United States General Accounting Office

GAO

Testimony

Before the Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate

For Release on Delivery
Expected at 10:00 a.m. EST
Wednesday,
April 26, 2000

DEFENSE ACQUISITION

Employing Best Practices Can Shape Better Weapon System Decisions

Statement of David M. Walker, Comptroller General of the United States

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GAO/T-NSIAD-00-137

Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to discuss issues the Department of Defense (DOD) faces in its acquisition of weapon systems and the application of best practices to help address those issues. With DOD's annual research, development, and production spending for weapon systems at about $85 billion—coupled with suggestions from within DOD and the Congress that it should be substantially higher—the Subcommittee's oversight of acquisition policy can have a major impact on the value the taxpayer gets for that expenditure.

After having done hundreds of reviews of major weapon systems over the last 20 years, we have seen many of the same problems recur—cost increases, schedule delays, and performance problems. At your request, we have undertaken a body of work that examines weapon acquisition issues from a different, more cross-cutting perspective—one that draws lessons learned from the best commercial product development efforts to see if they apply to weapon system development. In the past few years, leading commercial firms have developed increasingly sophisticated products in significantly less time and at lower cost. These firms include the Boeing Commercial Airplane Group, Bombardier Aerospace, Caterpillar, Chrysler Corporation, Ford Motor Company, Hughes Space and Communications, Motorola Corporation, and 3M. Our work shows that valuable lessons can be learned from the commercial sector and can be applied to the development of weapon systems.

My testimony focuses on how best commercial practices help shape improvements in the way DOD operates and makes decisions through the weapons acquisition process. Specifically, I will discuss why weapon system acquisition problems persist and how a process based on best practices can lead to better weapon system outcomes. These issues have significant implications for decisions made on individual programs and for DOD's larger modernization goals, which I will also discuss.

Results in Brief

The pressures of competing for the funds to launch and sustain a weapon system program create incentives for starting programs too early; overpromising performance capabilities; and understating expected costs, schedules, and risks associated with developing and producing the weapon. Leading commercial firms have adopted a knowledge-based approach to developing new products that embodies incentives that encourage realism, candor, and meeting product expectations. Making sure that new technology is mature—that is, demonstrated that it works—is the foundation for this approach. DOD's variances from best commercial practices result in higher costs, compromised performance, and questionable cost benefit approaches. A knowledge-based approach can be used to reshape DOD's acquisition process. By itself, such a process will not produce better program outcomes unless it influences the decisions made on individual weapon systems. If a knowledge-based acquisition process is put in place and used, there are potential benefits that transcend individual program outcomes. Specifically, the ability to execute a program more predictably within cost and schedule estimates would lessen the need to offset cost increases by disrupting other modernization programs.

Persistent Problems Are Reinforced By the Current Process

Despite good intentions and some progress, our ongoing reviews of DOD's major weapon system acquisitions are showing that significant reforms have not yet been reflected in the management and decision-making on individual programs. The flagship systems, as well as many other top priorities in each of the services, continue to cost significantly more, take longer to produce, and deliver less than was promised.

The differences in the practices employed by the leading commercial firms and DOD reflect the different demands imposed on programs by the environments in which they are managed. Specific practices take root and are sustained because they help a program succeed in its environment. The way success and failure are defined for commercial and defense product developments differs considerably, which creates a different set of incentives and evokes different behaviors from the people managing the programs. Attempts at reforming weapon acquisitions have not succeeded because they did not change these incentives. All of the participants in the acquisition process play a part in creating incentives. In this context, the Office of the Secretary of Defense, the Congress, and the services' organizations each play a critical role in getting the better outcomes sought on major weapon system programs.

The basic management goal for a weapon system program in DOD is similar to that of a major commercial undertaking: to develop and deliver a product that meets the customer's needs. The product development efforts of leading commercial firms are guided by achieving a sensible balance among customer needs, product capabilities, and investment resources. However, the pressures of successfully competing for the funds to start and sustain a DOD acquisition program make for a much different business case. Compared with commercial programs, the DOD environment encourages launching product developments that embody more technical unknowns and less knowledge about the performance and production risks they entail. A new weapon system is encouraged to possess performance features that significantly distinguish it from other systems. Consequently, DOD program managers have incentives to promote performance features and design characteristics that rely on immature technologies. These managers rely much more on maturing technology during product development—when attention should be focused on design and manufacturing—than do commercial programs.

