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REPORT

Public Private Partnerships and the Development of Space Launch Systems in the United States

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The dynamic between the governmental space sector and the private commercial space sector is shown in Figure 1. A successful outcome for space commerce is indicated by the acceptable region. One approach for government to develop space systems is to reduce risk through different models (risk reduction programs and capital formation programs) of public private partnerships (PPPs) and by establishing political and legal regimes that enable space commerce to support both governmental and commercial space activities, such as the licensing regimes for commercial space launch in the United States.

There exist two basic PPP models relative to the case of space launch systems in the United States: (1) contracting by negotiation; and (2) acquisition of commercial items. The first model entails contacting for technology development, and includes various applications of cost-plus contacting, fixed-price block buys (usually for services and not technology), competitive acquisitions, sole-provider acquisitions, and cost-sharing approaches. The second model is one where the U.S. government acquires technology and services as commercial items. With this approach to acquisitions, funded and unfunded public-private agreements and contracts are formulated to provide for government capital and expertise to private industry for technology development and operations, which, in turn, are applied through the agreements and contracts for government use under fixed-price arrangements. The intent of both models is to realize the goal of an "acceptable region" shown in Figure 1 for development and operations of space launch systems.

The two PPP models identified above apply in different ways to NASA's Space Launch System (SLS); United Launch Alliance's (ULA's) Evolved

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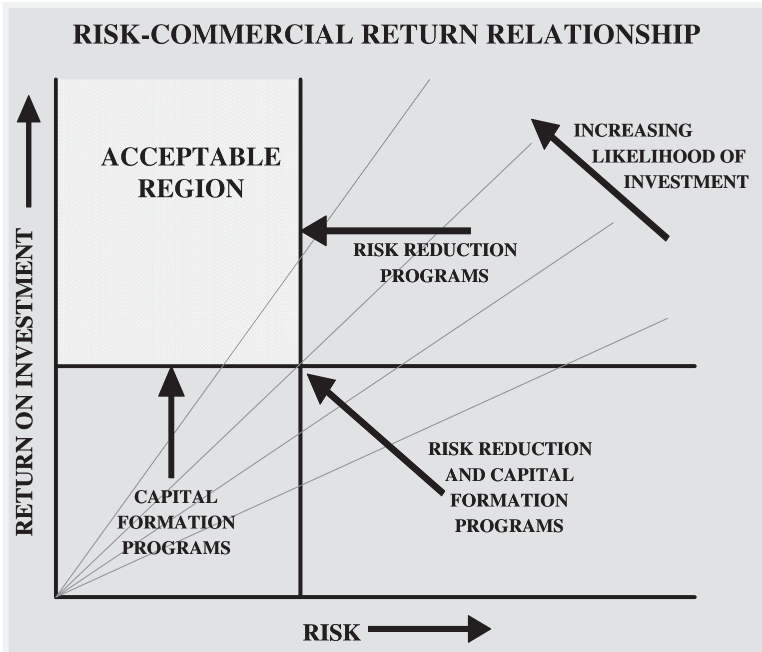

FIGURE 1 Public private dynamics.

Expendable Launch Vehicles (EELVs), the Atlas V and Delta IV; and Space Exploration Technologies' (SpaceX) Falcon 9. Table 1 highlights how the PPP models apply.

CONTRACTING BY NEGOTIATIONS

Contracting for technology development is the traditional procurement/acquisition approach. In the government's traditional relationship with industry, the government pays for technology development on a cost-plus basis that covers total cost for industry, as well as an additional amount for profit. With this model, the government is responsible for cost overruns and schedule delays. Of note is that approximately 90% of the work effort on space programs and projects are contracted out to industry under this contracting model. NASA and the U.S. Department of Defense (DOD) are the key government organizations in this regard.

There are extensive regulations in place for government oversight and compliance that directly affect development and management of any space system intended for government use, including space launch systems. These regulations are provided by U.S. Federal Acquisition Regulations (FAR) part 15.[1] FAR 15 and the associated cost-plus contracting impose government requirements that must be rigorously followed by industry under strict supervision of civil servants.

TABLE 1 Public-private models applicable to space launch

PPP Model	Activity	Results
Contracting by Negotiations	SLS program development based on cost-plus contracting.	SLS is under development with cost emerging as an issue for mitigating risk, meeting planned schedules (2017 test flight) and ensuring longer-term affordability given possible commercial alternatives (Falcon 9 for NASA Commercial Crew and the Falcon Super Heavy, and the Atlas V that is being human rated).
	EELV program development with dynamic acquisition strategies (cost-plus contacting, fixed-price block buys for services, competitive acquisitions, sole-provider acquisitions, and cost-sharing approaches).	Assured access for national security space assets achieved with EELV development with technical excellence (no launch failures with current EELV systems). Cost management issues led to block buy approach in acquisitions and a strategy of competitive acquisitions.
Acquisitions of commercial items	NASA Commercial Crew and Cargo Program	NASA's Commercial Crew and Cargo Program is achieving success.
	• Falcon 9 for crew and cargo • Atlas V with human rating • Space Act Agreements • Commercial services contracts	NASA's Commercial Orbital Transportation Services (COTS) program led to the successful development of commercial cargo services to low Earth orbit (LEO) and the International Space Station (ISS) by SpaceX. The result is a services contract between SpaceX and NASA to provide cargo transport to ISS.
		NASA's Commercial Crew Program (CCP) is directed to Commercial Crew Development (CCdev) and Commercial Crew Integrated Capabilities (CCiCap). CCdev phase 3 completed with the September 2014 CCiCap contract awards to SpaceX (use of Falcon 9) and Boeing, which plans to use the Atlas V.

