Open System Architecture as Applied to Air-Launched Weapons

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Modular Open Architecture Definition

The Department of Defense's (DoD) modular open systems approach (MOSA) is to design systems with **highly cohesive**, **loosely coupled**, and **severable modules** that can be competed separately and **acquired from independent vendors**. This approach allows the Department to acquire warfighting capabilities, including systems, subsystems, software components, and services, with more flexibility and competition. MOSA implies the use of modular open systems architecture, a structure in which **system interfaces share common, widely accepted standards**, with which **conformance can be verified**.

Weapons Open System Architecture (WOSA)

- **Non-proprietary architectural standards for all munitions developed and maintained with industry consensus**
  - **open key-interfaces, modularity and composition requirements**
- **Goal to improve acquisition efficiency**
  - **Reduce integration cost/risk**
  - **Reduce Lifecycle Cost**
  - **Enable adaptability and reuse**
  - **Decouple software/subsystem from hardware**
  - **Decrease development and integration time**
  - **Reduce obsolescence impacts via competition & rapid tech insertion**
- **Open Architecture products needed**
  - **Non-proprietary architecture (Government Owned)**
    - **Detailed architecture specification**
    - **Architecture Reference Model**
  - **Compliance testing tools**
  - **Compliance verification**

Government Owned Architecture Industry/Government Consensus

- Government and Industry have worked together through voluntary consensus-based WOSA Interface Control Working Groups
  - Modular design is based primarily on widely supported, consensus-based standards for key interfaces
- Interface Control Working Group (ICWG)
  - Quarterly meetings with technical interchange meetings monthly
  - Released Ver 1.3 WOSA Specification July 2019
  - Complete Weapon Specification
- Government architecture that can be independently tested to ensure compliance with standards

Partnership
through

NDIA

Weapon Open Systems Architecture Development Team

WOSA Government Team

Chaired by AFRL/RW

Government Support

- WINTEC, Inc. – An Innovative Engineering Company
- ENGILITY – Engineered to Make a Difference
- Space Dynamics Laboratory – Utah State University Research Foundation

