 1995, the SPO embarked upon several major modifications to extend the service life to 2020. The ICBM fleet was downsized in 2005 with the deactivation of 50 Peacekeeper missiles and a subsequent reduction in the Minuteman III fleet to 450 missiles on alert. Today, the 526 ICBMSG is charted to sustain and modernize the current Minuteman III fleet through 2030 and to manage any developmental work for a follow-on system as required by the warfighter to continue to ensure the viability of the nation's land based strategic deterrent.

The Future and Focus of the Air Force Nuclear Weapons Enterprise

The AFNWC continues with its charter of nuclear consolidation, successfully integrating new units and new personnel. With the recent introduction of new maintenance, technical, and program management units into the center, a critical mass of common missions has become obvious. In the near future, the center will integrate nuclear weapons maintenance and storage operations throughout the continental US and will add much needed expertise throughout the organization, bringing on nearly 300 new personnel. Synergy will be even greater under the next phases of the center's growth and the safeguarding of the Air Force's and our nation's nuclear expertise will be paramount amongst the center's plans and priorities.

All of these changes directly support the Air Force's goals to re-establish a nuclear culture of discipline and accountability, rebuild the nuclear expertise, invest in nuclear capabilities, organize to enable clear lines of authority, and reinvigorate our Air Force nuclear stewardship role.

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Col James D. Fisher (BS Electrical Engineering, Ohio University; MS, Business Administration and General Management, Lesley University, Massachusetts) is the commander, 526th Intercontinental Ballistic Missile (ICBM) Systems Group. The group is a tenant unit on Hill AFB and an AFMC Group reporting to the Air Force Nuclear Weapons Center located at Kirtland AFB, New Mexico. The group is responsible for inception-to-retirement integrated weapons system management of the Minuteman and Peacekeeper ICBM weapon systems. The group develops, acquires, and supports silo based ICBMs, while providing program direction and logistics support as the single face to the customer. The group is also responsible for acquisition, systems engineering, and depot repair; manages equipment spares, provides storage, and transportation; and accomplishes modifications and equipment replacement to maintain silo-based ICBM systems.

Colonel Fisher has been a missile launch officer, guidance system engineer/program manager, tech advisor to the assistant secretary of state for political–military affairs; Air Force Space Command lead for the Evolved Expendable Launch Vehicles Program; commander, Ascension Air Field South Atlantic Ocean; commander, National Reconnaissance Office (NRO) Communications Operations Launch Squadron; chief of safety and environmental, NRO Office of Space Launch; chief engineer, NRO Office of Space Launch; and substituted as deputy mission director on a recent NRO launch. He has worked in operations, requirements, acquisition, and political-military affairs while working in Office of the Secretary of Defense, two major commands, the intelligence community, and overseas.

Colonel Fisher is currently an engineer in training through the National Society of Professional Engineers, a project manager through Project Management Institute, and holds a Foundation Certificate in Information Technology Infrastructure Library.

Acquisition Education for Space Warriors

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You do not have to follow the news very closely to realize that space systems' acquisitions are in big trouble. Almost all the major space programs, Space-Based Infrared System, National Polar-orbiting Operational Environmental Satellite System, GPS III, and so forth, are over cost and/or behind schedule. So serious is this problem that President Barack Obama recently signed the Weapon Systems Acquisition Reform Act to ensure we get our programs back on track.[1] Guidance has also been issued by the undersecretary of defense for acquisition technology and logistics who said, "To operate effectively, the acquisition system must be supported by an appropriately sized cadre of acquisition professionals with the right skills and training to successfully perform their jobs."[2] In order to help meet this need, there are two organizations in the Air Force that are bringing space operators and space acquirers to common ground. The first is the Advanced Space Operations School (ASOPS) (under the Space Innovation and Development Center) and the second is the National Security Space Institute (NSSI) (under Air University).

The ASOPS expands space system understanding by providing a host of courses from the fundamentals of space operations to advanced courses. According to their Web site, they provide world-class instruction of space systems, capabilities, requirements, acquisition, strategies, and policies to support joint military operations and US National Security. The NSSI is the Department of Defense's focal point for space education that (according to their Web site) complements existing space education programs at Air University, the Naval Postgraduate School, and the Air Force Institute of Technology. They are responsible for providing space professional continuing education (PCE). The ASOPS and the NSSI are collocated in what is known as the Space Education and Training Center in Colorado Springs, Colorado.[3]

Both schools are so serious about their commitment to space acquisition education that their leaders recently signed a memorandum of agreement (MOA) with the Defense Acquisition University (DAU). This MOA gives DAU the responsibility of ensuring all space acquisition curricula for both schools are accurate and up to date. "We at the NSSI are proud to partner with DAU to teach our students the fundamentals of space acquisition and to reinforce the importance of personal and professional integrity to the process," says their vice commandant, Mr. Jim Moschgat.[4] DAU has even assigned a full-time liaison to the Space Education and Training Center who teaches across their courses and has plans to provide more instructors in the future.

Each school uses various methods to instruct space acquisition across many different knowledge levels. The remainder of this article will explain, in some detail, what each course covers.

Even in a very basic introductory course like the Space Fundamentals Course (SFC), it is very important for students to understand the acquisition process. The acquisition lesson is only one and a half hours and taught at the 50,000 foot level, but at least students get a peek at the process and understand how very complicated it is. Students leave SFC with the ability to identify key documents they may come in contact with as well as know the different roles acquirers and operators play in the acquisition process.

The Intercontinental Ballistic Missile (ICBM) Advanced Course provides a two week in-depth curriculum designed to develop missile professionals who comprehend US nuclear policy, strategy, doctrine, law, security, and surety to maintain ICBMs as a viable nuclear deterrent."[5] As mission area experts, students play a critical advisory role in the employment, tactics development, sustainments, and procurement of follow-on systems. The course covers topics such as the history of nuclear weapons, ICBM design, capabilities, effects, planning, strategy, doctrine, law, and future/advanced concepts. In the ICBM Advanced Course, the ASOPS provides missileers with a basic overview of the acquisition process with special emphasis on the sustainment piece of the process. Since we are not actively looking for many new ballistic missiles to carry new warheads, sustainment is the right place for emphasis. The acquisition lessons culminate with the students participating in a formal debate regarding the pros and cons of applying future concepts of the ICBM Weapon System.

The Missile Warning and Defense Advanced Course is a six week course designed to provide "depth of knowledge" in the areas of missile warning and missile defense. Students attending this course typically return to their assigned units "better prepared to incorporate missile warning and defense technology into tactics, technique, and procedures, as well as integrating technological advancements and operational concepts into doctrine."[6] In this course, the ASOPS places heavy emphasis on how requirements for new systems are developed. Giving this type of training to those who may eventually operate the systems is vital in helping them understand the potentially laborious process of bringing requirements into a reality. Students also learn about who the major players will be in the acquisition of their systems and are introduced to the roles of operators and acquirers in the Planning, Programming, Budgeting and Execution system.

Space 200 is where Department of Defense space professionals may have their first real taste of space acquisition education. This course is designed as a critical element of the Air Force's Space Professional Development Program (SPDP). The course prepares students for intermediate-level leadership roles within the military space community and is required to earn SPDP Level 2 certification. Space 200 is the one course that focuses on space applications and employment in operational and tactical levels. Space 200 provides an understanding of the design, development, and acquisition of space systems; explores space asset capabilities, limitations, and vulnerabilities; and associated application and employment in joint military operations. The students receive about three full days of acquisition instruction taking them from requirements development through a simulated source selection. Students use a much more hands-on learning method, actually developing key performance parameters for a satellite they design during the four-week course. They also learn how immature technology is plaguing current acquisition programs. The students conclude the block of lessons by demonstrating the ability to construct and present an acquisition strategy. "Interestingly our students often comment on how valuable the acquisition instruction is in our courses. Although these courses simply provide a general overview of the acquisition process, for several students it is their first time studying and engaging in informed dialogue concerning the challenges of acquiring space capabilities," says Col Michele Putko, NSSI dean of academics.[7]

Probably the most extensive piece of the space acquisition education occurs in Space 300. Space 300 is the NSSI's capstone course for space PCE. This course is designed to reinforce concepts from Space 200 while preparing students for leadership roles with the knowledge and understanding to address issues from a strategic perspective and the ability to integrate space effects into joint military operations and planning. Space 300 provides a comprehensive background on national security space asset employment and integration into joint military operations presented with context of national and subordinate strategy, policy, doctrine, and international and domestic law. It is a real thinker's course, using guided discussion techniques to teach tomorrow's space leaders to solve space problems bearing on national security. To my knowledge, no one has ever walked away from Space 300 and said, "That was easy!" Instructors give a short review of the acquisition concepts taught in Space 200 and immediately dive into a three-day immersion in space acquisition. Students are taken through the requirements development process, given an in-depth overview of how science and technology affect space acquisition, and even get a dedicated lesson on how the US space industrial base affects current acquisitions. Students use the Space-Based Infrared Satellite program as a case study to analyze technology and management issues that led to its first Nunn-McCurdy breach. They then develop and recommend a way ahead. They wrap up their acquisition lessons with an analysis on operations transitions issues and each student produces a case study analysis. Lt Col Nery Grieco states, "The primary objective of the acquisition process is to obtain quality space systems that satisfy user needs while improving mission capability and operation support in a timely manner and at a reasonable price. Successful acquisition can only be met by a collaborative effort between acquirers and operators. This is one the key messages we want our Space 200 and Space 300 graduates to take away and implement throughout their space professional careers."[8] Through the efforts of the NSSI instructors, this message comes through loud and clear.

Air Force Space Command recently released its command goals. Goal number five reads, "Reengineer acquisition to deliver capability at the speed of need."[9] In order to meet that goal, people must have the foundational training and education provided by schools like the ASOPS and the NSSI. Col Robert Gibson, commander of NSSI states, "We must have a clear vision of tomorrow's space needs in order to smartly, and appropriately, begin the acquisition processes today. Higher training and education provided by the ASOPS and NSSI is integral to preparing space leaders with the best acquisition know-how."[10] Through the efforts of the ASOPS and NSSI, students are getting the training and education they need to achieve the goal.

Notes:

1 Weapon Systems Acquisition Reform Act of 2009, Public Law 111-23, 111th United States Congress, 1st session.

2 Ashton B. Carter, Secretaries of the Military Departments and Chairman of the Joint Chiefs of Staff, Department Position on Acquisition Reform, memorandum, 12 May 2009.

3 For more information about the schools themselves, see their combined Web site at https://www2.peterson.af.mil/nssi/CESET/index.htm.

4 Mr Jim Moschgat, NSSI/CD.

5 ICBM Advanced Course Syllabus.

6 Missile Warning and Defense Advanced Course Syllabus.

7 Col Michele Putko, NSSI Dean of Academics.

8 Lt Col Nery Grieco, Systems Engineering Technical Committee Instructional Systems Development.

9 AFSPC Goals, 2009.

10 Col Bob Gibson, NSSI/CC.

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Dr. Anderson wrote the DoD Space Control Strategy and oversaw the publication of the DoD's first space doctrine while assigned to USSPACECOM, Peterson AFB, Colorado. He was deployed in the Future Operations Branch for Operations Noble Eagle and Enduring Freedom. He planned Special Access Program activities for Operation IRAQI FREEDOM that supported the liberation of that nation. He went on to be the Air Force's first space operator to command a squadron with a flying mission at the US Air Force Academy in 2003.

Dr. Anderson is a recipient of the General Bernard Schriever Award for Space and has been selected as one of our nation's Top 100 Outstanding Young Americans. He has been published in multiple periodicals and is a guest lecturer at the Massachusetts Institute of Technology, the United Kingdom's Joint Services Command and Staff College, as well as US professional military education institutions.

Acquiring Space Systems in an Uncertain Future: The Introduction of Value-Centric Acquisition

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…Pentagon planners may blithely assume away all uncertainty and essentially bet that the future they forecast is the one that will emerge. In this case the US military will be very well prepared—for the predicted future. But history shows that militaries are often wrong when they put too many eggs in one basket.[1]

~ Dr. Andrew Krepinevich

In an ideal world we would have a crystal ball. Using it we could foretell all future threats: all requirements would be known well in advance, and systems would be built to meet those needs with the requisite acquisition timelines. In the magical sphere, we would see future technical challenges faced in building space systems, and we could visualize the disruptive capabilities that would be deployable in the coming years. Failures would be predictable and designed away or new processes created to avert catastrophic consequences. Space system cost would be estimated to high precision. The entire cycle of planning, procuring, budgeting, and execution would run like clockwork. Risk would vanish. In summary, there would be no uncertainty.

Such a crystal ball is fantasy of course. Uncertainty has always been an unavoidable and inexorable fact of existence: to make matters worse, the ambiguity of the future will only accelerate. In a networked world of well educated benevolent *and* malevolent people and intelligent machines, uncertainty now increases at an increasing rate. In this, the 21st century, linear change has given way to jumps, or substantial discontinuities that ultimately shape our world. Elements under our main control in the acquisition framework—namely the space systems we build—have become so complex that great uncertainty exists in their successful procurement and operation.

Given we cannot *predict* the future, we are left with only one alternative: we must *prepare* for a future of uncertainty for the entire life cycle of all military systems. This impetus is particularly strong for space systems, which are high-value assets with lengthy development timelines, and which cannot be easily accessed for the duration of their operational life. The inevitability of an uncertain future *does not* mean that we throw up our hands, and simply wait to react to future shocks (eschewing the planning process). It *does* mean that we must explore a variety of potential futures (including very ambiguous ones), and create strategies and policies, as well as technical and architectural solutions that provide hedges for a variety of circumstances that could occur. In our domain, the manifestation of such an approach will be the acquisition of *flexible* and *robust* space systems. Flexibility will provide options for change throughout a space system's lifecycle (to include conceptualization, design, build, launch, and operations). Robustness will further enable our space assets to operate, as planned, through a variety of threatening environments. Today our space systems are notoriously inflexible and lack the robustness to survive in a variety of stressing scenarios, including programmatic ones. Requirements changes and technology readiness impediments can break these systems. The ability to rapidly scale, evolve, adapt, or maintain on-orbit space system assets (although demonstrated to a degree) has not yet been accepted or demanded for the national space architecture. Worse still, the complexity of our space systems creates a brittleness that threatens their successful deployment, regardless of the time spent developing them. We continue to be held hostage to a "one strike and you're out" architecture. After five decades, why have space systems not evolved to meet the demands of change? We argue that it is the current acquisition framework, one that rewards cost minimization for a fixed set of requirements, which leads us to build inflexible and non-robust systems. These systems and the process used to deliver them are, in themselves, a clear and present danger in a world of uncertainty. The counter to this cost-centric approach is the development and integration of what we call a *value-centric acquisition* framework. This value-centric model provides a rational and *quantitative* framework for trading flexibility, cost, performance, and risk. Using this methodology, tools are provided to decision makers which allow them to plan appropriately for an uncertain future, constrained only by the resources made available to them.[2]

The Status Quo: Cost Centric Acquisition

McNamara's lasting systems legacy was the Planning, Programming, and Budgeting System (PPBS).… It was a laudable approach to solve industrial era system complexity, which sought to match a complex analytical tool to the growing complex programs needed for defense in the early 1960's.… Unfortunately Department of Defense is still using this method forty years after its introduction. The rudimentary understanding of the complexities of the Information Age is its chief failing today…[3]

~ CDR Gregory Glaros, Office of Force Transformation

Before we describe value-centric acquisition, it is important to understand the historical development of today's cost-centric practices. This history begins with the 1960 appointment of the late Mr. Robert S. McNamara as secretary of defense, which brought about the most radical re-thinking of government procurement practices that had ever been undertaken. McNamara had started his career teaching analytical approaches to business decision-making at the Harvard Business School. During World War II; he worked for (then) Maj Gen Curtis LeMay analyzing the effectiveness of various bombers and helping systematically coordinate the allies' global bombing campaign. In 1946, McNamara joined the Ford Motor Company with a group of other young quantitative analysts—the so-called "Whiz Kids"—from General LeMay's staff. For the next 14 years, McNamara held various senior management positions at Ford, culminating in his ascent to the firm's presidency. His time at the auto maker is, perhaps, best remembered by the prescient admonition to his engineers: "Put in value, not cost."[4] McNamara emerged as an ardent advocate of safety, fuel efficiency, and reliability, while the prevailing wisdom in the industry (and among much of the rest of Ford's managers and engineers) favored size, chrome, and horsepower. Thirty four days after being named the company's president, McNamara accepted an offer from President-elect John F. Kennedy to run the Pentagon.

Nearly simultaneously with McNamara's appointment as Secretary of Defense Charles J. Hitch, an economist at the RAND Corporation, published a report (and later book) titled *The Economics of Defense in the Nuclear Age*.[5] The work was a summary of economic techniques applied to defense planning. Its major contribution was an extensive treatment of the application of economic tools to defense decision-making, particularly in the realm of procurement. It was the Harvard economist Mr. John Kenneth Galbraith who—having originally recommended McNamara to Kennedy for the Pentagon job—encouraged McNamara to read the book and meet with Hitch.[6] McNamara was enamored. Hitch's work formalized many of the ideas that McNamara had practiced and advocated for years. In January 1961, Hitch was appointed assistant secretary of defense (comptroller) and charged with architecting a new budgeting system for the Pentagon: enforcing the philosophy of his RAND work, he instituted what came to be known as PPBS in the course of a mere six months in 1961—in time to apply it to the fiscal year 1963 defense budget submission.[7]

In a 1965 retrospective on PPBS, Hitch described the resultant process of the system:

> Thus, the problem of allocating resources within the Department of Defense itself involves the choosing of doctrines, weapons, equipment, and so forth, so as to get the most defense out any given level of available resources or, what is logically equivalent, to achieve a given level of defense at the least cost.… Approaching the problem from the second point of view—achieving a given level of defense at the least cost, *which is the way Secretary McNamara prefers to look at the problem* [emphasis added]—we work in terms of marginal products and marginal costs in order to help the top decision-maker choose the appropriate level of resources.[8]

So, in the end, the analysis used in the PPBS process to determine the "best" system (in our specific case space systems) has a foundation on minimizing cost for a fixed set of requirements. As described in a previous *High Frontier Journal* article by Dr. Owen C. Brown and Mr. Naresh Shah,[9] the relevant result of this philosophy is the procurement of large, monolithic, and relatively long-lived space systems: Decision makers respond to increased marginal cost by increasing the scale of spacecraft to maximize the overall capability/cost quotient, and increasing lifetime to minimize amortized annual costs.[10] In a perfect world of no uncertainty (or certainty of the uncertainty) this is an appropriate decision. The scars of real world experience illustrate the true problems of this approach. These space systems, which (because of their complexity) take years to design and build, are designed to meet requirements based on the today's threat forecasts. With constantly changing threat environments, requirements change during the design and build phase. The result is redesign, which costs time and money for a large, tightly coupled system. Once launched, there is little hope the capability of a space system can be adapted to a new threat. Carrying multiple payloads, it takes a delay with only one of those payloads to delay the entire program and hence result in cost-overruns. Putting all eggs in one basket, the failure of a launch results in incredible setback—the same is true of a potential on-orbit attack or debris collision. All of these examples imply risk—but there is also little opportunity. New technologies advance at a breakneck pace. For the most part, technology growth is exponential, following Moore's law (more or less). But, technologies can also be disruptive, ushering in unpredicted capability in what seems to be overnight. These new technologies sit waiting for literally a decade or more, on the shelf, before being integrated into the next block of spacecraft or new spacecraft series to take advantage of them (the reverse, of course, is also true: some spacecraft may wait around a decade for a new technology to be matured).