Even though less information about a new product development is available at the time of launch, the competition for funding requires detailed projections to be made based on this information. Product development cannot be launched unless a program's development and production cost, as well as timing, coincides with available funding. Because DOD relies largely on forecasts of cost, schedule, and performance that are comparatively soft, competing for funds encourages the estimates to be squeezed into profiles of available funding. Additional requirements, such as high reliability and maintainability, serve to make the fit even tighter. As competition for funding will continue throughout the program's development, success becomes identified with the ability to secure the next installment. The risks associated with developing new technologies and the product together—within tight estimates—have come to be accepted as standard. Production realities are usually too distant to have a curbing effect on early technology decisions.

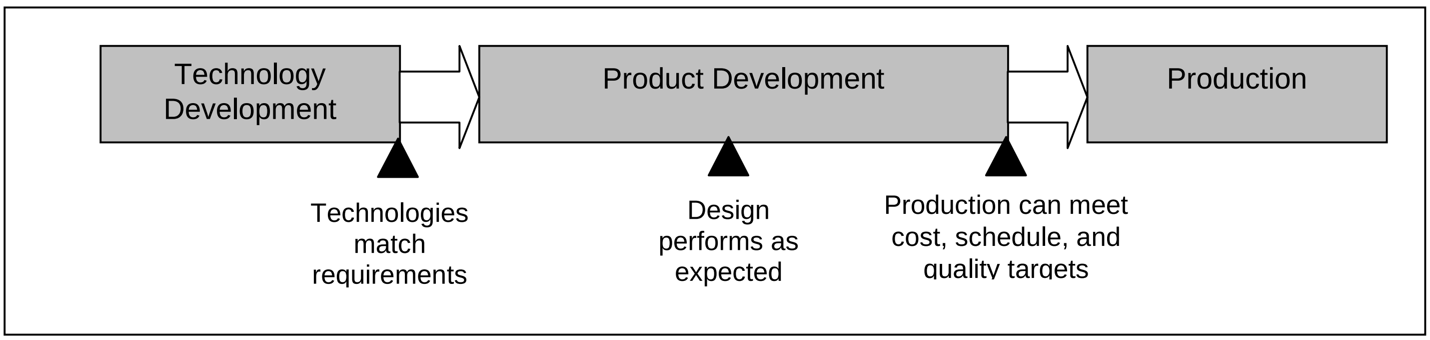
Rewards for discovering and recognizing potential problems early in a weapon system development are few. Less available knowledge makes it harder for program managers to say "no" to unreasonable expectations. Other factors, such as short tenures and career pressures, discourage program managers from saying no. In contrast with leading commercial firms, not having attained knowledge—such as the demonstrated maturity of a technology or a key manufacturing process—can be perceived as better than knowing that problems exist. For these reasons, the practices associated with successful commercial ventures are not readily adopted in DOD.

How a Knowledge-Based Process Can Lead to Better Weapons Acquisitions

Leading commercial firms expect that their program managers will deliver high quality products on time and within budget. Doing otherwise could result in the customer walking away. Thus, the firms have created an environment and adopted practices that put their program managers in a good position to succeed in meeting these expectations. Collectively, these practices comprise a process that is anchored in knowledge. It is a process in which technology development and product development are treated differently and managed separately. The process of developing technology culminates in discovery—the gathering of knowledge—and must, by its nature, allow room for unexpected results and delays. Leading firms do not ask their product managers to develop technology.

On the other hand, product development in commercial ventures is a clearly defined undertaking for which firms insist on having in hand the technology that meets customers' needs before starting. The process of developing a product culminates in delivery, and therefore, gives great weight to design and production. The firms demand—and receive—specific knowledge about a new product before production begins. A program does not go forward unless a strong business case on which the program was originally justified continues to hold true. This process is depicted in figure 1.

