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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APPROVED FOR PUBLIC RELEASE

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: BOTTOM LINE UP FRONT

- **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)

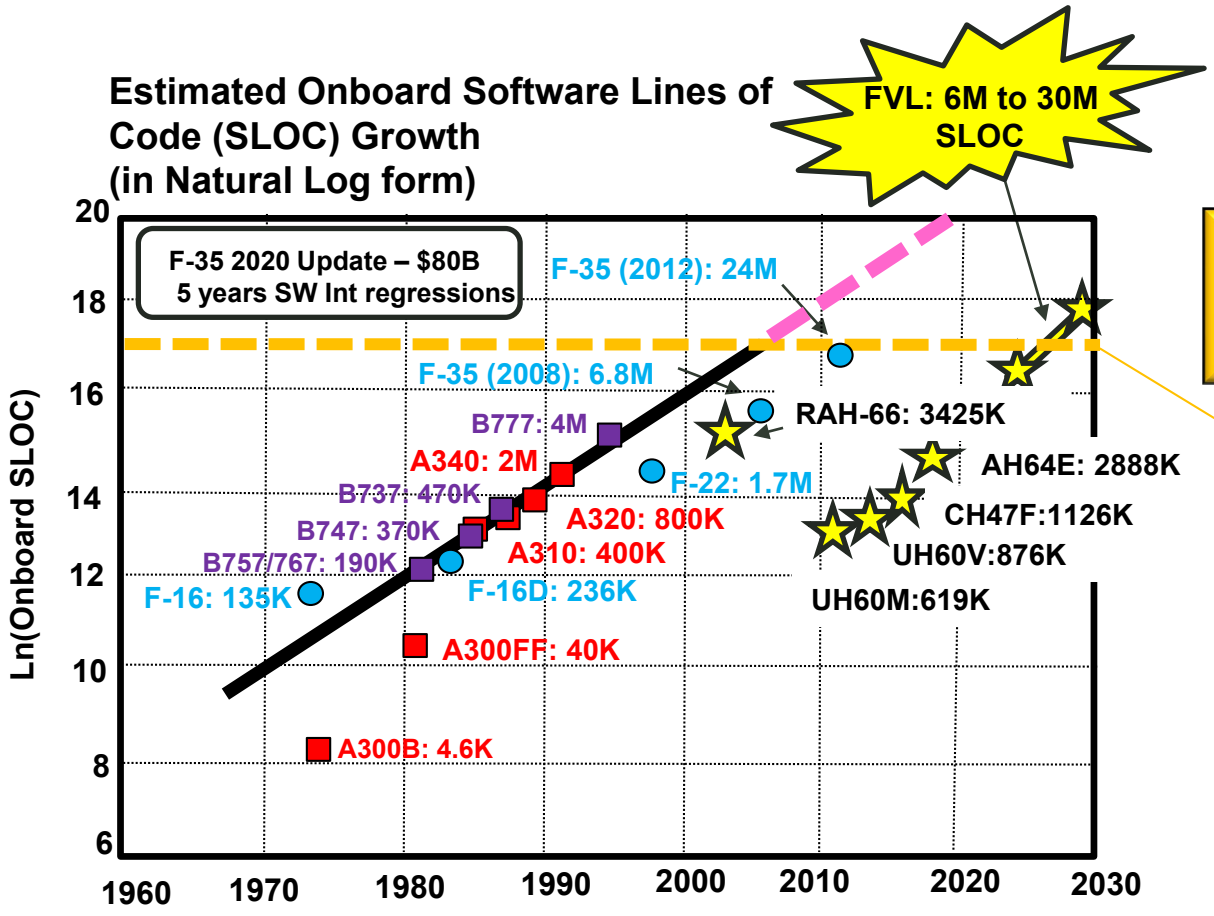
ACVIP significantly reduces risk in embedded software / hardware integration, and increase likelihood of delivering full capabilities on schedule and within budget

GROWTH IN AVIATION SOFTWARE DRIVES CAPABILITIES

DEVCOM AVIATION & MISSILE CENTER

SAVI System Architecture Virtual Integration
A Commercial Aviation Industry Consortium

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



Software as % of total system development cost
1997: 45%, 2010: 70%, 2024: 88%

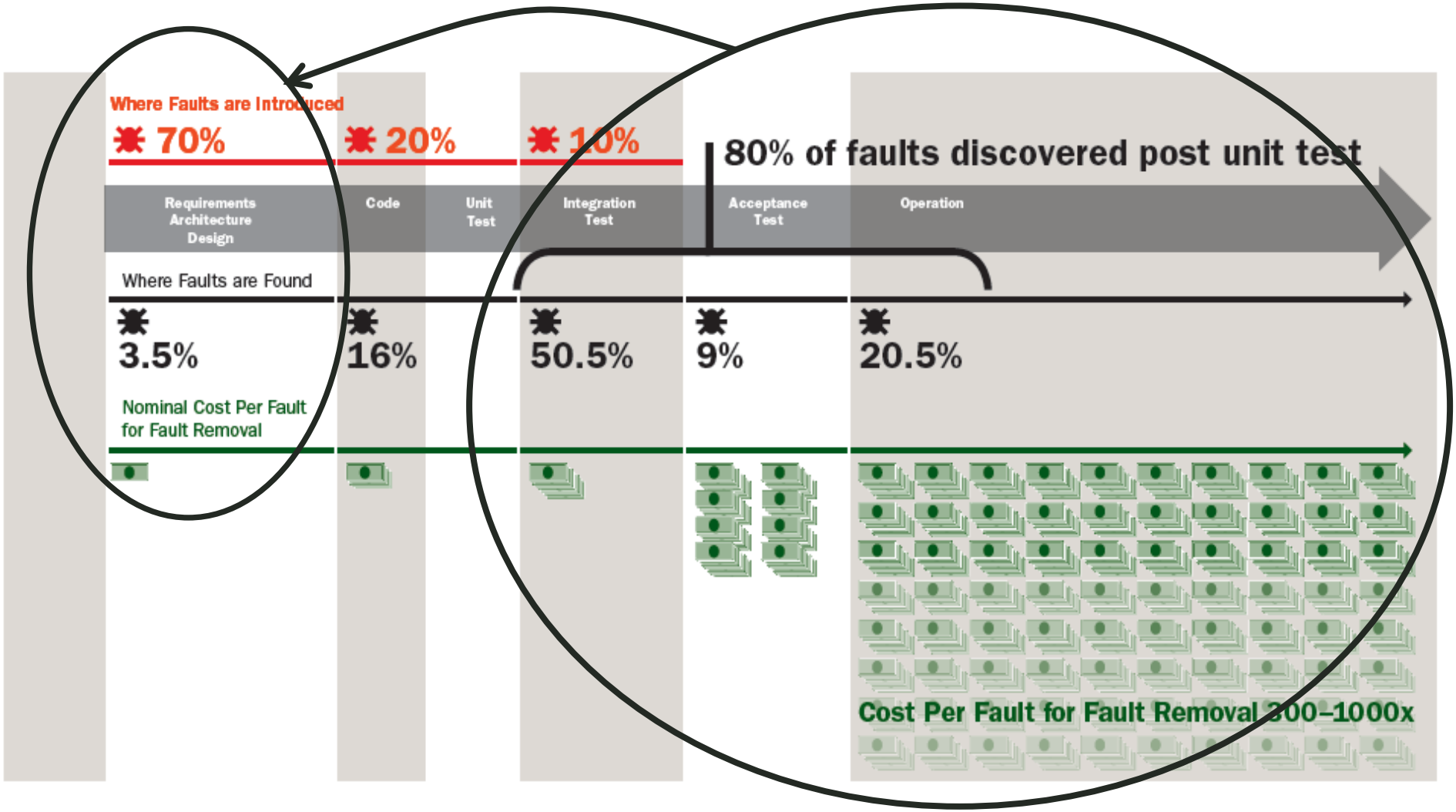
Projects a limit of affordability at 27.5MSLOC or $10B in software costs

