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Risk-Based COTS Systems Engineering Assessment Model: A Systems Engineering Management Tool and Assessment Methodology to Cope with the Risk of Commercial Off-the-Shelf (COTS) Technology Insertion During the System Life Cycle

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1.0 INTRODUCTION

Due to the rising costs of today's weapon systems, the U.S. Department of Defense (DOD) continues to implement strategies to reform its acquisition and procurement process. One such strategy seeks to reduce the cost of developing systems by purchasing commercial off-the-shelf (COTS) technology. The COTS technology ranges from components used to build a particular weapon system to functional pieces of gear used to support the weapon system, i.e., support equipment. The COTS technology may be instituted at the inception of the weapon system design or it may be inserted into the support of the weapon system at any point during its life cycle. The COTS technology is intended to reduce weapon system life-cycle costs by minimizing the expense of system design and testing.

While using COTS technology is beneficial to the DOD, several factors must be weighed before such technologies can be introduced effectively. Above all, the typical systems engineering thought process must be adjusted to incorporate the potential risks of COTS technology. One of the most significant risks involves parts obsolescence. Systems engineers must decide how and when to use rapidly changing COTS technology to keep pace with the commercial technology market. Technology manufacturers regularly develop new versions of electronics and software and new designs of mechanical parts. These rapid changes lead to technology "outpacing" fielded military systems, which often have long life spans and require legacy parts support. Previously, as one of the most influential players in the development of technologies such as electronics, the DOD often "drove" technology development to fulfill its needs. Now, increasing demands for electronic technologies from all sectors of the market (e.g., industrial, professional, personal, and government) have lessened the DOD's influence on the pace of technology development. And, while the DOD's desire to field new and innovative technologies has increased, acquisition budgets have actually decreased. As a result, the DOD finds it more difficult to drive major price efficiencies than in the past. Because the commercial industry currently views the DOD as a different kind of player in the technology market—one with more stringent requirements than other customers—the DOD no longer can easily influence technology suppliers to design, test, and support their products in the manner prescribed by the DOD. In short, technology suppliers are less willing to guarantee the configuration design stability and logistics support required by DOD systems engineers to ensure that a weapon system will be adequately supported throughout its life cycle. This diminished technology support, if not managed properly, can lead to parts obsolescence, which in turn can lead to increased life-cycle costs for a weapon system, as well as diminished mission readiness.

For example, there is an inherent risk if the DOD procures COTS equipment for a specific weapon system and the technology manufacturer ceases to provide replacement parts because technology has advanced since that equipment was fielded. In the best-case scenario, the manufacturer designed its equipment using open architecture and either the new, updated technology parts can directly replace the old parts in the fielded equipment or they can be integrated using a manufacturer-supplied interface. In the worst-case scenario, replacement parts are not available because the manufacturer has either gone out of business or did not plan to supply upgraded or original parts to the DOD over the lifetime of the weapon system. In either case, the DOD will have to cover the risk to mission readiness, as well as the cost of replacing obsolete parts or even redesigning/modifying the equipment to make it compatible with the new technology parts.

Additionally, one of the prevailing and flawed opinions in applying COTS technology to DOD weapon systems is that "if the technology exists in the commercial marketplace, it already must be appropriate for use in

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the military and, therefore, validation and testing of the technology are unnecessary requirements." This is an unacceptable risk because every piece of equipment must meet an acceptable set of requirements relative to the DOD operational environment for which it is intended. The military mission and operating environment can be distinctly different than those of industry, and technologies must be tested and validated to withstand factors such as extreme shock, vibration, and corrosion. The appropriate level of testing and validation must be determined based on the type of technology and how it will be fielded. Ideally, a COTS technology may be subject to a reduced level of DOD testing based on established commercial testing data. If this is the case, the DOD will realize a cost savings.

When specifying COTS technology, parts obsolescence, validation, and testing risks must be effectively balanced with system performance, life-cycle costs (affordability), and overall supportability. One management tool and methodology that helps systems engineers identify COTS technology risk factors was developed by the Naval Air Warfare Center Aircraft Division, Lakehurst, New Jersey (NAVAIRWARCENACDIVLKE) under the Naval Air Systems Command. The Risk-Based COTS Systems Engineering Assessment Model is a tool that addresses the need for better systems engineering integrated decision-making. The model can improve the military systems engineering management decision framework so that COTS technology integration is considered as an alternative to "cradle-to-grave" development of DOD weapon systems. Ultimately, the model reduces risk and uncertainty in the engineering of defense systems that use COTS technology.

2.0 ACQUISITION REFORM INITIATIVE

Several key measures facilitate the accelerated introduction of commercial technologies into DOD weapon systems.

2.1 COTS Technology

Various DOD directives have led to the current focus on procuring COTS technology. For example, DOD Directive 5000.1 prescribes a systems engineering approach throughout the entire life cycle of a system and categorizes the four basic types of acquisition in order of preference:

a. Modification of existing system
b. Procurement of a COTS item
c. Procurement of a nondevelopmental item
d. Development of a new system.

