SoSECIE Webinar

Welcome to the
2020 System of Systems Engineering Collaborators Information Exchange (SoSECIE)

We will start at 11AM Eastern Time

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NDIA System of Systems SE Committee

- **Mission**
  - To provide a forum where government, industry, and academia can share lessons learned, promote best practices, address issues, and advocate systems engineering for Systems of Systems (SoS)
  - To identify successful strategies for applying systems engineering principles to systems engineering of SoS
- **Operating Practices**
  - Face to face and virtual SoS Committee meetings are held in conjunction with NDIA SE Division meetings that occur in February, April, June, and August

NDIA SE Division SoS Committee Industry Chairs:
Mr. Rick Poel, Boeing
Ms. Jennie Horne, Raytheon
OSD Liaison:
Dr. Judith Dahmann, MITRE

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- I have muted all participant lines for this introduction and the briefing.
- If you need to contact me during the briefing, send me an e-mail at sosecie@mitre.org.
- Download the presentation so you can follow along on your own
- We will hold all questions until the end:
  - I will start with questions submitted online via the CHAT window in Skype.
  - I will then take questions via telephone; State your name, organization, and question clearly.
- If a question requires more discussion, the speaker(s) contact info is in the brief.

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2020-2021 System of Systems Engineering Collaborators Information Exchange Webinars

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March 10, 2020
Analysis of Interoperability to Support Mission-Oriented SoS
Dr. Ronald Giachetti

March 24, 2020
Extending the DoD Digital Engineering Strategy to Missions, Systems of Systems, and Portfolios
Ms. Philomena Zimmerman

April 7, 2020
Challenges for Systems of Systems / Mission Engineering in a Space Acquisition Environment
Lt Col Benjamin Bennett

April 21, 2020
Mission Engineering, Systems Engineering and Systems of Systems Engineering
Dr. Andreas Tolk

May 5, 2020
New Digital Engineering Enabled Systems and Mission Engineering Performance Measure
Dr. Ed Kraft

June 2, 2020
SERC: Methods to Evaluate Cost/Technical Risk and Opportunity
Thomas McDermott and Cody Fleming

July 28, 2020
Addressing Mission Engineering from a Lead Systems Integration Perspective
Dr. Warren Vaneman

Analysis of Interoperability to Support Mission-Oriented System of Systems Engineering

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Systems Engineering
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March 4, 2020

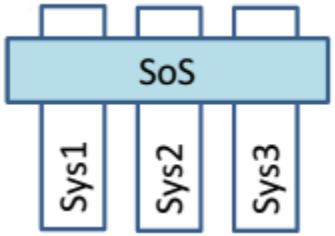
NAVAL POSTGRADUATE SCHOOL

Mission Engineering

Apply systems engineering processes and knowledge to the design of missions

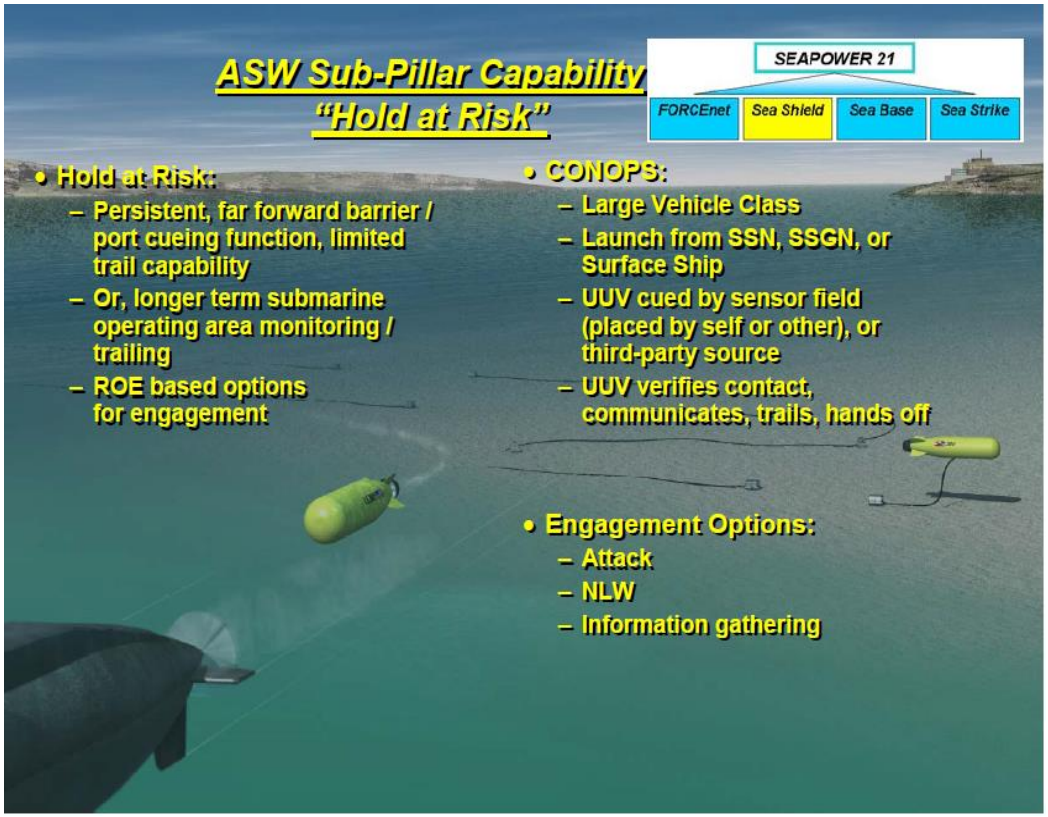
A mission-level system-of-system (SoS) is an acknowledged SoS:

