TECHNOLOGY INSERTION STRATEGIES FOR SPIRAL DEVELOPMENT OF COMPLEX WEAPON SYSTEMS

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Abstract

The increasing reliance on technology for the network centric weapons systems of the 21st Century requires that the Department of Defense (DoD) be able to harvest and integrate technologies in a timely manner from all possible sources. In order to maintain our current superior force capabilities, life cycle technology insertion (LCTI) strategies are the key to reducing the time to market of major systems so that the most technologically advanced systems can be fielded. Unfortunately, we do not know how to design, measure, and more importantly budget technology insertions to support spiral development. Though the technical issues are not trivial, most problems are more management and budgeting than technological. In this paper we will present some strategies that can be implemented throughout the systems life cycle. We will also discuss, philosophically, DoD acquisition practices and how they can be improved to support spiral development.

Introduction

Spiral development and evolutionary acquisition have become the buzzwords of the Department of Defense (DoD) acquisition community. As stated in DoD Memorandum 5000.2 (see DoD, 2003a, 2003b), "Evolutionary acquisition is the preferred DoD strategy for rapid acquisition of mature technology for the user. An evolutionary approach delivers capability in increments, recognizing, up front, the need for future capability improvements." The objective is to balance required system performance with available capability and resources, to put the best available system capability into the hands of the user quickly. Currently, the Air Force leads the other military services in adopting processes and procedures devoted toward instantiating evolutionary acquisition in their systems procurement process. However, the other services have all adopted varying guidelines (for example see US Air Force, 2004 and US Navy, 2004), on the implementation of evolutionary acquisition.

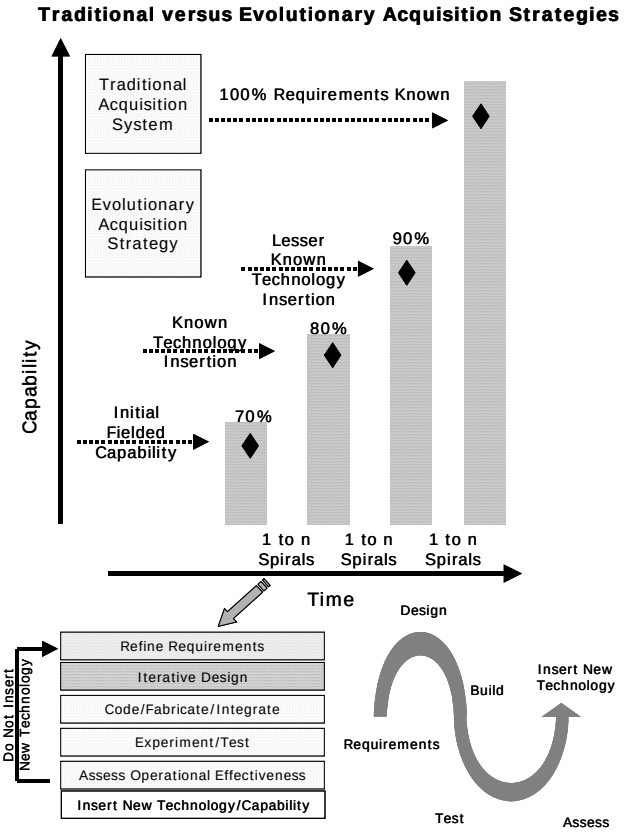
Numerous definitions exist relevant to evolutionary acquisition. Farkas and Thurston (2003) have researched extensively the role of evolutionary acquisition and spiral development in the DoD and have proposed the following definitions that we will adopt:

- Evolutionary acquisition – a plan to develop and deliver warfighting capability over time.
- Spiral development – an iterative process that include collaboration with stakeholders/users and continuous feedback in the decision to refine requirements to provide the best possible capability for a specific increment.

The US Navy uses the term Life Cycle Technology Insertion (LCTI, see US Navy, 2003) that originated in the software development community which implies planning for the preservation of the capability of a system over its life cycle by keeping the system sufficiently up to date to avoid obsolescence and associated sustainment problems. LCTI is probably a better term for describing the total process of incrementally upgrading systems as technology matures but is not as universally accepted. Additionally, the term LCTI is focused on technology, whereas as all system life cycle upgrades are not solely limited to technology. Consequently, it is important to note that spiral development is requirements focused. The term is often associated with the development and fielding of an incremental improvement in capability by systematically meeting additional system requirements over time.

