Chapter Seven

PILOT PROGRAMS: LESSONS LEARNED

INTRODUCTION

In Chapter Six, we examined commercial markets to glean insights into improved commercial-like approaches to military acquisition. We began by noting that key differences between commercial and government military markets make comparisons across these markets problematic. However, certain commercial markets, such as the commercial transport aircraft and aircraft equipment markets, exhibit many characteristics similar to the government military aerospace market. We showed how, particularly after deregulation of the airline industry in the late 1970s, the commercial aircraft market adopted a strategy of "must cost," in conjunction with mechanisms such as contractor risk-sharing and IPTs, to cope with potential performance shortfalls and price gouging in an increasingly price-sensitive environment. We concluded by suggesting that many of these "best" business practices may be exploitable in the military market.

Yet it can still be argued that there remain important differences between the commercial aircraft and the military aircraft markets—most notably the existence (in most cases) of a single buyer in military markets and the tendency (or necessity) of military programs to incorporate high-risk technologies to achieve the highest possible performance. These differences continue to raise serious questions in the minds of some CMI opponents as to the applicability of commercial market mechanisms to military acquisition programs.

The government has responded to these concerns by testing commercial-like approaches to military acquisition in a variety of innovative pilot and demonstration programs. And although some of these programs have been examined extensively in isolation, we are not aware of any studies that attempt to determine if they provide any across-the-board "lessons learned." This chapter takes such an approach, attempting to assess to what extent, and with what success, commercial-like approaches based on market mechanisms are being applied to military programs and what can be learned from them.

Two categories of programs, representing systems from munitions to potential weapon system platforms, were selected for review. The programs entail full-scale R&D and production as well as modification of existing systems. The first category, which is the only one reported on in detail here, includes three of the most important acquisition pilot programs currently under way. These programs aim at the development and production of a new generation of "smart" munitions for the U.S. Air Force and Navy: The Joint Direct Attack Munition (JDAM), the Wind Corrected Munitions Dispenser (WCMD), and the Joint Air-to-Surface Stand-Off Missile (JASSM). These official acquisition reform pilot programs have progressed beyond the concept development stage and (1) focus on developing military-unique combat systems from their inception under the direction of the user services; (2) were from the beginning intended to result in the full development, procurement, and operational deployment of actual weapon systems; and (3) make use of virtually every acquisition reform measure and concept proposed over the last several years.

The second category is made up of two programs initiated by the Defense Advanced Research Agency (DARPA) for the development and possible production of high-altitude endurance (HAE) unpiloted air vehicles (UAVs), plus an innovative modification program, DoD's Commercial Operations & Support Savings Initiative (COSSI). The UAV programs are the Tier II+ Global Hawk under development by Teledyne Ryan Aerospace and the stealthy Tier III– DarkStar under development by Lockheed Martin and Boeing.[1] Both of these pro-

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[1]The DoD cancelled the DarkStar program in early 1999.

grams have been designated as Advanced Concept Technology Demonstration (ACTD) programs and are operated under DARPA's Section 845 Other Transactions Authority.[2] The COSSI program is a joint Army-Navy-Air Force program that encourages the insertion of commercial technologies into military systems to lower long-term operations and support costs without degrading system performance. Like the DARPA programs, COSSI also operates under the Other Transactions Authority for prototypes.

The two DARPA programs contain many novel characteristics similar to formal Defense Acquisition Pilot Programs (DAPPs).[3] Nevertheless we comment only briefly on them at the end of this chapter, in part because they are technology demonstration programs not administered by the services and not necessarily intended to lead directly to procurement of operational systems, and in part because they are reported on in other RAND research.[4]

MUNITIONS PILOT PROGRAMS[5]

JDAM

JDAM is an early trial program for testing key aspects of the Clinton Administration's defense acquisition reform measures. Indeed, Lt Gen George Muellner, former Principal Deputy Assistant Secretary of the Air Force for Acquisition, characterized JDAM as "the linchpin" of "the broader Department of Defense's acquisition streamlining

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[2]In principle, ACTDs are intended to allow DARPA, in close association with potential user services, to rapidly integrate relatively mature technologies into prototypes to demonstrate a useful operational capability. Section 845 Other Transactions Authority eliminates nearly all normal procurement statutes and FARs to permit maximum program flexibility in developing demonstration prototypes of weapon systems. See DoD (1998).

[3]For example, both UAV programs have in principle a hard "must cost" unit fly-away price of $10 million in FY94 dollars, while all other aspects of the program are flexible and can be traded off against cost. The unit fly-away price is defined as the average price of air vehicles 11–20, including sensor payload, for both programs.

[4]See, for, example Drezner and Sommer (1999) and Sommer et al. (1997). After completion of the DARPA-run technology demonstration phase, these programs are to be handed off to the Air Force for full-scale development.

[5]Most of the information on these three programs was acquired from open sources, program documents, and interviews with the Program Offices (at Eglin Air Force Base, Florida), and with contractors.

activities" (Muellner, 1996). JDAM is an Acquisition Category (ACAT) 1D program, the most important Air Force acquisition category.[6]

JDAM originated as a traditional military acquisition program. Nonetheless, from the very beginning, the Air Force imposed a high-priority average unit price target of $40,000. In 1994, DoD designated JDAM as an official DAPP under the 1994 Federal Acquisition Streamlining Act (FASA), which mandated a wide variety of acquisition reform measures.[7] Dr. Paul Kaminski, sworn in as Under Secretary of Defense for Acquisition and Technology in October 1994, supported JDAM as a major test case for acquisition reform.

The JDAM program aims at developing sophisticated—but affordable—"strap-on" guidance kits that can be attached to standard Mk-83 and BLU-110 1000-lb "dumb" bombs, and Mk-84 and BLU-109 2000-lb "dumb" bombs. Through the use of an inertial navigation system augmented by updates provided by GPS, which guide active control surfaces, JDAM kits permit highly accurate delivery of bombs from a variety of aircraft platforms under a wide range of adverse weather and environmental conditions.[8] JDAM has a range of about 15 nautical miles when dropped from high altitudes.

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[6]ACAT 1D programs are Major Defense Acquisition Programs (MDAPs). According to the Defense Systems Management College, "An MDAP is defined as a program estimated by OUSD/A&T to require eventual expenditure for research, development, test, and evaluation of more than $355 million [fiscal year (FY)96 constant dollars] or procurement of more than $2.135 billion (FY96 constant dollars), or those designated by OUSD/A&T to be ACAT I." ACAT 1D programs are those where the Milestone Decision Authority resides at the highest level possible: OUSD/A&T.

[7]The DoD Authorization Act for FY94 designated five programs as statutory DAPPs: JDAM, Fire Support Combined Arms Tactical Trainer, Joint Primary Aircraft Training System, Commercial Derivative Engine, and Nondevelopment Airlift Aircraft (later dropped). FASA provided regulatory relief for these programs and gave authorization to treat them as commercial procurements. Later, the C-130J and the Defense Personnel Support Center were added as "regulatory" DAPPs. See OUSD/AR (1997a) and OUSD/A&T (June 30, 1997).

[8]U.S. and allied forces used a wide variety of existing "smart" munitions during Desert Storm combat operations in Kuwait and Iraq, often with great effect. However, many current smart munitions guidance kits use electro-optical, laser, or infrared sensors whose performance can be degraded in poor weather conditions, when the battlefield is obscured by smoke and dust, or by other factors. The requirement for JDAM and WCMD arose from the need to develop munitions guidance kits for unguided munitions that could operate well in all weather conditions and in other situations where visibility is poor.

The JDAM configuration and baseline weapons are shown in Figure 7.1.

WCMD

The Air Force WCMD program has some similarities to the JDAM effort. In response to FASA and DoD's acquisition reform, the Air Force designated WCMD a "lead program" to test out acquisition reform within the Air Force. WCMD is the only Air Force acquisition reform "lead program" for a totally military-unique combat weapon system developed from scratch.[9]

Compared to JDAM, WCMD is a somewhat simpler tail guidance retrofit kit employing an inertial navigation unit and active control

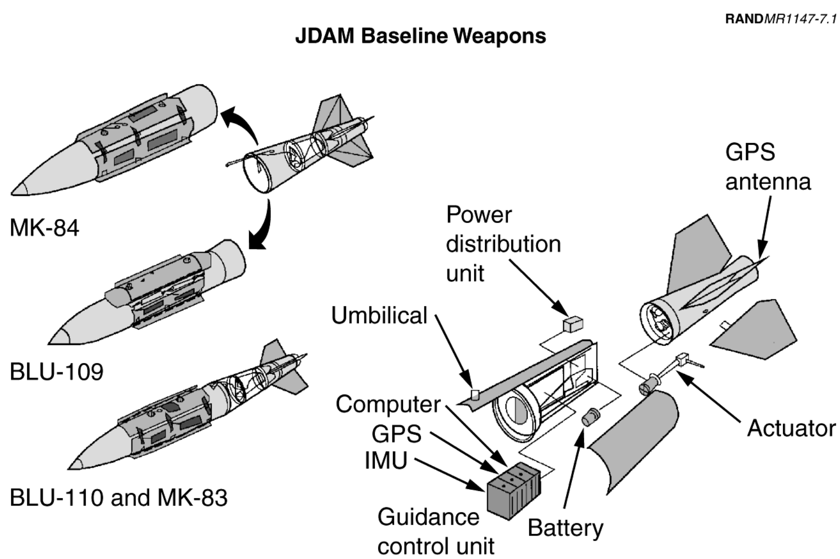

Figure 7.1—JDAM Baseline Weapon System

[9]WCMD is one of four Air Force "lead programs" selected to implement acquisition streamlining initiatives. The other three are Evolved Expendable Launch Vehicle, Ground Theater Air Communications System, and Space-Based Infrared Systems.

surfaces intended for use on three "dumb" air-dropped munitions dispensers: the CBU-87/B Combined Effects Munition, the CBU-89/B Gator, and the CBU-97/B Sensor Fused Weapon. WCMD kits are intended to enhance aircraft survivability by permitting a GPS-capable aircraft to drop munitions dispensers from medium altitudes with accuracies equal to or better than those currently achieved through dangerous low-level attack profiles. WCMD's inertial measurement unit (IMU), which can be updated with GPS-quality data from the launch aircraft, corrects for launch transients and wind deflections, thus providing medium-altitude all-weather capability. Its active control surfaces and wind estimation and correction software help WCMD achieve a target accuracy of 85-ft CEP (Circular Error Probable) from altitudes up to 45,000 ft.

JASSM

JASSM is the largest and most sophisticated of the three programs. Like JDAM, JASSM is a joint Air Force–Navy project with the Air Force in the lead role. However, JASSM is a much more complex autonomous stand-off munition. It is a long-range powered cruise-missile with stealthy characteristics. Like JDAM, the missile is equipped with an inertial navigation system and a GPS receiver for navigation. In addition, however, JASSM adds a sophisticated autonomous terminal guidance and automatic target recognition system for true stand-off fire-and-forget capability. JASSM will have a range in the hundreds of miles depending on the launch platform and altitude. With overall performance objectives similar to the ill-fated Tri-Service Standoff Attack Munition (TSSAM) (described below), JASSM is a technologically challenging program, particularly in overall system integration, autonomous guidance, and automatic target recognition.[10]

DoD approved development of JASSM in September 1995, designating it a "Flagship Pilot Program" for acquisition reform.[11] Former Assistant Secretary of the Air Force for Acquisition Arthur L. Money characterized the JASSM program as employing "an aggressive ac-

[10]See the description in GAO (June 1996).

[11]More accurately, JASSM is a "Flagship Pilot Program for CAIV."

quisition approach using virtually every acquisition reform initiative known to date." (Quoted by Chapman, 1996.) As an ACAT 1D program, JASSM, like JDAM, is also in the highest Air Force acquisition category.

MEASURES EMPLOYED TO ACHIEVE CMI GOALS

As noted in the introduction to this report, the primary objectives of a more commercial-like approach to military acquisition, or CMI, are to:

- Reduce costs of acquiring and supporting weapon systems
- Improve performance at Initial Operational Capability (IOC) and throughout the life-cycle of a weapon system
- Shorten development times
- Improve reliability and maintainability
- Help maintain the defense-relevant portion of the industrial base.