The DOD's Acquisition Reform Initiative is a mandated effort to reduce the cost of systems acquisition through measures such as COTS technology procurement. The benefits of DOD acquisition of COTS technology can be significant, especially with respect to eliminating developmental costs, but the appropriate risk factors must be explored for each unique case.

2.2 *Open System Architecture*

A major contributor to the success of COTS-based technology solutions is an open architecture design. DOD Directive 5000.2-R strongly encourages the design of open architecture for DOD-developed systems in order to ensure flexibility and scalability and to facilitate the insertion and integration of technology. In many cases, industry also has embraced open architecture in order to promote supportability, interoperability, and scalability as means of reducing production costs and gaining a competitive advantage. Manufacturers who employ the principles of open architecture represent reduced risk to the DOD when procuring COTS technology.

Some industry standards promote open architecture. For example, small components such as valves often are designed using open architecture standards to ensure that they can be applied to and interchanged with a wide range of systems. Unfortunately, other types of mechanical components, such as pumps, may not be adapted as easily between systems. For example, if a manufacturer develops a system that includes a unique component A, which for some reason becomes unavailable as a replacement part, then a new component B, possibly from a different manufacturer, must be integrated. If the system was not designed with open standards to accommodate a different component, it will require redesign work and/or a new interface for component B to be retrofitted into the system.

The interchangeability of critical parts is therefore an important factor when determining the risk of parts obsolescence and the supportability of a COTS system. The COTS systems, which are designed with open architecture and open standards, yield reduced risk and life-cycle costs.

3.0 SYSTEMS ENGINEERING

The impetus for greater application of COTS technology creates a new systems engineering challenge—to cost-effectively assess and integrate commercial technologies prone to continuous change. Predicting these changes and ensuring minimal risk can be a difficult task. The overall goal is to meet mission requirements while ensuring cost, schedule, and performance throughout the weapon system life cycle. This goal can be compromised by poorly estimating the risks involved with COTS technology insertion.

To compensate for rapid COTS technology changes, systems engineers must identify strategies and a common framework that will aid in projecting and

mitigating these issues early in the weapon system development cycle. By addressing market (i.e., technology manufacturer) concerns early, the volatility of COTS technology insertion can be controlled and potential problems, such as parts obsolescence, can be minimized.

The first step toward meeting this objective is to assess the viability of the commercial technology in the context of performance, complexity, criticality, supportability, and life-cycle cost factors. The Risk-Based COTS Systems Engineering Assessment Model is a common framework that allows systems engineers to meet the goals and minimize the risks of COTS technology insertion at any phase during the weapon system's acquisition life cycle. The model can be used as a life-cycle risk assessment methodology to determine lifelong buys versus COTS technology insertion, to identify open architecture and open standards, to assess supportability, to design processes, and to select materials. It is a life-cycle management tool for dealing with the risk of obsolescence and overcoming the barriers to using COTS technology in defense systems. An innovative aspect of the model is the use of a cube diagram to represent the relative risks of different COTS alternatives (reference Section 4.3).

4.0 ASSESSMENT AND VALIDATION MODEL

The Risk-Based COTS Systems Engineering Assessment Model was developed to ensure that systems engineers can select the most cost-effective COTS equipment based on its affordability, reliability, mission requirements, and ability to accommodate replacement and/or future modification. A risk-based approach to decision-making, the model enables systems engineers to apply a variety of risk perspectives while using information from technology market analyses. For example, market analysis information can be used to assess whether a manufacturer uses open architecture or is likely to have the "staying power" to provide long-term support. The model also assists with determining the level of validation and testing required to further reduce the risk of using COTS equipment. The model allows competing COTS equipment to be judged fairly in order to identify which manufacturer allows the DOD to take the greatest advantage of using COTS equipment (e.g., the manufacturer whose technology meets the mission requirements, uses open architecture, and provides verifiable data to limit the amount of DOD testing and validation required).

For instance, the model can assist in recognizing the worst-case parts obsolescence scenario—selecting equipment that has a high perceived risk of not functioning during a conflict as a result of the unavailability of parts or the incompatibility of newly upgraded parts with fielded equipment. The best-case scenario is one in which the equipment meets the mission by using readily available and supportable COTS parts and open architecture. In this case, components can be replaced to compensate for, as well as to take advantage of, advances in technology.

The model is intended to be a tool that can be applied throughout the lifetime of a system. Ideally, the model should be used to perform a baseline analysis when system development commences. The analysis can be revised and adjusted later during each major milestone or acquisition phase to account for new requirements or factors that were not originally relevant or defined. If a weapon system has progressed beyond the development stage, the model can still be applied at any time to assist with COTS technology decision-making. The model functions best when it is combined with a suitable life-cycle cost model.