Notes: Orbital Sciences Corporation has also concluded a COTS commercial services contract.

Nevertheless, the government has limited insight into a contractor's costs since government contracting officers cannot require cost or pricing data, even though the government is responsible for all costs including cost overruns. This is a key issue, as NASA has experienced cost overruns in the majority of its programs since NASA's cost-estimating management lacks the discipline needed to ensure that project life-cycle estimates are reasonable. Essentially, estimated costs are understated, and thereby subject to underfunding and cost overruns, placing programs at risk of being reduced in scope or requiring additional funding to meet their goals and objectives.[2]

NASA countermeasures to these issues encompass more sound cost-estimating management practices, "best practices,"[3] entailing full-cost accounting over the entire life-cycle development of programs/projects, placing cost management as a critical part of project management, strengthening center (e.g., cost analysis division at NASA Headquarters) and field center cost-estimating capabilities, and basing cost estimates on work breakdown structures that encompass both in-house and contractor efforts. To ensure implementation of these best practices, NASA developed project management guidelines for cost estimating that align costs in project management with accounting/budgeting, project life-cycle development, and cost risk assessments, evaluation, and mitigation.[4] NASA's cost-estimating process is shown in Figure 2. This applies to the development of SLS.

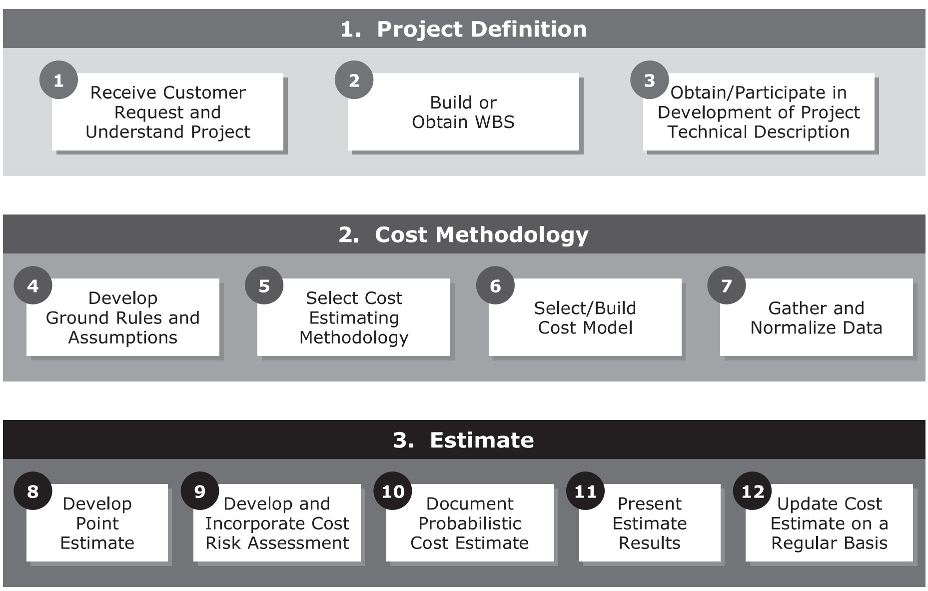

FIGURE 2 Cost estimating process at NASA.
Source: 2008 NASA Cost Estimating Handbook.

In the case of DOD, acquisition management practices define ways in which the contracting by negotiation model is applied. The top-level DOD guides for acquisition policy, regulations, and management are the Defense Federal Acquisition Regulation Supplement (DFARS) and DODI 5000.02.[5] The most recent DODI 5000.02 of 2013 establishes overall acquisition strategies and models with a focus on cost estimating and quality controls during systems development, operations, and sustainment. Overarching objectives of the 2013 DODI, which updated and replaced the previous 2008 version, entail streamlined rules, emphasis on program/project management process and planning, systems engineering guidelines, and product-tailored acquisition models.

Figure 3 represents the overall acquisition model from DODI 5000.02 that applies to the case of EELVs, which are classified under major weapons and hardware intensive programs for launch of U.S. national security space assets.

Space systems are difficult to execute and easy to derail. In space program/project development, one must get everything right the first time as there are no recalls or second chances. This problematic system creates a potential for significant wasted resources and program and project failures, the long-term consequences of which are seldom benign. The milieu of program/project management is punishing toward failure, and professional and programmatic credibility are fragile. For the EELV program, this led to an emphasis in project management to trade off costs to achieve technical performance directed at assured access to space that the DOD requires.

