MBSE Applied to System of Systems (SoS)

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Introduction

- **DoD System of Systems (SoS) complexity and cost challenges require System Engineering (SE) that informs design for affordability.**

- **Model Based System Engineering (MBSE) as a methodology within an Integrated Development Environment (IDE) provides an effective means to meet system engineering challenges.**

Agenda

- DoD System of System (SoS) Development Challenges
- System Engineering Challenge
- Design for Affordability
- Model Based System Engineering
- MBSE Integrated Development Environment (IDE)
- Netted ISR (NISR) Case Study Summary
- Conclusions
- Q/A

DoD SoS Development Challenges

- **Complexity Increasing**
  - **Context/environment,**
  - **Speed,**
  - **Threat/vulnerability,**
  - **Type/amount of information,**
  - **Node capability/capacity,**
  - **Interconnections.**
- **Cost Increasing**
  - **Adversarial capabilities maturing,**
  - **Development costs are out-stripping national resources,**
  - **Defensive development cycles are longer than threat development cycles.**

System Engineering Challenge

- **Meet/exceed performance requirements within constraints of …**
  - **Scientific laws,**
  - **Technology state of shelf,**
  - **Budget,**
  - **Schedule,**
  - **Resources.**
- **Manage …**
  - **Requirements,**
  - **Voice of the customer,**
  - **Complexity,**
    - **Decompose/partition.**
  - **Risk,**
    - **Validated performance,**
    - **Cost,**
    - **Schedule.**

Design for Affordability

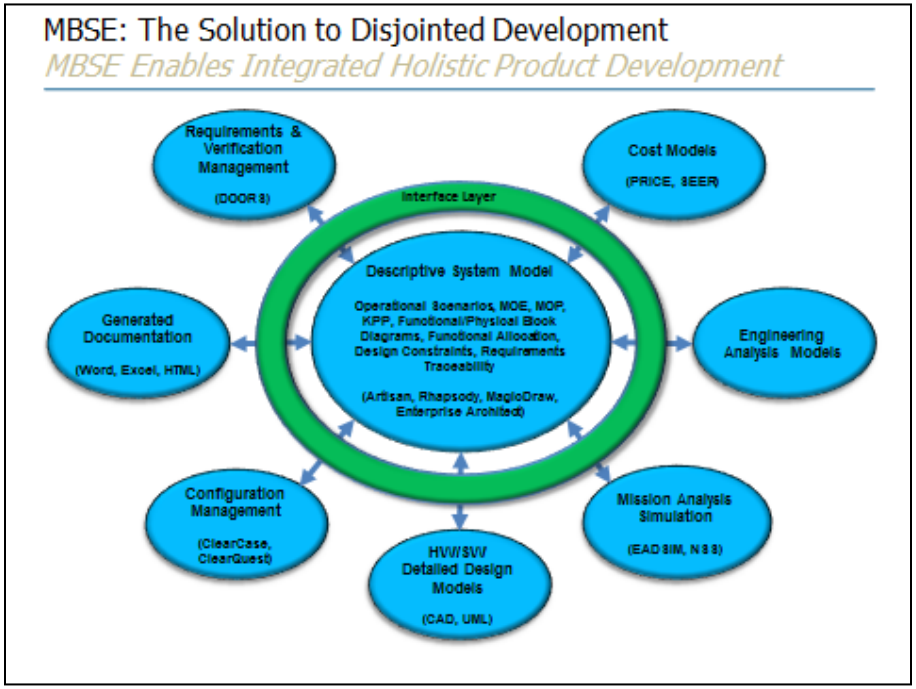
INCOSE [1] Affordability Working Group Definition:

- ***"Affordability is the balance of system performance, cost and schedule constraints over the system life while satisfying mission needs in concert with strategic investment and organizational needs"[2].***

- ***"Design for Affordability is the Systems Engineering practice of balancing system performance and risk with cost and schedule constraints over the system life satisfying system operational needs in concert with strategic investment and evolving stakeholder value"[2].***

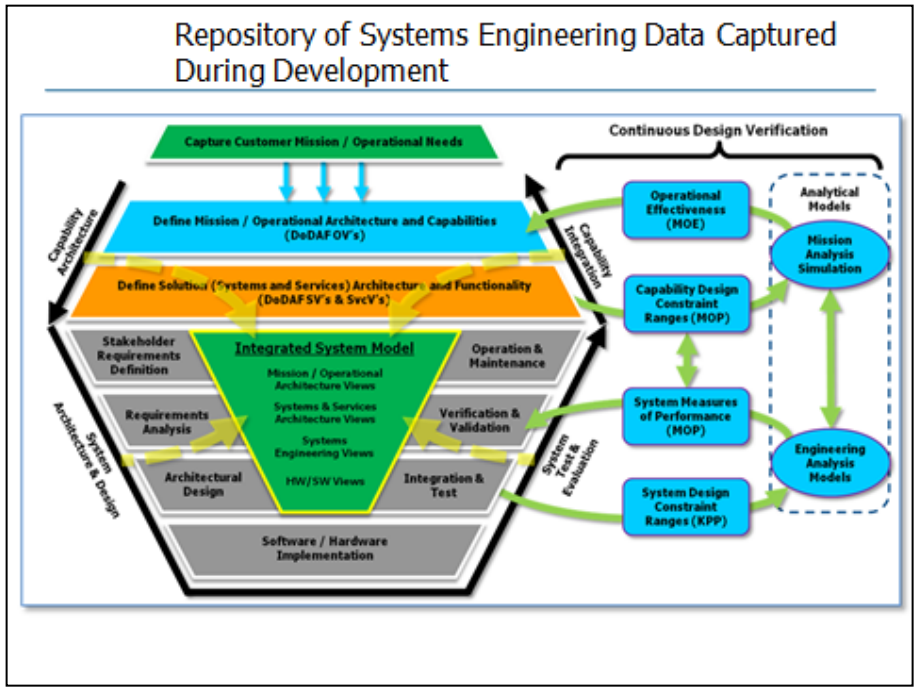
[1] International Counsel On System Engineering (INCOSE)
[2] http://www.incose.org/practice/techactivities/wg/details.aspx?id=affwg

INCOSE:
Model Based System Engineering (MBSE)



Integrated SE Repository:

- Requirements,
- Models,
  - Structural,
  - Behavioral,
- Parametric Performance Analysis,
- Hardware and Software (HW/SW) Implementation,
- Design Documentation,
- Verification and Validation (V&V) Test Results.



Holistic Integrated Development Environment:

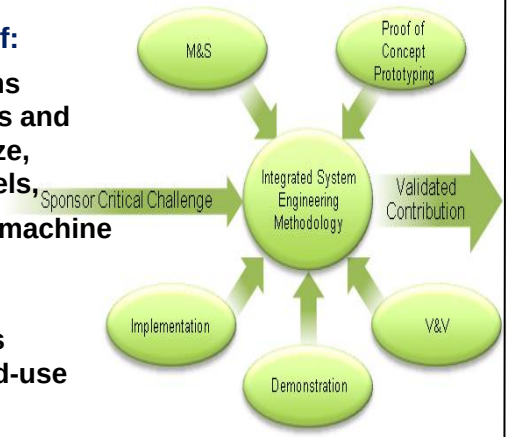
- Requirements,
- Methods,
- Tools,
- Framework/Reference Architecture
- Configuration Management
- Multi-discipline Models,
- System Interdependencies,
- Analysis/Effectiveness/Performance,
- Design/Documentation.

