# AADL Overview and Perspectives

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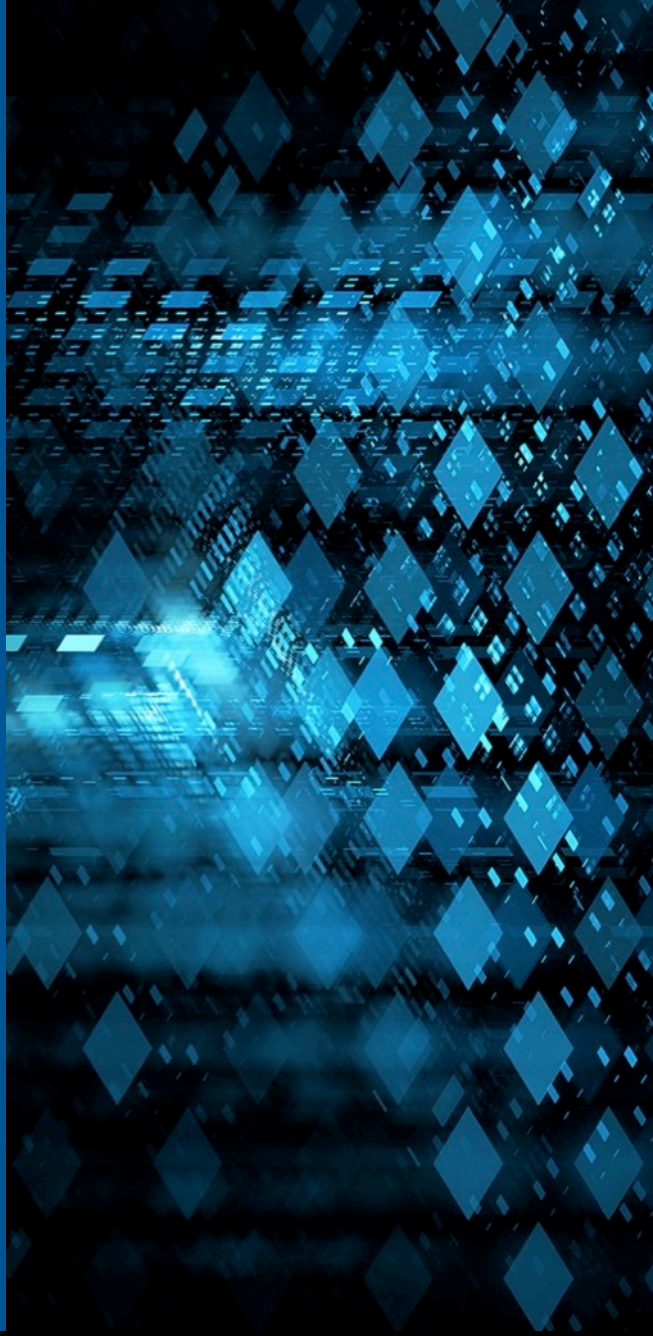

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DM19-1081

# Safety Critical Embedded Software System Challenge

## SAE AADL Standard and Virtual System Integration to the Rescue

## Embedded Software System Qualification and Assurance

# The Safety Critical Embedded Software System Challenge

**Problem:**

Software increasingly dominates safety and mission critical system development cost.

80% of issues discovered post unit test.

**Solution:** Early discovery of system level issues through virtual Integration and incremental analytical assurance.

**Approach:**

International standard based technology matured into practice through pilot projects and industry initiatives.

Open source research prototyping platform continually enhances analysis, verification, and generation capabilities.

***Reduced Defect Leakage through Early Analytical Assurance is Critical***

# We Rely on Software for Safe System Operation

**Quantas Airbus A330-300 Forced to make Emergency Landing - 36 Injured**

Written by htbw on Oct-7-08 1:48pm

From: soyawannaknow.blogspot.com


Thirty-six passengers and crew were
in a mid-air drama that forced a Qan
emergency landing, the Australian c
Tuesday.

The terrifying incident saw the Airbu
mayday call when it suddenly change
from Singapore to Perth, Qantas said.

Australian Transport Safety Bureau said yesterday. Th
650 feet within seconds, slamming passengers and crew
ceiling, before the pilots regained control.

`This appears to be a unique event," the bureau said,
Toulouse, France-based Airbus, the world's largest mak
aircraft, issued a telex late yesterday to airlines that fly
fitted with the same air-data computer. The advisory is ``aimed at
minimizing the risk in the unlikely event of a similar occurrence."

**FAA says software problem with Boeing 787s could be catastrophic**

By **Dan Catchpole**

***@dcatchpole***

The Federal Aviation Administration says a software problem with Boeing 787 Dreamliners could lead to one of the advanced jetliners losing electrical power in flight, which could lead to loss of control.

- **The Buzz**: Hipster's dilemma
- Boeing & aerospace news
- Aerospace blog

The FAA notified operators of the airplane Friday that if a 787 is powered continuously for 248 days, the plane will automatically shut down its alternating current (AC) electrical power.