- SoS has requirements, management, and resources
- Constituent systems are NOT subordinate to the SoS



Illustrative Mission-Oriented SoS

ASW **Hold at Risk** – patrol "choke points" to detect adversary submarines

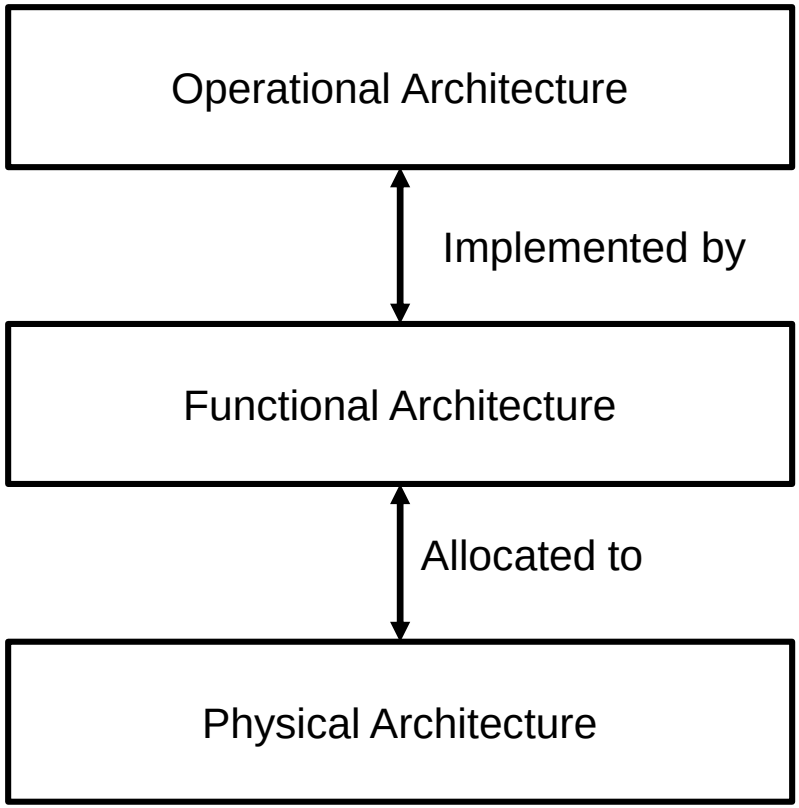


Source: R.W. Button, J. Kamp, T.B. Curtin, J. Dryden, *Unmanned Underseas Vehicles*, RAND 2009.

Constituent Systems:

1. Submarine
2. UUVs
3. Underwater Docking Station
4. Sensor Network

Architecture (military)



What the system does in operational terms.

The system functions to implement the operational activities.

The physical elements performing the system functions.

Interoperability

A measure of the degree to which various systems are able to operate together to achieve a common goal.

