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Jack R. Ferguson
Michael E. DeRiso

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Jack R. Ferguson
Michael E. DeRiso

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, Pennsylvania 15213

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Software Acquisition: A Comparison of DoD and Commercial Practices

Abstract: This paper will compare best commercial practice with the current Department of Defense (DoD) processes for acquiring software and to recommend some steps that can be taken to streamline DoD software acquisitions to minimize overall life-cycle costs.

Background

Defining the Issues

Two issues arise when discussing commercial practice in acquiring software. The first concerns methods used by industry to acquire software systems similar to those developed by the Department of Defense. Second is the use of commercial off-the-shelf (COTS) products to build these large software systems. Each of these issues brings benefits and risks to the DoD; and, while use of COTS is worthy of a major study itself, this paper will focus on the use of commercial acquisition methods and will discuss the use of COTS in the framework of these commercial methods.

Types of Software

Both the DoD and industry acquire and maintain three major types of software systems that have the following characteristics:

1. Real-time embedded control systems
    - Interrupt-driven
    - Large numerical processing requirements
    - Small databases
    - Tight real-time constraints (microseconds to seconds)
    - Relatively well-defined but diverse user interfaces
    - Requirements and design driven by performance constraints
    - Examples: Aircraft control system, steel processing control system

2. Information systems
    - Transaction-based
    - Moderate numerical processing requirements
    - Large databases
    - Relatively flexible time constraints (seconds to hours)
    - Flexible, complex user interfaces
    - Requirements and design driven by user interface—must match way of doing business
    - Examples: Accounting, personnel, and supply management systems

3. Command, control, communication, and intelligence (C3I) systems
   - Large numerical processing requirements
   - Large databases
   - Near real-time requirements (milliseconds to minutes)
   - Flexible, complex, and diverse user interfaces
   - Requirements and design driven by both performance and interface
   - Examples: Missile warning and control system, telephone switching system, manufacturing, package delivery

In the first two domains, there are numerous systems in existence or under development by both the DoD and industry using a wide range of acquisition techniques. Large C3I systems, however, have fairly limited applications in industry; but, as mentioned later, they will become more common in the future. In addition to these domains, commercial vendors produce tools and general purpose software such as operating systems, word processors, and spreadsheets.

Acquisition Methods

As the DoD is looking for ways to improve its acquisition methods, much attention has been given to commercial methods. The focus has been on hardware development and manufacturing, but similar comparisons between DoD and industrial acquisition methods may be used to improve DoD software acquisition. The following tables contrast best commercial practice with that used in a conventional DoD program. Note, however, that there are limited cases of DoD application of some of these commercial practices (the Air Force PRISM and the Army Common Hardware Software-2 programs are examples) and that the practices listed below do not reflect all situations. Note that DoD separates information system acquisition from mission-critical applications and employs different regulatory environments for different domains.

The tables cover the areas of requirements definition, vendor selection, development process, business practices, integration, testing, delivery, maintenance, and rights in data. They briefly describe some of the aspects of best commercial versus DoD practice in each area. Although not exhausting, the comparisons serve to identify aspects of software acquisition in which large differences exist between the two processes. In general, commercial practices are geared so that systems are delivered more quickly and maintained at less cost.

Comparison of Software Acquisition Methods

Requirements Definition	
Best Commercial Practice	**Current DoD Practice**
Requirements based on strategic plan and market analysis.	Requirements based on using command Mission Need Statement.
Requirements based on life-cycle resource constraints.	Requirements based largely on annual budget resource constraints.
Detailed requirements generated by interdisciplinary team including users, domain experts, and system engineers.	Detailed requirements generated by buyer in collaboration with user. Team generally includes domain experts and acquisition personnel.
Functional specification is modified by knowledge of availability of existing products.	Functional and/or performance specification; little to no regard for existing products.
Vendors involved early in study, analysis and prototyping with emphasis on reuse and evolution of existing systems.	May contract for prototypes, but contractor involvement in pre-award discussions is discouraged.
Level of documentation is negotiable based on individual user needs and complexity of system being developed.	Extensive (often redundant or unnecessary) documentation required under 2167A. Tailoring of documentation requirements is often minimal or discouraged.
More requirements tradeoff decisions (involving complexity and schedule) for reduced time to field.	Very little flexibility to trade off requirements creep versus complexity and schedule.
Tools used to create system models for use in requirements definition; e.g., GUI building.	Requirements definition based on Mission Need Statement.