Model Based System Engineering Proof of Concept Exploration/Validation

MBSE Methodology

that Integrates a Network of:

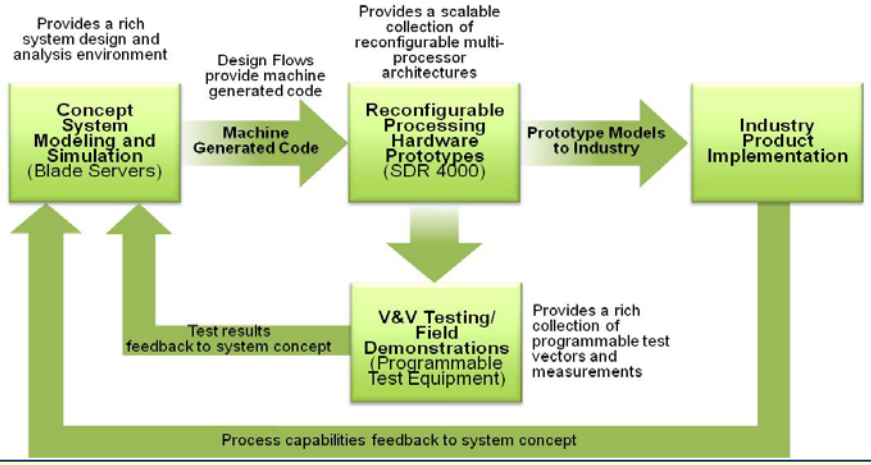
- **Rich top-down systems engineering processes and tools to design, analyze, optimize system models,**
- **Rapid and repeatable machine generated proof of concept prototypes,**
- **Credible requirements verification & intended-use validation,**
- **Environmental and field demonstrations,**
- **Implementation collaboration.**



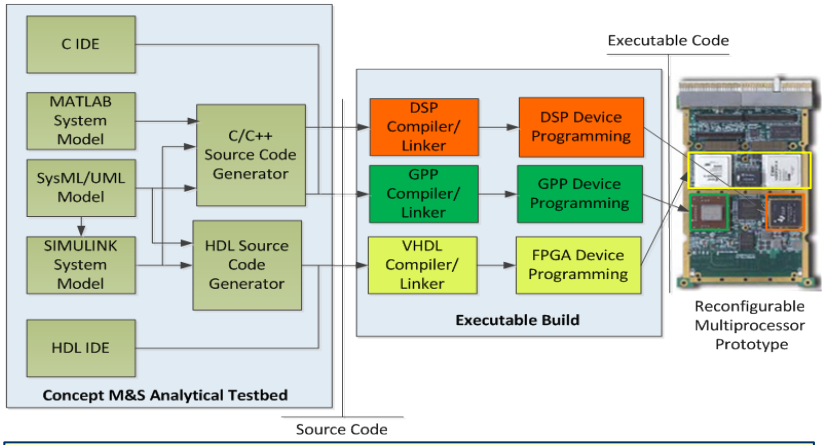
Performance, Cost, and Schedule Risk Management.

Model and Simulation (M&S): Blade engineering virtual prototype environment.

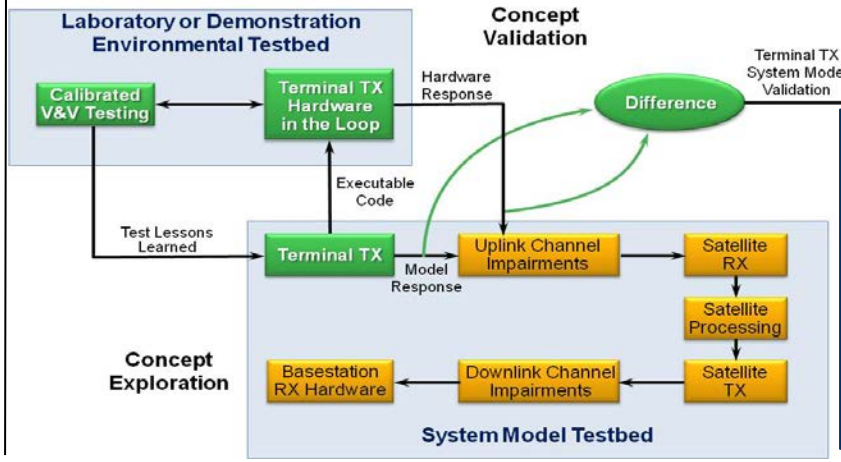
Target: portable reconfigurable processing chassis.



Low Cost of Change enables Agile Responses to Dynamic Requirements.

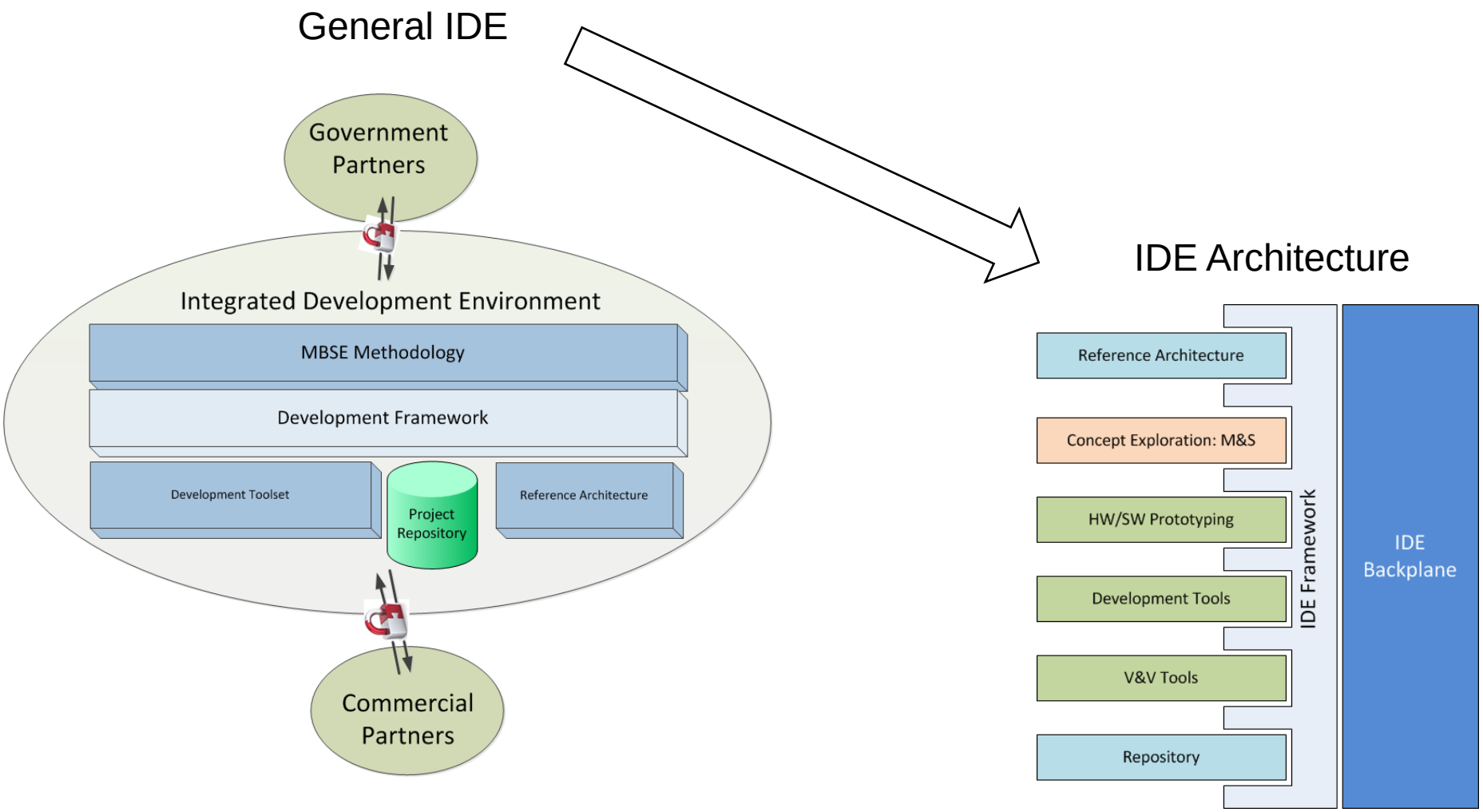


Rapid Generation of Executable Code; System models to POC prototypes.