Operational Interoperability

Coordination of the activities and performers conducting the mission

Technical Interoperability

The ability of systems to exchange data and resources

Previous Work on Interoperability

Many interoperability measures such as the Levels of Information Systems (LISI) model, which assign numbers to interoperability in an ordinal or interval scale

Such global measures of system interoperability do not provide any **guidance** on what to do to improve interoperability, nor do they **inform** decision makers whether systems will interoperate adequately for any particular mission

We seek to model and analyze interoperability at a greater level of granularity to specify interoperability requirements in mission-oriented SoS – we take a SoS program manager's perspective

Our Approach

- Model-Based Systems Engineering (MBSE) approach
  - Specify mission-oriented SoS architecture in models
  - Requirements captured in architectural models
  - Analyze Operational Interoperability
  - Analyze Technical Interoperability

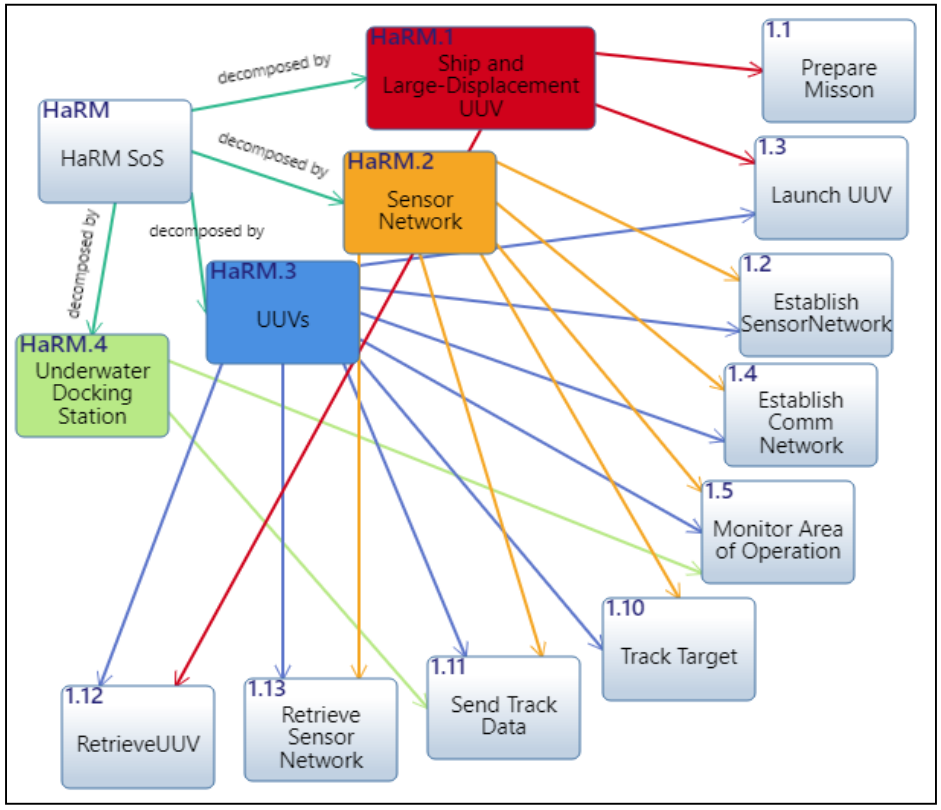
Interoperability Analysis Method (IAM)

1. Mission Interoperability Analysis
    1. Define CONOPs
    2. Define mission threads, measures of effectiveness, operational nodes, conditions, and standards
    3. Identify interoperability gaps in mission
2. Technical Interoperability Analysis
    1. Define information exchange requirements
    2. Define information elements
    3. Define network and transport links
    4. Define measures of performance
3. Specify and Allocate Interoperability Requirements