The three Air Force munitions programs examined here, as well as other DoD acquisition reform pilot programs, employ a variety of reform measures intended to ensure the achievement of these goals. Many of the measures are drawn from or attempt to replicate conditions in commercial markets. For example, they promote the use of commercial parts and technologies, and encourage the participation of commercial firms, in order to reduce costs and raise quality. At the same time, they are designed to incorporate the type of market-driven safeguards that act to ensure fair pricing and high quality in most commercial markets. These reform measures can be grouped under four general headings:

- Reduction of the regulatory and oversight burden
- Requirements reform and implementation of "must cost" concepts such as CAIV
- A more "commercial-like" R&D program structure, incorporating elements of both "textbook" and "best" commercial practices

- A more "commercial-like" purchase and support of developed systems based on performance incentives.

Reduced Regulatory and Oversight Burden

As discussed in Chapter Two, a key component of CMI is the reduction of the government-imposed regulatory and oversight burden that results in higher costs for DoD—many argue with little value added—and that discourages commercial firms from doing business with the Defense Department. A central purpose of the DAPPs established by the 1994 FASA legislation mentioned above, as well as other pilot programs, was to test outcomes of programs that had been granted relief from the regulatory burdens typically imposed on contractors by the government. In essence, DAPPs permitted DoD to experiment with purchasing a military system as if it were a commercial product. FASA granted DAPPs statutory exemptions that it had mandated for DoD purchases of pure commercial items and permitted DAPP program offices to seek waivers of other statutory regulations from the Secretary of Defense. Thus JDAM, WCMD, and JASSM all enjoy significant regulatory and statutory relief.

JDAM began as a traditional ACAT 1 program. After its designation as a DAPP, DoD eventually granted 25 FAR and 25 DFARS waivers (OUSD/AR, April 1997; SAF/AQ, 1997). These waivers permitted the program to be managed more like a commercial business relationship between buyer and seller/developer. Although cost and other data reporting were still required, the government accepted high-level data in contractor format for most data submittals, program reviews, design reviews, and accounting audits. Formal program and contractor oversight requirements were reduced, and the government greatly reduced the complexity of contract requirements and the Statement of Work (SOW). Contract Data Requirements Lists (CDRLs) were reduced from 250 pre-DAPP JDAM RFPs to 28.[12] The program office agreed to accept CDRLs in contractor format. In

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[12]By the accounting of the Under Secretary of the Air Force for Acquisition (SAF/AQ), the number of CDRLs was reduced from 146 to 22 if the comparison is made between the RFP release in August 1993 (FY95 President's Budget) and December 1997 (FY99 President's Budget). The remaining CDRLs were required mainly by the test and safety communities.

addition, the number of pages in the RFP fell from 986 to 285. The contractor SOW was changed to a Statement of Objectives (SOO) and reduced from 137 pages to 2 pages.

DoD experts estimated that as a result of regulatory relief, government contract administration hours required by the Defense Contract Management Command (DCMC) and its onsite representatives on a three-year R&D contract for JDAM declined by more than three quarters from over 20,000 to under 5000 hours. The JDAM Joint Program Office estimated that because of regulatory relief the total contract administration hours required for the program at the end of 1997 had decreased by nearly 40 percent.

Similar results are being reported for WCMD and JASSM. The WCMD RFP contained only 93 pages. The WCMD contractors developed and wrote their own SOWs, system specification, data requirements documents, and integrated master schedules. Only 18 CDRLs are on contract for WCMD. Although the Air Force uses C/SCS on WCMD, contractor costs during R&D are reported largely in contractor format and down only to the subsystem level, not the piece part level. In the case of JASSM, the government reduced the RFP even further—especially considering the greater complexity of the system—to only 78 pages. Government and industry cooperated closely to develop the original draft RFP on both WCMD and JASSM. Formal contractor proposals were limited to 320 pages on JASSM, including the system performance specification and integrated master plan and schedule. Cost data were limited to 10 pages. One-page SOOs replaced huge SOWs. The first-phase R&D contract for JASSM contained only 16 CDRLs. However, the government did impose CAS on the prime contractors.

It is difficult to quantify the cost savings enjoyed by either the contractors or the government as a result of reductions in the oversight and regulatory burden. Indeed, some studies suggest that the direct cost savings that accrue to contractors from reduction of reporting requirements and other regulatory compliance burdens are modest. However, an additional strong justification for reducing the regulatory and oversight burden is to make defense contracts more attractive to commercial firms and to encourage insertion of commercial parts and components. For this reason as well as cost savings, meaningful efforts were made to reduce the regulatory burden in all three of the munitions programs studied here.

For example, the government ended up imposing CAS on the JASSM prime contractors. But the SPO worked closely with the Office of the Secretary of the Air Force to overcome objections by potential commercial vendors and subcontractors to the imposition of CAS and to various RFP flowdown clauses. As a result, vendors and subcontractors who signed FFP contracts were exempted from CAS. Using the revised rules on contracting for commercial items, the SPO was able to reduce the number of flowdown clauses to the appropriate subcontractors to only four.

These reductions in regulatory and reporting burdens appear to have contributed to the ability of the prime contractors to subcontract more often to commercial vendors and to use much less expensive commercial parts and technology, thus apparently reducing the production costs to the government of their developed systems. This issue is discussed in greater detail in some of the following sections.

Requirements Reform

JDAM, WCMD, and JASSM are pioneering attempts at promoting CMI through requirements reform, including full implementation of CAIV processes. Each seeks to reduce costs by, first, using carefully crafted mission requirements that avoid gold plating and unnecessary capabilities; second, presenting system requirements to contractors in terms of mission performance rather than detailed design and technical specifications; third, minimal use of Mil-Specs; and fourth, contractor configuration control during R&D.

In the official Operational Requirements Documents given to contractors, all three programs replaced detailed technical specifications and "how-to" design-and-build directives with broad mission performance objectives. A few of these objectives were identified as nonnegotiable and were stated in terms of broadly defined "Key Performance Parameters" (KPPs). They were often defined in terms of multiple performance measures—which might be tradeable among themselves—but most had certain minimum "threshold" requirements that had to be met. The remaining objectives were identified as "nice-to-have" but not "must-have." The purpose of this categorization was to prioritize objectives to focus contractor efforts on the most important program requirements and, where appropriate, to facilitate and encourage tradeoffs for cost and other reasons.

Originally, the program planners intended to require no Mil-Specs whatsoever so that contractors could exploit off-the-shelf commercial technologies and parts to reduce costs. However, a few Mil-Specs were eventually adopted to ensure compatibility with host aircraft and for safety considerations. For example, the weapon stores and software interface with the host aircraft required the use of Military Standard (Mil-Std) 1760, whereas communications between the JDAM onboard processor and the host aircraft necessitated use of the Mil-Std 1553 high-speed bus. JASSM and WCMD experienced similar additions of some Mil-Specs.

Nonetheless, these programs show a dramatic reduction in Mil-Spec requirements compared with traditional programs. In the case of JDAM, the baseline pre-DAPP RFP included 87 Mil-Specs, compared with just a handful in the DAPP phase. Interestingly, JDAM also did not require any specific commercial specifications or standards, nor were any Mil-Specs or commercial standards imbedded in a SOW, because only a SOO was required from the contractors. WCMD eliminated all but two Mil-Specs.

All three programs remained close to the original intent of using only broad mission performance requirements instead of detailed technical specifications. In the case of JASSM, the Air Force and Navy user communities agreed that only three objectives were nonnegotiable KPPs: range, missile effectiveness, and aircraft carrier compatibility. Measures of merit for missile effectiveness were carefully developed and clearly communicated to contractors.[13] In addition, the government developed seven performance objectives that were considered desirable, but that contractors could trade off against each other and against other factors to reduce costs.

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[13]The government gave the contractors the official JASSM Operational Requirements Document. The government used a computer simulation to measure missile effectiveness. All contractors had access to the model and could use it to test their technical proposals. Furthermore, contractors could test and question the methodology, tools, and assumptions built into the model.

Yet, the JASSM contractors were not told *how* to achieve KPPs such as "missile effectiveness" while achieving the $400,000 production price target. For example, one defined characteristic of the "missile effectiveness" parameter was survivability, which could be achieved by increasing missile speed, lowering radar cross-section, or by a variety of other means. Or survivability could be traded off against other defined characteristics such as reliability or probability of damaging various types of targets, or against cost. It was up to the contractor's engineers to use creative new approaches to try to optimize the tradeoffs between a whole variety of factors, meet the target price goals, and convince the customer that the correct design decisions had been made.

KPPs did often contain some "threshold" requirements that were nonnegotiable. An example of a threshold requirement was missile compatibility with the B-52, F-16, and F/A-18E/F.[14] JASSM missile compatibility with a variety of other aircraft was labeled as an objective. Whereas all contractors had to achieve missile compatibility with the F-16, each contractor reached its own conclusions about the cost benefits of not achieving compatibility with, for example, the F-117. This helped the government and the contractors to understand clearly the cost of nonessential operational requirements and to decide if that capability was really worth the cost. The iterative process between contractors and the government led to changes in emphasis and priorities in the overall system requirements.

A fundamental JASSM program requirement that could not be traded, and that is enshrined in the Operational Requirements Document, is the "must cost" price ceiling of $700,000 in FY95 dollars for the Average Unit Production Price (AUPP) of JASSM, and the "should cost" price objective of $400,000 (FY95$). This requirement emerged in 1995 after the cancellation of the TSSAM program. Begun in 1986 by Northrop, TSSAM aimed at providing a stealthy, long-range cruise missile with autonomous terminal guidance and target recognition capabilities. However, after many years of development, the Pentagon cancelled TSSAM because the program was plagued with reliability problems and high costs. At the time of pro-

[14]The F/A-18E/F was later dropped as a threshold aircraft.

gram launch, government officials estimated an average unit production cost for TSSAM of $728,000 in then-year dollars.[15] By 1994, average unit production costs for approximately 2500 missiles were expected to exceed $2 million in then-year dollars. The Office of the Secretary of Defense (OSD) concluded that the program had to be cancelled because of excessive cost, and that a cost above $700,000 (FY95$) for a TSSAM follow-on missile would prevent procurement of adequate numbers of missiles. The cancellation of TSSAM and the continuing critical need for an affordable long-range low-observable stand-off missile with performance capabilities similar to TSSAM are the key reasons that OSD designated JASSM a flagship program for CAIV.[16]

The government structured the JDAM and the WCMD design phases in a similar manner, making sure that the contractors were presented with clearly prioritized requirements stated in terms of broad mission performance and emphasizing low cost as a key requirement. For example, the government formulated the following seven KPPs for JDAM:

- Target impact accuracy of 13 meters CEP with GPS
- Accuracy unaffected by weather conditions
- In-flight retargeting capability (before release)
- Warhead compatibility[17]
- Carrier suitability

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[15]Under cost-plus–type production contracts, DoD's relevant measure of cost is the average cost of production per unit plus the (positive) contractor profit allowed under DoD profit policy. With the switch to fixed-price contracts, "profits" may be either positive or negative, and the relevant measure is the average price DoD pays per unit of production.

[16]A requirement that drove up costs on TSSAM—and that was dropped on JASSM—was tri-service deployment capability. TSSAM had to be capable of launch from both Air Force and Navy aircraft, as well as from Army ground launchers. This requirement raised numerous technical difficulties for the TSSAM developers. JASSM dropped the Army ground-launch requirement and retained only the Air Force and Navy air-launch requirement.

[17]JDAM guidance kits had to work with the Mk-84 general-purpose 2000-lb bombs, the BLU-109 2000-lb penetrating bomb, and the BLU-110/Mk-83 general-purpose 1000-lb bombs.

- Primary aircraft compatibility[18]
- AUPP of $40,000 or less.[19]

The seventh KPP, an AUPP of $40,000 or less, was based on calculations that a JDAM-type weapon under a traditional acquisition approach would have an AUPP for 40,000 units of $68,000.[20] Because of budget limitations, senior Air Force officials concluded that JDAM could not be procured in adequate numbers at this price. An AUPP of $40,000 was the maximum that the government would be able to pay.

The focus on cost, the use of broad mission requirements, the emphasis on cost/benefits tradeoffs, the lack of Mil-Spec requirements, and the control of the contractor over configuration and technical solutions for the JDAM program produced some dramatic results. Several contractors took the initiative to exploit commercial technologies, insert COTS parts and components, develop creative technical solutions, and trade off performance against cost where appropriate to achieve significant cost reductions.