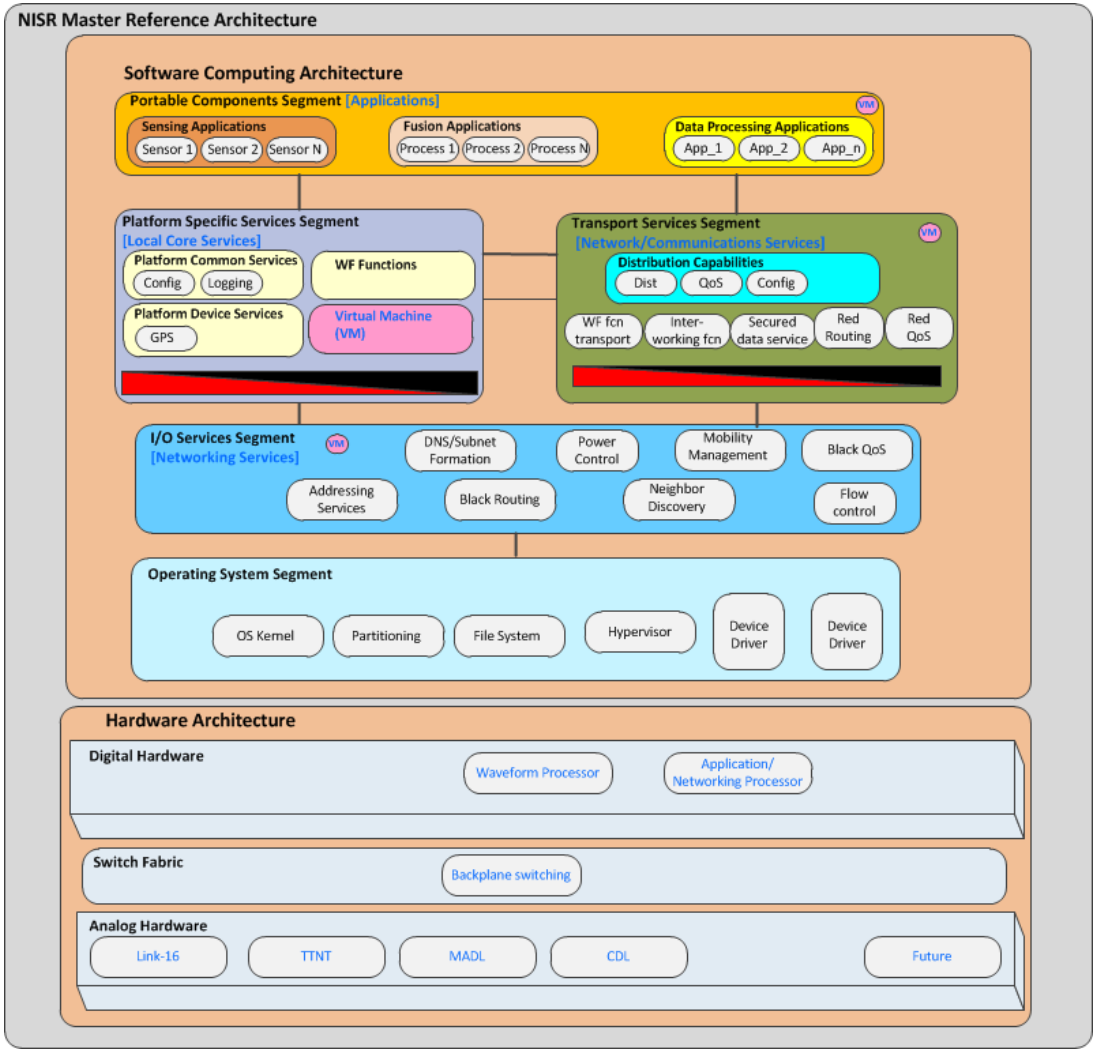
System Proof of Concept Prototype; Hardware/ Software in the Loop V&V Testing

Integrated Development Environment



A Master Reference Architecture

- **Consistent with Future Airborne Capability Environment (FACE) Technical Standard 2.0 *,**
  - **Applies fundamental software engineering principles,**
  - **Leverages extensive practical experience.**
- **Common computing software environment within processing segments,**
- **Application portability across all (legacy and new) platforms,**
- **Portable, capability-specific software applications across communications systems.**

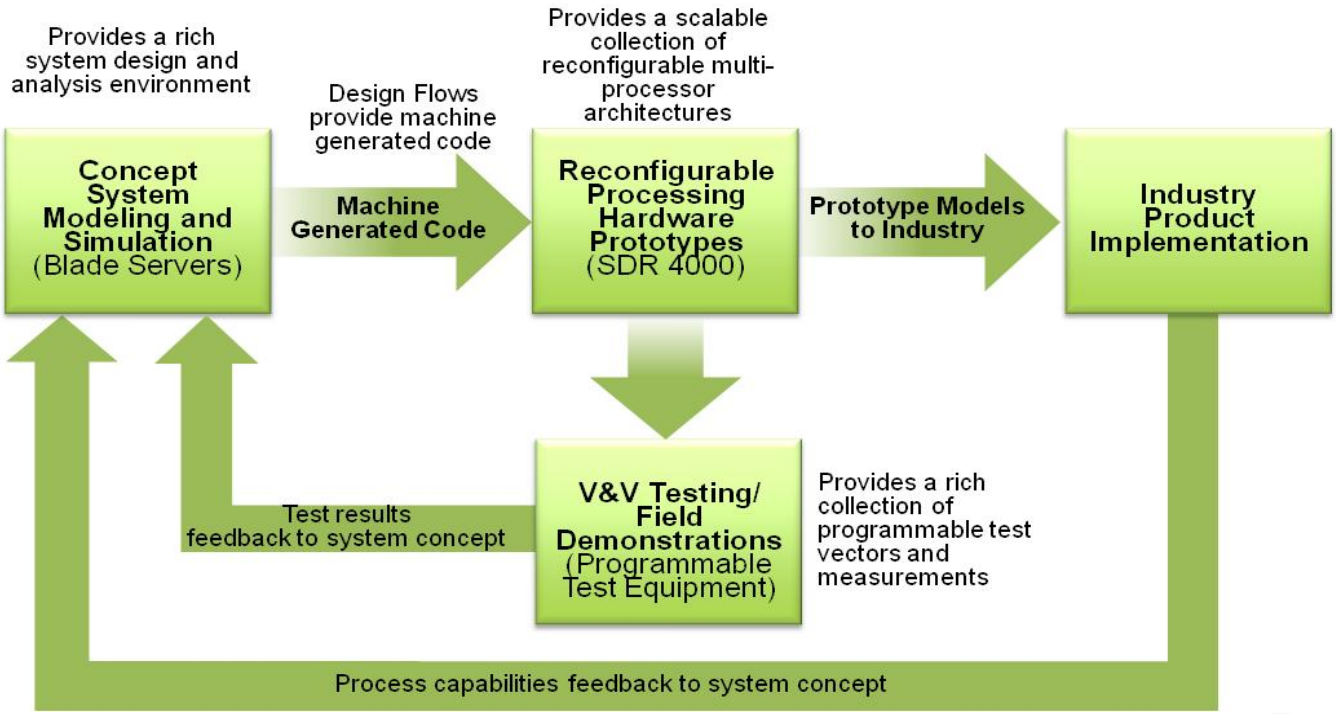


* Future Airborne Capability Environment (FACE) Technical Standard 2.0, NAVAIR Public Release 2013-149

IDE Methodology

Processes/Methods:

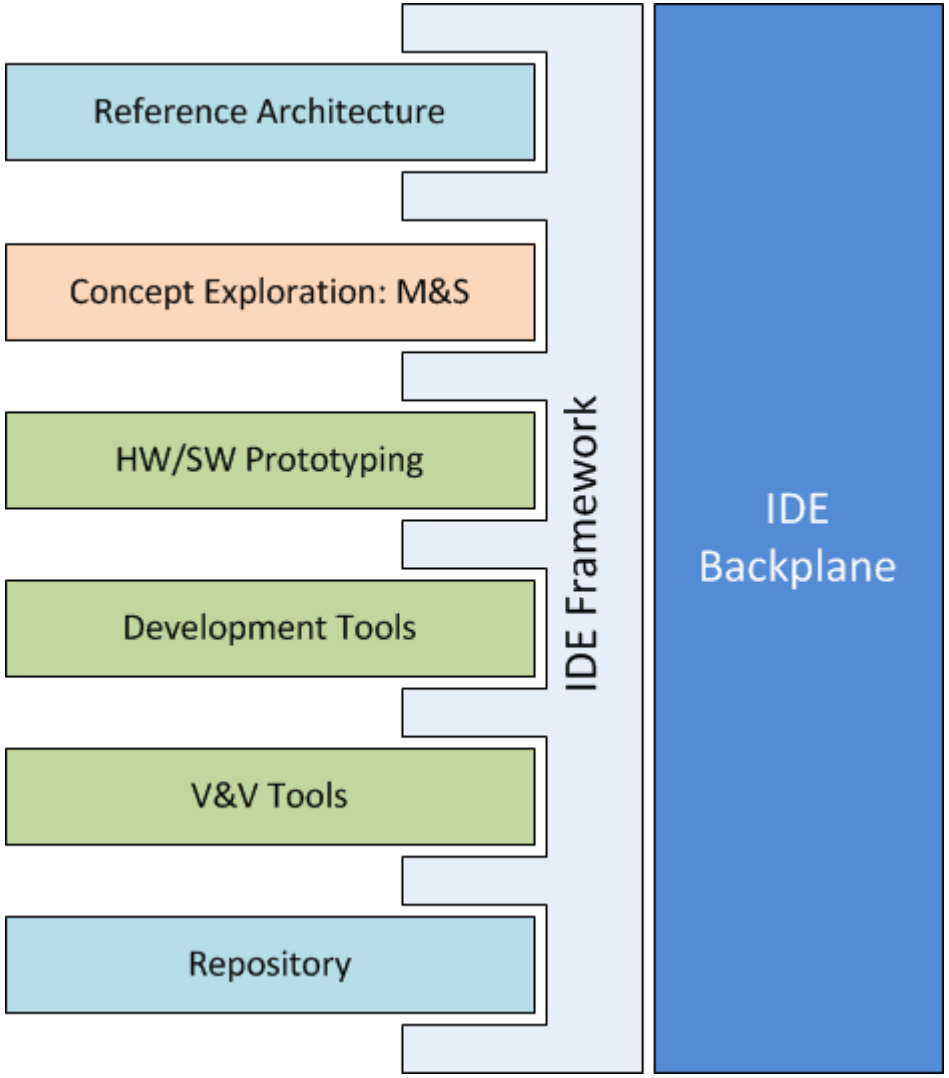
- Model Based System Engineering,
- Concept exploration,
- Concept implementation,
- Concept verification,
- Concept validation,
- Design for X where X is:
  - Affordability,
  - Manufacturing,
  - Assembly,
  - Test,
  - Six Sigma,
  - Others.



IDE Architecture

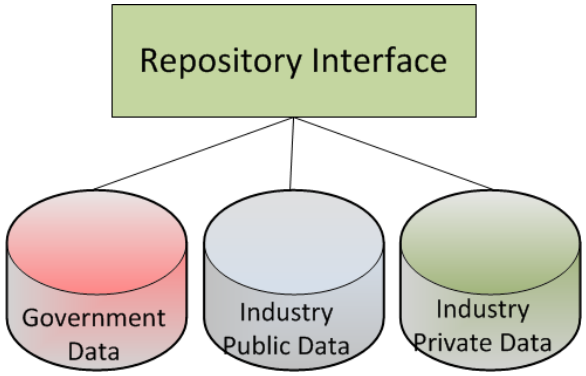
IDE Functions/Interfaces:

- HW/SW reference architecture,
- Concept exploration,
  - Modeling,
  - Simulation,
- HW/SW prototyping,
- Development Tools,
  - SW engineering,
  - Verification,
  - Validation,
- Repository,
- Framework/backplane.