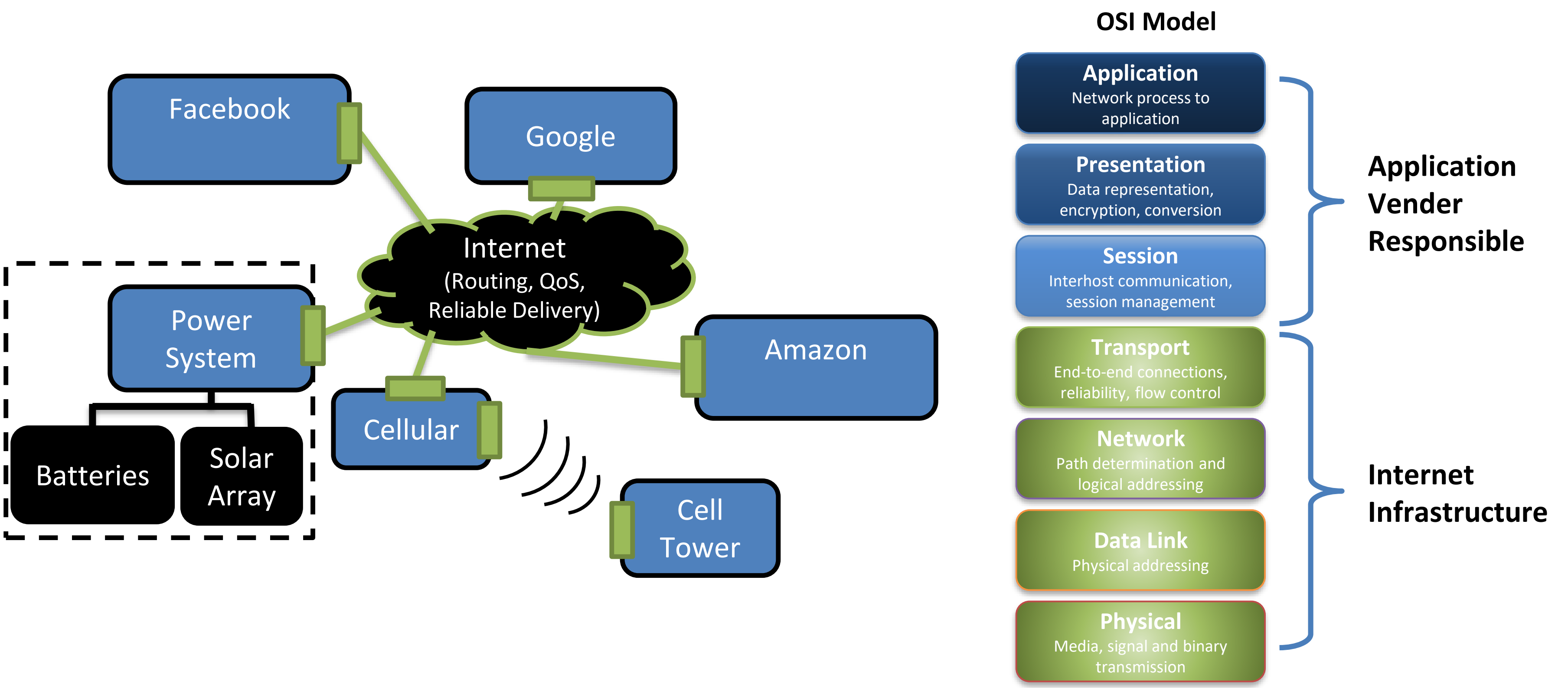
Prime Contractors

- Lockheed Martin
- Raytheon
- Boeing
- Textron

Consensus-based Open System Architecture Standards

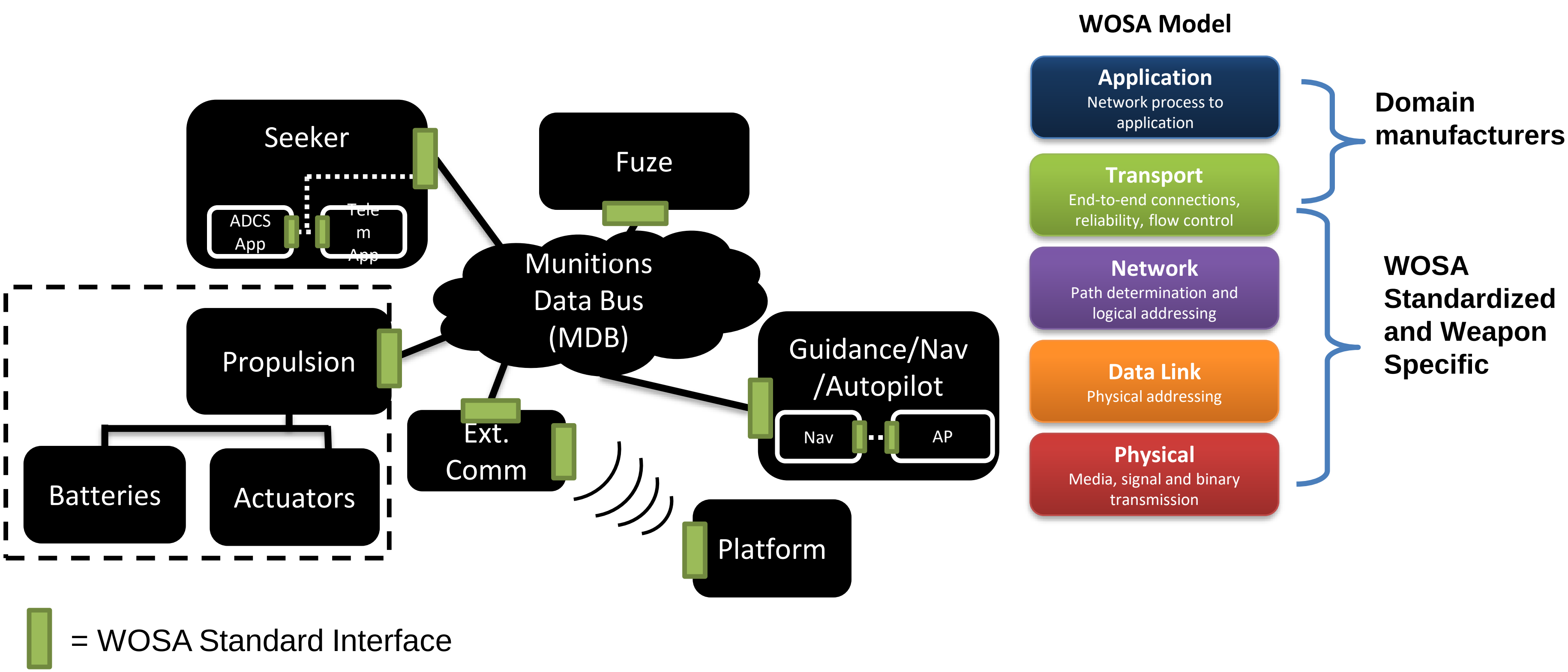
MBDA, Rockwell Collins, Northrop Grumman, General Atomics, Orbital-ATK, General Dynamics

