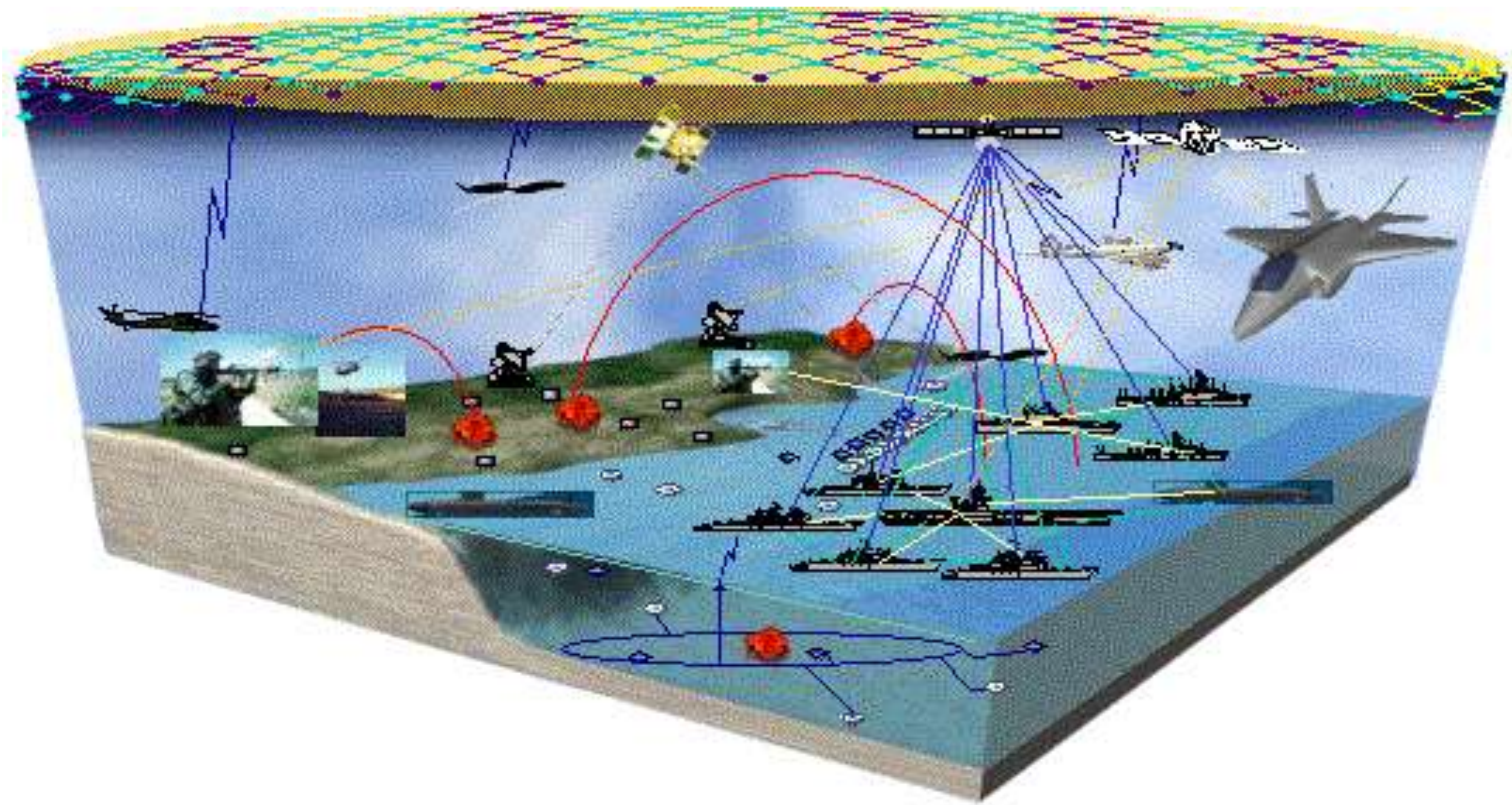
AY 2004 Spring Integrated Project

Maritime Dominance in the Littorals

3 June 2004

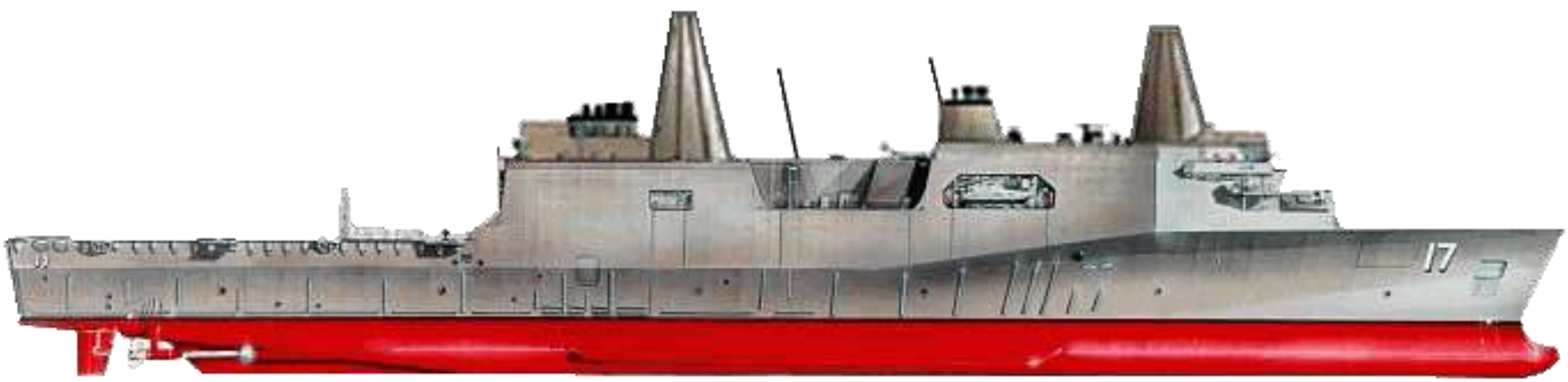


Presentation Purpose

Final Review

by SEA5

of the AY2004 Spring Integrated Project



Agenda

- Maritime Dominance in the Littorals Brief……………………………..0900-1145
    - Executive Overview ……………………………….…….LCDR Tran
    - SoS Development…………………………………….….ENS Tsikalas
        - Functional Analysis………………………..……..……...ENS Tubbs
        - Value Systems Design……………………..……..….ENS Tubbs
        - Architectures……………………………….…………...ENS Peterson
        - Threats & Scenarios ……..………………..……………LT Holmes
        - TDSI Integration....………………………..…………….ENS Hartling
        - Cost Analysis ……………………………...…………..LT Julien
        - Simulative Study …………………………...……..ENS Abbott
            - Engineering Physics Models..……………...…......ENS Poitevent
            - Platform/Combat System Models…………………ENS Poitevent
            - Force/Theater Models………..…………..……..ENS Smith
        - Architecture Ranking….……………………………...LT Graham
        - Configuration Selection Validation……………...……LT Winslow
    - Concluding Remarks….………………………………LCDR Tran
- Lunch Break……………………………………………………………1145-1300
- Breakout Session at Bullard 100 (Including Temasek Defense System Institute Poster Session)..…………………………...…………………1300-1400

Executive Overview

LCDR Quoc Tran

Executive Overview

- Project Overview
- Project Description
- Project Results
- Project Team Organization
- Project Schedule
- Project Effective Need

Project Overview

- Tasked to Develop a System of Systems Conceptual Solution For Maritime Dominance in the Littorals
- Developed a Project Management Plan
- Used a Systems Engineering Design Process
- Analyzed Threats and Defined Littoral Scenarios
- Generated Conceptual SoS Architecture Alternatives
- Used Modeling and Simulation
- Ranked SoS Architecture Alternatives According to Their Maritime Dominance Effectiveness and Cost
- Delivered The Final Recommendation

Project Description

- Execute Tasking from Deputy Chief of Naval Operations (CNO) for Warfare Requirements (OPNAV 7)
- Develop a Conceptual System of Systems (SoS) for Maritime Dominance that Enables SEA BASING and SEA STRIKE in the Littorals
  - Generate Alternatives Using Existing Systems, Current Programs of Record, and Future Systems
  - Recommend Cost Effective Conceptual SoS That Minimizes Risk To Allied Personnel While Accomplishing Objectives
- Deliver Results in a Final Briefing and Technical Report

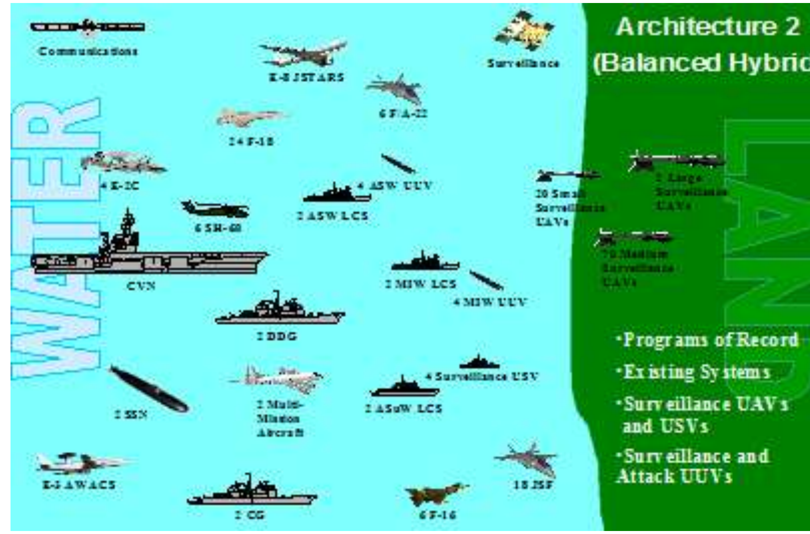
SoS Focus and Constraints

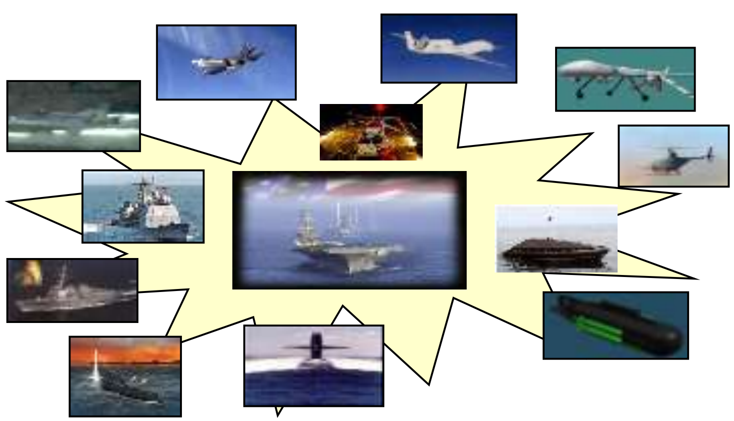
- **SoS Architectural Focus**
  - Combination of both Manned and Unmanned Systems
  - Surface, Subsurface, Air and Space Systems
  - Employment of Forces From All Services

- **Constraints**
  - Scenario Constraints
    - Land Forces Deployed up to 200 nm Inland
    - Striking/Supporting Maritime Forces Deployed up to 200 nm Offshore
  - Timeframe Constraint
    - Concepts of Operations Applicable within 2020 Timeframe
  - Cost Being a Necessary Selection Variable

Recommended System of Systems for Maritime Dominance in Littorals

- **Unmanned Vehicles Complement But Cannot Replace Manned Platforms**
- **Recommended System of Systems Enabling SEA BASING and SEA STRIKE in 200 nm by 200 nm Littoral Operation Area in 2020 Timeframe**
  - **Consists of Unmanned/Manned Vehicle Ratio of Approximately 1.5 to 1**
  - **Utilizes Distributed Communications with 100nm Physical Platform Distribution**
  - **Employs Decentralized Command & Control Structure**
  - **Is Cost Effective Relative to Other Alternatives**





- **Distributed Communications**
  - Faster Dissemination of Information
  - Minimum Impact on Throughput with Node Failures
- **Decentralized Command and Control**
  - Shorter Reaction Times
  - Less Network Demand
  - Single C2 Node Failure Avoidance
- **100 nm Platform Distribution**
  - Superior Overall Performance

2004 Integrated Project Interface

NPS Community

Faculty Advisors

Prof. W. Solitario-Overall Project Coord
Dr. T. Huynh-Proj. Mgmt, Sys. Design & Analysis
Dr. R. Cristi-Communications
Dr. D. Kapolka-Sensors
Dr. G. Karunasiri-Sensors
Dr. I. Kaminer-Land Systems
Dr. F. Papoulias-Land Systems
LCDR R. Gottfried-Operations Research
Prof. K. Burke-Information Systems

Temasek Defense Systems Institute Technical Teams

Berner, Andy USA; Chan, Chee Wai SGP; Cheak, Seck Fai SGP; Chen, Yuan Xin SGP; Cheng, Kah Wai SGP; Cheng, Wee Kiang SGP; Chow, Khin Choong SGP; Gonen, Ofer ISR; Koh, Jin Hou SGP; Lee, Kok Thong SGP; Lim, Kian Guan SGP; Monfore, Ken USA; Mui, Whye Kee SGP; Neo, Melvin SGP; Oh, Khoon Wee SGP; Ong, Chin Siang SGP; Phey, Khee Teik Augustine SGP; Poh, Seng Cheong Telly SGP; Quek, Yew Sing SGP; Seow, Yoke Wei SGP; Tan, Peng Soon SGP; Tay, Chee Bin SGP; Toh, Chee Hwee SGP; Wong, Chin Han SGP; Yong, Siow Yin SGP

Study Direction, SEA5 Technical Inputs Contributing Analysis

Performance Analyses

Industry
Boeing
Lockheed Martin
Northrop Grumman
Raytheon

Technology Resource

SEA5

Integrated Project Lead

LCDR Q. Tran

SEA5 Team

CDR. Dermentzoudis, GRC
LT C. Graham, USA
LT M. Holmes, USA
LT R. Julien, USA
LT J. Winslow, USA
ENS B. Abbott, USA
ENS K. Hartling, USA
ENS B. Peterson, USA
ENS S. Poitevent, USA
ENS R. Smith, USA
ENS M. Tsikalas, USA
ENS C. Tubbs, USA

Initial Study Plan
Periodic Updates

Input and Feedback

Operational Requirements

CNO N7
Fleet Commanders
(CAPT Kline, Dr. Olwell)

Technical Requirements

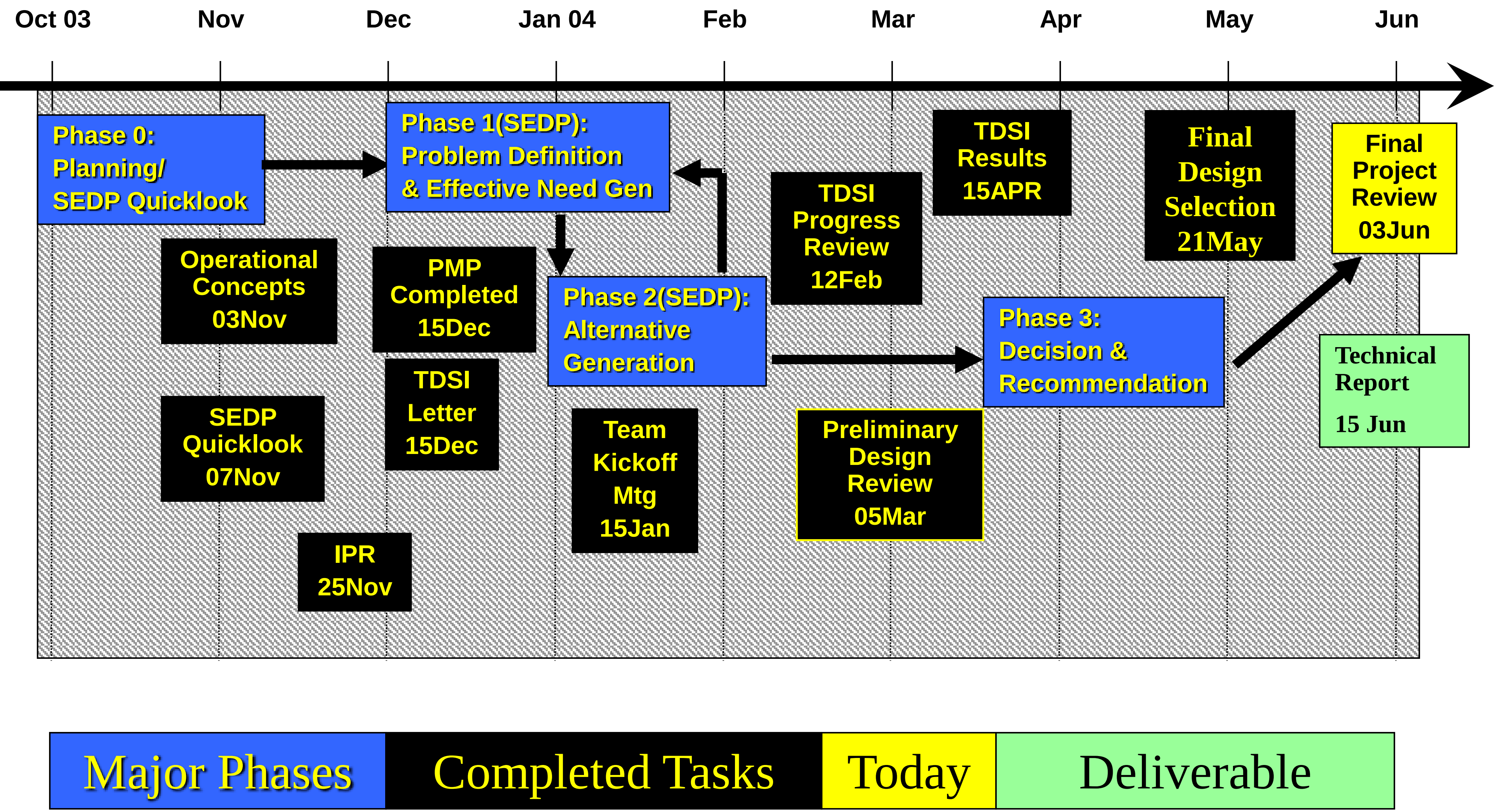
NAVSEA
FNMOC
NCAA
AFCAA

End User Requirements

Joint Military Community
Air Warfare
Amphibious Warfare
Land Warfare
PYSOPS/INTEL
Special Operations
Subsurface Warfare
Surface Warfare

Legend
Primary Coordinators
Internal Structure
External Stakeholders

Project Schedule



Effective Need

Develop a SoS Solution to Enable SEA BASING and SEA STRIKE by Providing Maritime Dominance in the Littoral Environment Through Cooperative Surveillance, Threat Analysis and Evaluation, Battle Management, and Engagement

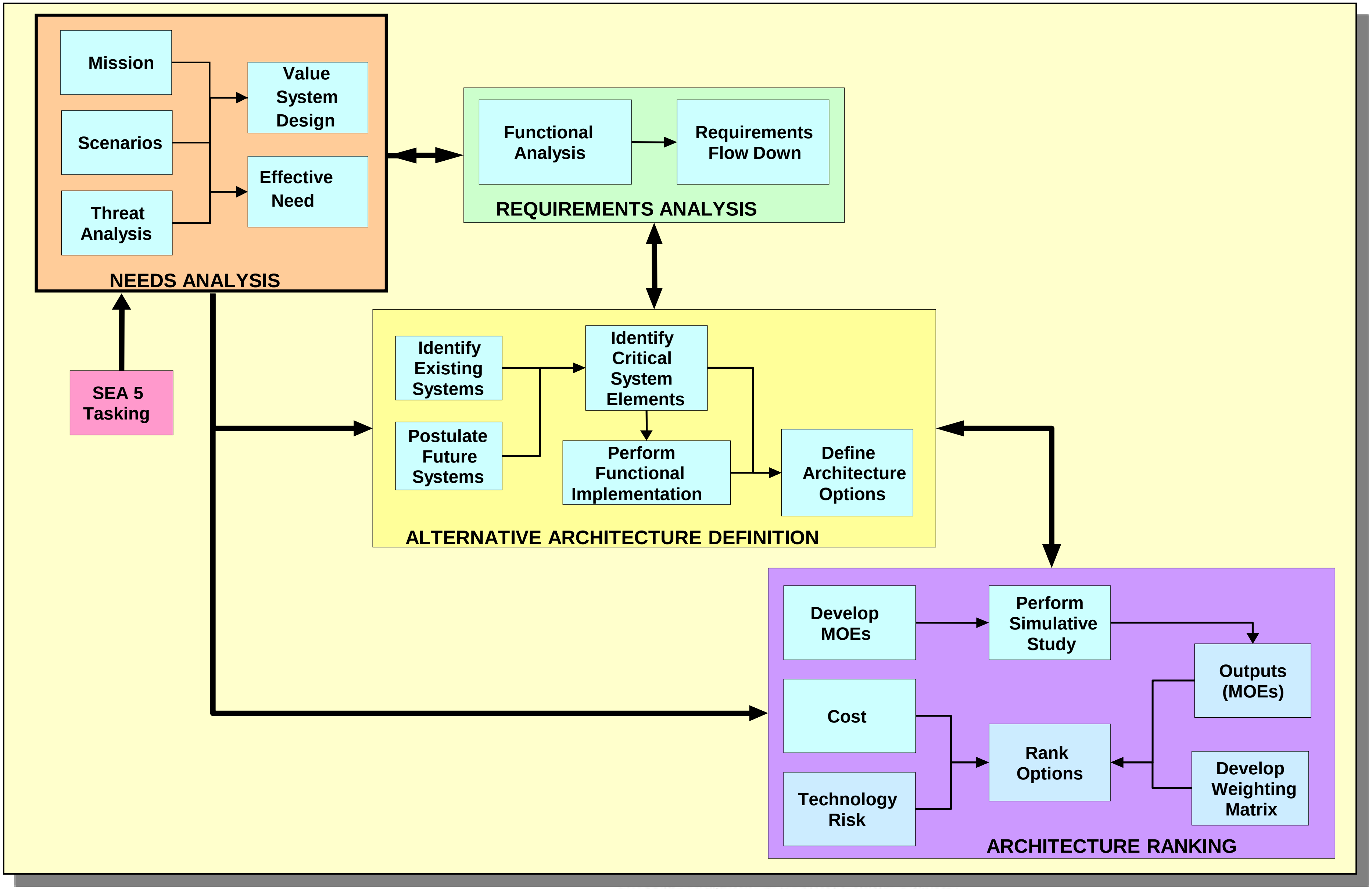
SoS Development

ENS Manny Tsikalas

Problem Definition

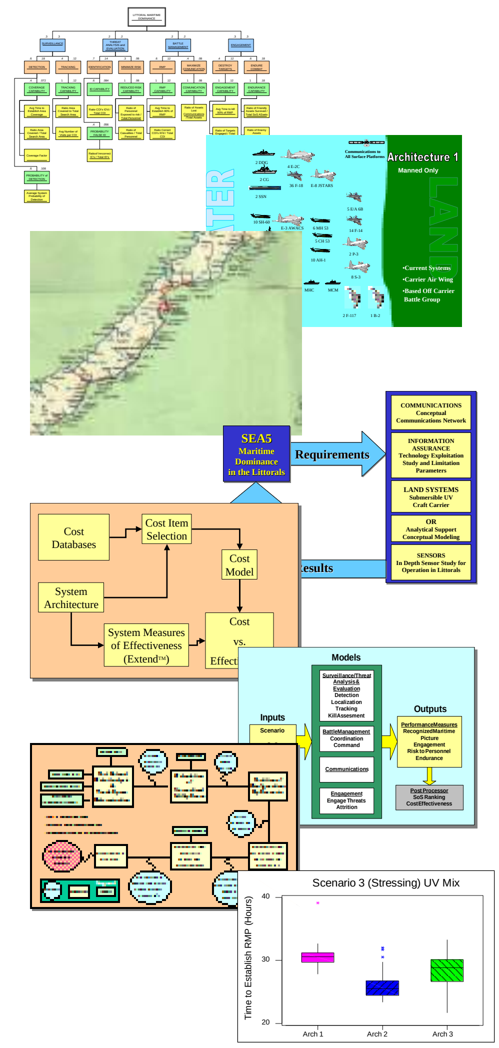
- Define and Select a Cost Effective System of Systems Architecture Consisting of Sea-Based, Land-Based, and Airborne Sensor and Weapon Systems that Are
  - Both Manned and Unmanned
  - In Existence, in Development, and Future Concepts
  - Networked Via Communication Links and Space Systems to Achieve Success of the Following Littoral Missions with Minimum Risk to Allied Personnel
    - Identification and, If Necessary, Reduction of Hostile Threats to Within Defensive Capability of the Sea Base
    - Enabling Projection of Offensive Capabilities From the Sea Base

SoS Development Process



SoS Development Overview

- Functional Analysis
- Value Systems Design
- Architectures
- Threats & Scenarios
- TDSI Integration
- Cost Analysis
- Simulative Study
- Architecture Ranking
- Configuration Validation