An interesting example is that of a JDAM power transistor proposed by one of the competing contractors for use with the braking mechanism on the shaft of the torque motor that turns the fins that steer the bomb. The original requirement called for a 2500-inch-pound stall torque capability. This necessitated the use of an expensive Mil-Spec power transistor that cost $25 per part. But because of the strong emphasis on cost reduction, and the freedom granted the contractor to try different and innovative non–Mil-Spec solutions, one contractor proposed redesigning the unit in a way that it argued maintained overall performance but lowered the stall torque requirement to 1600 inch-pounds. This meant a less-capable Mil-Spec

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[18]Four aircraft (F-22, B-52H, F/A-18C/D, and AV-8B) were listed as threshold requirement aircraft (1000-lb bomb versions only for F-22 and AV-8B), which means this capability requirement had to be met. Compatibility with nine other aircraft (B-1, B-2, F-16C/D, F-15E, F-117, F/A-18E/F, F-14A/B/D, P-3, and S-3) was listed as an objective. Compatibility with the objective aircraft was a requirement fully subject to tradeoff analysis with cost and other factors.

[19]For 40,000 units in FY91 dollars; in FY93 dollars, the AUPP was $42,175 (adjusted using the GDP deflator).

[20]In 1993 dollars.

power transistor could be used that cost only $15. The contractor then decided to examine commercial power transistors. Eventually a COTS part was proposed that cost $4.05.

By redesigning the component and qualifying a COTS part, the contractor argued that more than $500 per guidance unit could be saved, because each unit contains 24 power transistors. With a planned buy of 87,495 units, this could have resulted in a potential production cost savings of almost $44 million.[21]

Another example provided by the JDAM SPO is the shipping and storage container for the JDAM guidance kit. This container must be extremely rugged to guarantee full operational capability of the guidance kit after years of storage and transport in extreme environmental conditions. Traditional Mil-Spec containers of this type have one guidance kit per container, are made out of aluminum, and cost about $1600. Originally JDAM had separate Navy and Air Force requirements for the container. The Navy requirement was more demanding because of harsher conditions for shipboard storage and use. The Navy requirement in September 1994 called for a two-kit aluminum container that would cost an estimated $2200. The Air Force requirement also called for a two-kit container.

Trade studies were conducted between September 1994 and February 1995 on both container designs. To save costs, the Air Force agreed to substitute high-density polyethylene (HDP) plastic for aluminum, lowering the cost to $800. Later, the Navy agreed to accept a front-opening fiberglass container costing $1100. Meanwhile, the Air Force had moved toward a commercial electronics storage philosophy and was willing to accept a much simpler HDP plastic design using a vapor barrier bag. This container cost $600. Finally, in August 1995, McDonnell Douglas (now Boeing) came up with a design acceptable to both services that was made out of fiberglass and used a vapor barrier bag. McDonnell Douglas essentially derived this technology from the shipping and storage technologies found in the commercial electronics industry. The final container design had an estimated cost of $600, or $300 per guidance

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[21]This design was proposed by one of the losing contractors, so this COTS power transistor was never actually fully tested or incorporated into the final JDAM design for the fin braking mechanism.

kit, compared with the traditional Mil-Spec container at $1600 per guidance kit.

A final example is particularly interesting because one of the contractors directly challenged the cost-effectiveness of a specific system performance requirement and won his point. The contractor pointed out that by slightly reducing the required low-altitude captive carriage time in the worse-case scenario in which JDAM was intended to operate, a design change could be made that significantly reduced costs. The contractor argued successfully by using the results of the government combat model, which showed a relatively small decrease in overall combat effectiveness for a large decrease in design complexity and cost.

According to Boeing St. Louis, more than 200 cases of detailed tradeoff studies that reduced JDAM costs have been formally documented in the program's Affordability Trade Studies, although most of the specific cases are proprietary. One of these cases is discussed below as an example of insertion of dual-use technology.

Because of the emphasis on cost promoted by CAIV, the tradeoff analysis of performance versus cost that CAIV encouraged, and the elimination of most Mil-Specs, JDAM is able to make extensive use of COTS processors, boards, chips, and other commercial parts and components. Originally program officials and contractors had planned to acquire major subsystems and components from commercial sources or production lines. Table 7.1 lists the planned sources for various key components for the designs of the two competing contractors during the final competition phase. In the case of the Boeing design, the IMU, the GPS receiver, the mission computer (MC), and the control actuators make up 85 percent of the cost of the guidance kit. Although these subsystems are now acquired from military production lines, all of them contain commercial parts, are slightly modified versions of commercial items, are government off-the-shelf items (GOTS), or could be sold as commercial items.

For example, the Boeing JDAM mission computer, as shown in Table 7.1, was originally intended to come from a commercial source. Eventually, however, Boeing designed its own mission computer and selected Unisys (now Lockheed Martin Tactical Defense Systems) to manufacture the mission computer on a military production line.

Table 7.1

Commercial/Military Mix of JDAM Contractor Production Lines[a]

Item	Boeing[b]	Lockheed Martin
Integration/assembly	Commercial	Military
IMU	Military	Military
GPS receiver	Military	Commercial
Mission computer	Commercial	N/A
Circuit cards	Commercial	N/A
Connector	Commercial	N/A
Actuators	Commercial	Military
Power supply/distributor	Military	Commercial
Thermal	Military	Military
Container	Commercial	Military/Commercial
Fin	Commercial	Commercial
Tail	Military	Military/Commercial
Hardback/nose	Commercial	Military/Commercial

[a]As of late 1996. Boeing, the winning contractor, later switched the mission computer to a military production-line source. Sources for other items may also have changed.

[b]Formerly McDonnell Douglas, the winner of the Phase II contract.

Boeing's dedicated military mission computer is programmed using the Ada language, which is uncommon in the commercial world. Nonetheless, the mission computer's architecture is similar to computers that sit on many people's desks. At its heart is a Motorola microprocessor similar to the one that, prior to the JDAM program, was used by Apple Computer, Inc., as the basis for its Performa 470 series of personal computers. Boeing hopes to upgrade this chip with one similar to that used in the PowerPC or iMac.

Both JDAM and WCMD use the Honeywell HG1700 IMU, a highly miniaturized dedicated military IMU developed by Honeywell Military Avionics explicitly for applications such as smart munitions, UAVs, and missiles. Similar IMUs are used in commercial applications such as railroad vehicle control and landslide detection because of their low-cost and high-performance characteristics. Boeing and Honeywell implemented 11 design changes, or "affordability initiatives," to reduce production costs on what was already an inexpensive OTS item from the JDAM and WCMD perspective by a further 20 percent. These cost reductions were passed on (in part) to DoD.[22]

Boeing's Affordability Trade Studies document the reduction in cost of the Honeywell HG1700 IMU through commercial parts insertion. On the JDAM program, a Boeing/Honeywell IPT worked hard to reduce the cost of this item through the identification of cheaper commercial parts for insertion into the IMU, as well as through other reform initiatives. For example, the original HG1700 IMU connectors were expensive Mil-Spec parts. Eventually a way was found to use much less expensive Honeywell commercial IMU connectors, which saved about $100 per JDAM IMU. This change alone has the potential of saving millions of dollars in production costs over the planned JDAM production run.

The GPS guidance unit for JDAM is provided by Rockwell Collins Avionics and Communications Division, which is part of the Rockwell International's Defense and Electronics group. The GPS receive module is a deliberate variation on the company's widely used GEM III GPS embedded-module receiver, which is based on the Standard Electronic Module, Format E (SEM-E) standard. The redesigned receive module allows for greater spreading of the microprocessors, which in turn allows Rockwell to use less-expensive electronic parts.[23]

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[22]Some of the initiatives included changes in make/buy decisions, parts changes, investment in cost-saving capital equipment, and using commercial inspection processes. One such initiative is discussed in greater detail below.

[23]SEM-E may help standardize military avionics modules, but it also may make it more difficult to adapt commercial modules based on commercial standards. Avionics modules used in munitions, missiles, and tactical fighter aircraft are constrained by special factors such as size, weight, high-vibration, and shock requirements. SEM-E is a form factor standard for electronic modules and connectors that is increasingly popular in military avionics. It is based on conduction-cooled technology, a small form factor, and a blade and fork style connector that provides high reliability in high-shock and vibration environments. It is not used widely in the commercial world, but it is compatible with open architectures. Using the SEM-E standard permits upgrades by ensuring that modules are compatible in size and connectors. However, according to one source, the SEM-E standard size (approximately 6 x 6 inches) may make military avionics modules increasingly incompatible with the commercial market's larger module sizes. Thus it may be more difficult to adapt commercial modules for airborne avionics use. See Defense Advanced Research Projects Agency (DARPA) (1995).

Both prime and subcontractors conducted extensive testing of non–Mil-Spec commercial and plastic-encapsulated parts and their applicability to the environmental conditions in which JDAM would operate. A temperature range of –55°C to +85°C was eventually accepted as the baseline standard for electronic parts. On the high end, this standard permits use of catalog COTS industrial- or automotive-grade parts. However, the low end surpasses the requirements for commercial parts and is indeed the same as the Mil-Spec standard. Therefore, commercial catalogue parts usually had to be tested and/or screened.

According to one Boeing JDAM official, the contractor's experience with testing commercial parts for insertion into JDAM subsystems was highly variable. Some suppliers conducted their own testing for Boeing at a relatively low cost. Other suppliers were willing to conduct tests at their own facilities but charged Boeing a substantial premium. A third category of suppliers agreed to sell testing devices or data to Boeing so that the prime contractor could conduct its own testing. Again, depending on the part or subcomponent, Boeing's cost of testing the commercial parts itself varied considerably. Finally, some suppliers agreed to sell commercial parts but refused to conduct the necessary additional testing required and would not provide the data or devices necessary for the prime contractor to conduct the tests.

Boeing officials claim that the extensive trade studies and commercial parts testing conducted during the initial phase of the program to identify appropriate commercial parts for insertion into JDAM proved to be an expensive and time-consuming effort. Nonetheless, the extra effort to qualify commercial parts seems to have paid off in much lower production costs. According to one account, the use of plastic encapsulated parts saved $535 per unit.[24] This is about 3 percent or less of the AUPP of the JDAM in 1998.

Similar incentives instilled by the CAIV approach, in combination with the virtual elimination of the need to use Mil-Spec parts and processes, produced similar results on the JASSM program: extremely creative and innovative approaches to exploiting existing

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[24]Assistant Secretary of the Air Force (Acquisition), *JDAM—The Value of Acquisition Streamlining,* no date.

commercial and military technologies and parts to lower costs while still producing acceptable performance capabilities in a military environment. Two interesting examples are the process technologies chosen to manufacture the fuselage, the wings, and the vertical stabilizer. The winning contractor (Lockheed Martin) wanted to make all these structural elements primarily out of nonmetallic composite materials to lower weight and enhance stealthiness. However, experience suggested that finished load-bearing structural parts manufactured from traditional aerospace composite materials and processes generally averaged from $600 to $1000 per pound. Using these processes and materials could rapidly escalate the cost of JASSM past the target and even beyond the ceiling prices.

Lockheed Martin and its subcontractors began looking for solutions in the commercial world. Eventually engineers examined a process used for decades in making fiberglass hulls for pleasure boats called Vacuum-Assisted Resin-Transfer Molding (VARTM). This process produces finished fiber-composite parts that cost about $5 per pound. The resulting parts are not appropriate for aerospace applications. However, engineers experimented with variations on this process using different materials systems. Eventually an approach was discovered that, while more expensive than the VARTM process for boat hulls, turned out to cost only a fraction of the cost associated with traditional aerospace approaches that require high temperatures and pressures for curing, and thus need to be processed in expensive autoclaves. The modified VARTM approach was used for the body of JASSM. In addition, engineers developed a lower-cost automated braiding platform to lay down the fiber matrix for the body that was based on commercial machines used to braid socks, shoe laces, and freeway pillar reinforcement rings.

A similar approach of trying to find low-cost solutions from the commercial world was tried with the wings and vertical fin of JASSM. Lockheed Martin adopted a variation of the same process used by commercial firms to build surfboards and windmill blades for wind-driven electrical-energy generators. This process uses an outer composite shell and an inner foam core to form a durable, lightweight structure. Although the process had to be modified considerably, the contractor claims it resulted in a large savings compared with traditional aerospace composite structures costs.

