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Evaluation of COTS Hardware Assemblies

for use in Risk Averse, Cost Constrained Space-based Systems

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Overview

- Introduction to COTS
- Challenges associated with COTS usage
- Framework for evaluating usage of COTS
- Example evaluation
- Lessons learned

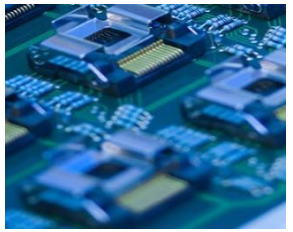
What is COTS?

- COTS = Commercial Off the Shelf
- Comes in many forms
  - Software
  - Assemblies
  - Small components (fasteners, rivets, resistors)

Scope of this paper is COTS Assemblies

http://aegispower.com/index.php/main

https://bluecanyontech.com/static/datasheet/BCT_DataSheet_Components_StarTrackers.pdf



https://wpo-altertechnology.com/cots-commercial-off-shelf/

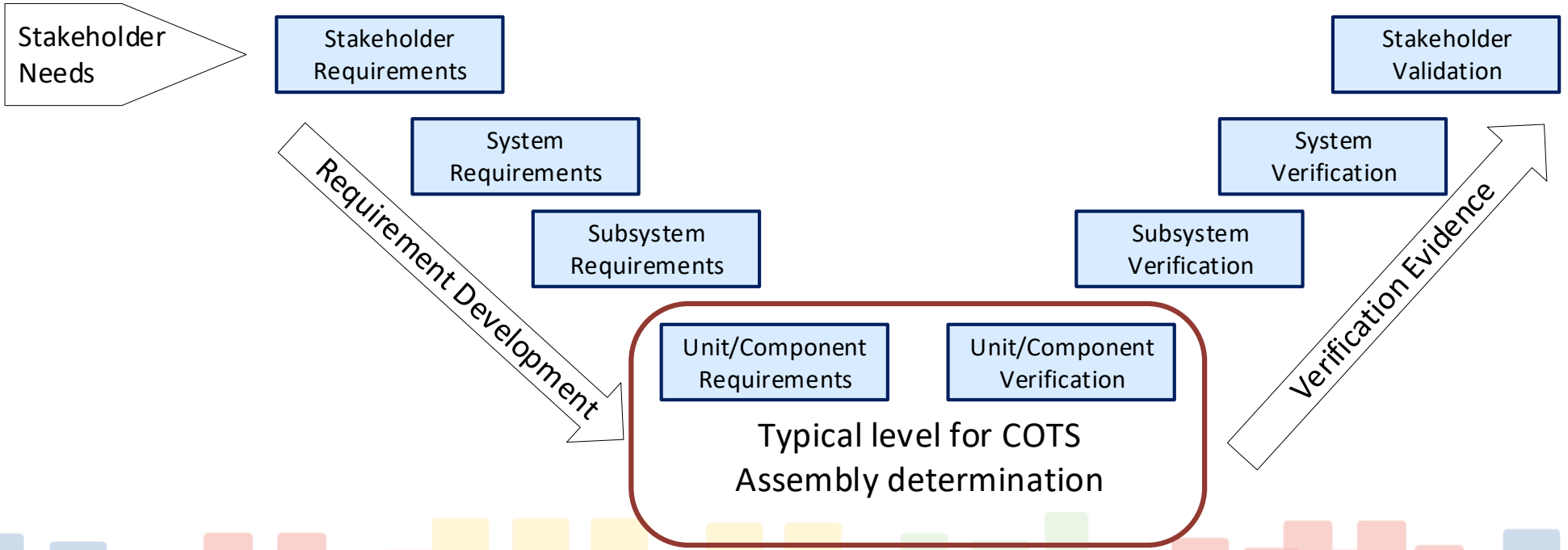
http://www.criterialabs.com/pems-rf-parts-upscreening-to-nasa-eee-inst-002-l1-l2/

https://militaryethernet.com/products/

https://www.slideshare.net/JosiahRenaudin/testing-in-the-new-world-of-offtheshelf-software

Why use COTS?