Functional Analysis and Value Systems Design

ENS Cavan Tubbs

SoS Development

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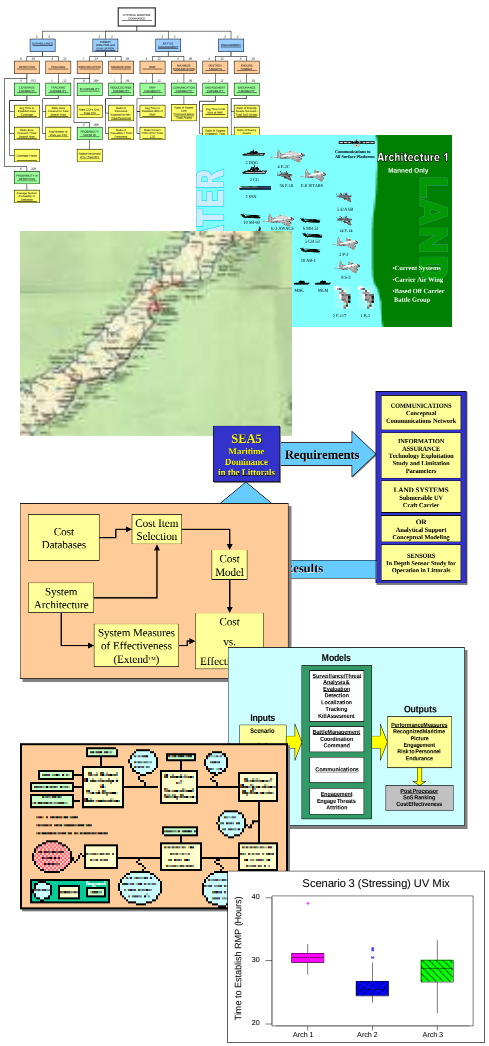
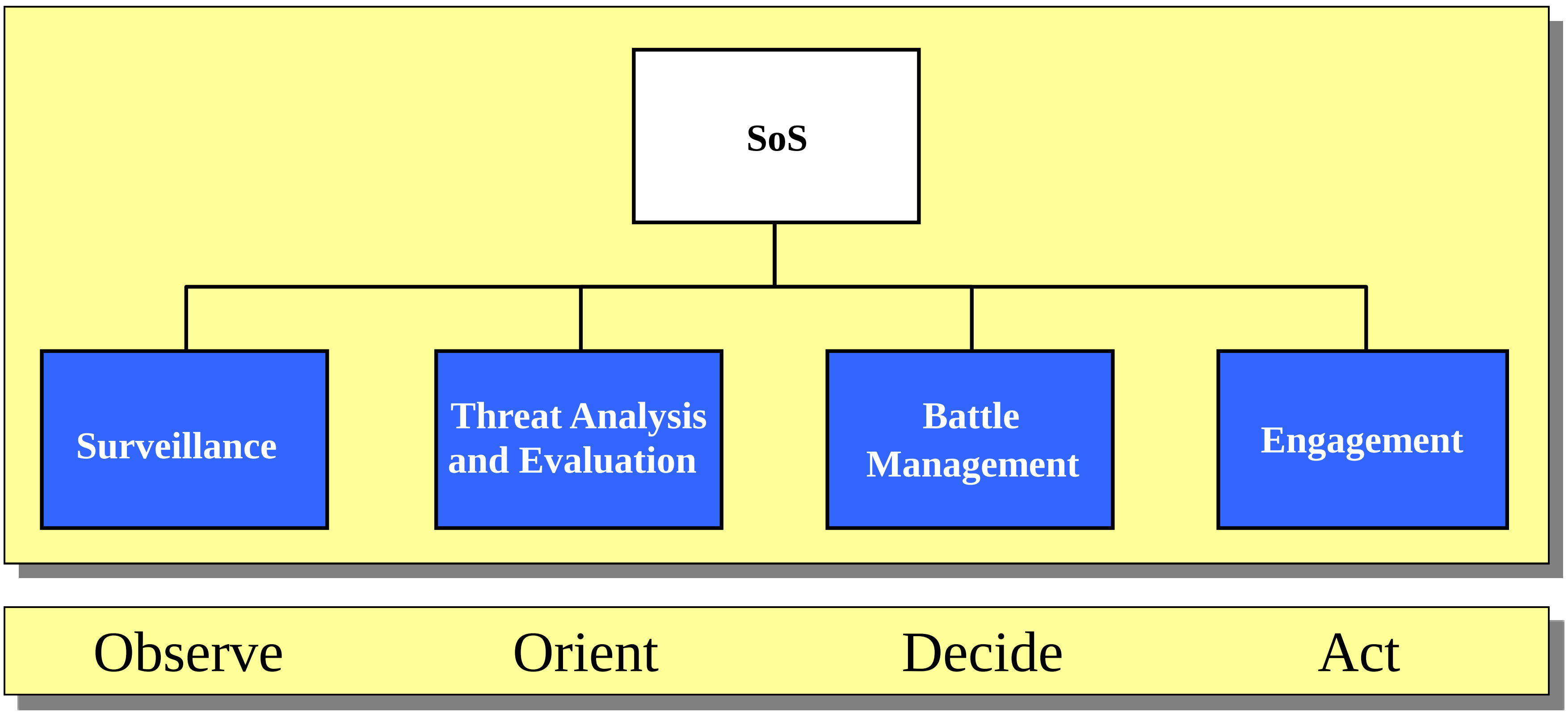


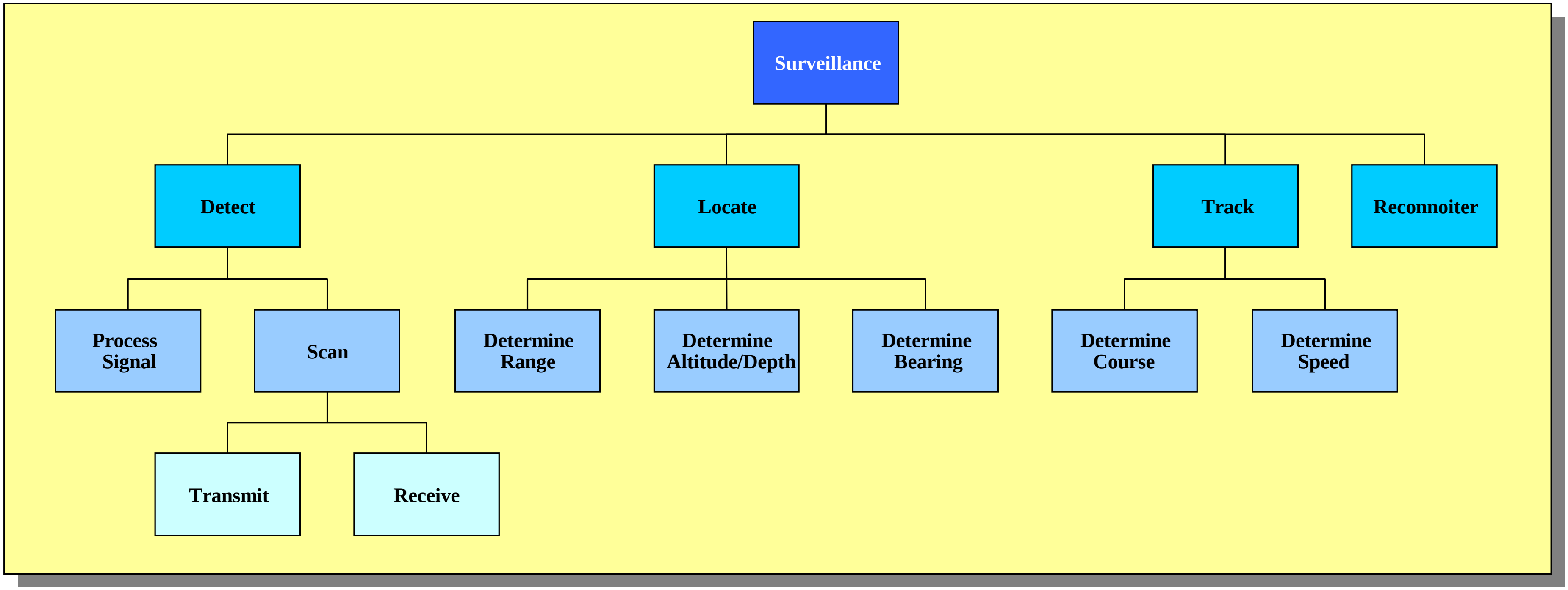
Functional Analysis

- SoS Design Requires
  - Identification of Functions to be Performed in Support of Mission Accomplishment
  - Decomposition of Identified Functions
- Four-Level Depth Functional Decomposition Embodies SoS Functionality

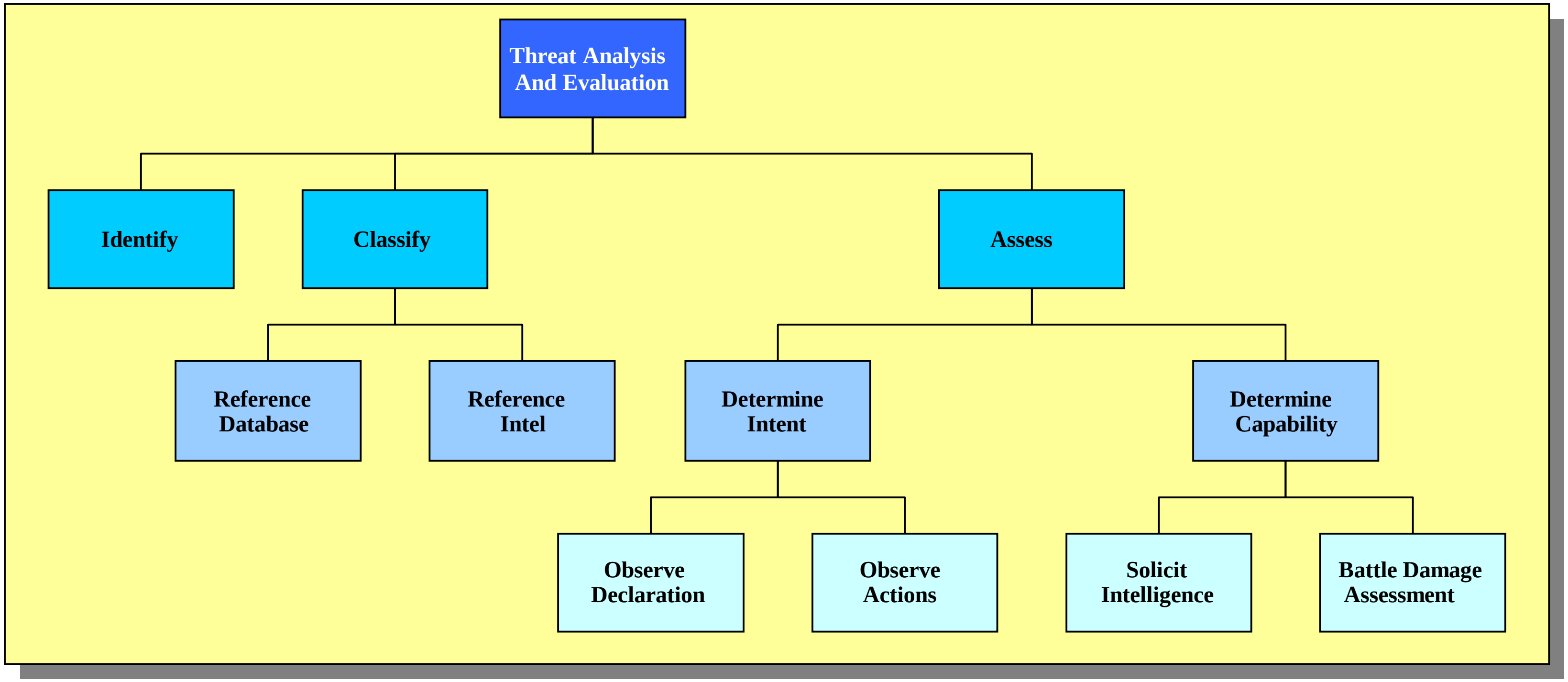
Functional Hierarchy



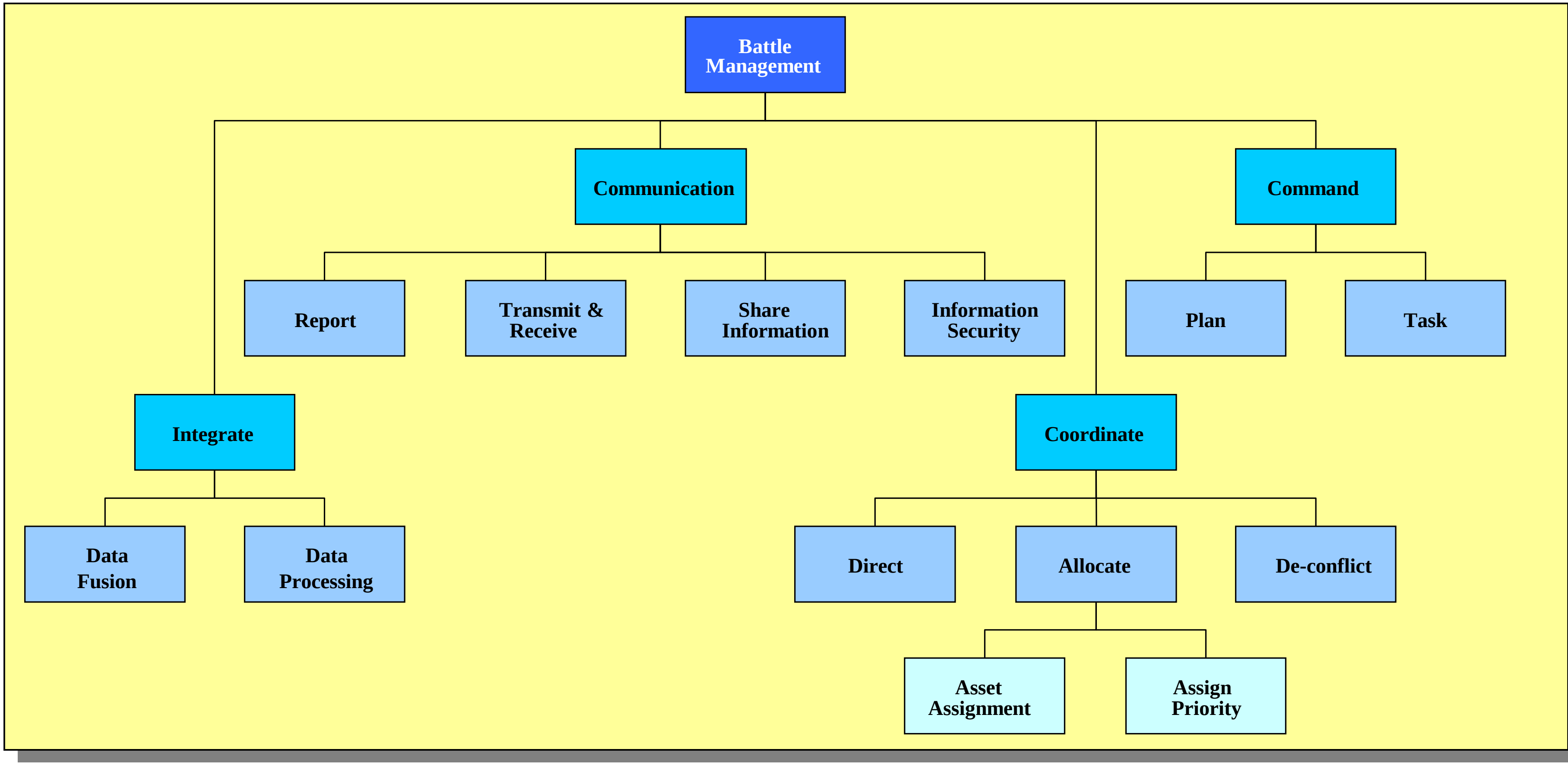
Surveillance Functional Decomposition



Threat Analysis & Evaluation Functional Decomposition

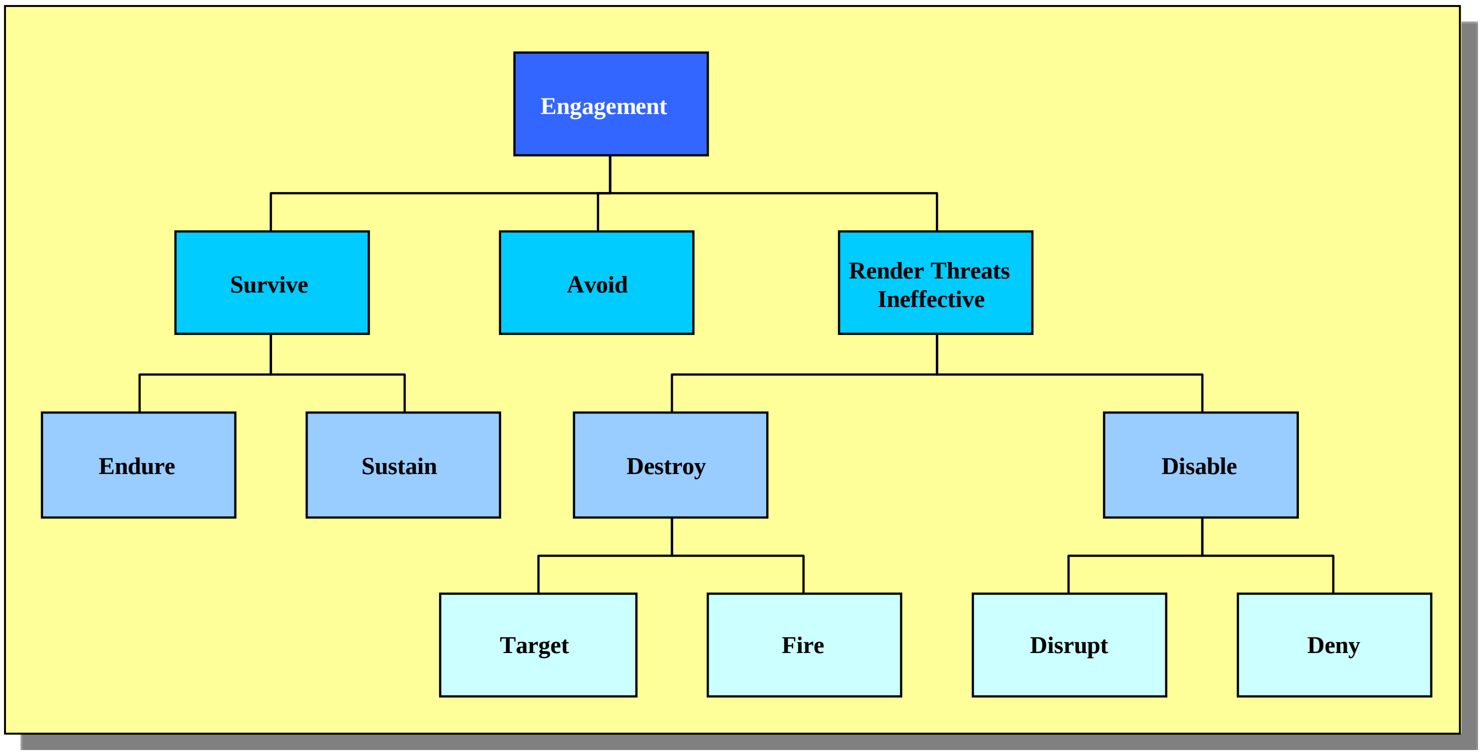


BMC4I Functional Decomposition

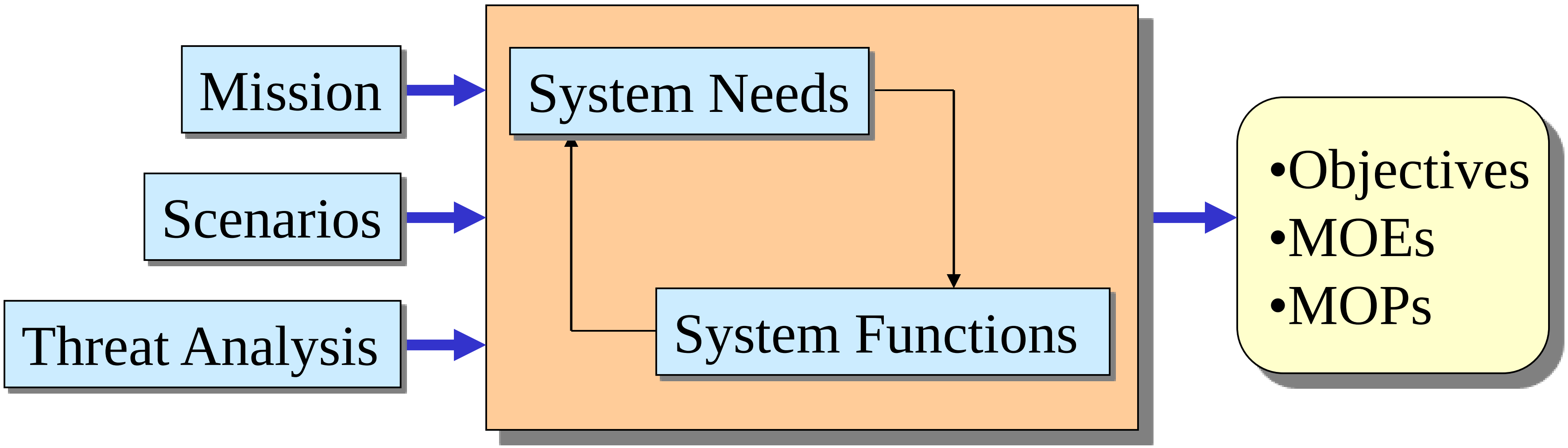


Battle Management Means Battle Management, Command, Control, Communications, Computers, and Intelligence (BMC4I)

Engagement Functional Decomposition



Value Systems Design Implementation



Balance System Needs and Functions in Support of SoS Missions of Enabling SEA BASE and SEA STRIKE

MOE – Measure of Effectiveness

MOP – Measure of Performance

Functional Decomposition

Surveillance Function		
Objectives	**MOE**	**MOP**
Detection	Coverage Capability	Average Time to Establish Complete Area Coverage
		Ratio Area Covered / Total Search Area
		Coverage Factor (Confidence)
	Probability of Detection	Average System Probability of Detection
Tracking	Tracking Capability	Ratio Contact of Interest (COI) Tracked / Total COI
		Average Number of Visits per COI

Functional Decomposition

Threat Analysis & Evaluation Function

Objectives	MOE	MOP
Identification	ID Capability	Ratio COIs Identified / Total COI
	Probability of False ID	Ratio of Incorrect Identifications / Total Identifications
Minimize Risk	Reduced Exposure to Risk Capability	Ratio of Personnel Exposed to Risk / Total Personnel
		Ratio of Casualties / Total Personnel

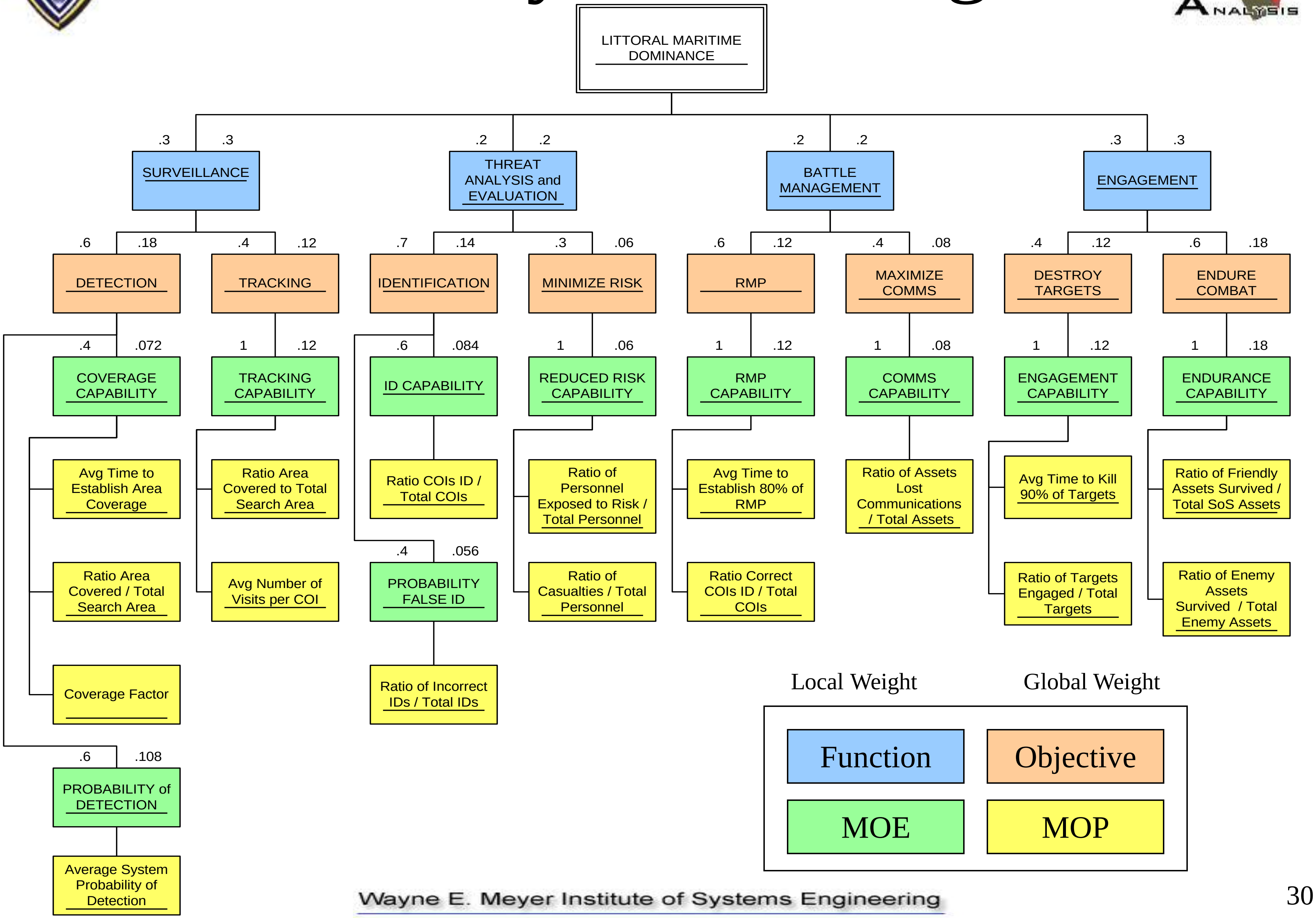
Functional Decomposition

Battle Management Function		
Objectives	**MOE**	**MOP**
Recognized Maritime Picture	RMP Capability	Average Time to Establish 80% of RMP
		Ratio Correct COI IDs / Total COI
Maximize Communication	Communication Capability	Ratio of Number of Assets Lost Comms / Total Assets