In the case of the JASSM engine, Lockheed Martin used a combination of approaches. First, to save development costs on a new engine, designers selected an existing GOTS engine that had been used to power the Harpoon antiship missile for two decades. Second, the prime contractor helped the engine vendor lower the cost of the engine by one third by replacing outdated Mil-Spec parts and technology on the engine with modern but much less expensive commercial parts and technology. For example, the old Mil-Spec analog engine controller was replaced by a modern digital controller. This latter technology was based on an off-the-shelf antiskid processor used by the automobile industry. As with WCMD, many other automotive- and industrial-grade non–Mil-Spec parts were used. In general, the prime contractor asked the subcontractors and vendors to qualify the commercial parts if extra testing was needed.

In all these areas, the JASSM prime contractors used a common mechanism from the commercial world to keep costs under control: "must cost." Aggressive cost targets for each major subsystem and component such as the guidance and control units were provided to vendors. This in turn encouraged vendors to insert COTS parts and technology to keep costs down.

In cases where no existing commercial product existed to meet the need, JASSM engineers sought out existing military technologies and parts to avoid the expense of having to develop entirely new items. To achieve its performance requirements for autonomous terminal target acquisition and guidance, JASSM needed to use advanced sensors with target recognition capability. No appropriate commercial technologies existed to meet these needs.[25] However, according to some published sources, Lockheed Martin and its subcontractors were able to develop a derivative of the Imaging Infrared (IIR) seeker developed for the Hellfire and Javelin antitank missiles that is appropriate for JASSM. It is claimed that this seeker fills the basic requirement and costs only $50,000.[26]

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[25]Early in the program, the U.S. GAO identified the automatic target recognition requirement and autonomous guidance system on JASSM as areas of high technical risk that could cause schedule slippage and cost growth (U.S. GAO, June 1996). More is said on this below.

[26]This seeker does not provide true all-weather capability. It is limited to a 1500-ft ceiling and 3-mi visibility. See *Aerospace Daily* (30 April 1998).

In a similar manner, Boeing, the losing contractor, worked closely with its subcontractors to reduce costs by adopting existing GOTS military hardware where commercial technology did not exist. In the case of the terminal guidance system, Boeing adopted a derivative of the infrared seeker already used in the AGM-130 powered standoff weapon. Instead of developing a new subsystem, Boeing incorporated the guidance system for its JASSM design that it was already using for its JDAM kit, and also used an antijamming GPS receiver already developed by the Air Force. Finally, Boeing's design also made use of the autonomous target recognition software that had already been developed for its Stand-Off Land Attack Missile Extended Response (SLAM-ER) missile under development for the Navy (Fulghum, 1998).

In summary, the focus on CAIV required a conscious effort to avoid gold plating and "requirements creep," the use of mission performance requirements, a heavy emphasis on "must cost" pricing, contractor configuration control, and Mil-Spec reform. This use of CAIV and a "must cost" commercial-like approach in turn encouraged contractors on these three munitions pilot programs to seek out commercial technologies and parts that could lower costs while maintaining adequate performance, or, if no commercial part existed, incorporate existing GOTS military parts and subsystems. Contractors were able to offer the government a richly varied menu of cost/benefit tradeoffs and alternative design solutions because the government provided no detailed system specification and did not demand the use of military specifications and standards. Indeed, the use of commercial parts, components, and processes was encouraged if it lowered costs and provided acceptable performance. The contractors were given almost total control over configuration, design, and technical solutions. If a commercial part slightly reduced environmental robustness, a contractor could still argue that the cost savings outweighed the loss in capability. The result was that the system design, its expected capabilities, the cost estimates, the technical solutions, the suggested parts and components, and so forth, all came from, and were "owned" by the contractors, not the government. Much lower costs than might be expected appear to have resulted from this approach. However, some doubts and potential problems remain.

More "Commercial-Like" R&D Program Structure

Another key aspect of approaches to military procurement that promote greater CMI is a more "commercial-like" R&D program with more "commercial-like" contractor selection. The three munitions programs under examination here focus on:

- Extended contractor competition during R&D
- Greater government-industry cooperation through IPTs and maximum sharing of information
- Past Performance Value (PPV) criteria and "rolling down-select."

Extended Competition. Many acquisition reform advocates clearly perceive continuous and intense competition as the driving force pushing firms in "textbook"-type commercial markets to lower their prices, increase the quality of their products, and improve their product performance. But in traditional military procurement programs, competition tends to last only during the initial concept development stage or the prototype demonstration/validation stage. In these munitions pilot programs, reformers hoped to maintain competition longer.

Originally, acquisition officials had hoped to fund at least two competing contractors through the entire EMD program for at least one of the munitions programs.[27] It rapidly became clear, however, that this was not feasible from a cost standpoint. Instead, the officials adopted the following approach. First, a considerable effort was made to attract as many competitors as possible—particularly nontraditional commercial contractors—into the initial conceptual design stage. These contractors then took part in an initial, low-cost paper competition. After completion of this phase of the competition, the EMD phase was divided into two parts. The first phase focused on lowering the technical risks associated with development and manufacturing and reducing unit costs. The government funded two competing contractors during this phase. At the end of the first phase, the government selected one of the competing contractors to

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[27]The R&D phases of all three munitions programs are essentially funded by traditional military cost-plus-fixed fee (CPFF) or cost-plus-incentive fee (CPIF) contracts. More is said on this at the end of the chapter.

complete development. A major factor in the selection of the winner was the contractor's ability to achieve a low production price.

Thus, at least eight contractors submitted serious proposals in the original WCMD design phase, including companies that might not normally have entered a military system design competition of this sort. For JDAM, five contractors competed in the initial design competition before it was designated as a DAPP. JASSM received seven serious design proposals at the beginning of the program. With respect to WCMD and JASSM, the initial build-up period to a final RFP was characterized by intense cooperative interaction between the government program offices and each of the competing contractors regarding requirements, design concepts and approaches, and so forth.

Government-Industry Cooperation. Reformers also have observed that highly successful commercial firms often have relatively open and trusting relationships with key customers and suppliers. Information is shared; problems are worked out together. This contrasts sharply with the traditional adversarial relationship between the government and its contractors.[28] By bringing government and industry personnel together in IPTs and other cooperative arrangements, reformers hoped that program outcomes would be improved.

To support greater government-industry cooperation, all three munitions programs introduced the idea of multiple integrated government-contractor teams during the competitive EMD stage. The SPO established three separate IPTs for JDAM during Phase 1 EMD. Each contractor had its own exclusive government-industry IPT, whereas the SPO formed a third government-only core team. The two government-industry IPTs were walled off from each other and had no access to each other's data or documents (which were all treated as source-selection sensitive). Only the core SPO team had access to both government-contractor IPTs.

Most interestingly, the government members on the two contractor IPTs for JDAM were instructed to do as much as possible to help their

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[28]Long-term cooperative relationships are also somewhat inconsistent with the "continuous and intense competition" that, as described above, was intended to be a key feature of these munitions pilot programs.

specific contractor win the competition. The government fielded teams of 10 to 12 military and civilian officials that "lived" at each contractor site, not to audit or check up on the contractor, but to help the contractor lower its costs and improve its approach. The contractors were allowed to use the government IPT members in any way they wanted. One contractor integrated the government members closely into its design and engineering groups, while the other used them more like consultants and advisors to clarify issues and problems. This concept was also meant to supplement the feedback provided by the periodic report cards issued by the core team during the rolling down-select process. In this way, the JDAM SPO hoped that both contractors would improve their proposals to such an extent during the EMD Phase 1 that it would be almost impossible to choose a winner.

Past Performance Criteria and Rolling Down-Select. Finally, reformers argue that contractors are motivated to perform well "in the commercial world" in part because they believe past performance helps to determine future success at winning contracts.[29] In contrast, government contracts in the past were generally awarded to firms whose proposals contained the lowest-cost estimates or promised the highest capabilities—with little regard for an individual firm's past record on delivering on promises. The PPV concept was developed to apply this commercial standard to the selection of military contractors.

The WCMD and JASSM competitions helped pioneer the concept of PPV as a criteria for contractor down-selects. In both WCMD and JASSM, past performance was assigned a weight equal to all other factors in the contractors' proposals for the down-select to the Program Definition and Risk Reduction (PDRR) phase. Perhaps most important, as part of the concept of a "rolling down-select," the contractors were informed of significant weaknesses and deficiencies in their proposals and their past performance evaluations. Contractors had full access to the criteria, standards, and methodology used in the evaluations. They also had numerous opportunities to respond

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[29] Reputation is most important in markets for complex durable products, such as transport aircraft. However, it is becoming increasingly important even in markets for mass consumer products, such as televisions and refrigerators.

to and discuss government criticisms of both the technical proposals and past performance.

In the case of JASSM, officials developed broad categories of contractor past performance such as cost and schedule, product performance, and product reliability. Similar or related products developed and/or manufactured by the contractor in the past were examined. Thus, only past performance and capabilities of direct relevance to JASSM were assessed, such as aircraft integration, software development, and so forth. The outcome of this assessment was given equal weight to the content of the actual current proposal. In the JASSM system proposals, assessments of development and production costs were given equal weight with achievement of KPPs and other requirements. As a result of this process, Lockheed Martin and Boeing became the JASSM finalists in June 1996 for the PDRR phase.

After a similar process, Lockheed Martin and Alliant Techsystems won the WCMD first-phase contract in January 1995. But WCMD added an additional element to the down-select of its "Pilot Production" phase by conducting a live fly-off (or bomb-off?) using the two competing contractors' tail kits. The same F-16 carried one contractor's system on one wing and the competing contractor's system on the other, so that the exact same conditions would apply to both. This direct competitive fly-off helped lead to the selection of Lockheed Martin in January 1997 to conduct the next phase of the project.

In April 1994, before JDAM became a DAPP, program officials followed fairly conventional procedures to select Lockheed Martin and McDonnell Douglas (now Boeing) to continue competing during the 18-month Phase 1 EMD contract. As a DAPP, however, the JDAM program adopted the rolling down-select concept during its EMD Phase 1. The two contractors had asked for, and received, significantly different levels of funding, because they took different technical approaches. At first, the contractors were measured against their own SOWs rather than directly against each other. During the first year and a half, government officials provided the two competing contractors at six-month intervals with detailed "report cards" on their proposals, showing areas of strength and weakness. The contractors understood the measures of merit and had a full opportunity to respond to and even criticize the standards used if appropriate.

The central objective of this approach was to provide the contractors with as much leeway and as much information as possible, and let them compete against each other in a manner that mimicked what takes place in the commercial marketplace. In the end, it appears to have provided good results. The final source selection for JDAM EMD Phase 2 came down primarily to a question of production price commitments, and even then the decision was a close call.

Thus, as in markets involving generic goods and services, competition remained the central tool used to try to ensure low price and high quality in programs where traditional regulatory safeguards had been removed. Indeed, these programs took special measures to level the playing field and intensify the competition. It is noteworthy, however, that in all three programs established defense contractors were down-selected at relatively early phases of development. This suggests that DoD's efforts to encourage competition by lowering regulatory hurdles to the entry of firms without defense contracting experience may be offset by the new hurdle imposed by PPV criteria in down-selects. Government regulations provide that contractors having no relevant past performance are to be rated "neutral," putting them at a clear disadvantage relative to long-time defense contractors with strong past experience.

More "Commercial-Like" Purchase and Support of Developed Systems

To ensure the production of low-cost, high-quality, reliable and maintainable systems, the government developed a strategy to structure the purchase and support of the three munitions in a manner that would achieve the benefits enjoyed by buyers in routine commercial transactions. The main elements of this strategy are:

- Competitive fixed-price production commitments made during R&D
  - Applicable to initial production lots
  - Price reductions encouraged for later production lots through a "carrot-and-stick" incentive system

- System performance guarantees
- Full contractor responsibility for life-cycle reliability and "bumper-to-bumper" maintenance included in the system purchase price.

Government planners believed the bulk of the savings that would be generated by a more "commercial-like" acquisition approach on the three munitions pilot programs would accrue during the production phases. During the R&D phases, the government still paid up front for all costs, and indeed incurred extra costs by supporting two contractors during the first phase of R&D. However, the central focus of the R&D programs was to develop effective systems with much reduced production costs. For all three programs, the government initiated the R&D phase by providing the participating contractors with a production cost goal and cost ceiling beyond which the item would not be purchased. For all practical purposes, these goals and objectives were similar to airline "must cost" requirements placed on airframe prime contractors. The production price commitments provided by the munitions contractors, and the credibility of the estimates were central factors determining which contractor won the down-select at the end of the first phase of R&D. These prices tended to be far below the original government price goals. The problem for the government program managers then became how to ensure that contractors met the production price commitments and the performance and reliability guarantees.