Overall, the model works iteratively to define requirements, insert market knowledge, and identify risk. Each COTS alternative is applied to the model. If alternative 1 yields unacceptable risk, consecutive alternatives are evaluated until the alternative(s) with the least risk is identified. If all of the available alternatives have unacceptable risk, either the mission requirements must be reevaluated or other suitable alternatives must be found through additional market analysis. The model defines risk as a function of mission criticality, technical complexity, and life-cycle costs. For example, the risk of parts obsolescence is translated as a risk to the mission and as a potential impact on life-cycle costs. Furthermore, unless the item has been designed using open architecture, the risk of parts obsolescence is evaluated according to the technical complexity of the COTS technology—the more technically complex the technology, the greater the perceived risk of parts obsolescence.

The goal of engineering suitable COTS equipment solutions can be reached by employing the model in accordance with the following steps:

a. Perform market surveillance and construct an ongoing commodity strategy for future needs.

b. **Logical Solution**—Perform an operational requirements analysis (e.g., define mission, performance, functionality, reliability, maintainability, supportability, and environmental requirements).

c. **Physical Solution**—Translate requirements into COTS solutions by applying market analysis.

d. **Alternatives Risk Assessment (a central element of the model)—**Perform an alternatives and risk assessment

- Evaluate the ability of each alternative to meet the defined requirements.
- Determine the requirements thresholds.
- Determine the requirements validation and testing required.
- Determine supportability plans and evaluate open architecture design.
- Determine risk factors to performance, cost, and schedule.
- Determine the estimated life-cycle cost.

e. **Mitigation of Risk**—Perform verification and qualification

- Analyze commercial data and past performance
- Determine required testing and validation of sample equipment.

Figure 1 summarizes these steps and shows how the model fits into the traditional systems requirements decision-making process.

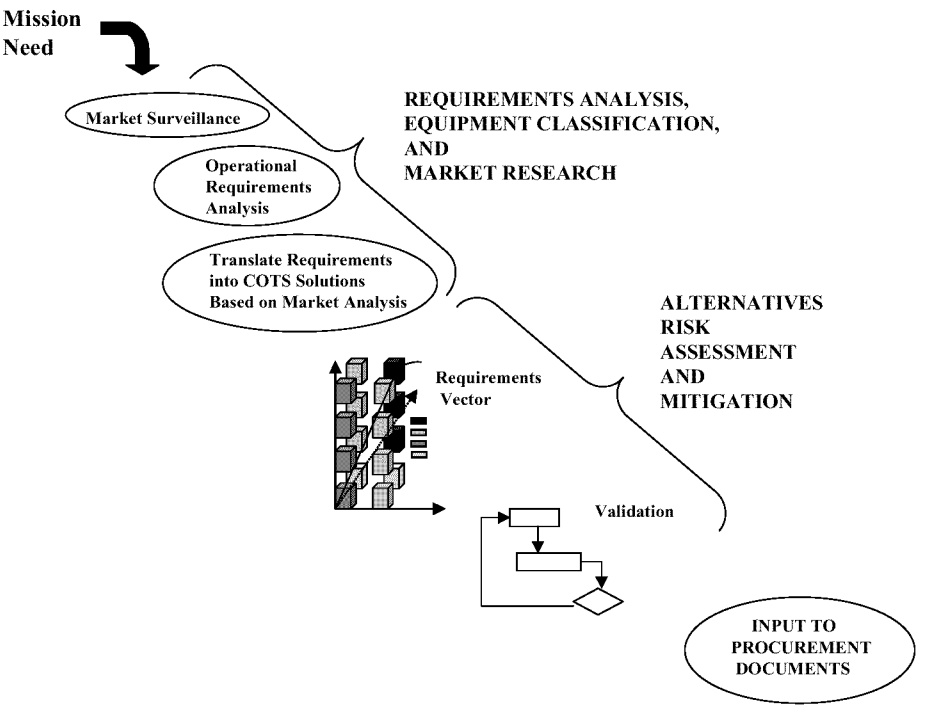

Figure 1. Summary

Figure 2 represents the iterative process that occurs after the need for a piece of equipment is defined. Blocks 1, 2, and 3 relate to defining requirements, determining market-based COTS solutions, and assessing each COTS alternative. If none of the COTS alternatives represents acceptable risk, the mission requirements must be reevaluated or a decision must be made to develop the equipment in-house (DOD design and develop) rather than procuring COTS equipment. If one or more COTS alternatives represent acceptable risk, a procurement strategy for COTS equipment should be formulated based on the best alternative.