**Two Crashes In Five Months**

**What's Wrong with Boeing's 737 Max 8?**

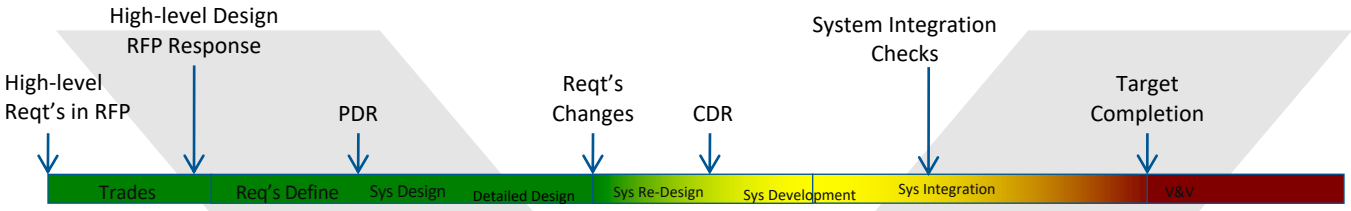
**Boeing's new airplane has only been around for two years and already two 737 346 people. The disasters may be attributable to a design flaw that emerged when engineers began cutting corners.**

Boeing's Max 8 is short, limiting ground clearance under the wings. The engine simply doesn't fit.

Embedded software systems introduce a new class of problems not addressed by traditional system safety analysis

Breakdown in human intensive safety assessment process

# Current Practice: Impact on Cost and Schedule



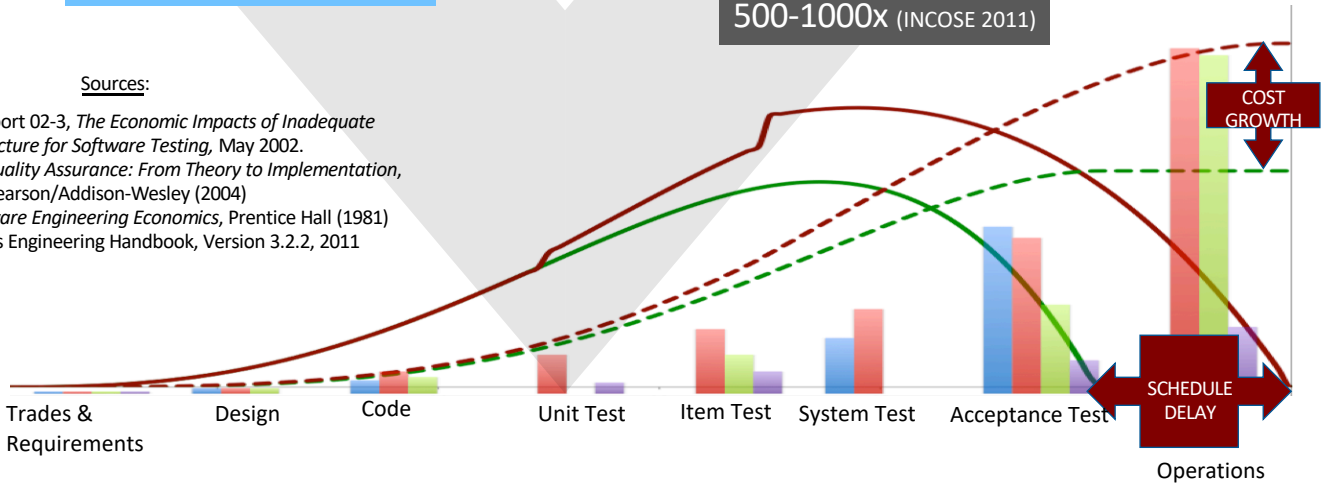

70% errors introduced
3.5% errors detected
1x cost to fix

10% errors introduced
80% errors detected
16-100x cost to fix

500-1000x (INCOSE 2011)

Sources:

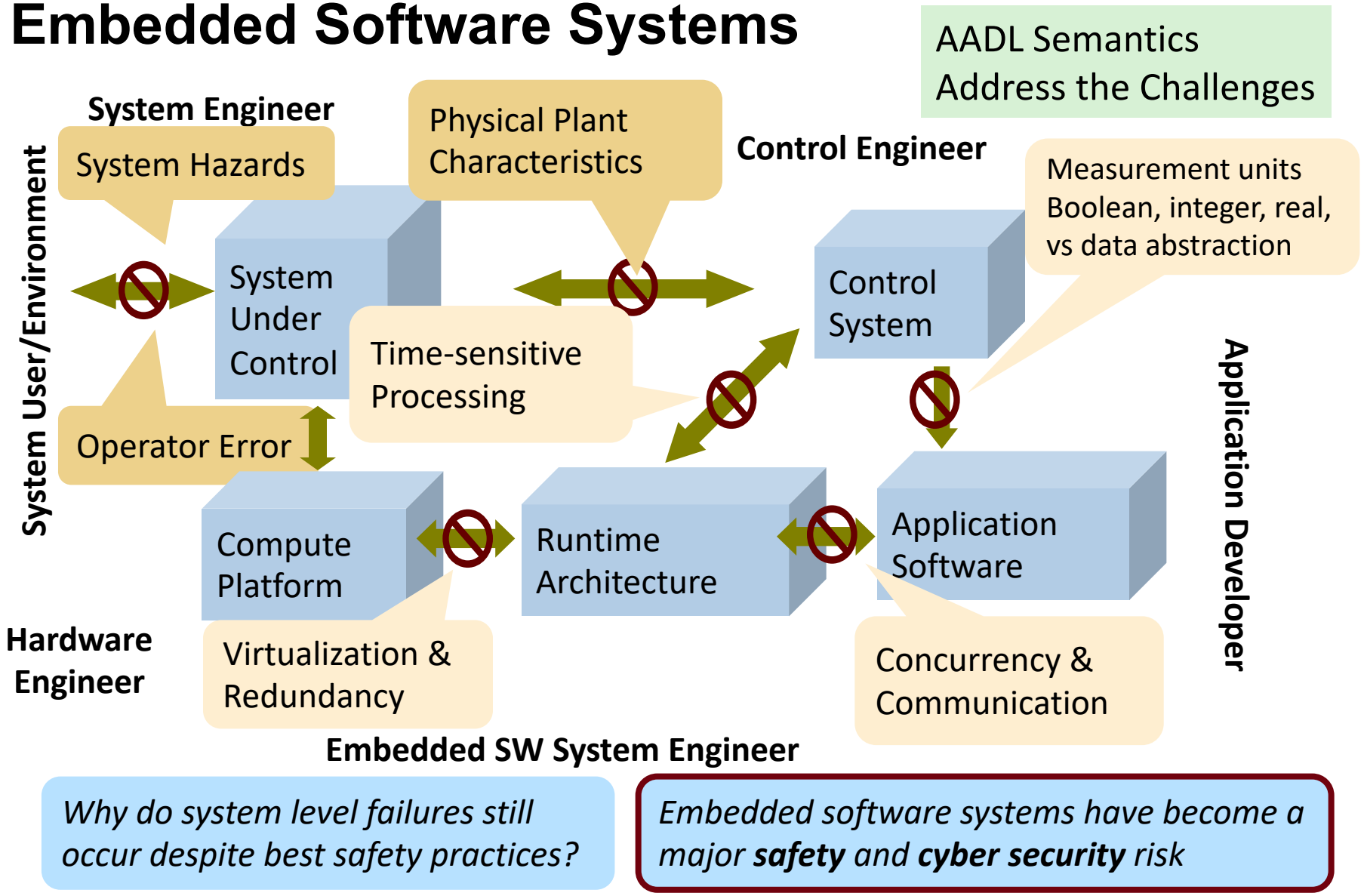
NIST Planning report 02-3, *The Economic Impacts of Inadequate Infrastructure for Software Testing*, May 2002.
D. Galin, *Software Quality Assurance: From Theory to Implementation*, Pearson/Addison-Wesley (2004)
B.W. Boehm, *Software Engineering Economics*, Prentice Hall (1981)
INCOSE Systems Engineering Handbook, Version 3.2.2, 2011




Software as % of total system development cost
1997: 45% → 2010: 66% → 2024: 88%

Post unit test software rework currently ~50% of total system development cost

# Technical Challenges in Safety-Critical Embedded Software Systems

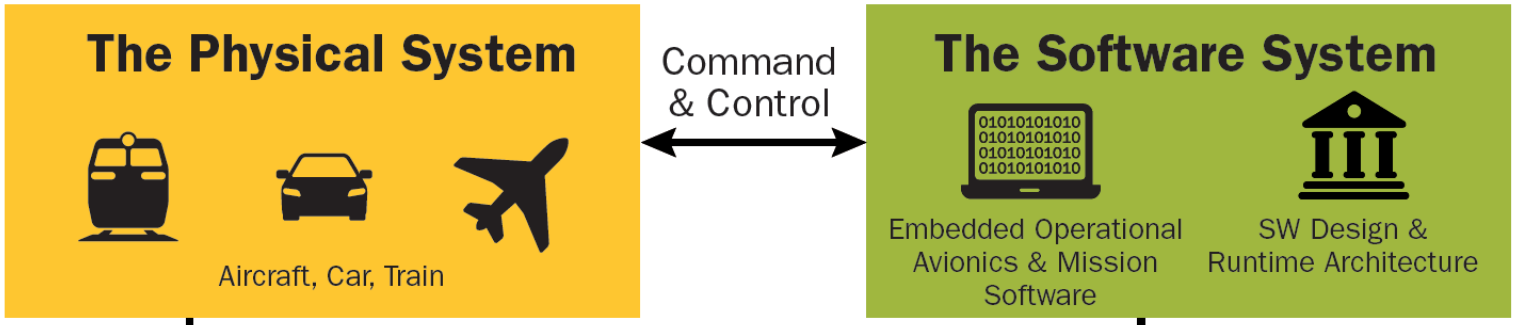


**Safety Critical Embedded Software System Challenge**

**SAE AADL Standard and Virtual System Integration to the Rescue**

**Embedded Software System Qualification and Assurance**

# Architecture Analysis & Design Language (AADL) Standard Targets Embedded Software Systems




Physical Interface
Platform Component

Deployed on
Utilizes

SAE International
AS 5506 Standard Suite

Standards provide long-term industry-wide solutions to support multi-organization model-based engineering