LEGEND
- 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

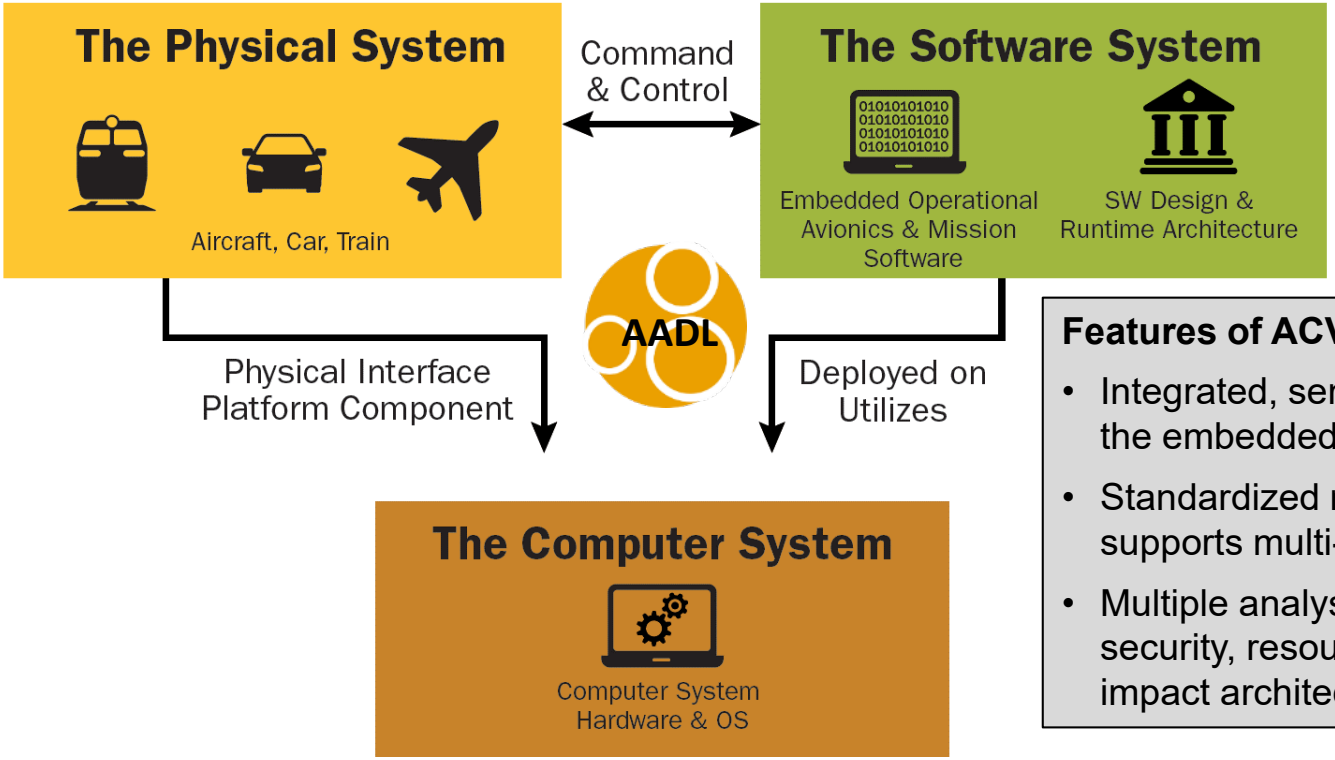


Goal: Find faults earlier through virtual integration, when significantly cheaper to fix

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 COMPLEMENTS THE ANALYSIS AND TOOLS IN THE CURRENT WORKFLOW

Mission System Requirements	System Concepts & Functions		Subsystem Architecture	Component Design & Implementation	System Integration & Qualification
CONOPS UCM-URN DoDAF UPDM	SysML	Computer Hardware	Schematic Capture Circuit board Hardware platform	Circuit logic Manufacture	System Integration & Assembly
		Embedded Software System	AADL Tasking & communication FACE Virtual System Integration CAMET LIBRARY Behavior	Embedded Software System Modeling & Code Gen AADL FACE python Java Source code	CAMET LIBRARY AADL Model-driven Integration & Field Testing
		Physical System	3DEXPERIENCE SCADE Suite ANSYS Structures MathWorks MODELICA	Thermodynamics Fluid Dynamics Electrical Controls & Signals Manufacture	System Integration & Assembly

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)