Further, the development of military space assets exists within a "less money, more mission" environment. This environment leaves the U.S. government vulnerable to sharp programmatic cost increases from year to year as the budget for military space swings up and down with implications for programmatic continuity/sustainment. The DOD's Future Years Defense

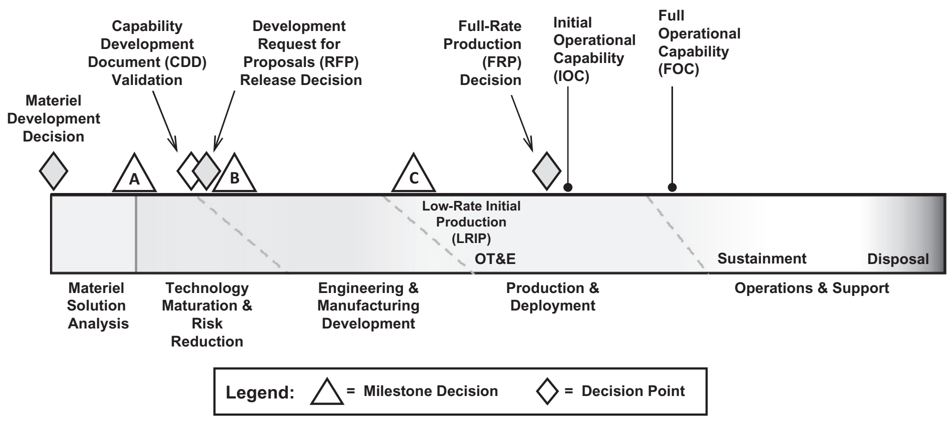

FIGURE 3 Hardware intensive program acquisitions model.
Source: Interim DOD Instruction 5000.02, Operation of the Defense Acquisition System.

Program (FYDP) has assessed that there exists a gap in resources between the demands placed on DOD's military space programs and the projected budgets for military space spending. In fact, there is the risk of cost growth with all DOD space programs/projects by as much as 40% in any one year and even risks of a doubling in costs over a five-year period or longer.[6] In the U.S. Government Accountability Office's (GAO's) must recent assessment (2014) of the EELV program, for example, the program's cost will be $70 billion through 2030, which is $35.7 billion more than the previous estimate from 2012.[7] "Several causes for this cost growth were identified including extension of the program life-cycle from 2020 to 2030, procurement of 60 additional launch vehicles, the inherently unstable nature of the demand for launch services, and space industrial base instability."[8]

In the acquisition management of space systems, escaping the "death spiral" (see Figure 4)—a failure to achieve programmatic and project goals, avoid significant overcharges, and curb wasteful spending—is an essential challenge. Program/project managers must be on guard and must be prepared to detect the distinct warning signs of impending failures, especially as to cost and technical performance, and to take management actions to confront them.

In the EELV case, launch cost growth, as previously mentioned, is a key issue. Since the program's start in 1996, a high degree of technology maturity has been reached and the program has been in a sustainment phase

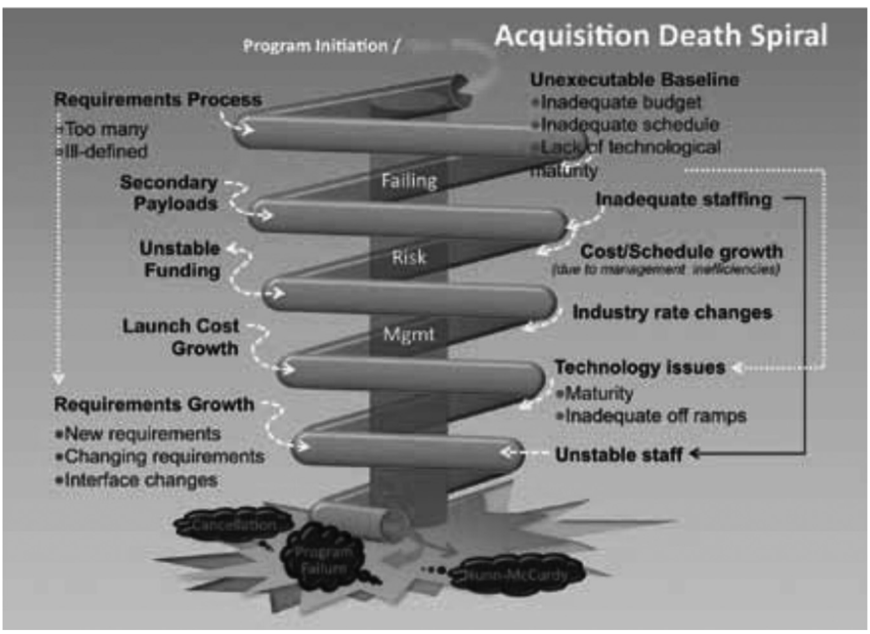

FIGURE 4 Acquisition death spiral.
Source: "Escaping the Space Acquisition Death Spiral," Air Force Space Command, August 2011.