Figure 1: Knowledge-based Process for Applying Best Practices to the Development of New Products

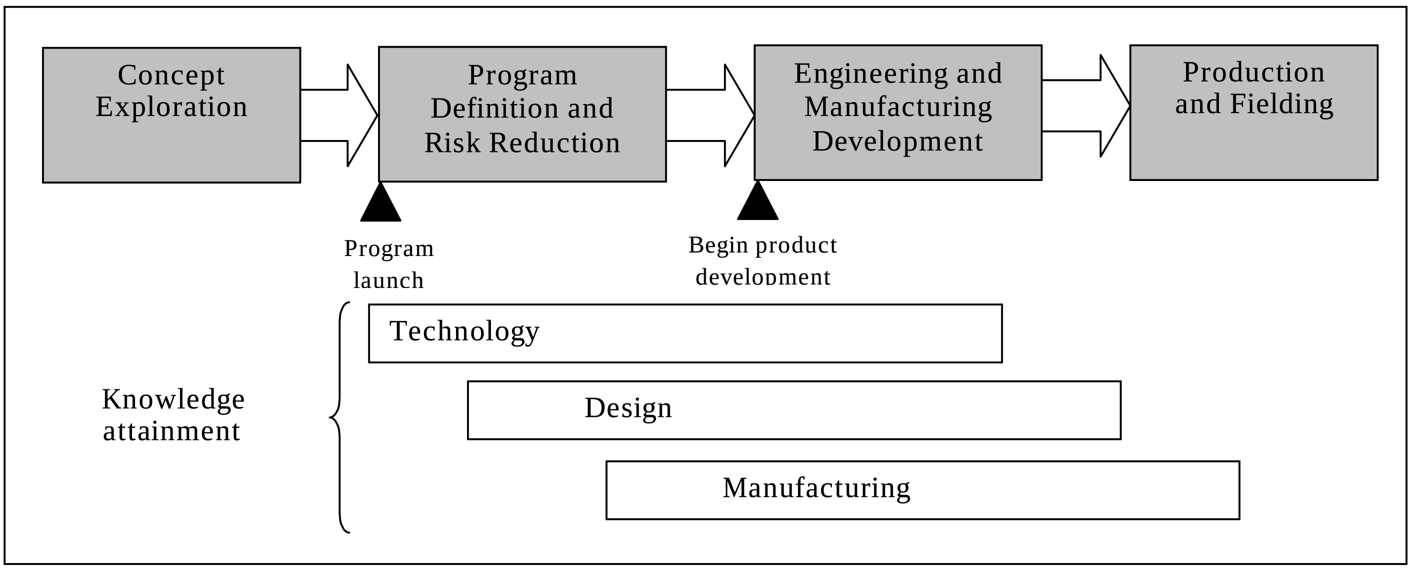


Such a knowledge-based process is essential to commercial firms getting better cost, schedule, and performance outcomes. It enables decisionmakers to be reasonably certain about critical facets of the product under development when they need it. This knowledge can be broken down into three knowledge points:

- when a match is made between the customer's needs and the available technology;
- when the product's design meets performance requirements,
- and when the product can be produced within cost, schedule, and quality targets.

There is a synergy in this process, as the attainment of each successive knowledge point builds on the preceding one. Metrics gauge when the requisite level of knowledge has been attained. The result is a product development process that delivers excellent results in a predictable manner. On the other hand, in DOD's current acquisition process, technology, design, and manufacturing knowledge is attained concurrently—in the higher cost environment of product development—throughout the weapon system phases. This process and the knowledge gathering that takes place is shown in figure 2.

Figure 2: DOD's Current Weapon System Acquisition Cycle



We have reported our findings on best commercial practices to DOD, and have made recommendations on how they can be applied to weapon systems. A listing of these reports is included in the appendix. DOD has agreed with these recommendations and they have been reflected in DOD's draft revision of its regulations that guide the acquisition process. We have incorporated some of the terms from the draft regulations in the acquisition process outlined in the pages that follow.

Technology and Requirements Must Match Before a Program Can Be Launched

As a technology is developed, it moves from a concept to a feasible invention to a component that must fit onto a product and demonstrate that it can function as expected. Leading commercial firms do not let a new technology onto the product development until it reaches this level of demonstration. To minimize technology development during product development, leading commercial companies employ disciplined processes to match requirements with technological capability before the product development is launched. Prior to launching the product development program companies confront production realities and demand proof that the technology will work and can be successfully produced. The companies bring solid technological knowledge to the requirements process in the form of current, valid information from predecessor programs, experienced people, and new technologies that have been demonstrated to a high level of maturity. In addition, the companies communicate extensively with customers to match their wants and needs with the firm's available technology and with its ability to manufacture an appropriate product. They have learned not to commit to new products that outstrip their technological know-how. These practices stem from their recognition that resolving technology problems in product development can result in at least a ten-fold cost increase; resolving them in production could increase costs by a hundred-fold.