Standardized Internet as of Today



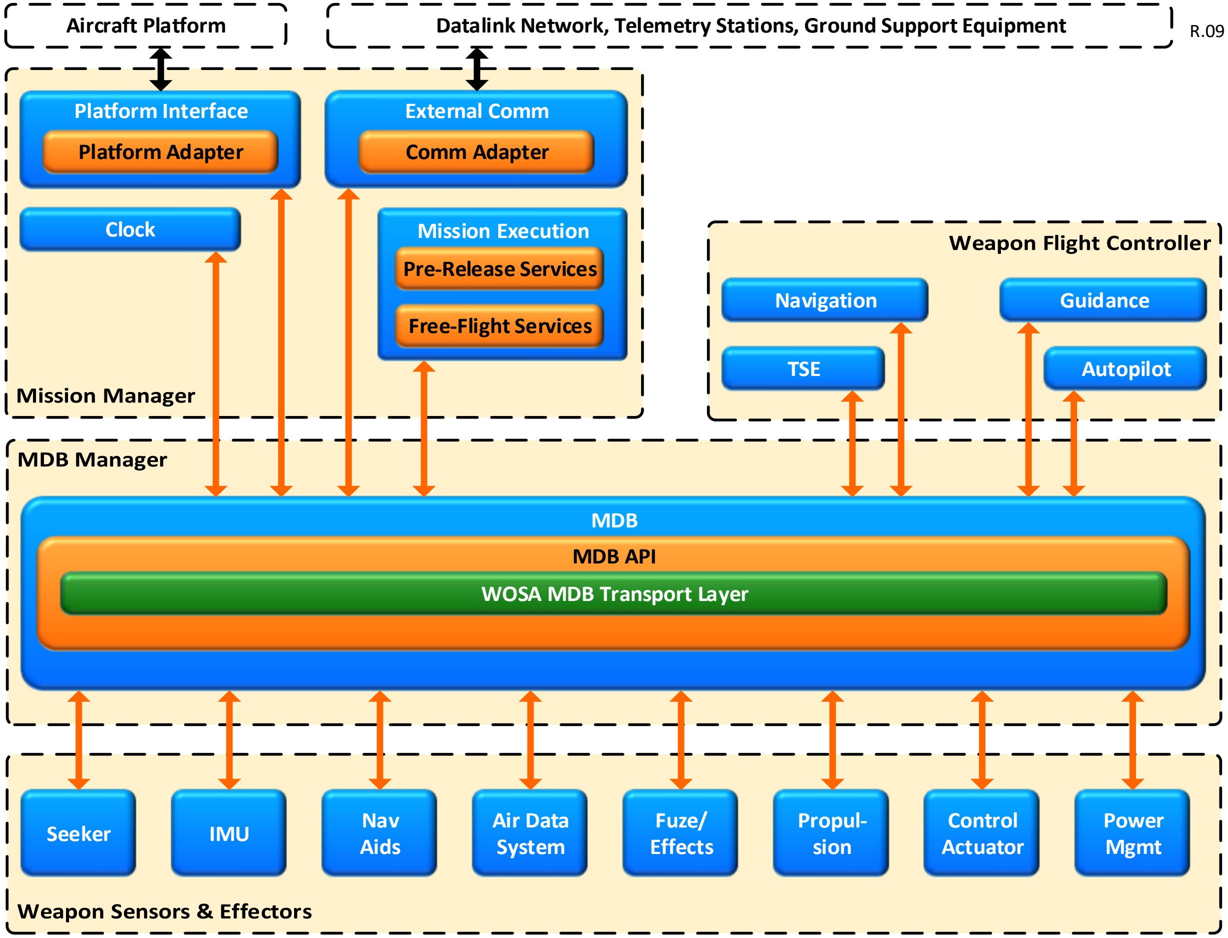
= Standard Internet Interfaces

WOSA Applied to Weapons



- **Munition Open Architecture Test and Evaluation Laboratory (MOATEL)**
  - **Evaluate performance of the Munitions Data Bus (MDB)**
  - **Will not evaluate performance of other domains (i.e. Seeker)**