- During the architecture and design definition phase a project may assess use of existing products against effort of developing a new product.
  - This is part of a “make vs. buy” trade, where the buy is an existing product (COTS) compared to paying a company to develop the product.
- Usage of COTS can save on development costs and schedule.
- Determination of COTS benefit is typically done with a trade that leverages heritage of the product and supplier.



Aerospace Challenges of Using COTS

- Aerospace space-based systems can vary!
- Government funded programs often have a risk averse customer that expects specific documentation for verification of the products being provided.
- New industry trends have utilized a more commercial approach with traditionally risk averse customers (DoD, NASA, other…), some of these still expect specific verification documentation based on safety concerns.
  - Example: NASA's Commercial Crew Program
- Challenges exist when the customer still expects the high amount of verification documentation on a commercial program, particularly as COTS products are limited in available data.

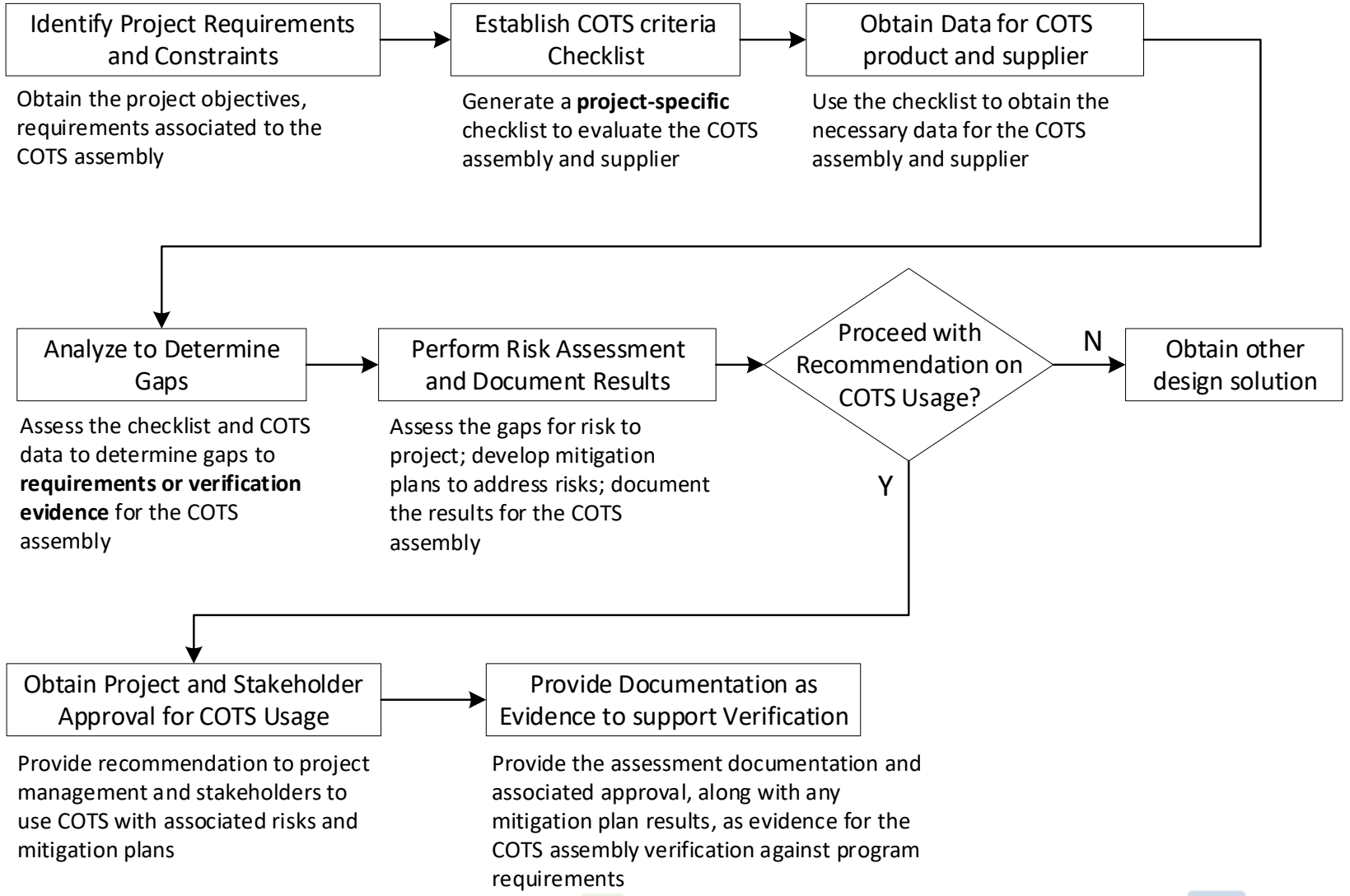
Existing COTS Evaluation Processes

- Prior to implementing this effort research was conducted to find existing processes which could be used to guide a program team in evaluation of COTS assemblies.
- None of the existing frameworks provided a complete assessment and ability to show verification records for COTS hardware assemblies.

Existing COTS Evaluation Framework	Evaluation Process
Overndorf, et al, An Activity Framework for COTS-Based Systems [1]	Discussed that the usage of COTS is an act of reconciliation identifying what is wanted and comparing with what is available.
Ferris, et al, The Impact of Understanding the Need and Available Products in COTS Selection [2]	Addressed issues associated with the selection of COTS assemblies, recommending parameters of interest for use in evaluating the potential of COTS subsystems.