For our purposes, we will use the definitions presented for evolutionary acquisition and spiral development. Another perspective is shown in Exhibit 1.

Exhibit 1. The role of spirals in the evolutionary acquisition process

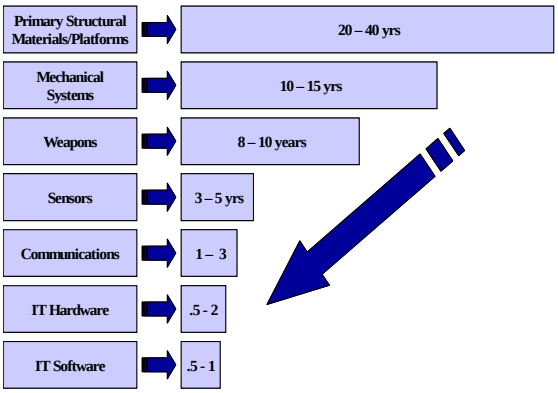


Spiral development is the process to develop, refine, and ready the capability for fielding and evolutionary acquisition is the strategy to deliver the capability. The key tenet of evolutionary acquisition is that the procurement strategy recognizes upfront the plan to initially field the system at a reduced capability. This allows the military to get the system into the inventory more quickly than the traditional acquisition process. Thus, allowing soldiers in the field to capitalize on the new system's enhanced performance capabilities and more effectively incorporate it into operational missions. As new technology matures and becomes available, they will be inserted into the evolving system until all system requirements are ultimately met or exceeded.

Since the end of the cold war, military investments in technology have decreased. By contrast, commercial investments within the technology arena have continued to increase. One of the byproducts/advantages of spiral development is that it takes advantages of these investments in technology by the private sector. In particular, the US Navy has embraced the concept of designing systems with a significant commercial-off-the-shelve (COTS) component. This is a great example of the benefits of evolutionary acquisition.

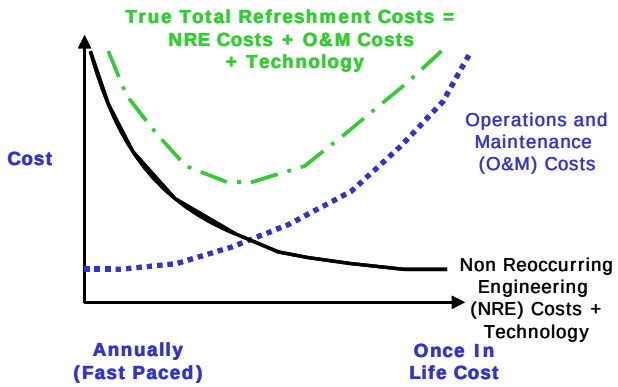
Unfortunately, DoD has had limited success in implementing the evolutionary acquisition process. Depending upon the acquisition costs, major systems (>$100M) often take 15 years from inception to fielding. To get the system into the hands of the user quickly the acquisition times of weapons, mechanical systems and platforms must be dramatically shortened (See Figure 2). Exhibit 2 also illustrates the vast improvement in capability that can be attained over the full life cycle of a system as major sub-components are upgraded to meet planned requirements. The next generation of systems will be network centric. Currently in the early stages of acquisition, the Army's Future Combat System will require an evolutionary acquisition strategy because of technology life cycles and the focus on information operations.

Exhibit 2. Components of military systems and the technology cycle time associated with major improvements (modified from NRAC, 2003)



The issues associated with evolutionary acquisition within DoD are very complex and include optimizing product cycle time upgrades (see Exhibit 3), architecting systems for commercial-off-the-shelve (COTS) and/or product upgrades, funding strategies for a technology insertion increments, baseline versus increment testing, program organization and execution, and the engineering challenges of inserting new capabilities into a baseline system.

Exhibit 3. Optimizing LCTI (modified from Tom Herald, 2004)



In this paper we will highlight where the DoD procurement process must be modified to incorporate evolutionary acquisition. Although obstacles exist within DoD to fully realizing the benefits of evolutionary acquisition, the military acquisition community is dedicated to developing a workable evolutionary acquisition strategy plan and implement technology upgrades. This will lead to reduced acquisition time but also a methodology for planning and inserting technology upgrades.