In 2008 Aerospace industry initiative chose AADL over SysML and other notations as it specifically addresses embedded software systems


**AADL captures mission and safety critical embedded software system architectures in virtually integrated analyzable models to discover system level problems early and construct implementations from verified models**

# SAE International AADL Standard Suite (AS-5506 series)

## Core AADL language standard [V1 2004, V2 2012, V2.2 2017]

- Focused on embedded software system modeling, analysis, and generation
- Strongly typed language with well-defined semantics for execution of threads, processes on partitions and processor, sampled/queued communication, modes, end to end flows
- Textual and graphical notation
- Revision V3 in progress: interface composition, system configuration, binding, type system unification

### Standardized AADL Annex Extensions

- Error Model language for safety, reliability, security analysis [2006, 2015]
- ARINC653 extension for partitioned architectures [2011, 2015]
- Behavior Specification Language for modes and interaction behavior [2011, 2017]
- Data Modeling extension for interfacing with data models (UML, ASN.1, …) [2011]
- AADL Runtime System & Code Generation [2006, 2015]

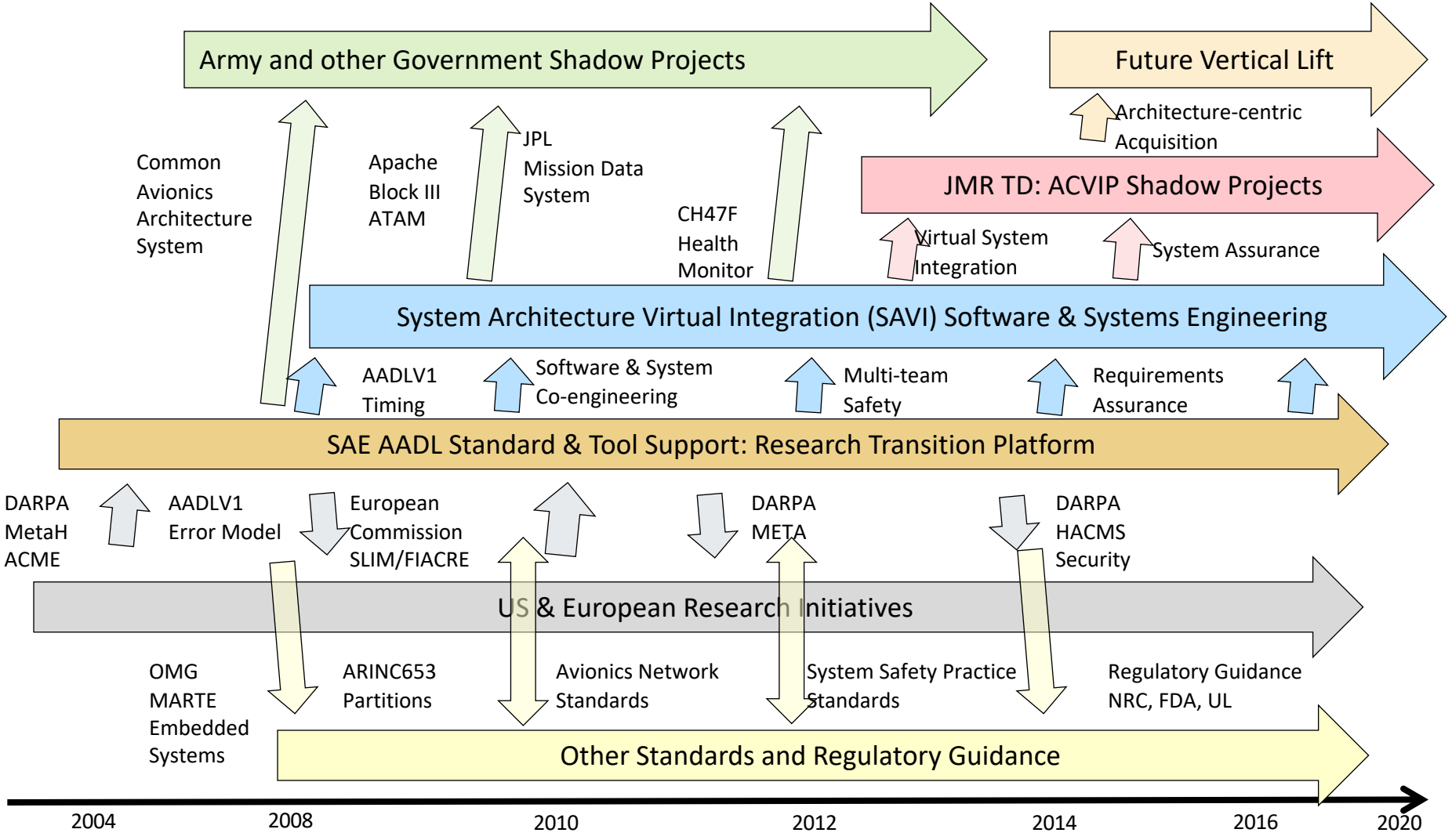
### AADL Annexes in Progress

- Network Specification Annex
- Cyber Security Annex
- FACE Annex
- Requirements Definition and Assurance Annex
- Synchronous System Specification Annex