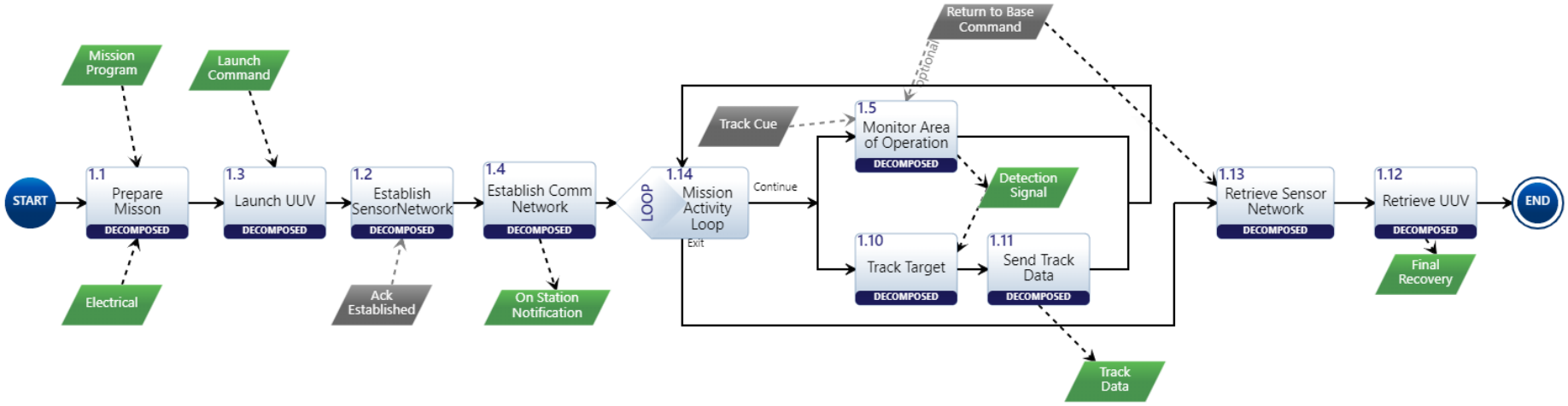
Hold at Risk Mission

- Five constituent Systems:
  - Submarine – launch UUVs and C2
  - Underwater docking station – recharge UUVs, comms hub
  - Sensor network – pre-positioned to detect underwater traffic
  - UUVs – to patrol choke point and detect underwater traffic