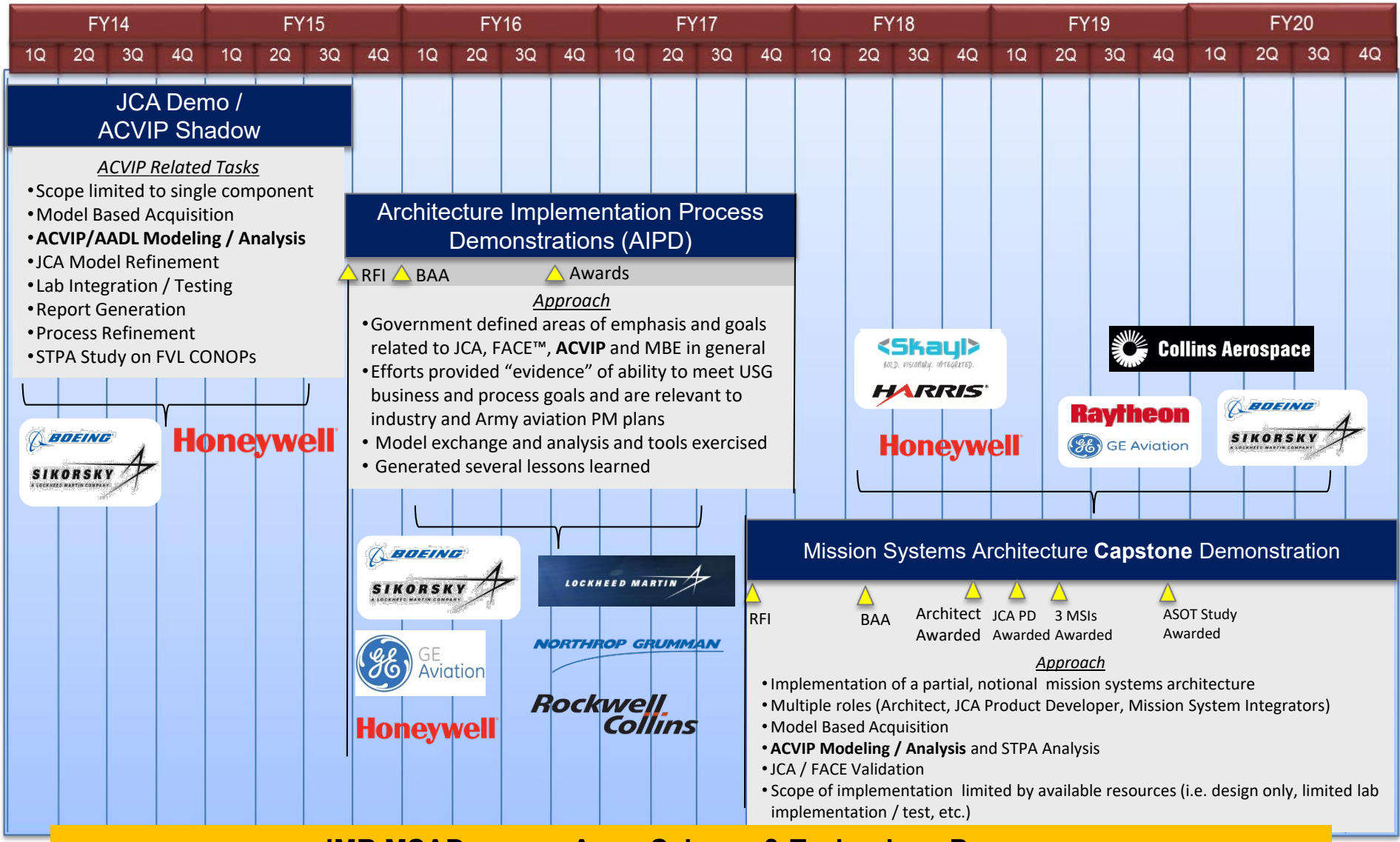
&

FUTURE VERTICAL LIFT (FVL) PROGRAMS OF RECORD

JMR MSAD S&T: AREAS OF EMPHASIS

- **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



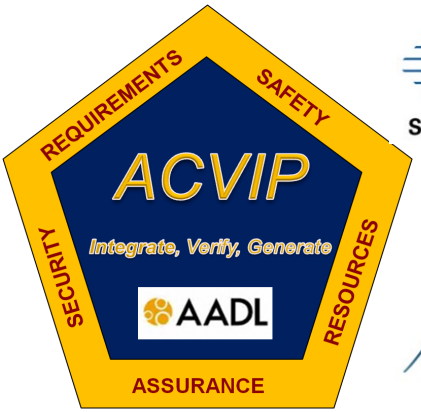
JMR MSAD was an Army Science & Technology Program of increasingly complex software integration demonstrations.

CAPSTONE DEMO OBSERVATIONS ON ACVIP

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



Software Engineering Institute

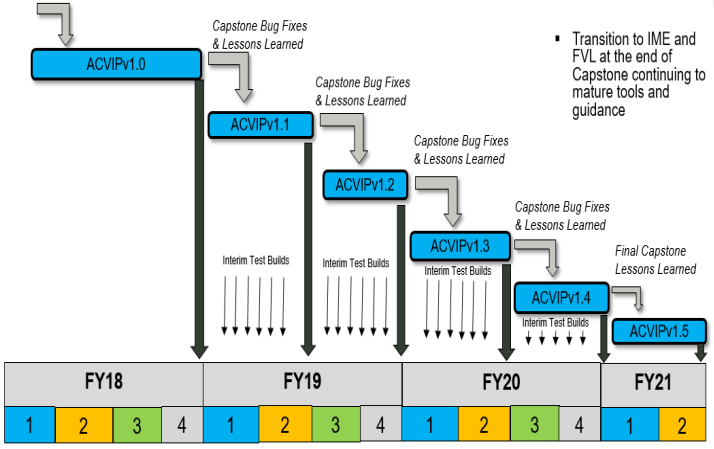
Adventium LABS

ACVIP VERSIONING RELEASE PLAN 2018-2021

- Biyearly Updates to:
  - OSATE & Plugin Tools by SEI & Adventium
  - ACVIP Handbooks

Note: Not all items get updated with each release

- Interim Test Builds will be available to address issues discovered during Capstone
- Transition to IME and FVL at the end of Capstone continuing to mature tools and guidance



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..

https://osate.org

https://www.adventiumlabs.com/our-work/products-services/model-based-engineering-mbe-tools

SAE INTERNATIONAL AADL Tool Expos

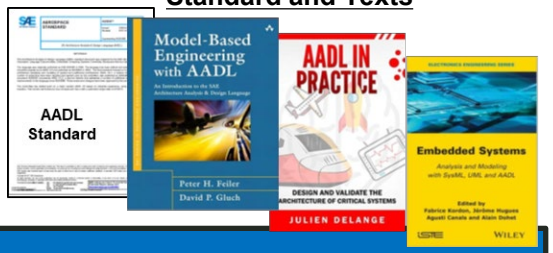
https://resources.sei.cmu.edu/news-events/events/aadl-user-day/