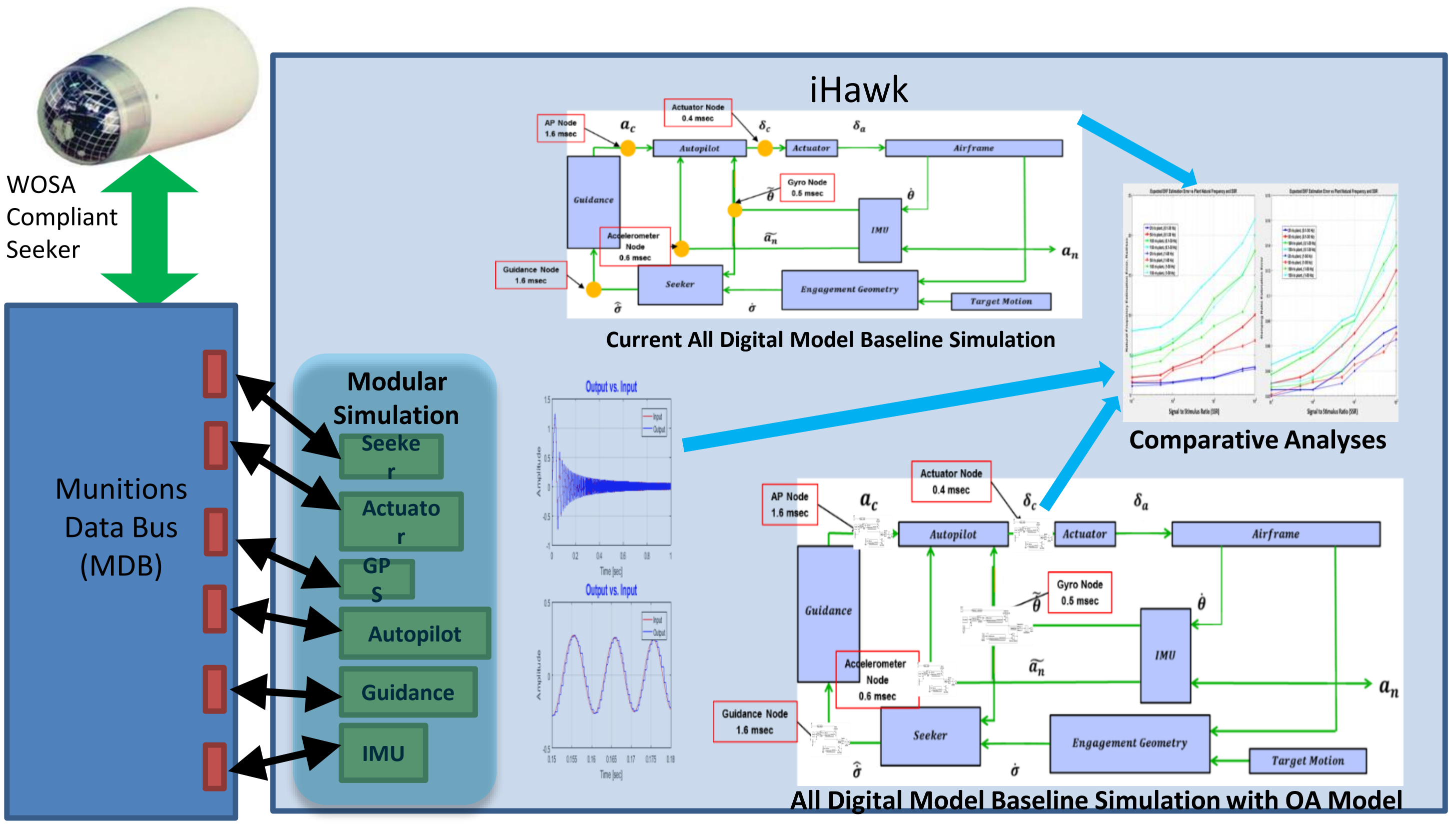
WOSA Framework



- Potential breakpoints of a system
- MDB is a message routing device (i.e Ethernet router)
- Message header / payload formats are defined by ICD
- Most important attributes of messages are Frequency, Latency and Jitter
- Custom message formats allowed for implementation specific scenarios

System Analysis

Munitions Open Architecture Test and Evaluation Lab (MOATEL)



- **Modular Test Environment**
- **Verification Plan**
- **Document review**
- **Real Time test tools**
- **Verification Report**
- **Architecture review**