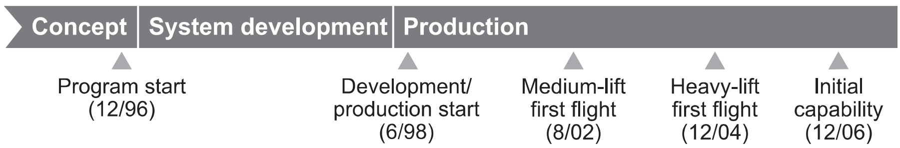

FIGURE 5 System development timeline for EELVs.
Source: U.S. Government Accountability Office.

since 2006 with initial operational capabilities achieved (see Figure 5). In the system development process, there were shared costs between government and industry. Over the course of development, investments totaled $1 billion on the part of DOD and more than $4 billion to $6 billion on the part of ULA.

Until 2011, costs for the EELV program were largely managed under a "cost-as-an-independent-variable" (CAIV) model. CAIV allowed for project managers to trade off costs to achieve technical performance directed at assured access to space that the DOD requires; under the CAIV program, acquisition unit costs for the EELVs grew by 358%.[9] On the other hand, the EELVs have a near-perfect record of operational space launch, including some of the heritage systems used beforehand. There have been several anomalies in launch, but the last launch failures took place in 1993.

Underlying this high degree of technical excellence is the emphasis on quality controls put into place by ULA. For management of the EELV rockets in terms of systems integration, operations, and performance, there are AS9100 quality management standards for operating requirements, ULA internal system manuals and overall compliance with ISO 9001:2008. Further, DOD monitors AS9100 compliance onsite and maintains oversight of ULA processes.

The 2013 DODI 5000.02 and associated acquisition defense memoranda (ADMs) institutionalized several key changes to address cost growth issues inherent with the EELVs and other major programs. First, a better buying power model (BBP), aimed at "affordability" as a requirement that is on par with operations and performance, was put into place. This model replaced the CAIV one with the intent to mitigate the trade-off of cost management with technical performance.

Second, a block buy model for EELV acquisitions of space launch services based on firm-fixed pricing was established and DOD acquired 36 launches from ULA in a block buy that covers 2012 to 2017.[10] This replaced the procurement of single launch units used previously, although EELV launch capability (the rocket technology) continues to be acquired on cost-plus basis for the 36 core rocket boosters. Fixed-price contracting exhibits lower cost growth because of its application to more mature, lower-risk technology that characterizes the EELV program.[11] The combined approach in contracting for EELVs is shown in Table 2.

TABLE 2 Cost-plus and firm-fixed price contracting for EELVs

	EELV Launch Capability	EELV Launch Services
Contract type	Cost-plus incentive fee.	Firm-fixed price.
Purpose	To acquire launch capability based on the strategy of assured access to space (requires a fixed, high-cost labor force).	To acquire launch hardware
Terms covered by contract	Incudes mission integration, systems engineering, production and management, propellants, transportation, and labor for launches.	Launch vehicle hardware, production, and direct labor.
Number of active contracts	One contact active at any time.	Multiple contracts.
Length of contract terms	Contract covers one year of launch capability.	Varies: contracts can be for one launch or multiple launches, and some contracts can last for multiple years.

Source: U.S. Government Accountability Office.

Third, in an effort to advance the "affordability" requirement of BBP, a model of competitive launches was established by DOD.[12] The goal is to use competition to spur the development of additional technology, maintain performance excellence, and contain costs. DOD established management procedures for this approach (FAR 15 competitively negotiated source selections) based on a "best value" model that covers two approaches to a competitive acquisitions strategy.[13] The first one is trade-off source selection between non-cost and cost factors to account for other factors (not necessarily the lowest cost or the highest technical); and the second one is lowest price technically acceptable source selection that bases selections primarily on cost, assuming technical requirements are met.

The competitive model certification standards for DOD's space launches are stated in the New Entrants Certification Guide (NECG) issued in 2011. The NECG outlines the risk-based approach DOD uses to certify the capabilities of new launch companies to compete for DOD space launches. NECG adopts a common standards framework for certification based on NASA certification criteria for space launch services risk mitigation contained in NASA Policy Directive (NPD) 8610.7D.[14]

The NECG, however, allows for DOD interpretation and certification requirements to differ as to number of launches to be completed (14 from 2012 to 2017), number of successful launches to be completed prior to certification (commercial launches are acceptable), standards for common space launch vehicle configurations that are acceptable, data and information sharing standards, and the overall order in which certification phases take place. DOD's launch directorate at the U.S. Air Force (USAF) Space and Missile Systems Center (SMC) is responsible for granting launch vehicle certification under NECG.