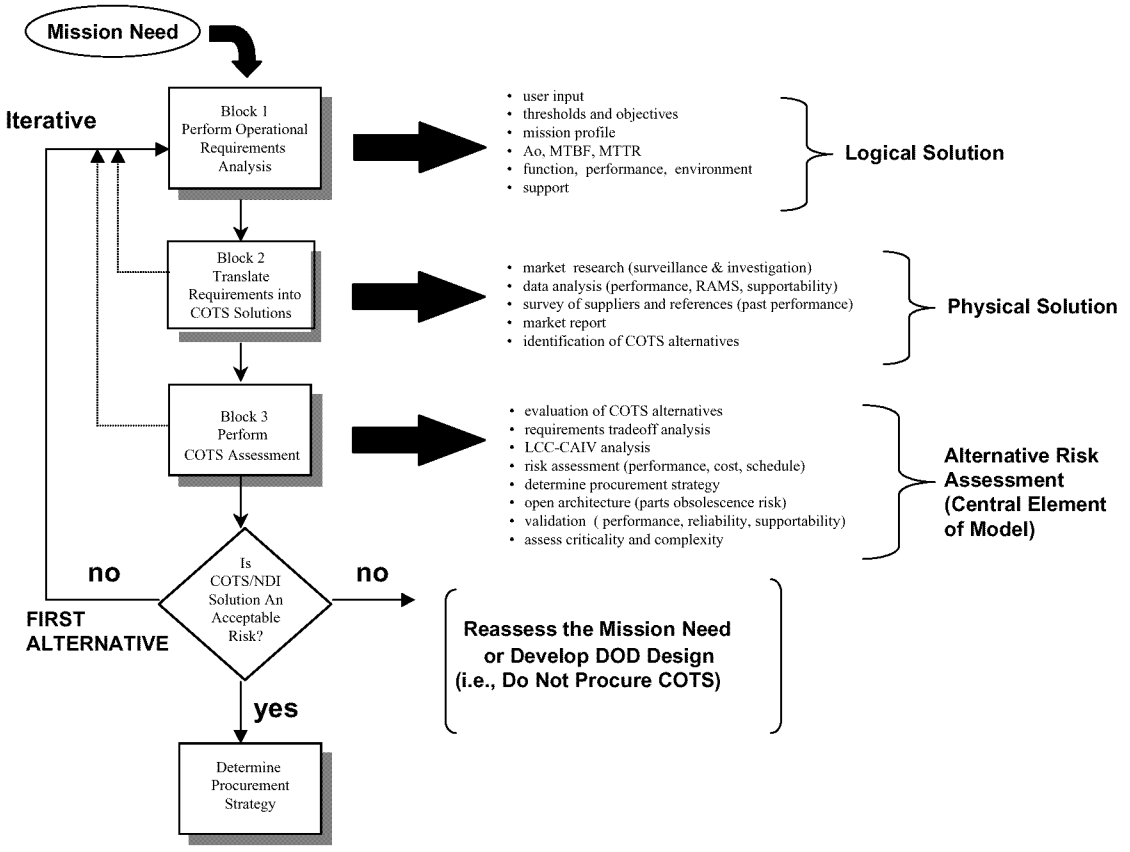

Figure 2. Iterative Decision Analysis Process

4.1 The Logical Solution

Block 1 of Figure 2, Perform Operational Requirements Analysis, includes the following substeps:

- Compile user input (e.g., feedback from shipboard/flight line personnel).
- Define the mission profile and mission analysis.
- Define thresholds and objectives.
- Perform a functional analysis.
- Perform a supportability analysis.
- Define performance attributes.
- Determine operational availability (Ao), allowable mean time between failures (MTBF), and mean time to repair (MTTR).
- Define the operational environment requirements (e.g., shock, vibration, weather).
- Determine estimated inventory and allocation allowances.

4.2 The Physical Solution

Block 2 of Figure 2, entitled Translate Requirements into COTS Solutions, includes substeps such as performing market research, analyzing market data, and surveying COTS equipment suppliers. Market research builds on continuous market surveillance to develop a commodity strategy and market investigation. The market investigation should yield COTS alternatives that meet the requirements of the logical solution (defined above). A typical market investigation results in an evaluation and report of the following items:

- Summary of market surveillance information
- List of potential sources
- Survey of potential supply sources (e.g., Internet search, journals, *Commerce Business Daily* contract awards, etc.)
- Input from references (i.e., current users of similar equipment)
- Compilation of equipment capabilities (e.g., performance, supportability, history, etc.).

Table 1 lists some factors that should be considered when reviewing open standards, equipment profiles, and their related technologies and products.

Table 1. Market and Technology Supplier Analysis

(Source: Next Generation Computer Resources (NGCR), Document No. AST002, Version 0.04 of the NGCR Supportability Guide, draft dated 27 April 1995, SPAWAR.)