Analysis Plan

- Linearize airframe from non-linear data
  - Design stable terminal autopilot
- Frequency domain stability analysis
  - Root locus
  - Bode plots
    - Phase and Gain Margin Baseline Design
  - Nyquist plots
- Add Open Architecture data transport delay models
  - Set cycle time (update rate) requirements to maintain stability and performance
- Time Simulation for non-linear modeling and trajectory analysis

Isolated Nodal Analysis: Varied Range

- Maximum allowable delay per factor for each variant.
  - Based on when the full loop system dropped below 6 dB gain margin and 45 degree phase margin
- Using different range for each variant based on its individual baseline test
  - Range per variant was based on the larger point where:
    - Gain margin = 8 dB
    - Phase margin = 65°

Architectural Delay	Variant 1		Variant 2		Variant 3		Variant 4		Variant 5		All Variants
	Range = 293.03 m		Range = 134.56 m		Range = 247.09 m		Range = 109.92 m		Range = 46.17 m		
	Breakpoint (msec)		Breakpoint (msec)		Breakpoint (msec)		Breakpoint (msec)		Breakpoint (msec)		
	G.M.	P.M.	G.M.	P.M.	G.M.	P.M.	G.M.	P.M.	G.M.	P.M.	Max Allowable Delay (msec)
Actuator Node	8.5	7.9	7.0	16.8	10.4	6.3	7.6	4.8	7.6	14.9	4.8
Gyro Node	33.2	38.6	5.1	9.9	44.8	49.8	33.0	36.2	18.2	39.8	5.1
Accel Node	27.9	12.3	219.7	1000.0	19.1	6.3	17.8	6.0	56.8	23.3	6.0
AP Node	17.7	33.4	401.4	1432.1	24.9	27.7	17.6	22.7	15.8	31.5	15.8
Guidance Node	17.7	33.4	401.4	1432.1	24.9	27.7	17.6	22.7	15.8	31.5	15.8

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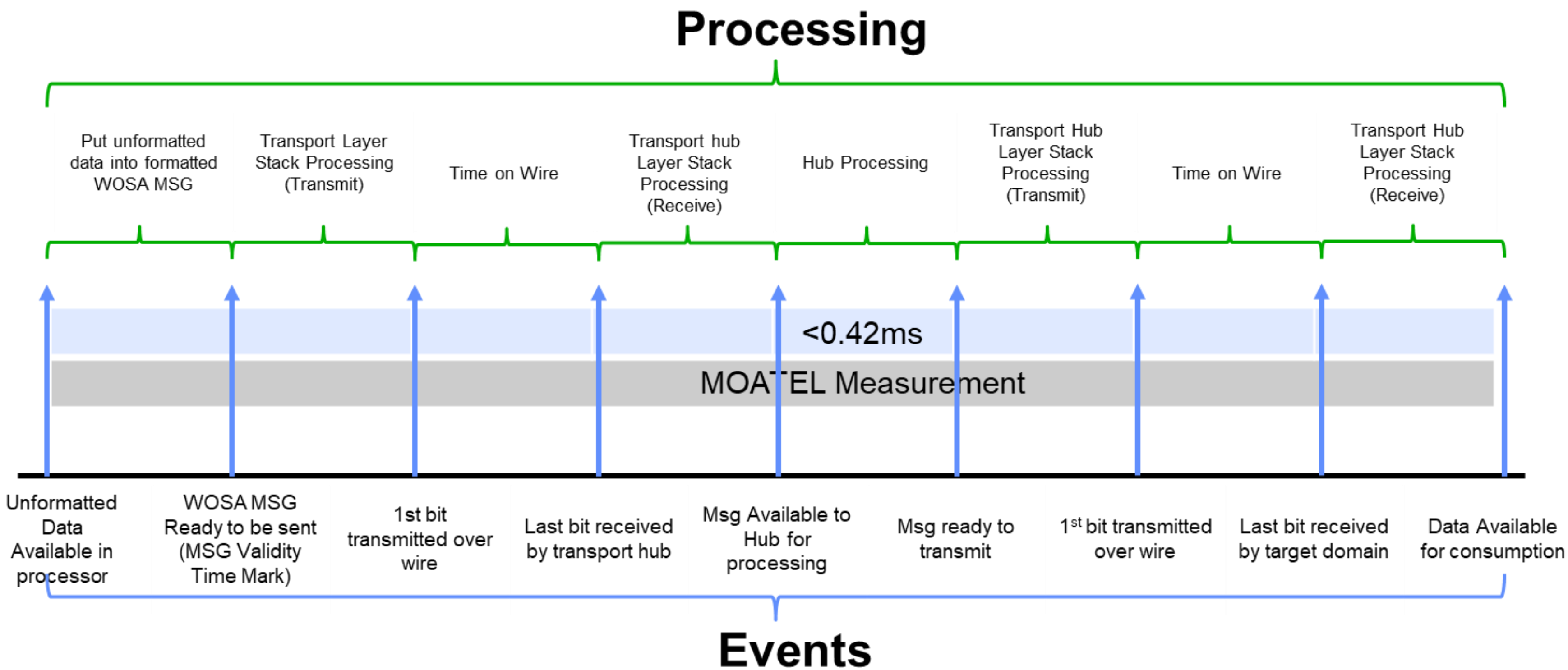
Munition Data Bus Latency Requirements