There are possible technologies and architectures that can limit the risk and enhance the opportunities in space systems discussed here. These approaches include:

- Distribution, such as building multiple smaller satellites that provide the same capability as a large one.
- Modularization—already adopted to a significant extent in new naval and aircraft architectures and being developed for satellites at the Air Force Research Laboratory—provides a plug-n-play approach for payloads and other components.[11]
- On-orbit servicing—demonstrated autonomously in Defense Advanced Research Projects Agency's (DARPA) Orbital Express demonstration—allows the means to upgrade and maintain space systems.[12]

DARPA's System F6 fractionated spacecraft program combines the strategies of distribution, modularization, and servicing into a single architecture, creating "virtual spacecraft" made up of free flying, wirelessly networked elements.[13] These newer approaches to spacecraft lifecycle management all have the hallmark of flexibility: by adopting these solutions, options would be provided to decision makers to change a space system, relatively rapidly, at any time in the lifecycle. Likewise, they offer greater robustness, as replacement strategies can be employed more rapidly, plus there is resiliency (graceful degradation) in the event of failure. The challenge is that the cost-centric acquisition framework provides no incentives for the development of flexible systems, and also makes it difficult to fully measure the impact of robustness features on cost and benefits. For a fixed set of requirements, flexible systems most probably cost more (assuming no or little uncertainty) than the conventional counterpart, and therefore are disadvantaged in a cost-centric analysis of alternatives. Of course, one could "require" flexibility. But how would such flexibility be measured and specified? What are the units of flexibility? Does that flexibility curtail capability or add to it? What will that flexibility cost? How much should one be willing to pay for it? Several single function spacecraft cost more than a multi-payload monolith, but are less prone to catastrophic loss of all capability: is this approach "worth it"? These are the pertinent questions that would be asked in the systems analysis required by Planning, Programming, Budgeting, and Execution System (PPBES), and rightly so. At present, there are no tools provided in the decision making process to make appropriate trades in flexibility, cost, risk, and performance. Value-centric acquisition principles, if adopted, could change that problem.

A New Approach: Value Centric Acquisition

I will never get to know the unknown since, by definition, it is unknown. However, I can always guess how it might affect me, and I should base my decisions around that.[14]

~ Nassim Nicholas Taleb

We introduce here the notion that the acquisition of space systems should be based on cost-benefit analyses firmly rooted in the metric of *net present value* (NPV)—and hence our approach is deemed "value centric acquisition." NPV, a measure used in making daily investment decisions in the business sector, is simply the *value* of a project, less its cost, over the lifecycle of the project. Inflows (value) and outflows (cost) are both measured in dollar units. Out-year net values are *discounted*. This technique accounts for a simple law of finance: a dollar received tomorrow is worth less (now) than one received today.[15] This follows from the notion that there is a time value of money. Put another way, there are opportunity costs for waiting for a valuable commodity. We then introduce a second element into this acquisition model—uncertainty. The lifecycle of a space system can be viewed as a series of uncertain events: the performance over time with the system is fully dependent on the interaction of these events. In this model, each key event has a possible distribution of outcomes. For example, a threat capability may slightly change with a probability of 15 percent, or dramatically change with a probability of 60 percent. Likewise, it may be predicted in pre-Phase A that the delivery of a TRL-3 payload has a 5 percent chance of occurring within one month of schedule, and a 80 percent chance of occurring two years late.[16] A launch may have a 98 percent chance of success. A specific hostile space event may have a 50 percent chance of taking place, conditioned on a regional conflict taking place. All such events can be modeled in a simulation.[17] If any options (such as the option to upgrade a system in-orbit) have been built in, they can be exercised in the simulation when the model determines an event has occurred which acts as a "tripwire" for that change. At the end of a single simulation run, a lifecycle cost and value (and hence a NPV) for a given system design will result. After another simulation run, events will take place in different fashion (because of the random nature of events) resulting in a different lifecycle cost and value (either better or worse than the previous). Through execution of many, many simulations, a distribution of possible outcome in cost and value will be accumulated.[18] The range of possible outcomes is representative of the uncertainty in cost and value which is intrinsically based on the forecast of many possible futures.

Placing value on a space asset requires a pricing scheme for its services. Presently, most space systems are purchased on a cost-plus basis, but this provides little information of their true value to the stakeholder.[19] But, current value based pricing models exist for many commercial space products (as a market exists), many of which are purchased by the government. Commercial communications bandwidth is valued and purchased on a per bit basis: the authors have previously conducted a NPV analysis of a satcom service for monolithic and fractionated architectures using reasonable market rates and demand variations.[20] Satellite imagery is sold commercially on the basis of image resolution. These value models could serve as an initial basis for the dollarization of equivalent military capability. Valuation of other space system products currently not offered on a commercial market has been performed: In a cost-benefits analysis conducted by National Oceanic and Atmospheric Administration for the Geostationary Operational Environmental Satellite Block R, the present value of the data products delivered by both payloads (imager and sounder) was calculated. Recognized as a lower bound in the estimates, the monetized benefits came from many stakeholder categories, including aviation (e.g., cost savings by reducing weather delays) and agriculture (e.g., frost mitigation). Benefits of other systems (e.g., GPS, reconnaissance missions) might prove more difficult to quantify in dollar terms, but techniques based on stakeholder interviews exist which can develop value relationships with capabilities.[21] Seemingly more elusive still are space systems designed to support others: in this case the value of such systems is derived specifically from the value of those systems supported.

Using the net value approach, with uncertainty modeled, many new insights arise during the analysis of alternative architectures and systems design of the most promising ones. Specifically:

1. **Flexibility is measurable and can be traded with cost.** In today's acquisition framework, flexibility has no units, and therefore measures of effectiveness are elusive and arbitrary. In an analysis of alternatives for example, flexibility may be given a qualitative score, such as "high" or "low." This score is typically somehow weighted and analyzed, apart from the base system capability scoring, and then added as part of the total score. But, in value-centric analysis with uncertainty modeled, flexibility is quantifiable *in dollar terms*. With flexibility, the capability of the system (hence its value) can be maintained and even increased once a change is made to the system. Say for example we build in the flexibility for a communications satellite to have its computer upgraded on-orbit. We can forecast today that a new computer may have twice the processing speed in three years. In this scenario, as-

sume that if this old computer is exchanged with the new one, the spacecraft can use an advanced signal processing algorithm that increases its bandwidth by 50 percent; hence, if value grows directly with bandwidth, the value of the system increases 50 percent at that time. In this case, the value of flexibility is the net value added to the system over its remaining lifetime because of the added bandwidth capacity. In this example, there would be added cost for serviceability, and it comes in two forms. First, adding the capability of servicing will add additional fixed cost to the spacecraft. Second is the cost of the actual servicing mission, but this cost would be optional—one could decide not to upgrade, and live with the system as is for the entire life of the system. Thus, from this approach it can be seen that flexibility value, measured in dollars, can be traded with cost. Note two other important features of flexibility that this example points out. First, the value of flexibility—which is measured apart from the cost—is *derived* from the value of an underlying asset. In this brief example, the value of flexibility is specifically derived from the value of communications capability. Many trades are currently done (incorrectly) with flexibility as a score separate from baseline capability: but, without capability, flexibility is worthless. Secondly, this example demonstrates that flexibility implies a choice: it is the right, but not the obligation, to exercise change in the future. This delineation is the formal definition of an *option*—like a stock option, where the owner has the right, but not the obligation to purchase stock in the future. Stock options have true monetary value, a value that can be determined using analysis that looks at the value of the underlying asset (the stock in this case) and the probability of future events changing the value of the asset (more often referred to as volatility). A body of academic work was started at Massachusetts Institute of Technology several years ago using options analysis to value space system flexibility by former Air Force Chief Scientist Dan Hastings (now the dean of undergraduate education and a professor in the Department of Aeronautics and Astronautics).[22] This work continues to serve as motivation for the acquisition philosophy amplified in this article.[23]

2. **Alternatives can be traded against one another based on value, cost, and *quantifiable risk*.** Risk analysis and management is based today on the use of the infamous tri-color (red, yellow, green) risk chart. The value-centric approach embraced here allows risk to be quantified—where risk is now the downside *variance in potential outcomes of cost* (and similarly, the value variance, specifically upside value, is a measure of opportunity). Thus, not only can alternatives be traded on a basis of possible net value, but also risk (to net value). In this context, many categories of robustness—such as resiliency and survivability—become quantifiable elements that limit risk throughout the lifecycle. A new feature introduced is that the risk tolerance or aversion of the relevant stakeholders can be explicitly and quantitatively incorporated into architectural decision-making, for example, the extent to which one might distribute or fractionate a system, and so forth. This is very similar to the way in which any investor of mutual funds chooses a plan—it is based not only on expected increase in value, but also the risk of the investment. Note that using the uncertainty analysis approach, managers can play a much more active and controlling role in the risk management process: a tool is now available that provides insights into how programmatic and design decisions quantitatively impact uncertainty in outcomes. Thus, changes in program philosophy or design can be analyzed in terms of the quantitative impact they have on program risk. This insight should undoubtedly lead to a further embrace of a portfolio of approaches that appropriately balance cost, value, and risk, including alternate architectures that are non-conventional (e.g., ground based solutions).
3. **The value of responsiveness is quantifiable and can be traded with cost and capability.** Discounting future cash flows in the NPV based analysis reveals the higher value of a capability when it is received sooner. Often we hear of the "70 percent solution" as the prototype of an approach that can get a space system (confidently) delivered sooner and less expensively than the total (100 percent solution). The NPV approach will allow the 70 percent and 100 percent system solutions to be compared equitably, with distinct value metrics provided to determine the benefit of one approach versus the other.
4. **A better measure of both cost and value uncertainty can be made, and therefore confidence in predictions can be much higher.** One of the key tenets of the net value approach is to utilize uncertainty in key events to forecast possible outcomes. Thus, both cost and value estimates yielded in the net value analysis are not discrete numbers, but rather are random variables contained within a probability distribution. Most conventional cost estimates performed today are given probability distributions, but the practice that leads to these estimates is specious. Current cost analysis uncertainty estimates are based on the uncertainty *in the cost estimating relationships that are derived from curve fits of programs in the past*. The more optimal approach described is to base uncertainty on costs *based on the forecast uncertainty of key events for the actual program in the future*.[24] The enormous advantage this approach provides is that the stakeholder now can quantify the impact of trade decisions on possible cost growth, as well as value growth (which would be a function of the flexibility built into the system!). This uncertainty analysis process also is used for the launch and operations phase of programs, which can be important in quantifying the *robustness* of architecture. A distributed satellite approach using multiple launch vehicles, for example, has been shown to be more robust to possible launch failures, as compared to a monolithic system launched on a single launch vehicle.[25] The latter "all eggs in one basket" approach means significant value is lost should the launch fail. If a replacement is built, additional cost is incurred,

and the value of the replacement is diminished because of the delay (accounted for in the discounting process). A distributed approach results in only partial reduction of capability, the impact of which if fully quantifiable in the value centric analysis. Of course, this effect needs to be traded with the extra potential costs of the distributed approach, which most probably would exceed that of the monolithic architecture *if everything goes right*. This same analytical approach also is suitable for the studying the impact of survivability and resiliency of systems in a threat environment.

Before ending this present discussion, we must note one of the much-touted reforms of the 1990s to the defense procurement process—that of "best-value" contracting, whereby more than just the cost of a system (for a given level of performance) is considered in procurement decisions; specifically, the alternative that offers the "best value to the government" is selected.[26] Unfortunately, while a good idea in principle, this particular acquisition reform fell far short of the mark. The impetus behind best best-value contracting was to provide an incentive scheme for rewarding systems that had desirable non-performance and non-cost attributes such as quality and schedule. In performing systems analyses or in making source selection decisions, these additional attributes are combined—either quantitatively or qualitatively—using an arbitrary weighting scheme to evaluate alternative systems.

There are at least two problems that compromise the merits of this approach. First, attributes such as flexibility and robustness, for which no commonly accepted definitions much less quantitative metrics are available (within the current acquisition framework) are still universally excluded. Second, the arbitrary weighting scheme provides no assurances that optimal balance between cost, performance, and other system attributes is attained. In fact, by imposing an ambiguous "best value" criterion in place of a clear and quantitative (albeit sub-optimal) minimum-cost one, the designer's ability to optimize the system is compromised. While the procurer undoubtedly has some conception of his relative weighting of the attributes, this is treated as private information by the procurement process (i.e., it is not disclosed to the performers proposing alternate system designs), they do not provide a viable metric for design optimization.[27] The value-based source selection criterion which we advocate here is much different than this existing "best value" paradigm by revealing quantitative measures of value and cost, based on design decisions.

Integration into the Planning, Programming, Budgeting, and Execution System—What Would Hitch Think?

Our proposal to use value centric analysis in space acquisition is modest in its scope but dramatic in its ramifications. We do not purport to supplant the half-century of wisdom that has accrued in what is today PPBES. We seek only to replace the criterion for selecting among alternatives for effecting a particular capability that nominally takes place during the programming activity. At the same time, comparable changes would need to take place in the criteria employed during execution, specifically in source selection, contract execution, and effects analysis.

So what would the creator of PPBS, Charles Hitch, think of this value centric approach, as opposed to the cost centric approach he advocated in writing 45 years ago? If one returns to the principal document that Hitch authored 50 years ago, which catalyzed his appointment to the Pentagon, answers can be found. In *The Economics of Defense in the Nuclear Age*, Hitch wrote, "In principle, the criterion we want is clear enough, the optimal system is the one which yields the greatest excess of positive values (objectives) over negative values (resources used up, or costs)." This articulated an identical criterion to the one that we have advocated here—net value. "But," Hitch continued, "this clear-cut ideal solution is seldom a practical possibility in military problems. Objective and costs usually have no common measure: there is no generally acceptable way to subtract dollars spent or aircraft lost from enemy targets destroyed. Moreover … there may be multiple objectives or multiple costs that are incommensurable."[28] Hence, Hitch was presented with two issues in implementing a value based approach. First, he understood the difficulty in monetizing capability. Second, there are "incommensurable" criteria that are likewise difficult to quantify. We have suggested approaches here that tackle the issue of monetization. In fact, space systems can be much easier to dollarize than other military systems, as commercial analogues exist for many capabilities. Flexibility and robustness seem to be difficult to quantify and to compare with cost, but the uncertainty analyses introduced here tackles that problem. Therefore, we believe that value-centric acquisition conforms more closely than cost minimization to Hitch's original thesis, and even to McNamara's admonition to his Ford Engineers, "Put in value, not cost."

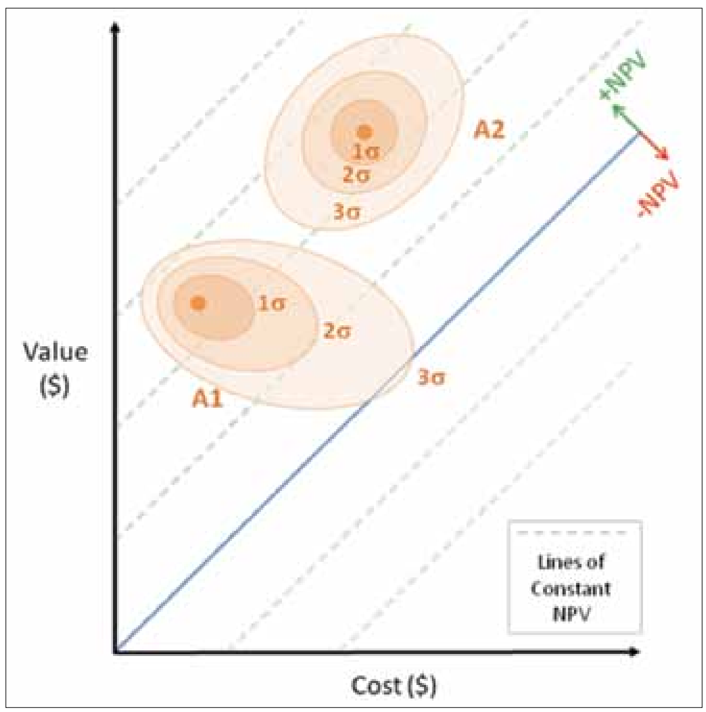

Figure 1. Plot comparing the cost and value distributions of two hypothetical space system architectures (A1 and A2).

A Brief Example of the Value-Centric Approach

NPV analysis, including an acknowledgement of the possible variation in cost and value inherent because of uncertain events, is the fundamental tenet of value-centric acquisition approach. An example is provided here to provide a better grasp of the concept. Figure 1 provides a notional depiction of a NPV comparison of two hypothetical space architectures. The horizontal axis of the graph is cost, in dollars. The vertical axis is value, also in dollars. Lines of equal NPV are shown as dashed lines for reference. The bold green line represents the points of zero NPV for all costs (the "break even" solution); all points above the green line have greater value than cost, and all points below the green line have greater cost than value. Architecture 1 (A1) is representative of a tightly coupled, complex, (but typically "cheaper") monolithic system, whereas Architecture 2 (A2) is representative of a distributed system. Both systems are designed to have the same initial baseline capability. Uncertainty ellipses are shown for A1 and A2 representing 1-sigma, 2-sigma, and 3-sigma confidence levels (equivalent to 66 percent, 95 percent, and 99.7 percent confidence levels, respectively). The first obvious behavior of uncertainty profiles is that A1 has a much larger range of levels in cost as compared to A2. This is a feature symptomatic of the monolithic approach where all eggs have been placed in one basket, and therefore all value is potentially spoiled at once (for example, a launch failure results in total loss of capability). Next note that the uncertainty profile of A1 goes down and to the right. In the case of total failures, the only path to recovery is to start over, which adds costs, but delays availability. With discounting, the value decreases. The effect is the same for delays in integration and test due to component delays etc. Hence, as cost builds, value decreases. For A2, the cost spread is reduced, and in fact, a large percentage of possible A2 costs lie in the same region of possible costs for A1. Fundamentally, this is the result of distribution: a loss or delay in one element does not result in total loss of the system: it is more robust. A2 also demonstrates a behavior in uncertainty profiles that as cost increases, so does value. This would be attributable to the value of flexibility. For example, a distributed system can be scaled—elements can be added as demanded to increase capability. Hypothetically, new elements can be added much more quickly with newer technologies. Is the increased value worth the added cost? In this case, note that as more costly solutions are chosen for A2, in general the NPV increases (as the solutions move to higher NPV lines). Thus, in this case, flexibility is worth the added cost. This approach is totally different from the conventional cost-centric deterministic approach: most likely a specific cost for each architecture would be determined for a notional case, with A1 showing the least cost in the "perfect world" scenario. Although this example is purely hypothetical, it is consistent with results obtained from four separate contractors who performed value-centric analyses of fractionated versus monolithic architectures in the first phase of DARPA's System F6 program.[29, 30, 31]

Conclusion

...In preparing for battle I have always found that plans are useless but planning is indispensable.

~ Dwight D. Eisenhower

We have introduced the concept of value-centric acquisition as a possible path to improved decision making in today's dynamic world. Rather than providing a crystal ball that allows us to better predict the future, value-centric acquisition acknowledges uncertainty, and provides a quantification of risk and opportunity, which are functions of programmatic and design decisions. Put another way, both flexibility and robustness—the prescriptions to uncertainty—become measurable units and can be traded with cost and performance. In this approach, we resist the technocratic urge to conclude that a few formulas will lead to perfection in plans and execution. We instead acknowledge the complexity of systems and the unpredictability of events: in the process we provide a technique that allows decision makers to determine a system's possible distribution of costs and benefits in a world of potential futures. The key to our approach is the introduction of the net value metric, which is an analogue to NPV in widespread employment for private-sector decision-making. We fully understand that our military space systems are not built to make money—but they are built to provide value to the warfighter. Our net value approach provides a new toolset that will provide the best assurance (and insurance) that our men and women in harm's way have the capability they need, when they need it. In fact, this approach may usher in more rapidly capability the warfighter had no idea could exist. In essence, our approach is a return to the gain-minus-cost formulation which the founders of PPBS, McNamara, and Hitch, rejected due to the problem of incommensurables. A half-century of progress in microeconomics, finance, and decision theory has placed it firmly within the realm of solvability.

Notes:

1 Andrew F. Krepinevich, *Seven Deadly Scenarios*, Bantam Books, February 2009.

2 A detailed description of the value-centric framework contained in this article is forthcoming in Owen Brown and Paul Eremenko, *Value-Based Decision-Making for Defense* (Cambridge University Press, 2010) (in draft).

3 Gregory Glaros, "Real Options for Defense," *Transformation Trends*, 6 June 2003.

4 Richard A. Johnson, "The Outsider," *Invention and Technology Magazine* 23, no. 1 (Summer 2007).

5 Charles J. Hitch and Roland N. McKean, *The Economics of Defense in the Nuclear Age*, Report No. R-346, (RAND Corporation, Santa Monica, CA, 1960). Later published in book form under the same title by (Harvard University Press: Cambridge, MA, 1961).