Other practices contribute to successfully developing technology. These are:

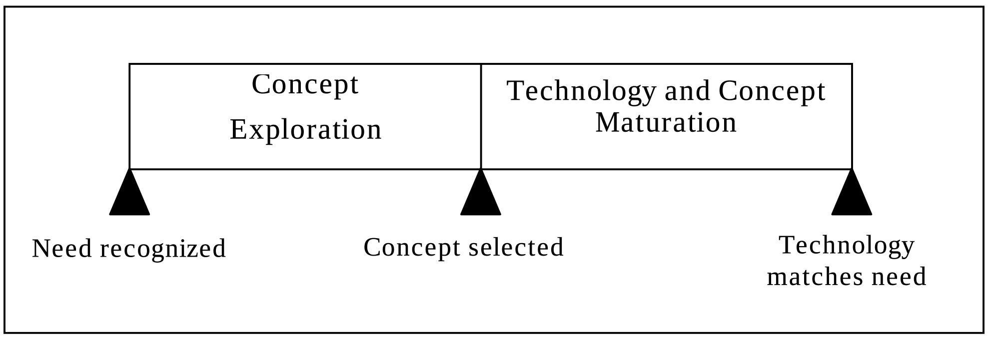
- flexibility in both the resources provided and the product's performance requirements to allow for the uncertainties of technical progress;
- disciplined paths for technology to take toward inclusion in products, with strong gatekeepers to decide when to allow it into a product development program;
- high standards for judging the maturity and readiness of technology;
- the imposition of strict product development cycle times; and
- rules concerning how much innovation can be accepted on a product before the next generation must be launched.

Collectively, these factors create a healthy environment for developing technology and making good decisions on what to include in a product.

These practices can be adapted to the front end of DOD's weapon acquisition process. They can relieve the pressure to launch programs with immature technologies and underestimated resources that are overmatched by requirements. In fact, in some cases because of unique circumstances, DOD has applied these practices with successful outcomes. For example, the Defense Advanced Research Projects Agency matured a revolutionary periscope technology to a very high maturity level before it was included on the Virginia class attack submarine development program. To date, this new technology has not caused cost and schedule problems for the submarine's development program. More typically, however, DOD launches programs with immature technologies and does not get a match between mature technology and the weapon's requirements until late in product development. For example, we found key technologies for the Army's Brilliant Antiarmor Submunition were at very low maturity levels when the acquisition program was launched. This was a significant gap between technology maturity and weapon system requirements that was not closed until well into the program. Problems with the technologies were a main contributor to the program's 88-percent cost growth and 62-percent slip in schedule.

DOD's current acquisition process begins with a determination that a military need must be met with a new weapon system. Different concepts are explored to determine the best type of weapon system to meet the need. Once the concept has been selected, DOD typically launches the development program and assigns a program manager responsibility for formulating the weapon system design and maturing essential technologies. DOD refers to this phase as program definition and risk reduction. In applying best practices, we have recommended that DOD not launch a program until the technologies needed to meet a new weapon's requirements are mature. To separate this technology development from the program, best practices suggest that a technology and concept maturation phase follow concept exploration and precede program launch. This and the concept exploration phase are illustrated in figure 3.

Figure 3: Weapon Acquisition Phases That Should Precede Launching A New Program



Once the concept phase has concluded with selecting a weapon system concept, such as a satellite, to meet a need, the technology and concept maturation phase would start. Practices included in this phase are:

- assigning science and technology organizations responsibility for identifying key technologies and maturing them to acceptable levels;
- developing a preliminary system design;

- identifying enabling technologies and applying standards for managing and assessing their maturity using technology readiness levels[1];
- using a hybrid organization or some other means to smoothly transition the responsibility for technologies from science and technology organizations to the program manager, and
- establishing a baseline set of weapon system requirements, within reasonable cost and schedule expectations, that can be met with mature technologies.