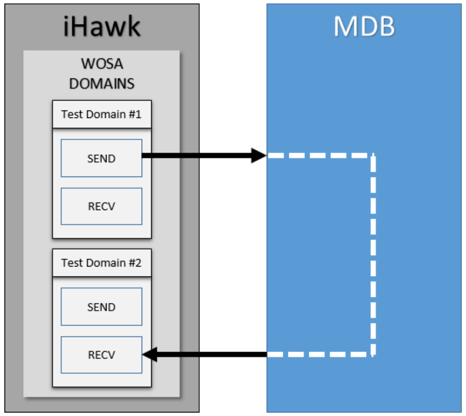


MDB Delay	Max Acceptable Latency (msec) Requirement
Actuator Node	0.42
Gyroscope Node	0.50
Accelerometer Node	0.56
Autopilot Node	1.25
Guidance Node	1.25

Interface Verification Test

Objective: Validate interface byte order and interface functionality

(MDB BIT/Status?)



Test Details:

- 2 Domains – 1 Sender, 1 Listener
- 24 byte signal will be sent across the bus at 1 Hz
- 10 second test
- Repeated fro all domain interface types pairings

Pass/Fail criteria:

- All 10 messages are received by listener domain for each interface type pair

		Test Domain 1 Interface Type			
		USB	UDP	RS-232	RS-422
Test Domain 2 Interfac e Type	USB				
	UDP				
	RS-232				
	RS-422				

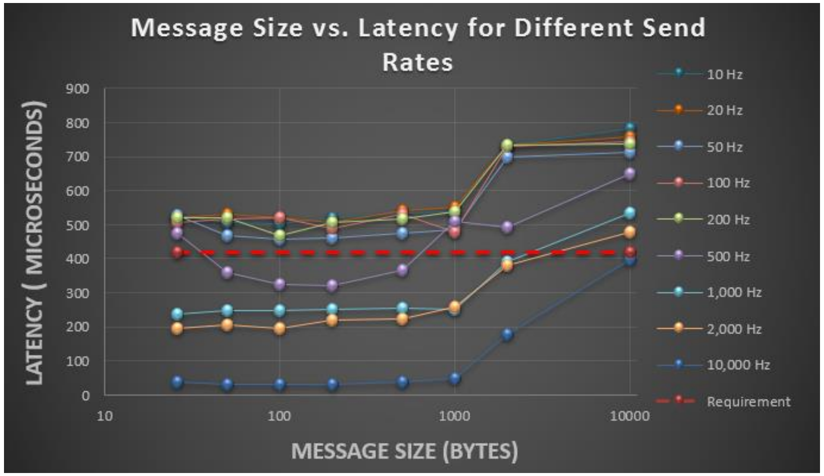
Interface Loading Test

Objective: Determine how the MDB will act under varying loads and see how varying throughputs affect the latency and jitter

		Rates (Hz)							
		10	50	100	200	500	1000	2000	10000
Size (Bytes)	2 4								
	50								
	100								
	200								
	500								
	1000								
	2000								
	10000								

Test Details:

- 2 Domains - 1 Sender, 1 Listener
- 9 rates tested (10 - 10,000 Hz) with 8 msg sizes (26 - 10,000 bytes) for a total of 72 tests



Pass/Fail criteria:

- No specific pass/fail identified
- Characterization of performance limitations of MDB

