U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – AVIATION & MISSILE CENTER

Architecture Centric Virtual Integration Process (ACVIP)
From Joint Multi-Role S&T to Future Vertical Lift

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AGENDA

• The Challenges with Embedded Computing Systems Integration
• Architecture Centric Virtual Integration Process (ACVIP) Defined
• ACVIP Workflow
• Joint Multi-Role Missions Systems Architecture Demonstration (JMR MSAD) S&T
• Future Vertical Lift (FVL) Transitioning and Application
• Future Capabilities
• Summary
• Questions
  – (Backup Charts)
The Challenges with Embedded Computing System Integration
ACVIP significantly reduces risk in embedded software / hardware integration, and increase likelihood of delivering full capabilities on schedule and within budget.

Platforms rely on software to deliver 90% of capabilities, but:
- 80% of problems are discovered during integration phases
- 70% of system dev cost is software. 70% of software development is rework.
- Software rework is HALF of total aircraft system development cost … and it’s growing

Substantial negative impact on Warfighter capability:
- Schedule delays (> 3 years) lead to cost overruns, reduced capabilities (e.g., F-35, B787, …)
- Programs cancelled due in part from software challenges –
  - Comanche, ARH, UH-60M Upgrade, Crusader, Future Combat Vehicle, Navy CG(X), USMC Expeditionary Fighting Vehicle, JTRS, Future Combat Systems, etc.

ACVIP directly addresses the software / hardware integration problem:
- Analyzes embedded sw/hw models during design to virtually identify interaction issues
- Meets DoD Digital Engineering Strategy and supports ACWG MOSA Initiative
- ACVIP is contained as a requirement in the Army’s MOSA ICRD and in FVL Arch Framework (FAF)
GROWTH IN AVIATION SOFTWARE DRIVES CAPABILITIES

Estimated Onboard Software Lines of Code (SLOC) Growth (in Natural Log form)

- F-35 2020 Update – $80B
- 5 years SW Int regressions
- Software as % of total system development cost:
  - 1997: 45%, 2010: 70%, 2024: 88%
- Projects a limit of affordability at 27.5M SLOC or $10B in software costs

- Airbus
- Boeing
- Air Force Fighter
- Army Rotorcraft

- Affordability limit
- Unaffordable projection
- Straight line curve fit

Transformational impact if solved

Limiting SW capability directly impacts strategic capabilities on weapon systems. Affordability problem is getting worse. Leadership is key.
ACVIP ANALYSIS FINDS INTEGRATION PROBLEMS EARLY, WHEN LEAST EXPENSIVE TO FIX

Goal: Find faults earlier through virtual integration, when significantly cheaper to fix
ACVIP Defined and Its Workflow
ACVIP FOCUSES ON REAL-TIME EMBEDDED SYSTEMS

- Analyzes software-controlled architectures to discover system level problems early
- Supports Digital Engineering, Model-based DevOps, and MOSA
- Tools matured from Army, DARPA, NASA, Navy, OSD, AF and SOCOM investments

Features of ACVIP:
- Integrated, semantic-based model of the embedded system
- Standardized model representation supports multi-vendor developments.
- Multiple analysis domains (i.e. safety, security, resources, performance) that impact architecture and integration

ACVIP addresses the interaction between three elements of embedded computing systems.
ACVIP fills the gap by providing virtual integration and then accelerates to spec to physical integration.
JOINT MULTI ROLE (JMR) MISSION SYSTEMS ARCHITECTURE DEMONSTRATION (MSAD) SCIENCE & TECHNOLOGY (S&T) & FUTURE VERTICAL LIFT (FVL) PROGRAMS OF RECORD
• Open Systems Architecture (OSA) using Modular Open Systems Approach (MOSA) and Open Standards (e.g., FACE, HOST)
  – Reduce development schedule and total life-cycle cost
    • Efficient (timely & cost effective) system modification
    • Integration/Interoperability/Adaptability
  – Competitive forces
    • Leverage commercial investment
    • Overmatch/Mitigate technology obsolescence
    • Mitigate risk of vendor lock

• Model Based Engineering (MBE)
  – Model-based specification and acquisition (using FACE and SysML)
  – Model-based analysis
    • Architecture Centric Virtual Integration Process (ACVIP)
      – *Early analytical detection of defects and integration issues*
      – Compositional, incremental and formal analyses
      – *FACE to AADL & SysML to AADL Bridges*
    • System Theoretic Process Analysis (STPA)
      – *Treats Safety & Security as a control and component interaction problem*
  – Enhanced productivity, quality and improved communications
  – Authoritative source of truth (ASoT) Requirements Study
**JMR MSAD DEMO SCHEDULE**