6 Alex Abella, *Soldiers of Reason: The RAND Corporation and the Rise of the American Empire* (Harcourt Trade, 2008), 135.

7 Charles J. Hitch, *Decision-Making for Defense* (University of California Press: Berkeley, CA, 1965), 29.

8 Ibid., 52.

9 Naresh Shah and Owen Brown, "Fractionated Satellites: Changing the Future of Risk and Opportunity for Space Systems," *High Frontier Journal* 5, no. 1 (November 2008).

10 Owen Brown, Paul Collopy, and Paul Eremenko, "Value-Centric Design Methodologies for Fractionated Spacecraft: Progress Summary from Phase 1 of the DARPA System F6 Program," paper presented, AIAA Space 2009 Conference and Exposition, Pasadena, CA, 14-17 September 2009.

[11] Jim Lyke, "Packaging, Plug-and-play, Modularity and the Impact of Wires," paper presented, CANEUS 2007, Dallas, TX, 28 March 2007.

[12] Owen Brown, Fred Kennedy, and Wade Pulliam, "DARPA's Space History," *Success Stories in Satellite Systems* (American Institute of Aeronautics and Astronautics, 2009) chapter 16.

[13] Owen Brown, Paul Eremenko, "The Value Proposition for Fractionated Space Architectures," paper presented, AIAA-2006-7506, AIAA Space 2006, San Jose, California, 19-21 September 2006.

[14] Nassim Taleb, *The Black Swan: The Impact of the Highly Improbable* (Random House, 2007), 210.

[15] OMB Circular No. A-94, "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs."

[16] Delivery time as a function of TRL has indeed been modeled. See Gregory Dubos, Joseph Saleh, and Robert Braun, "Technology Readiness Level, Schedule Risk and Slippage in Spacecraft Design: Date Analysis and Modeling," paper presented, AIAA 2007-6020, Space 2007 Conference and Exposition, September 2007, Long Beach, CA.

[17] Disagreements of course can arise on the uncertainty distributions of the key events: we propose that what is most important is not to be certain of the uncertainties, but rather understand the sensitivity of outcomes to a range of possible inputs.

[18] This more specifically is an example of a Monte Carlo simulation process.

[19] The other problem with this valuation strategy is that it would by default result in a positive net present value for all choices, and all choices would have net present values in the same range, more or less.

[20] Owen Brown, Paul Eremenko, and C. Roberts, "Cost-Benefit Analysis of a Notional Fractionated SATCOM Architecture," paper presented, AIAA-2006-5328, 24th AIAA International Communications Satellite Systems Conference, San Diego, California, 11-14 June 2006.

[21] One such method of overcoming the problem of valuing non-market based attributes comes from the field of decision theory. See, for example, John vonNeumann and Oskar Morgenstern, *Theory of Games and Economic Behavior* (Princeton University Press, 1947); Ralph Keeney and Howard Raiffa, *Decisions with Multiple Objectives: Preferences and Value Trade-Offs* (Cambridge University Press: Cambridge, UK, 1993).

[22] See, for example, Joseph Saleh et al., "Flexibility and the Value of On-Orbit Servicing: New Customer-Centric Perspective," *Journal of Spacecraft and Rockets* 40, no. 2 (March-April 2003), 279-291; Rania Hassan et al. "Value-at-Risk Analysis for Real Options in Complex Engineered Systems," working paper, MIT Engineering Systems Division, ESD-WP-2005-03, 2005.

[23] Some have vociferously objected to the use of the options framework in the context of procurement planning, given the recent failure of derivative vehicles in the sub-prime loan crisis. We reject these notions. The chief lesson from this crisis is that models used to value derivatives should be well understood, and uncertainty properly acknowledged in the model inputs. Equity markets have not disposed of hedging strategies because of the recent financial meltdown, and rely on them especially in today's volatile economy.

[24] Of course, there are assumptions that must be made in predicting the possible outcomes of key events.

[25] Owen Brown, "Reducing Risk of Large Scale Space Systems Using a Modular Architecture," paper presented, Aerospace Corporation Space Systems Engineering and Risk Management Symposium, Manhattan Beach, CA, 2004.

[26] The Federal Acquisition Regulations (FAR) § 15.302.

[27] FARs require only that the relative importance of source selection factors be stated, i.e., that they be ordered from most- to least-important and that a "state[ment] whether all evaluation factors other than cost or price, when combined, are significantly more important than, approximately equal to, or significantly less important than cost or price" be made. FAR §§ 15.101-1, 15.304(d)-(e). Thus, no actual quantitative weightings of the KPIs need be supplied to the offerors.29

[28] Charles J. Hitch and Roland N. McKean, *The Economics of Defense in the Nuclear Age*, Report No. R-346, (RAND Corporation: Santa Monica, CA, 1960), 120.

[29] Dragos Maciuca et al., "A Modular, High-Fidelity Tool to Model the Utility of Fractionated Space Systems," paper presented, AIAA Space 2009 Conference and Exposition, Pasadena, CA, 14-17 September 2009.

[30] David McCormick et al., "Analyzing Fractionated Satellite Architectures Using RAFTIMATE—A Boeing Tool for Value-Centric Design," paper presented, AIAA Space 2009 Conference and Exposition, Pasadena, CA, 14-17 September 2009.

[31] E. Eichenberg-Bicknell et al.,"Using a Value-centric Tool Framework to Optimize Lifecycle Cost, Value, and Risk of Spacecraft Architectures," paper presented, AIAA Space 2009 Conference and Exposition, Pasadena, CA, 14-17 September 2009.

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The Cyberspace-Development Dogfight: Tightening the Acquisitions Turn Circle

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Moore's Law	The number of transistors on a chip doubles annually
Rock's Law	The cost of semiconductor tools doubles every four years
Machrone's Law	The PC you want to buy will always be $5,000
Metcalfe's Law	A network's value grows proportionately to the number of its users squared
Wirth's Law	Software is slowing faster than hardware is accelerating

Table 1. Five Truths of Cyberspace Development.[1]

DoD [Department of Defense] has been able to develop and acquire the best weapons and support systems in the world. DoD and contractor personnel accomplished this feat not because of the system, but in spite of it. And they did so at a price … the nation can no longer afford to pay.

~ Former Secretary of Defense William J. Perry

There's a Hole In the Bucket, Dear Liza …

If we fail to keep up with the increasing rate of technological change, we will have made a *de facto* decision to fall behind. Moore's Law describes the trend for doubling the density of transistors in a microprocessor chip every two years, and it is often used to describe information technology advancements in general. Information technology will likely continue to double in capability on the order of months, not years. Similarly, Rock's Law describes how the cost of being able to produce these technology increases also doubles roughly every two years. At some point, Rock's Law dominates, and the age-old balancing act between resources and capabilities ensues.

In an article titled "5 Commandments. The rules engineers live by weren't always set in stone," Philip E. Ross adds three more laws, (see table 1). Machrone's Law may be thought of as "conservation of price," while Metcalfe's Law tells us there is strength in numbers, and Wirth's Law is a sort of "conservation of slowness" idea. While these ideas are more observation than "law," together they help form our mindset about all of the competing forces within cyberspace technology, so they are included here for completeness.

John Boyd's observe, orient, decide, act (OODA) model is often used to describe process cycles, yet he would be the first to say that we should not limit our focus only to the OODA parts. Boyd would often preach "People, ideas, hardware—in that order," and "machines don't fight wars, people do, and they use their minds."[2] The mindset of the OODA loop is similar to the energy-maneuverability concept familiar to any fighter pilot, since Boyd helped develop both concepts. If you use your energy to fly smarter, turn tighter, and get inside the enemy's turn-circle, you can win any dogfight. Similarly, the cyber-development OODA loop can be thought of as a "resource-maneuverability" relationship—if our "resource energy" is limited, we must outmaneuver our adversary using increased agility.

Limited resources are often an economic reality, but we are more limited by *how we use* our resources, not just the *amount* of our resources. We also tend to overlook how people fit into

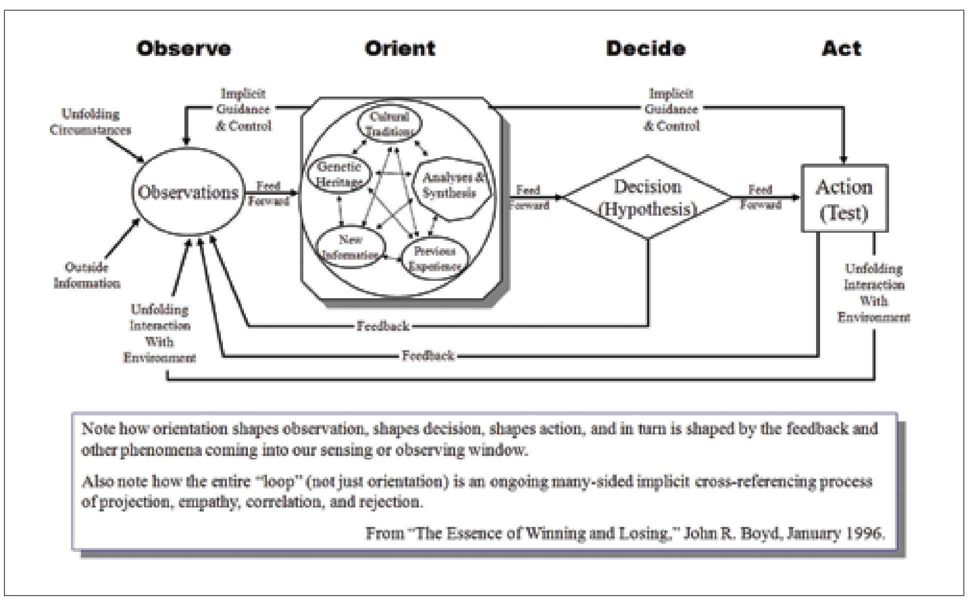

Figure 1. Col John Boyd's OODA Loop.[3]

the process; after all, a process does not run itself … yet! We cannot simply replace people with technology and expect things to work! The rate of technology change is increasing while manning and resources continue to shrink … yet our mechanisms for spending money, allocating resources, and adapting to changing technology requirements are either unchanged or take even longer to complete for each development cycle.

As the world moves faster, we must predict future warfighter needs earlier and earlier, peering into the crystal ball, only to realize that we cannot see our future requirements that well. The perceived risk-reduction and cost-savings gains of overly-bureaucratic processes are outweighed by real, but difficult to measure, costs from falling behind our adversaries. Lack of timely technological adaptations, poor transitions from the "old way" to the "new way," and "one-size-fits-all" solutions … hurt the mission-effectiveness of warfighters for the sake of pleasing managers with unnecessary and over-centralized micromanagement capability. Cyberspace development is the metaphorical "canary in the coal mine" in terms of highlighting acquisitions process breakdowns; software development is often the first to suffer from any weaknesses or mismanagement.

So what can we do about it and what has already been tried? First, we offer a brief history of acquisition reform (AR) efforts before focusing on process improvements specific to cyberspace development. Although not covered here, do not forget that personnel reforms and improvements go hand-in-hand with any process changes! If people do not adapt and accept change, the process changes will not work and will incorrectly be blamed for the failure.

Table 2 shows the history of recent US acquisition reform efforts, prior to the current Joint Capabilities Integration and Development System (JCIDS) and Defense Acquisition System (DAS).

1961	McNamara Initiative
1970	Fitzhugh Commission
1972	Commission on Government Procurement
1976	OMB Circular 4-109
1978	Defense Science Board Acquisition Cycle Study
1979	Defense Resource Management Study
1981	Defense Acquisition Improvement Program
1983	Grace Commission
1986	Packard Commission
1986	Goldwater Nichols
1989	Defense Management Review
1990	Quadrennial Defense Review

Table 2. Acquisition Reform Initiatives.[4]

The Good

In one of many Rand Corporation studies of DoD AR efforts, Dr. Ken Oscar, acting assistant secretary of the Army for acquisition, logistics, and technology, described the positive aspect of AR that laid the foundation for JCIDS in an article titled "Reexamining Military Acquisition Reform: Are we there yet?":[5]

> Overall, Oscar characterized the AR movement in the 1990s as having been energized by Secretary William Perry's "Mandate for Change" speech in 1994, and as having achieved three very important legislative accomplishments over the period: the Defense Acquisition Workforce Improvement Act of 1990, the Federal Acquisition Streamlining Act of 1994, and the Federal Acquisition Reform Act of 1996. In his view, those legislative actions (along with the AR efforts to internally reform the acquisition process—e.g., the rewrite of the 5000 Series2) have helped to improve the education and skills of the acquisition workforce, remove unnecessary laws, and reduce regulations—thereby contributing to an environment that allows for more creative approaches to acquisition than were previously possible.

The reforms of the 1990's reduced the "stovepipe" effect where organizations tended to communicate only vertically, up and down the chain of command. Lateral collaboration did not happen naturally. Dr. Oscar also highlighted the birth of "evolutionary acquisition," which divided large systems into smaller chunks—increasing delivery flexibility and decreasing scheduling risk.[6]

The Bad

These reforms reduced confusion, stovepipes, and some of the "red tape," thus paving the way for program managers (PMs) to have more creative control over the acquisition process, but there was still more to be done. "AR gives PMs authority to take risks, but not the resources.…" and, "We reformed the acquisition process, but not the financial process that supports it.…" were among the complaints fielded from surveyed PMs.[7] In some ways, many of the changes were more "lip service" than anything about substantive change. At the end of the day, the same 10 people pounded the same 10 rocks with the same 10 hammers, despite the nomenclature changes. As noted in the RAND AR study:

> Several of the participants provided frank assessments of the changes—or lack thereof—brought about under AR. A senior deputy program executive officer commented that "AR has been good at cranking out policies, but hasn't made anything faster, better, or cheaper," a remark with which many others participating in the group interview concurred. One participant noted, "There is no such thing as acquisition reform. We've changed the way PMs deal with contractors, but nothing else has changed."[8]

In another key finding, there was a general observation that not all organizations were playing along with AR efforts. It was widely felt that external organization resistance can still dominate and nullify AR:

> AR will remain suboptimized until they reform the financial, logistics, test, engineering, contracting, and legal communities. These communities can unilaterally kill any AR program, since they have full veto authority in most cases, while not being held accountable for their decisions.[9]

In their criticism about the testing portions of AR, several PMs felt this same refusal to change:

> The testing community is still in the old ways of doing business.… The test community is still living 30 years in the past.… The test community is still focused on their reporting requirements rather than testing to fix.…[10]

These observations all involve the concepts of authority, responsibility, and accountability, and these three concepts must be evenly distributed within one organization. When one organization is responsible for performing tasks but does not control its resources, the whole system fails. Quite often this lack of authority is felt in the area of funding control: "Many PMs felt constrained due to "color-of-money" restrictions on how they could spend the moneys within their budgets."[11] It seems that it is not just the lack of money or resources, but often the control that is inadequate.

Joint Capabilities Integration and Development System to the Rescue

Despite the shortcomings of AR, most of our past acquisition reform efforts have improved the system immensely, culminating in the current JCIDS process. Throughout the last decade, we've evolved JCIDS to be a "capabilities-based" method for deciding what to buy and what features we need and want. Quite literally, the needs are called threshold requirements and the wants are called objective requirements—nothing is procured unless there is a valid "need" for it.

However, the past reforms have not been all-encompassing, and we still have the same slow budget process. Revisions to JCIDS and the DAS have done well to fulfill valid and important reform ambitions; nonetheless the system is too cumbersome for meeting urgent warfighter information technology (IT) needs.

In 2005, Vice Chairman of the Joint Chiefs of Staff Admiral Edmund Giambastini gave written testimony on JCIDS to the House Armed Services committee. Vice Admiral Evan Chanik, chief of the Joint Staff J-8, Force Structure Directorate, commented on Admiral Giambastiani's testimony, suggesting future improvements to JCIDS, according to this excerpt from this February 2006, *Inside the Air Force* report, "Joint Staff officials will 'tweak' JCIDS to better address urgent needs":[12]

> …Chanik's comments come several months after Vice Chairman of the Joint Chiefs of Staff Adm Edmund Giambastiani, in written response to advance questions from the Senate Armed Services Committee during his confirmation process last summer, first raised the issue of tweaking JCIDS to address urgent requirements. In his responses, Giambastiani noted that the JCIDS process "is designed to impact mid- to far-term capabilities and funding (three years and beyond)" but has "less flexibility to quickly respond to emerging requirements ... in the near-term budget years (one to two years)."
>
> Ultimately, limited acquisition authority and other ad hoc measures Congress has enacted to address the problem should give way to more permanent solutions, Giambastiani wrote. "In the long term, the JCIDS process needs to change to fall more in line with the demands and pace of today's operations," Giambastiani noted.

Further criticisms of the acquisitions process, by current and former military officials, had been published in *Inside the Navy*, as described within the same *Inside the Air Force* article.

Marine Corps Lt Gen Paul Van Riper, retired, recently criticized the process in a private December e-mail message addressed to Chairman of the Joint Chiefs of Staff General Peter Pace, Marine Corps Commandant General Michael Hagee, and Army Chief of Staff General Peter Schoomaker. In the note, Van Riper slammed JCIDS for being "overly bureaucratic and procedurally focused."

> "My greatest concern is that as these concepts migrate into the curricula of professional military schools they will undermine a coherent body of doctrine creating confusion within the officer corps," Van Riper continued. "In fact, I have begun to see signs of just that!" In a response sent several days following Van Riper's e-mail, [US Marine Corp Lt Gen James] Mattis—who is now in the post Van Riper held when he retired in 1977—agreed wholeheartedly.[13]

Many of these criticisms have been taken to heart and on 1 May 2007, Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 3170.01F was released in order to "…refine the JCIDS process and the information they require to ensure they are making effective, appropriate decisions in a timely manner. This update to the policies and processes continues that evolution of JCIDS to ensure our ability to continue to meet the needs of the joint warfighter." As of this writing, CJCSI 3170.01G, 1 March 2009, is the current JCIDS policy release.

Since the acquisition system criticisms of 2005 and beyond were voiced by high-level military leaders, the system still needs more "tweaks." On 4 March 2009, General James Cartwright, joint chiefs vice chairman, spoke at the Naval IT Day conference, noting that our current methods for procuring IT were so cumbersome that by the time items are purchased, they are already out of date, and that "It takes longer to declare a new [program] start than the lifecycle of the software package."[14]

With the advent of JCIDS, the pendulum of AR has swung such that we are now excessively risk averse and there is a tendency not to accept failure as a necessary part of the development process. General Cartwright again highlighted this concept at the Naval IT:

> Aiming for a "perfect" IT solution is often the problem, Cartwright said. "We have this mindset that somehow whatever we field has to be perfect, so we'll spend a life of an application's utility testing it to make sure it's invulnerable and makes no mistakes," Cartwright said. "Looking for the perfect solu-

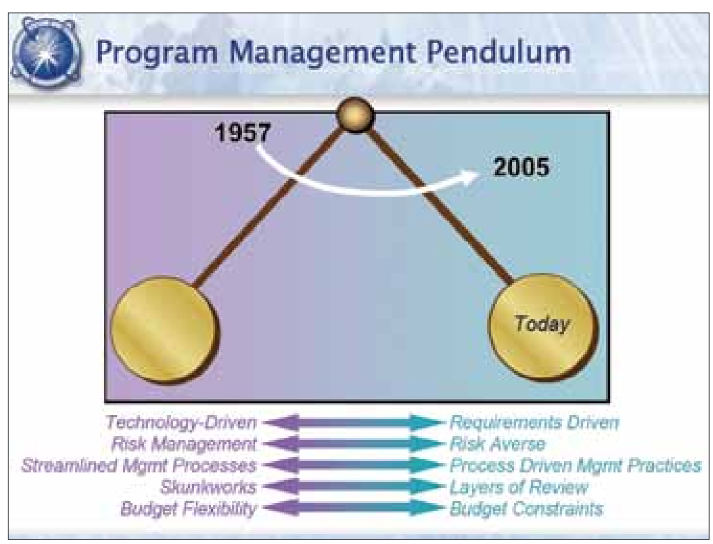

Figure 2. The Program Management Pendulum Swing.[15]

tion is almost always a recipe for irrelevance, and we've proved that over and over and over again."