Functional Decomposition

Engagement Function		
Objectives	**MOE**	**MOP**
Destroy/ Disable Targets	Engagement Capability	Average Time to Kill 80% of Targets
		Ratio Targets Engaged / Total Targets
Endure Combat	Endurance Capability	Ratio Friendly Assets Survived / Total Friendly Assets
		Ratio Enemy Assets Survived / Total Enemy Assets

Value Systems Design

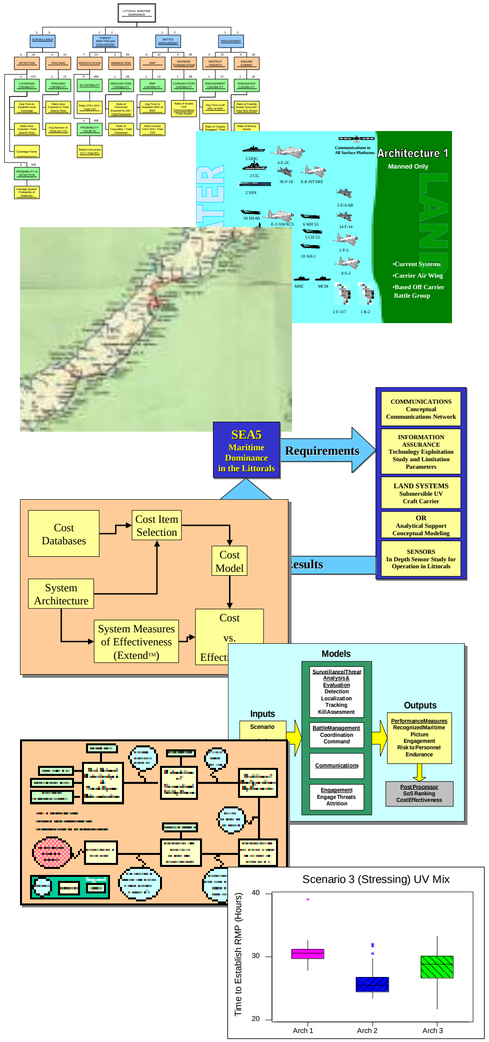


Architectures

ENS Bryan Peterson

SoS Development

- Functional Analysis
- Value Systems Design
- Architectures
- Threats & Scenarios
- TDSI Integration
- Cost Analysis
- Simulative Study
- Architecture Ranking
- Configuration Validation



Topics

- SoS Architecture Overview
- SoS Architecture Assumptions
- SoS Architecture Definition Process
- Functional Embedding
- UV Types and Functions
- Architectures
- Architecture Summary

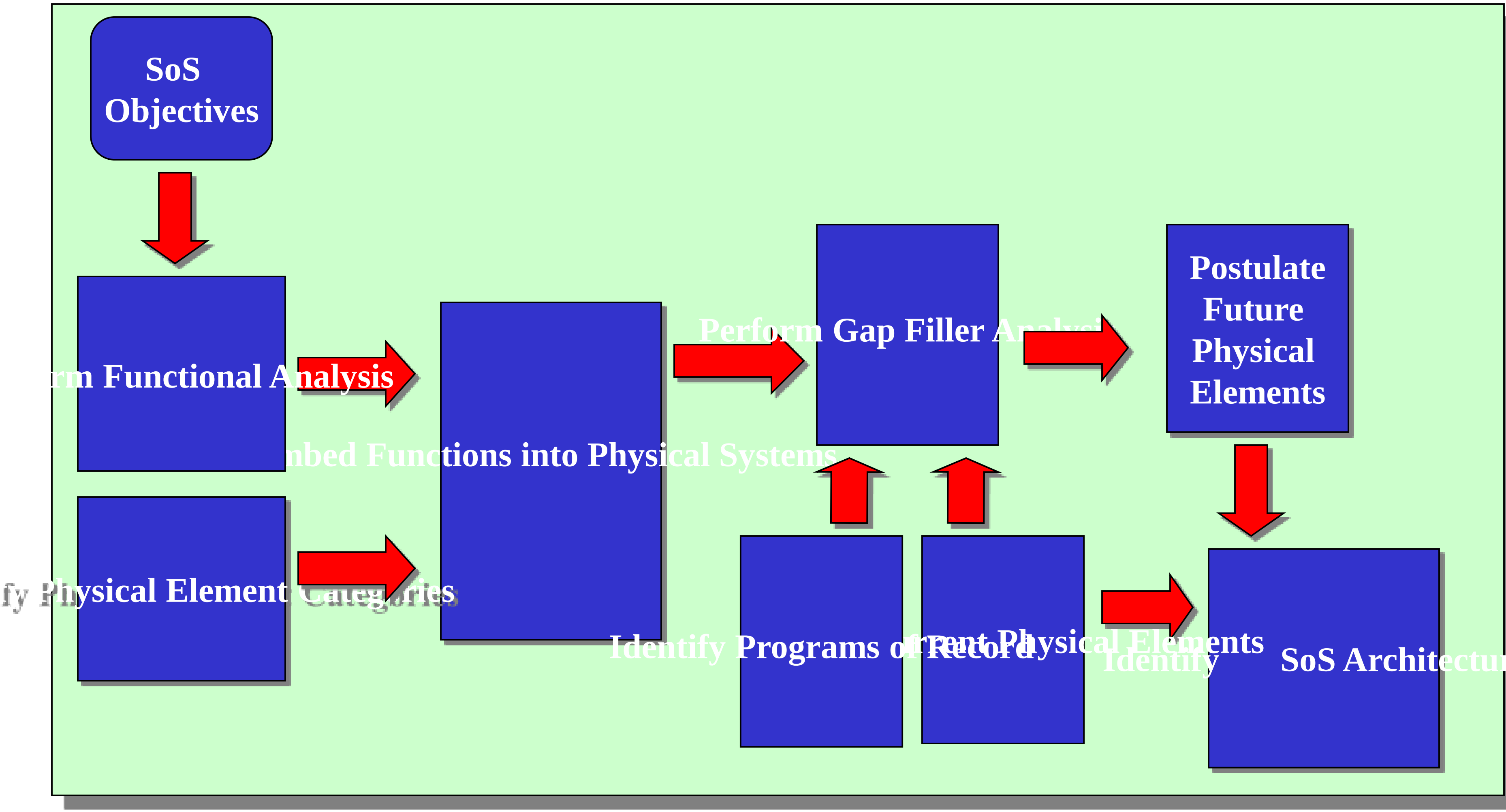
SoS Architecture Overview

- Ensured Gradual Increase of Unmanned Vehicles with Architectures
  - Manned Only (Architecture 1)
  - Balanced Hybrid (Architecture 2)
  - Primarily Unmanned (Architecture 3)
- Ensured Architecture 1 Consisted of Current Systems Only
- Accounted for 2020 Timeframe Technology
- Named Unmanned Vehicles According to Size and Functions

SoS Architecture Assumptions

- Manned Systems Still Required For Air to Air Combat in 2020 Timeframe
- Carrier-Launched and Recovered Medium-Sized UAVs Exist
  - Number of UAVs Determined by Size and Space Available on Carrier
- Availability of Postulated Systems in 2020 Timeframe
  - DDX, CGX, LCS, etc.

SoS Architectures Definition Process



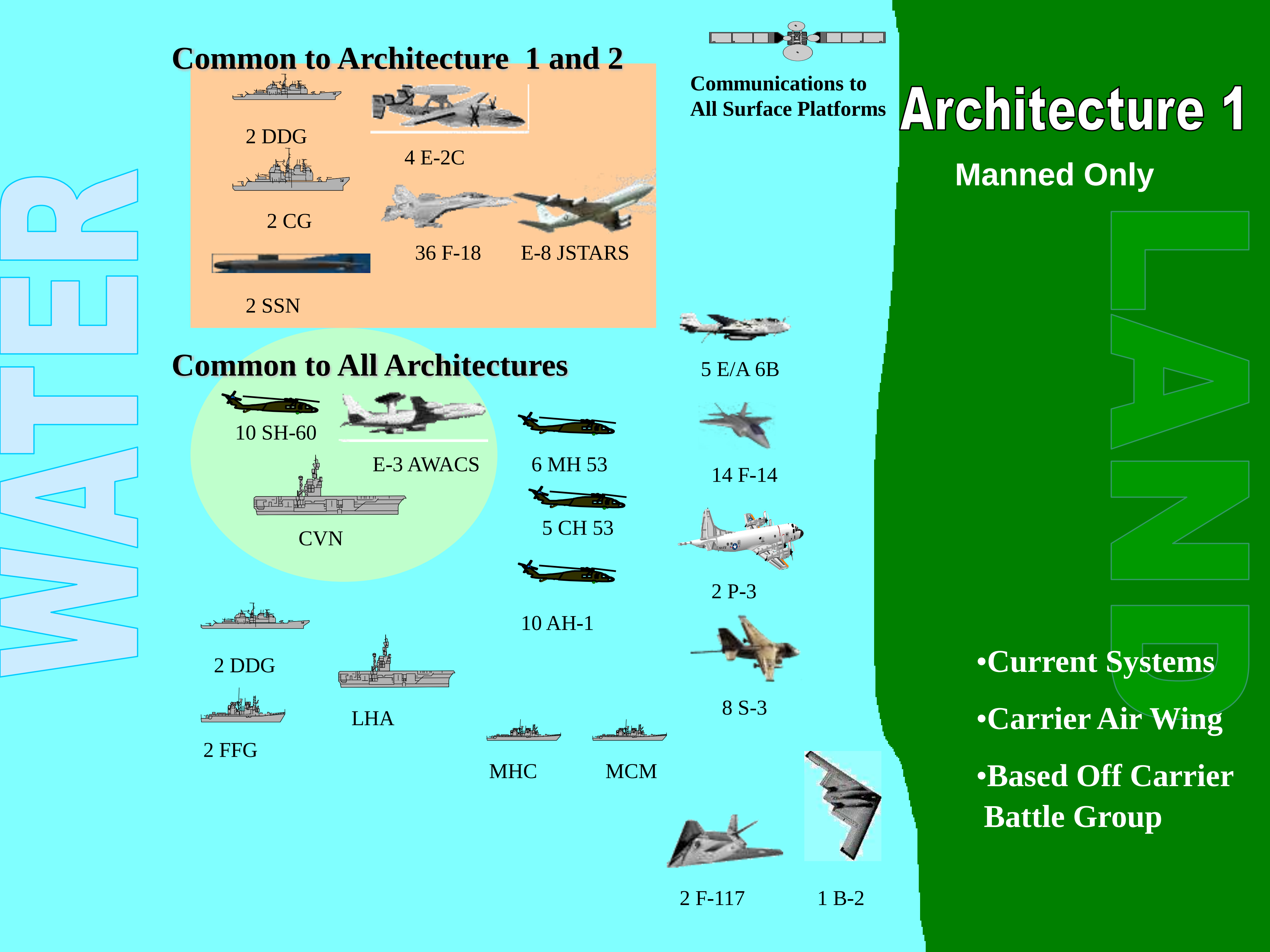
Functional Embedding

Functions		S-3	P-3	EA-6B	AH-1	B-2	F-14	F/A-18	JSF	C-2	E-2C	MH-53	SH-60	Strike UAV	Surv UAV
		Platforms													
Surveillance	Detection	X	X								X	X	X		X
	Tracking	X	X								X		X		X
Threat Analysis and Eval	ID Targets	X	X				X	X	X		X		X	X	X
	Minimize Risk													X	X
Battle Management	RMP	X	X								X	X	X		X
	Max Comms													X	X
Engagement	Destroy Targets	X	X	X	X	X	X	X	X				X	X	
	Endure Combat			X	X	X	X	X	X					X	

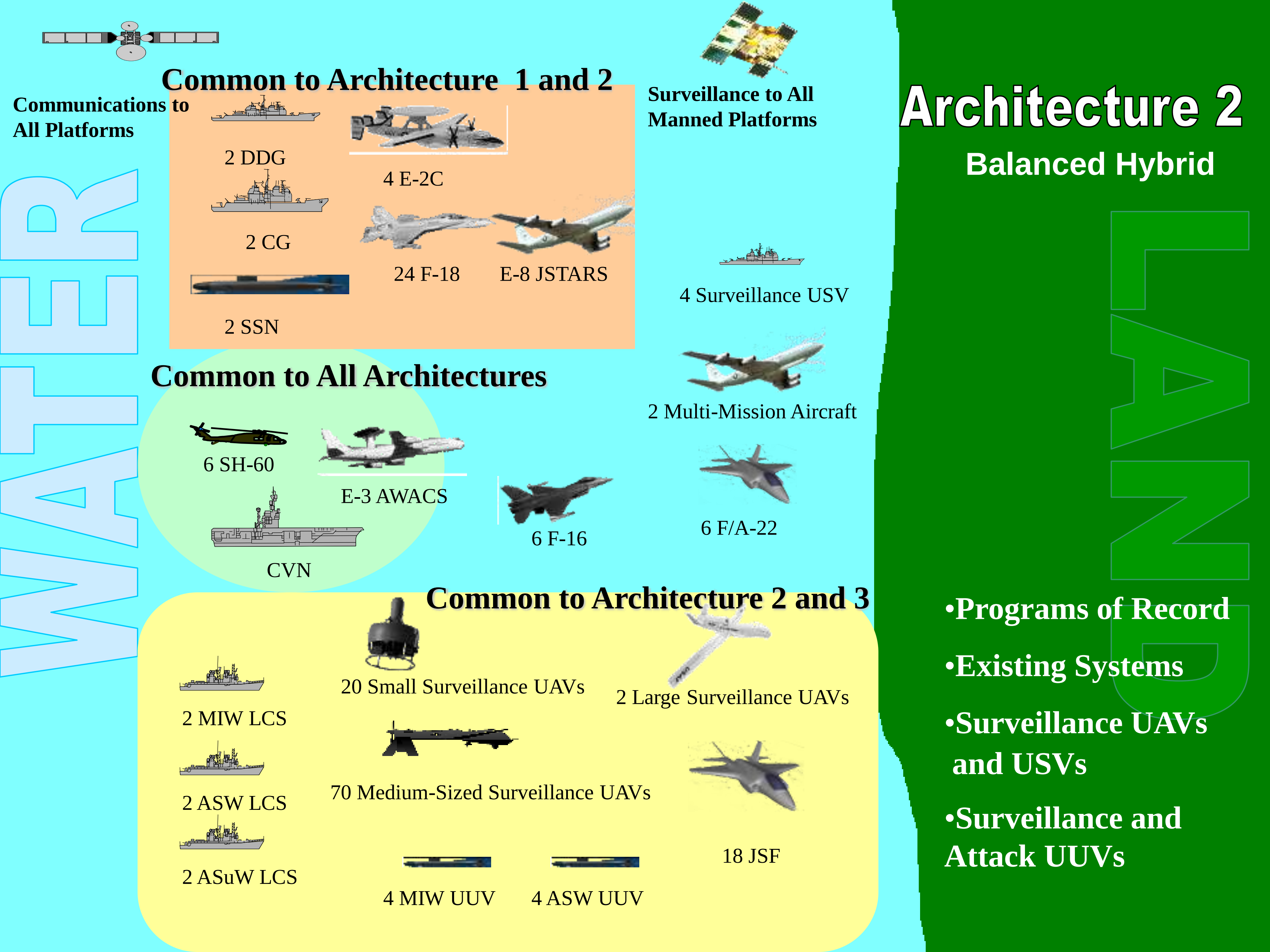
Architecture 1	Common to all Architectures
Architecture 2	Architecture 1 and 2
Architecture 3	Architecture 2 and 3

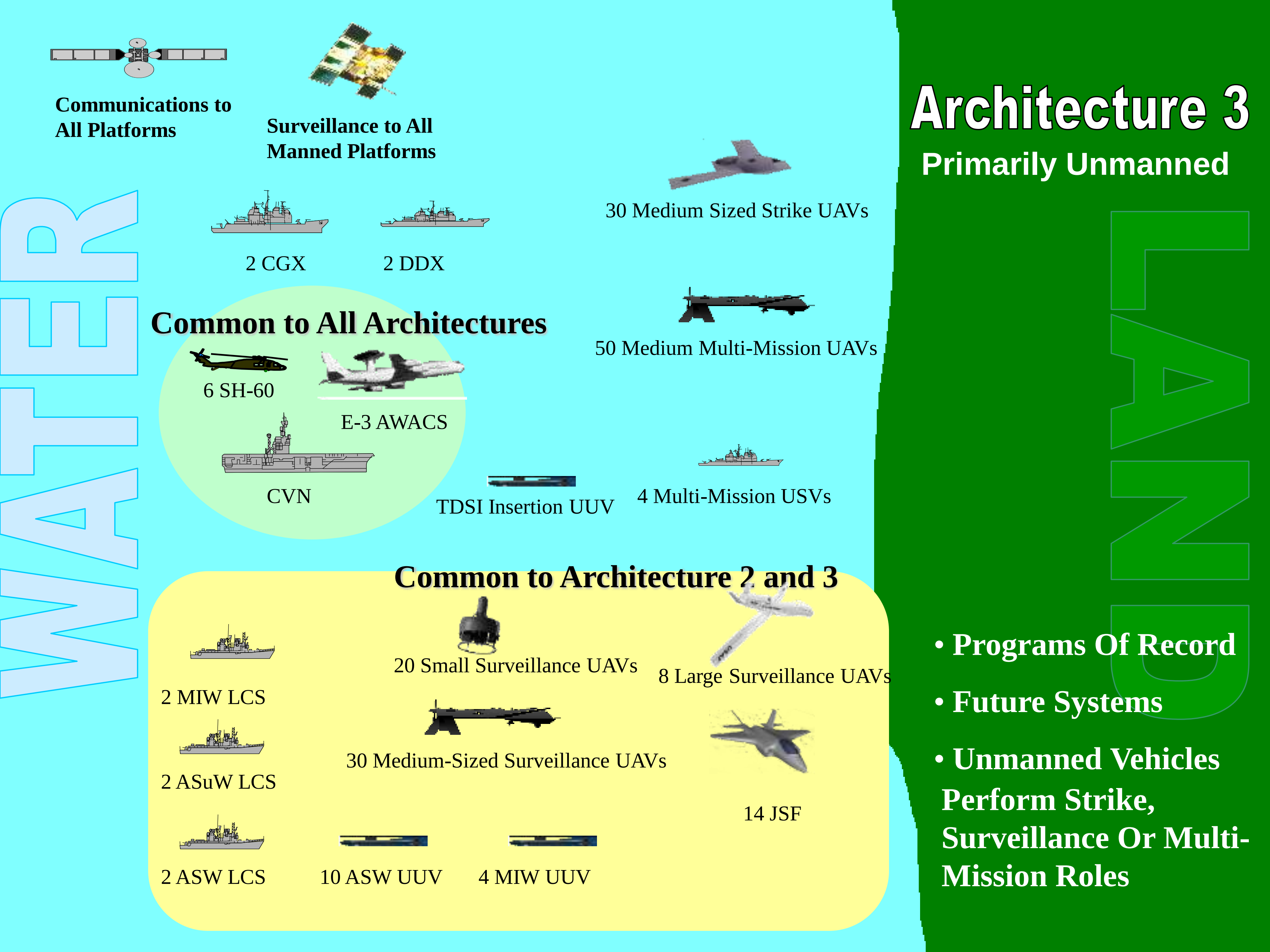
Unmanned Vehicle Types and Functions

Unmanned Vehicle Type	Sensors/Weapons/Functions
Large Surveillance UAV	Air/Surface Search Radar
Medium-Sized Surveillance UAV	TDSI FOPEN Radar, Infrared (IR) Sensor
Medium-Sized Strike UAV	Harpoon, JSOW
Medium-Sized Multi-Mission UAV	TDSI FOPEN Radar, Hellfire
Small Surveillance UAV	IR Sensor
Mine Warfare UUV	Sonar
Anti-Submarine Warfare UUV	Sonar, Torpedo
Unmanned Vehicle Insertion UUV	TDSI Unmanned Insertion Vehicle
Surveillance USV	Surface Search
Multi-Mission USV	Surface Search, Hellfire



Common to Architecture 1 and 2
2 DDG
4 E-2C
2 CG
36 F-18
E-8 JSTARS
2 SSN
Communications to
All Surface Platforms
Architecture 1
Manned Only
WATER
LAND
Common to All Architectures
10 SH-60
E-3 AWACS
CVN
6 MH 53
5 CH 53
10 AH-1
5 E/A 6B
14 F-14
2 P-3
8 S-3
2 DDG
2 FFG
LHA
MHC
MCM
2 F-117
1 B-2
•Current Systems
•Carrier Air Wing
•Based Off Carrier Battle Group


Architecture 2
Balanced Hybrid
Communications to All Platforms
Common to Architecture 1 and 2
2 DDG
4 E-2C
2 CG
24 F-18
E-8 JSTARS
2 SSN
Surveillance to All Manned Platforms
4 Surveillance USV
2 Multi-Mission Aircraft
Common to All Architectures
6 SH-60
E-3 AWACS
CVN
6 F-16
6 F/A-22
Common to Architecture 2 and 3
20 Small Surveillance UAVs
2 Large Surveillance UAVs
2 MIW LCS
2 ASW LCS
2 ASuW LCS
70 Medium-Sized Surveillance UAVs
18 JSF
4 MIW UUV
4 ASW UUV
WATER
LAND
•Programs of Record
•Existing Systems
•Surveillance UAVs and USVs
•Surveillance and Attack UUVs


Architecture 3
Primarily Unmanned
WATER
LAND
Communications to All Platforms
Surveillance to All Manned Platforms
2 CGX
2 DDX
30 Medium Sized Strike UAVs
Common to All Architectures
6 SH-60
E-3 AWACS
CVN
50 Medium Multi-Mission UAVs
TDSI Insertion UUV
4 Multi-Mission USVs
Common to Architecture 2 and 3
2 MIW LCS
20 Small Surveillance UAVs
8 Large Surveillance UAVs
2 ASuW LCS
30 Medium-Sized Surveillance UAVs
14 JSF
2 ASW LCS
10 ASW UUV
4 MIW UUV
• Programs Of Record
• Future Systems
• Unmanned Vehicles Perform Strike, Surveillance Or Multi-Mission Roles

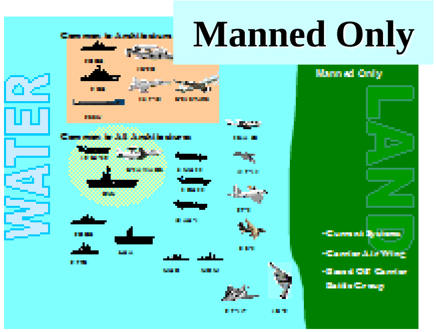
Architecture Composition

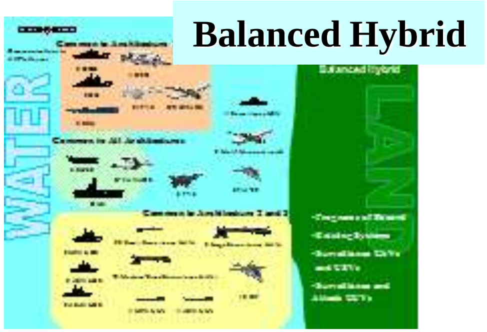
MANNED ONLY (ARCH 1)	BALANCED HYBRID (ARCH 2)	PRIMARILY UNMANNED (ARCH 3)
1 CVN	1 CVN	1 CVN
10 SH-60	6 SH-60	6 SH-60
1 E-3 AWACS	1 E-3 AWACS	1 E-3 AWACS
2 CG	2 CG	2 CGX
4 DDG	2 DDG	2 DDX
2 SSN	2 SSN	1 INSERTION UUV
4 E2-C	4 E2-C	4 MULTI-MISSION USV
36 F/A-18	24 F/A-18	30 MEDIUM-SIZED STRIKE UAV
1 E-8 JSTARS	1 E-8 JSTARS	50 MEDIUM-SIZED MULTI-MISSION UAV
2 P-3	6 LCS	6 LCS
5 CH-53	4 MIW UUV	4 MIW UUV
6 MH-53	4 ASW UUV	10 ASW UUV
14 F-14	18 JSF	14 JSF
8 S-3	2 LARGE SURVEILLANCE UAVS	8 LARGE SURVEILLANCE UAVS
5 E/A-6B	70 MEDIUM-SIZED SURVEILLANCE UAVS	30 MEDIUM-SIZED SURVEILLANCE UAVS
10 AH-1	20 SMALL SURVEILLANCE UAVS	20 SMALL SURVEILLANCE UAVS
1 B-2	6 F/A-22	
2 B-52	2 MULTI-MISSION MARITIME AIRCRAFT (MMA)	
2 F-117	2 SSGN	
2 FFG	4 SURVEILLANCE USV	
1 MHC	6 F-16	
1 MCM		
1 LHA		