These practices would separate technology development from an acquisition program. They would also result in an established baseline requirement, a best technical approach, and technologies matured to a high standard. This would make it possible to achieve a match between performance requirements and mature technologies—a key knowledge point—and would enable decisionmakers to not launch a program if the match was not demonstrated. Given a baseline design, decisionmakers could also defer unmet requirements and the associated technologies to future upgrades, allowing technology development to take place in a more flexible, failure-tolerant environment. Collectively, these practices would curb incentives to overpromise the capabilities of a new weapon system and to rely on immature technologies. This would put the program manager in a better position to succeed once the program is launched.

Product Development Should Deliver a Mature Design and Key Processes

The decision to launch a major new product development is a watershed event for leading commercial firms. A product development will not be launched unless the following elements are present:

- a clear market (customer requirements) exists;
- the firm possesses the technology and engineering capability to design the product and bring it to market on time;
- the firm can afford the financial investment to develop the product; and
- the product can be manufactured on time, at high quality, and at a cost that enables an acceptable return on investment.

If the firm does not have confidence in one or more of these elements, it does not launch the product. On the other hand, if all the elements are there, the manager of the product development effort is in a good position

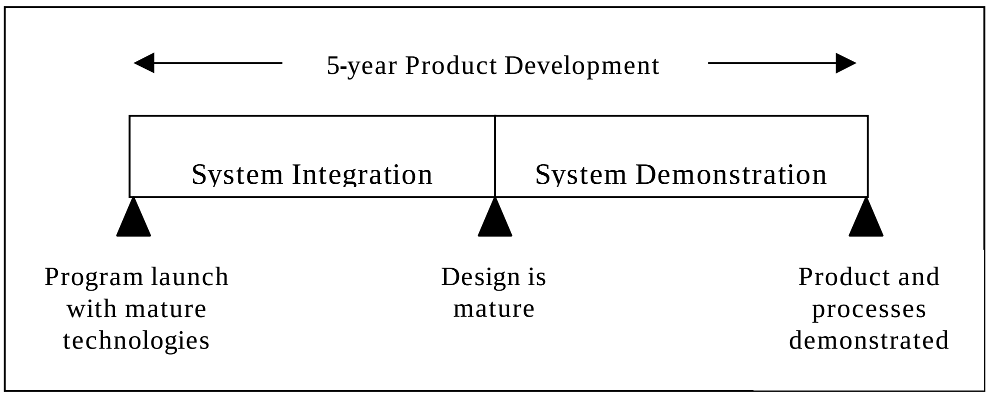
[1] In our review of best practices for including new technology in products (GAO/NSIAD-99-162, July 1999), we applied a scale of technology readiness levels pioneered by the National Aeronautics and Space Administration and adapted by the Air Force Research Laboratories. These levels have proven to be reliable indicators of technology maturity and eventual success in product development.

to succeed. The technology needed for the product is proven, the firm has evidence that it can develop and produce the product as scheduled, and the venture can be afforded. Time constraints are an important element. If the product development cannot be completed within a set schedule, competitors might beat the firm to market and the cost of schedule overruns would hurt profits. Time constraints are also used to limit the initial product’s requirements. Another, perhaps more basic, consideration limits the product development schedule: the amount of time one can reasonably expect people to drive to a goal like delivering a product. One commercial executive observed that it is unreasonable to expect people to focus on a goal (such as production start-up) that is 4 or more years away. To live within these time constraints and keep innovation alive, commercial firms have adopted the practice of saving requirements that cannot be met with proven technologies for the next generation product.

In DOD’s current acquisition process, the decision point that most closely resembles commercial firms’ product development phase is the engineering and manufacturing development decision. Although the decision to launch the weapon system acquisition program has already been made years earlier, the engineering and manufacturing development phase represents DOD’s effort to design, test, and begin production of the new weapon. Its broad scope places an enormous burden on the program manager. Technologies still must be matured and integrated into a system, testing conducted, and production processes readied. Although this range of activities can take 8 to 10 years, the program manager is expected to develop and be accountable for a precise cost and schedule estimate made at the decision to go forward with development. Because of their short tenures, it normally takes several program managers to complete this phase alone. Consequently, the program manager that commits to the cost and schedule estimate during the program definition and risk reduction phase is not the same person responsible for achieving it.