Albert, et al, Evolutionary Process for Integrating COTS-Based Systems (EPIC): An Overview [3]	Presented a method to evaluate software COTS using the COTS in the final software solution and assessing results.
Carney, et al, Identifying Commercial Off-the-Shelf (COTS) Product Risks: The COTS Usage Risk Evaluation [4]	Presented a method to evaluate software COTS by addressing the stakeholder's needs and ensuring the resultant usage was assessed against the needs.

Proposed COTS Evaluation Approach

- A proposed approach has been generated that leverages prior research and allows for customization by a project.
- Results of this approach include documented risk mitigations and records useable in product verification.

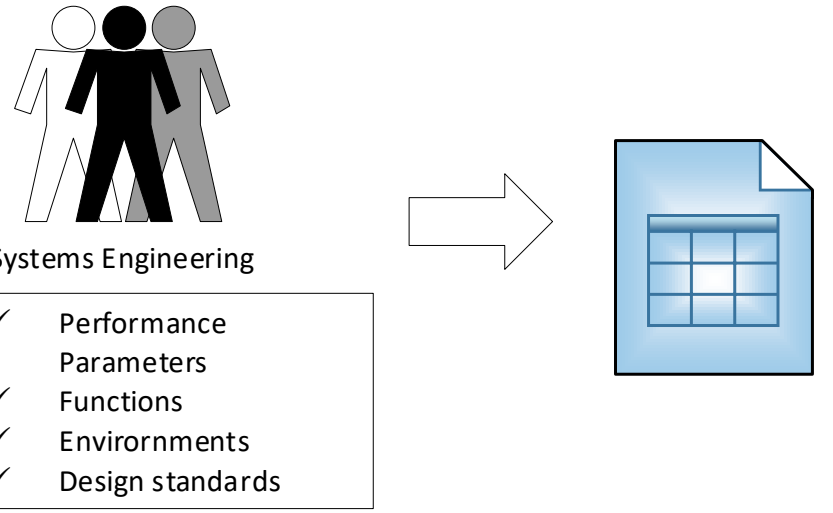


COTS Evaluation Approach Steps

1. Identify Project Requirements and Constraints
2. Create criteria for the project (checklist)
3. Obtain Data for COTS product and supplier
4. Analyze to Determine Gaps
5. Perform Risk Assessment and Document Results
6. Make Decision on Whether to Proceed with Recommendation of COTS Usage
7. Obtain Project and Stakeholder Approval for COTS Usage
8. Provide Documentation as Evidence to support Verification

Step 1 – Identify Requirements / Constraints

- Many parameters needed by the COTS item can be collected summarized by the systems engineers, including:
  - Performance parameters and Functions needed
  - Operational Environments
  - Non-functional design and quality requirements
  - Mission assurance process requirements
- Additionally, constraints may exist for both technical (interfaces) and programmatic (risk posture, reliability, safety criticality) which can also be provided.
- The project team collects this information to be used as a basis for risk assessments and understanding of expected verification data required for the product (formats can vary)