ACVIP/AADL Handbooks, Papers, Training and Texts

Handbooks & Papers

- Overview
- Modeling & Analysis
- OSD DEWG Overview
- Acquisition Management

Standard and Texts



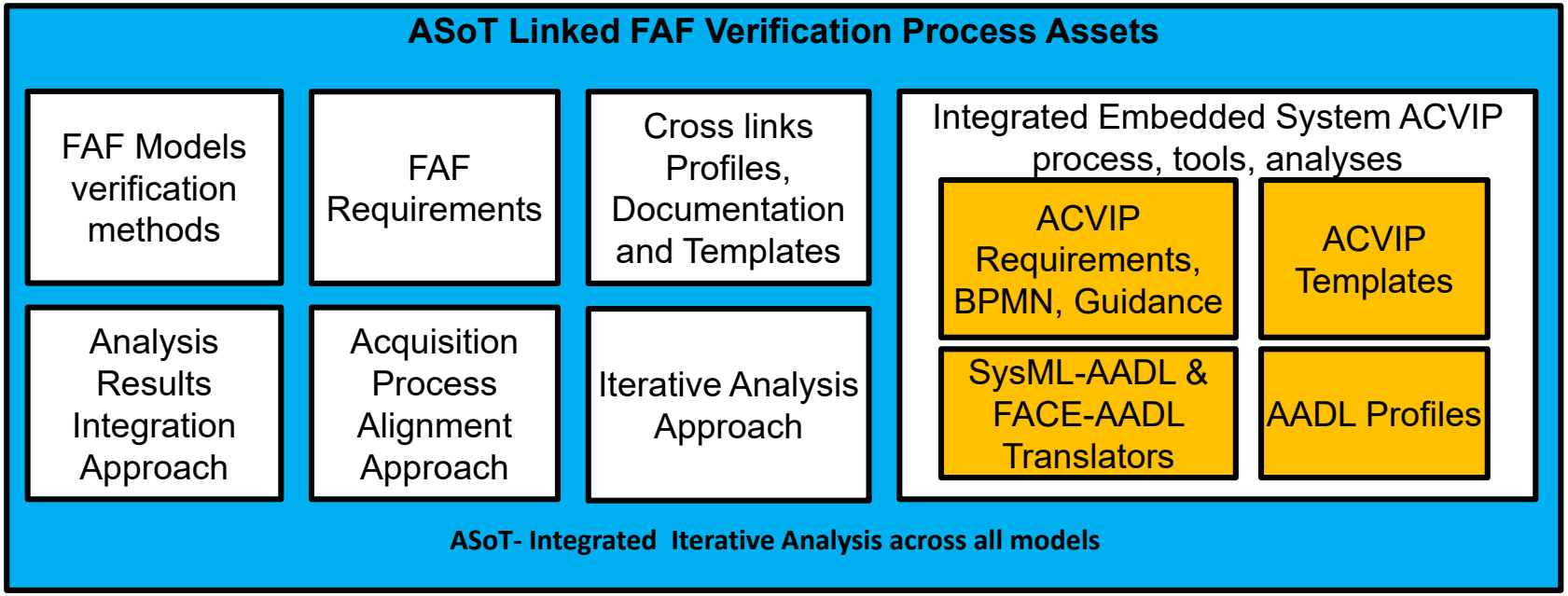
Training

- https://https://www.adventiumlabs.com/our-work/products-services/acvip-training
- www.sei.cmu.edu/education-outreach/courses/course.cfm?courseCode=V40