The NECG certification covers a number of phases highlighted below.[15]

- Prior to NECG consideration, USAF must approve an implementation plan with schedules. Plans are realized through an approved cooperative research and development agreement (CRADA) between industry and USAF and must include planned-for capabilities to integrate NSS payloads with the launch vehicle being considered for use.
- Based on the CRADA, which contains the vehicle's planned capabilities, a formal "Statement of Intent" to certify a vehicle is required. Capabilities must include at least 9000 kilogram (kg) low Earth orbit (LEO) lift capacity and the capability to launch at Cape Canaveral Air Force Station and Vandenberg Air Force Base in California.
- Launch certification can occur following approval of milestones and completion of activities outlined in the NECG. New entrants submit a formal "certification plan" that outlines the tailored certification approach through which a new entrant intends to achieve certification.
- A separate certification plan and process is required for each launch vehicle configuration. Additionally, if a certified launch vehicle undergoes changes that "substantially affect" certain factors outlined in the NECG, such as operating time or engine thrust profile, that vehicle must re-enter the certification process from the beginning.

The NECG provides the standards of risk that are acceptable for certification. There are three risk categories drawn from NASA definitions (see Table 3, which highlights category 3). These are defined as 1, 2, and 3 categories based on the risk associated with that vehicle; i.e., more risk with 1 and less risk with 3. To be certified for operational mission launch with the NECG, a level 3 of risk is required, which represents the most proven, least risky launch vehicle. Risks for launch vehicles are also matched with payload risks. DOD operational mission launches represent class A payloads that require category 3 with the space launch vehicle.[16] Higher-risk launch vehicles can launch for the DOD, but only with payloads that are of a technology demonstration type (non-essential to current military operations and needs).

In 2012, the USAF awarded an EELV-class launch service, Space Test Program-2, to SpaceX in an effort to support the demonstration of their capabilities as part of the NECG certification process. Of note, as well, is that launch failures do not invalidate previous launch vehicle certification if an engineering review board concurs with cause and corrective action.

TABLE 3 Launch vehicle certification requirements matrix

Launch Vehicle Risk Category	Category 3 (Low Risk)		
Payload Class	A (others can apply; NASA lists here B, C, & D as well)		
	Alternative 1	Alternative 2	Alternative 3
Management Systems	AS9100 Compliant	AS9100 Compliant	AS9100 Compliant
Flight Experience	14 consecutive successful flights (95% demonstrated reliability) of a common launch vehicle configuration, instrumented to provide design verification and flight performance data Post Flight Operations/Anomaly Resolution Flight Margin Verification	6 successful flights (minimum 3 consecutive) of a common launch vehicle configuration, instrumented to provide design verification and flight performance data Post Flight Operations/Anomaly Resolution Flight Margin Verification	3 (minimum 2 consecutive) successful flights of a common launch vehicle configuration, instrumented to provide design verification & flight performance data Post Flight Operations/Anomaly Resolution Flight Margin Verification
Design	Assessment of reliability	Assessment of reliability	Assessment of reliability
Manufacturing, Operations and Systems Engineering	None	Audits	Audits
System Safety	Demonstrated compliance with applicable Range Safety Requirements	Demonstrated compliance with applicable Range Safety Requirements	Demonstrated compliance with applicable Range Safety Requirements
Test and Verification	None	Design Certification Review	Comprehensive Acceptance Test results
Quality Systems/Process	None	Audit	Audit
Flight Hardware & Software Qualification	None	Design Certification Review	Engineering Review Boards on vehicle subsystems
Launch Vehicle Analysis	None	Comprehensive assessment	Comprehensive assessment
Risk Management	Risk Plan, Mitigated and Accepted Technical and Safety Risks	Risk Plan, Mitigated and Accepted Technical and Safety Risks	Risk Plan, Mitigated and Accepted Technical and Safety Risks
Integrated Analysis	None	None	Full Vehicle
Launch Complex	None	Design Certification Review	Engineering Review Board

Source: NASA Policy Directive 8610.7D.

Also, risk category 3 certification requires NASA (or DOD for the NECG) participation in the launch service contractor's failure review process.

ACQUISITION OF COMMERCIAL ITEMS

In contrast to the contracting model, there is government acquisition of commercial items (technology and services). The 1998 Commercial Space Act specified that commercial space transportation services be acquired as commercial items whenever such services are required by the government. Current U.S. National Space Transportation Policy (2013) and amendments to the Commercial Space Act of 2004 establish in U.S. policy and law the fostering of a space transportation industrial base, and the promotion and development of a viable commercial space transportation industry (cargo and crewed).[17]

The policies/laws regarding commercial space transportation are implemented under FAR 12 regulations.[18] These regulations define "commercial items" as those items that are used for non-governmental purposes, but that evolved under government solicitation and for government purposes. Key criteria important for commercial space launch under FAR 12 contracting include the financial wherewithal of industry to develop and commercialize the items, in addition to technical merit and performance. FAR 12 regulations prescribe procedures for the acquisition of commercial items, which include the use of firm-fixed price contracts and other provisions to streamline the acquisition process and regulatory framework.

Specific to commercial space launch, a performance-oriented, fixed-price-based approach under FAR 12 was used in combination with funded Space Act Agreements (SAAs) that fall outside FAR regulations, where any additional work to meet performance criteria, including cost overruns, is borne by industry. In this SAA/FAR 12 model, government payment is made to industry when performance is met by industry. NASA's Commercial Crew and Cargo programs are based on this approach.[19]

In NASA's Commercial Orbital Transportation Services (COTS) case (cargo program), performance milestones were established for design and development, test and production, and flight demonstrations covering external cargo delivery and disposal, internal cargo delivery and disposal, and internal cargo delivery and return. SAAs were applied for development[20] and FAR 12 contracting for LEO cargo transportation services to/from the International Space Station (ISS). The benefits of the SAA/FAR 12 model are shown in Table 4.