Best practices can be applied to this scope of activities, starting with the premise that key technologies are matured and matched to a basic set of user requirements. Best practices suggest a product development phase consisting of two elements—system integration and system demonstration—to be completed in 5 years. Leading commercial firms commit to product development as a single phase that combines both elements. About midway through product development, they become certain of the product design’s ability to meet customer requirements, indicated by having 90 percent of engineering drawings completed. In addition to this knowledge point, they also have all key production processes under statistical control by the end of product development—the third knowledge point.[2] In applying best practices to DOD, there may be more discovery—that is, more potential to find the unexpected—when the individual components and technologies are brought together as a whole. Thus, a distinct system integration effort makes sense. Similarly, DOD programs may also have more discovery on production processes, given the long time spans between programs. Therefore, key production processes should be demonstrated by the end of system demonstration, with full process control being achieved during low rate initial production. Figure 4 illustrates a product development phase incorporating best practices.

Figure 4: Product Development Phase to Deliver a Mature Design and Key Processes



The system integration component of this phase is the first point in the process that vests full responsibility in the program manager, but recognizes that a fair amount of system-level discovery can still occur when components and technologies are integrated into a complete weapon system. Because of this, the program manager should not be held to precise cost and schedule estimates to complete development and production because requisite knowledge is absent. Therefore, system integration activity should be accomplished in a flexible cost and contract environment. System integration should be used by the program manager

[2] Statistical process control is a technique for monitoring production processes to see if they are consistently producing output that is within the quality standards and tolerances set for the overall product.

to gather the knowledge necessary to build firm cost and schedule targets and to firm the weapon's design. Activities included in this phase are:

- program launch;
- integration of all technologies into a complete system;
- maturation of the system design;
- completion of at least 90 percent of the system's engineering drawings;
- development of knowledge-based cost and schedule estimates; and
- finalization of the system's requirements.

System integration should conclude with a critical design review of engineering drawings and confirmation that the system's design will meet requirements—a key knowledge point. It should also result in firm cost and schedule targets and a final set of requirements for the initial version of the weapon. Decision-makers should insist on a mature design—supported with completed engineering drawings—before proceeding to system demonstration. Having such knowledge at this point in time contributes to product success.

For example, Boeing had released over 90 percent of the engineering drawings for its 777-200 airplane half-way through its product development program. This allowed Boeing to have near certainty that the design for the 777-200 airplane would meet requirements. On the other hand, DOD's C-17 program had released only 56 percent of its engineering drawings at approximately the same point in development. We estimate that the C-17 program did not release over 90 percent of its initial drawings until more than three years later and after 7 production aircraft had been delivered. The C-17 encountered numerous technical problems in testing that resulted in redesigns, cost increases, and schedule delays.

I have mentioned the value of setting time constraints for product development. The leading commercial firms we have visited consciously limited their development phases, ranging from 18 months to just over 4 years. We have identified a 5-year limit for weapon developments that reflects both commercial practices and guidance provided by the Under Secretary of Defense for Acquisition, Technology, and Logistics that weapons should complete development <u>and</u> initial production within 7 years. This would make it possible for DOD to extend the tenure for a single program manager to the entire product development phase—providing the manager a more realistic responsibility but with more accountability. Accordingly, the system integration phase should last no longer than half—2.5 years—of the product development phase.

System demonstration is the point in product development when the program manager can legitimately commit to firm cost, schedule, and performance targets within which to deliver the weapon system. In turn, the program manager should secure a full funding commitment from DOD fund managers. Included in system demonstration are:

- building of weapon system prototypes;
- test and evaluation of those prototypes; and
- test and evaluation of the key processes used to build them.

Demonstrating the system should conclude with demonstrations of the product in a realistic environment and of the key manufacturing processes used to build the product. It should be completed no later than 5 years after the start of system integration. We believe this activity would make the program manager and contractor accountable for a low-risk product development phase with precise cost and schedule targets. It would enable the use of a tighter, less flexible contract that contains a pricing structure for which the contractor can be held accountable. At its conclusion, decisionmakers could make an accurate, informed decision to move from product development into production.