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

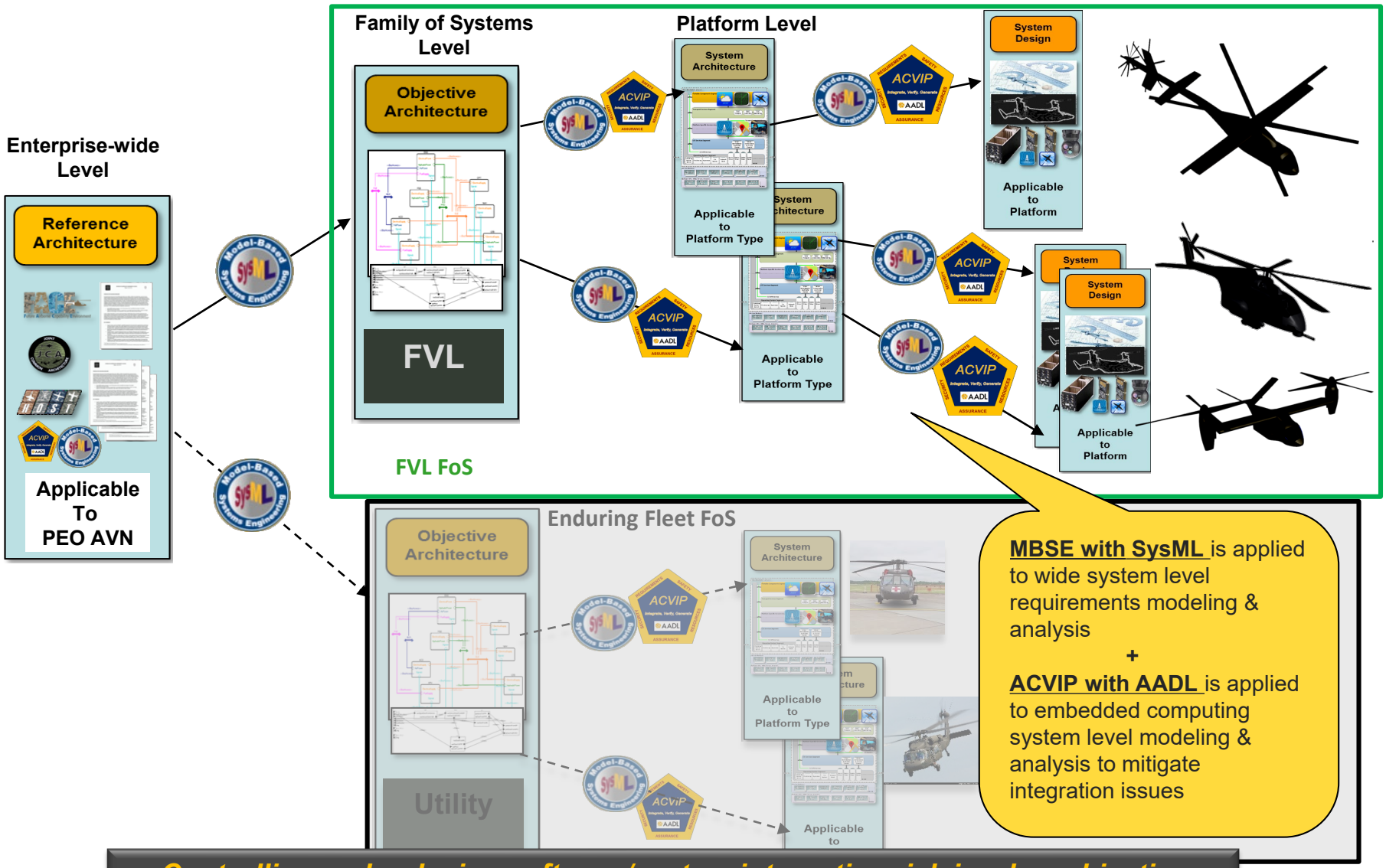
ACVIP IS INTEGRATED INTO FVL ARCHITECTURE FRAMEWORK (FAF) WITH GUIDANCE

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



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



MBSE with SysML is applied to wide system level requirements modeling & analysis

+

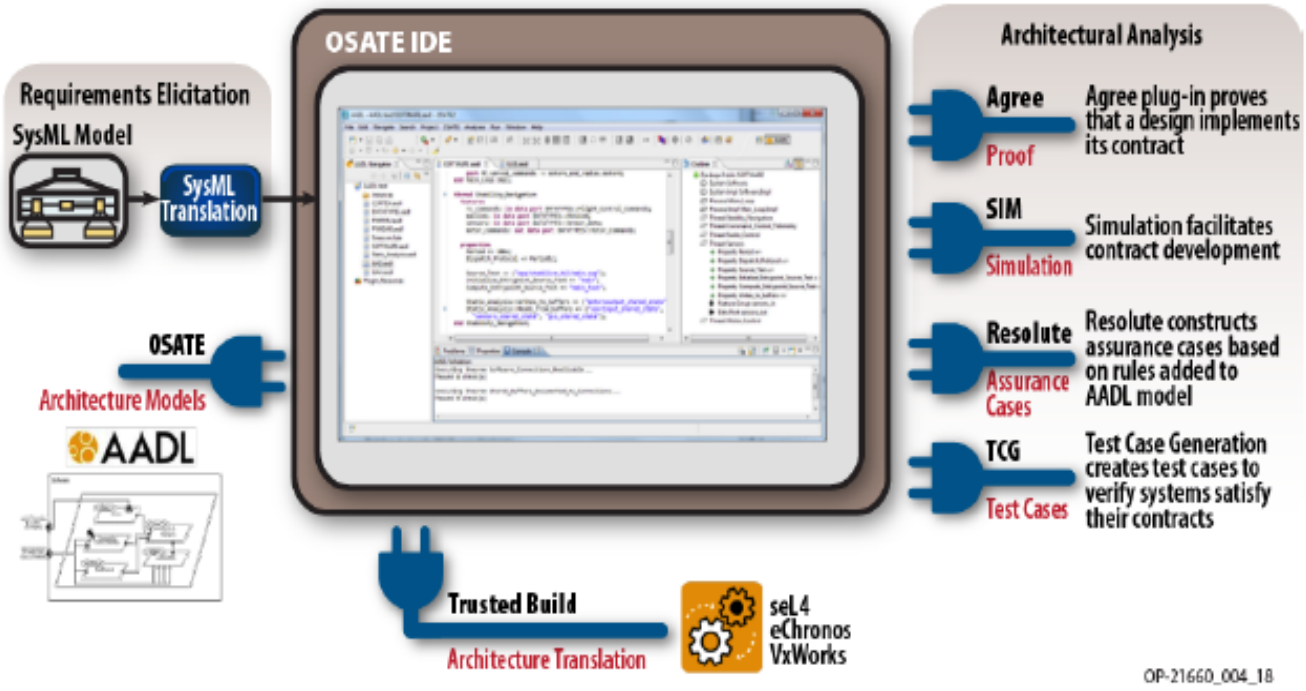
ACVIP with AADL is applied to embedded computing system level modeling & analysis to mitigate integration issues

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

DARPA: CYBER ASSURED SYSTEMS ENGINEERING (CASE) USING AADL

Architectural Modeling and Analysis

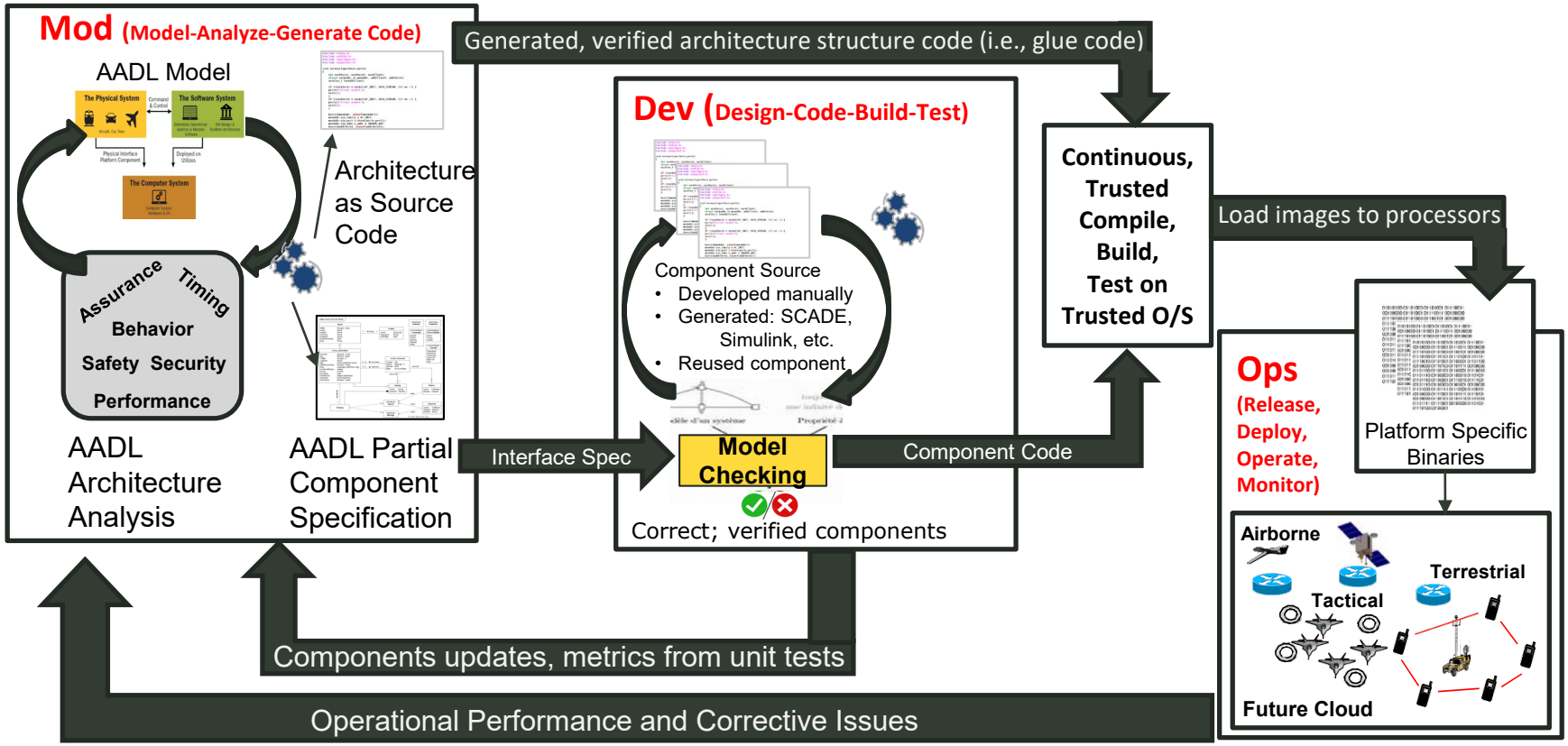


All too often architectures are modeled early in the engineering processes to be set aside and not leveraged to support design activities

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



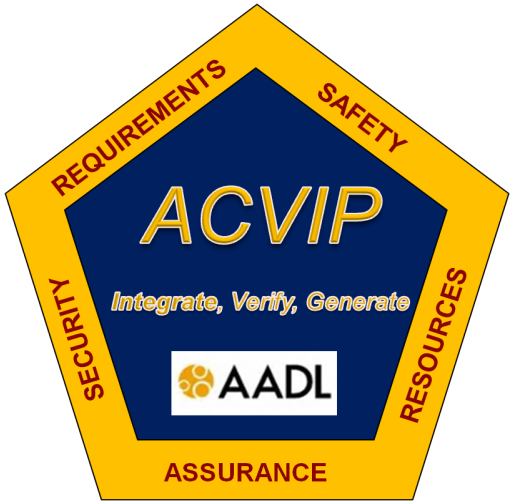
SEI Research with Demo Exists Regarding TwinOps
(see https://resources.sei.cmu.edu/library/asset-view.cfm?assetid=651118)

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?