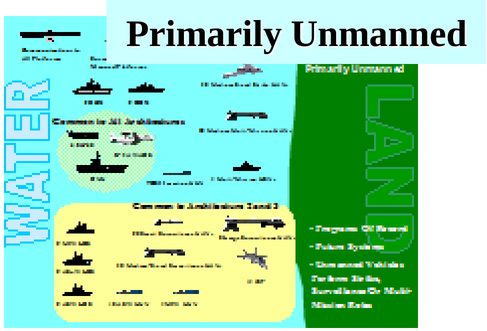
All Architectures | Arch1 and Arch 2 | Arch 2 and Arch 3

Architecture Summary

- Three Architectures With Progressing Reliance on UVs
  - Architecture 1: Manned Only
  - Architecture 2: Balanced Hybrid
  - Architecture 3: Primarily Unmanned
- Architecture Effectiveness Modeled in Simulative Study Against Test Scenarios







Threats & Scenarios

LT Matt Holmes

SoS Development

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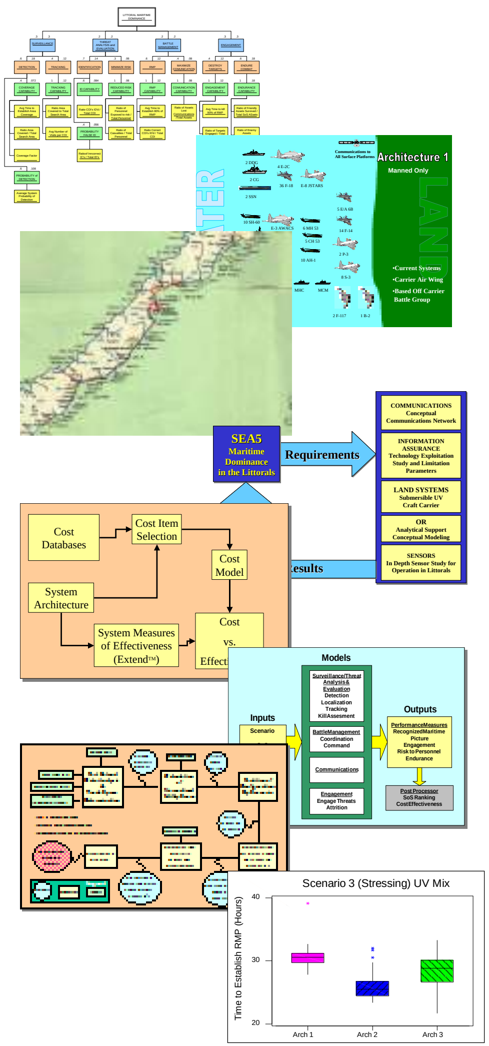


Topics

- Joint Campaign Analysis
- South China Sea Scenario
- Scenario Development Criteria
- Tactical Scenarios

JCA Referenced US Force Composition Criteria

- Joint Campaign Analysis as Point of Reference for Scenario Analysis
- Warfare Threats to NESG Prioritized
  - ASCM
  - ASW
  - MIW
  - ASuW

- JCA Study Format
  - Officers
  - Baseline Architecture
  - Lanchester Attrition Models
  - Larger Group Broken Into Mission Groups
  - Estimate of SoS Baseline Architecture Performance vs. Threat

South China Sea Scenario

- PRC Warship Strafed by Philippines Fighter
- PRC Naval Blockade of Puerta Princessa
  - Historical Rights and Economic Requirements
  - Need to Establish Safety Perimeter Around South China Sea
- PRC Reinforcement of Presence in the Spratly Islands
  - Paved Runways
  - Pier and Maintenance Facilities
  - ADA Batteries and Ballistic Missile Sites.
- PRC Invasion of Kepulauan Natuna (Indonesia)
- PRC Invasion of Palawan After a 30-day Blockade
  - Land, Air, Sea, and Missile Forces Moved to Island

Scenario Criteria

PRC Invasion Force

Aircraft 735

Surface 79

3 SOVREMMENY DDG

1 CV + 30 SU-30

55 DDG, FFG, & PGM

Subsurface 21

5 Type 091/093 SSN

15 Diesel SS (4 Kilo)

MARDIV 1

ARTDIV 1

INFDIV 7*

*3 Additional Reserve (Guangzhou)

No Heavy Armor Division

Light Armor Units With MANPADS

- **Tactical Littoral Environments**
- **Scenario Definition Guided By Complexity**
  - Mission
  - Enemy Force Structure
  - Level of Hostility

Scenario	Enemy	Conflict	Escalation
Benign	Neutral	Unlikely	Unlikely
Nominal	Aggressive	Medium	Low
Stressing	Hostile	High	Medium

Scenario 1 - Benign

Specific Scenario Elements

Day (-3): PRC Submarines Sweep Sulu

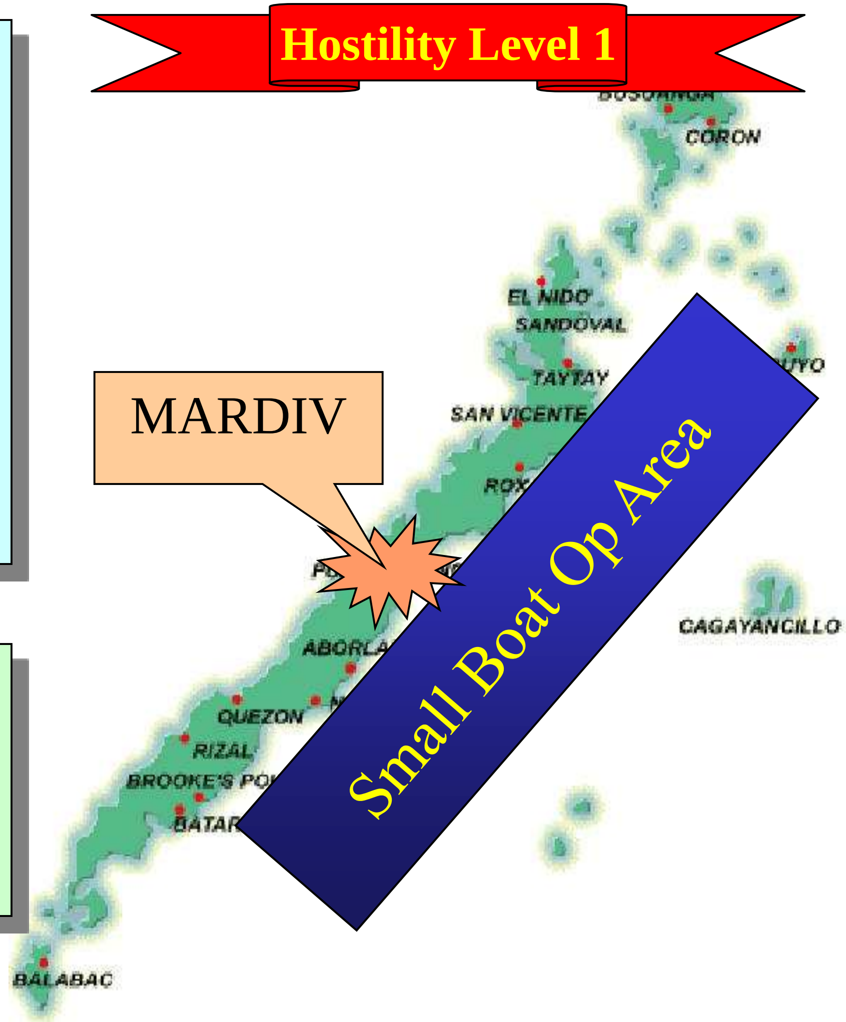
Day (0): PRC Maritime Division (MARDIV) Secures Capital City

: PRC Naval Forces Blockade Harbor

Day (1): PRC Reinforces Spratly Isles

SoS Mission Considerations

- Unlimited US Force Movement
- US Tasking: Reconnaissance (RECCE)



Scenario 2 - Nominal

Hostility Level 2

Specific Scenario Elements

Day (2): PRC Artillery/Inf. FWD Staged

PRC Fortifies Palawan Airport

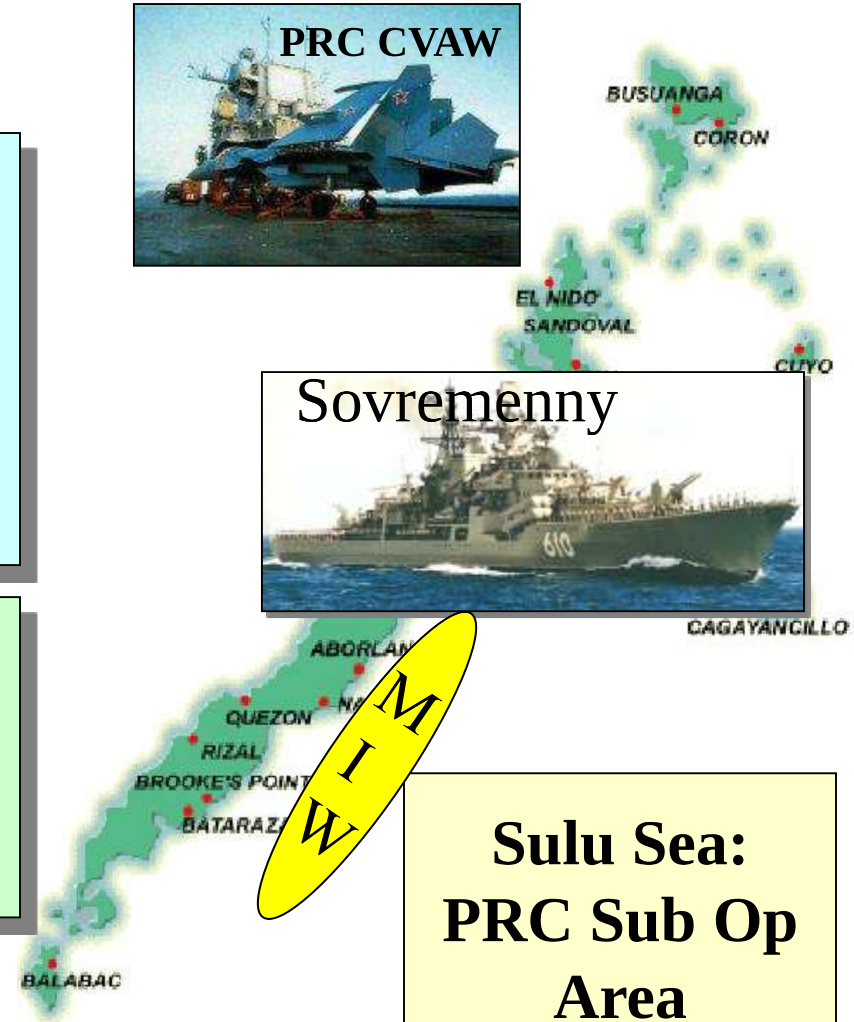
Day (3): PRC Naval Forces Mine Harbor

PRC TU-16s Begin Maritime Patrol

Day (12): PRC Reinforces Naval Presence

SoS Mission Considerations

- Restricted US Movement Outside 12 nm
- US Forces Actively Tracked
- US Tasking: RECCE and Targeting



Sulu Sea: PRC Sub Op Area

Scenario 3 - Stressing

Hostility Level 3

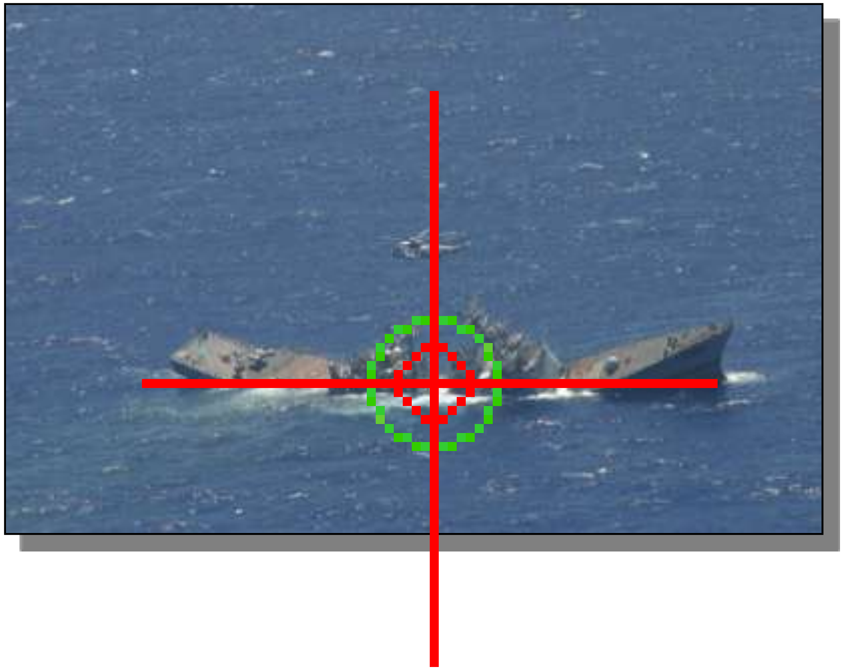
Day (13): PRC MARDIV Fortifies Puerta Princessa
Day (15): PRC INFDIV Disperse Into Terrain
PRC Air Corps Commence Aggressive Patrols
Day (16): SOVREMENNY Steam to North Rendezvous
Subs Deploy to Surf/Sub-surf Operating Areas
Day (18): PRC Surface Fleet Patrol/Interdict SSOA2

SoS Mission Considerations

- Enemy Hostile (Active Patrol Zones)
- Denial of US Assets to Littoral Region
- US Tasking: RECCE, Targeting, and Strike

Threats & Scenarios Summary

- Quantifying Capability vs. Risk
- Building the Operating Environment
- Identifying Future Threats
- Evaluating SoS Performance with Scenarios

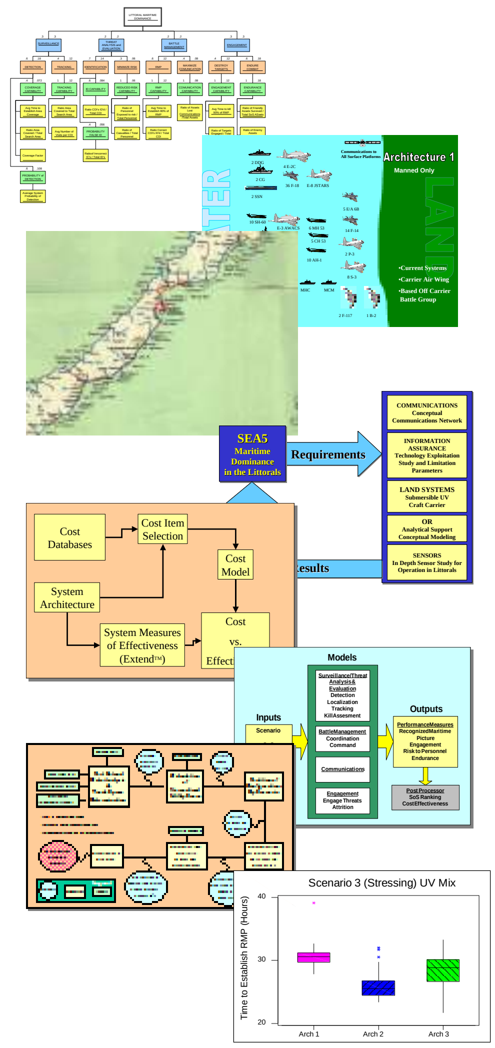


TDSI Integration

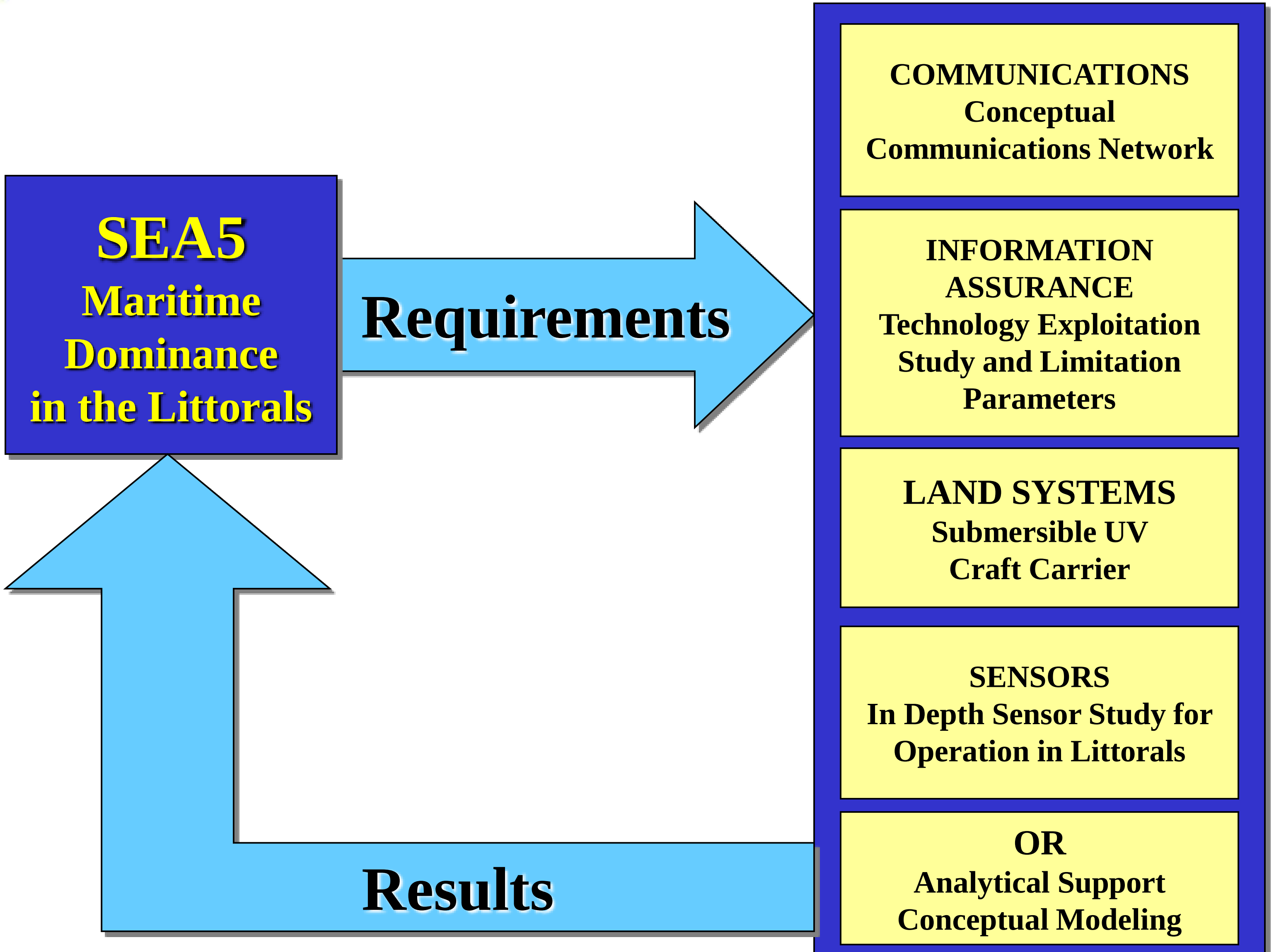
ENS Kara Hartling

SoS Development

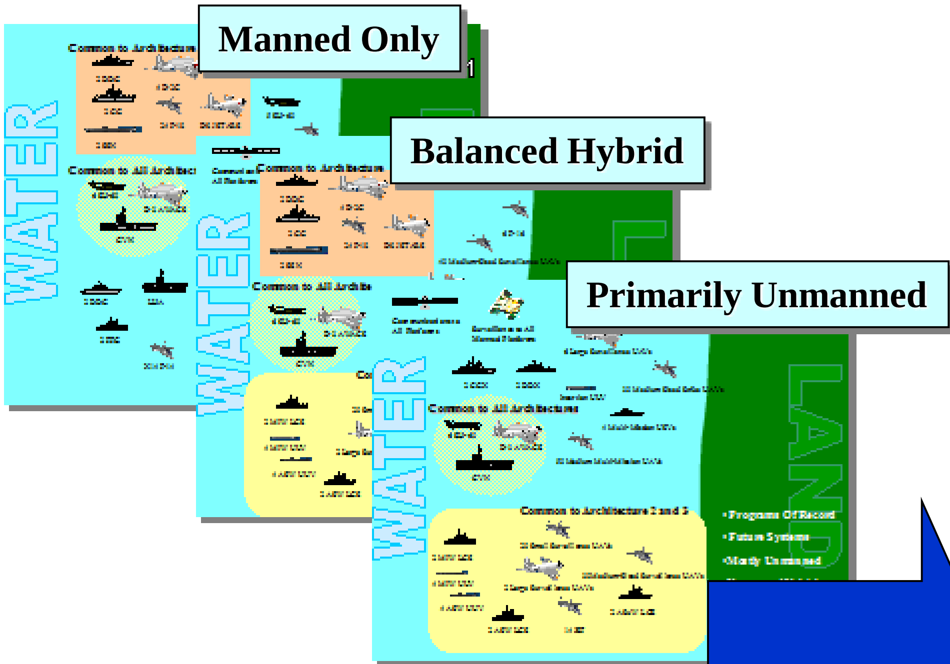
- Functional Analysis
- Value Systems Design
- Architectures
- Threats & Scenarios
- **TDSI Integration**
- Cost Analysis
- Simulative Study
- Architecture Ranking
- Configuration Validation



TDSI Requirements Process



Communications Track



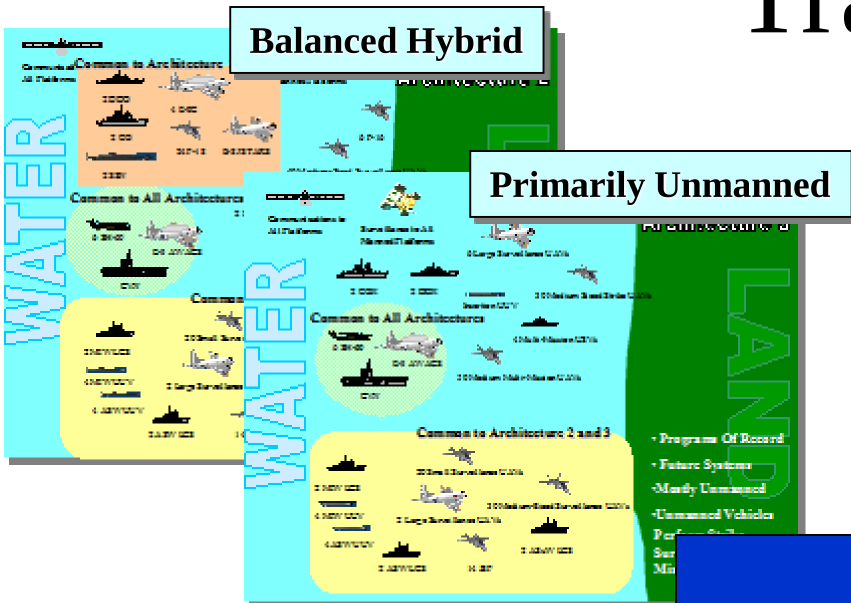
Architecture Needs

- Distributed
- Wireless
- High Data Rates

Comms Outputs

- Developed a Conceptual Inter-platform Communications Network
- Provided Interoperability and Bandwidth Constraints
- Focused on Emerging Technologies such as
  - Mobile *ad hoc* Networking
  - Adaptive Communication Software for Multi-platform System Interoperability (Software Defined Radio)