Successful Product Development Allows a True Production Focus

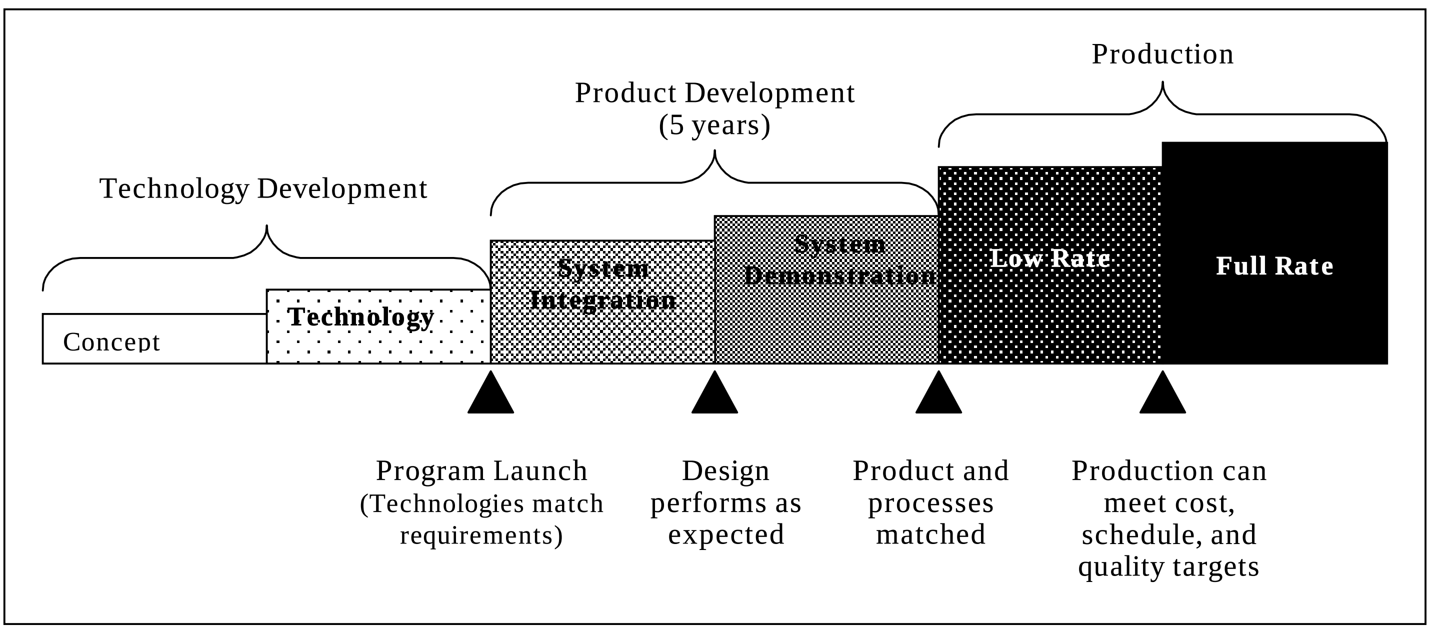
At the conclusion of product development, leading commercial firms reach the point at which they know that manufacturing processes will produce a new product conforming to cost, quality, and schedule targets before they begin producing a system. Reaching this point means more than knowing the product can be manufactured; it means that all key processes are under control, such that the quality, volume, and cost of their output are proven acceptable. Commercial firms rely on good supplier relationships, known manufacturing processes, and statistical process control to achieve this knowledge early. In fact, they have all their key processes under statistical process control when production begins. The ability to establish control for key processes before production begins is the culmination of all the practices employed to identify and reduce risk and is the final knowledge point. All of the companies we visited agreed that knowledge about technology and design early in the process makes the control of processes possible.

In the current weapon acquisition process, DOD breaks production into two phases—low-rate initial production and full-rate production. Ostensibly, the purpose of low-rate production is to produce the minimum quantity of a new weapon for operational tests and establishment of a production base that allows for an orderly increase to full production rates. Typically, however, development work is not concluded before low-rate production is started and thus both are done concurrently. Consequently, significant cost increases that cause schedule and other problems are not uncommon in early production, and production processes are often not able to be statistically controlled even when full-rate production begins.

Applying best commercial practices to the production of weapon systems could relieve the pressures to complete product development concurrently with low-rate production. If the product design and key manufacturing processes are fully demonstrated in product development, the scope of low-rate production can be reduced to building operational test articles and maturing the production processes. Low-rate production could safely conclude when a product has met user requirements in operational conditions and manufacturing processes are under statistical process control—the third key knowledge point.