REQUIREMENTS
SAFETY
ACVIP
Integrate, Verify, Generate
AADL
SECURITY
RESOURCES
ASSURANCE

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

CONTRACTOR MODELING & ANALYSIS REQUIREMENTS FOR ACVIP CONTAINED IN FAF

<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

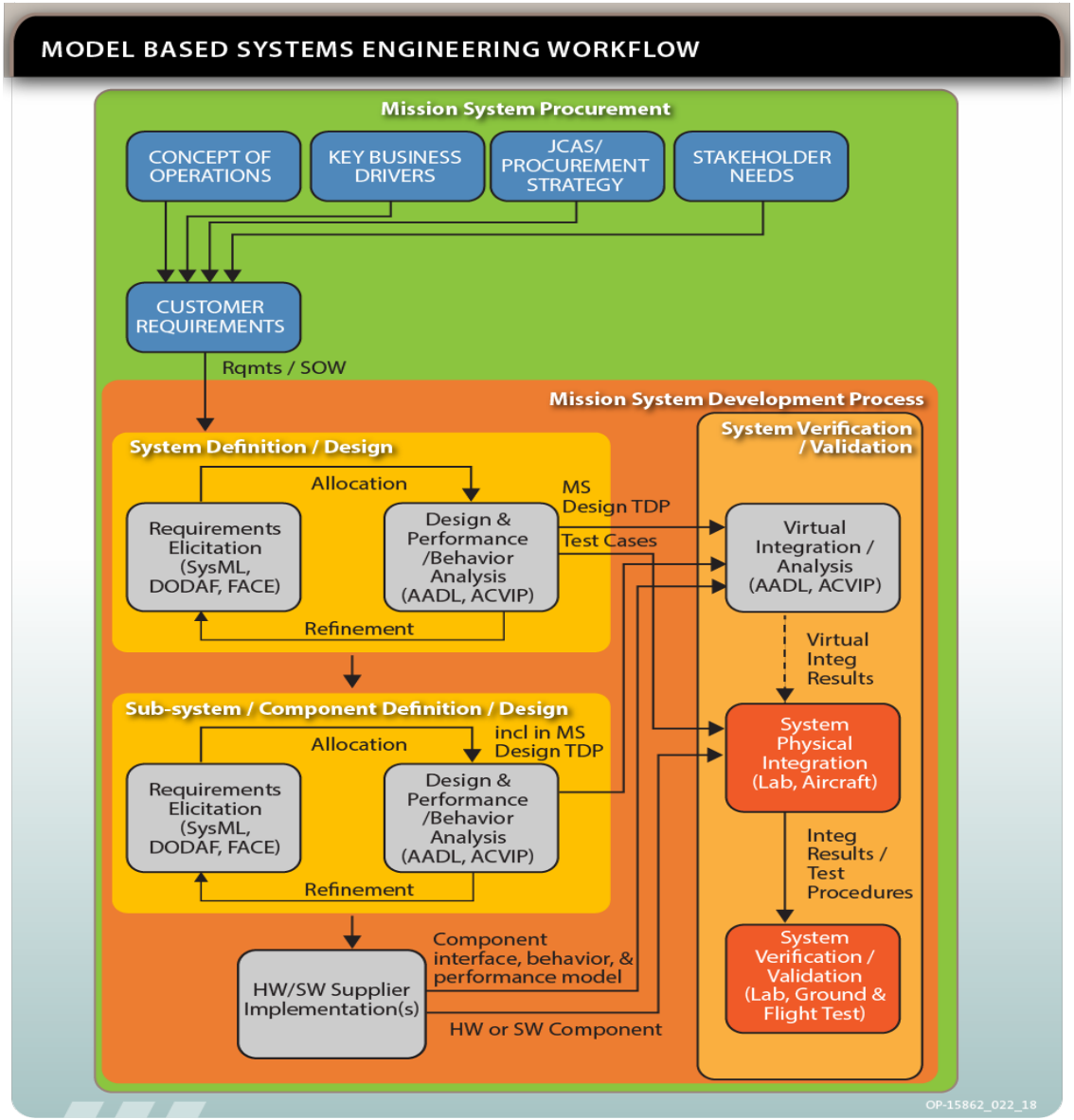
<REQM-1.4.1.1.4> Shall **leverage analytical results for qualification and certification** evidence

<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).

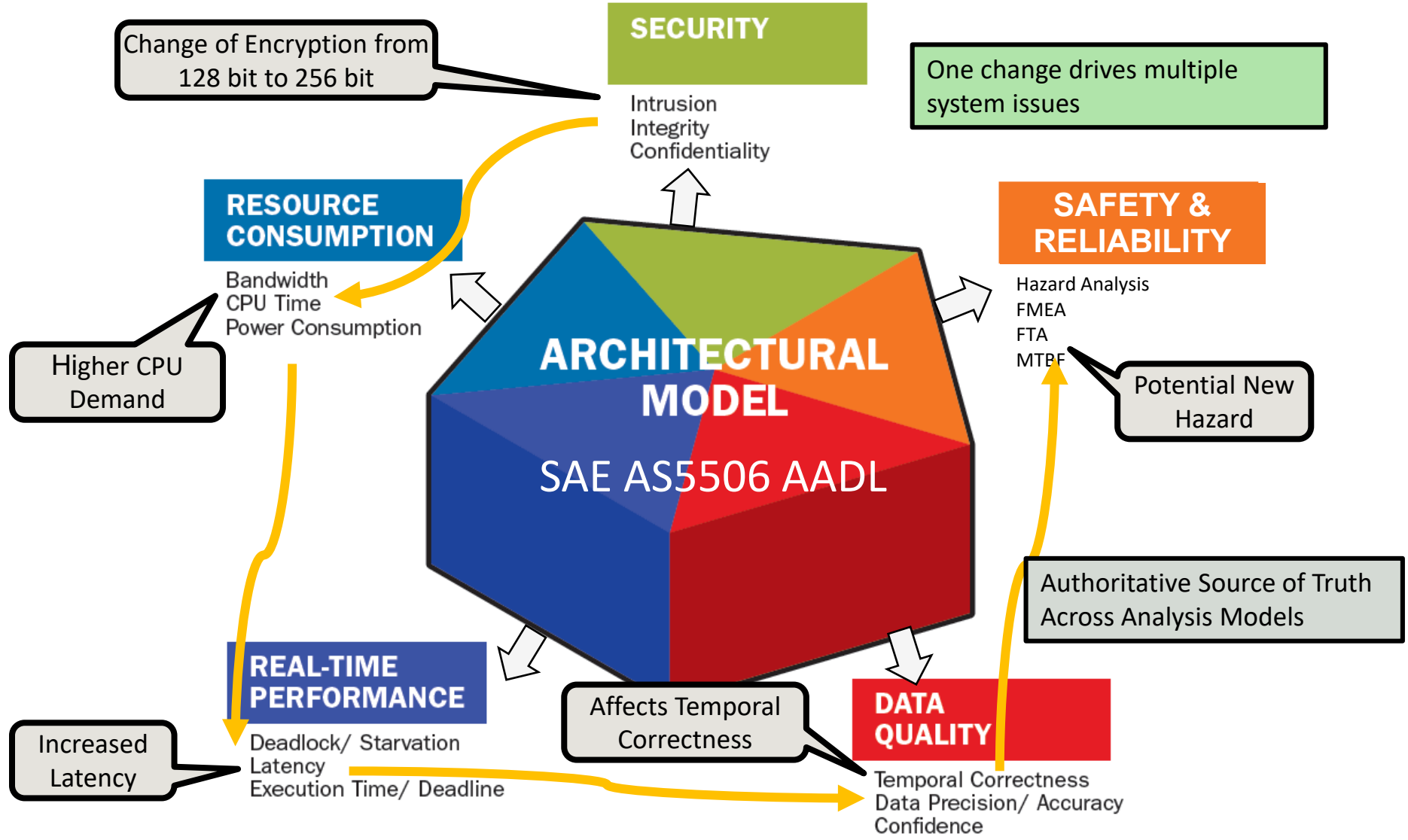
<REQM-1.4.1.1.6> Shall **deliver final complete model specification and analyses with no less than GPR** specifying all key interfaces enabling Government or 3rd party replication of analyses results.