Information Assurance Track



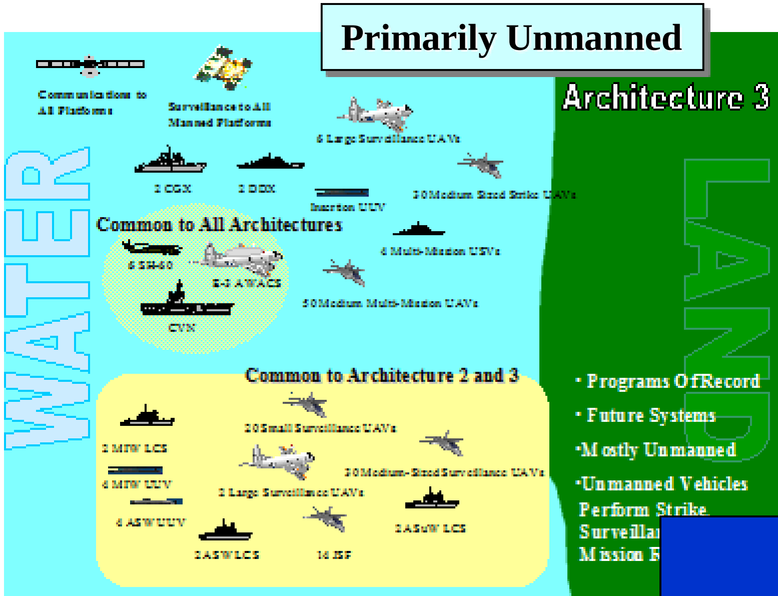
Architecture Needs

- Comparative Analysis on Information Security of Manned Versus Unmanned System

Information Assurance Outputs

- Performed Information Security Study on Means of Securing and Authenticating UV Communications
- Defined Inherent Organic Capabilities of UVs That Could Be Exploited
- Defined Ways to Minimize Enemy Exploitation of Captured UVs

Land Systems Track



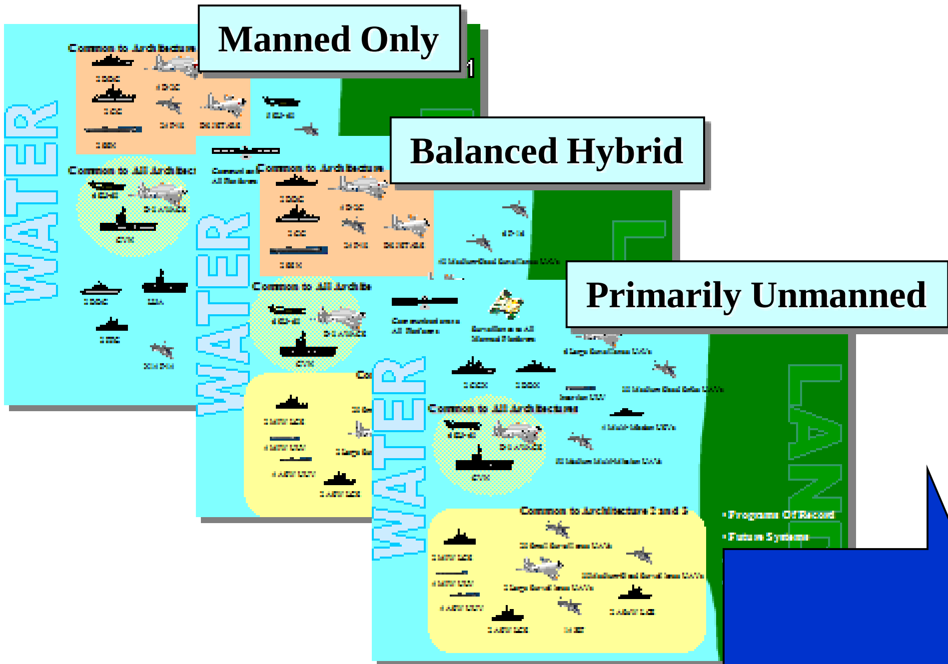
Architecture Needs

- Link Blue Water Platforms with Littoral Platforms (Long Range UV Insertion)

Land Systems Outputs

- Designed UV Craft Carrier
  - Submersible
  - Deployed from Surface Platform
  - Capable of Deploying and Recovering Mini UVs
  - Multi Mission Capable (MIW, ASW)
  - Extended Reach into Littorals

Sensors Track



Architecture Needs

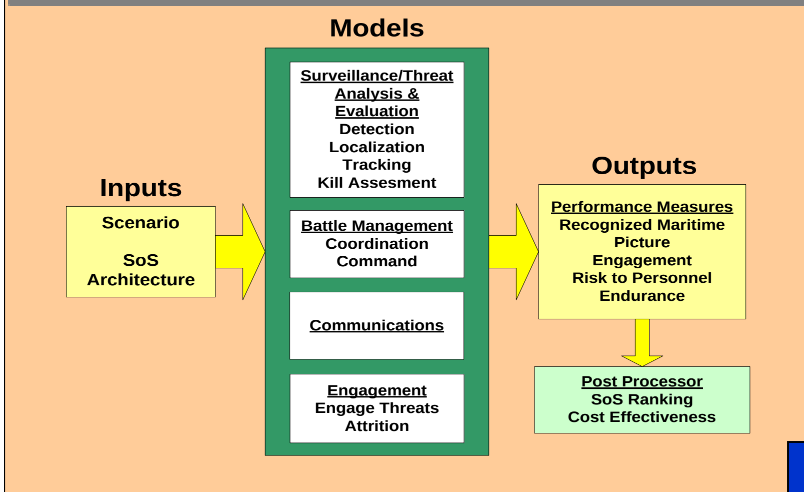
- Capability of Detecting and Tracking Land Targets in the Littorals
- Capability of Detecting and Tracking Submerged Threats
- Timely Detection of Contacts

Sensors Outputs

- Performed In-depth Environmental Analysis of Littorals
- Defined Requirements for Sensor Network to Detect Land Based Anti-Access Defensive Systems (FOPEN)
- Determined Means to Maximize Probability of Detection of Submerged Threats
- Developed Approaches to Detect Contacts That Operate on and Above the Sea in a Timely Manner

Operations Research Track

Simulative Study



Modeling/Simulation Needs

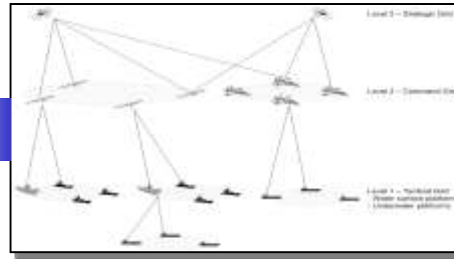
- Performance Analysis
- Analytical Support for TDSI Tracks

OR Outputs

- Develop Sensor Fusion Model (Quality Versus Quantity of UAVs)
- Determine Optimal Search Patterns for UAVs
- Determine Optimal Number of Comms Nodes for Undersea Network
- Provide Support to TDSI Tracks

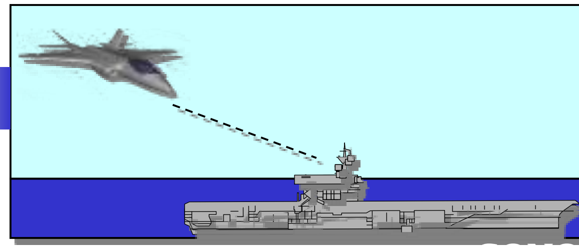
TDSI Inputs to Integrated Project

COMMUNICATIONS
Conceptual Communications Network



Extend™
Link Capacity 24 Mbps
Max. Comm. Range 60 km

INFORMATION ASSURANCE
Technology Exploitation Study and Limitation Parameters



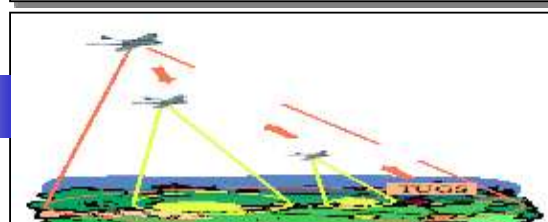
Littoral Deployment CONOPS

LAND SYSTEMS
Submersible UV Craft Carrier

Littoral Deployment CONOPS

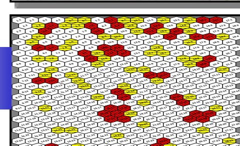
ALWSE-MC
- **5 Golden Eye UAVs**
- **20 iSTAR UAVs**
- **4 REMUS UUVs**
- **6 TALON Robot UGV**

SENSORS
In Depth Sensor Study for Operation in Littorals



Excel
- **Center Frequency 440 MHz**
- **BW 19.38 MHz**
- **Peak Power 1000 W**
- **Average Power 19 W**
- **Azimuth 3dB Beam Width 19°**
- **Elevation 3dB Beam Width 38°**
- **Nominal Gain 14 dB**

OR
Analytical Support Conceptual Modeling



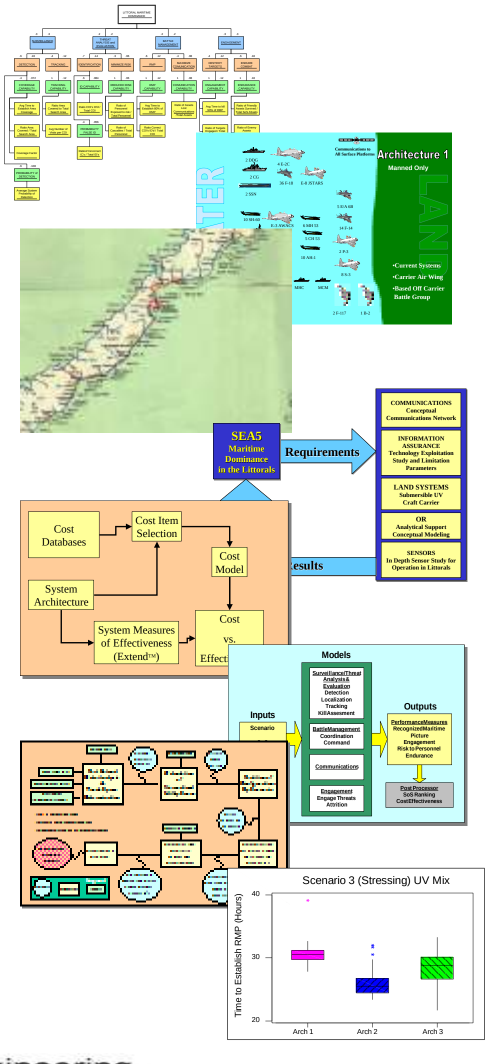
Littoral Deployment CONOPS

Cost Analysis

LT Rene Julien

SoS Development

- Functional Analysis
- Value Systems Design
- Architectures
- Threats & Scenarios
- TDSI Integration
- **Cost Analysis**
- Simulative Study
- Architecture Ranking
- Configuration Validation



Cost Analysis Preview

- Results
- Assumptions
- Methodology
- Process
- Data Collection
- Tools

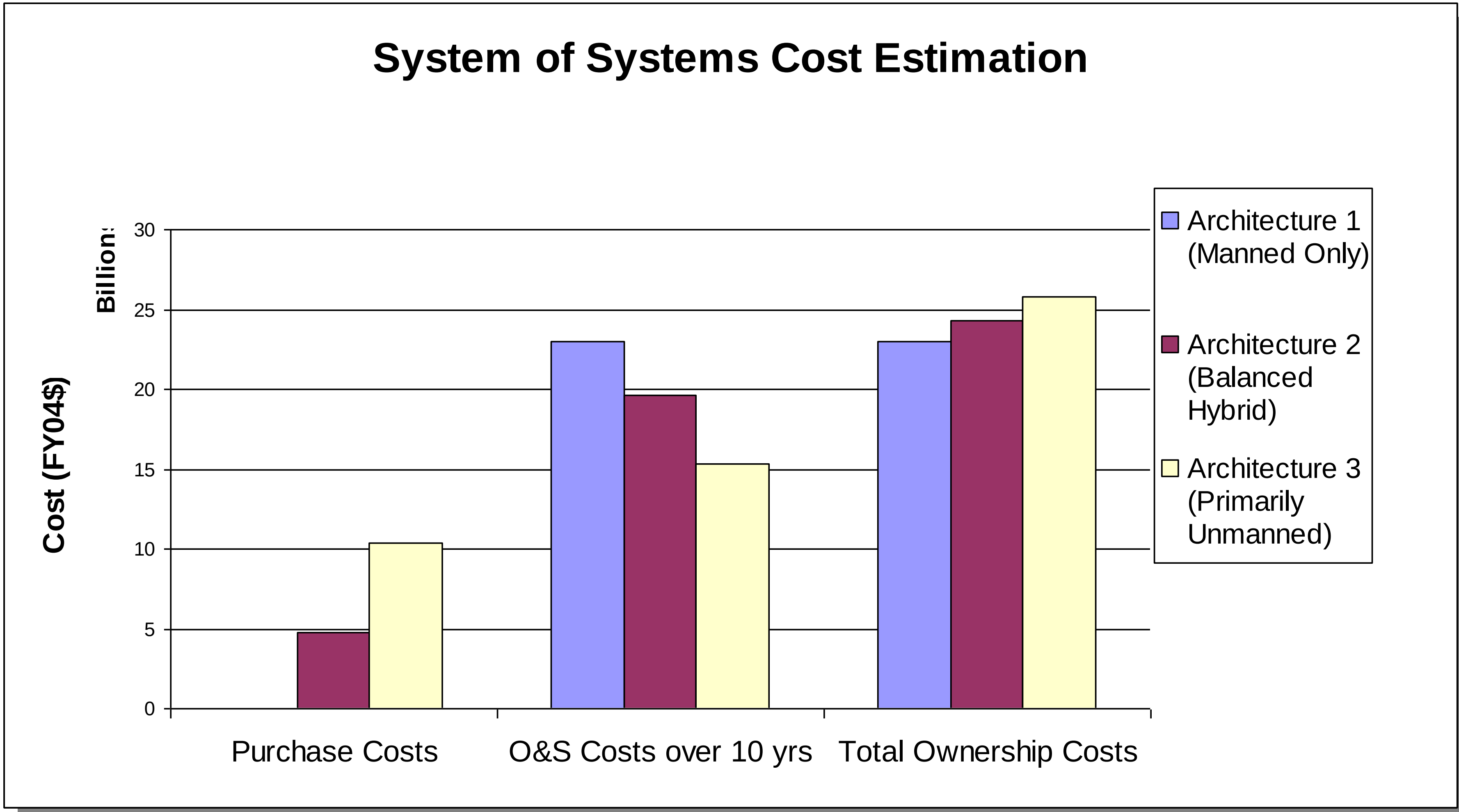
Cost Estimation Results

	Cost in FY04$B		
Architecture	**Purchase Cost**	**O&S***	**TOC****
Manned Only (Arch 1)	0	1.53	23
Balanced Hybrid (Arch 2)	4.7	1.34	24.3
Primarily Unmanned (Arch 3)	10.4	1.13	25.8

*** Per 1-year Basis**

**** Per 10-year Basis Including Inflation**

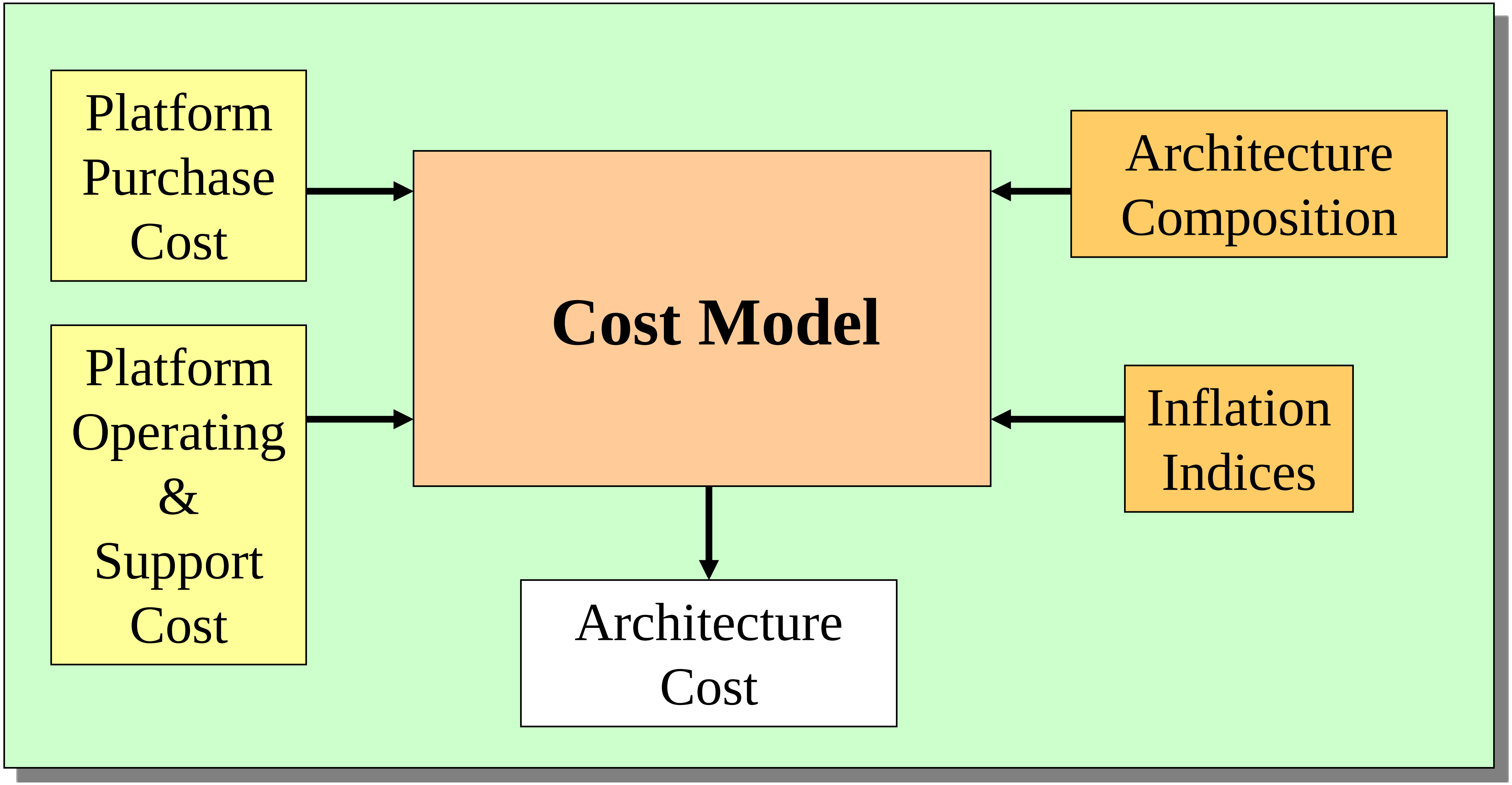
Systems Cost Comparison



Platform Cost Assumptions

- Fiscal Year Estimates
  - Not Available From Open Sources
  - Based on Proprietary Sources
- Future Manned and Unmanned Systems Equivalent in Cost to Manned Systems
  - UAV2-1 Cost Equivalent to E-2C
  - F-35 (Joint Strike Fighter) Based on F/A-18F O&S Data
- Current UAV O&S Costs Approximately 10% of Manned Equivalents
  - Based on Air Force Predator O&S Costs

Cost Process Methodology



Cost Estimation Methodology

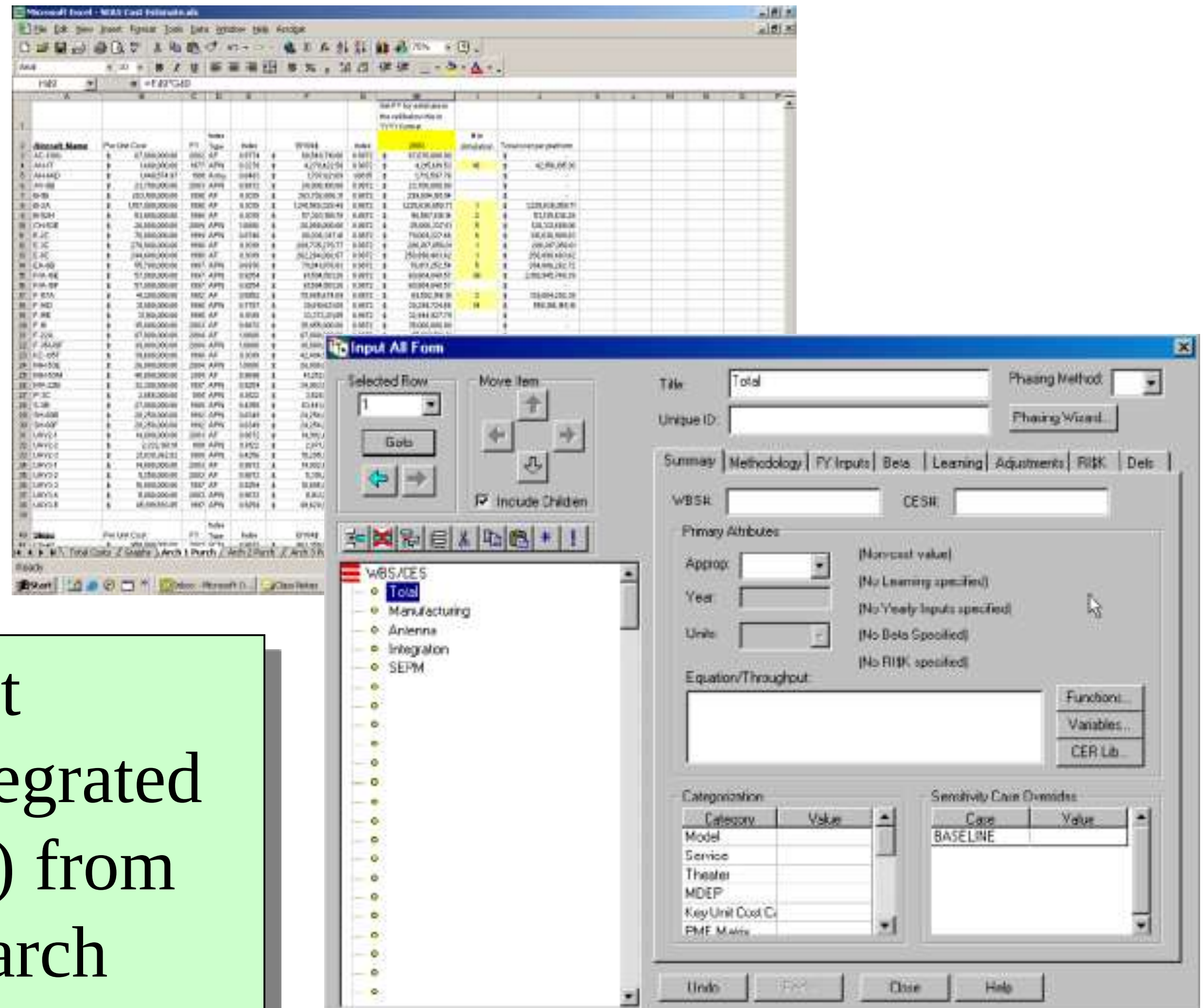
- All O&S Costs in FY2003 From VAMOSC, AFTOC and OSMIS Databases
- Costs for Future Systems (i.e., UVs and (X) Ships) Estimated Using Analogy Technique
- Derivation of Proposed Future System Unit Cost Using Cost Factors
  - Complexity
  - Miniaturization
  - Productivity Improvement

Cost Organizations

- Navy Center for Cost Analysis (NCCA)
- Air Force Cost Analysis Agency (AFCAA)
- US Army Cost and Economic Analysis Center (USACEAC)
- Defense Cost and Research Center (DCARC)
- Tecolote Research (ACEIT Software)

Cost Estimation Tools

Microsoft Excel



Advanced Cost Estimating Integrated Tools (ACEIT) from Tecolote Research

Simulative Study

ENS Bryce Abbott

SoS Development

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- Value Systems Design
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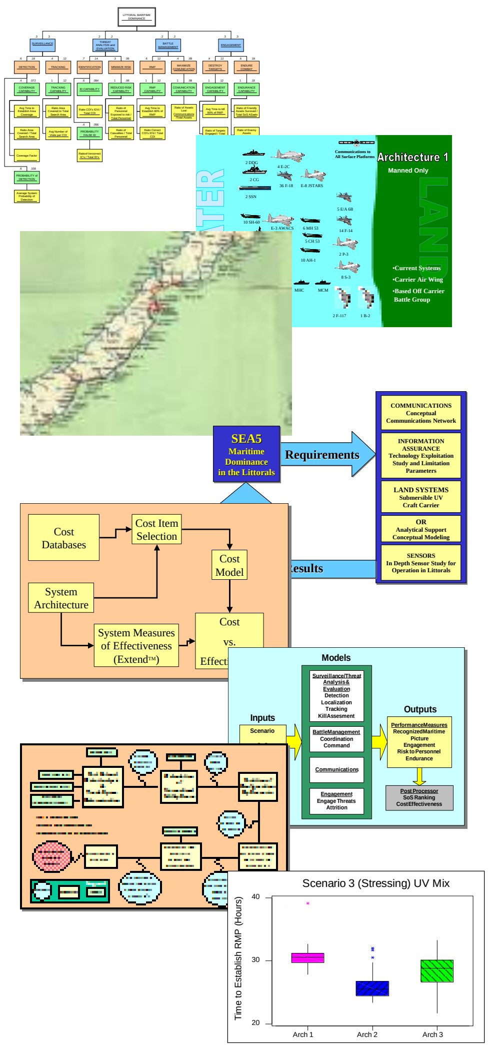
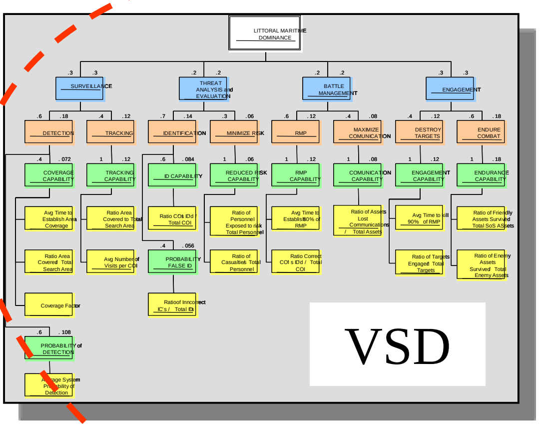
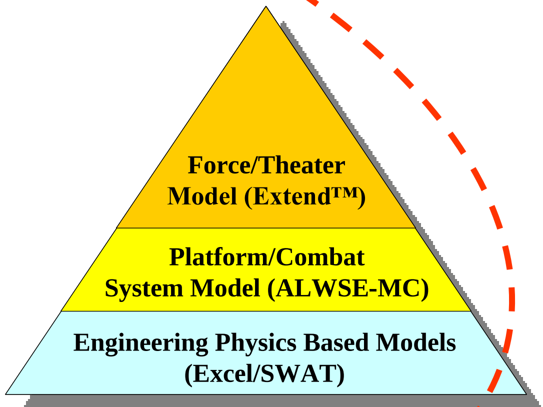