Constituent system allocation to mission activities

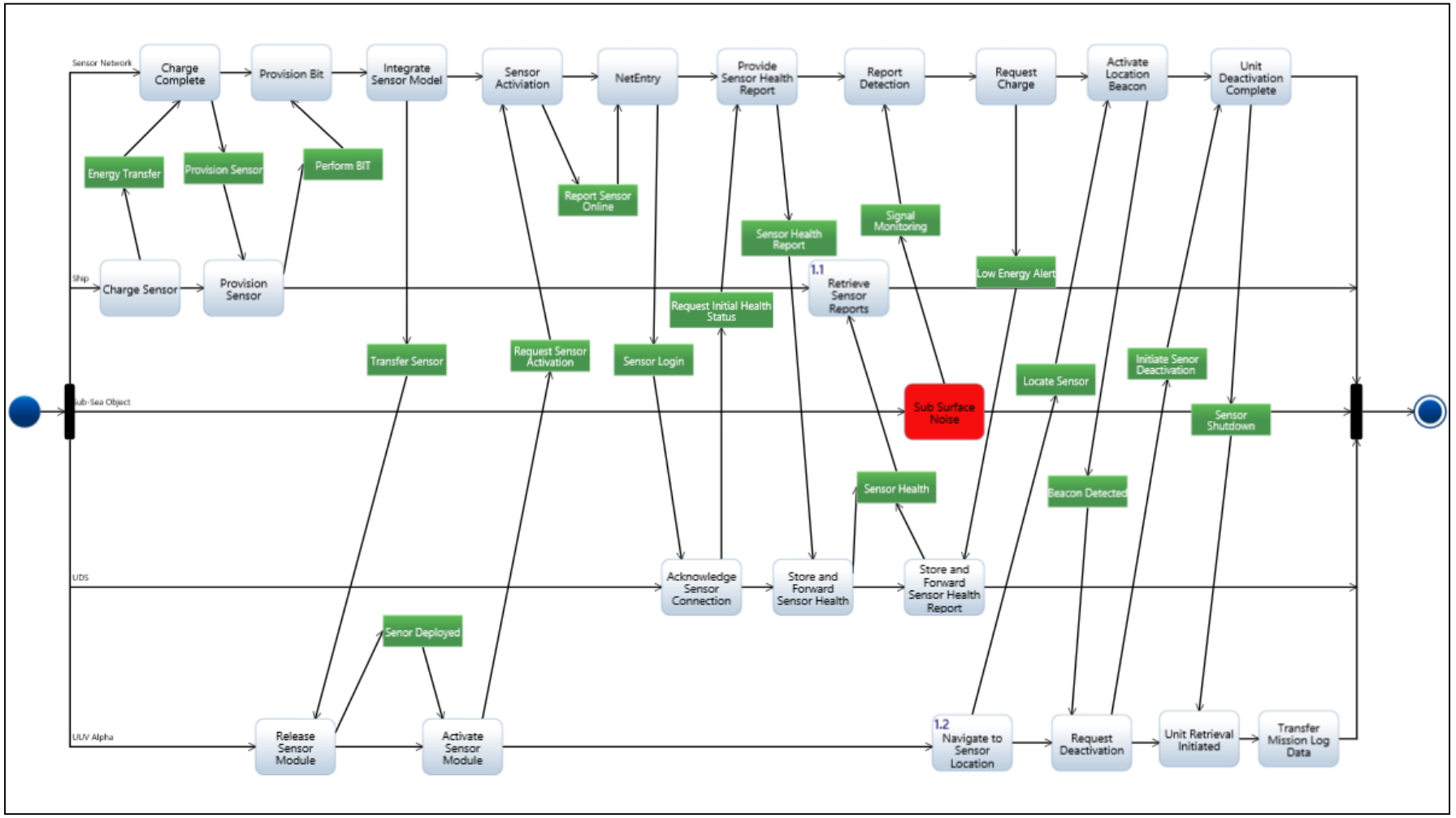


Mission thread



Mission Thread

Partial mission model showing operational activities to complete mission



Operational Interoperability

- Coordination is the work required when two or more operational nodes complete a task vice a single operational node
- Gaps may occur because models, architectures, and designs done by separate programs for each constituent system
- Coordination work includes:
  - Communication
  - Control actions
  - Scheduling and/or sequencing of activities
- Lack of coordination is evident in task inefficiencies, quality, and effectiveness

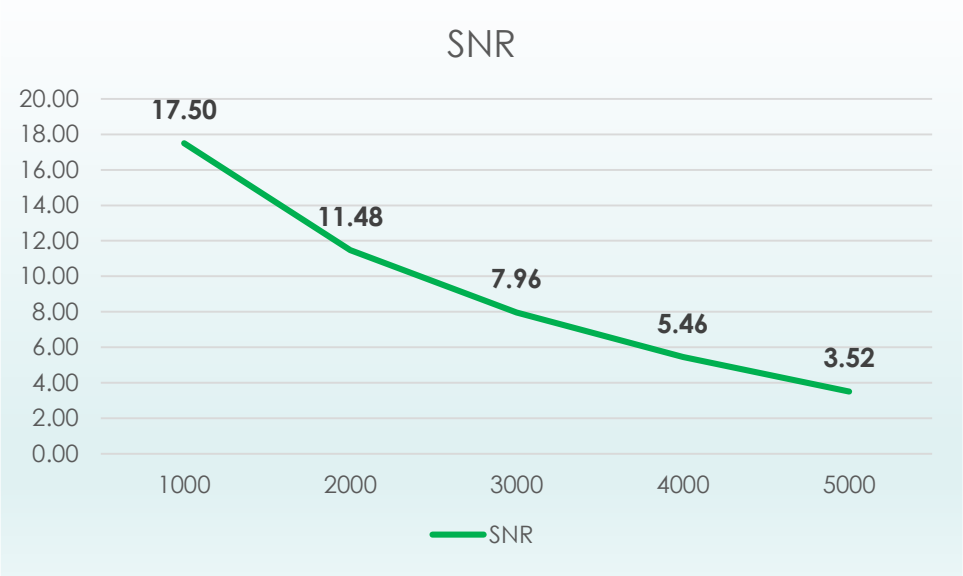
Operational Interoperability Gaps

Model	Activity	Input	Output	Description of Gap
Omega UUV	"Send Ready Status"	Battery Charge to UUV	Ready Status	The Ship UUV activity requires a readiness status from the UUV prior to "Launch UUV" activity can begin.
Omega UUV/Ship UUV	Deploy Sensor Network/Establish Sensor Network	Sensor Data Communication (Input from Deploy Sensor Network)	Sensor Data Communications (Output from Deploy Sensor Network)	An output from deploy sensor network should be "Sensor Data Communications" that serves as an input to the Ship activity "Establish sensor network"
Omega UUV	"Transmit Data to C2/Ship"	None	Detection Signal/Track Data	After the Omega UUV detects a target, the Ship must be notified so that the C2 node onboard the ship can track the target and send data to the various other nodes in the SoS (i.e. the ship should act as the hub of operations)
Alpha UUV	Ready for Launch Command	Battery Charge to UUV	Ready Status	The Ship requires the "Ready Status" input from the Alpha UUV but the UUV does not output this information
Alpha UUV	Send Payload GO Status	UUV Payload Ready	Payload GO Status	The Ship requires the "Payload GO Status" input from the Alpha UUV but the UUV define any input or output information flows