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**JCA Demo / ACVIP Shadow**

*ACVIP Related Tasks*
- Scope limited to single component
- Model Based Acquisition
- ACVIP/AADL Modeling / Analysis
- JCA Model Refinement
- Lab Integration / Testing
- Report Generation
- Process Refinement
- STPA Study on FVL CONOPs

**Architecture Implementation Process Demonstrations (AIPD)**

- **Approach**
  - Government defined areas of emphasis and goals related to JCA, FACE™, ACVIP and MBE in general
  - Efforts provided “evidence” of ability to meet USG business and process goals and are relevant to industry and Army aviation PM plans
  - Model exchange and analysis and tools exercised
  - Generated several lessons learned

**Mission Systems Architecture Capstone Demonstration**

- **Approach**
  - Implementation of a partial, notional mission systems architecture
  - Multiple roles (Architect, JCA Product Developer, Mission System Integrators)
  - Model Based Acquisition
  - ACVIP Modeling / Analysis and STPA Analysis
  - JCA / FACE Validation
  - Scope of implementation limited by available resources (i.e. design only, limited lab implementation / test, etc.)

JMR MSAD was an Army Science & Technology Program of increasingly complex software integration demonstrations.
MSIs all experienced a degree of success using ACVIP

• “ACVIP provides a powerful risk reduction methodology/mechanism if properly utilized”
• Early training necessary to understand breadth and scope of available modeling & analysis resources as well as effective tool integration (e.g., FACE, SysML, and AADL tools)
• Tool maturity has improved substantially since AIPD
• While most usage was during integration, the experience gained will improve outcome when applied earlier
• To realize full ACVIP value, must emphasize life cycle approach to analysis. Low fidelity models may have only budgets and estimates, but analysis should start there and undergo refinements – models and analysis in parallel – to validate requirements, architecture and design
• Much of the integration was manually performed and subjected to restricted schedule, which limited breadth of ACVIP use on Capstone
RESULTING ACVIP GUIDANCE & TOOLS

AADL Based Tools Available for Capstone Demo
- Open Source AADL Tool Environment (OSATE)
- AADL Template for Analysis Requirements
- Architecture Led Integrated System Assurance (ALISA)
- Architecture Topology Analysis
- ARINC 653 Analysis & Generation Tools
- Behavior Analysis
- Computer Resource Analysis
- Continuous Virtual Integration Test
- Functional Integration Analysis
- Model Based Testing
- Security Analysis (MILS, RMF)
- Safety Analysis Support (MIL-STD-882, SAE ARP 4761 & STPA)
- Structural, Compositional and Formal Method Analyses
- System of Systems Simulation
- Translators and Translation Guidance (FACE-AADL, SysML-AADL)
- Timing, Latency and Scheduling Analysis

Plus new tools from multiple Sources:
- SBIRs
- DARPA
- Europe
- etc..

ACVIP/AADL Handbooks, Papers, Training and Texts

ACVIP guidance and tools have been exercised, evaluated and matured on JMR MSAD to support legacy and future aviation systems

Training
- www.sei.cmu.edu/education-outreach/courses/course.cfm?courseCode=V40
ACVIP IS INTEGRATED INTO FVL ARCHITECTURE FRAMEWORK (FAF) WITH GUIDANCE

The FAF Architecture Analysis approach delivers independently managed but integrated set of models and documents based on the FAF model management plan.

ASoT Linked FAF Verification Process Assets

- FAF Models verification methods
- FAF Requirements
- Cross links Profiles, Documentation and Templates
- Integrated Embedded System ACVIP process, tools, analyses
- Analysis Results Integration Approach
- Acquisition Process Alignment Approach
- Iterative Analysis Approach
- ACVIP Requirements, BPMN, Guidance
- AADL Profiles

ASoT- Integrated Iterative Analysis across all models

System Architecture Requirements

AADL = Architecture Analysis & Design Language
ACVIP = Architecture Centric Virtual Integration Process
ASoT = Authoritative Source of Truth
FAF = Future Vertical Lift Architecture Framework
FACE = Future Airborne Capability Environment
MBSE & ACVIP is Being Applied to FVL

Controlling and reducing software/system integration risk is a key objective for Army Aviation. AADL/ACVIP will be used to directly address this issue.
DEMONSTRATIONS OF FUTURE CAPABILITIES IN RESEARCH
All too often architectures are modeled early in the engineering processes to be set aside and not leveraged to support design activities.