THESE ARE ACVIP MODEING AND ANALYSIS REQUIREMENTS LEVIED ON THE MISSION SYSTEM INTEGRATORS WHICH MAY PROPOGATE TO THEIR SUPPLIERS.

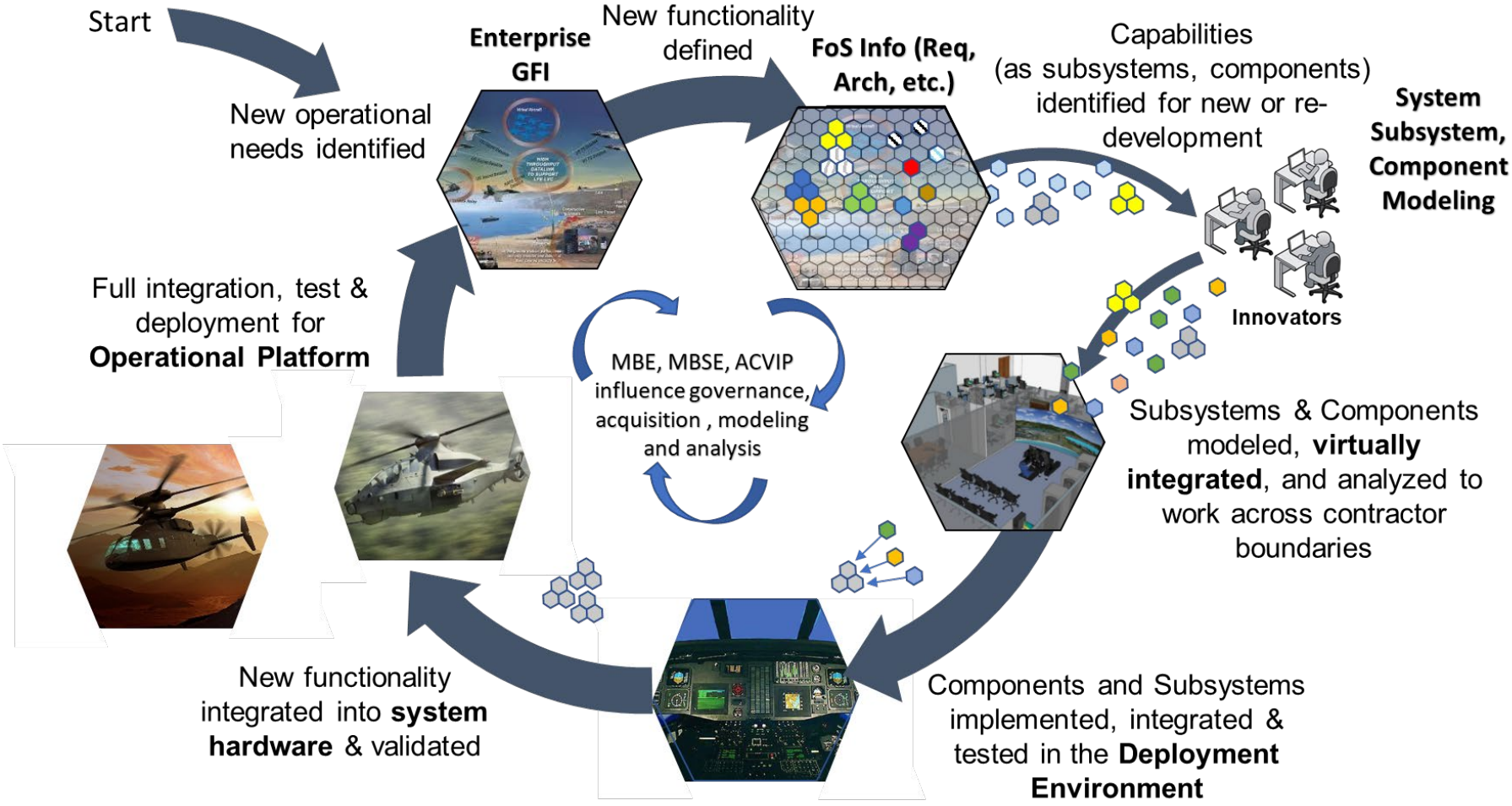
MBSE WORKFLOW (COLLINS AEROSPACE FROM RECENT JMR MSAD CAPSTONE DEMONSTRATION)