Step 2 – Develop a COTS Evaluation Checklist

- Once the project requirements and constraints are identified, a checklist of specific parameters can be developed (example shown on next slide).
- This checklist is an aid for evaluation of different COTS solutions to address specific criteria for the project.
- Subject areas to consider for the checklist include (but not limited to):
  - design data (performance, environments, part and material data, Interfaces)
  - heritage of use
  - fabrication processes
  - test program and data
  - security vulnerability
  - plans for product upgrade or obsolescence
  - past product failures
  - post-delivery support for product

Example Checklist

- The checklist includes the assessment of critical parameters needed to ensure the COTS satisfies program requirements
- Because this checklist simplifies the resultant verification data it will likely need to be agreed-to with customer and other program stakeholders prior to usage

Criteria	Concern / Rationale for Evaluation
Design Assessment	
Are the stated characteristics and performance data adequate for the application of use?	Ensures product meets basic need of project.
Environments – can the item survive the predicted environments; does it meet the program minimums for workmanship? (Thermal, Vibration, Shock, Radiation, Pressure)	Environmental parameters can impact functionality, performance; Establish if the design is qualified to the environment provided.
Hardware, Firmware and Software meet customer information assurance requirements.	Provides indication of security vulnerability.
Fabrication and Product Control Assessment	
Review the manufacturer's fabrication process and history as well as GIDEPs and ALERTs.	Provides indication of the quality of the manufacturer's process.
Configuration control maintained for all manufactured product	Ensures ability to trace changes of product to provide association to any past performance and variability of product
Source of components comply with requirements for supply chain.	Mitigates against counterfeit parts and prohibited suppliers.
Test	
Define the manufacturer's approach to testability of the item.	Ensure that the item testing is consistent with higher level needs and that the design includes appropriate test interfaces to the boards, modules or other areas required for integrated testing.
Inspection and Packaging, delivery and storage	
Are there any special inspection requirements upon receipt of product?	Determines need to coordinate with Quality Engineering and receiving organization related to COTS product.
Are there any special storage requirements for the item? Can performance of the item degrade over time or require recalibration?	As a unique piece of hardware, the COTS items need to be evaluated for early lifecycle degradation and periodic retest of spares because of limited traceability and unknown reliability.
Previous use and space heritage (characterization data)	
Determine if the item has been space qualified or characterized for use in space on previous programs.	Provide data as to heritage and how it applies to this application. If the selected COTS product is based on use in similar or previous system(s), then ensure product meets quality characteristic requirements for new application.
Higher Assembly Access (consideration for project design team)	
How readily can the COTS item be replaced or repaired once installed in the system?	If the item is not accessible for replacement or repair, or if the item could be a critical single point failure, then alternatives may need to be considered (*e.g.*, redundancy, placement of the hardware).

Step 3 – Obtain COTS Data

- Assessment of the COTS solution uses information about the COTS assembly and the COTS supplier themselves.
- COTS suppliers typically provide datasheets for public usage.
- Conversations with the suppliers may also yield additional data, and in some cases the supplier may be willing to support providing data towards the evaluation checklist.
- For some suppliers this is additional scope; they may either not provide this information, or provide at a substantial increase in cost.
- Any missing data is a risk and assessed accordingly.

COTS Available Data

Product X Datasheet:	
Envelope	12 inches x 24 inches x 13 inches
Mass	< 25 lb
Operating Life	> 10 years
Qualified Orbit	Low Earth Orbit
Temperature Range	-50 deg F to 100 deg F operational -60 deg F to 120 deg F non-operational
Vibration	Qualified to Expendable Launch Vehicle levels
EEE Parts	Q or V-Level parts with full EEE parts traceability
Data Interface	MIL-STD-1553, RS-422 option
Input Voltage Range	24 V to 52 V
Power Consumption	< 10 W
Performance Parameter X	[data]
Performance Parameter Y	[data]