Summary

Commercial is more flexible and open between users and suppliers, and requirements are based on a strategic plan. In the commercial world, there is more willingness to adjust requirements based on availability of products and thus to field a system sooner and evolve it to include more capability.

Vendor Selection	
Best Commercial Practice	**Current DoD Practice**
Solicit multiple (but not all) qualified vendors. Encourage teaming with a view to attaining a relationship that covers the entire life cycle and fosters tradeoffs in cost and schedule.	Solicit all possible vendors. Vendor proposals must meet 100% of requirements. Teaming seldom encouraged.; development and maintenance usually separate entities.
Compare vendor history and experience. Maintain long-term relationships.	Can compare previous performance, but normally can't have long-term relationships.
The organization that will be responsible for a system over its full life cycle is heavily involved from the beginning.	Maintenance organization not usually involved in vendor selection process.
Use site visits and demonstrations to gain knowledge of vendor capabilities.	Site visit only by capability evaluation team, or other expert teams. Visits are very structured.
Overall goals: (1) obtain product at reasonable cost as soon as possible; and (2) achieve the business case for the system.	Overall goal: Obtain lowest cost product that rigorously meets all requirements, but be fair.
Relatively few review and approval steps once vendor is selected.	Review and approval process more structured and complex once vendor selected.
Past performance weighted heavily (sometimes primary factor) in selection process.	Past performance considered, but usually only as a minor factor.
More flexibility in vendor selection based on metrics and overall assessment.	Selection of vendor forced by use of predefined metrics for proposal evaluation.
Summary	
Very different processes with commercial much more flexible but with no requirement for fairness, or to maintain the public trust. Commercial encourages vendors to offer best solution, but solution may not meet 100% of the requirements. Teaming and long-term relationships are more easily accommodated by industry.	

Development Process	
Best Commercial Practice	**Current DoD Practice**
Vendor often tailors existing systems and uses COTS. System designed to fit in a defined architecture or product line.	Varies with application. Some systems use COTS. However, usually a new system that doesn't reuse legacy software. Unique systems are built with little regard for architecture.
Buyer may have heavy involvement in design and development as part of the team (Integrated Product Development team)	Formal, structured spiral, or waterfall model. Buyer oversees, but team approach is not usually emphasized.
Reviews typically informal and stress progress against goals.	Reviews usually very formal and include technical design details in addition to progress metrics.
Heavy user involvement.	Limited user involvement. Heavy buyer involvement.
Vendor embraces one or more industry standards which improves interface and integration with COTS products.	Government and industry standards called out. Not all government standards enhanced by COTS products.
Buyer requirements may be translated to more "general purpose" requirements for potential software reuse.	Tailored system; little, if any, focus on designing in reusable code.
Management reviews and degree of oversight are commensurate with size and risk of program.	Notably more detailed reviews and oversight performed.
Prototyping common, with joint applications development teams (user and developer) working to clarify requirements and incorporate new requirements that do not affect cost or schedule.	Prototyping seldom used, but becoming more popular.
Summary Commercial more flexible with likelihood of a team approach and is biased toward reuse and tailoring of existing systems. Product improvements are anticipated.	

Business Practices	
Best Commercial Practice	**Current DoD Practice**
Informal contracting, joint ventures, partnerships with mutual economic benefit and vested interest in success.	Formal contract with little motivation to reduce cost.
Oversight built on established relationships.	Burdensome cost accounting procedures required; extensive oversight, reporting, and documentation requirements.
Can hire and fire vendors and managers.	Government personnel regulations, policies, and practices determine qualifications of its managers, rotations of assignment, and training.
Multi-year effort and funding.	Multi-year effort. Yearly, unpredictable funding.
Summary Commercial practice more flexible with greater incentives.	

Integration Testing and Delivery	
Best Commercial Practice	**Current DoD Practice**
Unless system is for a new plant, then there are major “cut-over” issues.	Similar “cut-over” or transition issues
Sometimes difficult to assemble complete system in laboratory environment due to cost. Testing usually done in client’s facility.	Usually integrate system in laboratory prior to operational testing. Development testing vs. operational testing via statutory mandate.
Beta testing widely used to quickly find errors.	Little beta testing.
Ultimate acceptance authority rests with buyer, not a separate organization.	Structured, specified operational testing conducted by separate authority. Acceptance authority rests with buyer.
Summary Integration and functional testing seem appropriate to the need. DoD use of separate test agency adds time and complexity.	