Essential to this model are streamlined regulatory and acquisition practices. This entailed industry control on meeting performance criteria; i.e., "commercial partners, not NASA, established their own requirements and were responsible for the design, development, and testing of their

TABLE 4 Benefits of SAA and FAR 12 acquisitions for space launch

- Enables portfolio investment in multiple, diverse commercial partners to reduce risks.
- Companies selected based on NASA's level of confidence in their ability to meet both the technical goals, as well as the execution of their business plan.
- Leverages NASA investment with additional company-provided capital.
- Application of corporate-based research and development (R&D).
- Enables known/limited cost and risk using pay-for-performance milestones. Pay is contracted and pre-negotiated and remains fixed. Cost overruns incurred by industry.
- Schedule delays (and cost overruns) are not cause for termination (key is technical progress that is acceptable to NASA).
- Limited termination liability. NASA may not unilaterally terminate the agreements for its convenience (termination only for failure to perform).
- Mitigates cost impacts due to evolving requirements. SAA partnerships permit the evolution of system requirements as system development takes place.
- Compliance with top-level system performance goals and objectives.
- Companies are free to innovate and optimize their system per their capabilities and management and life-cycle design methods. Commercial partners are responsible for the overall design, development, manufacturing, testing, and operation. NASA intentionally limits participation in the commercial programs to enable maximum use of innovative, cost-effective commercial practices. NASA's primary role is to monitor the progress through an assessment of the milestones and to make payment for successfully completed milestones. NASA provides expert technical assistance as requested or where considered necessary.
- Discrete mode for oversight. Validation and verification of requirements are milestone, performance-based ("burden of proof" of demonstrated capability on industry).
- Enables streamlined and flexible acquisition processes.
- Simplifies program management and oversight with objective milestone success criteria.
- Use of informal day-to-day communications with partners.
- Reporting requirements are performance-milestone-based and key technical reviews (e.g., critical design reviews).
- Performance incentives to manage cost and schedule.
- Commercial friendly intellectual property and data rights. Special provisions for minimal government retention, licensing and use of intellectual property developed by industry under agreements. Companies retain the benefit of their investment.
    - U.S. Federal Aviation Administration (FAA) licensing, liability, indemnification, and enforcement. Given the commercial nature of space launch for NASA's Crew and Cargo program (i.e., not government activities), legal jurisdiction falls under the FAA. Congress and the FAA adopted a strategy to foster the commercial spaceflight sector—enforcing safety where necessary, but also remaining cognizant of the need to critically examine rules and regulations to foster commercial spaceflight.
    - Since 1988, the government provided indemnification to commercial providers of launch services. In the case of an accident, the company will only be financially liable for what has been determined through the licensing process as "maximum probable loss." Any further amount will be the responsibility of the government. Both government indemnification and the moratorium on regulations are intended to encourage the industry and make companies successful and more competitive.

(*Continued*)

TABLE 4 (Continued)

- The 2004 Commercial Space Launch Amendments Act included a "learning period" from 2004 to 2012 that limited the FAA's ability to impose regulations for crew and spaceflight participants, which Congress extended until 2015. FAA also provides open lines of communication with industry representatives and coordinates closely with NASA Commercial Crew and Cargo Program. All this has proved pivotal to the success thus far of COTS and CCDev.

Notes: In June 2014, the NASA Office of the Inspector General found that NASA's use of SAAs lacked adequate transparency, accountability, and oversight. As a result, NASA agreed to revamp its procedures and policies for SAAs. Of concern, is a full accounting for costs and incorporating them in the closeout process for SAAs. There are four types of SAAs: (1) funded, where NASA provides funding to its partner to undertake a program (e.g., commercial crew and cargo); (2) reimbursable, where the partner reimburses NASA for all or part of the program; (3) non-reimbursable, where NASA and its partners provide their own resources used for research and development projects; and (4) international ones used for establishing joint programs with foreign partners (though NASA has made use of memoranda of understanding for international cooperation).

spacecraft"[21]; simplified documentation requirements, such as the development of a COTS Integration and Interface Requirements Document (IIRD), to allow for ISS support for cargo resupply; discrete reporting and oversight as technical or management needs/issues arose and to support major performance-based technical reviews (versus a model of continuous reporting requirements and oversight); and protections of industry proprietary data and know-how.