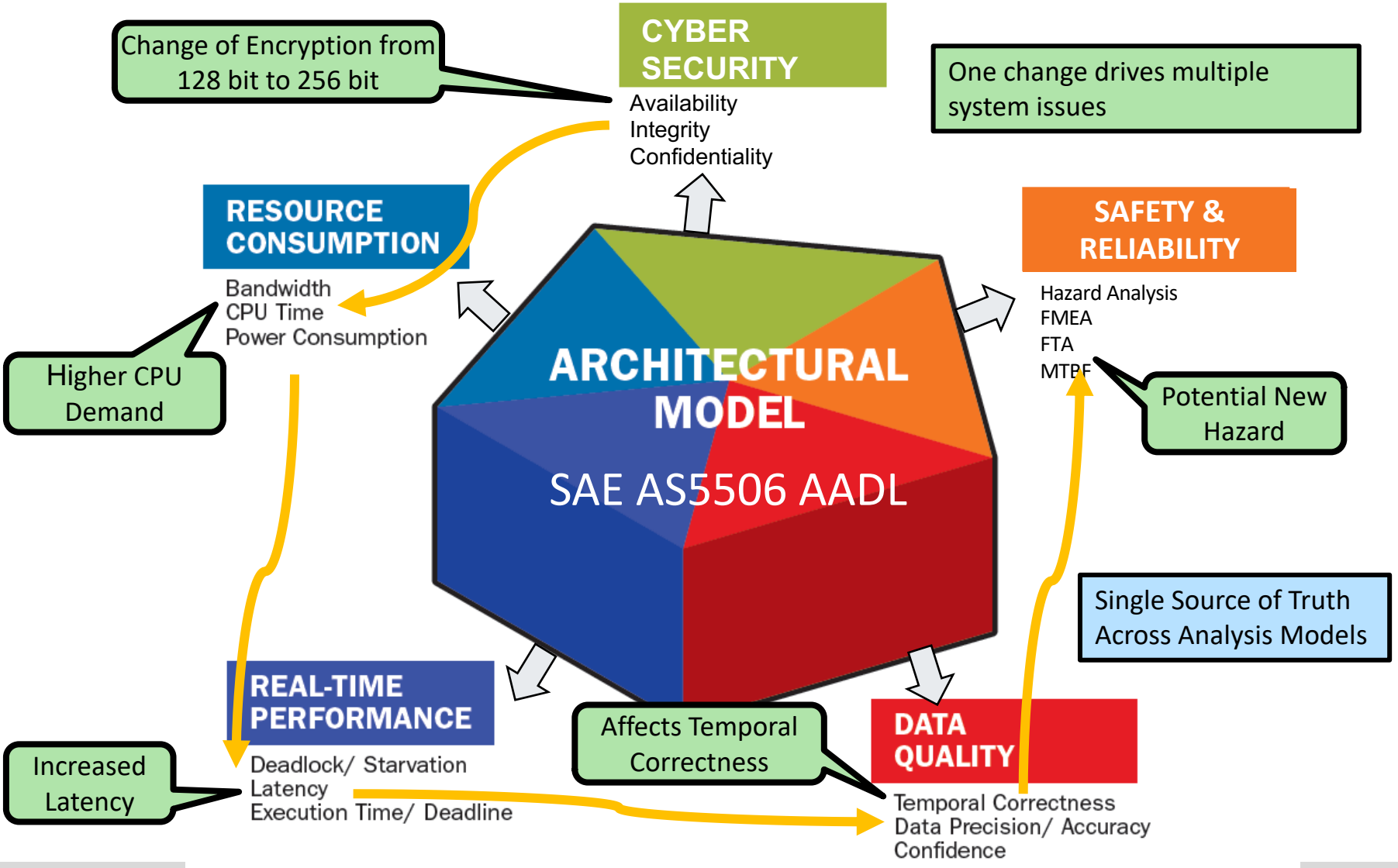
# SAE AADL & Architecture-centric Virtual Integration