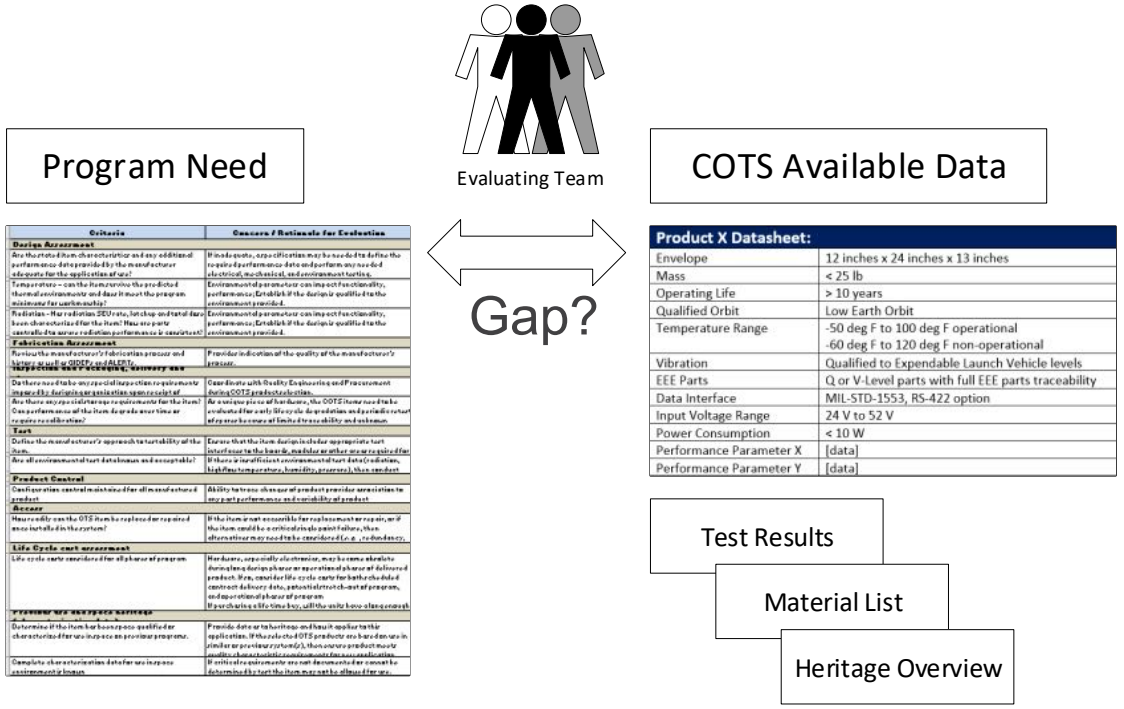
Test Results

Material List

Heritage Overview

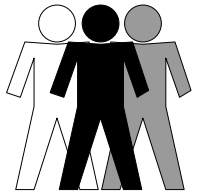
Step 4 – Analyze to Determine Gaps

- The project team compares the requirements and constraints against the COTS data to identify any gaps.
- Areas where the COTS product is either not meeting the project criteria, or the data is missing, are identified.
- For identified gaps, a trace to customer requirements identifies whether the customer will need to be included in any subsequent approvals towards the COTS usage.

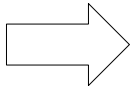


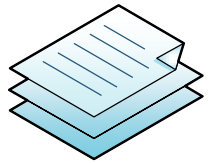
Step 5 – Perform Risk Assessment and Document the Results

- The project team performs a risk assessment for the parameters that do not meet the project requirements or processes.
- For the identified gaps, evaluations of mitigation options assess if the gaps can be reduced using techniques such as:
  - system design solutions by the project (isolators, etc.)
  - additional qualification tests by the supplier or project
  - additional analyses or inspections
- The results are captured into a report for the COTS assembly that shows the assessment of the COTS assembly against the requirements and any identified risks and mitigation plans.
- The amount of effort put into this assessment is a function of the risk profile of the project.