From “AADL for DoD” by Ray Richards, I2O given at AADL Demo Day in DC, Nov 2019
ACVIP Supports ModDevOps

- Predictive Modeling as a complement to DevOps
- Capture architecture, perform early integration analysis and synthesize middleware, leverage trusted build and execution infrastructure

SEI Research with Demo Exists Regarding TwinOps
(see https://resources.sei.cmu.edu/library/asset-view.cfm?assetid=651118)
SUMMARY OF ACVIP

- **Reduces program risk** in embedded software-hardware integration with aim of reducing schedule and cost in light of growth in software

- **Involves the modeling and analysis of embedded system** leveraging a uniform portable international standard language supporting third party change and lifecycle upgrades

- **Complements MBSE** and works with many model representations, analyses and tools in current lifecycle workflow

- **Developed, exercised and matured** in S&T

- **Ready for transition** to programs of record to use with assets and requirements available

- **Future advances in ACVIP application are already being demonstrated** in the areas of Cyber-Assured Systems Engineering and ModDevSecOps in highly automated rapid approaches with formal assurance

**ACVIP is ready to apply to reduce integration risks in embedded cyber-physical systems. Further S&T research needed in cutting edge areas.**
Questions?
BACKUP CHARTS
ACQUISITION PROGRAM REQUIREMENTS FOR ACVIP

1) Determine scope of ACVIP for an acquisition
   <REQM-1> The program shall assess the ACVIP scope of the acquisition and (1) identify the analyses that are required, (2) when the analysis results are to be provided, and (3) the contract deliverables (CDRLs).

2) Document ACVIP scope in the ACVIP Plan (RFP Attachment)
   <REQM-2> The program shall document the ACVIP scope in an acquisition artifact, the ACVIP Plan.

3) Incorporate ACVIP contract language into acquisition artifacts to require the contractor to perform ACVIP
   <REQM-3> The program shall include the ACVIP analyses as part of the expected scope for the acquisition and shall assess the offeror's response (ACVIP competency and budget) as part of the source selection.

4) Establish and Maintain a Program Office ACVIP Data Repository
   <REQM-4> The program should establish and maintain a data repository for ACVIP models and analyses to support the acquisition.

5) Perform Independent Verification and Validation
   <REQM-5> The program shall perform independent verification and validation for the contractor's ACVIP models and their alignment with the delivered software (CDRLs).

6) Determine and Communicate ACVIP Status
   <REQM-6> The program shall require the contractor to regularly communicate the status (metrics, issues, planned improvements) of their ACVIP instantiation and the program shall actively participate in a collaborative ACVIP IPT.

THESE ARE REQUIREMENTS FOR THE PM WHO COULD REAP RISK REDUCTION BY APPLYING INCENTIVES FOR THE CONTRACTOR TO APPLY
<REQM-1.4.1.1> - The performer shall perform ACVIP analyses supporting development of the mission and flight management systems using standardized modeling languages for embedded systems, tools, and analyses per the ACVIP Modeling and Analysis Handbook.

<REQM-1.4.1.1.1> Shall deliver an ACVIP Management Plan detailing modeling & analysis activities

<REQM-1.4.1.1.2> Shall perform analyses on an integrated real-time embedded computing system architecture model in an open semantically precise modeling language for embedded systems

<REQM-1.4.1.1.3> Shall deliver valid model and integrated analyses at appropriate reviews as specified by the ACVIP Management Plan

<REQM-1.4.1.1.4> Shall leverage analytical results for qualification and certification evidence

<REQM-1.4.1.1.5> Shall deliver a final model specification and analysis results to characterize the as-built system. (May contain proprietary info).

<REQM-1.4.1.1.6> Shall deliver final complete model specification and analyses with no less than GPR specifying all key interfaces enabling Government or 3rd party replication of analyses results.