In addition, NASA works to promote and foster the commercial industries in the COTS program. In this vein, NASA provides technical expertise and project management know-how. Such a transfer of knowledge was essential in the success of SpaceX with COTS. For example, early on in COTS work by SpaceX, schedule delays of more than two years were encountered. NASA helped SpaceX in several ways to address this issue. First, NASA showed flexibility and determined that the partnership would continue to exist as along as technical progress on key elements, like the Falcon 9, were evident. This drove accelerated technology development at SpaceX from the Falcon 1 to the Falcon 9 space launch vehicle in that SpaceX abandoned efforts for an intermediary approach with a Falcon 5 launch vehicle that it had originally planned on developing. Second, NASA directly influenced SpaceX management through the adoption of integrated schedules, more extensive documentation and configuration management processes, and improvements upon manufacturing processes.

Analogous to the COTS model of acquisitions management is NASA's Commercial Crew Development program (CCDev) that was initiated in 2009. CCDev is focused on developing vehicles and technologies needed for crew transportation to LEO for support of ISS by 2017. The fundamental challenge herein relevant for space launch is to ensure crew safety; i.e., safety requirements continue to be met and there is an established process for continuous improvement towards achievement of the safety goal.

Given this challenge, NASA made use of traditional cost-plus acquisitions under FAR 15 for initial certification purposes (Certification Products Contracts). The intent was to ensure a greater capacity for oversight to engage in the certification of technologies for the safety of crew. Following this, the SAA/FAR 12 model was used in similar fashion to COTS with initial SAAs for overall development followed by FAR 12 contracts for systems integration capabilities. CCDev phase 3 was completed in September 2014 with Commercial Crew Integrated Capabilities (CCiCap) FAR 12 contract awards to SpaceX, which will make use of Falcon 9 for launch, and Boeing, which plans to use the Atlas V.

Specific to the certification of human spaceflight for CCDev is NASA's Commercial Crew Transportation System Certification Requirements.[22] With crew safety as a principal requirement, a much more rigorous certification approach was applied as compared to COTS. These requirements are based on NASA's Procedural Requirements (NPR) 8705.2B, Human Rating Requirements for Space Systems.[23] NASA certification of a human spaceflight system consists of four separate functions: (1) validation of the technical and performance requirements and standards; (2) verification of compliance with those requirements and standards; (3) consideration of relevant operational experience; and (4) acceptance of technical risks.

The NASA Program Manager is responsible for ensuring that the operational and design certification requirements and standards are met through agreement milestones, statement of work, contract requirements, and engineering and operations plans. At the discretion of NASA, modifications to existing space systems along with the appropriate milestone reviews can be requested. The certification process can also be accelerated and milestones can be combined based on flight history and heritage of systems. Further, NASA evaluates all design, manufacturing processes, and testing to verify that the mission falls within the bounds of the certification and that anomalies are addressed. Mission authorization takes place through flight readiness certification and acceptable risk. During the operations phase, NASA monitors safety performance by evaluating risk based on any observed anomalies, and by updating independent assessments of safety performance.

Clearly, human-rating of the space launch vehicles selected by industry to support CCDev, Falcon 9 and Atlas V, is required. Human-rating involves meeting all of NASA's certification requirements. These requirements are met by adopting an integrated approach (launch vehicle and human spacecraft). Acceptable risk per the NASA Launch Vehicle Certification Requirements Matrix shown earlier must be at a category 3. Both SpaceX and Boeing are meeting certifications by evaluating requirements with Falcon 9 and Atlas V designs. Certification milestones based on acceptable performance were met by Boeing at 100% completion and 70% completion by SpaceX at the time of the selection of Space X and Boeing in September 2014 for the CCDev CCiCap contract award. Both Space X and Boeing also completed critical design reviews demonstrating the design maturity of the systems architect; i.e., the integrated human spacecraft, launch vehicles (Falcon 9 and Atlas V) and ground systems.

NOTES

1. See http://www.acquisition.gov/far/current/html/FARTOCP15.html (accessed October 2014). The FAR dictates an intense process to ensure fairness in government acquisitions of goods or services.

2. See *Lack of Disciplined Cost-Estimating Processes Hinders Effective Program Management*, U.S. Government Accountability Office, GAO-04-642, 28 May 2004, http://www.gao.gov/products/GAO-04-642 (accessed October 2014).

3. See *GAO Cost Estimating and Assessment Guide: Best Practices for Managing and Developing Capital Program Costs*, U.S. Government Accountability Office, GAO-09-3SP, March 2009, http://www.gao.gov/new.items/d093sp.pdf (accessed October 2014).

4. *2008 NASA Cost Estimating Handbook*, http://www.nasa.gov/pdf/263676main_2008-NASA-Cost-Handbook-FINAL_v6.pdf (accessed October 2014).

5. See DFARS at http://www.acq.osd.mil/dpap/dars/about_dfarspgi.html (accessed October 2014); and see "Interim DOD Instruction 5000.02, Operation of the Defense Acquisition System," 25 November 2013. This instruction updates and replaces DODI 5000.02 from 8 December 2008.

6. See, for example, *The Long-Term Implications of Current Plans for Investment in Major Unclassified Military Space Programs*, U.S. Congressional Budget Office, 12 September 2005, http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/66xx/doc6637/09-12-militaryspace.pdf (accessed October 2014); and *Long-Term Implications of the 2014 Future Years Defense Program*, U.S. Congressional Budget Office, November 2013, http://www.cbo.gov/sites/default/files/44683-FYDP.pdf (accessed October 2014).