Maturity of the Standards, Technologies, and Products	➢ Is the technology mature? ➢ Are the products fairly stable? ➢ What is the product "upgrade" cycle time? ➢ When is the next planned update? ➢ Are the products being refined or significantly changed during each cycle?
Multiple Product Sources	➢ Are there multiple sources for products that meet the requirements analysis? ➢ Are these products interoperable? ➢ Do these products merely accept data from each other or do they meet the same performance levels (interchangeability)?
Market Acceptance	➢ Is the standard, profile, or product well accepted in the commercial marketplace? ➢ What are the respective vendors' market shares? ➢ Are the commercial markets large enough to imply that long-term support and upgrade of the product will be an investment borne by the commercial market sector or will the DOD become the only user in a relatively short time?
Product Line Families	➢ Do product families exist? ➢ Will usage of a given product tie the DOD to a product family? ➢ Will such a relationship be expensive? ➢ Is the existing support structure well-suited to the operational requirements? ➢ Will supplements, upgrades, or replacements be necessary (e.g., technical data, training, repair, spare parts support, etc.)? ➢ Should the product family or the individual product alone be approved for use?
Test and Evaluation	➢ What ongoing test and evaluation parameters are employed by the vendor? ➢ How would the DOD test this product? ➢ Will the existing test capability and data meet the DOD's needs? ➢ Will test data from families of products be applicable? ➢ How much will required testing cost?
Technical Data	➢ Are the technical data provided by the various vendors sufficient? ➢ Are the data useable? If no, what problems can be foreseen? ➢ What workarounds are necessary? ➢ What additional data are necessary?
Configuration Management (CM)	➢ Is the contractor's CM program adequate to meet weapon system program office needs? ➢ Can the contractor's CM program be modified or supplemented if necessary? By the contractor or the government? ➢ What will the cost be and who will bear this cost?
Availability	➢ What is the operational availability (Ao)? ➢ What is the inherent availability? ➢ What is the mean time to repair (MTTR)? ➢ What is the mean time between failures (MTBF)?
Performance Monitoring and Built-in Test	➢ Does the product have a built-in self-test? ➢ Is the self-test capability sufficient from a systems-level viewpoint? ➢ Will the self-test be difficult to reintegrate when updates occur (e.g., engineering, training, configuration status and management, supply support)?
Quality Assurance	➢ Does the vendor provide a warranty and what is included in the warranty? ➢ Is the vendor ISO 9000 compliant? ➢ What other quality assurance measures does the vendor provide?

4.3 The Alternatives Risk Assessment

Block 3 of Figure 2, entitled Perform COTS Assessment, includes the following substeps:

- Classify each COTS alternative based on criticality and complexity. (Since each alternative is a possible solution for the same need, it is expected that the criticality will remain the same for each alternative; however, the complexity may vary with each alternative.).
- Evaluate the anticipated life-cycle cost analysis for each COTS alternative.
- Assess each COTS alternative based on:
  - Ability to meet threshold and objective requirements
  - Supportability (e.g., open architecture design reduces parts obsolescence)
  - Life-cycle cost.
  - Assess the risk of each COTS alternative:
  - Technical risk = *f* (mission criticality, technical complexity, life-cycle cost [LCC])

To perform the alternatives risk assessment—the central element of the model—the technical complexity and criticality of each COTS alternative must be established. The alternatives are categorized using the following definitions:

- Complexity
  - Non-Complex – A nonrepairable piece of equipment (i.e., consumable) or a repairable piece of equipment with no repairable subassemblies.
  - Complex I – Equipment with one or more repairable subassembly.
  - Complex II – Equipment that meets the definition of Complex I and is self-powered (i.e., engine, hydraulic, electric, or pneumatic-powered).
  - Complex III – Equipment that meets the definition of Complex II and has feedback control (i.e., does not have data acquisition).

- Criticality
  - Non-Critical – Requires scheduled and/or unscheduled maintenance, but is not considered mission- or safety-critical.
  - Mission Critical – Failure of this equipment could damage the weapon system or degrade the weapon system mission.
  - Safety Critical – Failure of this equipment could harm personnel.

Next, the equipment alternatives should be assessed to determine approximate life-cycle costs. At this point, the alternatives can be positioned on a three-dimensional cube that forms the basis of the Risk-Based COTS Systems Engineering Assessment Model (refer to Figure 3).

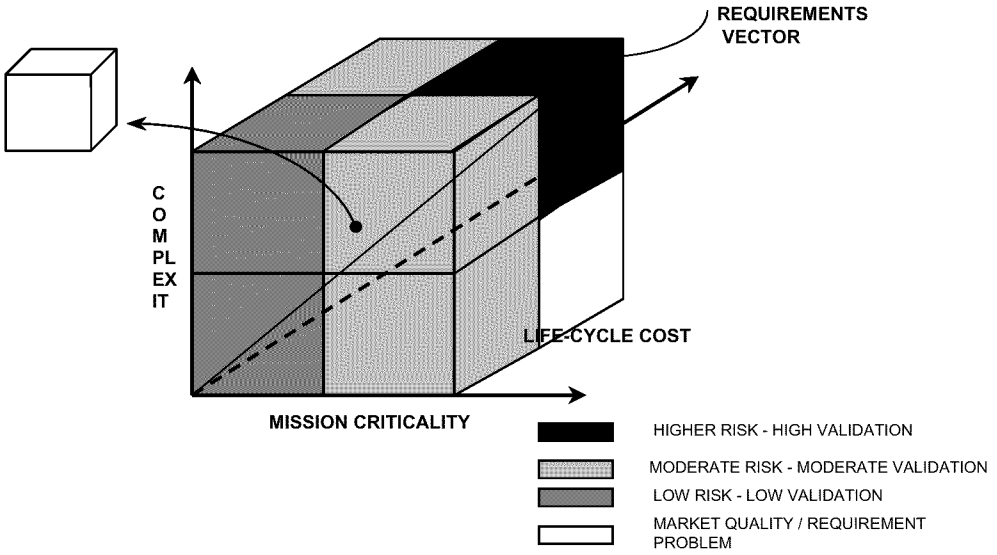

Figure 3. Degree of Validation as a Function of Technical Risk
Risk = *f* (mission criticality, technical complexity, LCC)