Simulative Study Overview





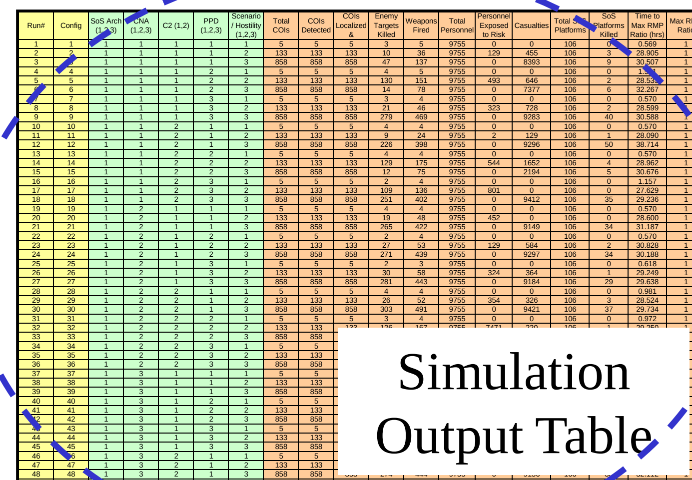
Modeling Framework

Result

- Quantitative Data Provided to Answer Important Questions

Method

- Important Questions and Sensitive Design Variables Identified
- Comprehensive Modeling Framework Developed to Answer the Important Questions



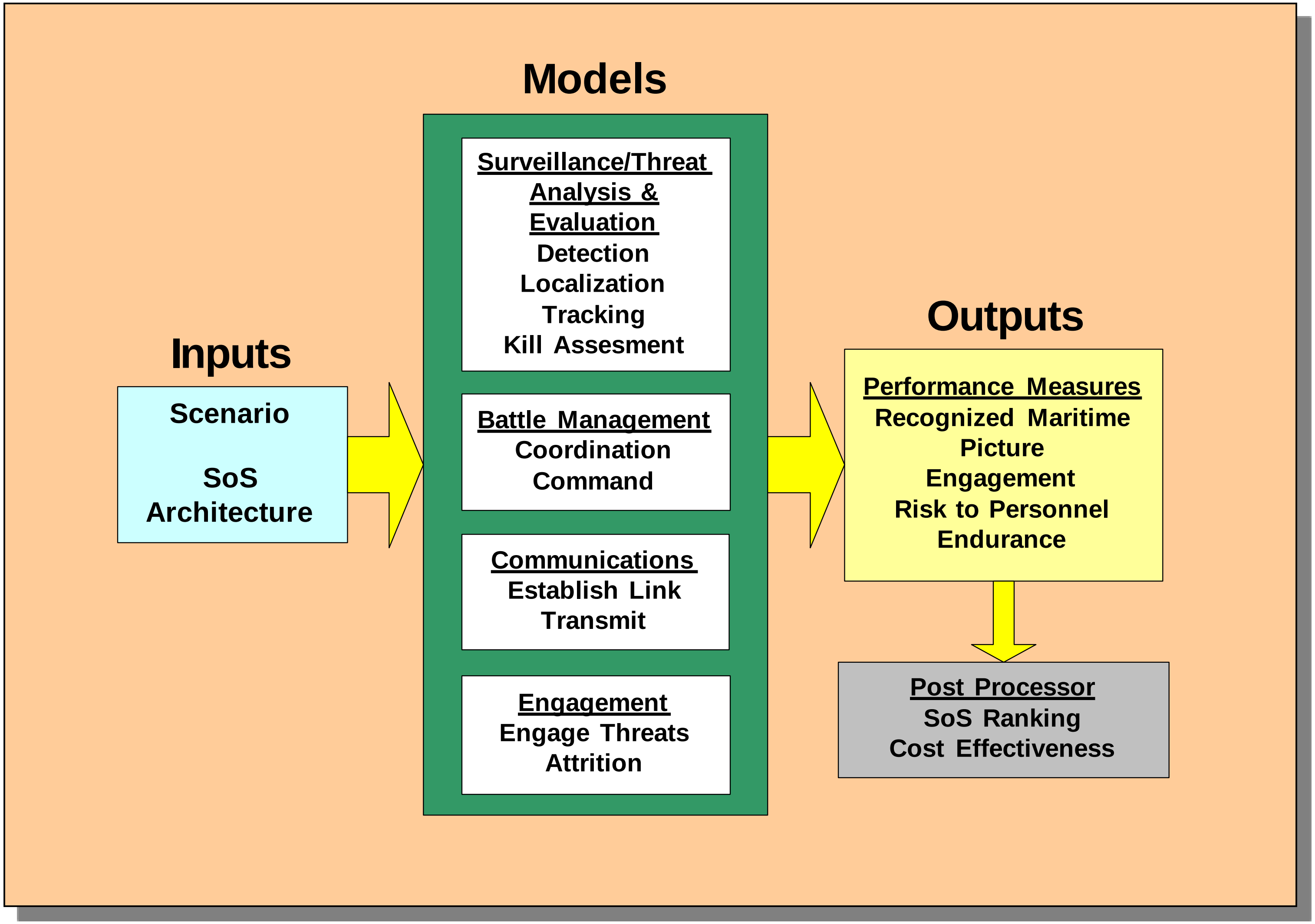
Simulative Study

- Objective
- Design
- Modeling Framework
- Modeling Tools
- Modeling Output

Simulative Study Objective

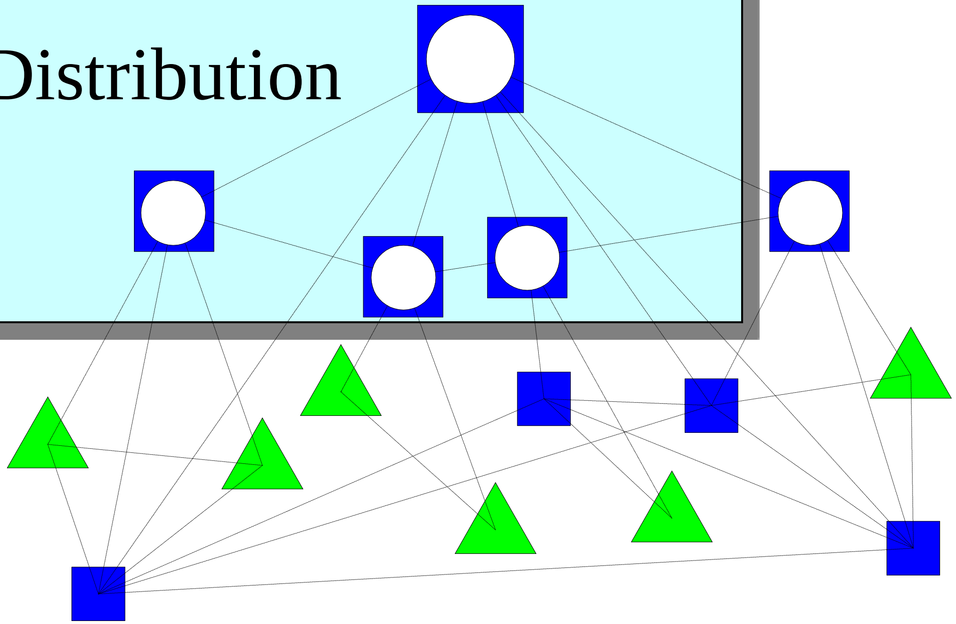
- Conduct a Simulative Monte Carlo Analysis to Quantify the Effectiveness of Alternative SoS Architectures by Answering
  - How Much Time Does the SoS Require to Establish the Recognized Maritime Picture?
  - How Well Does the SoS Engage Threats?
  - How Well Does the SoS Protect Personnel From Risk?
  - How Well Does the SoS Endure Combat?

Simulative Study Design



Simulative Study Design Variables

- SoS Architecture
  - Communications Network Architecture
  - Command and Control
  - Platform Physical Distribution
- Scenario



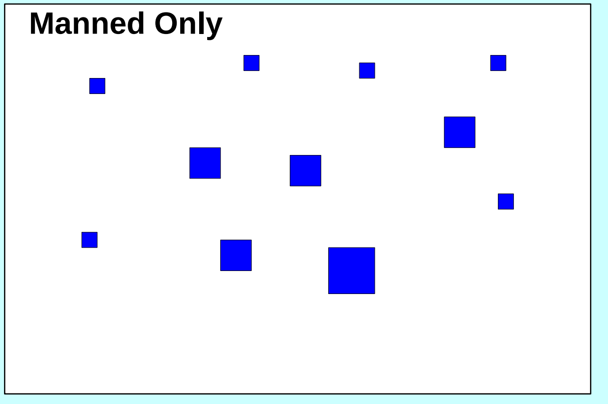
Simulative Study Design – SoS Architecture Variable

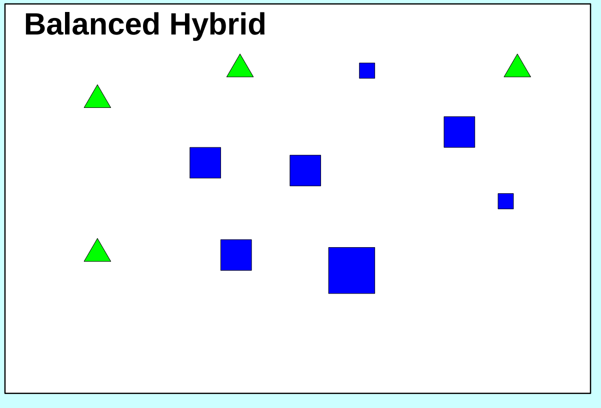
SoS Architecture Variable

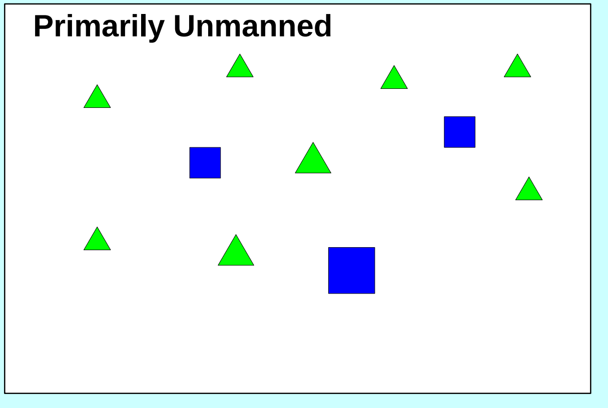
- Manned Only
- Balanced Hybrid
- Primarily Unmanned

Manned Platform

Unmanned Platform



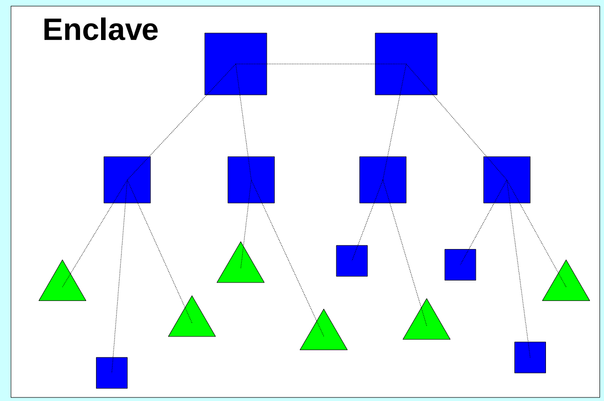




Simulative Study Design - CNA Variable

Communications Network Architecture (CNA)

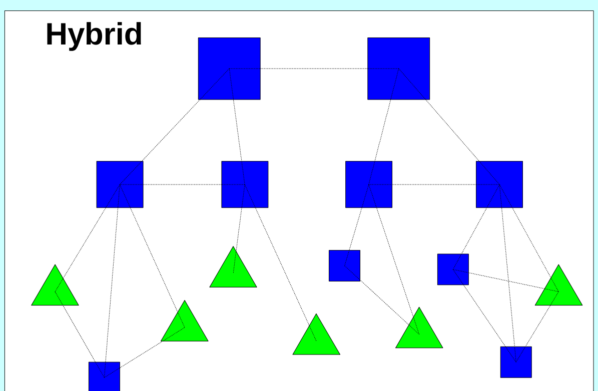
- Enclave
- Hybrid
- Distributed

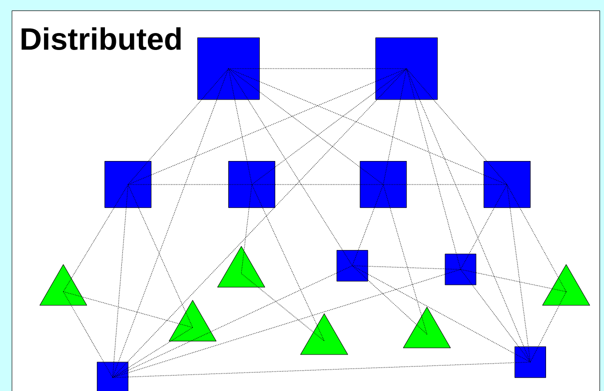


Manned Platform

Unmanned Platform

Line of Communication

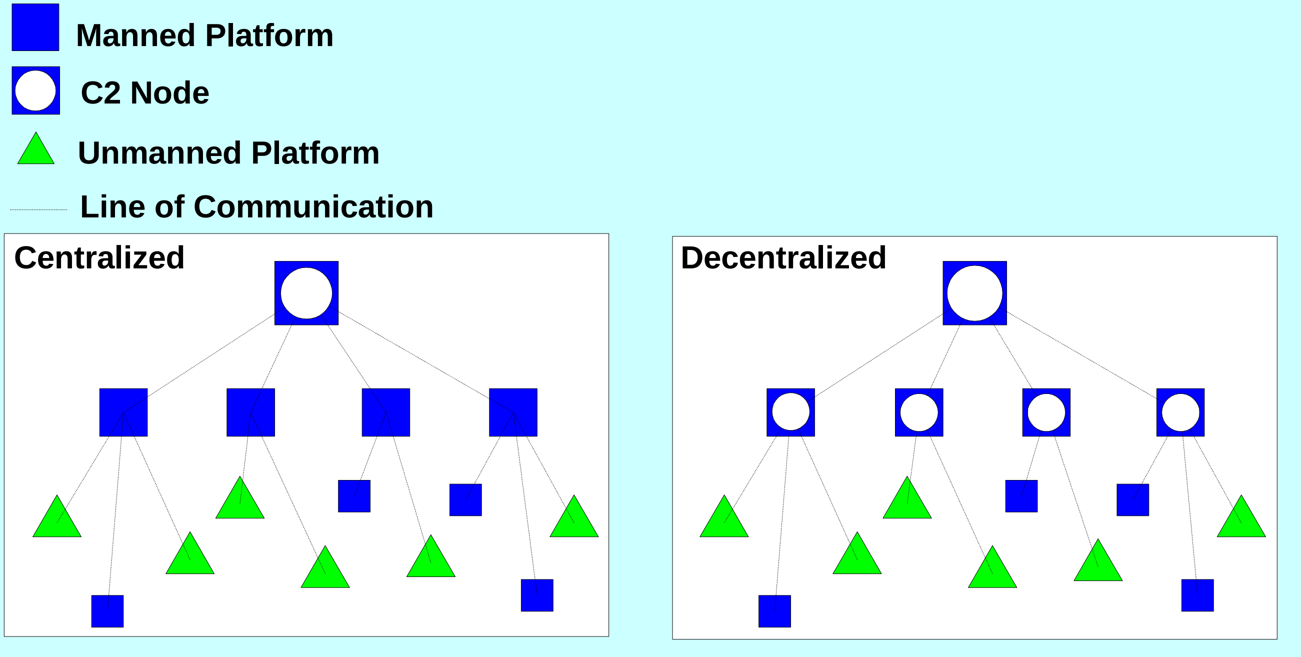




Simulative Study Design - C2 Variable

Command and Control (C2)

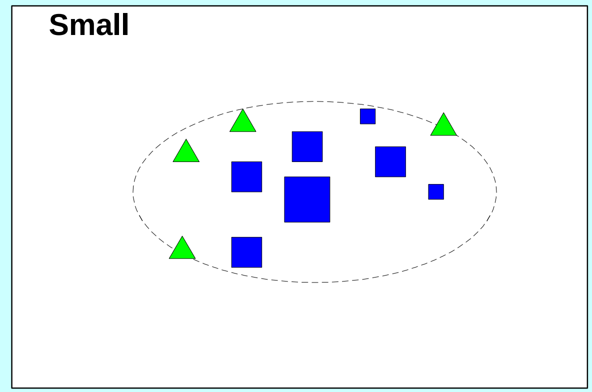
- Centralized
- Decentralized



Simulative Study Design - PPD Variable

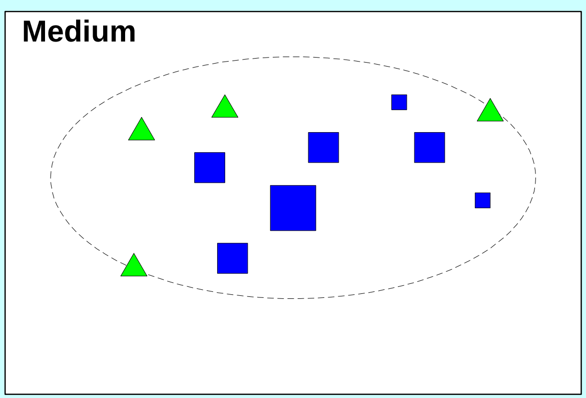
Platform Physical Distribution (PPD)