7. See "Defense Acquisitions: Assessments of Selected Weapons Programs," U.S. Government Accountability Office, GAO-14-340SP, March 2014, http://www.gao.gov/assets/670/662184.pdf (accessed October 2014).

8. Ibid.

9. *Implementing Effective Affordability Constraints for Defense Acquisition Programs*, Institute for Defense Analysis, IDA Paper P-5123, Alexandra, Virginia, March 2014.

10. An additional benefit here is that of maintaining successful operations and sustainment of the EELV program so that the program does not incur breaks in production lines.

11. See *Performance of the Defense Acquisition System, 2014 Annual Report*, U.S. Department of Defense, Under Secretary of Defense, Acquisition, Technology and Logistics, 13 June 2014, http://www.acq.osd.mil/docs/Performance-of-Defense-Acquisition-System-2014.pdf (accessed October 2014).

12. The Office of the Secretary of Defense, Acquisitions, Technology and Logistics issued an ADM in 2012 directing the USAF to introduce a competitive EELV acquisitions strategy with initial contract awards for up to 14 launch missions to commence as early as 2015.

13. See http://www.acq.osd.mil/dpap/policy/policyvault/USA007183-10-DPAP.pdf (accessed October 2014). Also, (according to the GAO) commercial companies that plan to compete for EELV-based NSS launches, including SpaceX, prefer FAR 12 acquisitions to focus the competition on price. DOD is reluctant to adopt this approach as it is an unfamiliar one, acquisition management is not in place for FAR 12, and oversight/compliance with regard to cost and performance data is inadequate as compared to FAR 15 acquisitions. However, DOD is open to consider FAR 12 acquisitions by 2018 after the end the block-buy contract with ULA.

14. See *Coordinated Strategy Among the United States Air Force, the National Reconnaissance Office and the National Aeronautics and Space Administration for New Entrant Launch Vehicle Certification* [undated memorandum of understanding], signed October 2011; and see *Launch Services Risk Mitigation Policy for NASA-Owned and/or NASA-Sponsored Payloads/Missions*, NASA Policy Directive (NPD) 8610.7D, http://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPD&c=8610&s=7D (accessed October 2014).

15. Phases are drawn from the NECG. The NECG document is unavailable to foreign governments due to U.S. export controls policies and laws. For insights on the NECG, see *Launch Services New Entrant Certification Guide*, U.S. Government Accountability Office, GAO-13-317R, 7 February 2013, http://www.gao.gov/assets/660/652037.pdf (accessed October 2014).

16. Payload risks are based on NASA's Procedural Requirements 8705.4.

17. See *National Space Transportation Policy*, President of the United States, 21 November 2013, http://www.whitehouse.gov/sites/default/files/microsites/ostp/national_space_transportation_policy_11212013.pdf (accessed October 2014); and the *Commercial Space Launch Amendments Act of 2004*, https://www.faa.gov/about/office_org/headquarters_offices/ast/media/PL108-492.pdf (accessed October 2014).

18. See https://acquisition.gov/far/current/html/FARTOCP12.html (accessed October 2014).

19. NASA Headquarters acknowledged this new way of business by revising NASA Policy Directive (NPD) 1000.5, the Policy for NASA Acquisition, to recognize the role that partnerships can play in meeting the space agency's mission needs. This new approach required NASA to "consider the full spectrum of acquisition approaches," including procurement, grants, cooperative agreements and Space Act Agreements. See odis3.gsfc.nasa.gov/displayDir.cfm?t=NPD&c=1000&s=5B (accessed October 2014); and see *Commercial Orbital Transportation Services*, NASA/SP-2014-617, February 2014, http://www.nasa.gov/sites/default/files/files/SP-2014-617.pdf (accessed October 2014).

20. "NASA was not acquiring a good or service for the Agency's direct benefit. Therefore, COTS was not procurement. Neither was it a grant or a cooperative agreement often used when NASA provides funding to a university for research. See *Commercial Orbital Transportation Services*, NASA/SP-2014-617, February 2014, http://www.nasa.gov/sites/default/files/files/SP-2014-617.pdf (accessed October 2014).

21. Ibid.

22. ESMD-CCTSCR-12.10 Revision-Basic, http://www.nasa.gov/pdf/504982main_CCTSCR_Dec-08_Basic_Web.pdf (accessed October 2014). In addition, NASA has put forward a series of Commercial Crew Transportation System Certification Requirement documents that include CCT-PLN-1100 (Crew Transportation Plan), CCT-DRM-1110 (Crew Transportation System Design Reference Missions), CCT-PLN-1120 (Crew Transportation Technical Management Processes), CCT-REQ-1130 (Crew Transportation Certification and Services Requirements), CCT-STD-1140 (Crew Transportation Technical Standards and Design Evaluation Criteria) and CCT-STD-1150 (Crew Transportation Operations Standards).

23. See http://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=8705&s=2B (accessed October 2014).