Evaluating Team

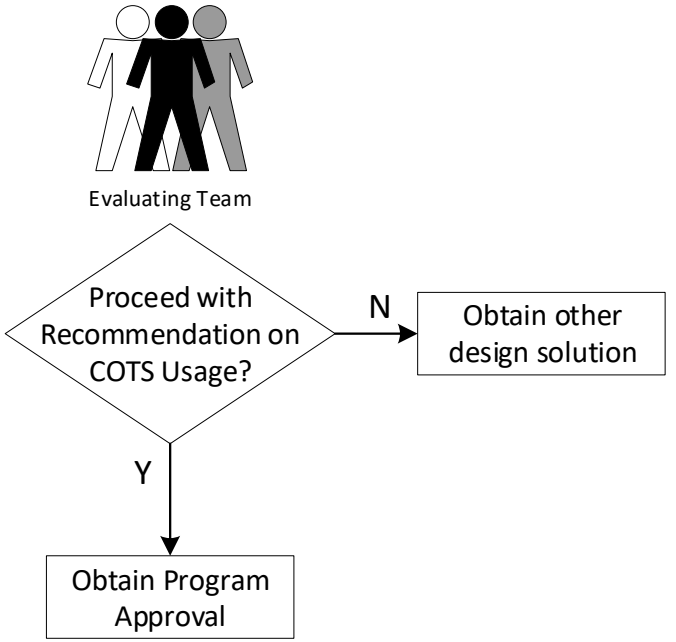




- ✓ Provide results of checklist
- ✓ Identify gaps to requirements
- ✓ Document any recommendations to close gaps (ex. recommend addition of Qualification Vibration Test)

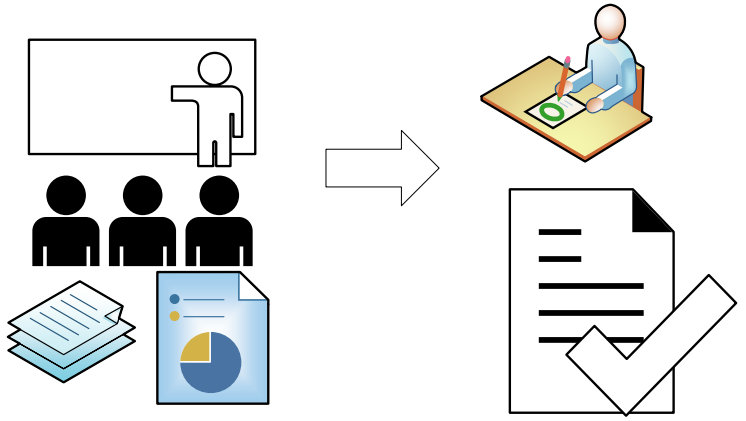
Step 6 – Recommendation of COTS Usage

- The project technical team determines if the COTS assembly is a fit for the project, forming a recommendation whether to proceed with the COTS.
- This consists of a trade study to ensure all parameters are evaluated against other options (e.g. developing a custom assembly, subcontracting with a supplier for unit development, or purchasing a different COTS product).
- Decision to proceed will lead to a more formal program acceptance of the product.



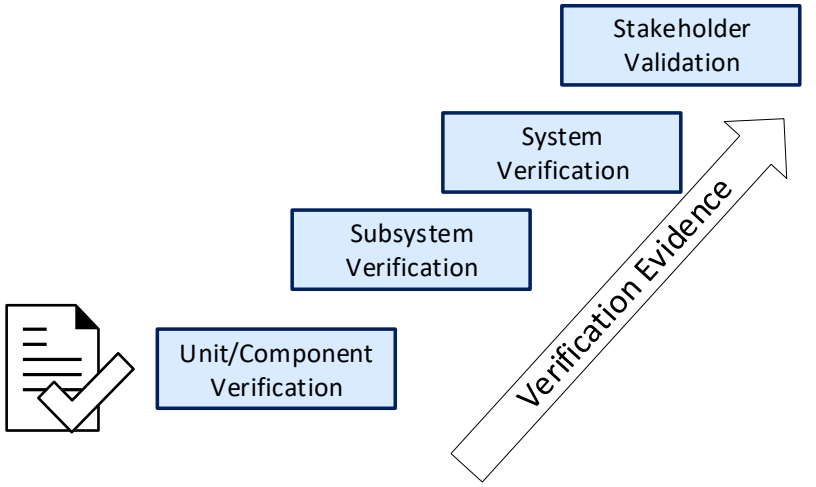
Step 7 – Obtain Project and Stakeholder Approval for COTS Usage

- Approval for the decision to use COTS will depend on the project, but at a minimum involves personnel with authority to accept any residual project risk or costs associated with the mitigation plans, such as a program review board.
- For projects with risk averse customers that require insight or oversight this may go to a customer review board for formal acceptance to ensure resultant verification evidence or requirement gaps are accepted.