## Evolution, Maturation and Transition

**AMRDEC has funded AADL standards development since 1999**



# Analysis of System Properties via Architecture Model
# A Contribution to Single Source of Truth



# Latency and Jitter Contributors

Control System Engineering View

Processing latency

Sampling latency

Physical signal latency

**Software System Latency Contributors**

Execution time variation: algorithm, use of cache

Processor speed

Resource contention

Preemption

Legacy & shared variable communication

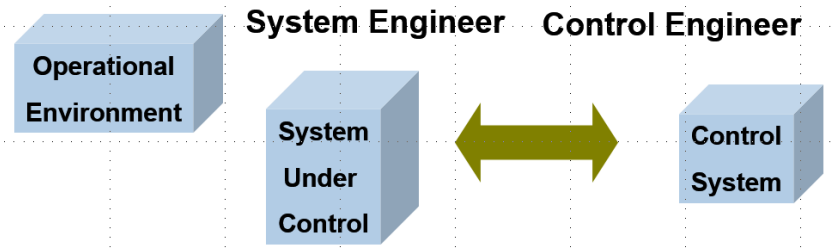
Rate group optimization

Protocol specific communication delay

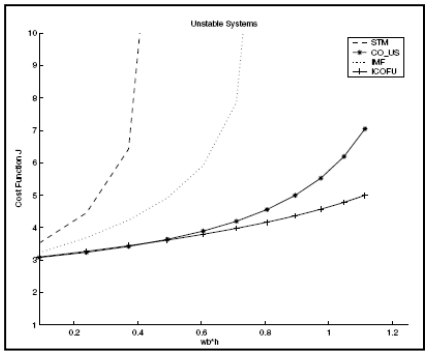
Partitioned architecture

Migration of functionality

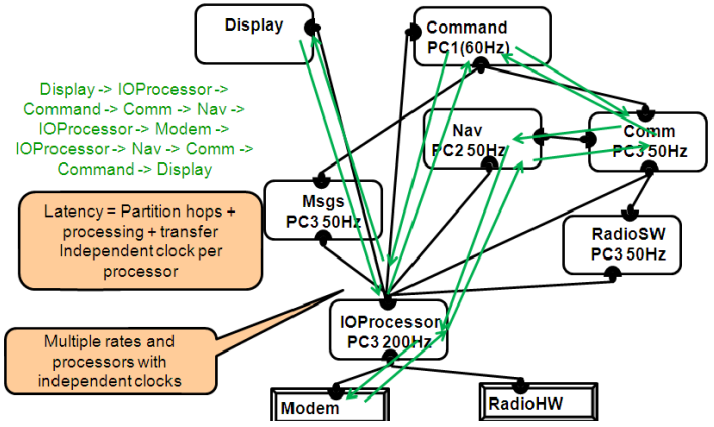
Fault tolerance mechanisms




Impact of Scheduler Choice on Controller Stability
A. Cervin, Lund U.
CCACSD 2006




**Flow Use Scenario through Subsystem Architecture**



# Safety Critical Embedded Software System Challenge

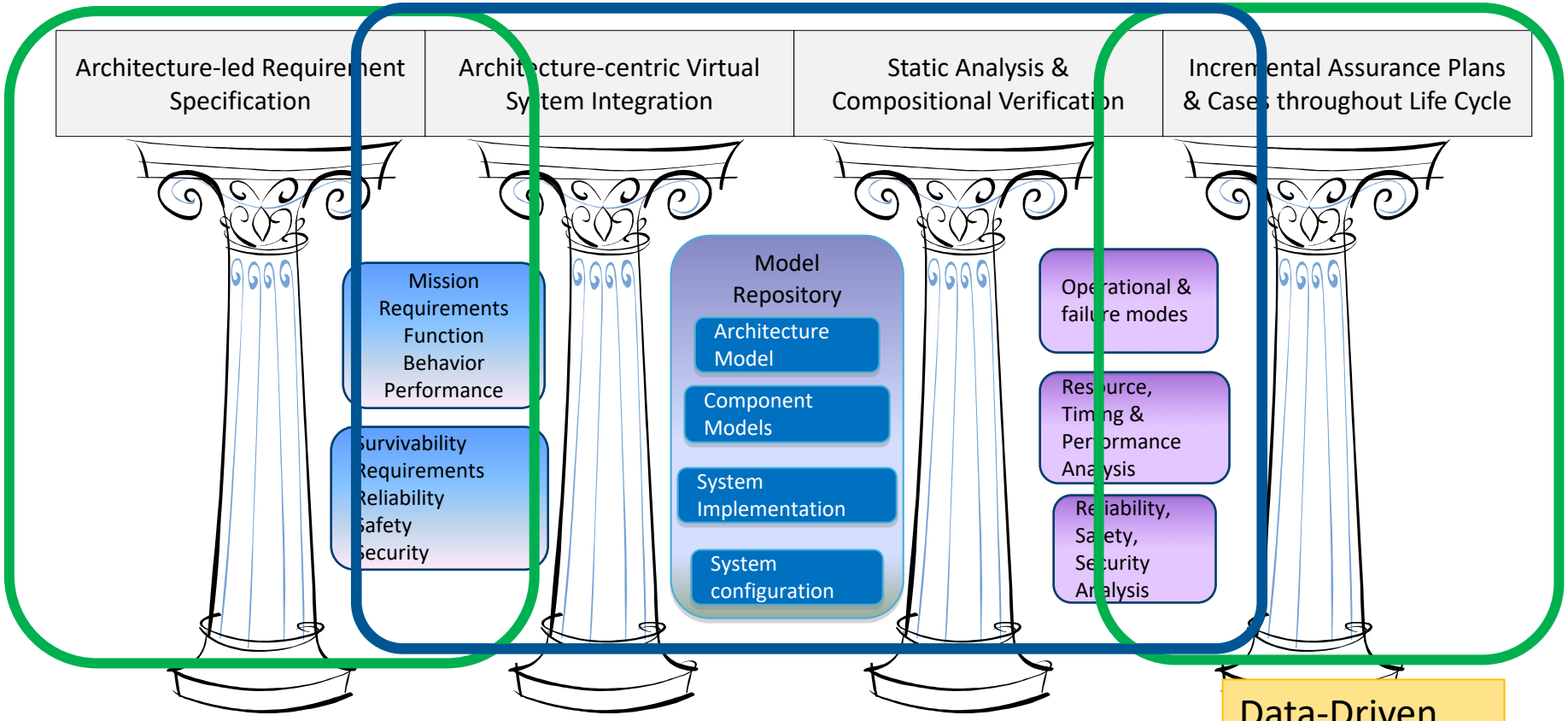
# SAE AADL Standard and Virtual System Integration to the Rescue

