Systems Engineering Processes Applied To Ground Vehicle Integration at US Army Tank Automotive Research, Development, and Engineering Center (TARDEC)

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## 1. REPORT DATE
19 AUG 2010

## 2. REPORT TYPE
N/A

## 3. DATES COVERED
-

## 4. TITLE AND SUBTITLE
Systems Engineering Processes Applied To Ground Vehicle Integration at US Army Tank Automotive Research, Development, and Engineering Center (TARDEC)

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## 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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## 8. PERFORMING ORGANIZATION REPORT NUMBER
21065

## 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

## 10. SPONSOR/MONITOR’S ACRONYM(S)
TACOM/TARDEC

## 11. SPONSOR/MONITOR’S REPORT NUMBER(S)
21065

## 12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

## 13. SUPPLEMENTARY NOTES
Presented at NDIAs Ground Vehicle Systems Engineering and Technology Symposium (GVSETS), 17 22 August 2009,Troy, Michigan, USA, The original document contains color images.

## 14. ABSTRACT

## 15. SUBJECT TERMS

## 16. SECURITY CLASSIFICATION OF:
a. REPORT unclassified
b. ABSTRACT unclassified
c. THIS PAGE unclassified

## 17. LIMITATION OF ABSTRACT SAR

## 18. NUMBER OF PAGES 20

## 19. NAME OF RESPONSIBLE PERSON

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*Standard Form 298 (Rev. 8-98)*

Prescribed by ANSI Std Z39-18
Mission:

CGVDI provides the Department of Defense a single project management office that coordinates activities across RDECOM and DoD to conduct the complete spectrum of activities required for design, development, fabrication, integration and testing of ground systems (manned or unmanned) from engineering changes to technology/capability insertion to full system prototypes in order to meet the needs of the warfighter.
Description

- Leverages RDECOM and DoD capabilities in a repeatable process to apply rigorous systems engineering to ground systems integration
- Provides customer partners a single entry point for cost, schedule, performance and risk management of system integration projects

Notable Recent Accomplishments

- MRAP Capability Insertion for Caiman, MaxxPro, RG-31 and RG-33 Systems
- Command and Control on the Move (Stryker and MRAP Integrations)
- Robotic Deployment System

Employs TARDEC organic Concepts, Analysis, System Simulation and Integration (CASSI), System Engineering (SE), and significant contributions from other RDECs and Organizations

CGVDI Projects (active):
- MRAP Capability Insertion
- C2OTM* – MRAP
- C2OTM* – Stryker
- LAV-R Upgrade
- RS-JPO
- PM-AMS

*Command & Control On The Move

MRAP Capability Insertion
- Vanguard
  — CROWS II Remote Weapon Station
  — Boomerang
  — Double Shot
- LRAS3
- Check 6 Camera
- OGPK Overhead Protection
- Overhead Wire Mitigation
- IBIS TEK Lights
- RPG Protection
- Power Upgrade (derived requirement)
- C4I Architecture (derived requirement)
- Thrown Object Protection System
CGVDI combines TARDEC’s Ground Vehicle Integration Center and Prototype Integration Facility to create an improved, integrated capability.
CGVDI Projects

- **Initial MRAP CI Scope**: Capability Insertion System Integration for Caiman, MaxxPro, RG-31, and RG-33
  - System Development & Integration
  - Analyses
  - Installation Manuals
  - VAL/VER Kit
  - Spare Parts
  - Initial Production
  - Level III TDP

- **New MRAP Scope**
  - MaxxPro Dash CI
  - MATV CP 11-12
  - Caiman Ambulance

- **Other Significant Efforts**
  - Command & Control On The Move (C2OTM)
    - Caiman
    - Stryker
    - MATV
  - LAV-R Upgrade
  - Robotic Deployment System
  - MRAP Egress Assistance Trainer
  - Universal Combat Lock Tool
Sample Deliverables

- Updated Architecture Requirement
- Updated Architecture Requirement
- Systems Integration Lab
- Fully Integrated Test Asset
- Fully Integrated Caiman First Unit Equipped Asset

8 Vehicle A Kits for Installation

- 2 Spare Kits
- 1 Validation Kit

Antenna Analysis
Power Analysis
Thermal Analysis
Blast Analysis
HFE Analysis
Safety Analysis

- Level II Drawings
- FSR Level Install-Manuals
- Level III Drawing Package
**Purpose:** To ensure rigorous system engineering principles are applied in a repeatable fashion to all TARDEC System Development & Integration projects.
System Development & Integration Process

SYSTEMS ENGINEERING AND INTEGRATION

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System Integration Process

1.0 Receive & Analyze Capability Request
2.0 Program Definition & Agreement
3.0 Technology & Integration Analysis
4.0 Solution Set Meets Vehicle SWaP constraints?
5.0 Component Development/Maturation
6.0 Prototype Development
7.0 System Meets Customer Expectations?
8.0 Fielding Support

Requirements Review
Integration Review
In-Progress Reviews
Initial & Final Design Reviews
Ship to Test Review

Customer Decision

- JUONs
- CPD
- PM Directed
- MOA
- IMS
- Budget
- Models
- Trade-offs
- Integration Concepts
- Approved Concept
- TRL 6 Components
- Prototype Solution
- Level II Drawings
- Integration Validation
- Level III Drawings
- Test Support

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DEPARTMENT OF DEFENSE SYSTEMS ENGINEERING PROCESS MODEL 2009
- Infused SE Processes Throughout the CGVDI System Development & Integration Process.
- Developed and Documented a Systems Engineering Plan (SEP) to Layout Operating Process.  
  - Form the Basis for Developing Standard Operating Procedures (SOPs).
- Foundation for Planning “What” SE Processes to Implement and “How” to Implement.
Requirements Management Process Implemented to:

- Capture Project Requirements
- Organize Project Requirements
- Analyze Project Requirements
- Trace Project Requirements

Requirements Gathering From Sources Such As:

- Project Statement of Work
- Customer Input/Documents
- System Requirements
- Derived Requirements
- Lessons Learned
REQUIREMENTS INFORMATION MODEL

Statement of Work (SOW)

Work Breakdown Structure (WBS)

Plan_Links

Decisions

Decision_links

Architecture

Decision_Architecture_Links

Requirements

- Sources
- VoC
- System

Requirements_Links

Vee-model

Issues

Issue_Links

Issues may be linked to objects in any module

Plan_Links

Test_Links

Allocation_Links

Test_Links

Requirements_Links
- **Requirements Decomposition** – Ensures Requirements are:
  - Singular
  - Concise
  - Unambiguous
  - Verifiable

- **Requirements Traceability** – Provides Confidence in Project Completion (Gap Analysis):
  - All Requirements Are Allocated to Architecture/Solution
  - All Requirements Are Linked to Verification Method
**DECISION ANALYSIS**

- Alternative Solutions Selection
  - Define Criteria
  - Assign Weighting Factors
  - Assign Relative Category Importance (Cost, Schedule, Performance)
### Vehicle Winch Alternative Selection Matrix

| Criteria | Scoring Quantifiers | Weighting Factor (Priority within Category: 1 Low to 10 High) | Normalized Weighting Factor | Option 1 | Option 1 Weighted Score | Option 2 | Option 2 Weighted Score | Option 3 | Option 3 Weighted Score | Option 4 | Option 4 Weighted Score | Option 5 | Option 5 Weighted Score | Option 6 | Option 6 Weighted Score | Option 7 | Option 7 Weighted Score | Option 8 | Option 8 Weighted Score |
|----------|---------------------|-------------------------------------------------------------|-----------------------------|---------|------------------------|---------|------------------------|---------|------------------------|---------|------------------------|---------|------------------------|---------|------------------------|---------|------------------------|
| Performance | 30% | 8 | 0.9362231 | 5 | 0.3232077 | 3 | 0.1975245 | 3 | 0.1213712 |
| Criterias1 | 6 | 0.270523 | 6 | 0.163145 | 5 | 0.124223 | 3 | 0.1075245 | 3 | 0.081245 |
| Criteria2 | 5 | 0.210523 | 6 | 0.124223 | 3 | 0.1075245 | 3 | 0.081245 |
| Criteria3 | 4 | 0.210523 | 6 | 0.124223 | 3 | 0.1075245 | 3 | 0.081245 |
| Criteria4 | 3 | 0.210523 | 6 | 0.124223 | 3 | 0.1075245 | 3 | 0.081245 |
| Criteria5 | 2 | 0.210523 | 6 | 0.124223 | 3 | 0.1075245 | 3 | 0.081245 |
| Criteria6 | 1 | 0.210523 | 6 | 0.124223 | 3 | 0.1075245 | 3 | 0.081245 |
| Criteria7 | 0 | 0.210523 | 6 | 0.124223 | 3 | 0.1075245 | 3 | 0.081245 |
| Sum of Criteria Weighted Scores | 65 | 2.0907592 | 1.2925245 | 1.270245 |
| Sum of Weighed Subtotals | 50% | 2.348456 | 7.3925245 | 7.370245 |
| Cost | 20% | 0.6327586 | 0.225818 | 0.2261459 | 0.1223524 |
| Criterias1 | 8 | 0.830887 | 0.278258 | 0.181582 | 0.278352 |
| Criterias2 | 7 | 0.830887 | 0.278258 | 0.181582 | 0.278352 |
| Criterias3 | 6 | 0.830887 | 0.278258 | 0.181582 | 0.278352 |
| Criterias4 | 5 | 0.830887 | 0.278258 | 0.181582 | 0.278352 |
| Criterias5 | 4 | 0.830887 | 0.278258 | 0.181582 | 0.278352 |
| Criterias6 | 3 | 0.830887 | 0.278258 | 0.181582 | 0.278352 |
| Criterias7 | 2 | 0.830887 | 0.278258 | 0.181582 | 0.278352 |
| Criterias8 | 1 | 0.830887 | 0.278258 | 0.181582 | 0.278352 |
| Criterias9 | 0 | 0.830887 | 0.278258 | 0.181582 | 0.278352 |
| Sum of Weighed Subtotals | 63 | 1.07417 | 0.7324523 | 0.950443 |
| Grand Total | 100% | 1.5403586 | 1.435423 | 1.650543 |

**Total Option Score – Highest Value Chosen**

- Less Formal Implementation (Formal Reviews Reserved for Major Defense Acquisition Programs)

Reviews Include:

- Project Requirements Review
- Project Functional Review
- Integration Review
- Initial Design Review
- Final Design Review
- Risk Management Reviews
- Stakeholder Integrated System Review
- Functional Verification Audit

Entry/Exit Criteria Used To Determine Outcome (Pass, Fail, Pass with Follow-Up).
Project Risks Continuously Evaluated In Areas Such As:

- Performance
- Cost
- Schedule

RISK MANAGEMENT TOOL

SYSTEMS ENGINEERING AND INTEGRATION
The Systems Engineering Revitalization In the Department Of Defense is Gaining Momentum At TARDEC Through the Systems Engineering Group’s Effort.

The Center For Ground Vehicle Development And Integration’s System Development And Integration Process Has Become An Excellent Implementation Of The Systems Engineering Process Model.