Maintenance	
Best Commercial Practice	**Current DoD Practice**
Organic support shifting to outsourcing or vendor.	Organic support, with reluctance to be dependent on vendor. Use of depot maintenance makes interoperability issues more manageable. Also, must be responsive to user for critical systems.
Summary	
The DoD and industry have different requirements and must be careful when selecting a maintenance strategy appropriate to their needs.	

Rights in Data	
Best Commercial Practice	**Current DoD Practice**
If custom development, buyer gets all rights, but vendor may retain right to subsequent sales.	Specified by contract. Government usually demands all rights for government use due to organic support and maintenance needs, and competition (via statutory mandate).
If tailored version of standard system, buyer only gets rights to tailored parts.	Same as commercial May have exceptions for proprietary material
Summary	
Similar, but commercial is a little more flexible especially regarding resales.	

Observations

As described in the table, some commercial acquisition practices are significantly different than those used by most DoD programs. Some of these appear to be more efficient. Some would require changes to federal law and the Federal Acquisition Regulations (FAR), but most can be adopted more easily by changing acquisition practices. However, the current mindset of the DoD acquisition process leads to a very conservative approach versus a more flexible and aggressive process. The DoD culture tends to prevent government program managers from taking advantage of even relatively simple changes to current practice. Some activities are now underway in the Defense Acquisition Pilot Program to gain relief from federal law and FAR requirements. Specific actions taken by each program director should be collected along with lessons learned as the acquisitions proceed.

The following section highlights a few of the more significant practices in the requirements, source selection and development phases and discusses some regulatory aspects of changing DoD practice. It should be noted, however, that the DoD should not simply copy attractive commercial practices. Rather, the practice must be analyzed and possibly modified to take advantage of the most efficient aspects that would apply to the specific DoD application. Since DoD program managers must maintain the public trust, care must be taken when applying new acquisition techniques.

Requirements

The largest differences between commercial and DoD practices lie in the user-buyer-developer relationship. Industry considers the availability of existing products in this phase and is more willing than the DoD to trade functionality with availability to decrease cost and schedule. Systems are thus delivered earlier and are then evolved to include later requirements. In addition, the best commercial practice is when an integrated product development (IPD) team, including suppliers, is formed early and is kept together throughout the program lifetime. Also, companies that provide software think in terms of product lines that fit into standard architectures with tailorable products. Service acquisition professionals could set up test acquisitions that take advantage of the functionality/cost tradeoffs without modification of the FAR. They can also organize with a team approach. By tailoring DoD STD 2167a, unnecessary documentation and accounting overhead could be saved. A study by Air Force Electronic Systems Center indicates that documentation requirements can be reduced by over 60% for mature developers. In addition, use of IPD teams gives the government visibility into programs that cannot be obtained through 2167a documentation alone.

Vendor Selection

Industry and the DoD have significantly different practices here. Since industry has a fundamentally different relationship with suppliers, major changes to the FAR would be required. The ability to negotiate with suppliers and to engage in long term contractual relationships which cover both the development and maintenance phases is, so far, forbidden by regulations or interpretations of regulations. Due to the requirement to maintain public trust and to be rigorously fair, the DoD is constrained in its ability to radically change vendor selection techniques.

Use of Commercial-Off-the-Shelf (COTS) Software

Development

As some development agencies are beginning to pioneer, COTS products can be used to build much of a system, especially infrastructure elements. However, use of COTS is not without risk. As noted in the SEI appraisal of software development risk management, problems can be encountered in using COTS in the following areas:

- Customizing: Changes to interfaces and accommodation of version releases can have significant impact on other parts of a system.

- Testability and integrability: No clear traceability nor clear line of responsibility.
- COTS quality versus system quality: Reliability figures typically don't apply to software.