The challenge facing the DoD with IT procurement isn't that technology is too advanced, it's that the culture for procurement isn't working and needs to change, Cartwright said.[16]

This pendulum swing is shown in figure 2, in an excerpt from a slide presentation by Dr. Pete Rustan, of the National Reconnaissance Office. The figure shows that as of 2005, the DoD is in a state of risk aversion, resulting in higher costs. In 1957 (beginning of the space race), the mindset was one of risk acceptance. Risk acceptance is more cost effective, but there is a higher "potential energy" for failure.

The fact that our process is swinging and unstable at all is itself a major concern. We should seek stable equilibrium that balances between cost and risk. This equilibrium will likely be different for a large acquisition, such as an aircraft carrier, than it is for smaller IT software development projects—our system must accommodate the range between these extremes. If we do not apply a different balance for IT projects, we will continue to lag behind the pace of technological change.

So Fix It, Dear Henry …

After observing Dr. Rustan's pendulum swing effect for systems acquisition, it becomes clear that what is "optimal" for large acquisition programs may be different than what is "optimal" for smaller, more agile, IT software development projects. Figure 3 shows a slide from an acquisition action officer introductory briefing. What is interesting is how space programs are handled differently than non-space acquisition category (ACAT) programs. This is due to the unique aspects of the space environment. Currently, non-space IT software development falls under ACAT I or ACAT III. There is no ACAT II for IT system software and Major Defense Acquisition Programs do not solely include IT. Thus only Major Automated Information Systems, non-major ACAT III systems, and "technology and other projects" categories include IT software development programs.

		Information Technology Programs	Non-Space Programs	Space Programs
Classification	Sub-Designation	MDA	MDA	MDA
MDAP	ACAT 1(D)	(1AM) ASD/DoD CIO	USD(AT&L)	USecAF and SecAF
	ACAT 1(C)	(1AC) SAF/AQ and SecAF	SAF/AQ and SecAF	
Major System	ACAT II	TBD	SAF/AQ or AFPEO	AFPEO/SP
Non-Major System	ACAT III	AFPEO or DAFPEO	AFPEO or DAFPEO	AFPEO/SP or DAFPEO/SP
Technology and other projects	ATD/ACTD, Joint War-fighting Experiments, Concept Refinements	Varies with category	Varies with category	Varies with Category
Relative Cycle		Short-term	Medium-Term	Long-term

Note: MAIS is removed and incorporated within MDAP. Also, it is possible that we should rename "A", "B", "C", or "D" suffixes for ACAT I programs.

Table 3. Redesigned Acquisition Categories for IT.

Acquisition categories are cost-based, as opposed to risk-based or complexity-based. Of all the competing motives, we should try not to be so budget-centric (gasp!). Instead, perhaps we should modify the ACAT table by adding a new column for information technology programs, as shown in table 3.

Although merely a cosmetic change at first, separating IT programs in this way makes it easier to separately assess the cost-risk pendulum balance for the short-term nature of "purely IT" software development. In short, we should not treat software development in the same way that we do an aircraft carrier or a satellite. Automated information systems that may be thought of as "stand-alone" systems, where the software itself is a service or capability, belong under the "IT programs" column. Software that is integral to non-IT programs will not fall under this new IT column, as specified in DoD Instruction 5000.2.

For software development, agile development techniques show promise and have proven spectacular for companies like Google, Inc., enabling nearly continuous development of full-featured, easy-to-use, large-scale software applications. There are many companies claiming to do agile development, so we must be careful to regard only the best and brightest examples. We do not need to build a perfect agile process, but it will fail unless the surrounding personnel, resource, and budget systems are also agile. Perhaps a portion of the budget can be designated specifically to IT, with the lowest possible decision authority. Working capital funds can work, but these are typically assessed annually. IT funds must allow for nearly continuous updates and changes.

Another concept that should be explored further is major command (MAJCOM) business centers, also known as rapid application development offices. These custom software development shops can produce small-scale software products much faster than trying to incorporate

		Non-Space Programs	Space Programs
Classification	Sub-Designation	MDA	MDA
MDAP	ACAT ID	USD(AT&L)	
	ACAT IC	SAF/AQ as delegated by USD(AT&L) and SecAF	USecAF as delegated by USD(AT&L) and SecAF*
MAIS	ACAT IAM	ASD(NII) / DoD CIO	
	ACAT IAC	SAF/AQ as delegated by DoD CIO and SecAF	
Major System	ACAT II	SAF/AQ (or appropriate AFPEO if delegated)	AFPEO/SP
Non-major System	ACAT III	Appropriate AFPEO or Deputy AFPEO	AFPEO/SP or Deputy
Technology and other projects	ATDs, ACTDs, joint warfighting experiments, concept refinement	Varies with category	Varies with category

*Authority presently retained by USD(AT&L)

Figure 3. Acquisition Categories and Milestone Decision Authority.[17]

the same capabilities within a larger enterprise development. They also alleviate the need for stovepipe programming efforts by individuals trying to fill technology gaps, while waiting for the enterprise ship to come in. If we can fully embrace agile programming and modular, open architecture coding, then the software, developed by various business centers at MAJCOMs and air operations centers (AOCs), will work with enterprise software. Enterprise developers must know up front that we expect their software to allow third-party access to databases and information stores. Third-party modules must be able to interface with larger enterprise software, using what are known as application program interfaces.

We also believe the DoD can develop better methods for transition and integration of advanced concept technology demonstrations (ACTD) and advanced technology demonstrations (ATD) from the Defense Advanced Research Projects Agency and the service research laboratories into JCIDS for quicker operational fielding to the warfighter. Currently, too many ATDs, ACTDs, and joint ACTDs (JACTDs) are not sponsored or ultimately never incorporated into operational systems. Perhaps if we increase the use of MAJCOM and AOC business centers, they can advocate and "pull" a limited number of these advanced technologies through the appropriate system program office (SPO) and aid fielding efforts.

An example of how ACTDs can ultimately benefit the warfighter, consider the Joint Precision Air Drop System (JPADS), which uses the Global Positioning System to help guide cargo pallet drops using steerable parachutes. JPADS allows the cargo aircraft to stay safely out of harm's way while reliably dropping urgently needed supplies within several feet of the warfighter location. The JPADS ACTD received high visibility and it was fielded relatively quickly. One has to wonder, if this system had not been developed during wartime, as a joint urgent operational need (JUON), would it have received the backing and funding it needed to give the program a kick start? Future JPADS development spirals have been retroactively reworked according to the JCIDS process, but the rework was not easy.[18]

JPADS was a success story in that it was a valuable system that quickly achieved operational fielding to meet urgent warfighter needs. JPADS was also successfully integrated into JCIDS for future increments. This was not the case for another ATD, targeted for AMC command and control (C2) users, that to date has not been operationally fielded.

The tanker airlift control center (TACC) commands and controls all transient AMC aircraft throughout the world. A TACC-managed aircraft is landing or taking off somewhere in the world every 90 seconds, so the TACC can be a busy place at times. Several custom programming projects had been created by people with computer skills, usually involving spreadsheets that had been made to help TACC controllers with repetitive tasks—improving upon the software used by the floor operators to keep track of the nuances of each AMC mission they controlled.

Work-centered interface distributed environment (WIDE) and global response and synchronization (GRS), from an operational perspective, has extremely impressive C2 capabilities. WIDE/GRS is akin to "Google Earth for C2" in that, like Google Earth, the software was graphical and easy to use. It let the user refine, filter, and re-filter the data down to only what they wanted to see—significantly reducing problem complexity. The software featured fully interactive mouse-enabled drag-and-drop capabilities to graphically manipulate and query the data visually. If necessary, the raw text data was available for precise and detailed analysis. In this way, WIDE/GRS presented the best of both worlds by allowing the user to quickly operate on the data graphically and intuitively, yet also allowing the user to "drill down" into the textual data as needed.[19]

WIDE and GRS software was tested from 2006 and 2008 using TACC controllers. Tests were run using both the legacy software systems ("information-equivalents" similar to what the controllers were already familiar with in the TACC) and then using the WIDE/GRS software. After a 30-minute familiarization training session, the controllers were presented scenarios and evaluated on the timeliness and quality of their solutions to the scenarios. An example scenario might involve finding the best airplane to perform an emergency medical evacuation of a patient, on short notice, while minimizing the impact on other missions. WIDE/GRS proved to be a drastic improvement, especially for the less experienced controllers and enabled them to get the correct solution in significantly less time—often less than half the time.[20]

A concerted effort was made to integrate WIDE/GRS technology into existing TACC C2 software. However, due to funding difficulties and issues with building a dynamic interface to the centralized mission data, the efforts to field WIDE/GRS technology to the operational TACC controllers are currently on hold. There is an ongoing effort to integrate this ATD into software used by US Transportation Command, the result of which has yet to be determined.[21]

Conclusions

You will never understand bureaucracies until you understand that for bureaucrats procedure is everything and outcomes are nothing. ~ Thomas Sowell, The Hoover Institution

Many IT organizations, such as Google, are adopting agile development processes to meet the high tempo demands of IT and remain viable in an ever-changing world. We should take our cue from these organizations, integrate ATDs, ACTDs, and JACTDs by default, not by exception, and improve the military IT acquisitions process. In summary, we offer the following ideas on how we can improve our acquisition for cyberspace and IT capabilities in general:

- Software projects must be scoped and scheduled for development cycles on the order of *months*, not years, using open architecture, agile development methods, and scalable designs with modular code;
- Budgets must be stabilized for long-term integrity, with a working capital fund reserved for short-term IT needs and urgent warfighter IT needs—similar to JUONs, but not necessarily limited to "life or death" needs;

- Encourage and fund increased use of MAJCOM- or AOC-level business centers to produce software modules that plug into larger agile programs built to accept them;
- Take more advantage of Air Force Research Laboratory's ATD efforts, giving MAJCOM and AOC business centers budget authority to "pull" a limited number of ATDs from research labs, through SPOs, to produce and field operational software; and,
- Continue periodic working groups and conferences, but with emphasis on IT standardization and sharing of lessons learned between military services, MAJCOMs, and AOCs. There must be a "to-do" list for everyone to accomplish before the next conference.

Using the aerial combat analogy, our existing acquisition processes represent a large turning radius, limiting the maneuverability of our metaphorical acquisitions aircraft. The IT pace of change is like the tiny Mig-15 fighters of the Korean conflict … small, able to tightly turn, and able to out-maneuver our less agile F-86 Sabre jets. Yet, with our superior tactics and training, our pilots were enabled, empowered, and indeed expected to out-fly the Korean enemy—which they eventually did with better than an eight-to-one kill ratio. We must be better prepared for quicker IT and software development. The "cyberspace dogfight" is now upon us! Check six!

Notes:

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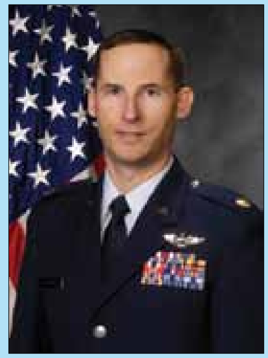

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Is Acquiring Space Systems a Wicked Problem?

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According to the National Security Space (NSS) Acquisition Policy, "the acquisition of Department of Defense (DoD) space systems results from the interaction of three complementary processes: the Joint Capabilities Integration and Development System under the authority of the chairman of the Joint Chiefs of Staff; the Planning, Programming, Budgeting, and Execution process under the authority of the DoD comptroller; and the NSS acquisition process under the authority of the DoD Space MDA [Milestone Decision Authority]."[1] Said differently, the space acquisition process closes the gap between what capabilities the national security space enterprise has now and the capabilities it needs to achieve national security objectives in the future. What is left then, but to resolve the open problem of designing and acquiring the space systems to close the gap? Space acquisition professionals know intuitively and from experience that this is no simple problem to solve. But it might not just be a complex problem either. Acquiring space systems may be a *wicked* problem which, while not impossible to solve, requires special handling. This article assesses space acquisition against the nature of wicked problems, reviews mitigating techniques for wicked problems and evaluates the current system on incorporating these techniques.

Recognizing Wicked Problems

The concept of wicked problems is not new. The phrase is generally attributed to two University of California-Berkeley professors, Horst W. J. Rittel and Melvin M. Webber, who in 1972 initially defined the characteristics of wicked problems in the context of government policy and societal issues.[2] Rittel and Webber distinguished 'wicked' problems from 'tame' problems, such as those in science, mathematics, engineering, or even recreation. And while tame problems are not necessarily simple to solve, they can be solved to closure: a road can be constructed to withstand environmental conditions; bridges can be designed to hold a certain capacity; chess games are usually won or lost on skill, and so forth. By contrast, the nature of wicked problems is such that there may be no single correct answer, for example: Where in a city should the highways be? At what point along a river shore should a bridge be built? Because the problem behind social or policy questions is usually ill-defined, the professors dubbed these questions as 'wicked', meaning vicious or tricky.[3] Rittel and Webber identified 10 properties of wicked problems:[4]

1. There is no definitive formulation of a wicked problem.
2. Wicked problems have no stopping rule.
3. Solutions to wicked problems are not true-or-false, but good-or-bad.
4. There is no immediate and no ultimate test of a solution to a wicked problem.
5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.
6. Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
7. Every wicked problem is essentially unique.
8. Every wicked problem can be considered to be a symptom of another problem.
9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.
10. The planner has no right to be wrong.

Briefly evaluating each of these properties from a space acquisition perspective can help to answer the fundamental question of whether it is wicked problem or merely a complex tame problem.

There is no definitive formulation of a wicked problem.

Space systems are ultimately acquired to meet national security requirements: bandwidth shortfalls, navigation and timing accuracy, remote sensing data, and so forth. The DoD choice of these systems signals a predisposition toward a certain solution—in this case a space-based capability within certain budgetary or time constraints. In an unrestricted sense there are other solutions—either less technological or terrestrial in nature—which could be employed: additional line-of-sight communication systems could be acquired to provide bandwidth, a better map and compass for navigation, high-altitude airships for remote sensing, and so forth. As discussed later herein, the space systems approach to meeting requirements is a tell-tale sign (consistent with other wicked problems) because some assumption about the nature of the solution is necessary in order to truly address the underlying problem. Wicked: Yes

Wicked problems have no stopping rule.

The conclusion to a space acquisition is generally not based on reaching a resolution to the underlying problem. Systems become operational, programs run out of money, contracts reach their conclusion. None of these solve the initial problem for which the acquisition was initiated. Recall that the crux of the problem in space system acquisition is to close a gap between current and future capabilities. Closing that gap is possible, but the timeline involved typically means that another, future gap will exist leading to additional programs in the future to solve the same problem. Consider that almost no national security space system currently deployed or in advanced development is a first generation capability in its mission area. GPS IIF, Space-Based Infrared System, Global Earth Observation System of Systems/National Polar-orbiting Operational Environmental Satellite System, Advanced Extremely High Frequency, Space Surveillance Network: all represent a continuously evolving march of technology. Wicked: Yes

Solutions to wicked problems are not true-or-false, but good-or-bad.

Few military space capabilities are evaluated on a 'yes-no' scale, equivalent to 'true-false.' Instead the capabilities are considered inherently good, and a 'good enough-not good enough' basis is more appropriate. If unsure of how to assess this criteria consider the statement, "The military has intelligence, surveillance, and reconnaissance (ISR) capability." That is not really a point of contention. "The military has *enough* ISR capability" highlights the difference. NSS acquisition programs are more frequently created to focus on the latter than the former. Wicked: Yes

There is no immediate and no ultimate test of a solution to a wicked problem.

Rittel and Webber suggest that the solutions to a wicked problem may have repercussions over time—second and third-order effects—which can continuously affect the goodness of the solution over long periods.[5] With few exceptions (such as intentional space debris created by launch or disposal operations) the timelines involving military space systems are sufficiently finite (one to two decades) so the effects of the system can be traced and accounted for. Wicked: No

Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.

This is largely self-evident for space systems. Once large amounts of time and money have been spent on a program, the military is committed to this course of action. Cost overruns and schedule delays may slow the system from being fielded, but the decision of a space system as the solution is rarely in doubt. Wicked: Yes

Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.

A space acquisition request for proposals will typically attract multiple offers. However, there is no way for a program office to identify or consider all the possible space systems which could provide acceptable solutions. Therefore the space acquisition professional "…relies on realistic judgment, the capability to appraise 'exotic' ideas and on the amount of trust and credibility … that will lead to the conclusion 'OK let's try that'."[6] Wicked: Yes

Every wicked problem is essentially unique.

It may appear contrary to suppose that each space acquisition is unique give the earlier assertion that each space system is an evolution of a previous system. However the circumstances which define a specific acquisition program (budgets, contractors, government personnel, users, scenarios, regulations, etc.) differ substantially from all other programs to the point where there is no beneficial category (i.e., wideband military satellite communications, or even GPS) in which the solution from a previous acquisition can be wholesale applied. Wicked: Yes

Every wicked problem can be considered to be a symptom of another problem.

In a world without conflict, the military would not require space systems to support warfighting operations. It is our understanding of the nature of current conflict which eventually leads down to the level of the requirement for national security space systems. However it is not within the scope of the space acquisition to solve the higher-level problem. A more reasonable expectation is to not disrupt the state of affairs at the next higher level up. One example: as space becomes a contested environment internationally, the space systems we use for national security could actually degrade national security if they are seen as a threat to enemies who would take hostile action against our systems. Wicked: Yes

The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.

This property of wicked problems largely addresses the ambiguity which can occur when different points of view on the same problem lead to differences of opinion as to the nature of the problem. Because it's a characteristic of wicked problems that they cannot be evaluated logically or strictly on the goodness of a solution, the nature of the problem may not be universally recognized or accepted. Wicked: No

The planner has no right to be wrong.

In scientific or academic circles, a theory or explanation can be postulated then tested to failure—at which point the theory must be revised or scrapped. In space system acquisition, there is no do-over since there are cost and mission consequences for failure. In short, wicked problems do not have to be fair: there may not be a correct systemic or programmatic solution, but there can be countless incorrect solutions which do not adequately resolve the initial problem. Wicked: Yes

It is fair to say from this analysis that space system acquisition is or very closely approximates a wicked problem, exhibiting eight of the 10 properties. Fortunately, there are methods by which wicked problems can be tamed, or at least broken into marginally tame problems for solution.

Coping with Wicked Problems

Dr. Jeff Conklin, in studying ways to reduce or cope with social complexity and other wicked problems, developed a technique called Dialog Mapping in which he identified six ways a wicked problem could be made more manageable:[7]

- Lock down the problem definition.
- Assert that the problem is solved.
- Specify objective parameters by which to measure the solution's success.
- Cast the problem as "just like" a previous problem that has been solved.

- Give up on trying to get a good solution to the problem.
- Declare that there are just a few possible solutions and focus on selecting from among these options.

In addition, Prof Nancy Roberts of the Naval Postgraduate School has put forth three strategies for coping with wicked problems, differentiated by where the power is dispersed among the stakeholders involved or impacted by the problem. Her three strategies are collaborative, competitive, and authoritative.

> Following the path for wicked problems, we then ask how power is dispersed among the stakeholders. If power is concentrated in the hands of a small number of stakeholders, then authoritative strategies can be employed to identify the problem and its solution. If power among the stakeholders is dispersed, we proceed to a third question. Is power contested among the diverse set of stakeholders, meaning is there a struggle for power that characterizes their interactions? If power is dispersed and contested, then competitive strategies can be employed. If power is dispersed but not contested, then collaborative strategies can be utilized. Thus, we find three generic strategies for coping with wicked problems.[8]

Assessing How Space Acquisition Copes with Wicked Problems

By now, several of these mitigation techniques should look familiar to practitioners of space systems acquisition.

- Lock down the problem definition: Freezing system requirements early, as well as developing cost profiles and delivery timelines.
- Assert that the problem is solved: Milestone Decision Authority evaluates key decision points.
- Specify objective parameters by which to measure the solution's success: Identify and track measurable key performance parameters.
- Cast the problem as "just like" a previous problem that has been solved: Acquiring evolutionary systems and standardizing acquisition processes.
- Give up on trying to get a good solution to the problem: not applicable here.
- Declare that there are just a few possible solutions and focus on selecting from among these options: Self-regulated by the number of offerors for a particular contract, though acquisition laws prohibit government-imposed restrictions.