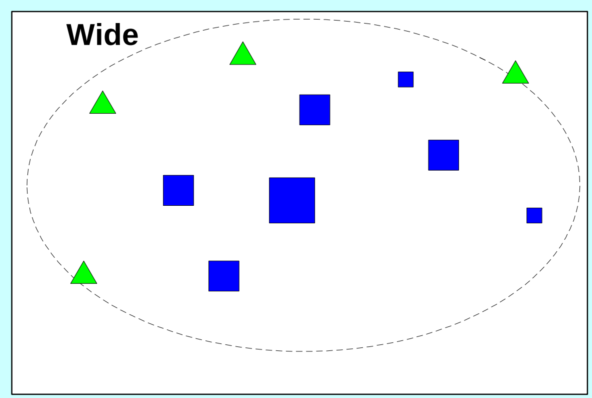
- Small
- Medium
- Wide



Manned Platform

Unmanned Platform

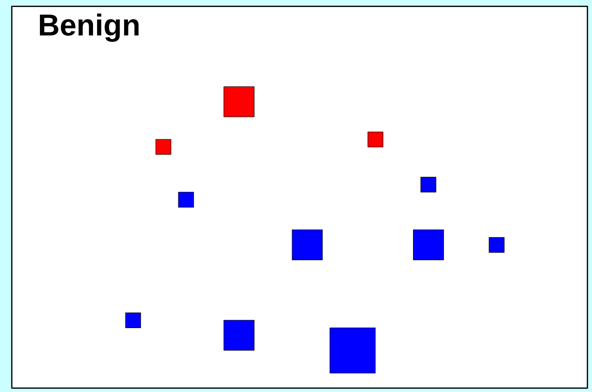




Simulative Study Design - Scenario Variable

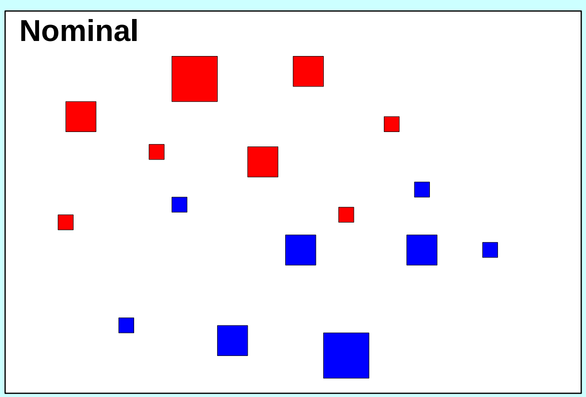
Scenario

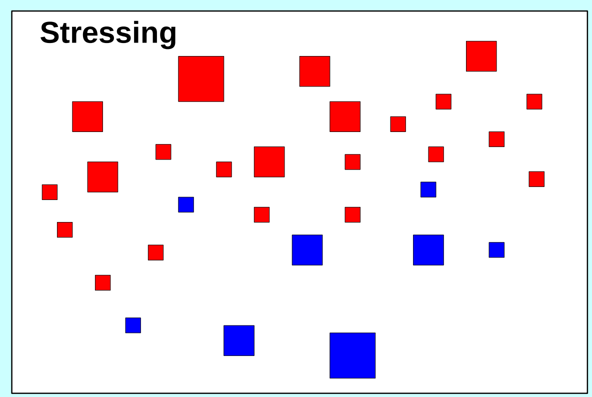
- Benign
- Nominal
- Stressing



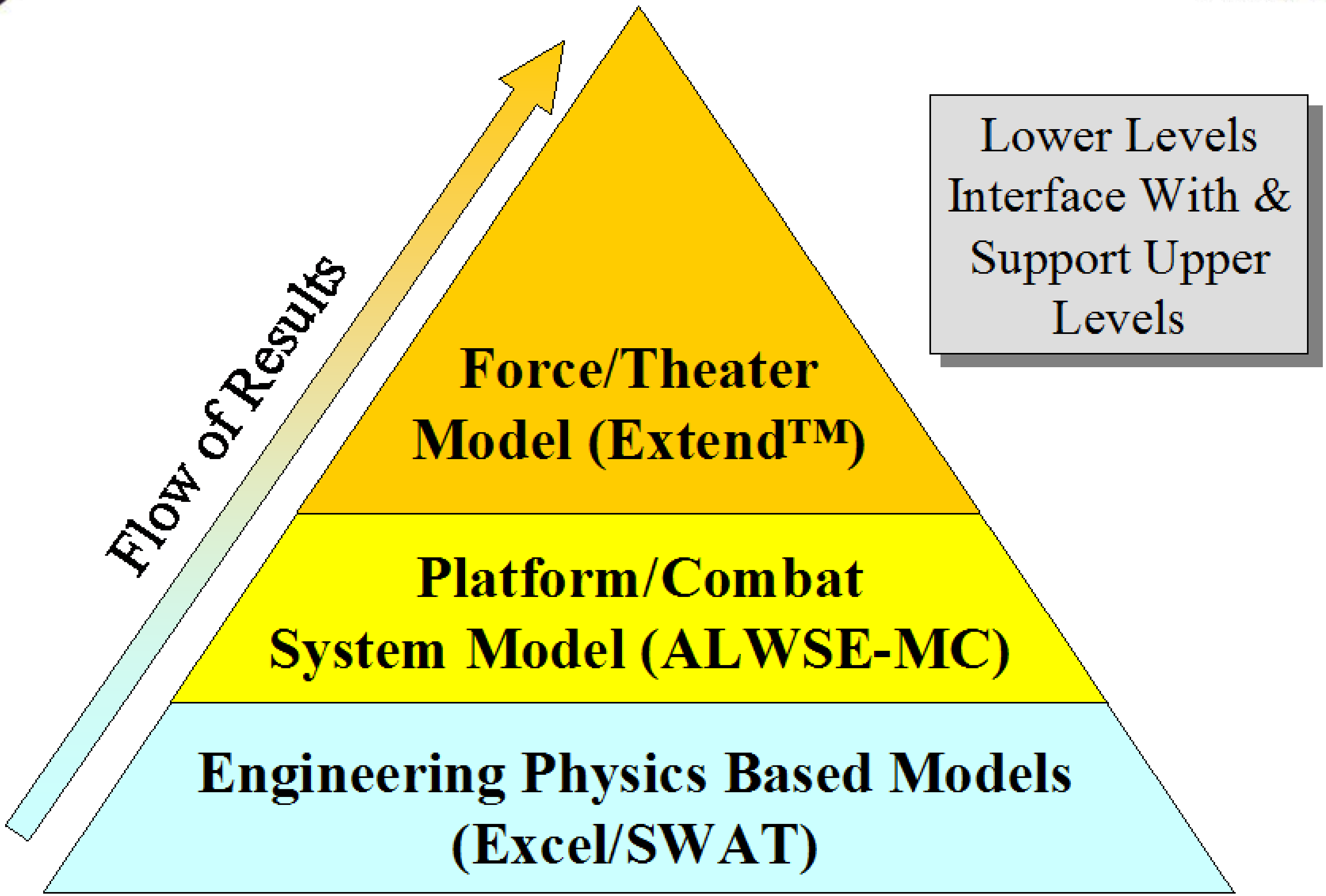
Friendly Platform

Hostile Platform



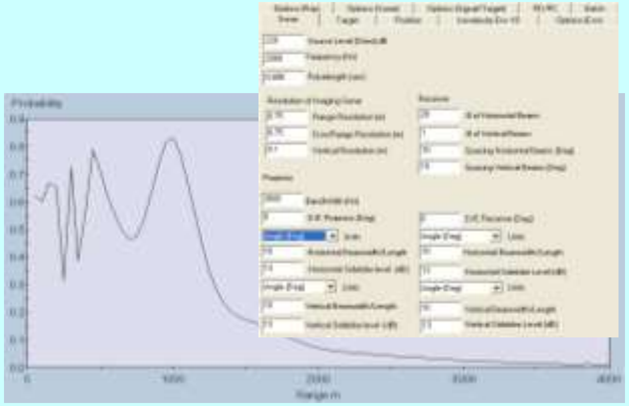


Modeling Framework



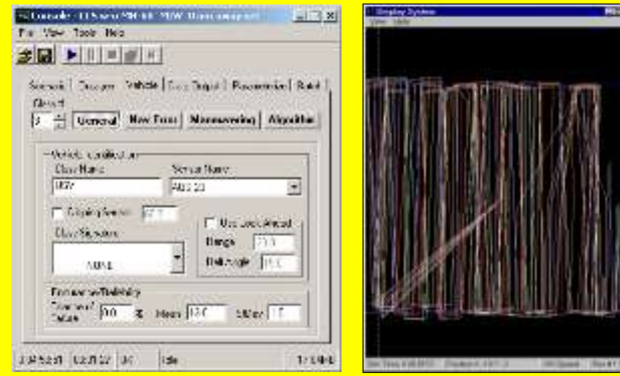
Modeling Tools Interface

Excel/SWAT



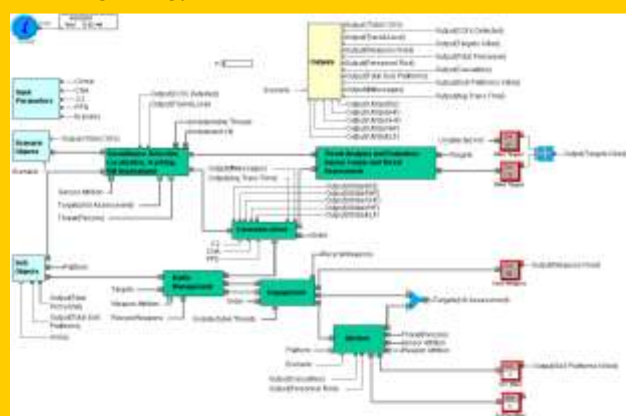
Lateral Range Detection Curves

ALWSE-MC



Database Tables

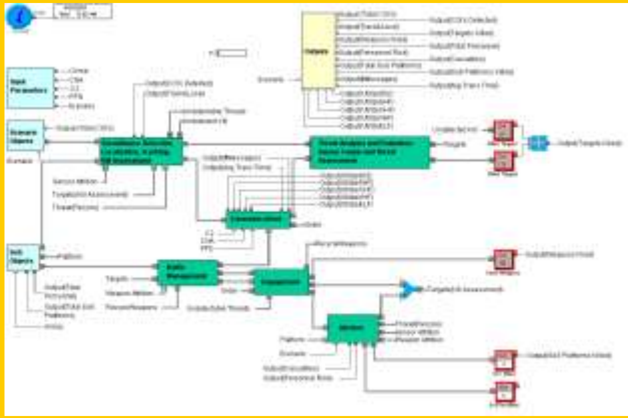
Extend™



Time To Detection Data

Modeling Output

Extend™



Run#	Config	SoS Arch (1,2,3)	CNA (1,2,3)	C2 (1,2)	PPD (1,2,3)	Scenario / Hostility (1,2,3)	Total COIs	COIs Detected	COIs Localized &	Enemy Targets Killed	Weapons Fired	Total Personnel	Personnel Exposed to Risk	Casualties	Total SoS Platforms	SoS Platforms Killed	Time to Max RMP Ratio (hrs)	Max RMP Ratio
1	1	1	1	1	1	1	5	5	5	3	5	9755	0	0	106	0	0.569	1
2	2	1	1	1	1	2	133	133	133	10	36	9755	129	455	106	3	28.905	1
3	3	1	1	1	1	3	858	858	858	47	137	9755	0	8393	106	9	30.507	1
4	4	1	1	1	2	1	5	5	5	4	5	9755	0	0	106	0	1.501	1
5	5	1	1	1	2	2	133	133	133	130	151	9755	493	646	106	2	28.533	1
6	6	1	1	1	2	3	858	858	858	14	78	9755	0	7377	106	6	32.267	1
7	7	1	1	1	3	1	5	5	5	3	4	9755	0	0	106	0	0.570	1
8	8	1	1	1	3	2	133	133	133	21	46	9755	323	728	106	2	28.599	1
9	9	1	1	1	3	3	858	858	858	279	469	9755	0	9283	106	40	30.588	1
10	10	1	1	2	1	1	5	5	5	4	4	9755	0	0	106	0	0.570	1
11	11	1	1	2	1	2	133	133	133	9	24	9755	2	129	106	1	28.090	1
12	12	1	1	2	1	3	858	858	858	226	398	9755	0	9296	106	50	38.714	1
13	13	1	1	2	2	1	5	5	5	4	4	9755	0	0	106	0	0.570	1
14	14	1	1	2	2	2	133	133	133	129	175	9755	544	1652	106	4	28.962	1
15	15	1	1	2	2	3	858	858	858	12	75	9755	0	2194	106	5	30.676	1
16	16	1	1	2	3	1	5	5	5	2	4	9755	0	0	106	0	1.157	1
17	17	1	1	2	3	2	133	133	133	109	136	9755	801	0	106	0	27.629	1
18	18	1	1	2	3	3	858	858	858	251	402	9755	0	9412	106	35	29.236	1
19	19	1	2	1	1	1	5	5	5	4	4	9755	0	0	106	0	0.570	1
20	20	1	2	1	1	2	133	133	133	19	48	9755	452	0	106	0	28.600	1
21	21	1	2	1	1	3	858	858	858	265	422	9755	0	9149	106	34	31.187	1
22	22	1	2	1	2	1	5	5	5	2	4	9755	0	0	106	0	0.570	1
23	23	1	2	1	2	2	133	133	133	27	53	9755	129	584	106	2	30.828	1
24	24	1	2	1	2	3	858	858	858	271	439	9755	0	9297	106	34	30.188	1
25	25	1	2	1	3	1	5	5	5	2	3	9755	0	0	106	0	0.618	1
26	26	1	2	1	3	2	133	133	133	30	58	9755	324	364	106	1	29.249	1
27	27	1	2	1	3	3	858	858	858	281	443	9755	0	9184	106	29	29.638	1
28	28	1	2	2	1	1	5	5	5	4	4	9755	0	0	106	0	0.981	1
29	29	1	2	2	1	2	133	133	133	26	52	9755	354	326	106	3	28.524	1
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31	31	1	2	2	2	1	5	5	5	3	4	9755	0	0	106	0	0.972	1
32	32	1	2	2	2	2	133	133	133	126	167	9755	7471	220	106	1	29.250	1
33	33	1	2	2	2	3	858	858	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
34	34	1	2	2	3	1	5	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
35	35	1	2	2	3	2	133	133	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
36	36	1	2	2	3	3	858	858	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
37	37	1	3	1	1	1	5	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
38	38	1	3	1	1	2	133	133	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
39	39	1	3	1	1	3	858	858	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	40	1	3	1	2	1	5	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
41	41	1	3	1	2	2	133	133	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
42	42	1	3	1	2	3	858	858	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
43	43	1	3	1	3	1	5	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
44	44	1	3	1	3	2	133	133	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
45	45	1	3	1	3	3	858	858	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
46	46	1	3	2	1	1	5	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
47	47	1	3	2	1	2	133	133	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
48	48	1	3	2	1	3	858	858	858	274	444	9755	0	9156	106	38	32.112	1
49	49	1	3	2	2	1	5	5	5	4	5	9755	0	0	106	0	0.818	1

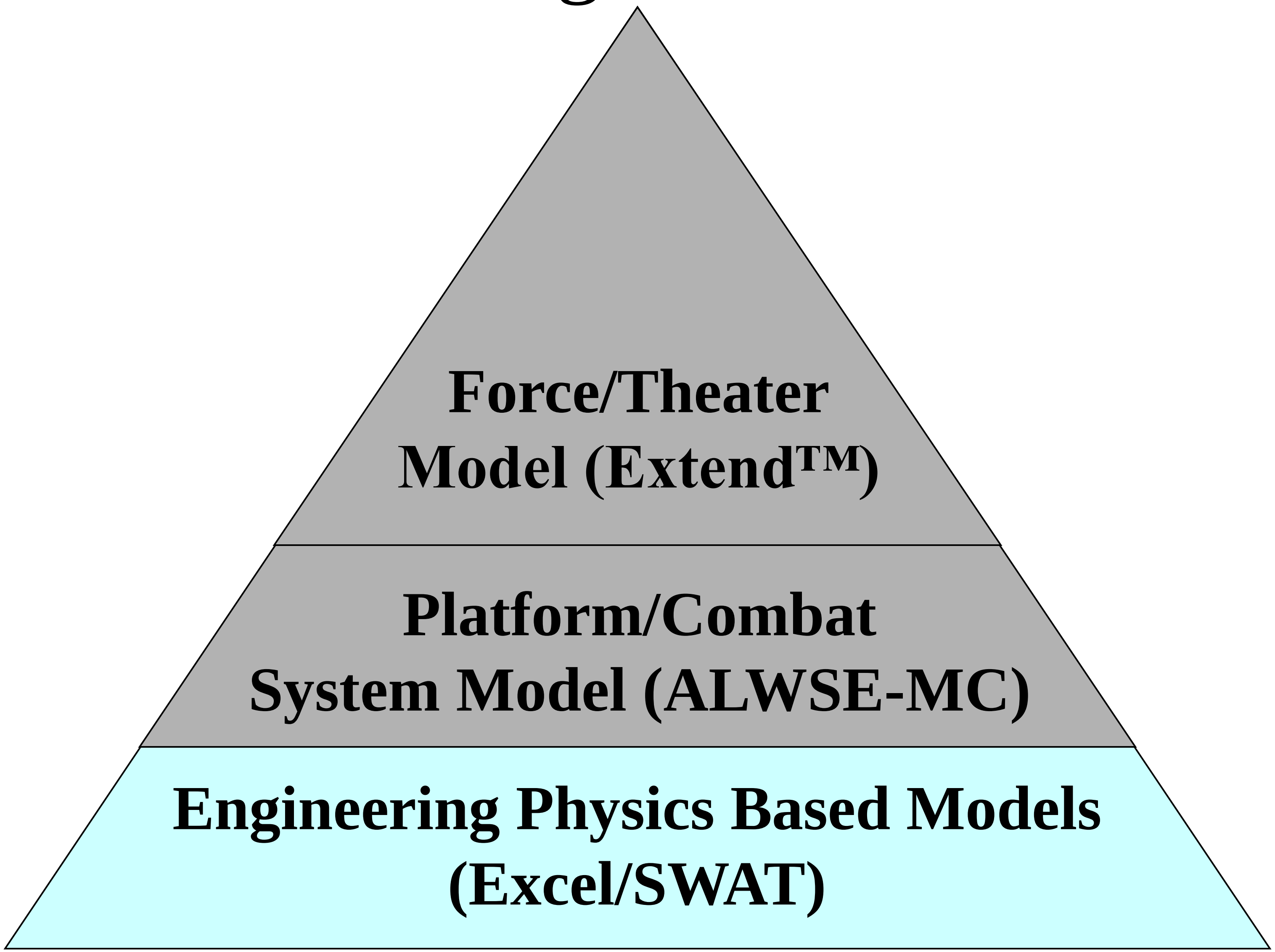
Simulation Output Table

Quantitative Data Provided to Fulfill Simulative Study Objective

Engineering Physics Models (Excel/SWAT)

ENS Scott Poitevent

Modeling Framework



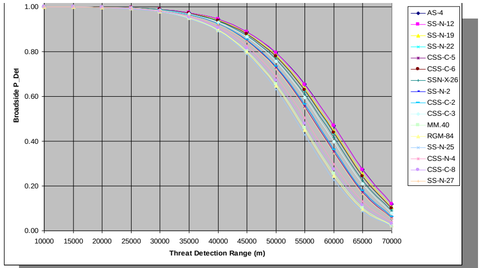
Excel/SWAT

- Provide Flexible Tool for Detection Simulation with Sensor/Target Pairs
- Implement Physical Laws for Analytical Application
- Generate P_det vs Range Curves

Sensor

Target

Excel/SWAT



P_det vs Range Curve

Engineering Analysis Models (Excel/SWAT)

- Engineering Physics Based Modeling Performed to Create Database Tables and Lateral Range Detection Curves for Sensors / Threats Pairs
- Sensor-Target Models
  - Probability of Detection (P_det) vs Range Curves
- Physics Models*
  - Radar Based on Swerling II
  - Acoustic Based on Manning P_det
  - Infrared (IR) Based on Johnson's Criteria

*R. Harney, *Combat Systems Sensors Vol. I & II,* Naval Postgraduate School 2004, Unpublished Manuscript

Engineering Model Inputs

- Sensor Parameters
- TDSI FOPEN Radar Performance Parameters
- Specific Enemy Threat Characteristics From Scenario
- Environmental Parameters

IR Input Table

Mach Conversion Table

km/hr	m/s	Mach	km/hr	m/s	Mach
720	200	0.6061	1,098	305	0.9242
738	205	0.6212	1,116	310	0.9394
756	210	0.6364	1,134	315	0.9545
774	215	0.6515	1,152	320	0.9697
792	220	0.6667	1,170	325	0.9848
810	225	0.6818	**1,188**	**330**	**1.0000**
828	230	0.6970	1,206	335	1.0152
846	235	0.7121	1,224	340	1.0303
864	240	0.7273	1,242	345	1.0455
882	245	0.7424	1,260	350	1.0606
900	250	0.7576	1,278	355	1.0758
918	255	0.7727	1,296	360	1.0909
936	260	0.7879	1,314	365	1.1061
954	265	0.8030	1,332	370	1.1212
972	270	0.8182	1,350	375	1.1364
990	275	0.8333	1,368	380	1.1515
1,008	280	0.8485	1,386	385	1.1667
1,026	285	0.8636	1,404	390	1.1818
1,044	290	0.8788	1,422	395	1.1970
1,062	295	0.8939	1,440	400	1.2121
1,080	300	0.9091	1,458	405	1.2273

Reflectance = 0.0100
Emissivity = 0.9900
Pi = 3.14
TA Radians = 0
Sensor Freq(M) = 3.0E+09

Reqd CNR 0.69
Power (watts) 3.0000E+09
Aperture Diameter (m) 4.000
Bandwidth (Hz) 1.00E+08
Freq (Hz) 3.00E+09
Noise figure 1
Antenna Temp (K) 300

Generic Threat Categories

Threat	Length (m)	Diameter (m)	Reflectivity	RCS (m^2)	Body temp. (K)	Engine temp. (	Emmisivity	Target angle (r	IR Area (m^2
ASCM-1	3.75	0.42	0.1	0.0138474	351.894	1000	0.9900		0.1370893
ASCM-2	8.9	0.67	0.1	0.03523865	675	1000	0.9900		0.3488626
ASCM-3	11.6	0.92	0.1	0.0664424	1800	1000	0.9900		0.6577798
Ambient temp (K)	300								

RF Input Table

$$R = \left[\frac{\pi P_T D^4 \sigma}{64\lambda^2 kTBF(CNR)}\right]^{1/4}$$

Pi = 3.14
Pt (W) = 100
Sigma =
T = 299.7
TBF =
CNR = 0.79
BW = 1.05E+08

Reflect = 0.0100
Noise Fig. = 1

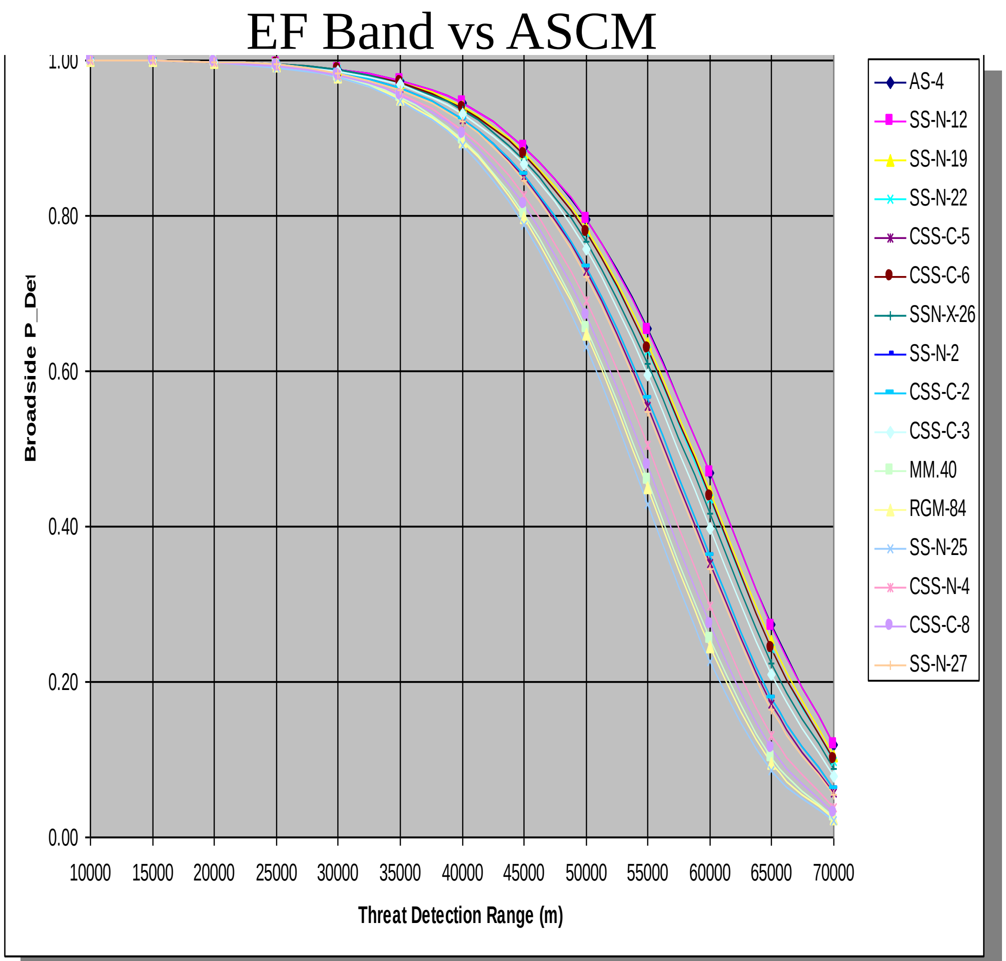
TA (Rad) = 0
Ant F (Hz) 3000000000
Ant Ap = 0.003

RCS (m^2)	Length (m) ASCM	Detection	Detection	Length (m) A/C	Detection	Detection
Diameter	7.34	Range (m)	Range (nm)	10.00	Range (m)	Range (nm)
0.01	7.9E-07	1.6E-01	9.0E-05	7.9E-07	1.6E-01	9.0E-05
0.02	3.1E-06	2.3E-01	1.3E-04	3.1E-06	2.3E-01	1.3E-04
0.03	7.1E-06	2.8E-01	1.6E-04	7.1E-06	2.8E-01	1.6E-04
0.04	1.3E-05	3.3E-01	1.8E-04	1.3E-05	3.3E-01	1.8E-04
0.05	2.0E-05	3.7E-01	2.0E-04	2.0E-05	3.7E-01	2.0E-04
0.06	2.8E-05	4.0E-01	2.2E-04	2.8E-05	4.0E-01	2.2E-04
0.07	3.8E-05	4.3E-01	2.4E-04	3.8E-05	4.3E-01	2.4E-04
0.08	5.0E-05	4.6E-01	2.5E-04	5.0E-05	4.6E-01	2.5E-04

Engineering Model Outputs

- Threat Signatures (Radar, IR, Acoustic)
- P_det vs. Range for Sensor-target Pairings

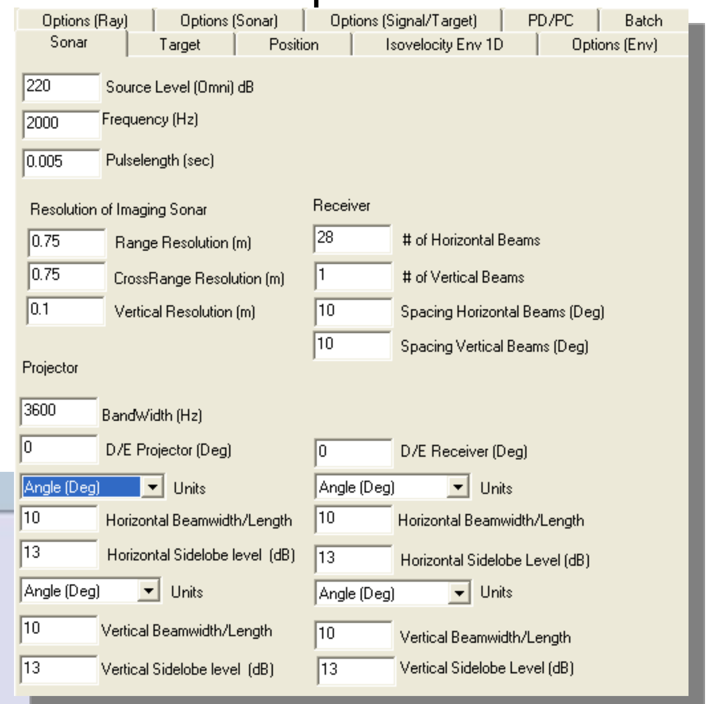
Threat Signatures

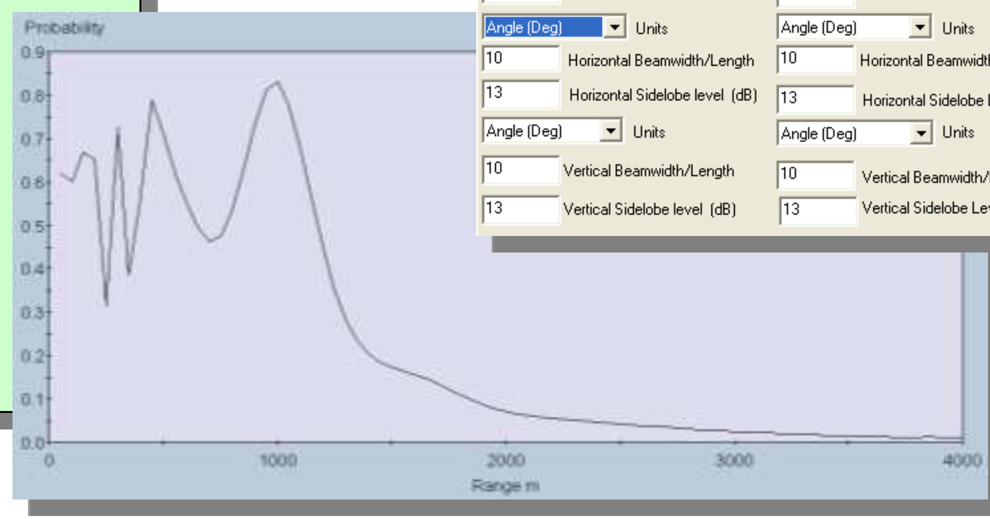


Engineering Models – SWAT

- Shallow Water Acoustics Toolset (SWAT) - NAVSEA
- Inputs
  - Environment
  - Sensor Parameters
  - Target Parameters
- Outputs
  - P_det vs. Range