For all three munitions programs, government officials have used procedures meant to emulate commercial-market approaches to guaranteeing production prices and system performance: Production Price Commitment Curves (PPCC) and warranties. The final contractor proposals for the second phase of R&D for these programs included fixed prices for low-rate production. The competing contractors for JDAM each agreed to submit an Average Unit Procurement Price Requirement (AUPPR) in FY93 dollars as part of the official System Specification they themselves wrote. The AUPPR had to include the cost of a full "bumper-to-bumper" warranty. The AUPPR applies to production lots 1 and 2, which make up the initial Low-Rate Initial Production (LRIP) phase. The system specification also included procurement price objectives for quantities in excess of 40,000 and 74,000 units, which in essence provided an estimate of the contractor's production learning curve. Thus, the contractors committed to a firm fixed price for the first LRIP lots at the beginning of full-scale development. Unlike customers in commercial commodity markets, the government required that cost data be submitted to back up the AUPPR. Nonetheless, the cost data requirements were simpler than those for a traditional program and were limited to "only" 15 pages.[30]

At the end of first phase of R&D, the contractors in all three munitions programs also provided a good-faith estimate of the production prices for production lots following LRIP. In the case of JDAM, the contractors provided nonbinding PPCCs for lots 3–5 (a total of about 8700 units) and agreed to submit PPCCs for lots 6–11 at the time of their lot 4 final price proposals. The government required no supportive cost data for these post-LRIP production PPCCs, but the contractors agreed to an extensive array of "carrot-and-stick" incentives to encourage their attainment. For example, should the contractor submit production prices when bidding for post-LRIP production lots that were at or below the original PPCC for lots 3–5, the contractor would enjoy the following benefits:

- The contractor remains the sole production source for an agreed number of lots, and the government will not request changes in subcontractors.
- The contractor retains full configuration control as long as changes do not reduce performance or affect safety of flight; however, changes must be documented and reported to the government.
- If the contractor is able to reduce its production costs through the insertion of new technologies or other efficiencies, such savings are retained entirely by the contractor as additional profit.

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[30]It has been pointed out that the credibility of the AUPP estimates was built up over two to three years of working with government cost analysts and decisionmakers, and was supported by numerous affordability reports and briefings documenting specific design, manufacturing, management, and support concept changes. Note also that business relationships in many commercial industries—including the transport aircraft industry—do involve extensive sharing of cost data between buyers and suppliers. However, data-sharing in the commercial world is a product of mutually beneficial partnering arrangements, not TINA-type presumptions of attempted abuse.

- The contractor does not need to submit any type of cost or technical data to the government if performance, reliability, and delivery schedules are being met.
- The government will actively assist the contractor in reducing costs if requested, but will not pay to implement changes.
- There is no in-plant government oversight or inspection of the contractor or subcontractors and all acceptance testing is done by the contractor in accordance with mutually agreed upon procedures.
- The contractor receives an incentive fee if the accuracy and reliability of production units exceeds the specification.

Some analysts consider these “carrots” to be nearly revolutionary. Of particular importance is the profit incentive for the contractor to become more efficient and insert new technologies on his own initiative, aided by the elimination of the need to provide cost data to the government. This mechanism was intended to encourage the contractor to offer the lowest possible AUPP at the end of Phase 1 R&D. However, for the government to eventually enjoy some price benefit from contractors who continue reducing costs throughout production below the PPCC, the PPCC would have to be negotiated for later lots.

The munitions contracts also contained “sticks” to protect the government from unsatisfactory contractor performance, particularly in price and system performance. These measures can be implemented by the government if the contractor submits a price bid for a production contract lot that exceeds the PPCC for previously negotiated lots. However, there is a grace period during which the contractor can explain the reasons for exceeding the PPCC. If the government does not accept the explanation, the following measures can be taken:

- The contractor must submit fully compliant certified cost and pricing data in accordance with TINA and other regulations.
- The government may reestablish control over configuration.
- The contractor must prepare and provide a fully compliant Mil-Spec data package free of charge within one year.

- The contractor must fully qualify at his own expense and within 12 months a new contractor as a second source for production, where full qualification is defined as delivery and acceptance of a production unit by the second-source contractor and 10 successful flight tests.[31]
- The government may impose in-plant oversight and testing.
- The incentive fee option is eliminated.

Clearly, the most undesirable "stick" from the contractor's perspective is the requirement to qualify a second source at his own expense. This stick is an attempt to simulate the incentives in the commercial world where, in most cases, an unsatisfied buyer has the option of turning to a competing supplier of the same or similar product. This option encourages the original supplier to fulfill his promises to the buyer. In the case of unique military hardware, especially when the government does not control the data package, the existence of other suppliers of nearly identical items is unlikely. Therefore, the contractor's penalty for failing to meet the promises to the government buyer on the three munitions programs is that the company must create a new supplier at its own expense—a severe penalty indeed, and presumably a strong incentive to perform as promised.[32]

At least some JDAM contractor representatives view the reality somewhat differently. According to one contractor representative, in practice the formal incentives against price gouging become relatively weak by production lots 6–11, which represent the bulk of all production. From the contractor's perspective, a hard fixed-price commitment clearly exists for LRIP lots 1 and 2; and a somewhat softer commitment exists for lots 3–5. But in the contractor's view, it would be difficult for the government to enforce the requirement to qualify a second source if there are problems with the PPCC, particu-

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[31]The government may impose fines of $20,000 for each working day up to a total of $5 million for failure to meet these requirements within schedule. Some of the terms may vary for each system or have been amended. For example, the WCMD contract apparently permits the contractor 18 months to qualify a second source.

[32]There is some question, however, as to the credibility of the threat to second source the hardware because of the proprietary nature of the data rights. Loss of reputation may be a more significant threat, especially given the increased importance of PPV in DoD source selection.

larly for lots 6–11, primarily because of issues related to proprietary data. According to another contractor representative, there really is no credible element among the contractual "sticks" that prevents price gouging in lots 6–12.

On the other hand, the contractor representatives say that there is a strong incentive to hold to the PPCC and not price gouge—reputation plus the trend toward using past performance in future contract awards. This incentive, they argue, works extremely well in the commercial aerospace world, and good faith and past performance are the keys to protecting the government from price gouging.

In addition to cost, government planners were concerned about system performance, including reliability. The government decided to provide three types of incentives to ensure that the contractor achieved system performance goals. These included:

- A commercial-style "bumper-to-bumper" warranty that includes system performance, reliability, and support
- Linking receipt of the PPCC incentive "carrots" to achievement of the performance specification
- The establishment of a formal dispute resolution process.

From the beginning of the program, both competing contractors accepted the concept of a commercial-style performance guarantee that requires that contractors meet all of the system specification requirements. The terms of the guarantee are flowed down to the major suppliers and vendors by the prime contractor. In the commercial transport industry, prime contractors often provide specific performance and reliability guarantees that entail cost penalties to the prime contractor if they are not achieved. Sometimes airlines try to negotiate the tradeoff of some warranties and performance guarantees for lower system prices. In the case of JDAM, there is no explicit cost penalty for not meeting specification requirements. However, unless all the contractor's kits meet the full specification requirement as determined by the government customer, the contractor does not enjoy the benefits of the PPCC "carrots," most particularly the promise not to "compete out" the production of the system to another source.

The JDAM warranty, which is similar to the warranties for the other two munitions programs, requires the contractor to replace or repair any JDAM kit that does not meet the system specification requirement or that contains defects in materials or workmanship, as determined by the government buyer. The warranty remains in force for 20 years if the kit remains in its shipping container and for five years outside of the container. If the kit is properly repacked in its container, the 20-year warranty goes back into effect. The warranty also applies to 50 hours of carriage life on the pylon of a combat aircraft, and includes a specific number of on-off operating cycles of the system during flight.

Many of the aspects of the warranty are similar to the standard commercial transport rules for Aircraft on Ground (AOG) resulting from a broken part. The warranty requires the contractor to ship out repaired or nondefective kits within a specific time period (within one business day for the early low-rate production lots). The contractor must pay for the cost of shipping to any place in the world. The warranty is not unconditional. It does not cover combat damage, uncontrollable events or misuse or abuse by the government.[33] On the other hand, in the case of JDAM, neither the contractor nor the government expect detailed records to be kept on specific kits that can prove how long the kit has been out of its container or how many hours it has flown on a pylon. In other words, implementation of the warranty is predicated on good-faith intent on both sides.

Nevertheless, all three munitions contracts also include provisions for a formal third-party dispute resolution process if the government and contractors disagree regarding the application of the warranty or other aspects of the contracts. The process entails the use of a Dispute Resolution Board (DRB) made up of three members who do not represent either party. Two of the members are chosen by each party from a list of five candidates provided by the other party. These two members choose the third member. Acceptance of a DRB finding is voluntary by both parties. However, all opinions and materials used in a DRB proceeding can be used in traditional dispute resolution procedures or in litigation.

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[33]Past government attempts to take advantage of commercial-style warranties have failed because DoD could not prove that its usage patterns constituted normal and allowable wear and tear. See Kuenne et al. (1988).

Ultimately, the most important enforcement mechanism for the warranty is the same as in the commercial world: Reputation and past performance. If a contractor refuses to honor a warranty obligation that the government customer believes is clearly legitimate, this behavior will become part of the contractor's past performance record, which will be evaluated in competitions for future system development programs. This same incentive encourages companies in the commercial world to honor their performance claims and warranty commitments. Of course, for this incentive to be effective, there must be more than one credible source or contractor for future competitions, and past performance criteria must be important elements in down-selects.

In summary, these three munitions programs have been structured in a radically different manner from traditional programs in order to mimic the market incentives of the commercial world, promote insertion of commercial technology, and reap the claimed cost savings and efficiencies that are prevalent in the commercial marketplace. Although still in their early stages, the programs appear to be achieving many of the hoped-for benefits, namely, the rapid development of lower-cost, more-effective weapon systems.

MUNITIONS PILOT PROGRAM OUTCOMES

Program Cost

The three munitions programs were all structured to mimic the emerging "must cost" environment in the commercial transport sector. At least in the cases of JDAM and JASSM, the government customers established "must cost" maximum price thresholds above which the system would not be purchased. Later, contractors were encouraged through intense competition and the application of CAIV to develop aggressive price targets that were considerably below the maximum price thresholds. Finally, the contractors committed contractually to meet LRIP production price objectives, and accepted a series of "carrot-and-stick" contractual incentives to ensure the price goals would be met.

JDAM. As noted above, original government estimates for a JDAM-type weapon kit came to an AUPP for 40,000 units of $68,000 in 1993 dollars. After DoD designated JDAM as a DAPP, a "must cost" threshold of $40,000 or less per unit was established. Two additional pre-DAPP and post-DAPP estimates of JDAM program costs and AUPP are shown in Table 7.2. The data are from OUSD/AR's *1997 Compendium of Pilot Program Reports.* The first two columns are President's Budget (PB) actuals in then-year dollars. The second two columns are estimates in constant FY95 dollars projected by the Cost Analysis Improvement Group (CAIG).[34] The pre- and post-DAPP numbers from the President's Budget and the CAIG projections for comparable categories differ because of varying definitions and assumptions, and because the numbers were generated at slightly different times. Nonetheless, they both show a decline in AUPP for JDAM of at least 50 percent from the pre-acquisition reform numbers (columns one and three) to the post-acquisition reform numbers (columns two and four). Both sets of estimates show a 40–50 percent

Table 7.2

Pre- and Post-DAPP JDAM Program Costs and AUPP (in $ millions except for AUPP)

Cost Element	PB FY95	PB FY98	CAIG I (FY95$)	CAIG II (FY95$)
R&D	549.7	462.9	346	380
Aircraft integration	TBD	TBD	893	478
Procurement	4874.9	2062.8[a]	3593	2012
O&S	TBD	TBD	290	130
Total cost	5558.8	2525.7	5122	3000
AUPP[b]	65.9	23.4	48.6	24.4

SOURCE: Based on data from OUSD/AR (1997b, p. 1–4).

NOTE: O&S: Operations & Support; TBD: To Be Determined.

[a]Assumes total procurement of 87,496 units. All other numbers assume total procurement of 74,000 units, except for the AUPP numbers, which assume 40,000 units. Current total production is expected to be 89,000 kits plus foreign sales.

[b]Thousands of dollars; 40,000 units.