Also, COTS performance and short lifetimes can seriously affect a large system development. When performance limitations are found to be due to COTS components, alternatives are sometimes limited to substituting a different product that may have different interfaces and upgrading the hardware platform. Neither of these alternatives is usually cheap nor quick. COTS products tend to change rapidly, with attendant testing and analysis requirements for system builders. A new operating system, for example, can take a team of people six months to adequately test and validate for use on a major project. COTS use also affects programmatic decisions concerning maintenance and product lifetimes. The aforementioned volatility and the chance that a vendor will go out of business can affect systems with expected lifetimes of decades. These risks can be mitigated as long as they are recognized. For example, domain engineering allows both continuous assessment of COTS products as well as current familiarity with industry standards.

Support

In the post deployment software support (PDSS) phase, support agencies must develop a sustainment plan that addresses defect and enhancement maintenance. Defect maintenance of COTS software may best be handled through a warranty. However, this should be negotiated judicially to ensure total warranty for all defects. COTS enhancements must be supported by an innovative contract that defines well the contractor's responsibility for delivering new COTS products that support functionality enhancements. This requires a P3I enhancement plan for future COTS insertion.

Evolutionary development is one means to expand a system based on resource and technology constraints. Evolutionary software maintenance has come about because of the ease of adding new functionality into a system through software improvements vs. hardware. However, the insertion of COTS software places an added element of risk for software enhancements. Some questions related to support of COTS products are discussed below:

1. How does the life cycle software support (LCSS) activity stimulate competition for COTS that will ensure a fair and reasonable cost?
2. How does the LCSS ensure that the COTS will technically integrate into the system and continue to maintain an open architecture evolutionary development?
3. Reuse has a very cost effective role in evolving systems. What is the effect of COTS vs. reuse? Is there a process for reusing COTS for different system domains, and what would the proprietary issues be?
4. Software engineering methods and techniques that are now becoming practice emphasize model-based software architectures. This new approach to developing software produces a well defined design that offers substantial potential for reuse. Will COTS support this cost effective maintenance approach? Is this currently being used in commercial practices? Available data shows limited introduction for commercial development.

How does a vendor support a commercial system? There are numerous ways in practice, the most common being the maintenance warranty. Maintenance warranties vary depending on the type of system, and essentially how much the buyer is willing to pay for the support. Generally, a warranty only covers maintenance of defects. If a commercial buyer desires to improve a system through evolutionary means, there is a costly maintenance contract required since most of the enhancements are accomplished through reengineering.

COTS has yet to scale up for insertion into some software architectures unless it has been specifically engineered for a given domain. However, the engineering approach taken by the PRISM project to build a reusable COTS product line for a specific domain (command and control) is an example of successful use of COTS in one large domain.

Commercial practices for PDSS tend to be rather ad-hoc. Commercial systems software is supported by an add-on contract that generally covers defect detection and resolution. Enhancements are normally contracted for at system project initiation for the insertion of new functionalities. Both commerce and government have put more thought into the architectural and acquisition aspects of COTS, but different approaches to PDSS means that commercial experience may not easily map to the government.

Convergence of C3 Projects

Industry, with the move toward just-in-time ordering and agile manufacturing, is beginning to experience the need for large near real-time command and control systems similar to those long used by the DoD. Indeed, some industries, such as communications and manufacturing, have already developed systems similar to those used for tactical military command and control. These systems, depending on the application domain, consist of between 60% and 80% infrastructure (database, user interface, etc.). The market for this infrastructure will thus grow from one customer (the DoD) to many. The role of the DoD in the future, then, should be to cooperate with industry to encourage the development of commercial dual-use products to populate this infrastructure. This would make more robust technology available for both DoD and industrial systems.

Recommendations

Commercial Practice Experiments

The DoD should encourage and closely monitor pilot projects that employ carefully chosen commercial practices in the requirements definition, vendor selection and development phases of selected program acquisitions. As the Defense Science Board Task Force Report on Engineering in the Manufacturing Process points out, these experiments should demonstrate the following benefits:

- Reduce ambiguity
- Eliminate delay
- Reduce risks
- Reduce cost
- Increase quality
- Increase maintainability
  - Responsiveness
  - Preservation of design/architectural integrity
- Enhance integration with legacy systems
  - Responsiveness to original integration and to changes
  - Reliability of interfaces

Attaining these benefits in the software area should be goals of experiments that use the following techniques in the first three program phases:

1. Requirements Phase
   - Reduce ambiguity by extensive simulation and prototyping. Specify data model and global standards.
   - Maintain prototypes as the baseline throughout the development to quickly analyze changing requirements.
   - Eliminate delay and improve quality and efficiency by specifying standard interfaces to minimize data manipulation.
   - Perform functionality/cost tradeoffs early in the requirements phase to determine if dramatic time or cost savings can be obtained with relatively small changes to requirements.
   - Maximize flexibility by stating system performance and functional requirements as broadly as possible, consistent with supporting the intended mission.
   - Tailor documentation requirements to emphasize those items needed by the end user to understand, use and maintain the final software product and minimize the amount of (often unused) documentation associated with recording each step of the design process.