# Embedded Software System Qualification and Assurance

# Assurance & Qualification Improvement Strategy

Assurance: Sufficient evidence that a system implementation meets system requirements

*2010 SEI Study for AMRDEC*
*Aviation Engineering Directorate*



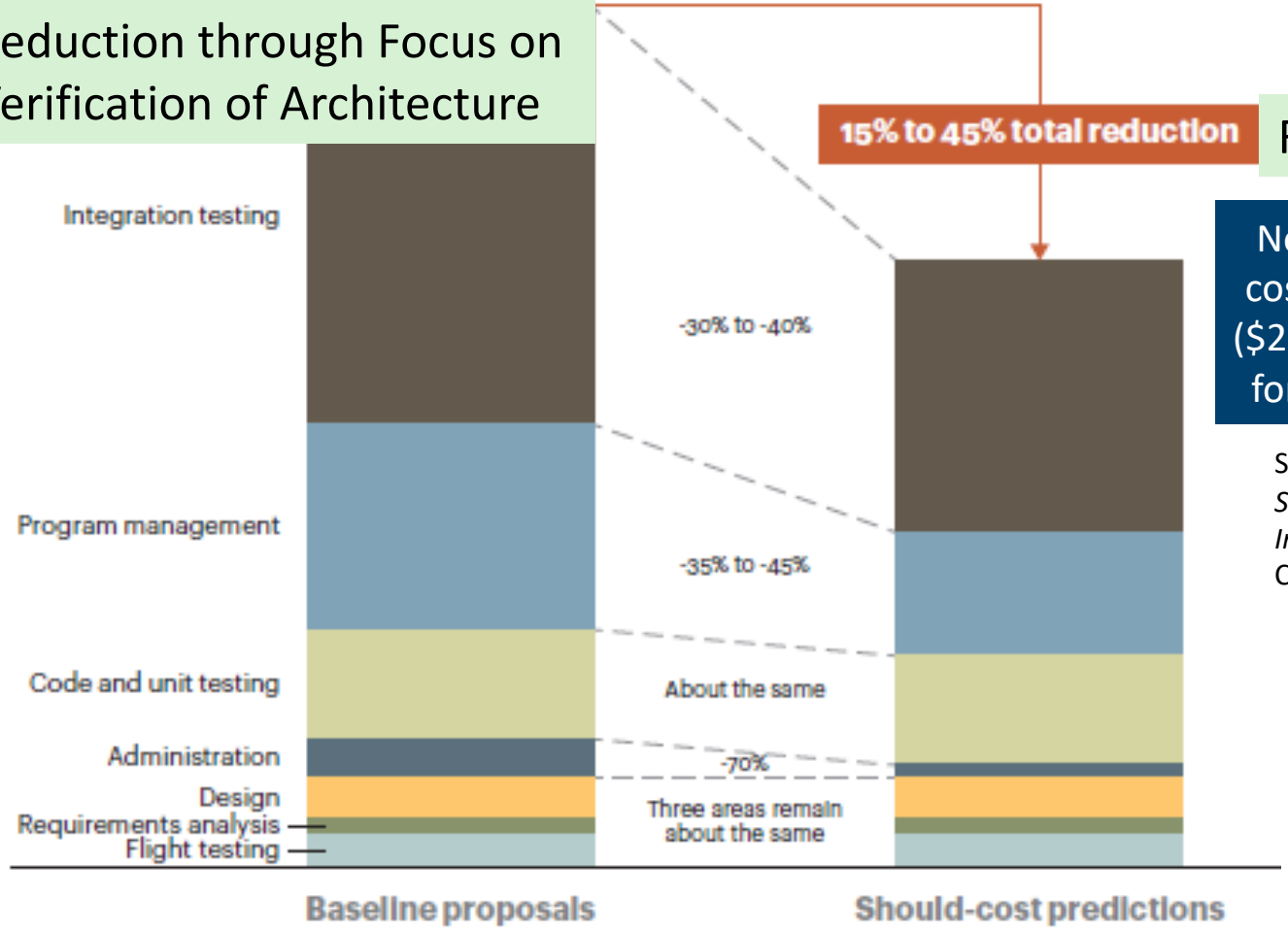

Architecture Centric Virtual System Integration Practice (ACVIP)