THESE ARE ACVIP MODEING AND ANALYSIS REQUIREMENTS LEVIED ON THE MISSION SYSTEM INTEGRATORS WHICH MAY PROPOGATE TO THEIR SUPPLIERS.
MBSE WORKFLOW (COLLINS AEROSPACe FROM RECENT JMR MSAD CAPSTONE DEMONSTRATION)
ANALYSIS OF SYSTEM PROPERTIES VIA ARCHITECTURE MODEL
A CONTRIBUTION TO AUTHORITATIVE SOURCE OF TRUTH

Change of Encryption from 128 bit to 256 bit

One change drives multiple system issues

Higher CPU Demand

Potential New Hazard

Authoritative Source of Truth Across Analysis Models

ARCHITECTURAL MODEL
SAE AS5506 AADL

REAL-TIME PERFORMANCE
Increased Latency

Deadline/ Starvation
Latency
Execution Time/ Deadline

SECURITY
Intrusion
Integrity
Confidentiality

RESOURCES CONSUMPTION
Bandwidth
CPU Time
Power Consumption

SAFETY & RELIABILITY
Hazard Analysis
FMEA
FTA
MTBF

DATA QUALITY
Temporal Correctness
Data Precision/ Accuracy
Confidence

Affects Temporal Correctness
ACVIP GENERAL WORK FLOW (FROM SEI)

Start

New operational needs identified

Enterprise GFI

New functionality defined

FoS Info (Req, Arch, etc.)

Capabilities (as subsystems, components) identified for new or re-development

System Subsystem, Component Modeling

Full integration, test & deployment for Operational Platform

MBE, MBSE, ACVIP influence governance, acquisition, modeling and analysis

Subsystems & Components modeled, virtually integrated, and analyzed to work across contractor boundaries

Components and Subsystems implemented, integrated & tested in the Deployment Environment

New functionality integrated into system hardware & validated

Innovators
COST REDUCTION POTENTIAL THROUGH VIRTUAL INTEGRATION OF EMBEDDED SOFTWARE SYSTEMS

For a 27.5 MSLOC system, nominal development cost reduction of 26% (e.g., $2.4B out of $9.2B on a projected 2024 program).


Reduction through Focus on Verification of Architecture

AT Kearney “Software: The Brains Behind U.S. Defenses Systems”
VISION
To be the scientific and technological foundation of the Future Force Modernization Enterprise through world-leading research, development, engineering and analysis.

MISSION
To provide the research, engineering, and analytical expertise to deliver capabilities that enable the Army to deter and, when necessary, decisively defeat any adversary now and in the future.
Deliver collaborative and innovative aviation and missile capabilities for responsive and cost-effective research, development and life cycle engineering solutions.
**BY THE NUMBERS**

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**Core Competencies**

**Science and Technology:**
- Materials and Structures
- Guidance, Navigation, Sensors/Seekers
- Propulsion, Explosives, Energetics, Warheads, Fuzing and Actuation
- Air Vehicles Technology
- Aviation Autonomy and Missiles Technology
- Air Defense Sensor Technology

**Capabilities Engineering:**
- Software Engineering
- Weapons Assurance
- Modeling and Simulation
- Configuration Management
- Prototype Design and Development
- Multidiscipline Acquisition and Project Engineering
- Systems Engineering, Integration, and Interoperability
- Airworthiness
- Aviation and Missile Product Performance

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**FY20 Strength by Location:**
- Colorado Springs, CO: 1,000
- Joint Base Langley – Eustis, VA: 500
- NASA Ames – Moffett Field, CA: 300
- Corpus Christi, TX: 200
- Redstone Arsenal, AL: 100
- HQ: 20

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**FY20 Funding by Percentage:**
- Aviation S&T: 4%
- Missile S&T: 5%
- Army: 65%
- Other: 26%
#1: People
People are the Army’s greatest strength and its most important weapon system.

#2: Readiness
The Army must be ready to defeat any adversary, anywhere, whenever called upon, under any condition.

#3: Modernization
The Army must modernize to remain lethal and ready to fight tomorrow, against increasingly capable adversaries and near-peer competitors.

#4: Reform
The Army will improve the way we do business, including how we implement our top priorities, to make the Army more lethal, capable, and efficient.
S&T PRIORITIES ALIGNED WITH THE ARMY MODERNIZATION STRATEGY

Supporting Army and Joint Readiness now and in the Future MDO Environment

RESEARCH ISO FUTURE FORCE

Driving the discoveries and innovations which will be critical to realizing new capabilities for the Army of 2030 and beyond.

ANALYSIS

Conducting objective experimentation and systems analysis to support the equipping and sustaining of our Warfighters.

ENGINEERING

Providing lifecycle engineering expertise to support fleet development and readiness across warfighting battlefield operating systems.
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