This cube allows the systems engineer to determine the degree of validation required as a function of technical risk. Risk is a function of three factors: criticality, complexity, and life-cycle cost. The cube enables systems engineers to visualize alternatives as a composite of their contribution to the mission versus their ease of repair and supportability versus cost. The y-axis of the cube represents increasing complexity,

and the x-axis represents increasing criticality. The z-axis represents increasing life-cycle costs. Each available COTS alternative should be positioned in a sector of the cube. The cube is color-coded to indicate which sectors represent low, moderate and high risk, which correspond to low, moderate, and high requirements for equipment validation. For example, the color-coded location of the sector for those alternatives that are noncritical and noncomplex with a low life-cycle cost indicates low risk and, therefore, relatively low requirements for equipment validation. The color-coded location of the sector for those alternatives that are highly mission- or safety-critical and highly complex with a high life-cycle cost indicates high risk and relatively high validation requirements. The model also indicates potential acquisition problems, such as alternatives that fall into the sector for low complexity and low criticality with high life-cycle costs. Such sectors are color-coded to indicate either a problem with the availability of an appropriate alternative in the marketplace or that the requirements have been poorly defined.

Figure 4 illustrates a fragmented version of the cube that enables better visualization of each sector. This model expands the cube to include sectors based on all four definitions of complexity.

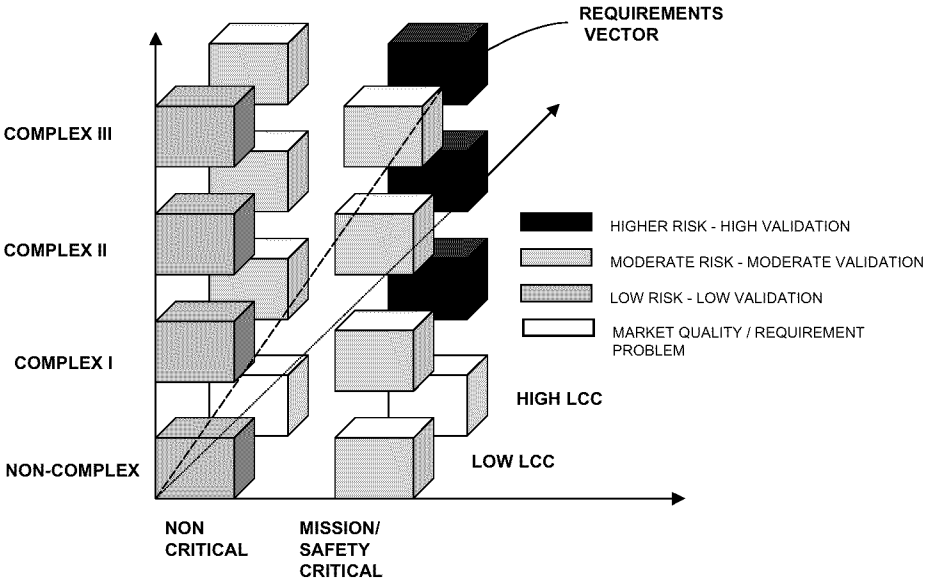

Figure 4. Degree of Validation as a Function of Technical Risk - Fragmented Cube
Risk = *f* (mission criticality, technical complexity, LCC)

As an example of the different components and support equipment that comprise a weapon system, Figure 5 is a version of the fragmented cube with various pieces of aircraft support equipment labeled on the appropriate sectors. By using the fragmented cube to visualize an entire weapon system, systems engineers can select the areas that may be most appropriate for COTS equipment to be inserted and/or ensure that the appropriate level of validation occurs when evaluating COTS equipment based on risk.

Acronym List

SETS-standard engine test system
HCTS-hydraulic component test stand
JASU-jet air start unit
ADTS-air data test set
MEPP-mobile electric power plant
AGTS-aircraft generator test stand
NDI-nondestructive inspection equipment
O_2 GEN-oxygen generating cart
MAINT PLAT-maintenance platform

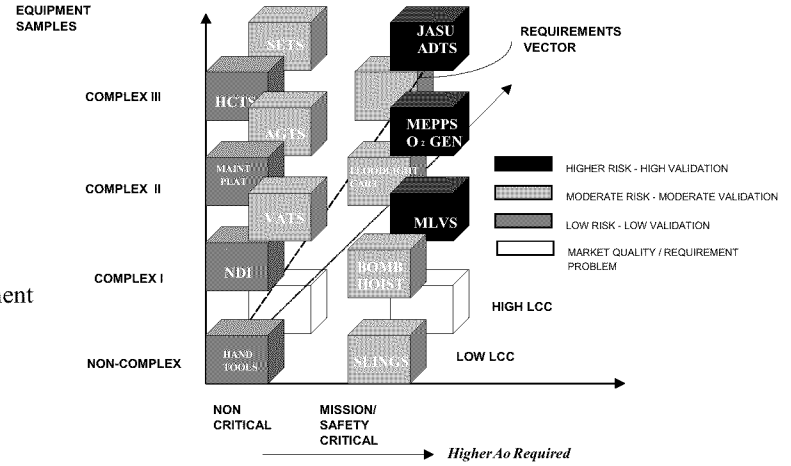

Figure 5. Weapon System Example of Fragmented Cube
Risk = ***f*** (mission criticality, technical complexity, LCC