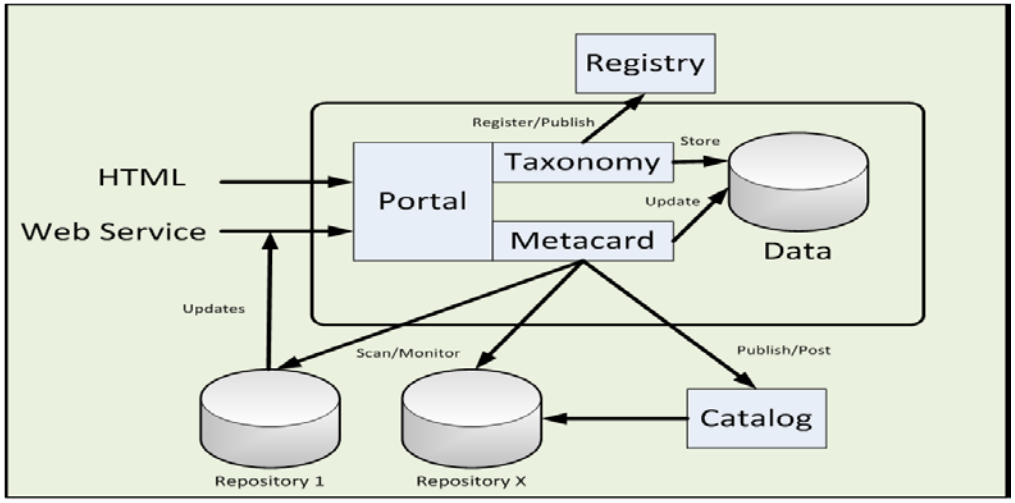


IDE Repository

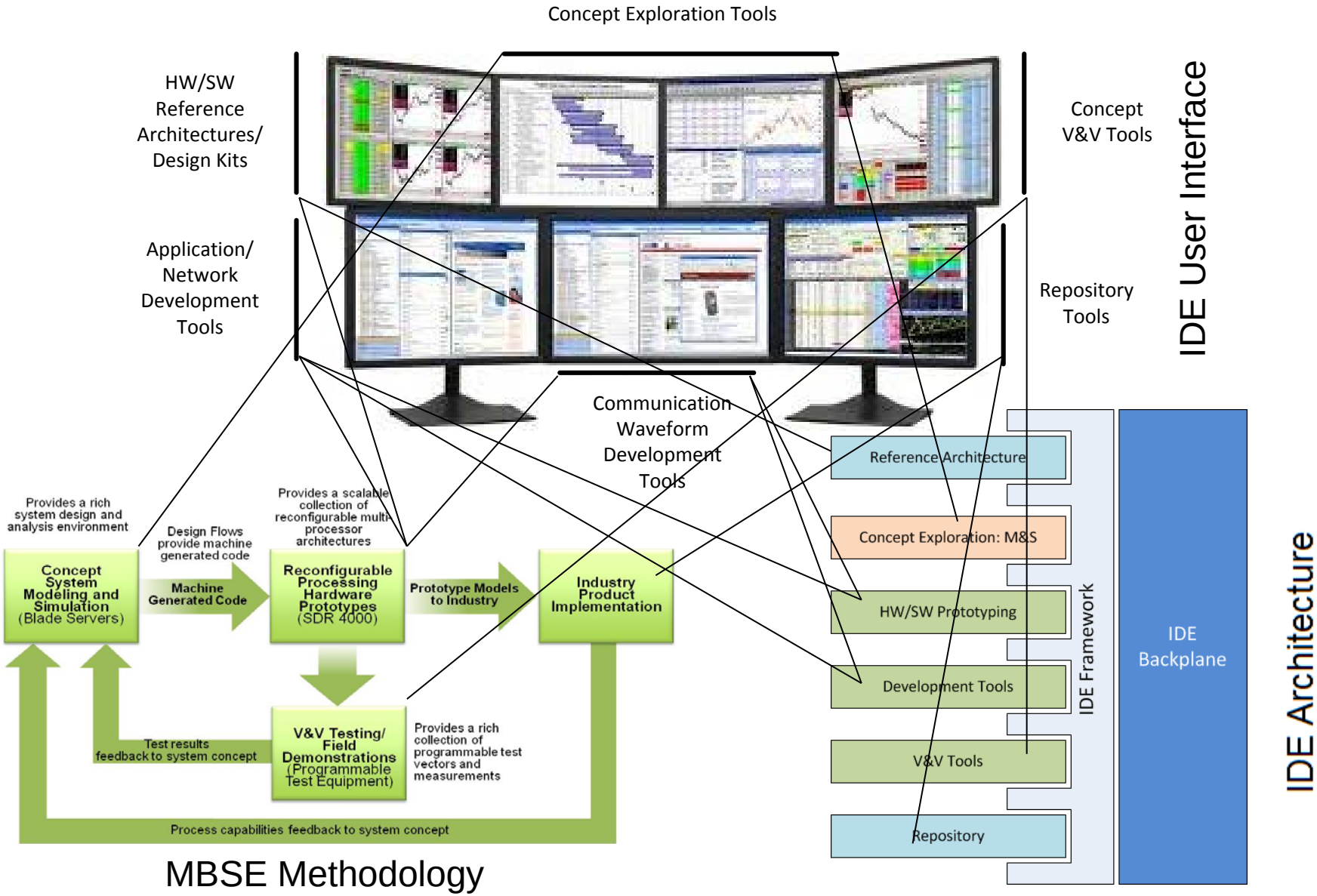
IDE Repository Architecture



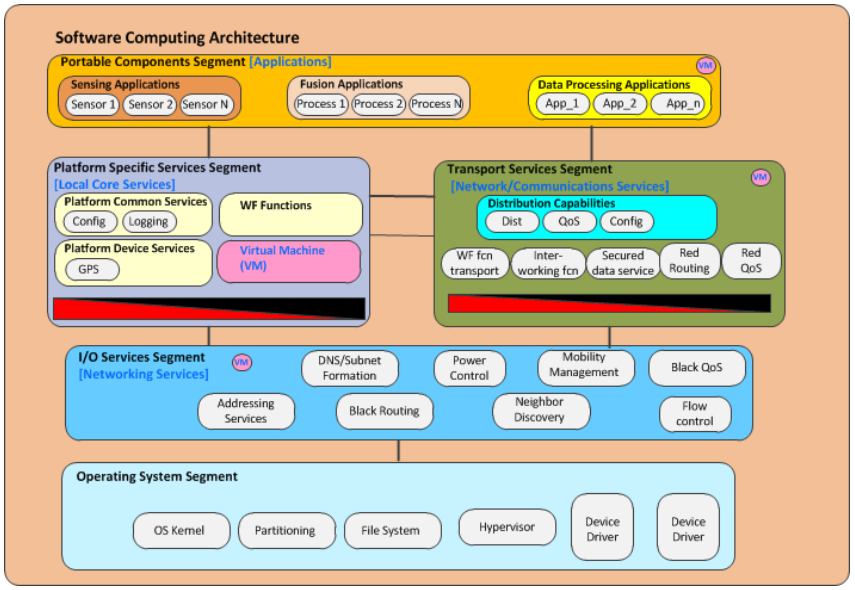
IDE Repository Interfaces



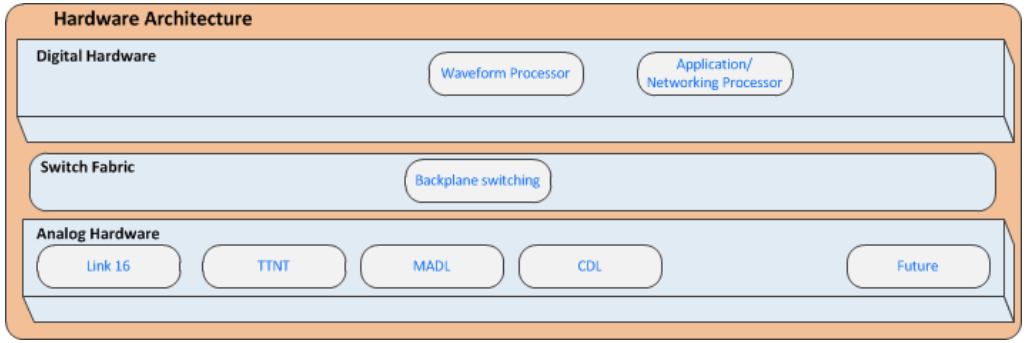
IDE Methodology/Framework Integration



IDE Reference Architecture Integration

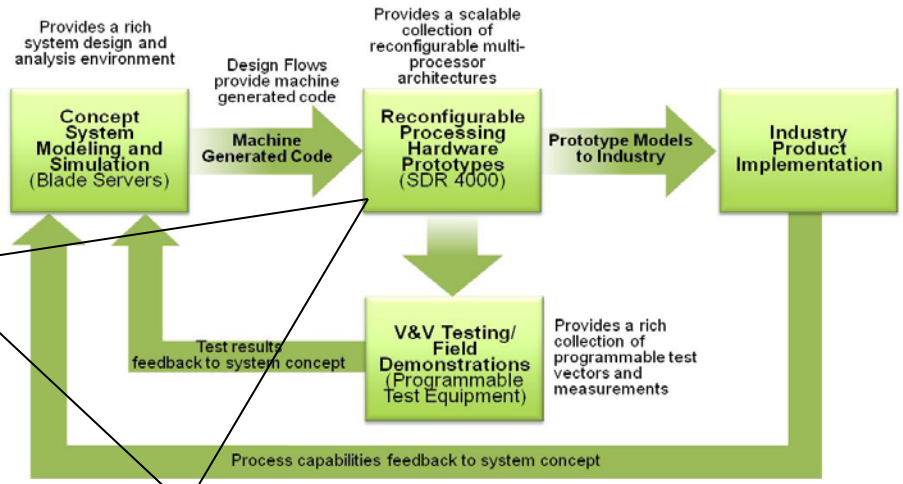


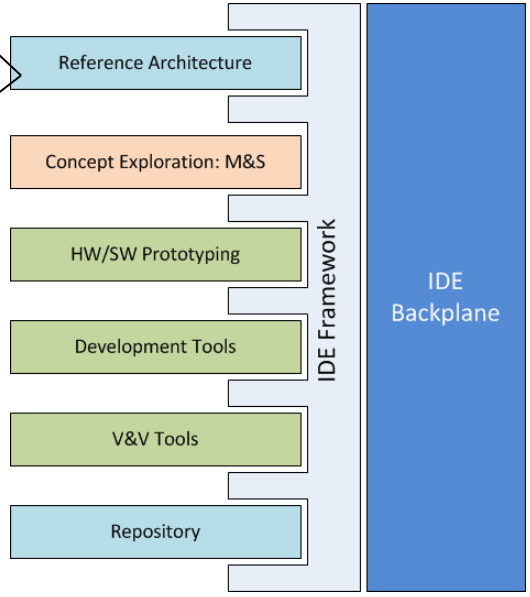
Software Reference Architecture



Hardware Reference Architecture

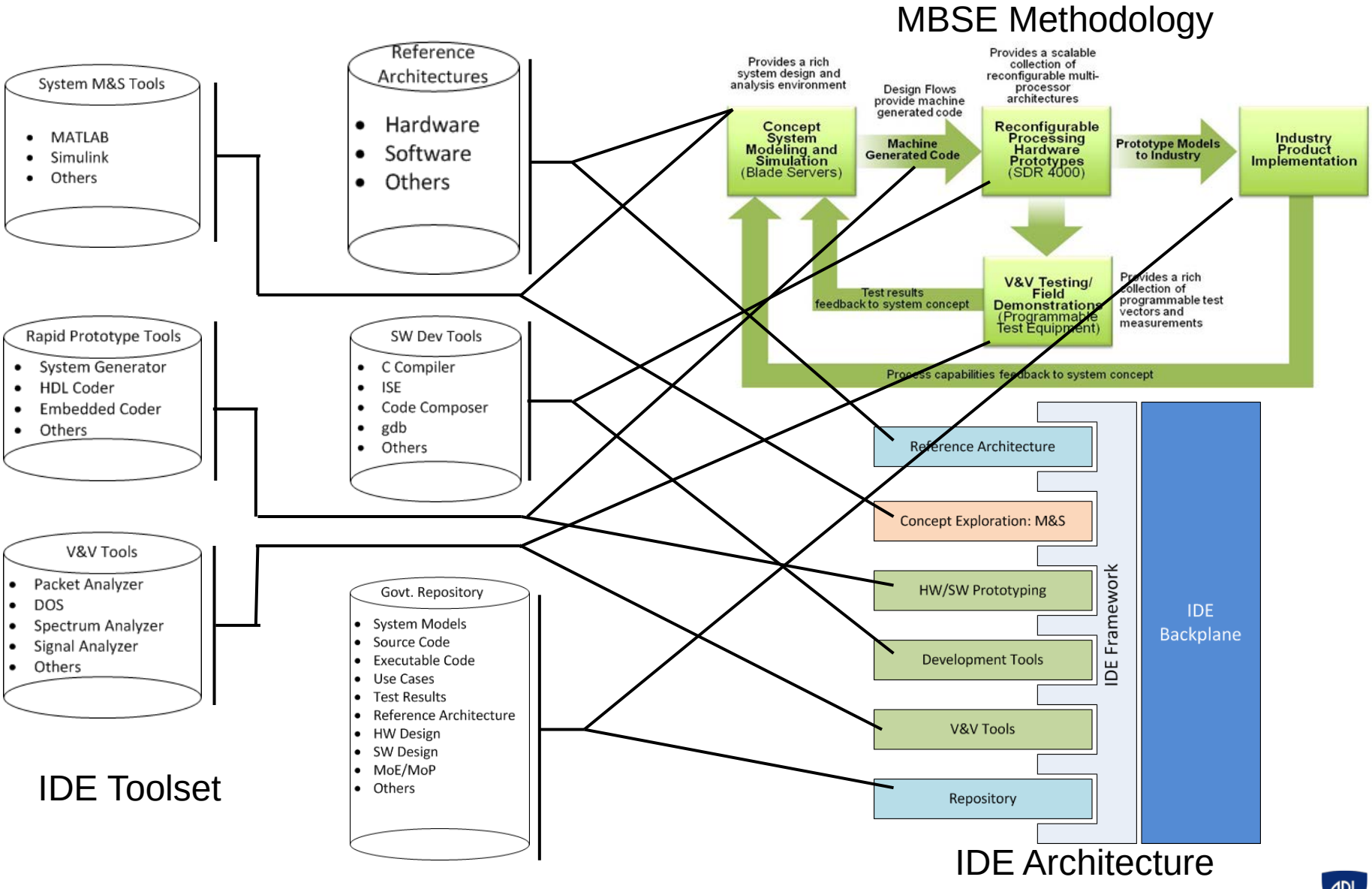