Perils and Promises of Spiral Acquisition

Rapid development in a system ill equipped to deal will evolving baselines, multiple owners requirements, and not profit driven requires communication and mutual trust and flexibly of off all parties. However, spiral acquisition can offer some unique advantages over the traditional procurement process (modified from Johnson and Johnson, 2002) to include:

- Incremental capabilities can be fielded quickly, giving the warfighter more capability sooner.
- Risks can be spread across a series of spirals, allowing demonstrated capability to the user.
- Lessons learned in earlier fielded spirals can be interjected more quickly.
- Technology can be incorporated faster – lean, agile acquisition by its very nature.

Exclusive of the government procurement system not being to design to agile development, difficulties and problems exist with spiral development to include:

- A spiral approach does not work if the user cannot accept fielding a significantly less (80% for example) than desired solution when the baseline is fielded.
- Spiral acquisition is inherently flexible and could lead to budget cutbacks in difficult times. The program must be designed to weathers delayed insertions without catastrophic failure (rejection by the user community).
- The test community must be involved at all phases of the program. Partial long-term capability must be seen as success. The test community cannot delay fielding waiting for a 100% solution.
- The requirements must evolve and be flexible with possible updates in the middle of the acquisition.
- Expectations must be managed. Pundits will compare the baseline system with legacy system it was designed to replace. The ultimate system must be compared against the legacy system.
- The logistics community must buy into having multiple configurations fielded.
- Communications must be continuous and trust built among the team. This is not limited solely to program manager and contractor but among members of the government team. For example, tensions have existed for many years between the acquisition and testing communities.
- The leadership (DoD and congressional) must accept that spirals are subject to change based upon technology and user needs.
- Can the user philosophical accept multiple configurations of a system? Also, can the user plan and execute spiral upgrades (spirals need a series of smaller, discrete upgrades; otherwise it is essentially a block upgrade).
- One unavoidable consequence of evolutionary acquisition is that the commercial sector drives the product lifecycle to include support. Systems run the risk of not having an adequate support system.

Major Issues Associated with Spiral Acquisition within the DoD

DoD Acquisition and Sustainment Processes.

In the simplest of abstractions, major DoD programs are analogous to a matrix organization with numerous stakeholders. Organizationally,

the requirements developer, the material developer, tester, and the user are all typically stovepipe service organizations governed by federal law, policy memorandums, regulations, memorandums of agreement, etc. Many of those documents are so unwieldy that significant resources are expended on peripheral issues. For example, the document that governs testing and evaluation of any major Army system (Department of the Army, 2003) is 483 pages in length! Cutting across these organizations are the functions of research and development, testing, engineering, etc. All of these organizations have typically been focused on fielding a stable and mature system that meets the user requirements. A contractor is then hired to build the system. All of the parties involved are interested in fielding the most stable system. Without profit as a motivator, time to market is often not an issue – especially given the technological edge the DoD has in most modern weapons systems.

Organizational and Cultural. The argument has been presented that time to market is not usually the overriding consideration for the DoD. Whereas, in most industries time to market drives all decision once the requirements have been developed. For example, within General Motors a product manager has the responsibility of all aspects of the design and testing of a new car. All schedules are worked backwards from the product delivery date. When major tasks slip, other tasks are prioritized, shortened, etc., to prevent a delayed product release date.

A major DoD system is a forward planning process with no incentive or mechanism for faster development. The government/contractor systems must be incentivized to reduce the time to market and accommodate spiral development. Since the DoD is not profit driven, the best means to improve the time to market will require different ways of doing business. For example, if the DoD/contractor team has significant program delays, contractors should be structure to allow for easy termination. More importantly, program management teams within the government should be held accountable just like the private sector.

The issue of reducing the time to market for fielding baseline of systems is different but related to spiral development and the associate incremental upgrades. Because there is significant overlap in processes, organizational and cultural issues must be changed.

Once a baseline system has been fielded, contractors must be rewarded to improve performance, reliability, and cost effectiveness. This can be accomplished using value engineering (agreements to share cost savings with the contractor during pre- and post-production), annual post product research and development budget, and/or have mechanisms for incentives (cost plus to implement or specific performance criteria in the contract with rewards) in the contract to improve

- Reliability,
- Capability/Performance, and
- Life Cycle Costs.