4.4 The Mitigation of Risk

When assessing COTS alternatives, it is necessary to determine what, if any, performance and environmental degree of reliability and maintainability (R&M) validation and testing are required. Figure 6 shows an example of a logical flow diagram validation strategy for COTS equipment R&M validation decision factors based on criticality and complexity. The goal is not to "overtest" or "undertest" COTS equipment.

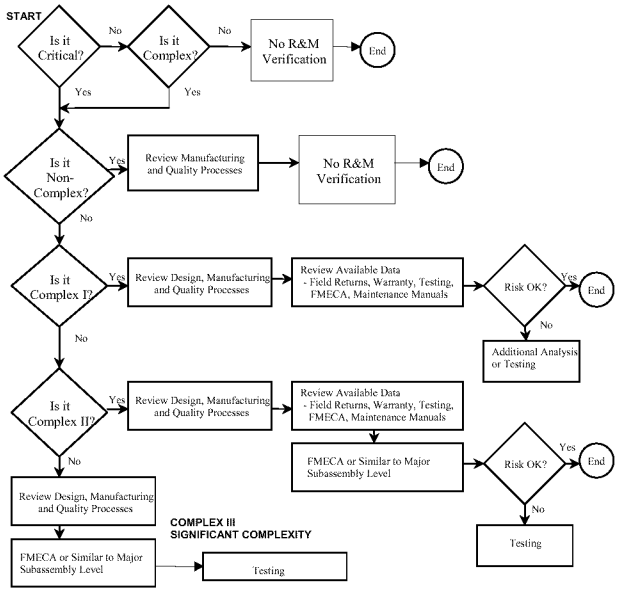

Figure 6. Reliability and Maintainability Validation Strategies
(*Source: Janet L. French, NAVAIR Reliability Engineering)*

Tables 2 and 3 represent the types of commercial equivalent data and equivalent testing that can be used to assess the degree of additional testing or validation that may be required. In each case, a lack of commercial data or testing protocols increases risk and may necessitate full or partial DOD testing of the equipment. The goal is to take advantage of existing data and testing to reduce the cost of required R&M testing and validation.

Table 2. R&M Validation Analysis and Data

Analysis Data Required	Critical & Noncomplex	Complex & Not Critical	Electrical/ Electronic Critical & Complex	Mechanical Critical & Complex	Critical & Complex II	Critical & Complex III
R design practices			✓		✓	✓
R prediction			✓		✓	✓
FMECA			✓	✓	✓	✓
M design practices*			✓		✓	✓
M prediction*			✓		✓	✓

*Maintenance philosophy-dependent

Table 3. R&M Validation Testing

Testing	Critical & Noncomplex	Complex & Not Critical	Electrical/ Electronic Critical & Complex	Mechanical Critical & Complex	Critical & Complex II	Critical & Complex III
ESS			✓		✓	✓
RQT			✓	✓	✓	✓
RD/GT*					As required*	As required*
M demo**			✓	✓	✓	✓

*For systems where several COTS items are integrated.
**Maintenance philosophy dependent

Legend:

R—reliability
FMECA—failure modes effects and criticality analysis
M—maintainability
ESS—environmental stress screening
RQT—reliability qualification testing
RD/GT—reliability development/growth testing

When conducting an R&M risk assessment, the following pertinent questions should be included:

- Has the vendor provided sufficient information to indicate that R&M requirements can be achieved?
- Are there any new or untried technologies or components within the product that have a limited or nonexistent record of reliability performance?
- What techniques does the vendor use to maintain or improve product reliability and quality?
- How does the vendor select subvendors (e.g., qualified lists, lowest cost, etc.)?
- Does the vendor verify component quality?
- Are there any frequent failures that could impact safety or the mission?
- Are there any frequent failures of high-cost items? Hard-to-replace items? Hard-to-maintain items?
- Is the commercial use environment sufficiently similar that the data are indicative of the types of failures likely in the DOD environment?
- Are there any test data and are they verifiable?

Figure 7 illustrates the decision factors related to COTS equipment supportability validation requirements. This analysis shows that open architecture is beneficial to COTS equipment alternatives.