MBSE Methodology





IDE Architecture

IDE Toolset Integration



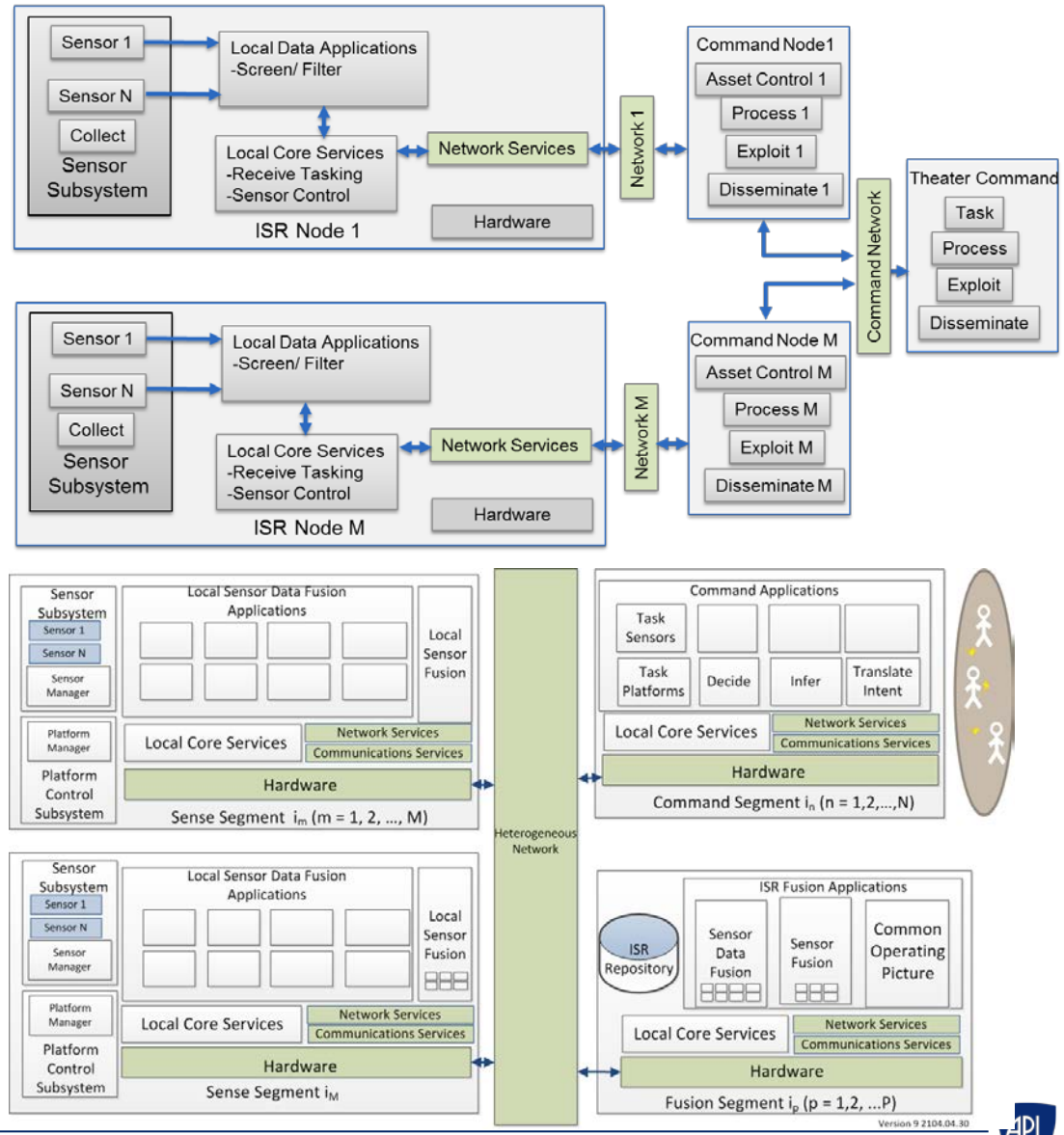
ISR Reference Architecture: As-Is and To-Be

<u>As – Is:</u>

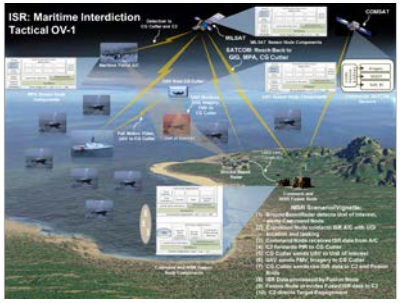
- Hierarchical network,
- Limited information scope,
- Limited collaboration.

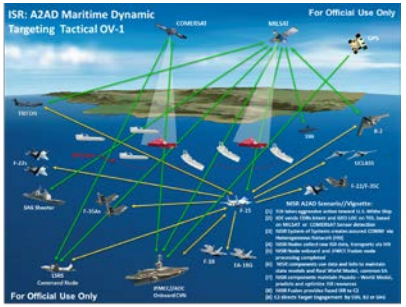
<u>To – Be:</u>

- Heterogeneous network,
- Flatter hierarchy network,
- Full information availability,
- Reduced timeliness,
- Full Collaboration.