Putting all of the pieces together, DOD could adopt a weapon acquisition process that is knowledge-based and reflects best commercial practices, as shown in figure 5.

Figure 5: Potential DOD Technology and Product Development Process Incorporating Best Practices



This process centers on the separation of technology development from product development and the accumulation of technology, design, and process knowledge measured at key junctures. As I noted earlier, DOD is currently rewriting its acquisition policy to reflect these concepts among many other changes. It should be recognized that the acquisition offices preparing this new policy cannot succeed without the agreement and cooperation of other key communities that influence the acquisition process. These include the organizations responsible for writing and approving weapon system requirements, conducting science and technology, and programming modernization funds.

Implications of a Knowledge-Based Acquisition Process for the Future

While an acquisition policy anchored in best practices principles is essential to getting better program outcomes, it is the actions taken on individual programs that determine whether real change will occur. Within the current process, actions are taken on individual programs that run counter to policy and compromise sound principles. Yet individual actions—not policy—communicate the broader message of "what will work" to others in the process. The real test of a policy that applies best practices will be the decisions made on individual program launch and funding decisions. These decisions define what success means in DOD and what practices contribute to success. Decisions to advance or fund programs that do not have enough knowledge to meet best practices standards send signals to managers that not having the necessary level of knowledge is acceptable.

The principles embodied in policy have proven difficult to apply on individual programs. Pressing circumstances are invoked as reasons for making exceptions for the program at hand. Thus, on a case-by case basis, decisions to approve programs despite knowledge shortfalls or their failure to live up to advertised expectations can be rationalized in a number of ways: an urgent threat needs to be met; a production capability needs to be preserved; despite shortfalls, the new system is more capable than the one it is replacing; the new system's problems will be fixed in the future. The challenge for acquisition participants is to treat individual program decisions as more than the case at hand. They must weigh and be accountable for the broader implications of what is acceptable or "what will work" and be willing to say no to programs that run counter to best practices. We have made recommendations along these lines to the Secretary of Defense and the Congress. Acting on them will be key to the success of an acquisition policy anchored in best practices.

If DOD succeeds in applying knowledge-based practices to the weapons acquisition process, the benefits transcend the management of individual programs. Programs managed using best practices are more likely to be executed within cost and schedule estimates. This will minimize surprises in the form of cost and schedule increases that are often accommodated by disrupting the funding of other programs. Without such disruptions, DOD can better stabilize its overall modernization effort. Decisionmakers may be more able to focus on a balanced investment strategy rather than continue the practice of making decisions about how much each program's funding and quantities should be reduced so that all programs can continue to be funded.

We also believe that the idea of a phased investment strategy for a program—with contracts tailored for more clearly defined phases of work, such as technology maturation, system integration, and system demonstration—can leave the potential for competition open longer, both across the defense and nondefense industries. Finally, limiting product development cycle times to 5 years or less would allow for more frequent assimilation of new technologies into weapon systems, thereby reducing obsolescence and allowing better management of the industrial base. Reduced cycle times, coupled with planned upgrades, could make for more frequent and predictable work in production, where contractors and the industrial base can profit.

Mr. Chairman, this concludes my prepared statement. I would be happy to respond to any questions you or other Members of the Subcommittee may have.

Contact and Acknowledgments

For future contact regarding this testimony, please contact Mr. Lou Rodrigues at (202)512-4842. Individuals making key contributions to this testimony include Katherine Schinasi, Paul Francis, Michael Sullivan, Matthew Lea, and Katrina Taylor.

Related GAO Products

Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes (GAO/NSIAD-99-162, July 30, 1999).

Defense Acquisitions: Best Commercial Practices Can Improve Program Outcomes (GAO/T-NSIAD-99-116, Mar. 17, 1999).

Defense Acquisition: Improved Program Outcomes Are Possible (GAO/T-NSIAD-98-123, Mar. 17, 1998).

Best Practices: Successful Application to Weapon Acquisition Requires Changes in DOD's Environment (GAO/NSIAD-98-56, Feb. 24, 1998).

Best Practices: Commercial Quality Assurance Practices Offer Improvements for DOD (GAO/NSIAD-96-162, Aug. 26, 1996).

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