Conklin does offer a cautionary note though, that taming wicked problems in the short run may lead to failure in the long run—a wicked problem is still a wicked problem even when dissected or packaged differently.[9]

With regards to Professor Roberts' strategies, it's clear that the military espouses a combination of authoritative and collaborative strategies to tame the wicked acquisition problem. The authority rests at various levels, but flows continuously from through the DoD acquisition hierarchy from Milestone Decision Authority to program management team. Collaboration is witnessed from the requirements definition phase through to system operational acceptance. Operators, users, acquirers, and budgeting experts all join forces to find an acceptable solution. However competitive strategies do not apply well within the space system acquisition framework since the decision-making power, while somewhat diverse, is generally not contested.

Space systems acquisition has never been portrayed as an easy task. In fact, as discussed here, it's wicked business. Fortunately, the space acquisition framework mitigates the wicked nature of the problem. By rigorously following the system put in place and maintaining vigilance for the pitfalls of wicked problems this wicked problem can be tamed.

Notes:

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[2] Horst W. J. Rittel and Melvin M. Webber, "Dilemmas in a General Theory of Planning," paper presented, Policy Sciences, American Association for the Advancement of Science, Boston, December 1969.

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[4] Ibid.

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After receiving his commission from the United States Air Force Academy in 1995, Major Martin was assigned as a spacecraft engineer at the 1st Space Operations Squadron, Schriever AFB, Colorado where he supported the GPS and DSP satellite constellations. From 1998 to 2002, he led the spacecraft engineering section for the Space-Based Infrared System and Defense Support Program ground stations (2nd Space Warning Squadron) at Buckley AFB, Colorado, maintaining space system safety during the ground system transition from acquisition to operational status. Major Martin then served on the staff of the Logistics Management Directorate and the Ogden Air Logistics Center, Hill AFB, Utah. In 2004 he was assigned as chief systems engineer, TSAT Mission Operations System, MILSATCOM Systems Wing, Space and Missile Systems Center, Los Angeles AFB, California. He served in that position until 2007 when he reported as a student to Fort Leavenworth, Kansas for the US Army Command and General Staff College.

Ten Rules for Common Sense Space Acquisition

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Many of the problems in space acquisition are caused by factors outside the control of program managers. These factors include the loss of institutional systems engineering and engineering talent, the elimination of program cost and schedule reserves, the volatility of program funding, and lack of stable requirements. While many studies and panels have well-documented these findings and even offered some viable solutions, little has changed in response to their recommendations. Furthermore, most panels focused on institutional problems rather than how a program manager can effectively design, develop, deliver, deploy, and support a space system given the realities of the acquisition environment.

At the end of the Cold War in the early 1990s, there were tremendous pressures on space program budgets as the US sought to participate in the expected "peace dividend."[1] The US space program was growing, as were the dependencies on it by the military services. Strategies were promoted to cope with disparate demands and decreasing budgets, such as total system performance responsibility (TSPR) and faster-better-cheaper (FBC) to name two. These ultimately turned out to be strategies of false hope. They attempted to achieve savings without a fundamental understanding of where they could feasibly be achieved. These approaches can be categorized as wholesale failures, at worst, or deficient because of their top-down resource-reduction focus, at best. Business management strategies (such as Organizational Development,[2] Total Quality Management,[3] Six Sigma®[4]) were also employed; while these provided useful constructs, that—when implemented properly—can show savings, their benefits were touted before the hard work was done. In the end, they provided little positive benefit to our many complex space programs.

The reality is that the space community cannot complete the fundamental hard work of effectively building and deploying space systems by reading the findings of studies and panels on institutional and resource challenges and/or brushing up on the management philosophies de jour. Despite these ever-changing factors, systems still have to be engineered, built, and delivered. The question is: *How can a program manager best manage and engineer a space program for success in the dynamic environment of the real world?* There clearly is no simple answer.

Throughout the history of space programs, there have been many great program managers. Some would frequently dispense unsolicited, wise, and useful advice, while others were more reserved and sage. The authors have been fortunate to have had many of these great leaders as mentors.

The space program leaders of the past had both successes and failures. In fact, the early days of space acquisition programs were fraught with failures—but at times great wisdom can be gleaned from mistakes. There was once a greater tolerance for failure. It is important to build upon the foundation of wisdom and knowledge gained through past programs as we strive for future successes. The successes achieved and failures suffered equipped the great program managers with the "street smarts" needed to successfully design and build complex space systems.

In this article, the authors mine their own years of experience and distill that wisdom passed on to them over the years by leaders and mentors into a set of common-sense recommendations or "rules" for program managers designing, developing, delivering, deploying, and supporting space systems. These rules focus on issues within a program manager's control. When combined with strong managerial and leadership skills, it is hoped that these rules or "guideposts" will help give program managers the best chance of achieving success, even while overcoming program limitations within a difficult and ever-changing environment.

The Findings and Recommendations of Studies and Panels

Finding problems associated with space systems acquisitions is not something new. Over the years, there have been a myriad of studies conducted by government-chartered study panels consisting of the best, brightest, and most experienced government, commercial, and educational leaders in the space business.[5] These experts have documented a wide range of irrefutable and intractable management issues, most of which are far beyond the responsibilities of a program manager, and therefore cannot be solved by a program manager alone. Similar related studies of the defense industrial base and its management of the acquisition of defense systems have also offered numerous findings and recommendations echoing those pertaining to space systems acquisitions. Some study panels made very good recommendations for addressing the findings. The following is a summary of some of the many recommendations:

- Streamline organizations.
- Use technology to reduce costs.
- Balance cost and performance.
- Stabilize programs/realistic budgets and cost estimates.
- Expand use of commercial products.
- Enhance quality of acquisition personnel and rebuild program management and engineer processes.
- Improve the requirements process.
- Conduct planning and risk reduction activities and separate technology programs.

- Establish quality program baseline/expectations and resources.
- Set minimum thresholds for technology maturity.
- Establish mission success as the guiding principle.
- Allow program managers to trade requirements if needed.
- Train and develop staff.
- Clearly define authority/accountability and responsibility (including contractors).
- Develop robust systems engineering.
- Align contracts for success.
- Budget programs to 80 percent success.
- Schedule approaches to field needed capabilities rapidly.
- Utilize risk-based source selection.
- Pay attention to critical systems engineering processes early in the program, before making key acquisition decisions.
- Reinstitute development planning.
- Establish key systems engineering/program manager personnel experience and stability.

The recommended solutions generally address problems at the resource level. Unfortunately, little has changed in response to these studies and their recommendations. The collective wisdom of these panels has been lost in the bureaucracy, or "astropolitics,"—and quality recommendations have basically gone unimplemented.[6] These well-meaning efforts have not changed the environment in which program mangers operate. This is unfortunate as most of the study panelists have been recognized for leadership in their professions. They have had a unique ability to shape their own personal and business environments, creating conditions for tremendous success. The authors have heard these leaders mention, in private conversation, that they participate in an earnest and patriotic hope to improve national space and defense efforts.

What should be done? What should we study next? Defense Secretary Robert M. Gates was on-target when he told the Senate Armed Services Committee on 27 January 2009 that repairing the defense acquisition system will take more than another study. According to Secretary Gates, "Since World War II, there have been nearly 130 studies [of procurement policy] to little avail."[7]

Nearly all of the studies cite institutional and resource shortcomings, inadequate budgets, insufficient institutional systems engineering and engineering talent, weak program cost and schedule reserves, volatile program funding, instable requirements, and the like. While the studies addressed these issues solidly and with sound prescriptions, they did not focus on what program managers could do specifically to better acquire a space system. A program manager must live with the reality of resource issues, especially today when the Department of Defense (DoD), US intelligence community, and National Aeronautics and Space Administration (NASA) acquisition efforts fight for priority with competing societal needs and a severely damaged economy.

Limited Success of Tried Coping Strategies

Given the environment of long-standing resource limitations and ever-evolving priorities, national space institutions have explored various coping strategies, some of which achieved modest success. However, these strategies did not solve the over-arching issues partly because of their top-down resource and management focus.

The early years of the National Reconnaissance Office (NRO) provide a shining example of the establishment of a lean, mean, and effective space acquisition program. The NRO recognized the need for streamlined processes and procedures that would enable it to speedily and effectively achieve its significant national mission objectives. This produced intense pressure to create tight, cohesive government management teams. The rules for organizing these small management teams were set out in Battle's Laws, which, shown in figure 1,[8] were crafted by the Corona/Discoverer satellite system director, Col Lee Battle, as part of an early effort to achieve hard-hitting, rapid success.

Battle's Laws

Listed more or less in their order of importance:

1. Keep the program office small and quick-reacting at all cost.
2. Exercise extreme care in selecting people, then rely heavily on their personal abilities.
3. Make the greatest possible use of space systems development supporting organizations. You have to make unreasonable demands to make sure of this support.
4. Cut out all unnecessary paperwork.
5. Control the contractor by personal contact. Each man in the program office has a particular set of contractor contacts.
6. Hit all flight checkout failures hard. A fault uncorrected now will come back to haunt you.
7. Rely strongly on contractor technical recommendations, once the program office has performed its function of making sure the contractor has given the problem sufficient effort.
8. Don't over communicate with higher headquarters.
9. Don't make a federal case out of it if your fiscal budget seems too low. These matters usually take care of themselves.
10. Don't look back. History never repeats itself.

Figure 1. Battle's Laws.

Battle's Laws provided an important foundation for the NRO's early successes. A thoughtful examination reveals that Battle's Laws are all about organizing the government program office. Early NRO management successes in acquisition, operation, and sustainment of important satellite systems were legendary, and they were accomplished through smart, lean, well-funded, empowered program offices working together as a tight-knit team with the best contractor teams in US industry. The combined government and industry teams also had the resources, gumption, mission, and the secrecy needed to survive repeated failures until major successes were achieved.

No doubt, well-funded, powerfully staffed government and contractor teams can get vital work done.

The organizing paradigm of the early NRO has since changed. In its early days, the NRO leadership was able to acquire the best military space system engineers available. The officers and enlisted personnel assigned to the organization were given stable, decades-long assignments in Los Angeles, Washington, DC, or elsewhere, making them a special-class member of the military. However, the advantages that the NRO had in hiring the best talent, and through other personnel practices, have been lost over time. As the US Air Force downsized, the number of personnel with strong engineering talent entering and staying in the military decreased, shrinking the available resource pool; at the same time, the demands for DoD and NRO space programs increased, leading to a shortage of quality engineering talent that has impacted both the DoD and NRO space communities in recent years. These communities currently suffer from staffing pressures, and there is an unhealthy reliance on relatively inexperienced, junior officers who are manning program offices. To complicate the NRO's problems, its funding practices are now subject to more stringent and intrusive management reviews than in the past. Its traditional ability to employ management reserves to defeat engineering challenges is also gone.

Not even Battle's Laws can make up for the lack of smart and wise acquisitions or systems engineering expertise; without a good mix of experienced, knowledgeable staff on the NRO acquisition teams, their programs took hits just like other military, civil, and commercial programs.

Besides the NRO, other governmental and corporate organizations attempted to respond to the difficult challenges of efficiently and effectively acquiring space systems in a resource scarce environment. During the 1990s, NASA implemented FBC as a way of ensuring the currency of its engineering community and responding to significant and draconian budget pressures that were evident during the Clinton Administration. NASA reasoned that it could sustain and invigorate the vitality of its industrial and engineering base by conducting a wide variety of programs, albeit managed in a high-risk environment.[9] It was hoped that these programs would be worked successfully with a streamlined management approach. FBC attempted to "improve performance by being more efficient and innovative."[10]

The real driver behind FBC was that NASA's culture had grown to performing only "flagship" class, very expensive, missions in the 1980's, like Magellan and Cassini—each costing $2.5 to $3 billion. At that price, NASA could only afford one or two missions per decade. The FBC paradigm shift attempted to accomplish planetary missions at a much lower cost. It was successfully demonstrated by John Hopkins University's Applied Physics Laboratory (APL) with the Near-Earth Asteroid Rendezvous (NEAR) mission (i.e., the first Discovery mission) and by the Jet Propulsion Laboratory (JPL) with the Mars Pathfinder mission (i.e., the second Discovery mission). NEAR was built, launched, and landed on an asteroid for $125 million; the APL even returned money to NASA. With the greater risk assumed by FBC, failure was more acceptable. Loosing a $150 million mission was deemed acceptable when compared with loosing a $3 billion flagship system where the guarantee that the system would work drove up costs.[11]

Unfortunately, spectacular failures in the late 1990s, all of which were tied to simple engineering errors, doomed significant aspects of the FBC approach. The pendulum had swung too far toward cutting cost. FBC died because there were two failures in a row.[12] FBC was a Faustian bargain; and its failures led to a crisis within NASA.

> **Author Thomas D. Taverney:** One of the wisest assessments of FBC was kept on the wall of the graphics department at Infotec, when I worked there. It said: "Faster-Better-Cheaper … pick two." Our graphics department always knew you could not have all three at once when producing documents and briefings. This clearly is also relevant to acquiring space systems.

Another management philosophy, TSPR, was first adopted and then discarded by NASA, but then practiced by the US Air Force during the 1990s. This coincided with DoD's dramatic reduction in force and the devastating loss of its engineering and acquisition talent. The thinking behind TSPR was to give, as the name implies, total system performance responsibility to a contractor. It was argued that this would achieve savings and efficiencies within the total program by reducing the government acquisition and intrusive monitoring teams. It was hoped that TSPR would also give the contractor the flexibility to simplify the integration of all aspects of a program, determine the best resources to get the job done, and reduce costs by eliminating redundant management systems.[13]

Unfortunately, several space contractors did not effectively deploy TSPR on significant and very expensive space acquisition programs. They received the increased TSPR responsibilities while the DoD was cutting program budgets. They were given more responsibility and more to do in performing this responsibility, but—combined with reduced budgets—this was a prescription for disaster. The bigger issue was that these programs were improperly baselined from the beginning; they were basically non-executable from the start. TSPR exacerbated this by constraining visibility into these pending disasters. Under TSPR, serious issues were not visible to the US government and were therefore not addressed.

As noted in a 22 March 2002 article in *Defense Daily International*, Mr. E. C. "Pete" Aldridge, the DoD's former senior acquisition official, complained, "The problem with the current TSPR concept … is that the interests of prime contractors—the need for short-term profit—is fundamentally different from the needs of the Pentagon that is charged with maintaining long-term national security, and the preserving means to produce the sophisticated tools of war."[14] With TSPR, a government management team was often unable to effectively intervene and assist its contractors. The US government's professional acquisition and engineering workforce had been eviscerated by changes in manning strategies. Instead, there was a dependency on contractors to provide that expertise. The catastrophic effects of TSPR and associated staffing philosophies were not limited to the Space-Base Infrared System (SBIRS) and Future

Imagery Architecture (FIA) programs.[15] The program office director on another system bluntly told the US Air Force Scientific Advisory Board that his program was non-executable because of manpower losses. These losses were only partly resolved by reaching into the US Air Force Reserve for officers who were willing to return to active duty to assist.

Where Does this Leave Us Today?

The reality is that the success of these programs cannot depend on institutional and resource changes nor on the management philosophies de jour to complete the hard work of effectively building and deploying space systems. Satellites and their supporting components of space lift, ground-based planning and operational components, and sustainment systems still have to be engineered, built, and delivered. So the question is: *How can a program manager best manage and engineer a space program for success in the dynamic environment of the real world?*

The Rules

Ultimately the program manager's job is to successfully acquire space systems, and to do this within the projected budget and cost. Rules or guidelines that capture and provide thought leadership and perhaps even lead program managers towards success can be very valuable.[16] The rules we present in the remainder of this article are really "thought guideposts" based on time-tested axioms and wisdom gleaned from the past. They are applicable to actions undertaken by entire government, contractor, and customer teams, and include specific engineering guidance. They are intended for consideration as program managers establish baselines and manage their programs. It is hoped that they would help empower a program manager to surpass program limitations, difficult and ever-changing environments, and evolving management approaches.

1. Put together the right team—one that is small, agile, intellectually honest, quick to respond; this team is the foundation for success.

The old adage that "time is money" is certainly true in the space business. Rapid decision-making is essential. It is also true that "standing army costs" on an ongoing basis can be the undoing of any program. How does one achieve an agile and speedy organization? It is critical to establish the right team — acquire the best and right people. Organize a lean team and clearly define responsibilities, authorities, and accountabilities. Foster open, healthy, and professional relationships; having a close-knit team that has trusting and rapid communication channels is fundamental.

A lean management team needs to be cohesive. It is also important to invigorate team morale. Reward good people and give credit freely and appropriately. Also, do not underestimate the power of high morale or the risk to the program when morale is low. Sadly, some managers use punishment as a tool for motivation—but it is no sign of success. Program managers should turn from the "my win, your loss" paradigm to one that suggests, "our win, our loss—we need to accomplish this together."

The authors have found that teams that laugh together are more likely to share information and a common, positive destiny; on the other hand, they found that teams composed of members who take themselves and their positions too seriously or are intimidated by or distrustful of the other members have poor communications and are more likely to perform poorly or fail.

Finally, demand intellectual honesty. Being honest does not mean you cannot be cordial. Foster professional respect and keep the focus on program issues, not on personal issues.

1a. Acquire the best people possible, empower them with enough authority to do their jobs, and hold them accountable.

Hire people who know how to get your business done. Staff the program with people who have the right skills and experience, then give them the training and tools to do the job.

Unfortunately, this ideal staffing scenario is usually not a reality. If you cannot staff with the right skills and experience, you must factor this into your risk assessments and baseline negotiations (see rules 3 and 5). Also, be ready to reposition your strongest resources—people—to where they can best serve the program objectives as program phases, challenges, and priorities change.

When the best-of-the-best US Air Force engineers were being specially selected to work on the NRO's early programs, those who were chosen were known for their fearlessness, technical competence, and ability to focus on the bottom-line of program success. Too many today are unwilling to stick out their necks for what is right for the taxpayer and necessary for program success; they are more concerned about the consequences to the next 20 years of their careers.

Those who care about a program's success will have opinions on how best to accomplish the objectives.

> **Taverney:** At one point in my career, I managed the replacement of a Vietnam-era transportable and mobile landing system. My company had undertaken this program as a fixed price contract, and had underbid the incumbent by 33 percent. We were clearly in a tough position. We had a short 18-month schedule to complete the effort. I assembled a small team of our very best systems engineers, hardware engineers, software engineers, planners, trainers, operators, logisticians, and technicians. All of these people were section leaders, and a few had managed programs in the past, so I tried something innovative and new. I told the team that the responsibility for program management would rotate between the specialties depending on the program's phase. We started out with a systems engineer as the program manager—as we firmed up the requirements and completed the systems engineering and test and evaluation management plans. The program manager role then rotated to the hardware developers, then to the software developers as we built and performed integration and test on the system. A "loggie" (logistician) was the program manager as we rolled out the system for field test and acceptance. Then a senior trainer took over the role as we transitioned the system to the US government. While, I wouldn't recommend this approach as a universal solution, it drew our small team tightly together. We knew that we would each have a turn as a program manager, and this made everyone very sensitive to the challenges of that role.

Another key lesson learned over the years is that having "feet on the ground" in the contractor's facility and "face-to-face" time with the users on a regular basis is vital to understanding what is really going on; these give another perspective to the facts provided in earned value management system reports and program management reviews.

> **Author James D. Rendleman:** I worked on a program where the prime contractor demanded the government deliver a very specific space shuttle launch window for its payload. This presumed launch window did not match any calculations made by NASA's engineers and its vast array of computer-based mission planning resources. The dispute festered until one day, while walking through the contractor's facility, the government mission design lead saw a globe with a string hanging from its North Pole. He asked, "What's the string used for?" "To calculate the launch window requirements." This is a rather sad, but true story.

Value brilliance no matter how it is packaged. Select excellence always.

> **Rendleman:** I have seen contractor managers thrown out of meetings by NASA because they didn't know their systems; interestingly, in a moment that demonstrated excellence really mattered, the same Texas-bred, blue-jeaned NASA engineer managers then insisted on only talking to the contractor's uniquely flamboyant software engineer, because that engineer really understood the system. Refreshing!