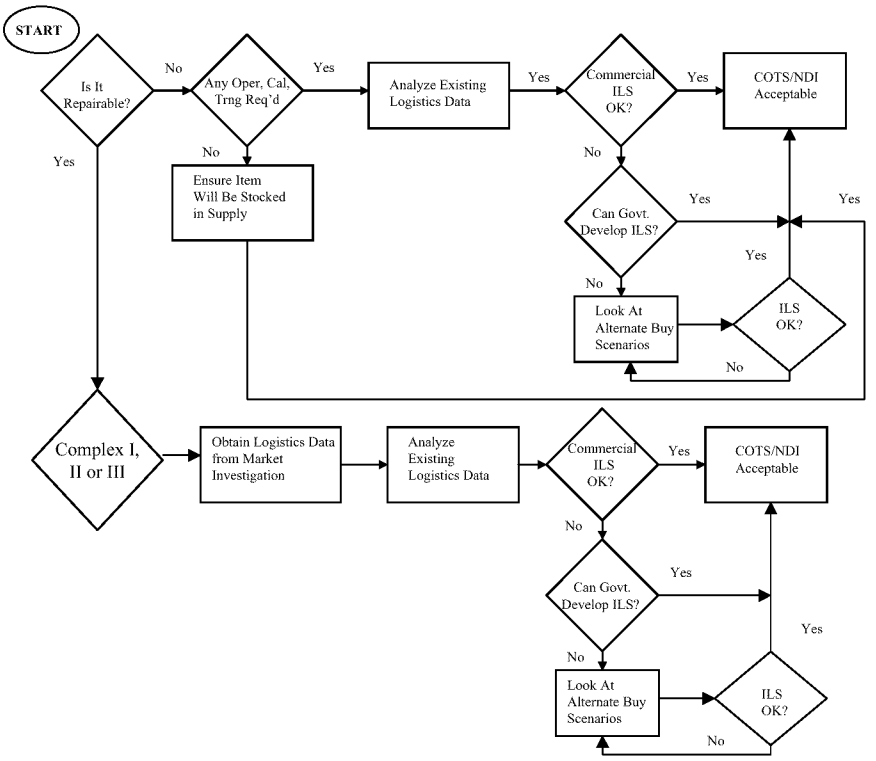

Figure 7. Supportability Validation Strategies
Logistics Validation
(Source: Edward F. Waraksa, NAVAIR Logistics Management)

Various types of commercial data may be available to perform R&M and supportability analyses of COTS alternatives. Table 4 illustrates several key sources.

Similar validation flow diagram strategies must be developed to address performance as well as environmental requirements.

Table 4. Commercial Data Sources Related to Validation of R&M and Supportability

Historical R&M Experience	• Estimates of expected reliability • Warranty provisions • Customer satisfaction indices
Internal Manufacturing Quality Procedures	• Production controls • ISO 9000 or similar techniques • Testing procedures
Vendor or Component Selection Policy	• Parts control methods • Quality control techniques • Testing procedures • Environmental stress screening
Design Approach	• Environmental approach • Part derating procedures • Fault tolerance features • Ruggedization concepts • Built-in test features • Ease-of-maintenance features

In summary (refer to Figure 1), the Risk-Based COTS Systems Engineering Assessment Model components can be summarized as the following steps - beginning with the mission need, requirements definition and analysis, market research and identification of COTS solutions, use of the fragmented cube and validation flow charts to assess and reduce risk and, finally, providing input for procurement.

5.0 CONCLUSIONS

In summary, the DOD's increasing reliance on advanced technology, such as electronics, dramatically increases the cost of developing weapon systems, as well as the operational cost of redesigning and upgrading these systems as technologies change. To avoid some of these costs, the DOD must take advantage of industry's ability to bring components and systems to market faster than the DOD can develop them. It is important to weigh the risks of COTS technology over the life cycle of the system and insert these commercial technologies where the risks and benefits are prudent. Without proper management, COTS can be a drawback as a result of poorly defined risk—such as the likelihood of performance and cost risks as well as parts obsolescence in the field. The Risk-Based COTS Systems Engineering Assessment Model serves to define such risks and helps systems engineers make informed decisions.

The Risk-Based COTS Systems Engineering Assessment Model provides a common framework for making COTS technology decisions by assessing the relative risk of each COTS alternative. It also provides assistance in determining the appropriate degree of validation required to verify that a COTS alternative can be transferred to the military environment.

To take advantage of COTS technology and better apply the model, the systems engineering community needs the following:

- Better requirements analysis tools that incorporate risk.
- Better industry information (i.e., life-cycle cost data, time until market release/update data, and supportability data.
- Better market surveillance and segmentation (i.e., systems engineers must become cognizant of market factors and sectors for different technologies).
- Better system of open architecture standards in the marketplace (e.g., electronic and mechanical standards that incorporate open architecture).
- Better assessment tools that are standardized and used by all NATO military organizations.

The Risk-Based COTS Systems Engineering Assessment Model offers important benefits and insight to the overall weapon system acquisition management process. It should be noted that significant work must still be invested to make the application more efficient, such as refining the functional interrelationship between complexity, mission, and cost. The need to further optimize the model is necessary if better fidelity is desired. Integrating and automating the complexity criteria with mission criticality and cost analysis is the ideal formula for concurrent engineering analysis, which when applied improves the chances of selecting effective commercial equipment. Automating and combining the model can significantly improve implementation and accelerate the transfer of commercial technology in a synergistic manner.

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