Model Based Verification
Netted ISR Scenario Driven Message Model





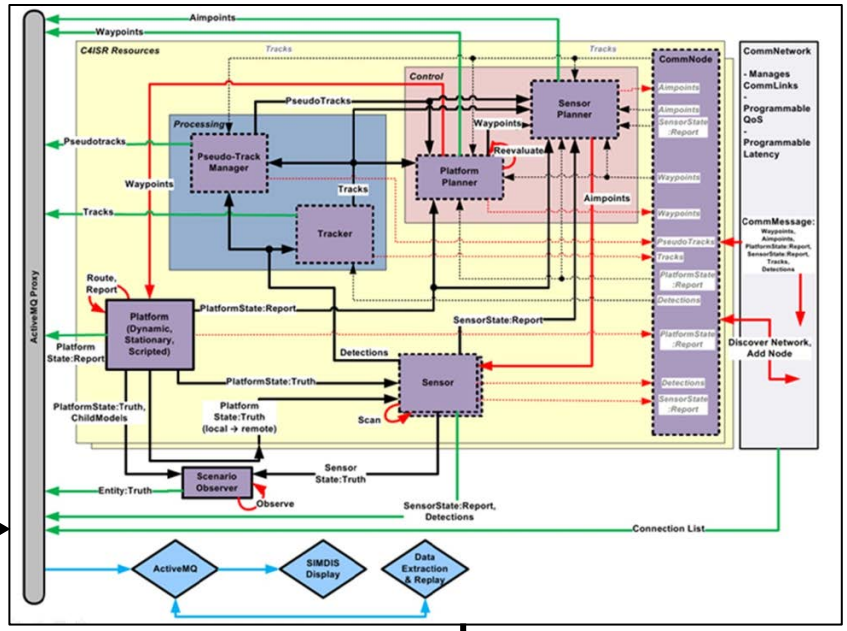
Scenarios
- Maritime Interdiction
- A2AD Maritime Dynamic Targeting

Scenario Assumptions for Simulation
- 15 min. ISR Mission preceding a maritime interdiction
- Square Open Ocean battlespace (30 nm)
- Shipping Lane 10 nm wide
- 10 non combatants
- 10 hostiles in southern 1/3 of shipping lane
- LEO Satellite with optical sensor overflies 4 mins into scenario

Netted ISR Assumptions for Simulation
- 2 UAVs/1 Satellite with representative mobility
- Collaborative Learning / Mission Planning

Traditional ISR Assumptions for Simulation
- **6** UAVs/1 Satellite with representative mobility
- **No** Collaborative Learning / Mission Planning

Closed Loop ISR Application

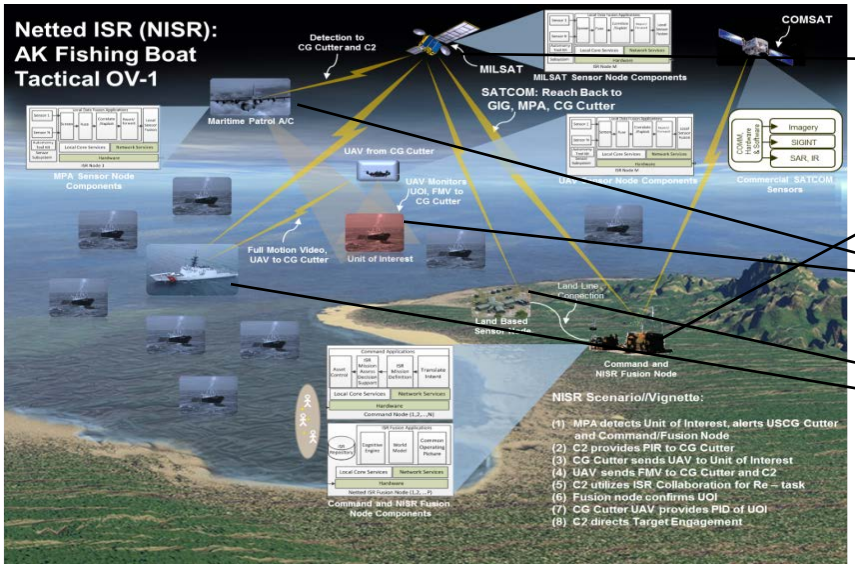


Message Logs
from simulations using CLISR Application

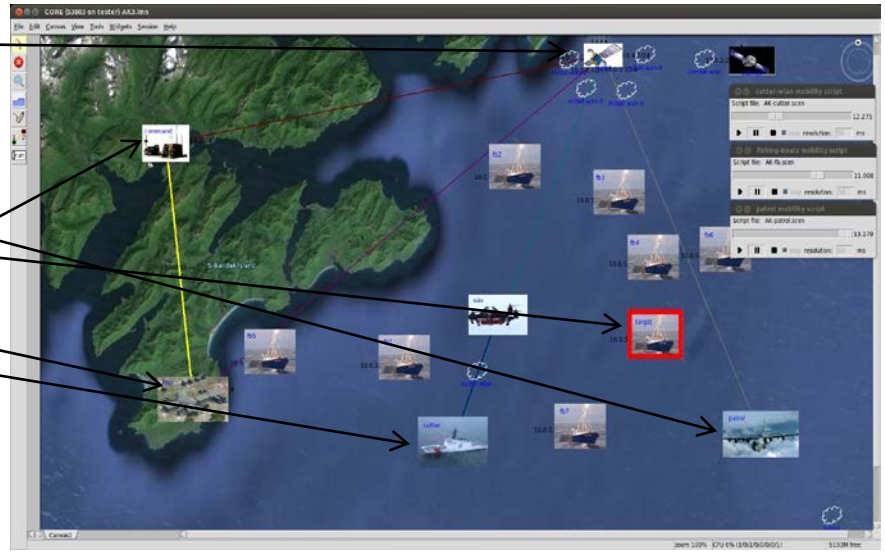
Model Based Concept Exploration
Netted ISR Virtual Prototype

- Scenario Driven Nodes
- NISR Reference Architecture Modeling
- Network Link Virtual Prototyping
- CLISR Message Model
- Network Concept Exploration