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[34]The CAIG resides within the Defense Department's Office of the Director, Program Analysis and Evaluation. The CAIG advises the Defense Acquisition Board on weapon system cost estimation, reviews, and presentation of cost analysis of future weapon systems. The CAIG also develops common cost-estimating procedures for DoD.

decline in total program costs for JDAM after acquisition reform. In addition, although not shown in exactly comparable terms, the AUPP numbers are considerably below the $40,000 "must cost" threshold established at the beginning of the program.

In contrast, JDAM R&D savings as shown in the *1997 Compendium of Pilot Program Reports* (Table 6) appear small or non-existent. Excluding aircraft integration costs, the PB numbers show about a 15-percent savings. However, the CAIG projections show an increase in R&D of about 10 percent. The CAIG numbers indicate an almost 50-percent decline in aircraft integration costs, but this improvement arose primarily from a reduction in the number of "threshold" aircraft requiring integration. On the positive side, the CAIG projections estimate a greater than 50-percent decrease in O&S costs.

Table 7.3 presents evidence from recent published sources at the U.S. Air Force Air Staff, using slightly different data. These data show a slightly smaller savings in development, at just under 15 percent. On the other hand, they indicate an even larger decline in AUPP to less than one half the cost in FY93 constant dollars, even when shown in then-year prices unadjusted for inflation.

The most recent published and unpublished sources suggest that by 1998 the AUPP for JDAM in FY93 dollars stood at around $15,000, and that the then-year dollar AUPP in FY98 stood at about $18,000. However, resolution of some technical problems that were detected in 1997 during development and testing may lead to a real increase of 4–5 percent in both development costs and AUPP. According to one published source, the added cost to the JDAM unit price in FY98 dollars is about $850 (*Aerospace Daily*, 26 August 1998). More is said on this below.

Table 7.3

Pre- and Post-DAPP JDAM Development Cost and AUPP

Cost Element	PB FY95	PB FY99
Development ($ million)	$549.7	$469.3
AUPP[a] ($ thousand)	$42.2 (FY93)	<$20

SOURCE: SAF/AQ (December 1997).

[a] 40,000 units.

In summary, in constant FY93 dollars, the 1998 AUPP remains less than one half the procurement price estimated before the program became an acquisition reform pilot program. With a total buy now projected on the order of 89,000 units, this results in an inflation-adjusted procurement cost savings to the U.S. government of at least $2.0 billion.

WCMD. AUPP savings for WCMD on a percentage basis roughly equal those of JDAM when initial pre-reform estimates are compared with post-reform estimates. At the beginning of the program, the AUPP for WCMD had been projected at $25,000 in 1994 constant dollars for 40,000 units. This price included the Average Field Installation Unit Price, which covered contractor installation of the kit in the field. As of mid-1997, the 1994 constant dollar AUPP stood at $8937—a full 64 percent below the original "must cost" price (SAF/AQ, 1997).

In late 1996, with R&D for WCMD nearly complete, Air Force officials estimated a cost savings on EMD of 35 percent resulting from acquisition reform. This estimate was based on comparing the initial government estimate of supporting two contractors at a then-year dollar cost of $65.6 million compared with a projected total EMD then-year dollar cost of $42.9 million. Unfortunately, a year later in late 1997, several technical problems were identified during testing that required correction. The technical fixes led to a small increase in total EMD costs. Published sources claim, however, that the contractor agreed not to increase the AUPP (*Aerospace Daily*, 23 March 1998).

JASSM. Finally, although still in an early stage of development and experiencing some test problems, JASSM also appears to be fulfilling the promise of a more commercial-like acquisition approach by greatly surpassing its original goals for low-cost pricing. JASSM began with a must-not-exceed ceiling average unit price goal of $700,000 in FY95 constant dollars, and target price goal of $400,000 in FY95 constant dollars, for a production run of 2400. The $700,000 price ceiling goal was confirmed by a CAIG estimate. Government analysts estimated total development costs in FY95 constant dollars at $675 million.

In early April 1998, the Air Force down-selected to one contractor to complete development of JASSM. The winning contractor, Lockheed Martin, committed to an AUPP for the first 195 missiles of $275,000 in FY95 constant dollars, more than 30 percent below the target price of $400,000 and more than 60 percent below the threshold ceiling price of $700,000. Boeing, the losing contractor, also came in with an offer under the target price with an AUPP of $398,000 for lot 1.[35]

The development phase is also expected to cost approximately 30 percent less than original projections, and far less than the amount spent on the failed TSSAM program. Measured in FY95 constant dollars, the contracts awarded to the two contractors for the JASSM initial PDRR phase totaled $237.4 million (*Air Force News,* 1996). The full-scale development phase was expected to cost on the order of $200 million. However, a restructuring of the development schedule, as discussed below, has led to an estimated increase in EMD costs to about $240 million. This is still well below the original FY95 constant dollar projections of $675 million.

Performance and Schedule

Probably the single biggest concern of the opponents of a more “commercial-like” acquisition approach is that the elimination of regulatory safeguards and the insertion of commercial technologies into weapon systems will result in inadequate performance or performance shortfalls. For the most part, the three munitions pilot programs under consideration here do not indicate that these concerns are warranted, although certain technical difficulties have raised some red flags about the compatibility of commercial-like tradeoffs between flight safety and cost reduction and DoD’s traditional desire to “gold plate” systems to ensure high margins of safety.

JDAM has experienced several high-visibility technical problems during its aircraft integration testing. Most of these have been solved without difficulty. For example, early in the flight test program problems were experienced with radio-frequency components and the

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[35] See *Aerospace Daily* (30 April 1998). Recent accounts report the price has risen to $317,000 in FY95 constant dollars because of a decrease in the size of the initial buys. Yet this AUPP is still more than 20 percent below the original target price.

GPS systems. Later testing showed that the 2000-lb BLU-109 and the 1000-lb Mk-83 versions of JDAM were unstable at high angles of attack. This problem reduced the delivery envelopes for both weapons. To solve it required redesign of the aerodynamic strakes attached to the sides of the bomb as well as flight-control system software redesign and retesting (ODT&E, February 1998).

In addition during the JDAM flight test program, engineers found that unanticipated system vibration was causing problems in the transfer alignment of the inertial measurement unit (IMU). The problems arose only with the Mk-84 2000-lb variant of the JDAM kit and only when it was mounted on the inboard pylons of an F/A-18 Hornet operating at low altitudes and high speeds. This concurrent combination of kit type, aircraft type, mounting position, altitude, and speed is quite unlikely, especially given that the F/A-18's inboard pylon is typically used for fuel tanks, not weapons. Boeing had not designed JDAM for such a scenario. Nevertheless, Boeing was able to fix the problem by modifying the IMU's vibration isolator ring and sculling algorithm.

However, when the JDAM test units were then subjected to this high dynamic-load region for more-extended periods of time, it was found that the commercially derived friction brake could not withstand the unexpectedly high aerodynamic forces. The friction brake holds the fins steady prior to launch, so the result was fin and fin shaft fatigue from excessive vibration and movement. Once again, this caused problems in the transfer alignment of the IMU, and worse, caused fins to move or fin shafts to break prior to aircraft separation.

Boeing's initial attempts to solve the friction brake problem proved inadequate. Boeing engineers then adopted an entirely new approach based on a positive fin-locking mechanism that "nails-down" the fin until launch by inserting a metal pin into a hole in the fin. The pin retracts into the tail kit within one second when the JDAM-equipped bomb is dropped. In addition, the fin shafts and other parts had to be strengthened.

The additional nonrecurring engineering and the need for using more-expensive parts during production have resulted in a 4–5 percent increase in EMD costs and in AUPP, as mentioned above. This is not trivial with a buy of approximately 89,000 units; the additional procurement cost is on the order of $75 million or more. Nonetheless, the JDAM price is still well below the threshold and target prices established at the beginning of the program.

Were the JDAM technical problems caused by the use of commercial parts and technologies as part of CAIV? The direct answer appears to be no. Although the friction brake that proved inadequate was an inexpensive commercial derivative item, its inadequacy probably arose from Boeing's failure to calculate correctly the magnitude of the dynamic forces to which the JDAM Mk-84 tail fins would be subjected under certain special conditions. However, the problem occurred in part because Boeing placed a heavier emphasis on cost reduction than on designing for a low-probability worst-on-worst case scenario. Thus, it could be argued that the commercial-like approach taken by Boeing was incompatible with DoD's desire to achieve very high margins of safety.

Interestingly, both WCMD, developed by a different contractor, and the Joint Stand-Off Weapon (JSOW),[36] which is not an acquisition reform pilot program, experienced similar problems during development. During testing in late 1997, WCMD showed fin vibration and flutter problems when carried on an F-16 at supersonic speeds. Lockheed Martin engineers concluded that they had to use the same type of fix as Boeing engineers developed for JDAM: a positive fin-lock mechanism. The Air Force also encountered problems with the WCMD autopilot software during testing in late 1997. This problem was resolved fairly quickly (*Aerospace Daily*, 20 February 1998).

In most areas unaffected by technical developmental problems, JDAM and WCMD seem to have already met or exceeded their critical performance and reliability requirements. Probably the single most important requirement for these two weapons is accuracy. JDAM started with a 13-meter CEP requirement. During developmental and operational testing by the Air Force in late 1996 and early 1997, JDAM achieved an average CEP of 10.3 meters. By late 1998,

[36]Developed by Raytheon Texas Instruments, JSOW is a winged stand-off unpowered precision glide munition that comes in three variants and delivers unitary or submunition warheads of approximately 1000 lb. It has a range of 15 to 40 n mi depending on launch altitude. Like JDAM and WCMD, JSOW is guided by a GPS link and an on-board IMU. Like JASSM, a planned JSOW variant (AGM-154C) will have an IIR terminal seeker. The program is a joint Navy-Air Force program led by the Navy.

one source claimed that JDAM was achieving an average 9.7 CEP with an actual average miss distance of 6.5 meters (*Aerospace Daily*, 22 September 1998). Because of the success of the initial developmental tests, the Air Force authorized low-rate initial production in April 1997.

The true test for JDAM, however, came during the extended air campaign over Kosovo in early 1999. Between late March and early May, six B-2s delivered in excess of 500 JDAMs against targets in Kosovo—11 percent of the total bomb load dropped by U.S. forces during this period. Taking advantage of the GPS Aided Targeting Systems (GATS) on B-2s, JDAMs reportedly scored an average CEP of 6 meters, compared to the original 13 meter requirement.[37]

WCMD started with a threshold accuracy CEP requirement of 100 feet and a target CEP of 80 feet. WCMD has consistently achieved accuracies that greatly exceed the target CEP in developmental testing with launches at subsonic speeds. During testing in mid-1998, WCMD is reported to have achieved miss distances of 5 to 30 feet. It is for this reason that the Air Force approved low-rate initial production in August 1998 (*Aerospace Daily*, 4 August 1998). Once the fin-locking mechanism is installed in later production lots, accuracy with launches at supersonic speeds is expected to meet or exceed the initial requirement.

JDAM's technical problems have led to a restructuring of the developmental and operational test programs, the production program, and a delay of about a year in the procurement of the BLU-109 2000-lb bomb variant. In April 1997, the Air Force authorized LRIP of 900 JDAM kits for the Mk-84 bomb. Confidence in the weapon was so high that in 1997 Boeing delivered 140 "Early Operational Capability" JDAM kits to the operational B-2 wing at Whiteman Air Force Base. Originally the Air Force had planned to enter into full-rate production in 1998 with both the BLU-109 and Mk-84 2000-lb bomb kit variants. In late 1997, however, the Air Force delayed full-rate

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[37]The most infamous example of JDAM's remarkable accuracy came when B-2–launched JDAMs precisely hit a building the heart of a dense urban area in Belgrade. Unfortunately, the U.S. government had misidentified the building. Instead of an important Serb target, it was the Chinese Embassy. See Bill Sweetman, "Coming to a Theatre Near You," *Interavia Business and Technology*, July 1999.

production and substituted a second lot of low-rate production made up exclusively of Mk-84 variants. The purpose of this change was to permit additional flight testing to work out the flight instability problems encountered with the Mk-83 and BLU-109 JDAM kits, and to continue development of the fin-locking mechanism necessary to qualify the Mk-84 for the F/A-18 inboard pylons. Air Force officials claim that this change will have little effect on the production program, since approximately the same number of kits in the same bomb size category will be procured as originally planned in 1998.[38] Because of the Kosovo air war, JDAM production was increased by 50 percent in May 1999.[39]

The WCMD technical problems led to a similar restructuring of the operational test and production phases of the program. The Air Force had originally planned to authorize LRIP in February 1988. Following the discovery of the supersonic launch-fin flutter and autopilot software problems in November 1997, the Air Force stopped operational testing and delayed LRIP until fixes could be found. However, it was determined to maintain the schedule for initial operational deliveries in July 1999. As a result, the Initial Operational Test and Evaluation (IOT&E) phase of the program was divided into two parts. The first part of the restructured IOT&E program tested subsonic launches from B-52s. These tests, which proved highly successful, permitted the authorization of LRIP in August 1998 and meant that initial operational deliveries to B-52 squadrons could take place early in 1999, three to five months ahead of schedule. The second part of the restructured IOT&E program flight-tested the fin-lock mechanism that had already been designed and ground-tested. Program officials claim that this restructuring had little effect on the production schedule. The only significant consequence, they argue, is that the money that was going to be used to incorporate a small electronics upgrade in the WCMD kit had to be spent on the software and fin-lock fixes (*Aerospace Daily*, 29 April 1998).