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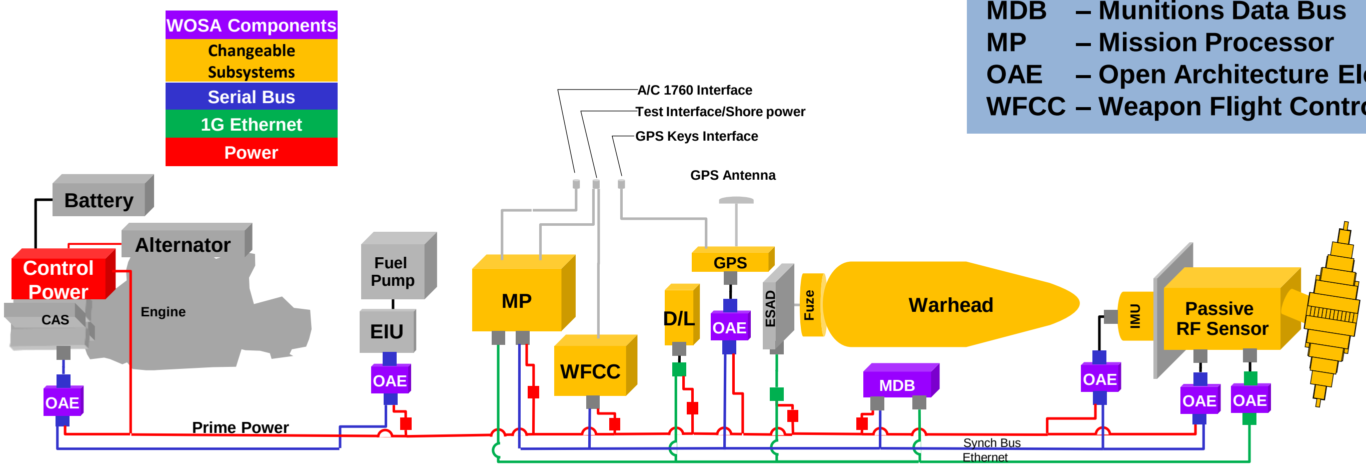
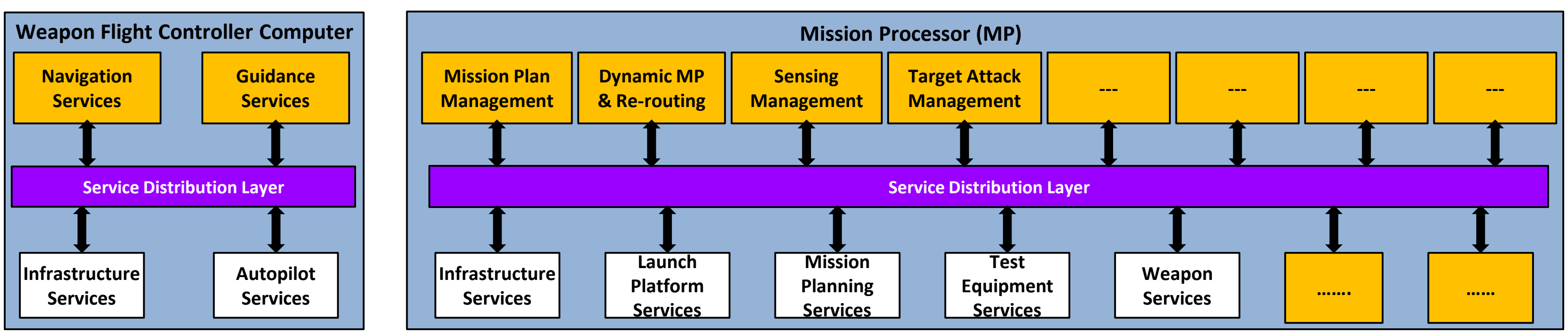
Weapon System Decomposition

CAS – Control Actuator System
D/L – Data Link
EIU – Engine Interface Unit
ESAD – Electronic Safe And Arm Device
MDB – Munitions Data Bus
MP – Mission Processor
OAE – Open Architecture Electronics
WFCC – Weapon Flight Controller Computer





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Acquisition Strategy Implementing Open Architecture

- Weapon designed with Open Architecture (based on WOSA)
  - Assume four major components (propulsion, GNC, effects, and seeker)
  - Government defines breakpoints
  - Government defines and owns physical and logical interfaces between components

Open Architecture Based Acquisition Strategy

- Industry's Business Strategy that implements Open Architecture should be based on specific acquisition strategy for that particular weapon
  - Warfighter, acquisition program office, test community, and logistics must work together to establish battle rhythm for development / test / production / sustainment of weapon
  - Open architecture should enable new, more flexible modification methods to weapons throughout its lifespan
- Acquisition strategy can then be conveyed to industry to adjust their business model accordingly
- Acquisition Strategy examples (Use Cases) can be used to talk through issues or identify potential risk areas