- Include COTS products surveys and vendor site visits as part of the requirements generation/request for proposal (RFP) writing process to allow requested functionality and performance requirements to be adjusted to accommodate existing software products when consistent with mission capabilities.
- Include contract mechanisms for incremental requirements definition/improvement activities rather than trying to cast all requirements in concrete at program go-ahead.
- Give users incentive to follow/encourage commercially available functions and forego military service unique requirements.

2. Vendor Selection Phase
   - Reduce cost and risk by using integrated product teams.
   - Involve vendors early in the conceptual phase.
   - Encourage the use of product lines in standard architectures.
   - Emphasize quality engineering processes.
   - Adopt an acquisition strategy that readily accepts change to accommodate volatile requirements.
   - Encourage adherence to commercial open systems standards, rather than restricting offerers to compliance with military standards. This would be easier to accomplish if government personnel involved in RFP preparation received training in existing and emerging commercial standards.
   - When appropriate and feasible, vendor compliance to the goals of the SEI Capability Maturity Model ought to be a heavily weighted selection criterion.
   - Include metrics associated with the extent to which COTS is used to satisfy requirements as an explicit part of the evaluation criteria.
   - Use “best value” procurement techniques to allow more advantageous tradeoffs between requirement satisfaction and costs.

3. Development Phase
   - Use open systems standards to reduce ambiguity, reduce cost and improve quality.
   - Eliminate delay by enforcing interface standards and reducing the number of Engineering Change Proposals. Eliminate “nice to haves” and delay “have to haves” to pre-planned product improvement (P3I) modifications.
   - Reduce risk and improve product quality by thoroughly evaluating COTS products, enforcing interface standards and by using virtual interfaces, such as developed by the STARS and PRISM programs.
   - Consider the use of selected commercial software development practices in place of tailoring 2167a or other military standards.
   - Encourage incremental or spiral development approaches with provision for hands on user evaluations of early software releases (similar to the idea of beta tests in the commercial world).
   - Tailor Program Management Review/Design Review agendas to focus on programs, plans, and status rather than on inappropriately detailed design presentations. Relegate detailed design oversight activities to less formal forums, and implement via government membership in integrated development teams.

- Give contractors incentive to commercialize items modified or developed under the contract whenever possible. This can be done in ways which can ensure that the government will get low cost upgrades to government owned systems as new commercial versions are developed and released. Such arrangements can also decrease the government's maintenance support costs.
- Give incentive to contractors to use reuse libraries.
- Establish "clearing houses" for determining what commercial products are useful for acquirers.

Suggested Approach

In addition to the pilot projects, the government could apply selected commercial practices to an existing Advanced Technology Demonstration (ATD) that has a significant software content, such as the Advanced Field Artillery System Fire Control/Battlefield Management System. ARPA can underwrite the use of practices in an ATD that would be viewed as risky in a major program acquisition, both technically and managerially, but that has significant potential payoff in the way that the DoD acquires systems.

Infrastructure Development

ARPA should work with leading edge industries to determine command and control system infrastructure requirements and initiate development of dual-use technologies to populate the infrastructure.

One way to accomplish this is to encourage the development of product lines based on architectures such as those defined in the Domain-Specific Software Architectures Project. Tailorable products from these lines could then be used by both the DoD and industry to populate infrastructures of systems in all three domains, but particularly in C3 systems that are large, complex, and expensive. One of the issues that must be explored concerns the tradeoffs in ownership of architectures. At least three cases should be considered:

1. Ownership by the government (customer).
2. Ownership by the community, such as with standards.
3. Ownership by the vendor.

It is important that infrastructure efforts be cognizant of the Technical Architecture Framework for Information Management (TAFIM) program. In particular, the DISA DoD TAFIM Volume 2, published in June 1993, provides a solid framework into which the various standards used to characterize open systems can be placed.

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