Give team members authority and power and then hold them accountable. Ensure individuals are accountable, not committees; you cannot hold committees accountable. Proper alignment of authority, power, and accountability are essential and must apply to everyone at all levels. Numerous texts and studies point out that authority, power, and accountability must be consistent. The problems created by TSPR that were described previously are a classic example of how improper alignment of authority, power, and accountability can cause programmatic failures; under TSPR, US Air Force program managers had no authority to resolve the problems they faced.

1b. Organize to be lean and mean.

Keep management teams small and focused; always be prepared to optimize team staff and organization as the program evolves. This approach reflects the best sentiments of Battle's Laws and philosophy.

Today, this approach is in practice at the mission control stations for DigitalGlobe® and GeoEye®,[17] in small payloads at the University of Colorado, and in operations at the US Air Force Reserve 6th Space Operations Squadron—the backup for the National Oceanic and Atmospheric Administration's Defense Metrological Satellite Program. The APL is flying a mission to Pluto and another to Mercury out of the same mission control center—which, based on the physical space, the JPL or Johnson Space Center would consider a conference room. The footprint of the 45th Space Wing and Space and Missile Systems Center military launch combined task force has been dramatically reduced, as the business case for United Launch Alliance activities bears out.[18] In terms of acquisitions, this approach is successfully employed in payloads that are being developed by the Defense Advanced Research Projects Agency and the Air Force Research Laboratory.

Also, use committees and integrated process teams (IPTs) judiciously. If you form one, it should have a specific purpose and be disbanded when its purpose is fulfilled. Committees do not make decisions and the staff and lawyers only tell you what you already know or cannot use—so minimize the use of committees to that which is necessary. You still need individuals who you can hold responsible.

> **Rendleman:** Once, while visiting former Deputy Secretary of Defense Gordon England in his office, while he was executive vice president of General Dynamics, I asked him where his staff was. He replied, "I don't need a staff. I hire people who know their business. Staff will only tell me things I already know." England was part of a management team that helped General Dynamics restructure and become more efficient.

IPTs have a place and are valuable when used properly. Do not let IPTs (or committees) take on "a life of their own." Some programs get hopelessly bogged down in committee meetings and management reviews, expending hour upon hour of the government and contractor teams' time in preparing for, attending, and debriefing meetings. Team optimization might entail eliminating IPTs (or their equivalents) if they are not as effective as they were in an earlier stage of the program. Alternatively, it might be better to streamline IPTs and/or shift resources among IPTs for greater effectiveness.

1c. Build and maintain healthy, open, professional relationships with team members, counterparts, and contractors.

Rely strongly on the recommendations of your team members, but make sure they give problems sufficient consideration. Make sure their decision loops are short; they have solid, agreed-to definitions of their authorities and accountabilities; and that they understand the processes for making decisions.

> **Taverney:** While commander of Space Launch and Range, I was fortunate to have previously-developed relationships and friendships within each of the launch contractors. When I would hear about a problem, I was never shy about calling the contractor's expert in-the-know to get the on-the-ground truth. Contractors do not usually try to hide anything from you; but when a problem surfaces, it may be hard at first to determine what precisely has occurred—as the communications may come through various paths and may be filtered by a variety of people.

Putting your feet in your contractor's or user's facility is also a great way for creating and nurturing working relationships. As the authors moved up in the ranks, the relationships they built while working at contractors' facilities later gave them direct communication channels they could rely on to ascertain what was really going on.[19]

Enhance communication with your industry counterparts with consistent, frequent personal contact. This is critical to success in all businesses. The authors have met successful managers and leaders in various industries and it was clear that their success was invariably tied to personal partnering with customers, team members, and suppliers. One cannot foster solid relationships by reading status reports or other documents of success or failure.

2. Execute, or suffer execution.

As noted by Mr. Anthony "Tony" Spear,[20] in his scathing yet folksy *NASA FBC Task Final Report*, "The project manager is 'Captain of the Ship.' The buck stops with him or her."[21] A program manager is usually picked to lead a program because of his or her expertise, experience, and—hopefully, moxie.[22] Unfortunately, organizations have a tendency to load up and sometimes crush these leaders with ministerial tasks or administrative duties that can take up to 60 percent of their valuable time and focus. This is not done maliciously; work and activity naturally gravitate to people who get things done—it happens.

Levying additional duties on program managers without considering the impact to the programs, or potential alternatives, is misguided and entails risk. It detracts from the program-focused leadership that is vital to steer work to completion. Program managers must push-back against non-essential tasks; and their supervisors must wrestle with handing out additional, non-essential, or distracting tasks to their program managers.

Treat your time like it is gold; your time is one of the key currencies of a successful program. Your job is to deliver the product you have been charged to build, on-time, and on-budget. Let your people know that this is your priority. Forge a clear understanding with your bosses; have them affirm this priority—even though other tasks will arise. Get their buy-in on this priority early, and use it to make decisions regarding how you spend your time and on what you will focus. Have the courage to say no to other demands that conflict with what it takes to execute your program.

Of course, cut out unnecessary paperwork (and e-mails). Again, these sentiments are fully reflected in the legendary Battle's Laws. Staff communications that are not directly related to program execution and their associated coordination, at some point, become more of a burden than a benefit. Also, understand the value of every meeting you attend. Set a time for a meeting, and do not let it run over. People will get the message when you stop the meeting at its appointed time. They will learn to focus on the issues and drive them home in the allotted time.

> **Taverney:** While vice commander of Air Force Space Command, I told everyone that we would start meetings on time and end them on time. When a meeting started, I would emphasize that those in attendance should make sure that they told me what they needed me to hear—early on, so that at the end of the meeting, their key points were not left unsaid. When, in my first meetings, I got up and walked out at the appointed end times, it became apparent that I was serious. Within a week, the people in these meetings got to the point quickly. I also had people categorize meetings by their purpose. Knowing the purpose and subject allowed me to establish a time budget for the meeting commensurate with its value. I also asked for background information so if the same subject were discussed in some other meeting, I could appreciate its context.

The point here is simple. You can get help on anything except on getting someone else to take responsibility for executing your program. The program is yours and cannot be delegated. You are charged with significant responsibilities and must address a myriad of requirements; you are responsible for delivering the program—that is job number one. There will be pressures to do many other things—and many of those things will have to be done; but if these activities prevent you from giving the appropriate and necessary attention to executing your program, you must decide when to say "stop" or "enough."

3. Establish a solid baseline.

An improperly baselined program cannot be executed successfully—even by the best program office. Programs that start with a non-executable baseline can only struggle going forward.

The poster children for these problems are the aforementioned SBIRS and FIA fiascos. SBIRS and FIA were started without enough money or resources to successfully execute. The technology readiness levels for the proposed systems and architectures were woefully inadequate. Cost estimators and systems engineers did not stand up and say that disasters were pending. As badly birthed programs, they continued to struggle, despite the upgrade of the program office and contactor staffs to the very best people available. The lesson is that even the very best mangers, with the very best program office personnel, cannot successfully execute a non-executable program.[23]

How can one establish a solid baseline? Pay special attention to the wide spectrum of systems engineering tasks: requirements analysis and traceability, engineering change control, interface definition and control, system design reviews, and test and verification planning. Unfortunately, systems engineering talent is often not valued by management. Systems engineers are often sent to record meeting action items and track requirements rather than to challenge every requirement, assumption, constraint, ground rule, and so forth, and provide real trade-off and cost/benefit analyses. Systems engineers must perform these vital functions.

The program manager and project team must understand the requirements; a space system should be built to satisfy a particular mission need. Ensure you have a robust systems engineering process in place to establish and refine the stated requirements, the derived requirements, and the allocation process to the various components of the overall system. Engage with the user, developer, and verification team during requirements development to ensure they are understood, achievable, quantifiable, and verifiable.

> **Rendleman:** Requirements matter. I worked on a program where the contract called for the delivery of a non-standard government furnished equipment space shuttle elliptical/polar flight out of Vandenberg to perform intercepts with U-2 aircraft circling over the pole. There were huge costs associated with the planned non-standard polar orbit and the aircraft's sorties required significant combat search and rescue support. My team and I looked at the program requirements and found that a standard space shuttle 28.5 degree inclination of 150 nautical mile orbit would work just fine. It turned out that the new orbit provided the same number of daily intercepts as those available over the pole, and the U-2 sorties could easily be orchestrated and supported from existing bases from lower latitudes (e.g., Hawaii, Texas). Of course, the prime contractor complained, saying we would be in breach of the contract by not providing intercepts with the target aircraft every orbit for the duration of

the mission. I challenged the contractor to show me how the U-2 pilot could stay up 24/7 for a week or more. The point was made and the mission parameters were changed within the real requirement.

Ensure the program has an adequate budget with program reserve and an executable schedule with margin. There will always be problems and obstacles to achieving success. Reserve and margin allow for the determination of solutions and the development of tools to implement them. A contractor's bid does not assure the quality of the baseline. The bidding organization must dig into the elements that support it. In general, experience tells us that there should be a generous financial reserve and even greater schedule slack depending on technology maturity and program phase. While there are pressures to take reserve and slack from your program, fight as hard as you can for them. You may not get management reserve, but you should always have schedule margin.

Employ quality software engineers as a foundation to your systems engineering process. Software engineers are the penultimate systems engineers; they track more than 1s and 0s across your system—they track requirements and connections. Unfortunately, failure to properly engage software engineers early in the program can lead to problems, even when the hardware solutions are working nicely. Software problems can derail the best hardware engineering success, and these types of problems have been with us for decades. SBIRS and inertial upper stage programs have had serious software problems, and so have many other systems.

At the end of the day, you are not always in control of the baseline. Frequently you are assigned programs that cannot close (that is, cost/schedule versus technical requirements).[24] If you are handed such a program, you have two options. You can set up a stoplight (red, yellow, green) chart that matches the programs cost and schedule risks. Set up as many risk areas as you can. Within these risk areas, define cost, schedule, and technical risks, with dollars and schedule, and brief these at every status review. When risks become real, book them with the requisite cost and/or schedule impact. As a second option, you can make cost and schedule your primary metrics, and define the requirements that you can deliver, making the others optional or available for purchase with additional dollars and schedule. Do not just blindly accept a program that you know to be non-executable with the hope that things will change and get better in the future.

A ground-to-air view of the space shuttle Challenger during liftoff from launch complex 39A.

4. Control the baseline; it is your lifeblood.

Changes have the potential to destroy a program—so a program manager must be vigilant against external and internal pressures to implement them. Rebaseline when executing any substantive changes. Tony Spear recommends establishing a challenging but realistic mission target, obtaining upfront agreements and maintaining them, and defining the mission scope within the constraint of resources, providing for acceptable risk and adequate reserves.[25]

It is easy to fall into the trap of making changes to a program in the name of flexibility; but programs are not well-enough resourced to accept changes without impacting their baselines. Once a program is awarded and program execution has begun, various outlying players will suddenly take an interest in the capabilities that the system might provide them. As a result, the demands or suggestions for requirements tend to grow. Over the life of a long-duration program, the ultimate players—the US Congress and those in the budgeting process—will move funds and leadership priorities will change. Either any or all of these will compel the program manager to rebaseline.

How should the program manager control his or her baseline? First of all, do not accept increased risk. The military, civil, and commercial programs derailed by increased risk are too many to count. A classic and most tragic example of where this occurred is NASA's Space Shuttle program. With schedule pressures to launch all DoD and civil payloads nearly exclusively on the space shuttle in accord with 1982 National Space Policy, NASA managers accepted additional risk and forced a launch outside its established weather and temperature parameters; this led to the 1986 Challenger O-ring failure and disaster.

Rendleman: I was in a US Air Force meeting where the decision was made to not help NASA fund heater elements for the external boosters. We disposed of the request based on a conclusion that NASA would not fly when the weather was so cold that they would be required. While NASA's human safety ethic and mission delays were causing scheduling problems for the US Air Force at that time, we accepted the situation because of the national policy. Who knew that NASA would take on a can-do spirit and ignore its responsibilities to its astronauts by accepting additional risk?

Program managers should carry prioritized sets of their program requirements with them, so they can be jettisoned or modified on a moments notice to ensure the core requirements are achieved. That said, managers will be challenged to investigate additions or insertions of new technologies. They must carefully appraise the need for them and the opportunities they present. These in turn must be balanced against the risks and schedule impacts they may bring. Similarly, proposals to descope and/or reduce technological complexity on a program must be evaluated. All are important.

> **Rendleman:** During the early 1980s, I worked on a program that required real and substantial improvements in the navigation capabilities of the space shuttle for mission success. This was long before the GPS system was declared fully operational. My solution to solving this technical challenge was to propose a program that employed a then-new technology—an off-the-shelf F-16 GPS receiver—instead of selecting and constructing a new "space-qualified" receiver that would sit on a pallet in the shuttle bay. NASA hesitated at first; its leadership was uncertain about the US Air Force's intentions for completing the new precision navigation and timing system's constellation. NASA did not want to accept the risk until it could be better understood. We won NASA over and were given the green light to begin the program. What a difference a quarter century makes in attitudes regarding integrating GPS capabilities!

Once underway, increased risk will emerge and can get in the way of a program's success. Program managers must refuse to accept new requirements, cost, or schedule changes without changing the program baseline, and realigning expectations. Budget cuts should reasonably mandate a reduction in requirements. Requirement additions should reasonably result in added costs and expanded schedules.

Establish correct and measurable metrics for each phase of the program. Each metric must take into account the level of program complexity involved. Analyze key metrics thoroughly to make sure you understand the implications of adverse indications to the second and third orders of consequence. Do not overburden the program with metrics of dubious utility. Then, monitor, monitor, monitor these metrics.

> **Taverney:** Later in my career, I was asked to take over a distressed program. The customer had said, "Not a dollar more, not a day later; we will use whatever you deliver in these constraints, as long as it is better than ballast." I decided to make "Better Than Ballast" a rallying cry on the program. It forced us to think about what we were doing whenever someone thought we could do something a little better with a little more time and/or money. It kept us focused on cost and schedule as much as capability. It became a sense of pride to deliver something far, far "Better Than Ballast." This program was pioneering three different challenging technologies in parallel, but our rallying cry kept our eyes on delivering what could do the job. We have all heard the old adage: "Perfect is the enemy of good enough." In the end, this program was extremely successful. While its success was the result of the great people performing the work, the rallying cry of "Better Than Ballast" turned out to be an excellent management tool for keeping the team focused on controlling the baseline and not accepting increased risk; it even helped to build a sense of pride within the team.

Since money begets stability and technical success, simplify spending to achieve core requirements. Fight for program money to help ensure you can keep and control your baseline intact. Shareholders and customers will always wish you success, but you must have the money needed to achieve it. Fiscal problems will generally be resolved only if your program is perceived as important. Funding stability is critical to program success.

If your program is not properly funded, you need to get additional funding, cut requirements, extend the schedule, or all of the above. Determine your real funding requirements, then firmly and persistently advocate for the added funding until you get it. If your program is not adequately funded, you may need to rebaseline or even cancel the effort. If your program does not obligate and expend on time, the money will be taken away! The government program office and its contractors have different motivations. The government program office balances cost against the product; while the contractors live from quarter to quarter and are driven to deliver profit and growth to their shareholders.

5. Manage risk; it never goes away on its own.

A program manager must establish a robust and proactive risk management approach. He or she should always know the program's risks, and—above all—take ownership of them! Again, Tony Spear had it right when he said:

> The project manager and team are responsible for ensuring that all elements of a project are being implemented with acceptable risk for those project elements under their control and for those outside their immediate project control.…
>
> While project risk at the outset may be high, it must be sufficiently assessed and mitigated throughout development and operations. Not having enough funding or schedule resources are never excuses for failure, and it takes a project manager with good judgment and courage to declare under pressure that the project is not doable for the available resources. This ability to judge, to walk the fine line between challenge and risk, is even more important in today's environment.…[26]

Spear recommends conducting rigorous system and subsystems engineering to establish standards; conducting continuous, rigorous risk assessment and mitigation throughout development and operations; balancing the use of available and advanced technology to achieve mission success; and establishing and maintaining metrics for mission risk and technical, cost, and schedule performance.[27]

A program manager must live, breathe, and satisfy high-payoff, achievable requirements. Not all requirements are created equal. We do not build slam-dunk systems in the space community; there will always be risk (cost, technical, schedule, and programmatic) to achieving success. Eliminating risk is not feasible. In the space systems business, prudent risks must be taken. But, you need to understand the risk, and have a plan to mitigate or handle it should it materialize. Prioritize your risks, and understand their impacts to the mission. Managing (and owning) risk is critical. Program managers should review the risks and the risk mitigation plan early and often. They should do this with the contractor team and with the user representatives to ensure that risk issues get the attention they deserve.

You must also prioritize the requirements that will be worked during a spiral or program increment. Make sure to work the

While performing work on the NOAA-N Prime spacecraft, being prepared to launch in 2008 for the National Oceanic and Atmospheric Administration (NOAA), the satellite was dropped.

priorities with the users and get concurrence on them, the timelines, and budget. The users may not know what is possible, so it is essential that the program manager help them understand the options available and the reasons for any recommendations.

Be prepared to jettison low-priority requirements when programmatic changes or new compelling requirements arise. Use building blocks or spiral development approaches to keep it simple. Work with your users and the contractor to break down the big requirements (which can often take years to satisfy) into smaller, more manageable, "little requirements," and to break down their associated timely spirals and increments. This is especially important for software intensive systems. This approach enables the program to deliver needed capabilities faster within rapidly changing technology refresh cycles.

Simplicity is hard to accomplish, but it saves "big-time."

> **Rendleman:** In 1982, sometime after the failure of an Atlas E engine (from the old iconic Wheatfield strategic missiles), I was selected to serve on a tiger-team to develop a way forward for the remaining launch vehicles. The failure had occurred because a coolant hole was plugged by sealant. This changed the flows within engine's gas generator and caused the engine's ultimate failure (a burn-through) after just a few seconds. The contractor's proposed solution was to drill a second hole. That, in turn, would require an extensive set of new engine tests and requalification firings to reduce or assess the risk of failure because of the changed flows inside the gas generator. I brought my old Air Force Rocket Propulsion Laboratory boss—a cagy, seen-it-all, senior rocket engineer—to the meeting where the need for the drilling and requalification tests were explained and its pricing discussed. His habit was to wait until all of the cards were on the table and commitments have been made before telling everyone where mistakes were made. With about 50 people in the room, he did it again. The contractor's business capture, pricing folks, and division chiefs were in the room—all salivating for the contract changes and new business. The US Air Force procurement contracting officer was also in attendance. The pricing for the "drill-the-hole change to the engine" was discussed along with the costs for the expected, expensive requalification tests. Then the system program office director leaned forward and said words to the effect, "I guess we have to put this to paper in a contract. It has to be done. We have a mission to fly." That is when my old boss struck: "We've never had this type of failure before in hundreds of launches. The Atlas is a good system. Can't we just look up in the engine with a borescope and see if the goop is in the way?" It was such simplicity. I have never seen so many red faces; it was hilarious and great. The solution required no drilling and no requalification tests—and it resulted in a good launch.

Far too often, the risk management approach becomes just another reporting process. To make sure this does not happen, establish a true contractor/program office partnership. Use appropriate contract types and incentives; the level of risk should determine the contract type and the priorities should determine the incentives. There must be competence on both sides of the partnership; this generates mutual respect and a thorough understanding of each party's interests. Defining and enforcing the right risk strategy is basic to success. If possible, have alternate risk mitigation or solution paths.

There is no place that risk has more impact than in the launch business. It is an activity that has an inherent 90 percent probability of success, but 100 percent success is demanded and scarily planned for. Even though some satellite systems have large constellations, we presently do not build spare satellites to cover the risk of launch failure. So when we lose a launch, we also lose critical capabilities for our warfighters.

There is an old saying in the launch business, "A rocket on the pad is better than one in the ocean." But this is tempered by another saying, "There is nothing worse than a good rocket on the pad that we do not launch." The implication is that, if you wait long enough, things will start to go badly. Each launch is a one-of-a-kind, unique event, that is indeed "rocket science." Prudent risks must be taken to carry out a launch.