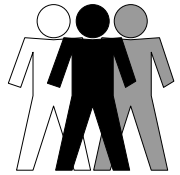


Step 8 – Provide Documentation as Verification Evidence

- Upon approval for usage of the COTS assembly, the assessment report serves as record for the evaluation effort for the COTS hardware assembly usage.
- This report, along with evidence obtained from any mitigation plans, serves as the verification evidence for the COTS assembly against the project requirements.

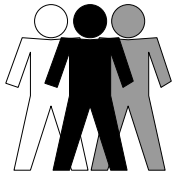


Example Evaluation



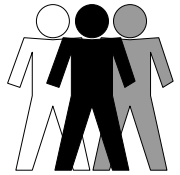
Systems Engineer

- ✓ Identifies non-mission critical classification
- ✓ Identifies NASA-STD-6016 M&P requirements needed



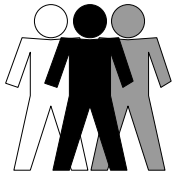
Systems Engineer

- ✓ Adds need for material list to COTS checklist



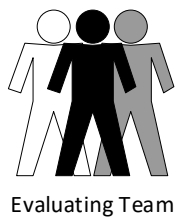
Responsible Engineer

- ✓ Obtains material list from COTS supplier



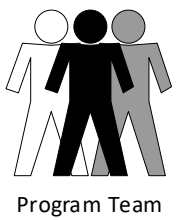
M&P Engineer

- ✓ Reviews Material List to assess for prohibited items, flammability, off-gassing, outgassing, compatibility with application of use
- ✓ Discusses risks with customer counterpart
- ✓ Provides recommendation of compliance and risk

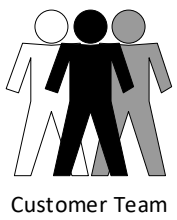


Evaluating Team

- ✓ Obtains and documents the M&P recommendation
- ✓ Identifies gap to full verification of all NASA-STD-6016 requirements
- ✓ Collects assessments on other requirement topics
- ✓ Recommends COTS usage to program and customer

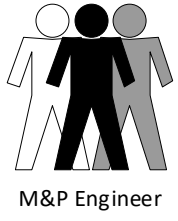


Program Team



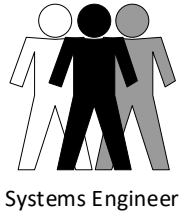
Customer Team

- ✓ Agrees to COTS Usage



M&P Engineer

- ✓ Generates Material Usage Agreement with Customer for COTS materials



Systems Engineer

- ✓ Provides assessment report and MUA as verification towards NASA-STD-6016 requirement

An example of the application of the COTS framework is shown through evaluation of a specific set of material and process (M&P) requirements on a project.

The resultant effort would reduce a 200 requirement standard to a material list request and evaluation of a handful of parameters by a subject matter expert.

Lessons Learned

- While applying this to the author's program a few items were observed:
  - The engineering staff required training to understand the concept of meeting intent of requirements and addressing associated risk, this was a new paradigm for them as they were previously conditioned to ensure every individual requirement shows verification evidence.
  - The checklist needed a few iterations to ensure it was complete and singular; time was spent after the first few evaluations to adjust the checklist for use on subsequent evaluation efforts.
  - Systems engineering needed to identify and communicate the full program list of COTS assemblies and their evaluation process (became an SE oversight function).
  - Safety and Mission Criticality of the COTS assemblies is a key factor in the evaluation.
  - COTS piece-part and COTS assemblies can vary in what evaluation process and which stakeholder approval is required; Having both types of processes defined and communicated was key to addressing this confusion.

References

1. Overndorf, T, Brownsword, L, Sledge, CA 2000, An Activity Framework for COTS-Based Systems, CMU/SEI-2000-TR-010 addressed the
2. Ferris, TLJ, Do, Q 2010, The Impact of Understanding the Need and Available Products in COTS Selection, INCOSE IS 2010
3. Albert, C, Brownsword, L 2002, Evolutionary Process for Integrating COTS-Based Systems (EPIC): An Overview
4. Carney, DJ, Morris, EJ, Place PRH 2003, Identifying Commercial Off-the-Shelf (COTS) Product Risks: The COTS Usage Risk Evaluation, CMU/SEI-2003-TR-023

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