Architecture Led Incremental System Assurance (ALISA)

Data-Driven
High Leverage
Cost Effective

# Cost Reduction Potential through Virtual Integration of Embedded Software Systems

Reduction through Focus on Verification of Architecture



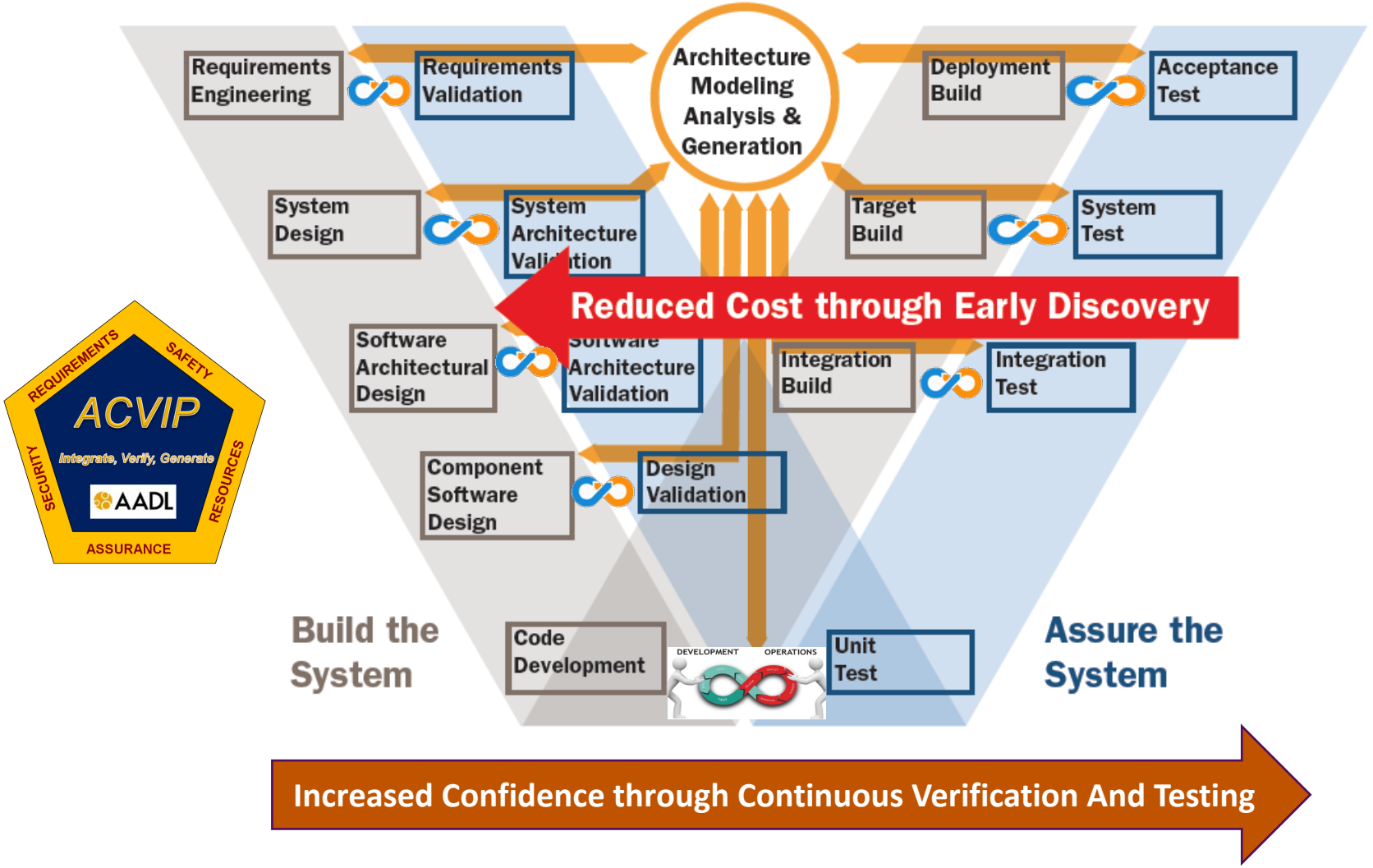

ROI on AADL Pilot

Nominal development cost reduction of 26.1% ($2.391B out of $9.186B) for a 27 MSLOC system

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

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

# Benefits of Virtual System Integration & Continuous Lifecycle Assurance



# Summary

Safety Critical Embedded Software Systems are facing exponential growth in software development cost exceeding 70% of total system development cost.

AADL is basis for a set of technologies and practices that specifically have been designed to provide early detection and continuous verification throughout the life cycle.

A number of case studies and pilot projects by different organizations have demonstrated the benefit of virtual system integration with AADL.