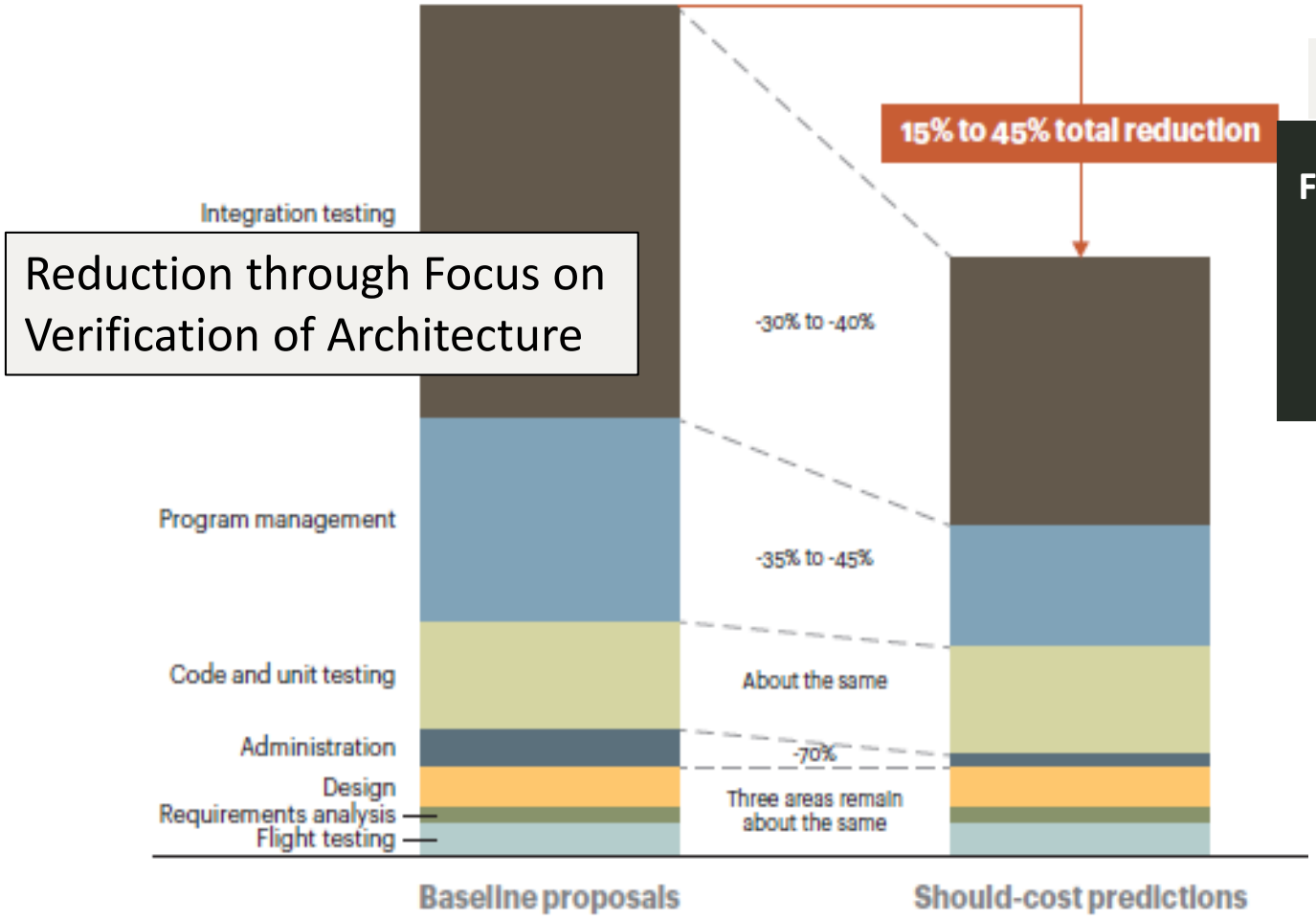
ANALYSIS OF SYSTEM PROPERTIES VIA ARCHITECTURE MODEL A CONTRIBUTION TO AUTHORITATIVE SOURCE OF TRUTH



ACVIP GENERAL WORK FLOW (FROM SEI)



COST REDUCTION POTENTIAL THROUGH VIRTUAL INTEGRATION OF EMBEDDED SOFTWARE SYSTEMS



Reduction through Focus on Verification of Architecture

ATKearney "Software: The Brains Behind U.S. Defenses Systems"

ROI on AADL Pilot

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)

Source: *ROI Analysis of the System Architecture Virtual Integration Initiative*
CMU/SEI-2018-TR-002

DEVCOM VISION AND MISSION

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.

OUR MISSION

Deliver collaborative and innovative aviation and missile capabilities for responsive and cost-effective research, development and life cycle engineering solutions.

BY THE NUMBERS

11,942	2,982	10	~8,940
FY20 Strength	Civilian	Military	Contractor

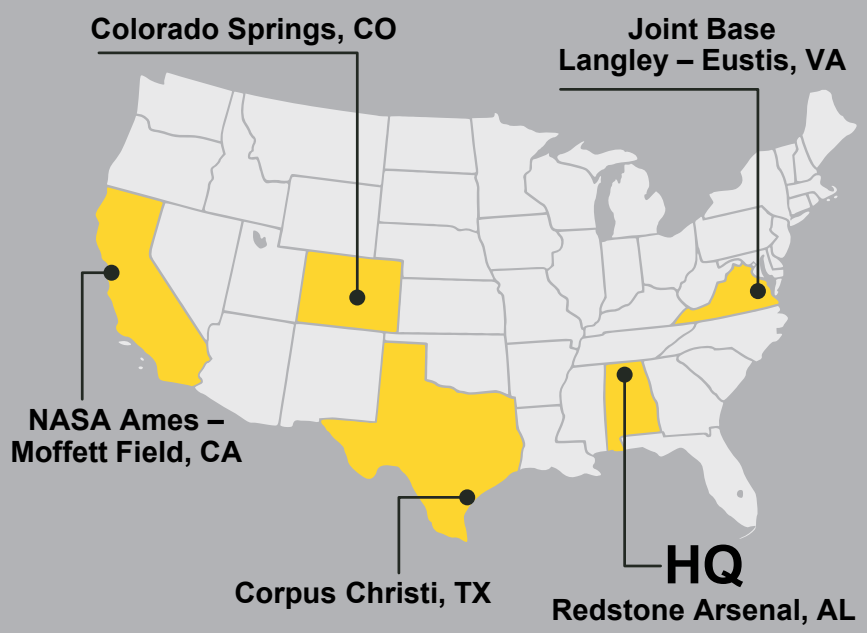
FY20 Funding
$4.3B

4%
Aviation S&T

5%
Missile S&T

65%
Army

26%
other



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

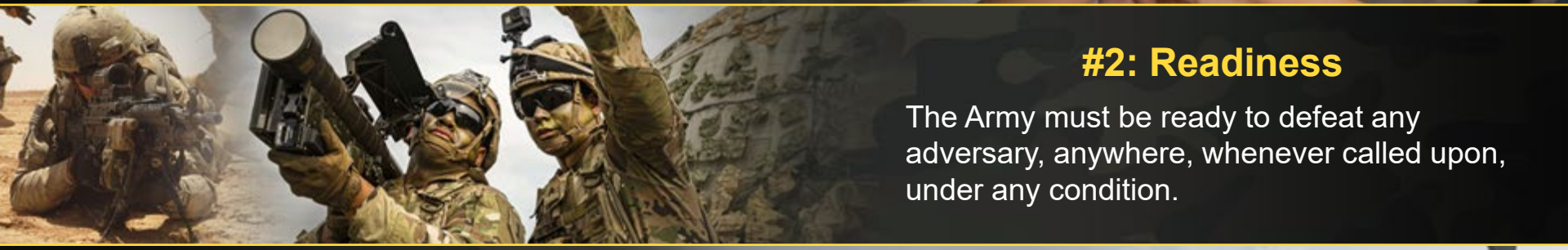
Capabilities Engineering:

- 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

ARMY PRIORITIES

#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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