Operational Interoperability

Mission Performance

SNR versus distance for UUVs



(all values are fictional)

Probability of Detection given estimated operational availability

	Ao	P(detect)	Overall P(detect)
Both Available	0.7225	0.8	0.578
One Available	0.255	0.7	0.179
Neither Available	0.0225	0	0.000

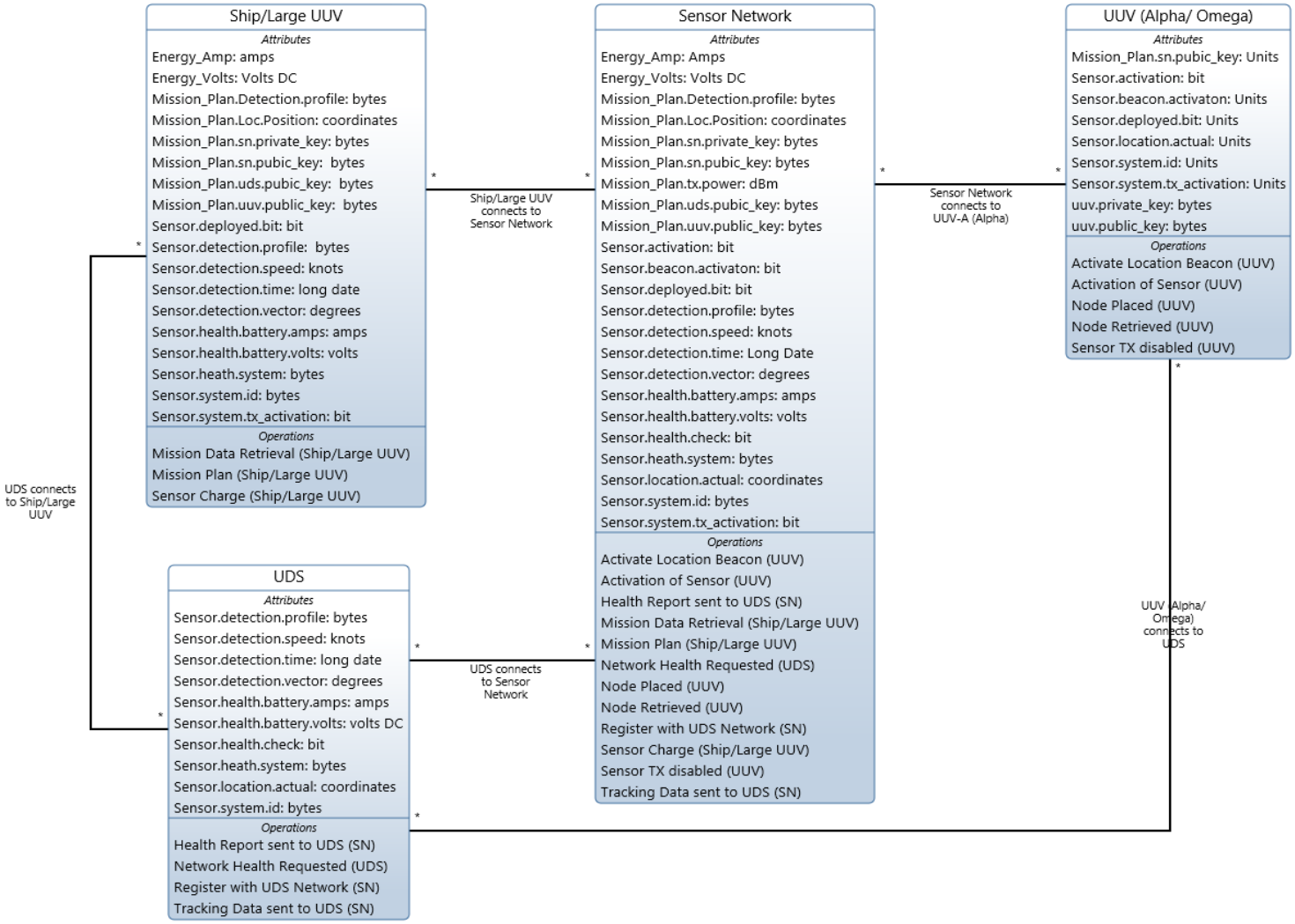
Probability of Detection

Distance (m)	P(False Alarm)	SNR	P(Detect)
1000	0.10	17.50	0.88
2000	0.10	11.48	0.83
3000	0.10	7.96	0.77
4000	0.10	5.46	0.70
5000	0.10	3.52	0.60

Interoperability Gaps

Activity	Interacting System	Input	Output	Gap
2.1 Sensor Configuration	**Ship / Large UUV** (Figure 4)	*Mission Plan to Sensor Network*	None	Sensor Network Activity HaRM.2.1 needs to interface with Ship/Large UUV Activity 1.1, adding the trigger "mission Plan to Sensor Network" for programing sensors.
2.2 Sensor Deployment	**UUV Alpha** (Figure 5)	*UUV Sensor Deployed (UUV Alpha equivalent = Nodes Placed)*	None	Material interface for deploying sensor, Name of interfaces differs but equates to the same activity.
2.2 Sensor Deployment	**UUV Omega** (Figure 3)	*UUV Sensor Deployed*	None	UUV Omega calls out an activity "O 1.7 Deploy Sensor Network" and does not have an action showing a material interface between the two systems. Recommend adding trigger output to UUV Omega activity called "UUV Sensor Deployed"
2.3 Sensor Activation	**UUV Alpha** (Figure 5)	*UUV Activation Request*	None	Sensor Network activity HaRM.2.3 calls for an activation request from the UUV. UUV Alpha has no activity to directly activate the sensor network, though activity 1.4 "Establish Comm Network" is directed at the UDS and could conceivably include a reach-through call to the sensor network
2.3 Sensor Activation	**UUV Omega** (Figure 3)	*UUV Activation Request*	None	UUV Omega calls out an activity "O 1.7 Deploy Sensor Network" and does not have an action showing an energy interface between the two systems. Recommend adding trigger output to UUV Omega activity called "UUV Activation Request"