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[38]See *Aerospace Daily* (15 December 1997 and 17 December 1997). The BLU-109 is designed to penetrate and destroy harder targets than the Mk-84, so some capability will be lost. Also, the first two LRIP production lots of Mk-84 JDAMs will not have the pin-locking mechanism fix, so they will not be usable on F/A-18s. Also see ODT&E (February 1998).

[39]See *Aerospace Daily* (3 May 1999).

The JASSM program is still in the early stages of R&D. GAO published a report on the JASSM program in 1996 that concluded that in the long run the risk of cost growth and schedule slippage was high (GAO, June 1996). This conclusion was based on the view that the JASSM development schedule was too short to permit maturation of the high-risk technical areas on the program—automatic target recognition, autonomous guidance, and aircraft integration.

Beginning in 1997, a variety of factors, including concerns over the level of technical risk remaining in the program, led to a restructuring of the program schedule. The original program schedule envisioned a 24-month PDRR phase beginning in June 1996, followed by a 32-month EMD phase beginning in June 1998. The nominal target date for the authorization of LRIP was April 2001. However, spurred by declining Navy interest in the program and significant congressional funding cuts in late 1997,[40] the Air Force restructured the PDRR phase. First, it was decided to down-select to one contractor on 1 April instead of in late June or early July at the planned beginning of EMD to save money. Second, the beginning of the PDRR phase was extended by about three months. Eventually, however, this evolved into a six-month extension or more, until November 1998. Thus, if one counts from the original contract award to the two contractors for the PDRR phase (June 1996), the PDRR phase has been extended by 25 percent over original estimates.[41] This length-

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[40]The Navy was convinced that the Boeing Stand-off Land Attack Missile-Expanded Response (SLAM-ER), a modification of the existing Navy AGM-84 SLAM system (itself a modification of the Harpoon), would meet its requirements at less cost than the JASSM. Like JASSM, SLAM-ER is slated to have an automatic target acquisition system. It will have a >100 n mi stand-off range and deliver a 500-lb warhead. Congress authorized an analysis of which system best served both services' needs. A GAO study concluded that the JASSM potentially could be fielded earlier with superior capabilities and at less cost than the upgraded SLAM-ER Plus version, development of which would be necessary to meet all key JASSM performance objectives. OSD directed the Navy to maintain at least minimal participation in the JASSM program, but with the withdrawal of the F/A-18E/F as a "threshold" aircraft, active Navy participation essentially ended. See *Aerospace Daily* (29 September 1998).

[41]A contributing factor was the many weeks of delay the program experienced after the down-select to two contractors because of an official protest filed by Hughes, one of the contractors who lost in the first phase of the program. Because of the heavy use of "past performance" criteria by the government, all three of the munitions programs examined here filed formal protests after the initial down-select process. This led to considerable lost time and effort. However, in all cases, the government won its case against the protests.

ening of the PDRR phase provided more time for the contractor and the Air Force to reduce technical risk prior to full-scale development. In addition, technical risk was further reduced by eliminating some of the developmental tasks that had to be completed during the PDRR. For example, since the Navy had decreased its involvement in the program, the need to focus on early integration of JASSM with the F/A-18E/F fighter was eliminated.

In November 1998, press accounts reported that DoD also intended to restructure the full-scale development EMD phase by lengthening it considerably. According to these accounts, the EMD phase would be stretched from 34 months (originally 32 months) to 40 months, an increase of 25 percent, to further reduce technical risk prior to flight testing. According to a program official, "We [the Air Force and Lockheed Martin] decided that we needed to do more ground and captive-carry testing than we had planned in order to not have big surprises during the flight test program."[42] These schedule increases, officials predicted, would cause a commensurate increase in overall R&D costs.

At the time, these schedule extensions did not appear to be the product of major technical difficulties or problems caused by the innovative commercial approach but rather arose from a development schedule that the program director characterized as "unrealistic," given the level of technical risk involved. Even after the extension, the program director characterized it as "still the most aggressive new development for a weapon" in a long time.[43]

In April 1999, the first JASSM flight-test vehicle crashed, delaying the flight-test program at least a month. A "make-up" flight-test was scheduled for August. On August 12, Lockheed completed a successful separation and maneuver flight test.[44] Two weeks later, the Air Force announced a major restructuring of the EMD program. The Air Force and Lockheed agreed to delay the decision to begin LRIP by 10 months, from January to November 2001, to permit additional

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[42]Terry Little, JASSM Program Director, quoted in *Aerospace Daily* (11 November 1998).

[43]*Ibid*.

[44]See *Jane's Defense News*, 19 August 1999.

flight tests of production-standard JASSM vehicles. The Air Force blamed technical problems and the contractor for the delays. According to press accounts, there were problems with engine development, the missile casing, and the air data system.[45]

There is no reason to believe that any of these developmental problems were related to the CMI approach adopted in the program. It is likely that such problems are common in the development of any complex new system. For example, JASSM's competitor, the SLAM-ER, failed its operational tests in August 1999, and as a result the Navy delayed full-scale production until at least the spring of 2000. SLAM-ER is usually considered a technologically lower-risk program than the JASSM because it is not a new development but a modification of the Harpoon/SLAM series of missiles.

The original 56-month development program has now been extended to 78 months, an increase of nearly 40 percent. Nonetheless, the new schedule is still well below the average munition development schedule of 110 months, according to the JASSM program director.[46] Assuming that the new development schedule can be met, JASSM will still be developed in less time than TSSAM. TSSAM was cancelled after about eight years of R&D, with development still incomplete. JASSM is now scheduled to be fully developed in six and a half years from program initiation, a schedule improvement over TSSAM of at least 18 percent.

THE NEED FOR GREATER RISK-SHARING IN ACQUISITION PILOT PROGRAMS

R&D Costs and Risks

Probably the least-imaginative aspect of the three munitions pilot programs under consideration here is that the government ended up negotiating what amounted to simple cost-plus R&D contracts[47]—

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[45]*Aerospace Daily*, 30 August 1999.

[46]*Aerospace Daily*, 31 August 1999.

[47]For example, in the case of JDAM, the initial Engineering and Manufacturing Development (EMD-1) phase had a CPFF contract, whereas the EMD-2 phase had a CPIF contract.

fairly traditional military R&D contracts in which the government agrees to pay the contractor up front for essentially the entire cost of R&D before deciding whether to procure production items. These types of contracts place most of the financial risk on the government and can reduce the contractors' incentives to control costs. We believe higher-risk acquisition reform pilot programs need to be structured so that the R&D risk and costs can be shared by the contractor. This approach is necessary to help control R&D costs and production price in higher-risk programs.

As is discussed in Chapter Six, in the commercial aircraft sector, R&D risks and costs are increasingly shouldered by informal consortia of prime contractors and major subcontractors. Subcontractors become risk-sharing partners. Corporate investments in R&D often rise to the hundreds of millions and even billions of dollars with no certainty that a reasonable return on the investment can be earned through the sale of production items. This suggests that a greater degree of R&D risk-sharing by contractors is also possible in the military context provided that performance requirements are well defined.

The government considered requiring contractors to finance some portion of the R&D costs in at least one of the three munitions programs discussed here. This option was rejected. Government planners believed that no company would risk its own money developing an expensive high-technology item that had no realistic customer other than the U.S. Air Force or Navy. Rather, the antidote to the problem of contractor incentives in cost-plus contracts was seen as a strategy of maintaining competition as long as possible through R&D.

The reasoning went as follows. Contractors seek to win production contracts where the potential for profit is greatest. Thus, maintaining competition through R&D greatly increases government leverage over the contractors' performance. Program planners also reasoned that to bring new and innovative commercially oriented firms into the competition—firms that might not have the same financial clout as the defense industry giants—the government had to pay for R&D. The new contractors would not be familiar with the military environment or might be too small to risk self-financing a large R&D effort in an unfamiliar business area.

Two critical problems arose with the government strategy. First, inadequate budgetary resources existed to support more than one contractor during the critical second EMD phase. Indeed, in the case of JASSM, budgetary shortfalls necessitated the elimination of one of the competing contractors during the pre-EMD PDRR phase well before the beginning of full-scale development. In the case of WCMD, program officials had originally hoped to maintain competition into the second phase of R&D, but were unable to because of cost considerations. Second, acceptance of all R&D risk and cost by the government did not ultimately result in serious new competitors entering the market. Although multiple contractors competed for the first concept development phase of all three of the munitions pilot programs, in each case the two finalists were the same two military aerospace giants that dominate the aerospace sector: Boeing and Lockheed Martin.[48] The recent introduction of PPV criteria for source selection suggests that these two firms' dominance of military aerospace is likely to continue.

The commercial world clearly demonstrates that maintaining and enhancing competition among upper-tier contractors is a key element in ensuring lower-cost, high-quality weapon systems in a commercial-like environment. As discussed in Chapter Six, fear of losing a contract to either an existing competitor or a new entrant into the market is a powerful mechanism for motivating contractors to provide the lowest-cost, highest-quality product possible. Ironically, since the government paid for all R&D on most of the programs under consideration in this chapter, it became impossible to maintain competition into full-scale development. Furthermore, as demonstrated above, total government financing of R&D did not help new firms or commercial firms make it into the final stages of the competitions. To the contrary, defense contractors from the pre-acquisition reform era dominated all the competitions.

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[48]The first-phase competitors for the munitions programs were: JDAM: Lockheed Martin, McDonnell Douglas (now Boeing), Raytheon, Rockwell (now Boeing), and Texas Instruments (now Raytheon); WCMD: Alliant, Boeing, Brunswick teamed with Rafael, Lockheed Martin, McDonnell Douglas (now Boeing), Rockwell (now Boeing), and Raytheon; and JASSM: Lockheed Martin, McDonnell Douglas (now Boeing), Hughes (now Raytheon), Texas Instruments (now Raytheon), and Raytheon teamed with Northrop Grumman.

Of course, there is still the problem of high market risk resulting from a single government buyer and the difficulty of selling military-unique items to other customers, which discourages firms from self-financing military R&D. There is significant merit to this argument, especially for large-scale, high-cost defense-unique items such as fighter aircraft. Nonetheless, as Chapter Six points out, the commercial transport market, where a few large consolidated airlines with similar requirements dominate the market, is less different from the military aerospace market than might initially be thought. Furthermore, even today the U.S government military market is far from monolithic. For many items there are significant separate military service markets. For example, the JASSM program has had to struggle to survive in the face of stiff competition both from the Navy-led SLAM-ER being developed by Boeing and from the JSOW under development by Raytheon Texas Instruments.[49]

In short, there is reason to believe that contractors will grudgingly accept more R&D cost and risk sharing, which will be necessary to maintain and enhance competition during R&D. On relatively low-cost, low-risk systems, or systems that are genuinely dual-use, contractors may be expected to finance R&D entirely on their own. For high-cost, high-risk, military-unique items, creative cost-sharing arrangements can be developed. Three existing programs illustrate creative ways in which this can be accomplished.

DarkStar, Global Hawk, and COSSI

Two programs initiated by DARPA, plus a modification and upgrade program administered by the services, illustrate some of the possibilities for increased R&D risk sharing between the government and defense contractors. DarkStar and Global Hawk, DARPA/Air Force programs for the development and possible production of HAE UAVs, each included terms that required the contractors to share in unanticipated R&D cost growth.[50] COSSI, a program leveraging commercial technology developments to reduce the operations and

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[49]This competition has worked both ways. Raytheon and the Navy have had to dramatically reduce the projected unit price of the AGM-154C (Unitary) variant of JSOW in part because of price competition from JASSM.