The contractor teams must be empowered to improve the systems. Complex and unwieldy regulations and oversight leading to delays in timely technology insertions will prevent the leveraging of technology to field the "best" system.

Incentives Based Contracts. Because of congressional oversight and visibility**,** most major procurements within DoD are firm fixed-price. Price based acquisition and variations of firm-fixed price contracts are being used within DoD for some small programs. However for DoD to fully realize the benefits of spiral development, creative contracts must be written. For example contracts could be written to include:

- Performance based incentives – these incentives can be monetary or non-monetary with penalties for missing program milestones.
- Non-cost incentives – these incentives could mean guaranteed follow on work or reduction in production amounts based upon poor contractor performance (i.e., not meeting prescribed time or performance based insertions).
- Incentive fees – these can be successfully implemented on a range of contract goals.
- Step ladder incentives – these would involve cost sharing between the government and the contractor. For example, should the contractor fail to meet prescribed insertions because of technology/integration issues costs would be shared on a cost plus agreement in a manner very different if delays in the insertions were caused by

delays in testing, government processes, etc.

Funding. One of the biggest challenges of funding for spiral development is how to budget for technology insertion. As shown in Exhibit 1, one of the key elements of spiral development is that as technology matures it should be inserted in the base line system. Given the rapid pace of change, few can predict how technology will evolve in the 2 to 5 year time horizon. Processes must be developed that allow for both time and capability driven insertions.

Unfortunately, in an era with shifting funding priorities because of rapidly changing geopolitical environment, time driven insertions (similar to the block upgrade approach currently used) are hard to defend – especially when the capabilities that will be delivered are uncertain because of evolving technology. For significant lapses of time after release of the baseline, technology insertions should planned and programmed based upon capabilities deliver. Thus, when funding is not provided, a shortfall in capabilities can be demonstrated. If this capability is planned for as part of the baseline release, the program will be easier to defend during the funding processes.

Testing. Current testing and evaluation (T&E) costs and testing cycle times are significant. Often, the total system is tested at a government site independent of the contractor. In order to support spiral development a major shift in testing philosophy must occur to include

- T&E must be funded at adequate levels (for NASA projects 8% to 10% of system cost is used for testing),
- More component level testing should be allowed (with government oversight),
- Testing at contractor sites (with government oversight) (reduces time and costs)
- Program Manager (PM) and the Contractor should have more oversight of component level testing and should not conduct system testing for component spirals, Spiral Development requires testers to be involved with PM and System Developer throughout acquisition process

Engineering Challenges. Systems must be designed up front for spiral development and conform to existing DoD and commercial standards for interoperability. Spiral development/technology refresh candidate components must be designed to be backwards compatible. Functional and physical architectures must be described and the interactions documented and modeled. Requirements and the systems architecture evaluation must include criteria such as open standards based, open systems orientation, and physical and functional modularity

Selecting the proper set of commercial/DoD standards will be one of the keys to maintaining a technology insertion strategy. Open systems design principles allowing for the interchangeability of components from multiple vendors will promote a competitive environment among contractors – accelerating the time between spirals. One of the biggest engineering risks is the government paradigm to purchase proprietary software. Allowing the use of proprietary software (especially for systems integration) should not be allowed.

Conclusions

DoD is embarking on an ambitious path with the goal of accelerating the acquisition of complex systems. Evolutionary acquisition coupled with spiral development provides our acquisition community with the means to develop appropriate acquisition strategies and a methodology for implementing technology insertion. To effectively establish this concept current DoD business practices must be modified to pave the path ahead. This will not be an easy task, but is sufficiently necessary for our nation's military forces to transform to meet the challenges of the 21st Century.

Spiral development holds the promise of delivering capabilities to the warfighter sooner. Risks can be spread across many insertions with the lessons learned from earlier spirals easily incorporated into the next insertions. The system can also evolve depending upon operational needs. Spiral development as part of the evolutionary acquisition process holds the promise of leaner and more agile acquisitions. Unfortunately, the biggest obstacles are institutional ways of doing business within the DoD.

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