Define Information Exchanges



Information and Energy Exchanges

Informational Element	Description	Source	Destination	Format	Domain
Energy_Volts	Status of system current draw	Ship/Large UUV 1.2 Establish SensorNetwork (proposed)	HaRM.2.8 Sensor Energy Store	float	[0,24]
Energy_Amp	Status of System Energy levels	Ship/Large UUV 1.2 Establish SensorNetwork (proposed)	HaRM.2.8 Sensor Energy Store	float	[0,5]
Mission_Plan.Detection.profile	Reporting sensitivity threshold	Ship/Large UUV 1.1 Prepare Mission (proposed)	HaRM.2.1 Sensor Configuration	integer	[1,100]
Mission_Plan.Loc.Position	Planned location placement of sensor	Ship/Large UUV 1.1 Prepare Mission (proposed)	HaRM.2.1 Sensor Configuration	64-bit	N/A
Mission_Plan.sn.public_key	Encryption key	Ship/Large UUV 1.1 Prepare Mission (proposed)	HaRM.2.1 Sensor Configuration	64-bit	N/A
Mission_Plan.sn.private_key	Encryption key	Ship/Large UUV 1.1 Prepare Mission (proposed)	HaRM.2.1 Sensor Configuration	64-bit	N/A
Mission_Plan.tx.power	Power setting—balancing dispersion vs. emcon vs. battery life	Ship/Large UUV 1.1 Prepare Mission (proposed)	HaRM.2.1 Sensor Configuration	float	[0,47]

Summary

- Interoperability Analysis Method to support both ***operational*** and ***technical*** interoperability for mission-oriented system-of-systems
  - Operational Interoperability -- degree of coordination of the operational activities in mission architecture
  - Technical Interoperability – degree the systems can exchange materials, energy, and information as required

Summary

- The IAM works with the **architecture deliverables** programs already generate and identifies specific and actionable **interoperability requirements** in the models

- We conducted some **verification and validation** of the method by comparing modeling recommendations to field study experience for a separate search and rescue mission