[50]The DarkStar program was cancelled in early 1999.

support costs of legacy systems, requires contractors to share the costs of developing and testing a prototype ready for insertion in a military system.

The DarkStar Phase II (prototype) R&D baseline agreement is essentially a traditional CPFF/CPIF instrument. The government agreed to pay all Phase II R&D costs up to $115.7 million. The contractor could earn a relatively small fixed fee as well as a small incentive fee for meeting performance goals in four areas.[51] These fees would amount to about $8–$9 million or roughly 8 percent of R&D cost.

However, in a radical departure from traditional programs, the contractor agreed to pay 30 percent of Phase II R&D costs if they rose above $115.7 million, and 50 percent of R&D costs above $162 million. Further, the parties agreed to an absolute cap of $220 million on Phase II. Since relatively serious problems were encountered during the prototype flight-test program—resulting in a lengthening of the Phase II schedule—it is likely that the $220 million ceiling will be reached. If that is so, the contractor will be responsible for paying for nearly $43 million or more than 40 percent of a cost overrun of $104 million. This has been a painful experience for the prime contractor and a strong incentive to reduce technical risks and control costs in future phases of the program. It has saved the government a significant amount of money and made the contractor a risk-sharing partner in the development program, as is the case in the commercial world.[52]

The Global Hawk program has also experienced technical problems, cost growth, and schedule slippage during Phase II R&D. Program managers had originally planned to impose cost and performance discipline on the program by maintaining competition with at least two contractors throughout Phase II. However, funding shortfalls required an early down-select to one contractor. The Phase II agreement remained a traditional CPFF/CPIF instrument. As the result of significant cost growth, the parties renegotiated the Phase II

51The areas covered performance of the air vehicle (altitude and endurance), sensors (radar, electro/optical, IIR), and the command and control ground station.

52Although the contractors developed fixes for most of the developmental problems experienced during R&D, DoD decided to cancel DarkStar in early 1999 in order to focus on the potentially more operationally useful Global Hawk.

agreement in mid-1997. The new agreement resembles the DarkStar Phase II clauses that require the prime contractor to pay a percentage of cost overruns beyond a certain threshold and cap total government expenditure on the phase. The new Global Hawk program also requires major subcontractors to share in cost overruns, now typical procedure in the commercial aircraft industry.

In some ways, DoD's COSSI is even more innovative in cost sharing than the DARPA UAV/Air Force programs. COSSI projects are not subject to the normal DFARS regulations, functioning instead under the Other Transactions Authority for prototypes that is often used for DARPA programs. Whereas DarkStar and Global Hawk required contractor cost sharing only for cost overruns, COSSI requires contractors to share at least 25 percent of expected development costs.[53]

Although the basic technology for insertion under COSSI must be commercial (as broadly defined by DoD), it is recognized that significant Non-Recurring Engineering (NRE) is likely to be necessary both to adapt the commercial technology to the military system and to modify the military system to accept the commercial technology. In the last several years, COSSI has stimulated scores of proposals, many of them from nontraditional and commercial firms. On average, the firms have proposed that the government finance just 50 percent of the NRE. In some cases, contractors are paying up to 70 percent of the NRE. Interestingly, COSSI provides absolutely no guarantee that upon the completion of Phase I (NRE and operational testing) the participating military service will buy any of the kits for insertion into military systems (DoD, 31 August 1998).

COSSI programs tend to be small. The average Air Force program in FY97 was funded at about $6 million a year from the government for two years. Total annual COSSI funding has been on the order of only $100 million a year, covering about 30 projects, and much of this money has been cut as a result of the "Bosnia Tax."[54] This money

[53]Contractors obtaining government funds through COSSI are expected to sell the final product at a target price agreed upon at the beginning of prototype development. It is not clear how this will work in practice; no COSSI prototypes have yet entered full-scale production.

[54]Funding for COSSI projects is expected to be on the order of $90 million for FY00 (DoD, 2 February 1999).

goes almost entirely to the NRE and testing necessary to permit the commercial technology to be used in military-unique items. If the participating service does not then procure the technology, the contractor has few other potential customers for its militarized item. Thus, like the DarkStar and Global Hawk programs, COSSI seems to demonstrate that under certain conditions both commercial and defense contractors are willing to risk their own funds to finance military-specific R&D—even when there is no assurance that the government will procure the final product.

CONCLUSION

In our view the JDAM, JASSM, and WCMD munitions programs have gone a long way to demonstrate that a commercial-like "best" practice acquisition strategy can be applied to military-unique items, and that significant benefits, particularly in terms of production price, can be achieved. As in the world of commercial transports described in Chapter Six, a rigorously applied commercial-like "must cost" environment can produce dramatic results for the military. The experiences of DarkStar, Global Hawk, and COSSI suggest that greater risk-sharing between the government and contractors may also be possible, thus further reducing the costs to the government of weapon system acquisition.

In all three of the munitions programs, the likely acquisition prices appear to be considerably less than half of what they would be in a traditional military procurement program. With the large procurement numbers involved, this results in significant savings to the government. R&D costs so far appear to be running on the order of 20–30 percent less than traditional programs. Although R&D is not complete on any of these programs, and some technical problems have been encountered, operational performance capabilities appear on the whole to be meeting or exceeding original requirements. Some R&D schedule slippage has appeared, but all three of these programs began with aggressive schedules compared with traditional programs for similar products. Even with the schedule slippage, the R&D phase for all three has remained relatively short by traditional military developmental standards.

Key Elements Contributing to Success

In our judgment, the key aspects of the munitions pilot programs that have helped to achieve success are:

- Requirements reform and a closer customer-developer relationship through mechanisms such as IPTs, within a CAIV or "must cost" environment
- Contractor ownership of and responsibility for design, technical content, performance, reliability, and price.

In 1996, WCMD and JDAM program officials provided Air Force Materiel Command (AFMC) officials with a subjective percentage allocation of EMD and production savings accruing to their programs as the result of various acquisition reform initiatives (AFMC, 1996). In the EMD phase, 90 percent of acquisition reform savings were attributed to six features of the programs: CAIV (20 percent); IPTs (20 percent); performance objectives instead of specifications or SOOs vs. SOWs (25 percent); Total (Contractor) System Performance Responsibility (TSPR)[55] (20 percent); and insertion of nondevelopmental items and elimination of Mil-Specs (5 percent). For the much larger anticipated production savings, a full 90 percent was attributed to these same items plus contractor configuration control (10 percent), with the bulk of the savings attributed to CAIV (40 percent), TSPR (20 percent), and Mil-Spec elimination (20 percent).

One could quibble with specific percentages, but overall this assessment conforms with ours. The key elements are: (1) Making cost a fundamental system requirement ("must cost" in the commercial world), which is the objective of CAIV, and (2) granting system design authority and responsibility to the contractor, and the freedom to

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[55]The "Acquisition Strategy" section of the AFMC *Guide to Acquisition Reform Cost* . . . (1996) explains that TSPR:

> . . . provides industry not only increased latitude in the design process for implementing system level solutions aimed at long-term sustainment, but provides clear accountability in design (CAID). Under TSPR the government continues to control system functional requirements while industry controls design/product requirements. Thus, the contractor is fully responsible for the integration of all systems, subsystems, components, government furnished property, contractor furnished equipment, and support equipment and must ensure no performance degradation after integration.

use that responsibility creatively. The latter element is characterized in the AFMC study by the concepts of performance objectives rather than technical specifications (SOO vs. SOW), contractor configuration control, and TSPR. Mil-Spec elimination and nondevelopmental items are enablers that permit contractors to seek out the lowest-cost, highest-leverage technologies whether they are in the commercial or military sector.

We believe it is crucial that future higher-risk, larger-scale acquisition reform pilot programs employ strong commercial-like "must cost" frameworks for the design, engineering, and development phases, and commercial pricing approaches for the production and procurement phases. A key element of each of the three munitions pilot programs is a strong focus on lowering production price, with "must cost" production price targets included in the operational requirement.

However, we believe that, as in the commercial world, contractors can take on greater price risk in the production phase as well as cost risk in the R&D phase. All the munitions programs assumed that the government should pay for all or most of the higher nonrecurring costs at the beginning of the program as the contractor moved down the production learning curve. This is why the concepts of AUPP and PPCC were developed. The AUPPR and AUPP represent average actual recurring costs for relatively small lots of very large production programs, after the nonrecurring costs have been paid by the government through a CPFF/CPIF-type contract. In contrast, commercial transport aircraft developers price even their first aircraft according to a projected average recurring and nonrecurring cost over a relatively large production run, even though they have no guarantee that they will sell any aircraft at all. This is because customer airlines in the commercial marketplace would not tolerate paying the high price necessary to cover the actual recurring costs to the manufacturer of the early production aircraft, which are high up on the learning curve.

Thus, a commercial aircraft developer may price his aircraft so that his financial breakeven point, where he begins to make a profit, does not come until many hundreds of aircraft have been sold. This approach encourages the manufacturer to continue every effort to reduce production costs, maintain high quality, and remain responsive to customer needs. Furthermore, it imposes greater discipline on the must-cost aspects of the design and development stage.

Defense contractors are beginning to consider commercial pricing approaches. There are some indications that Lockheed Martin adopted a modified commercial pricing approach for JASSM, by charging a price to the government for the first LRIP lot that is less than the company's actual production costs for that lot. On the C-130J Hercules program, Lockheed Martin has offered the government a commercial price alternative based on the assumption of significant sales over time, which requires the contractor to bear a significant amount of the cost risk during production.

A commercial pricing strategy combined with a fixed-price long-term contractor logistics support agreement based on mission performance goals could in principle further motivate contractors to offer lower fixed commercial-like production prices, insert cost-saving new technologies and processes into the production line, and enhance system reliability. This approach was discussed in Chapter Five. However, little experience with this approach has been gained on the munitions programs under consideration in this chapter, since they are to receive virtually no active maintenance during their storage lives. In addition, support contracts have not been negotiated for the Office of Technology Assessment (OTA) UAV programs. However, several contractors have negotiated interesting TSPR support contracts with the government on such aircraft as the F-117 and the C-17, which warrant further study.

Applicability of Lessons Learned

There are, however, legitimate concerns about some aspects of these munitions programs that suggest that the lessons learned may have limited applicability. First, all three programs aim at the development of single-use, unmanned systems. Reliability and maintenance concerns for multiple-use manned systems are therefore not addressed. Second, they are unusual in that they represent military-unique items that are intended for production and procurement in numbers that are very large by military standards.[56] It could be argued that the bulk of the overall program cost savings arises from the large number of items procured, so that the experience of these pilot programs may not be applicable to more traditional military procurement programs that have—by commercial standards—low procurement numbers. Third, some have considered these pilot programs to be relatively low-risk technologically. Indeed, candidates for DAPPs were required to be "low risk" to qualify for consideration (DoD, June 1998).

The third point can be disputed, particularly in the case of JASSM, which is not an official DAPP but contains most of the program elements of a DAPP. With its long and difficult development history, JASSM's predecessor, TSSAM, clearly demonstrated the technological complexity and risk inherent in developing a stealthy long-range cruise missile. In the case of JDAM and WCMD, both contractors dispute the alleged low-risk nature of the developmental programs. The contractors argue that even the integration of OTS subsystems into a new system, as well as the integration of the tail kits with the host aircraft, is technologically challenging. The technological problems already encountered on the JDAM and WCMD developmental programs, particularly with aircraft integration, seem to confirm that the development and integration of military-unique weapon systems is never without risk. Even in a fully commercial-like environment, realistic schedules must be developed to take into account the inevitable technical risk inherent in such systems.

In sum, we believe that a commercial-like acquisition approach as defined here could bring significant benefits to major Air Force acquisition programs, including those that entail much higher technical risk and the development of manned combat aircraft or other reusable systems with relatively lower production numbers. We recommend that DoD seek to expand the DAPP effort to include such programs. The JSF program has already made extensive use of CAIV and IPTs during its early phases. JSF would be an excellent candidate pilot program for application of the full panoply of acquisition reform measures during EMD. Based on our analysis of the commer-

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56Anticipated production buys are: JDAM, 89,000 units; WCMD, 40,000 units; and JASSM, 24,000 units.

cial aerospace industry in the previous chapter, and the experience of DarkStar, Global Hawk, and COSSI, we recommend that future programs be structured to include greater risk-sharing between contractors and the government.