> **Taverney:** For a while, I was the program manager for the Ground Guidance Station at Vandenberg. In those days, we launched the Titans (III Bs and III Ds) out of Vandenberg using radio guidance. When I took over the contract, I soon came to the realization that the computer we were using was quickly becoming obsolete. Spare parts would soon become hard to find. I discovered that the US Navy (which was previously a big user of these computers) was rapidly decommissioning them. I contacted Navy sources to let them know that I would take all of their decommissioned computers and pay for shipping. Soon we began getting spare computers. I then came up with the idea of having a redundant backup, in case the primary flight computer went down, and we set up that system. So, on the first launch with two computers, as the countdown was proceeding, one of the contractors piped up and said that we had to hold or scrub the launch (and we only had a 10 minute launch window, so a hold usually meant a scrub). When I asked why, he replied that the backup computer was down. We had launched with only one computer for years, so I told him that we could launch with one computer for now. It was a risk, but, a prudent one.

We all know that "time is money"—but so are technical and resource risks. You have to measure and monitor all three. Of course, what gets measured gets done.

6. Make the program schedule a leading metric.

Many in government have worked on programs that have chronically slipped their schedules. This is a luxury we are fast losing. As our nation has garnered a number of near-competitors in the space domain, we will be challenged even more than ever to deliver timely and responsive space capabilities to the warfighter. A capability that provides 90 percent of what the warfighter needs and that is on-orbit and operating is far better than one that promises more, but remains on the drawing board.

Establish an integrated master schedule (IMS) and integrated master plan and include contractors and subcontractors in the schedule. Know the program schedule critical and near-critical paths, especially dependencies. Focus schedule activities on those that lead to mission success. Understand and assess long-lead items and any issues pertaining to them and their impacts. One must be comprehensive in determining what is or is not a long-lead item. Skepticism can help. The emphasis on the schedule can be strengthened by pointing out that certain key dates (e.g., deliveries, initial operational capability) will be part of the baseline; all members of the government and contractor team must work to these dates via the IMS unless and until the baseline changes.

Treat schedule slack as if it is gold. Time is the coin of the program management realm. Do not give up schedule slack easily. Do not let it erode early in a program when it seems like it is pad. It is not pad! You will need that slack late in a program, so be sure to monitor and control it personally.

Have a method for managing the critical path and resources applied to the contract. The method must begin with diligent scrutiny and depend on the accountability of your people. Ensure adequate systems engineering effort is accounted for in the schedule. Make sure there is enough time for rework in assembly and test. Again, do not give away the schedule margin. Every program manager should be intimate with the critical path, know when every important activity on that path is scheduled to happen, and follow-up on the scheduled dates to see if these activities have indeed happened. If you miss a day on the critical path, you miss a day on the entire program, and on big programs, there are significant carrying/sustainment costs.

7. Nip problems in the bud; they usually do not get better with time.

Hit failures hard, since unresolved failures will haunt the program. Attack problems right away, communicate the specifics up the chain quickly and get help wherever possible. Prepare for problems by making an adequate number of spares and budgeting for rework. The reality is that spares are not optional—they are vital for success. They must be addressed with the same energy and persistence that is applied to more glamorous aspects of the program.

There are truly a lot of very smart people who can help—but they cannot help you if they do not know that you need help.

8. Test and verify; one test is worth a thousand opinions.

Tony Spear strongly recommends: "TEST, TEST, TEST, and TEST [it] as you [would] FLY [it].... Early proof of concept test, early end-to-end flight-ground functional/interface test, extensive subsystem and system space qualification and performance tests and burn-ins, prior to [assemble test and launch operations], using flight operations [hardware] and [software]."[28]

Space qualified systems must meet requirements. Some have fallen into the trap in recent years of agreeing to accept certain parts (e.g., batteries, chips, other materials) that are unfit for space missions. Some companies that have made space-qualified parts for years have seen the retirement of the generation that designed and made them; this is happening throughout the space industrial base. Changes in design or manufacturing processes may also result in non-qualified parts or systems. TSPR did not help this situation.

Validate, verify, and test your systems for success. Make decisions based on real data and analysis. Incremental testing is the only way to get early detection of system level issues. Additionally, as we increasingly focus on the enterprise, we need to ensure there are enterprise-level tests to verify that the "system of systems" is performing as planned. Get the test team on board early, including both development test and operational test personnel so they are involved in the test planning and execution from day one.

Unless a lack of time makes it prohibitive, always build at least one engineering model, and test it in conditions as close to flight test requirements as possible. Test it like you plan to fly it! Do this with enough time in the schedule to feed the information gleaned from the test back to the flight unit design.

9. Communicate; it is more important than organizing.

Information is power. A program manager must make his or her people, team, and bosses powerful, so he or she should foster effective communication up and down the chain of command and across the organization.

Take control of the reporting process. Define process owners and information requirements and establish vehicles to deliver that information in a timely fashion.

Internally: Employ regular meetings with well-defined agendas. Make sure meetings have a purpose and goal; drive the focus of the meeting to the goal and do not get distracted. New issues will need their own processes. Do not let a meeting take on a "life of its own;" continually reassess the value of the agenda topics, and jettison a topic when its value is gone.

> **Taverney:** Very early in my career, while managing a program that was automating the satellite contact scheduling process, I noted that one team member always brought a tape recorder to my meetings. After awhile, my curiosity got the best of me and I asked about it. I was shocked to learn that the team did not always understand what I was saying, and they referred to the tape for clarification when they had questions. I thought I was always perfectly clear. But, I learned a good lesson: just because a point is clear to me, it is not necessarily clear to everyone listening. From then on I used various techniques to make sure people understood what I meant.

Externally: Employ routine reviews with your contractor and users. You need to strike a balance so as to get the right amount of interaction without overwhelming your contractor team, which needs to be working on the end product. Supplement periodic reviews with a steady presence in the contractor's facility.

Never surprise your team or your boss. Holding your cards close to the vest wins only in cards. Supercharge your networks. Some people know the answers, but will not tell you until you have made a stupid decision.

> **Rendleman:** Of course, any boss can orchestrate information systems in his or her own way. As a young officer, before the "email information sharing" age, my colleagues and I would draft correspondence to external agencies and submit these to our boss. Not knowing better, our letters would drone on for pages, sometimes 10 or more, detailing the problems and issues, and setting out the points we wanted made. The colonel would take the drafts and set to work, ending up with impressive letters of no more than a few sentences; but his short masterpieces said everything that needed to be said. When I found out he was doing this, I proposed that we make the extra effort to give him to-the-point letters as our drafts. I was told in no uncertain terms the colonel wanted our long drafts; this was how he found out what was going on.

Although timely, accurate reporting is critical to program success, you must be careful not to devote so much effort to reporting (especially by your best people) that you compromise your ability to manage the program in the first place. Simplify the essence and speed of reporting. Taking too much time to tell customers or each other what you are doing does not get your work done. Managing the program is far more critical than reporting the program.

> **Taverney:** In 1992, I was asked by a US Air Force customer if I could come explain why one of its programs was a chronic poor performer. I first went to the contractor and walked the floor. I randomly asked people what the program is trying to accomplish, how the individual contributes to the program's goals and objectives, what the individual is accountable for, what authority the individual has to accomplish his or her job, and with whom the individual communicates to get this job done. I found that most of those questioned knew what the program was trying to accomplish, but only a little more than half understood how they fit into the program. Fewer than 10 percent knew what his or her authority was and with whom he or she should be communicating to get his or her job done. While some of these problems can be resolved by applying the 10 rules spelled out in this article, in this case, it was clear that program communication was an issue.

10. Deliver; it is all about delivering the needed capability to the user.

There will ultimately be users for the system that is being built. The program team must build the system to provide a capability or set of capabilities to the users.

Build the system for what the customer needs. Do not lose that vision or focus. Each requirement must be tied to a concept of operations (CONOPS) or employment. Clearly define each requirement and understand its linkage to the CONOPS—and always have an updated CONOPS.

Use a building block or spiral development approach, as mentioned in rule five on managing risk. This allows the program to field its systems early and often. While you are building the system, talk to the users. It is invaluable that they understand what they are getting, and that you (and the program office) understand what they expect, and how they operate. However, make sure that you do not accept requirements from the users. While they may not be able to get everything they want in the first block or spiral, encourage them to vet requirements through the proper channels to get them in a future block or spiral.

Getting something into the user's hands early will help you get the feedback necessary to define the next blocks/spirals. The operator's view of the system is usually different from the engineer's view. A program can meet every requirement documented in the engineering specification and still leave a customer not fully satisfied. Work hard with the user/operator to understand and control the CONOPS; it is essential for developing a comprehensive and consistent set of technical requirements. At times, users do not know how to describe what they want; using a little time and money upfront to demonstrate, prototype, or analyze requirements will pay big dividends later in the program.

> **Taverney:** Another program I worked on in the old days was the data systems modernization (DSM). The legend behind this program is that we built a system with no user inputs or interface. Yep—you guessed it—that was not a good thing. The government program manager prohibited the contractor team from any kind of communication with the user. The colonel's point of view was that, since the team knew computer technology and capability far better than the users, we could build a modern marvel and the users would be happy. I suspect this was just one of the many programs throughout history that was begun and executed based on this fallacy. When DSM was delivered, it was indeed a marvel of technology; but the users found it far too different from the way in which they currently operated. Fortunately, within the next few years, with many user-friendly modifications, the system lived up to its promise—but those first few years were painful for all involved.

Concluding Thoughts

Studies and panels have documented many problems in space acquisition caused by factors outside the control of program managers. These have not really told a program manager how to better acquire a space system. Without adequate resources, national space institutions have all tried varied coping strategies to achieve mission success in spite of limitations and evolving priority environments. We cannot depend on institutional and resource changes to complete the hard work of effectively building and deploying space systems. Space systems still have to be engineered, built, and delivered. The 10 rules for common sense space acquisition spelled out in this article are derived from lessons passed down from great mentors and years of experience and observation. They are intended to provide the program manager with the tools needed to better manage and engineer space programs for success.

The 10 rules may indeed be more like guidelines than rules, but careful consideration of these with respect to your programs will allow you to perform the critical thinking necessary to have control of your program. While some people may call it sandbagging, under-promising, or just being more conservative in setting expectations, these guidelines can allow a program manager to surpass some of the limitations inherent in the current space acquisition environment. The rules are actionable;

to the point; measurable; and empower the program manager to get started on his or her way to program success.

This business is never easy, and managing a program is a contact sport, requiring high energy, flexibility, and commitment. You need to know many things and manage them, but you cannot know and manage everything. Hopefully, this article points you to the issues that are important. Own your risk, be responsible for your critical path, maintain your program baseline, get good people and have them in the right spot, and align authority and accountability while empowering those accountable. Nothing is more rewarding than seeing a system for which you were responsible successfully perform critical functions in space.

Notes:

[1] The peace dividend was a popular slogan used during the end of the Cold War to describe a potential long-term benefit as budgets for defense spending are assumed to be at least partially redirected to social programs and/or economic growth. Retrieved on 7 July 2009 from Wikipedia, http://en.wikipedia.org/wiki/Peace_dividend.

[2] Richard Beckhard, an adjunct professor at the MIT Sloan School of Management, helped define organizational development as "an effort (1) planned, (2) organization-wide, (3) managed from the top, to (4) increase organization effectiveness and health through (5) planned interventions in the organization's 'processes,' using behavioral-science knowledge." Richard Beckhard, *Organizational Development: Strategies and Models*, (Addison-Wesley, June 1969), 9.

[3] As defined by the International Organization for Standardization (ISO), ISO 8402:1994: "TQM is a management approach for an organization, centered on quality, based on the participation of all its members and aiming at long-term success through customer satisfaction, and benefits to all members of the organization and to society."

[4] Jiju Antony, Pros and cons of Six Sigma: an academic perspective, 7 January 2008, http://www.improvementandinnovation.com/features/articles/pros-and-cons-six-sigma-academic-perspective; Initially implemented by Motorola, Six Sigma is a set of practices that seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and variation in manufacturing and business processes; Six Sigma is a trademark/registered trademark of Motorola, Inc., in the US and/or other countries

[5] Here are references to some of the many studies and panels:

(a) Packard Commission, *A Quest for Excellence: Final Report to the President by the President's Blue Ribbon Commission on Defense Management* (June 1986).

(b) *Commission on the Future of the United States Aerospace Industry* (September 2002). See also Thomas S. Moorman, "The Health of the Space Industrial Base, An Update," Presented to the Commission on the Future of the United States Aerospace Industry (Washington DC, 14 May 2002).

(c) *Space Acquisitions: Actions Needed to Expand and Sustain Use of Best Practices*, Government Accountability Office (GAO), GAO-07-730T, 19 April 2007.

(d) *Space Acquisitions: Improvements Needed in Space Systems Acquisitions and Keys to Achieving Them*, GAO-06-626T, 6 April 2006.

(e) *Defense Acquisitions: Improvements Needed in Space Systems Acquisition Management Policy*, GAO-03-1073, September 2003.

(f) *Space Acquisitions: DoD Needs to Take More Action to Address Unrealistic Initial Cost Estimates of Space Systems*, GAO Report GAO-07-96, 17 November 2007.

(g) *Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs* (May 2003)—otherwise known as the Young Report. Also refer to its follow-up, 2004.

(h) *2006 Quadrennial Defense Review, Defense Industrial Base Assessment: US Space Industry* (Dayton, OH, 31 August 2007.

(i) *Defense Acquisition Performance Assessment Project (2006), Defense Acquisition Performance Assessment Report* (Washington DC: January 2006); the project was chaired by Lt Gen (USAF, retired) Ronald Kadish.

(j) National Research Council, *Pre-Milestone A and Early-Phase Systems Engineering: A Retrospective Review and Benefits for Future Air Force Acquisition*, The National Academies Press, 2008.

[6] Of course, if these recommendations had been implemented in any meaningful way, they would have made the execution of space programs much less risky, and our national space programs would have had much better success.

[7] Secretary of Defense Robert M. Gates, submitted statement, Senate Armed Services Committee, 27 January 2009, 11, http://armed-services.senate.gov/statemnt/2009/January/Gates%2001-27-09.pdf

[8] These laws were first openly described on 5 September 1961 in a published memo from C. L. Battle to Colonel Bleymaier, www.thespacereview.com/archive/1333.pdf.

[9] This thinking reflects some of the best conclusions of Booz Allen Hamilton, *Space Industrial Base Study* (McLean, VA, 16 February 2000); see also Project Air Force's Mark A. Lorrell and Hugh P. Levaux, *The Cutting Edge: A Half Century of US Fighter Aircraft R&D* (RAND Corporation, 1998); and the National Research Council, *Review of the Future of the US Aerospace Infrastructure and Engineering Disciplines* (2001). These studies highlight the importance of challenging engineers. With system cycle times growing to 20 to 30 years or more, engineers are not provided enough challenges to keep their skills sharp.

[10] Fostering smaller program offices was one of the best things to come out of NASA's FBC. NASA set up the Discovery/New Frontiers Program Office at the Marshall Space Flight Center under this model rather than using the traditional large program office. This office has been very successful with a string of exciting and leading-edge science missions (e.g., NEAR, Mars Pathfinder, MESSENGER, New Horizons). These programs have also performed well within cost and schedule when compared to the traditional program office—the average cost growth is generally 15 percent versus the traditional 30 percent within NASA.

[11] Tony Spear, *NASA FBC Task Final Report*, 31 March 2000, 2, http://klabs.org/richcontent/Reports/fbctask.pdf.

[12] Simple engineering errors were root causes of the failures, but the real failure was a breakdown of the systems engineering and quality assurance. Simple engineering errors occur during development of every space mission; however, they can be spotted and mitigated if there is a system in place to check, double-check, and review. On FBC missions, this process was cut thin as a way to reduce cost. Therefore, a junior engineer's simple mistake of forgetting to convert an important calculation from English to metric systems was not caught by the program before the failure. Even then, when some navigation errors cropped up in the "real" data, the operators explained them away as insignificant versus checking on their source.

[13] Henry P. Pandes, "Total System Performance Responsibility," *Contract Management* (March 2002), 24-29.

[14] James H. Gill, "TSPR Not for Developing Systems," *Contract Management* (August 2002), 26-27, citing *Defense Daily International*, 22 March 2002.

[15] In 1996, the DoD implemented the Space-Based Infrared System (SBIRS) to update and replace the Defense Support Program (DSP) missile detection and warning system. However, the program was restructured several times due to budget and schedule constraints—even the program goals were revised in 2002, 2004, and 2005. The program suffered a major set back in 2007 when flight software was tested and failed causing further program restructuring to occur. Cristina T. Chaplain, "Space Acquisitions: DoD's Goals for Resolving Space-Based Infrared System Software Problems Are Ambitious," 30 September 2008, www.gao.gov/products/GAO-08-1073; In 1999, the Future Imagery Architecture (FIA) program was commissioned by the NRO to design reconnaissance satellites. According to the *New York Times* the FIA is "perhaps the most spectacular and expensive failure in the 50-year history of American spy satellite projects." Philip Taubman, "In Death of Spy Satellite Program, Lofty Plans and Unrealistic Bids," *New York Times,* 11 November 2007, www.nytimes.com.

[16] In addition to Battle's Laws, other rules have been promulgated relating to the acquisition of complex systems. For example, within Lock-

heed's Skunk Works, Kelly Johnson established 14 basic operating rules to govern his aircraft projects. See James S. Huggins, "Kelly Johnson's Rules," Refrigerator Door, http://www.jamesshuggins.com/h/u-2a/u-2_kellys_rules.htm).

[17] DigitalGlobe is a trademark/registered trademark of DigitalGlobe, Inc., in the US and/or other countries; GeoEye is a trademark/registered trademark of GeoEye Corporation in the US and/or other countries.

[18] In May 2005, The Boeing Company and Lockheed Martin Corporation formed a join venture that brought together two of launch industry's most experienced and successful teams, Atlas and Delta. Under the terms of the joint venture, both the Delta and Atlas Evolved Expendable Launch Vehicle (EELV) rocket systems are available for individual missions, ensuring the US government customer is able to make decisions based on launch vehicle and launch site available options to meet the goal of assured access to space. The ULA team carries out all mission activities, including launch vehicle integration, payload processing, launch operations and mission support, www.ulalaunch.com/index_about.html.

[19] This point is strongly related to rule 9 on communications.

[20] A space exploration project manager and visionary, Tony Spear led the Mars Pathfinder mission in 1996, marsprogram.jpl.nasa.gov/MPF/bios/team/spear1.html.

[21] Ibid, 4.

[22] The 'program manager' is now called an "acquisition space wing commander" in the US Air Force wing structure; this position was formerly a "system program office (SPO) director."

[23] The snickering and schadenfreude (German for pleasure derived from the misfortunes of others) about SBIRS and FIA problems have tempered as other programs have experienced their own cost management troubles. The James Webb Space Telescope (JWST) and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) have breached the Nunn-McCurdy Act for similar technical, cost growth, and scheduling issues. As to NPOESS, the House Science Committee Chairman Sherwood Boehlert (R-NY) opined in 2005: "You would think that, given how much is riding on NPOESS, this would be an especially closely supervised, well-managed program. It is now clear that, almost from the outset, decisions were made with too little analysis of the technical challenges involved in building NPOESS. It is clear that contracts were awarded at prices that did not take into account the technical risks the program faced. And it is clear the program was inadequately supervised, allowing problems to fester and worsen before being addressed...." House Science and Technology Committee, "NPOESS is as much as $3 Billion over budget, as many as 3 years away, witnesses say," SpaceRef.com, 16 November 2005, press release, http://www.spaceref.com/news/viewpr.html?pid=18317). European systems are suffering the same problems.

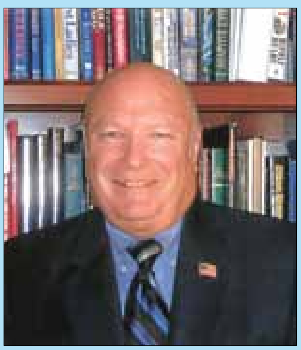
[24] Unfortunately, the sad truth is that programs that cannot close are generally the rule rather than the exception. But one has to realize that there are tremendous programmatic pressures. For example, during the formulation stage, everyone—from the acquirers to the contractors to the appropriators to the planners to the budgeters—takes an optimistic and incremental mindset to win funding and achieve a contract award. However, the same team is not likely to execute the program and the implementation team is not going to have the same objectives.