AK Scenario

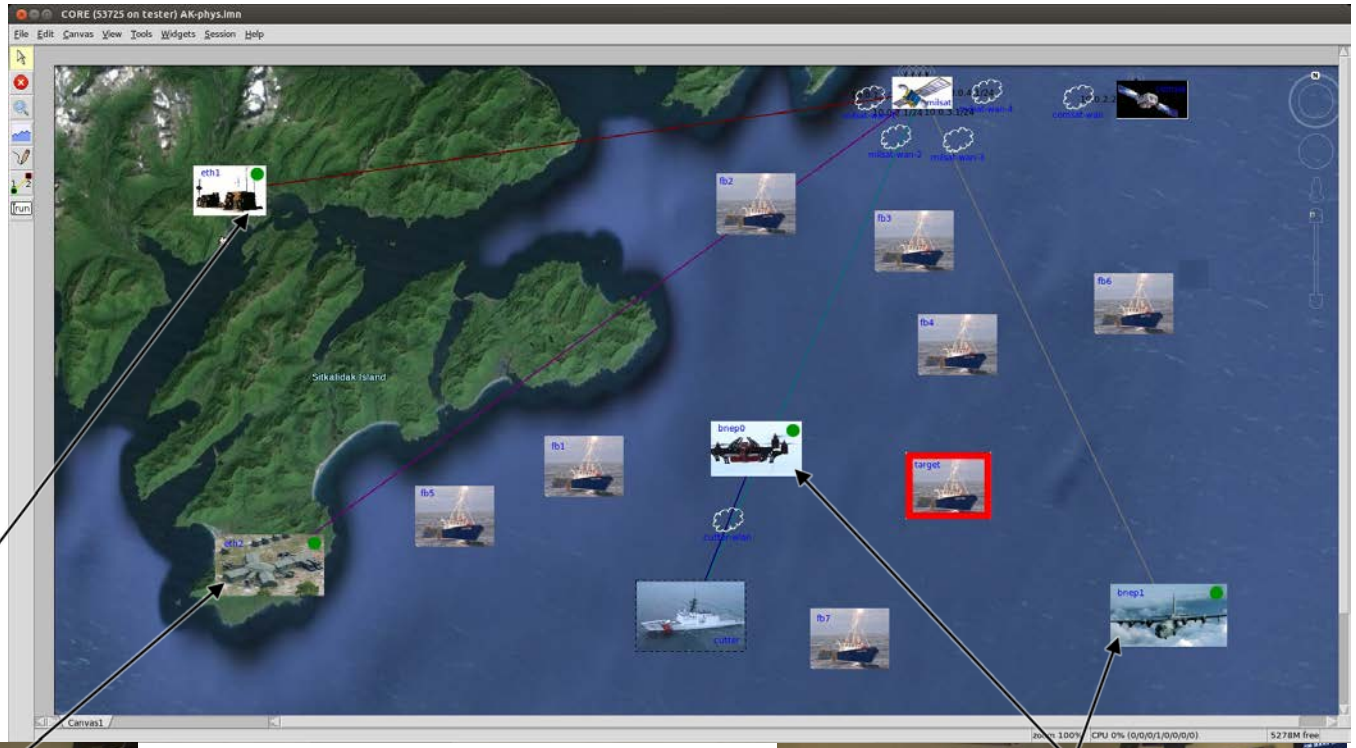


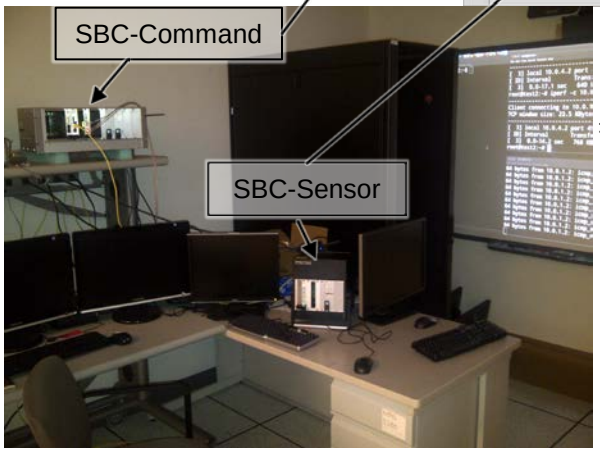
AK Virtual Prototype

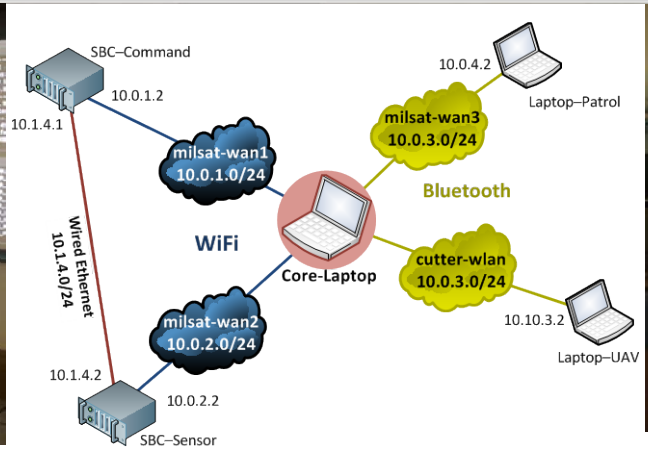


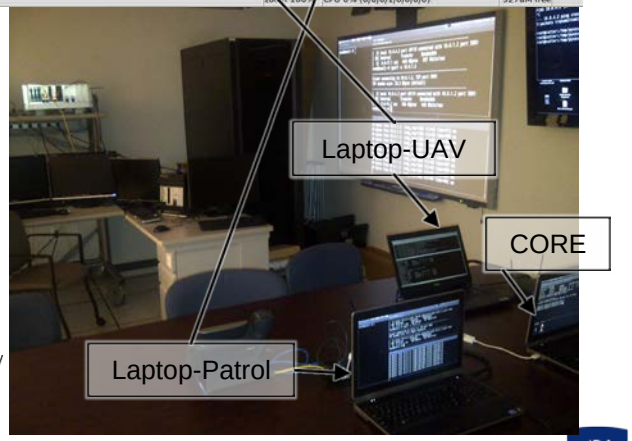
Model Based Concept Verification
Netted ISR Physical Prototype

- Physical Nodes Interconnected Through Network Virtual Prototype
- CLISR Message Model
- Real Time Software Hosted on Real Hardware
- Interactions Across Representative Network Links
- Verification and Validation Testing
- NISR Concept Validation





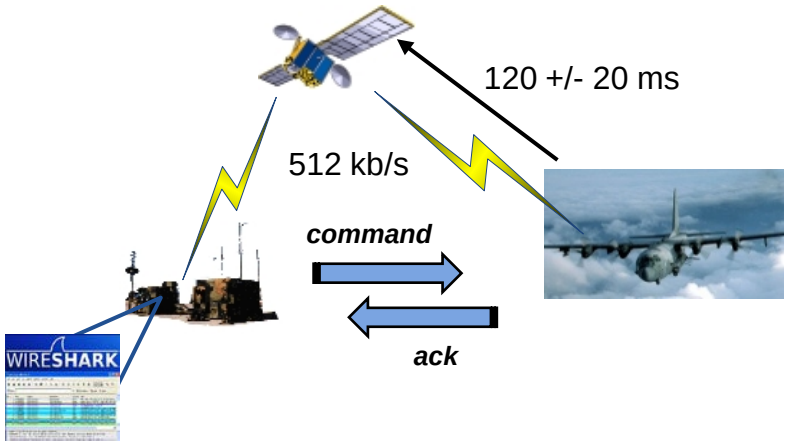




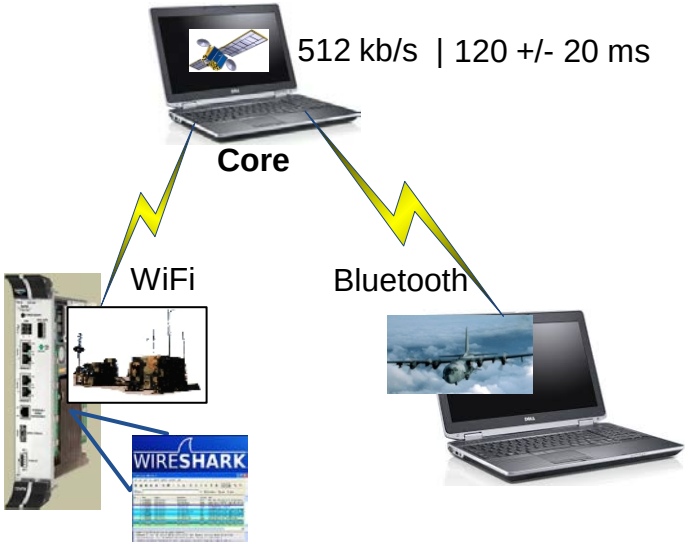
Model Based Verification
Netted ISR Verification Testing

Case		Command Node to Sensor Node, *ping*	Sensor Node to Command Node, *iperf*
#1	C2 Traffic Only	Continuous / 1 s interval	
#2	C2 Traffic + Sensor Data Transfer	Continuous / 1 s interval	Attempt transfer of ~1MB in 15 sec w/5 sec wait

PoC Virtual Prototype



PoC Physical Prototype



Affordability Impact of MBSE

- **Integrated, iterative, multi-discipline, multi-loop (I2M2) methodology enables efficient concept exploration, prototyping, and verification; Result…**
  - **Rapid concept maturation cycle time.**
  - **Low cost of change.**
- **Integrated development environment (IDE):**
  - **MBSE methodology,**
  - **Reference architectures,**
  - **IDE framework,**
  - **Toolsets.**
- **MBSE informed affordability of the NISR SoS concept:**
  - **Reduction in required resources,**
  - **Reduction in manpower.**

Conclusion

- **DoD SoS complexity and cost challenges require SE that informs design for affordability.**

- **MBSE as a methodology within an IDE provides an effective means to meet system engineering challenges.**

- **MBSE contributed to Netted ISR study results:**
  - **To-Be netted ISR concept "verified" increased effectiveness in complex environments and reduced cost compared to As-Is ISR,**
  - **Established framework for follow-on study.**

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