Open Architecture Based Acquisition Strategy Use Case #1

Premise – Weapon designed for technology refresh

- **Assumptions:**
  - Gov owns interface between components
  - OML / mass properties don't change but functionality can incrementally improve
  - Interfaces have been designed to accommodate future operational growth
- **Example:**
  - Seeker is the component identified for tech refresh
  - Warfighter accepts a "60% performance" for first weapon variant
  - Interfaces, OML, mass properties, etc. are Gov owned and fixed
  - First weapon variant takes off-the-shelf seeker and integrates components together
  - S&T community matures next generation seeker
  - Vendor takes new seeker and integrates with existing components
  - Process is repeated until desired seeker performance is achieved
- **Benefit to Gov:**
  - Quickly delivers a capability to warfighter – inventory begins to grow
  - Conduct A/C integration once – first variant goes through all steps, next do not
  - Reduce logistics costs – replace old seeker with new and have only one variant in inventory

Open Architecture Based Acquisition Strategy Use Case #2

Premise – Common component used across multiple weapons

- **Assumptions:**
  - Gov selects a specific function (i.e. component) within a current weapon
  - Breakpoints (i.e. interfaces) between component and rest of weapon are Gov owned/defined
  - Specific function (i.e. component) is mature ("EMD" or later)
  - Gov mandates this function to all future weapons that need that function
- **Example:**
  - Function (i.e. component) is a processor board that hosts the Guidance, Nav, Control, and Target State Estimator software for current weapon
  - New program starts and has a function similar to existing weapon
  - Gov will GFE component (i.e. processor board) to vendors of new program
  - Vendors will develop their own software to address new program's specific requirements (i.e. modified TSE or Guidance algorithms)
  - Vendor that is manufacturing processor board will be required to increase production rates to satisfy both programs
- **Benefit to Gov:**
  - Stops re-inventing the wheel – makes use of the time and dollars already invested
  - Increases production rates – each new program added drives cost down of component
  - Lift of incremental improvements – all programs reap benefits of constant improvements

Open Architecture Based Acquisition Strategy Use Case #3

Premise – Common weapon with 2 functionally different sub-components

- **Assumptions:**
  - Gov owns interface between two pieces of weapon
  - Program requires two variants of sub-component and nothing else changes
  - Two "variants" have been successfully integrated on platform
- **Example:**
  - Warfighter desires weapon to have two different ranges – short and long
  - Program matures two different rocket motors (i.e. two different OMLs)
  - Front end (seeker, GEU, warhead, batteries, etc) are common except for software to account for extra propulsion
  - Integrator will "tune" software to accommodate both rocket motor variants
- **Benefit to Gov:**
  - Warfighter flexibility – ability to select weapon range based on needs of mission
  - Incremental improvement – each portion can be upgraded separately

Open Architecture Based Acquisition Strategy Use Case #4

Premise – Weapon has four major components and three breakpoints

- **Assumptions:**
  - Gov owns interface between four major components
  - OML does not change but any component within OML can
  - Gov, or their agent, is the system integrator
- **Example:**
  - Each of the four major components (i.e. seeker, GNC, warhead, propulsion) are competed separately
  - Interfaces, OML, mass properties, etc. are fixed within each component grouping
  - Gov issues performance parameters for all four components
  - Gov, or their agent, integrates four components
  - Production vendor builds all-up-round with four GFE components
  - As technology improves for each component, it can be quickly integrated into weapon
- **Benefit to Gov:**
  - Best capability to warfighter – each component is competed separately
  - Accommodates tech refresh – each component can improve as S&T delivers new capability
  - Increase competition – second-tier vendors can now compete directly

Open Architecture Based Acquisition Strategy

- Acquisition Program Manager (PM) can not predict or control:
  - Funding
  - Requirements / threat changes
- Open Architecture Based Acquisition Strategy helps mitigate issues
  - Funding Reduction
    - PM can switch tech refresh from expensive component upgrade to less expensive technology
    - PM can reduce the number of risk reduction options
    - PM can skip upgrade and wait till funding available
  - Requirements / threat changes
    - PM can change tech refresh technology to immediately address threat change
    - PM can switch technology to quickly transition from S&T community

Contact Info

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Questions

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