[25] Ibid, 13.

[26] Ibid, 4.

[27] Ibid, 13.

[28] Ibid, 13-14.



Maj Gen Thomas D. Taverney, USAF, retired (BS, US Air Force Academy; MS, University of Southern California). is employed as a senior corporate vice president for SAIC, a leading provider of scientific, engineering, systems integration and technical services and solutions. In his civilian capacity Mr. Taverney has extensive engineering design and development expertise along with significant program and organizational management experience. He has held the positions of chief engineer, vice president of engineering, group vice president, president and chief operating officer. Mr. Taverney has led and managed many space systems development programs, of many sizes and complexity. He has been a designer of such systems as the airborne anti-satellite weapon and numerous subsystems that have successfully flown in space.

Mr. Taverney has been involved in space operations and space systems development for over 41 years, as an active duty and reserve officer, and within the commercial space industry. During operations Enduring Freedom and Noble Eagle, Mr. Taverney was recalled to active duty to help provide space launch and range operations leadership. He was also called to active duty to serve as Vice Commander of Air Force Space Command (AFSPC).

Mr. Taverney is a past recipient of the Air Force Scientific Achievement Award. He is also a Schriever Fellow. He is a level-3 space professional and trained director, Space Forces, and has supported the AFSPC commander in the development of Space warfighting doctrine and operational concepts. In addition to being on advisory boards at Chapman University and Cal State Fullerton, Mr. Taverney was the first national chairman of the National Security Industrial Association Space Committee. He is currently on the SMC SPAG and has supported the AFSPC ISAG. He is also Chairman of the Board, Air Force Association General Bernard A. Schriever Chapter 147 (Los Angeles).

Col James D. Rendleman, USAF, retired (BS, Chemistry, University of North Carolina—Chapel Hill; MBA and MPA, Golden Gate University; JD, Whittier College School of Law; LLM, University of San Diego School of Law). Mr. Rendleman was commissioned a second lieutenant through the Reserve Officers Training Corps at the University of North Carolina—Chapel Hill. He has held a wide variety of science and technology, engineering, management, and policy positions within Air Force laboratories, the space acquisition community, Headquarters Air Force Space Command, the Air Staff, and the National Reconnaissance Office, working to improve national and coalition space; missile; command, and control; and intelligence capabilities.

He is a level-3 space professional and trained director, Space Forces (DIRSPACEFOR). He is the author of technical and policy articles and speeches on international missile defense and space cooperation, space and missile technology plans, and liquid rocket propellants. He served as study director for The National Academies study of "The Future of the US Aerospace Infrastructure and Aerospace Engineering Disciplines to meet the needs of the Air Force & the Department of Defense." An attorney and member of the State Bar of California, Mr. Rendleman engaged in law practice as a partner, solo practitioner, and associate with firms in Los Angeles, San Francisco, and Napa, California. He is a member of the American Institute of Aeronautics and Astronautics' Legal Aspects Aero and Astro Technical and International Activities committees, and the International Institute of Space Law. He also taught management theory for Cerro Coso Community College and Golden Gate University.

Weapon Systems Acquisition Reform Act

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On 22 May 2009, President Barack Obama signed into law the Weapon Systems Acquisition Reform Act of 2009, a bill sponsored by Senators Carl Levin (D-MI) and John McCain (R-AZ), the chairman and ranking member of the Senate Armed Services Committee. At the White House Rose Garden signing ceremony, President Obama stated the bill will "eliminate some of the waste and inefficiency in our defense projects—reforms that will better protect our nation and better protect our troops." He also added, "We will always give our men and women in uniform the equipment and support that they need to get the job done. But I reject the notion that we have to waste billions of taxpayer dollars to keep this nation secure."[1]

The bi-partisan bill passed unanimously in both the House and the Senate on its way to the White House and is titled "An act to improve the organization and procedures of the Department of Defense (DoD) for the acquisition of major weapon systems, and for other purposes."[2] Just before signing the bill, President Obama said, "While we have a long way to go to end this waste once and for all, the legislation I am about to sign is a very important step into creating a government that is more efficient, more accountable, and more responsible to keeping the public's trust."

The Weapon Systems Acquisition Reform Act of 2009 contains the following provisions divided into three Titles:

Title I: Acquisition Organization

Sec.101. Establishes a director of cost assessment and program evaluation. The director is to assume the functions of the Office of Program Analysis and Evaluation, including the functions of the Cost Analysis Improvement Group. The director is required to submit an annual report on cost assessment activities to congressional defense committees no later than 10 days after the President's Budget is submitted to Congress.

Sec.102. Establishes director of developmental test and evaluation and director of systems engineering. Requires the directors to issue joint guidance and submit a joint annual report on activities undertaken.

Sec.103. Requires a senior official responsible for performance assessments and root cause analyses for major defense acquisition programs (MDAPs).

Sec.104. Directs assessment of technological maturity of critical technologies of MDAPs by the director of defense research and engineering.

Sec.105. Directs Joint Requirements Oversight Council (JROC) to seek and consider input from the commanders of the combatant commands in identifying joint military requirements.

Title II: Acquisition Policy

Sec.201. Requires the secretary of defense (SECDEF) to ensure that mechanisms are developed and implemented to require consideration of trade-offs among cost, schedule, and performance objectives in DoD acquisition programs. Requires the JROC to ensure trade-off consideration for joint military requirements. Requires the SECDEF to ensure that each new joint military requirement recommended by JROC has sought and considered input from commanders of combatant commands and complies with trade-off consideration requirement.

Sec.202. Directs SECDEF to ensure that acquisition strategies for each MDAP include measures to ensure competition, or option of competition, at both the prime and subcontract level throughout the lifecycle and adequate documentation of the rationale for the selection.

Sec.203. Directs SECDEF to modify DoD guidance to ensure that the acquisition strategy for each MDAP provides for competitive prototypes before Milestone B approval unless the Milestone Decision Authority (MDA) waives the requirement under certain rules. Requires comptroller general to review MDA waivers on the basis of excessive prototype costs.

Sec.204. Requires MDA, within 30 days after receiving notification from a program manager that the MDAP is experiencing cost growth or schedule delays by more than 25 percent, to submit a report to congressional defense committees that identifies the root cause of the growth or delay and appropriate acquisition performance measures for the remainder of the development of the program. The report must also include a written MDA certification stating the necessity of the MDAP or a plan for terminating the MDAP if the MDA determines that such action is in the interest of national defense.

Sec.205. Adds additional requirements for certain MDAPs.

Sec.206. Directs SECDEF, if the program acquisition unit cost or procurement unit cost of a MDAP or designated subprogram increases by a percentage equal to or greater than the critical cost growth threshold for the program or subprogram to

While we have a long way to go to end this waste once and for all, the legislation I am about to sign is a very important step into creating a government that is more efficient, more accountable, and more responsible to keeping the public's trust. *~ President Barack Obama* determine the root cause for the cost growth and carry out an assessment in consultation with the director of cost assessment and program evaluation. After conducting the assessment, the SECDEF shall terminate the program unless the SECDEF notifies Congress the decision not to terminate.

Sec.207. Requires SECDEF to revise the defense supplement to the Federal Acquisition Regulation to provide uniform guidance to eliminate or mitigate organizational conflicts of interest in MDAPs.

Title III: Additional Acquisition Provisions

Sec.301. Directs SECDEF to commence an awards program for DoD personnel for excellence in the acquisition of products and services. Authorizes SECDEF the use of cash bonuses for the award program.

Sec.302. Amends earned value management elements of the Duncan Hunter Defense Authorization Act for fiscal year (FY) 2009.

Sec.303. Expands national security objectives of the national technology and industrial base.

Sec.304. Requires comptroller general of the US to report on costs and financial information on MDAPs.

US Air Force's Acquisition Improvement Plan

As the Weapon Systems Acquisition Reform Act was going through the legislative process, Secretary of the Air Force (SECAF), the Honorable Michael B. Donley, and Air Force Chief of Staff (CSAF), General Norton A. Schwartz, sent out a memorandum on 4 May 2009 implementing the Air Force Acquisition Improvement Plan (AIP) as "our strategic framework for the critical work of modernizing and recapitalizing our air, space, and cyber systems." The memo reemphasized the Air Force's commitment to "recapturing acquisition excellence" via the AIP, which established five goals and 33 actions to ensure "rigor, reliability, and transparency across the Air Force acquisition enterprise."[3]

SECAF and CSAF designated the Office of the Assistant Secretary of the Air Force for Acquisition (SAF/AQ) as the AIP implementation lead. The five AIP goals and 33 associated actions build upon lessons learned from past shortfalls in the procurement process. Designated office of primary responsibilities and office of collateral responsibilities of the goals include: Acquisition Integration (SAF/AQX); Deputy Chief of Staff, Manpower, Personnel, and Services (AF/A1); Deputy Chief of Staff, Operations, Plans, and Requirements (AF/A3/5); Deputy Chief of Staff, Strategic Plans, and Programs (AF/A8); Office of Assistance Secretary of the Air Force for Financial Management; Program Management and Acquisition Excellence Office; and commanders (CC) of Air Combat Command, Air Mobility Command, Air Education and Training Command, Air Force Special Operations Command, Air Force Materiel Command (AFMC), and Air Force Space Command (AFSPC). The five AIP initiatives and subtasks are:[4]

1. Revitalize the Air Force Acquisition Workforce

1.1 Exploit newly delegated expedited hiring authority to fill current civilian vacancies.
1.2 Increase and fund military and civilian personnel authorizations, as required.
1.3 Fully utilize the recruitment, training, and retention funding derived from Sec. 852 of the FY 2008 National Defense Authorization Act.
1.4 Develop and implement recruitment and retention initiatives, including management training programs and bonuses where appropriate.
1.5 Increase manning priority for civilian and military acquisition positions.
1.6 Examine the mix of military and civilian acquisition personnel.
1.7 Develop a succession planning procedure for acquisition leadership in functional specialties.
1.8 Establish training and experience objectives as part of the career paths for each acquisition specialty.
1.9 Assess the acquisition workforce to determine the appropriate level of personnel needed to accomplish inherently governmental work.
1.10 Examine the possibility of reassigning responsibility for acquisition workforce management to AFMC as the lead command.

2. Improve Requirements Generation Process

2.1 Ensure acquisition involvement and leadership in support of the lead command early in the development of program requirements.
2.2 Require senior acquisition executive and, when applicable, AFMC/CC or AFSPC/CC to certify that the acquisition community can successfully fulfill the requirements in the capabilities development documents.
2.3 Require program executive officer (PEO) to coordinate request for proposal with lead requiring major command (MAJCOM)/CC or designee.
2.4 Carefully minimize key performance parameters and ensure all requirements are finite, measurable, prioritized, and can be evaluated during a source selection.
2.5 Require incremental acquisition strategies that reduced cost, schedule, and technical risk.
2.6 Freeze program requirements at contract award.

3. Instill Budget and Finance Discipline

3.1 Establish program baselines for cost, schedule and technical performance after Preliminary Design Review.
3.2 Identify and implement means to increase cost estimating confidence levels and establish more realistic program budgets.
3.3 Stabilize program funding.
3.4 Establish a formal review of contractor overhead costs for reasonableness.
3.5 Review individual contract profitability to ensure profits and award fees are comprehensively tied to cost, performance, and schedule.
3.6 Place renewed emphasis on contractor earned value management system.

AFSPC and its acquisition arm at Space and Missile Systems Center are closely working together on acquisition issues arising out of the Acquisition Improvement Plan to ensure smooth and streamlined processes are implemented.

4. Improve Air Force Major System Source Selection (SS)

4.1 Modify Air Force SS procedures to strengthen SS governance.
4.2 Improve SS training.
4.3 Require use of Multifunctional Independent Review Teams.
4.4 Appoint a team of the most qualified Air Force SS experts to provide on-call SS augmentation.
4.5 Create a designation for both civilian and military personnel records to identify individuals with competency and experience in SS procedures.
4.6 Review the current acquisition planning process.
4.7 Simplify SS process wherever possible.

5. Establish Clear Lines of Authority and Accountability within Acquisition Organizations

5.1 Reassess wing/group/squadron structure.
5.2 Explore a realignment of the rating and reporting chain for the contracting function to ensure independence of the contracting officers.
5.3 Reassess PEO construct and offer recommendations for improvement.
5.4 Assess value of re-establishing functional matrix management at the centers.

The AIP priority is to rebuild the Air Force acquisition culture so that we can regain our acquisition excellence by delivering products and services on schedule, within budget, and within legal guidelines.

AFSPC's Goal—"Deliver at the Speed of Need"

One of AFSPC five goals in its strategic plan is to "reengineer acquisition to deliver capability at the speed of need."[5] This goal adopts Air Force's priority to "recapture acquisition excellence" and sets it as a MAJCOM priority.[6] During the recent AFSPC strategic planning offsite, two areas were discussed that apply directly to acquisition improvement and are impacted by the Weapon Systems Acquisition Reform Act.

First, AFSPC must "get ahead of the curve." This focus area is about maintaining our military advantage by staying ahead of the pace of change, which is exponential for technology advancement. To achieve this focus area, AFSPC must work to accelerate the pace of identifying and satisfying requirements, acquisitions and technology development.

Second, AFSPC must "bring agility, speed, and discipline to acquisition." Developing, delivering, and sustaining space and especially cyberspace systems requires a new strategy that is more agile and responsive than the "industrial age" acquisition processes and management methods used in the past. The cyberspace domain is a contested domain, vulnerable to threats, that requires rapid detection, analysis, response, and recovery technology solutions to secure our networks.

Important to these acquisition improvement processes are the people involved. AFSPC must recruit, train, and retain America's best. Building and maintaining acquisition expertise is crucial to the acquisition process.

AFSPC and its acquisition arm at Space and Missile Systems Center are closely working together on acquisition issues arising out of the Acquisition Improvement Plan to ensure smooth and streamlined processes are implemented. Through the implementation of the Weapon Systems Acquisition Reform Act of 2009 and the Air Force's Acquisition Implementation Plan, we will recapture acquisition excellence and provide our Airmen the needed equipment on time and on cost—to fly, fight, and win in air, space, and cyberspace.

Notes:

[1] The White House Press Office, "Remarks by the President at the signing of the Weapon Systems Acquisition Reform Act," 22 May 2009.
[2] Public Law 111-23, "Weapon Systems Acquisition Reform Act of 2009 (S.454. enrolled as agreed to or passed by both House and Senate)," 22 May 2009.
[3] SECAF, CSAF, memorandum, "Air Force Acquisition Improvement Plan," 4 May 2009.
[4] Office of the Assistant Secretary of the Air Force (Acquisition), "Acquisition Improvement Plan," 4 May 2009.
[5] 2009-2010 Air Force Space Command Strategic Plan, 18 May 2009.
[6] 2008 United States Air Force Strategic Plan.

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DEPARTMENT OF THE AIR FORCE

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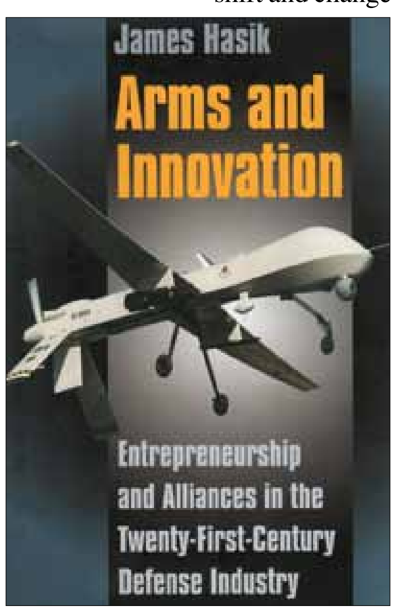
Arms and Innovation: Entrepreneurship and Alliances in the Twenty-First-Century Defense Industry

Arms and Innovation: Entrepreneurship and Alliances in the Twenty-First-Century Defense Industry. By James Hasik. New York: University of Chicago Press, 2008. Bibliographical References. Index. Pp. 224. $35.00 Hardcover ISBN-13: 978-0-226-31886.

Author James Hasik, a consultant and student of current defense industry trends, writes a compelling book based on the proposition that defense industry businesses not only can, but must join together creatively in this century to provide military forces with pro-active, innovative and timely solutions to the problems and conditions of the modern battlefield. Hasik describes two wars that are going on. The first is the fight against terrorism, the second is the battle among the various defense contractors, both great and small, for a share of the Department of Defense funding toward providing solutions needed by warfighters.

Hasik uses several decisive examples of collaborative efforts that have been successful in helping DoD support warfighters around the globe. Rather than take a monolithic view of, for example, the space arena, he tackles areas as varied as marine catamarans, armored vehicles and smart munitions. He asks the question; are small, innovative, agile businesses in a better situation than their larger brethren to provide solutions within the framework of a fluid requirement set. His premise is that smaller companies can innovate extremely well because they are not so bureaucracy and paradigm bound as larger companies. Additionally, he examines the advantages of alliances, not the either-or aspect of the question. He uses his case studies to examine a number of different alliances, proving that there is no set model, but that, on a case by case examination, defense contractors need to examine the potential for creative alliances that will solve the problem at hand, satisfy the government customer and leave the allied companies better off at the completion of the contract.

Hasik argues that small firms have made exceptional contributions to the force in the last decade. He describes a number of alliance potentials, including several small firms coming together to bid on substantial government contracts. He also explores the effectiveness of small, agile firms teaming with larger, more bureaucratic companies so that the advantage of outside-the-box thinking and quick turnaround of prototypes can be enhanced by the financial capabilities of a much larger firm. Finally, he examines the advantages of two large firms with differing capabilities partnering on a particular project. In this instance, he believes the melding of different skill sets and knowledge bases can make an effective team.



The layout of the case studies is of particular interest. His examination of the original problems, historical backgrounds and the following analysis make the flow of the case studies particularly reader friendly, even when the reader is not familiar with the technological issue. Additionally, his case studies cover a broad and diverse set of problems and solutions. From the Space Based Infrared Satellites which were designed to provide early warning of missile launches; to seagoing catamarans capable of extremely high speeds and platform variety for a number of littoral missions, Hasik addresses problems of the warfighting community, creatively solved by contractor innovation.

The case studies examined all have the ability to embroil supporters of one solution over another, however, Hasik remains aloof from partisanship and keeps his focus on his thesis. Defense contractors and the governments that employ them are faced with a new set of challenges and a requirement for a new, fluid set of paradigms in meeting them.

The conclusion offers sound advice to both companies and government officials who deal with contractors. He explains why the government should foster and maintain sound relationships with small companies because "smaller firms thrive in industries where progress is evolutionary rather than revolutionary … continuous, incremental and recombinative."

Hasik's warning that "small firms should choose their friends carefully" is a clear reminder of the second battlefield where companies jockey for position in a volatile and infinitely dangerous economic combat zone. This is an arena where alliances shift and change as need requires and there are dangers as well as rewards for the smaller companies that might not have the experience or the fiscal endurance of larger, more established firms.

Finally, Hasik's analysis of the modern defense contracting market, his studies of what worked well and what worked badly are explicit examples of the nature of the contracting industry. This book is excellent reading for defense contractors, those who think they might want to become defense contractors and for military and government civilians who work with the defense industries. This volume offers clear strategies for providing positive, intelligent and timely solutions to air, ground and marine warfighters in today's and, more importantly, tomorrow's war on terror.

Reviewed by Mr. Edward T. White, author and historian.

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We are interested in what you think of the ***High Frontier*** Journal, and request your feedback. We want to make this a useful product to each and every one of you, as we move forward to professionally develop Air Force Space Command's space, cyberspace, and missile workforce and stimulate thought across the broader National Space Enterprise. Please send your comments, inquiries, and article submissions to: HQ AFSPC/PA, *High Frontier* Journal, 150 Vandenberg St, Ste 1105, Peterson AFB, CO 80914-4020, Telephone: (719) 554-3731, Fax: (719) 554-6013, Email: afspc.pai@peterson.af.mil, To subscribe: hard copy, nsage@sgis.com or digital copy, http://www.af.mil/subscribe.

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