SWAT Input Table



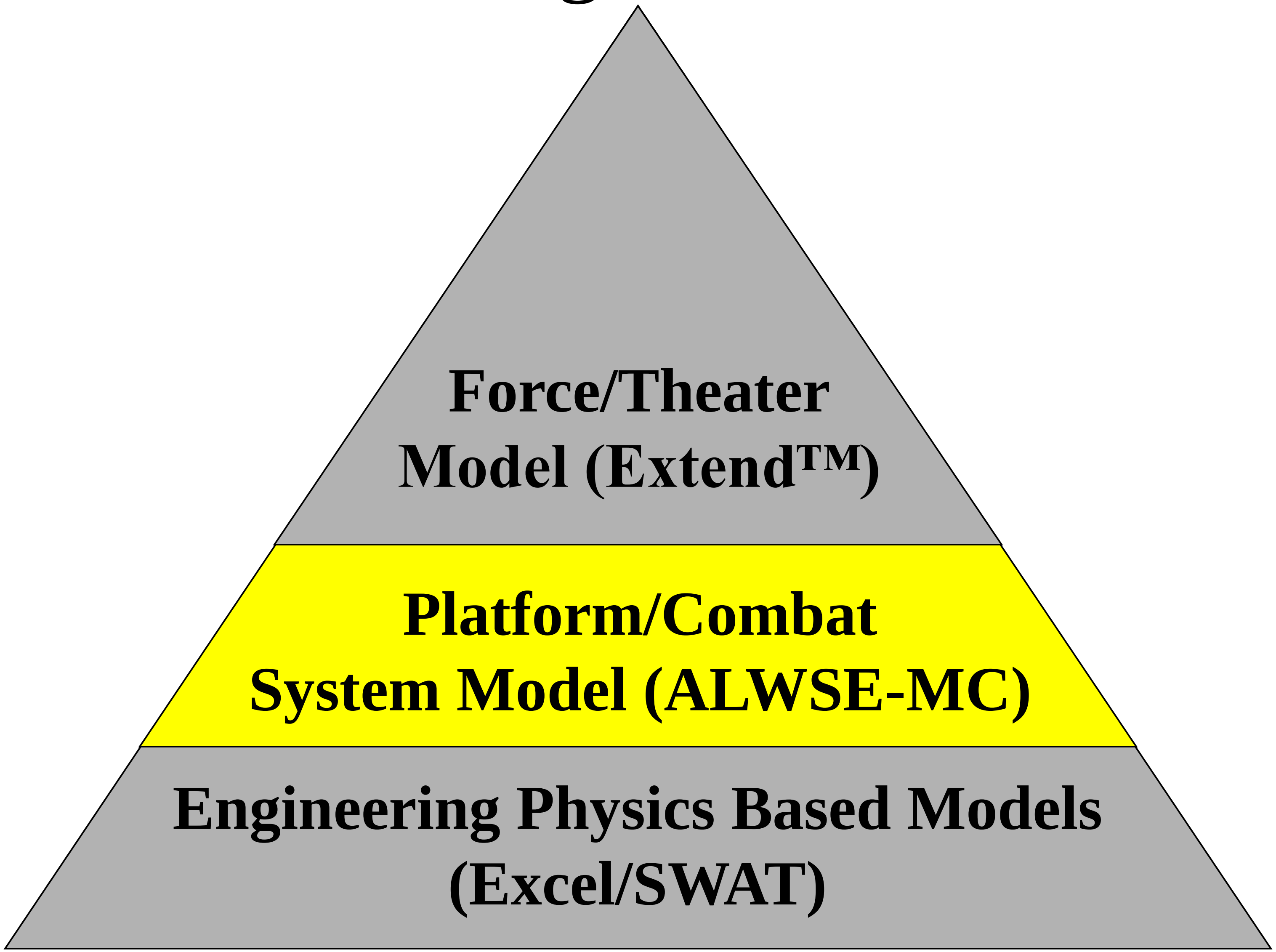


P_det vs Range Output Chart

Platform/Combat System Model (ALWSE-MC)

ENS Scott Poitevent

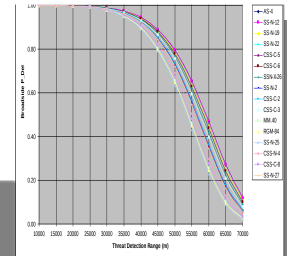
Modeling Framework



ALWSE-MC

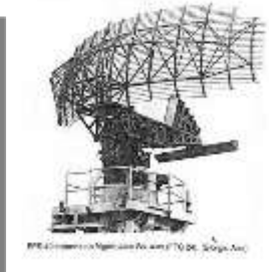
- Simulate Tactical Level Employment of Sensors Against Threats
- Make Use of Sensor P_det vs Range Curves in Performance Analysis

P_det vs Range



Target

Sensor



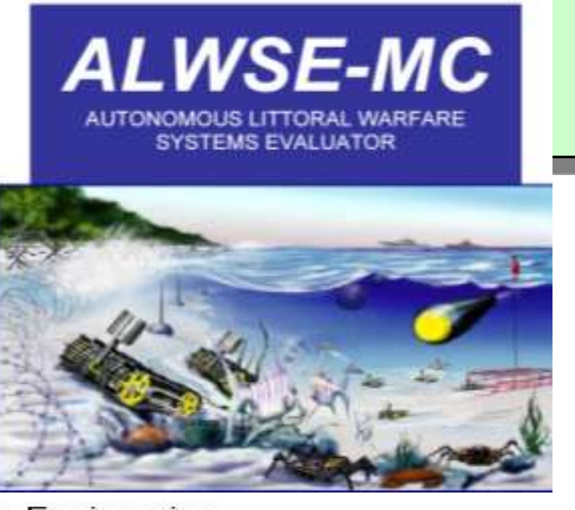
ALWSE-MC

	DD/EF	DD/K-Band	DD/X-Band	DD/SPS67	DD/SPS55	DD/B-Band	DD/EF-SH-60-IR
Run #/Col #	1	2	3	4	5	6	7
1	4695	27768	27765	27765	13895	3138	2018
2	27768	10488	8897	27765	25724	5333	2014
3	11576	11171	1320	41541	27768	7634	2015
4	462	22686	9221	13891	25941	4864	2016
5	27768	13896	13892	4427	27768	4615	7732
6	41580	5621	27770	10765	13895	2661	7603
7	27769	3286	3652	27764	2154	7028	2017
8	13891	913	13890	13885	7025	2016	3472
9	13889	13892	3188	13889	55073	7570	2017
10	3883	10277	27767	13173	38561	2015	5531
11	12527	9377	5876	13886	19997	8505	2015
12	13890	41582	13895	13654	25795	3259	2016
13	2282	27768	13892	11743	55389	5652	7177
14	13893	13886	8928	11202	5327	3735	2015
15	6994	12026	13885	27765	41577	6942	2016
16	41578	13782	69204	5355	13885	3632	2016
17	27767	27764	27766	9478	27769	7493	7172
18	13891	2075	20988	13892	24262	6052	5419

Time-to-Detect Distribution

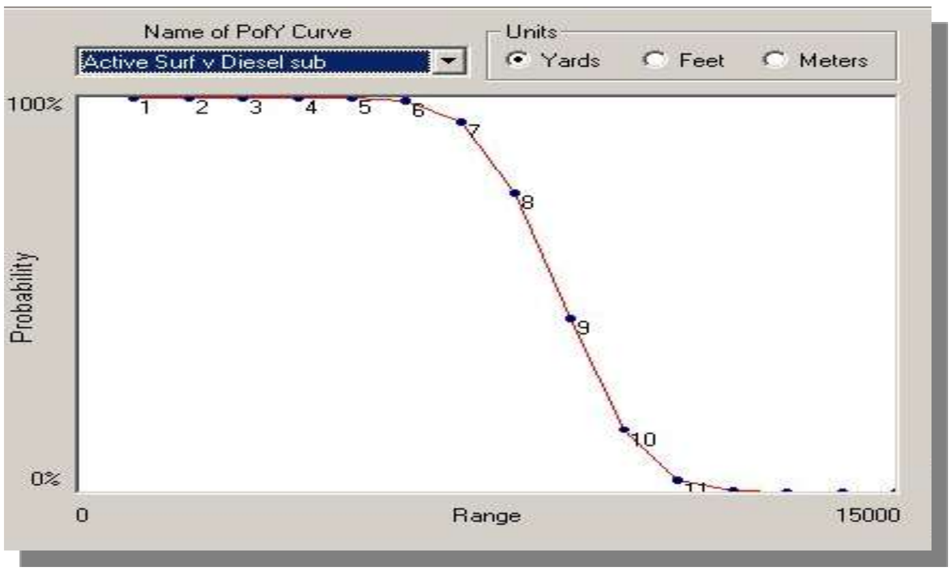
ALWSE-MC

- Discrete Event Simulation Tool Developed by NAVSEA Panama City, FL
- Integration of Engineering Level Detection Curves Into Tactical Simulation
- Simulation of Vehicle Characteristics, Sensor, and Employment for a Variety of Unmanned Systems

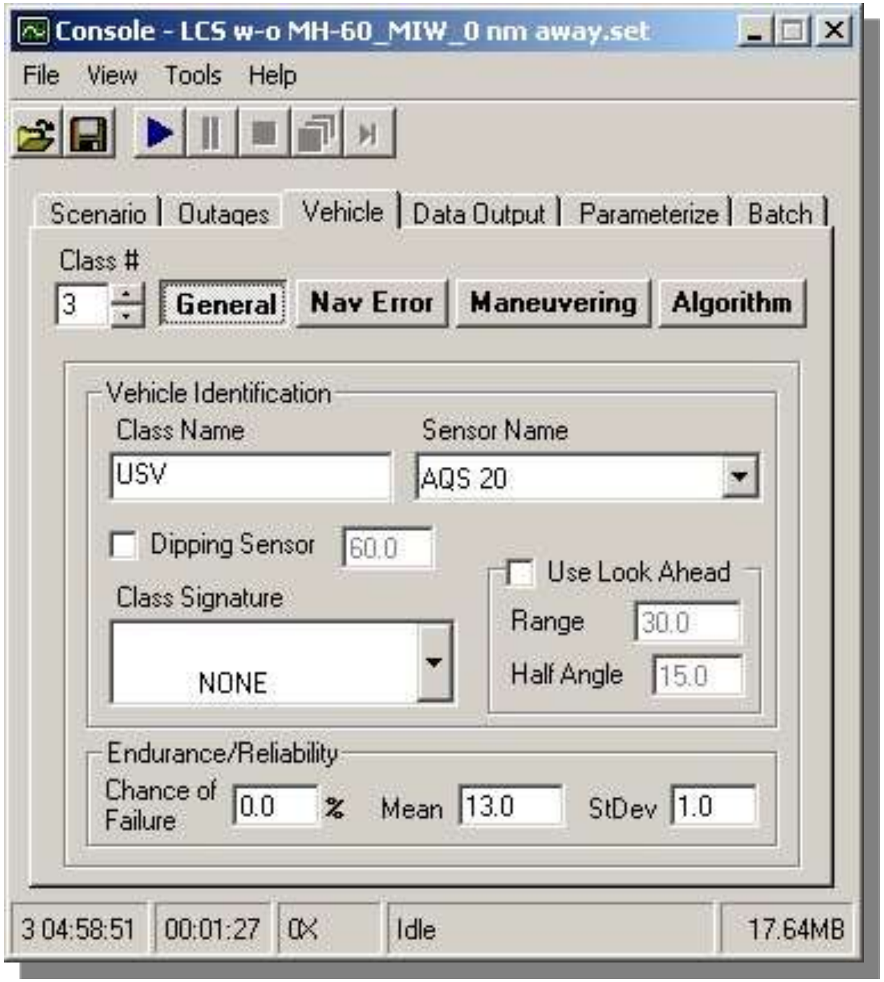


ALWSE-MC Inputs

- P_det vs. Range Curves
- Vehicle Parameters
- Threats
- Environment



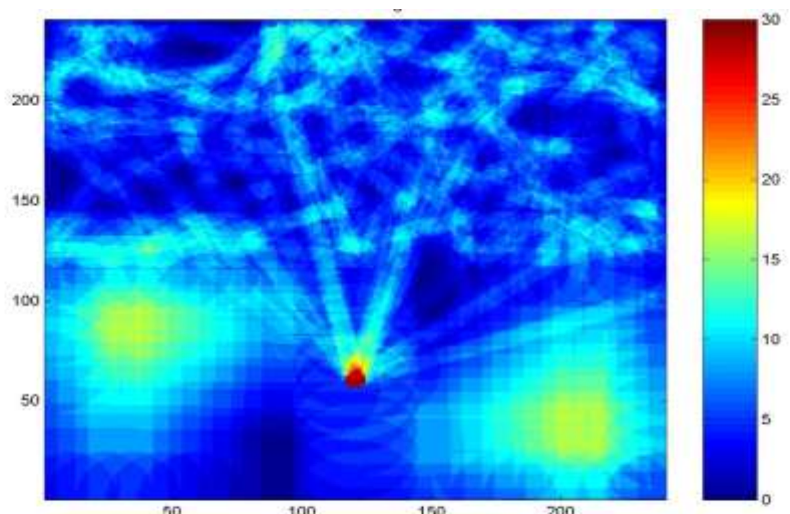
ALWSE P_det Input Chart



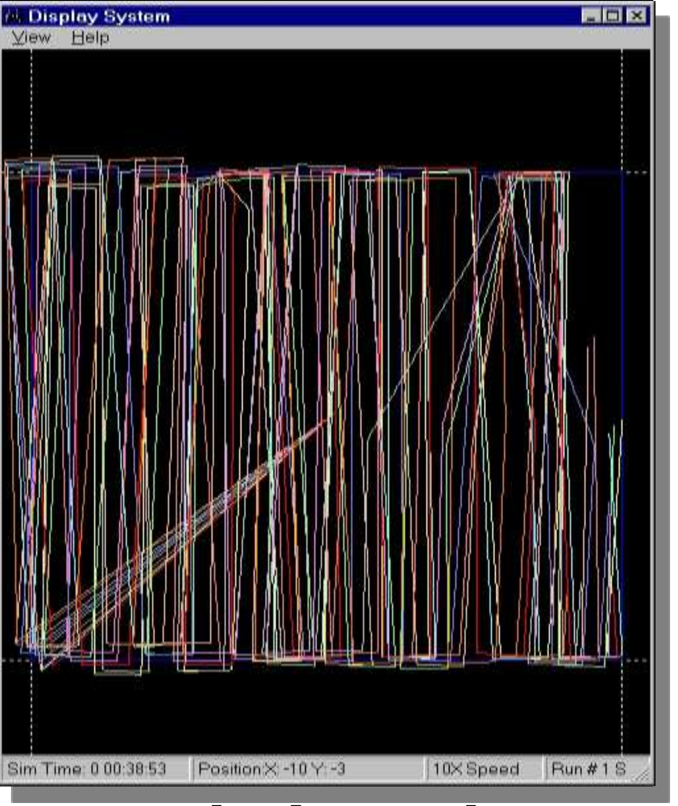
ALWSE Vehicle Editor

ALWSE-MC Outputs

- Effective Probability of Detection
- Vehicle Tracks
- Time to Detection
- Area Covered



Area Covered



Vehicle Tracks

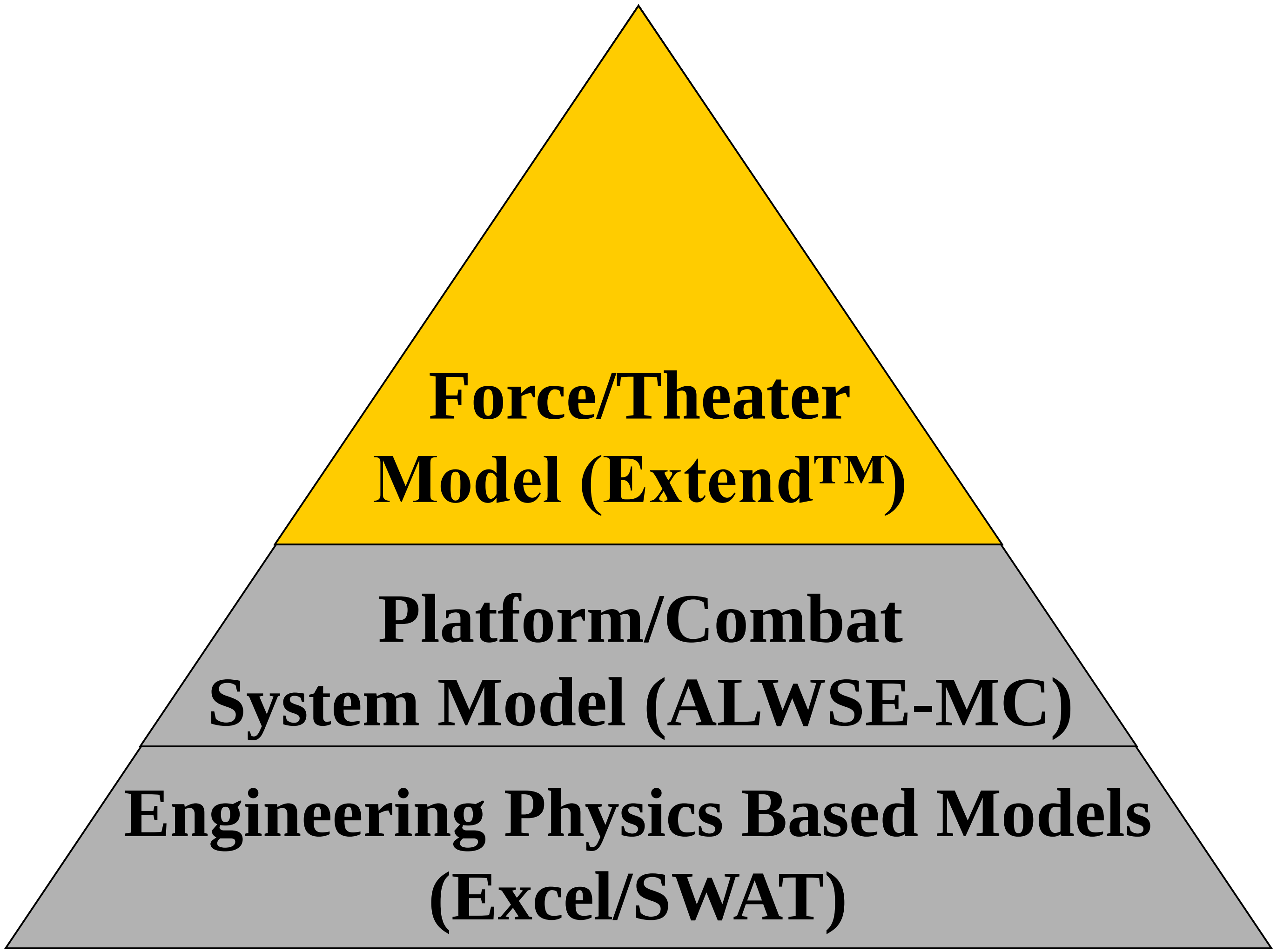
ALWSE-MC Utilization

- Platform/Combat System Modeling Performed to Incorporate Operational Implementation of Sensors/Threats Pairs and Produce Time to Detection Data
- Monte Carlo Analysis (200 Runs per Sensor/Target Pair)
- ALWSE-MC Simulation Missions
  - Surface (ASuW) Threats: DD, FFG, PGM
  - Anti-submarine (ASW) Threats: Diesel, Mini, Nuclear
  - Air (AW) Threats: Fighter, Bomber
  - Mine (MIW) Threats: Moored/Bottom (25 Each)
  - Land Threats: 50 SAM Launchers
- Use of P_det Curves For Each Sensor/Target Pairing
- Generation of Distributions of Average Detection Time For Sensor–Target Pairings Used As Input Into Extend™

Force/Theater Model (Extend™)

ENS Rob Smith

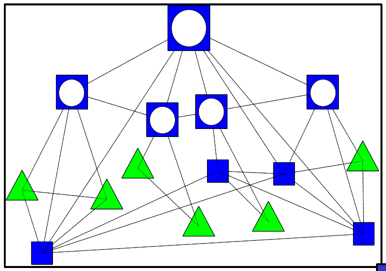
Force/Theater Model (Extend™)



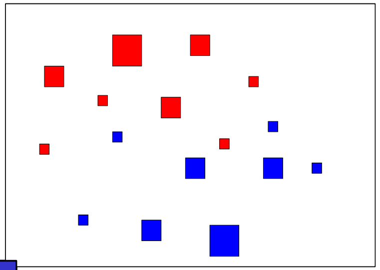
Force/Theater Model Overview

- Process Model of Maritime Dominance Concept
- High Level Interactions Between Opposing Forces
- Effects of Changing SoS Force Structure and Architecture Attributes on Outcome

SoS Architecture



Scenario



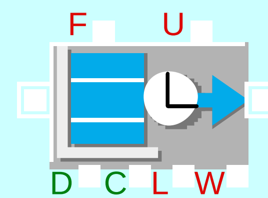
Extend™ Model

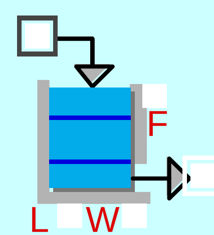
Simulative Study Performance Measures

Run#	Config	SoS Arch (1,2,3)	CNA (1,2,3)	C2 (1,2)	PPD (1,2,3)	Scenario / Hostility (1,2,3)	Total COIs	COIs Detected	COIs Localized &	Enemy Targets Killed	Weapons Fired	Total Personnel	Personnel Exposed to Risk	Casualties	Total SoS Platforms	SoS Platforms Killed	Time to Max RMP Ratio (hrs)	Max RMP Ratio
1	1	1	1	1	1	1	5	5	5	3	5	9755	0	0	106	0	0.569	1
2	2	1	1	1	1	2	133	133	133	10	36	9755	129	455	106	3	28.905	1
3	3	1	1	1	1	3	858	858	858	47	137	9755	0	8393	106	9	30.507	1
4	4	1	1	1	2	1	5	5	5	4	5	9755	0	0	106	0	1.501	1
5	5	1	1	1	2	2	133	133	133	130	151	9755	493	646	106	2	28.533	1

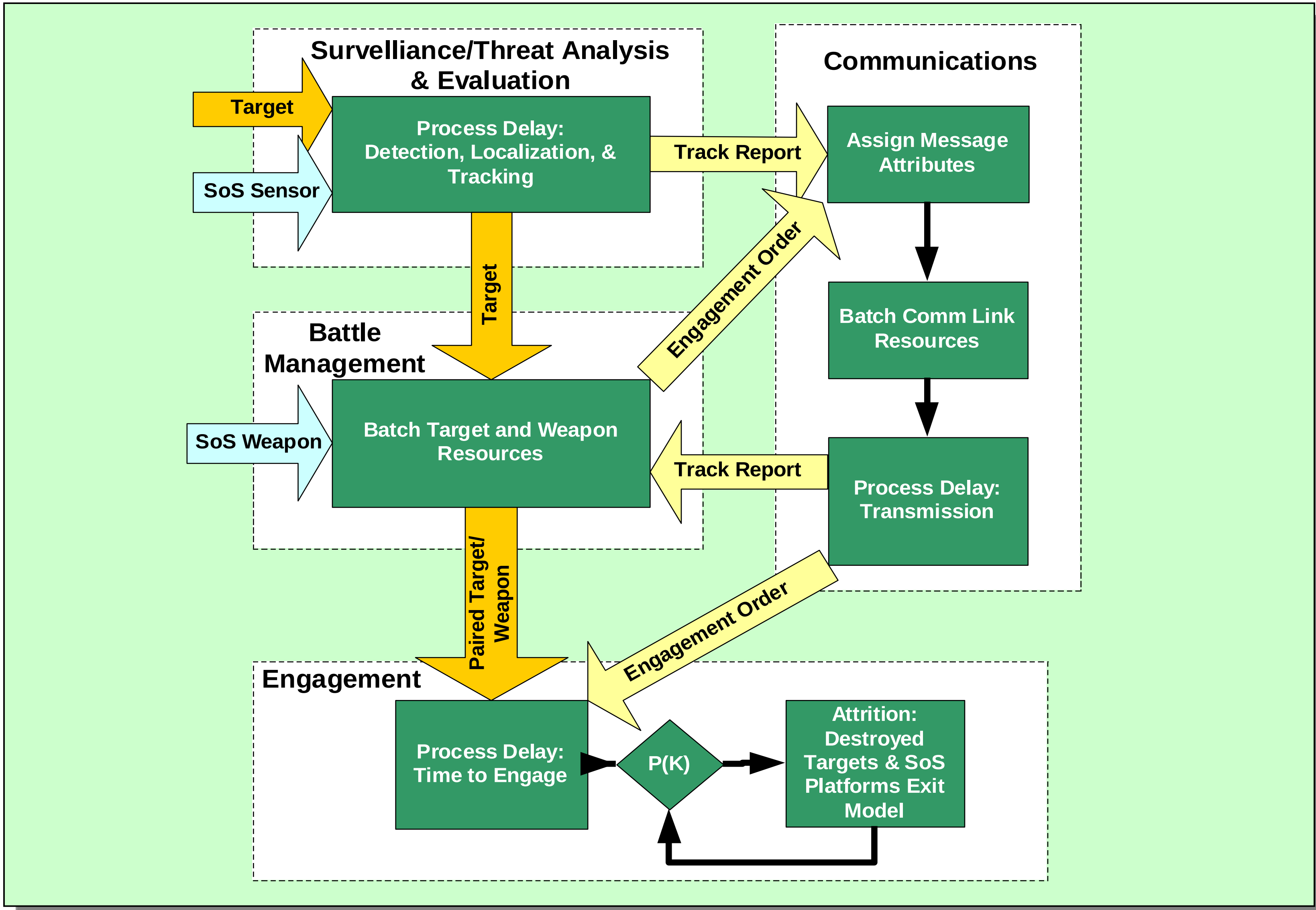
Modeling Tool: Extend™

- Discrete-Event Simulation Tool
- Multi-Layer Simulation
- Object-Oriented Design
- Extensive Libraries of Alterable Icons Representing Simulation Processes
- Integrated Database Utility

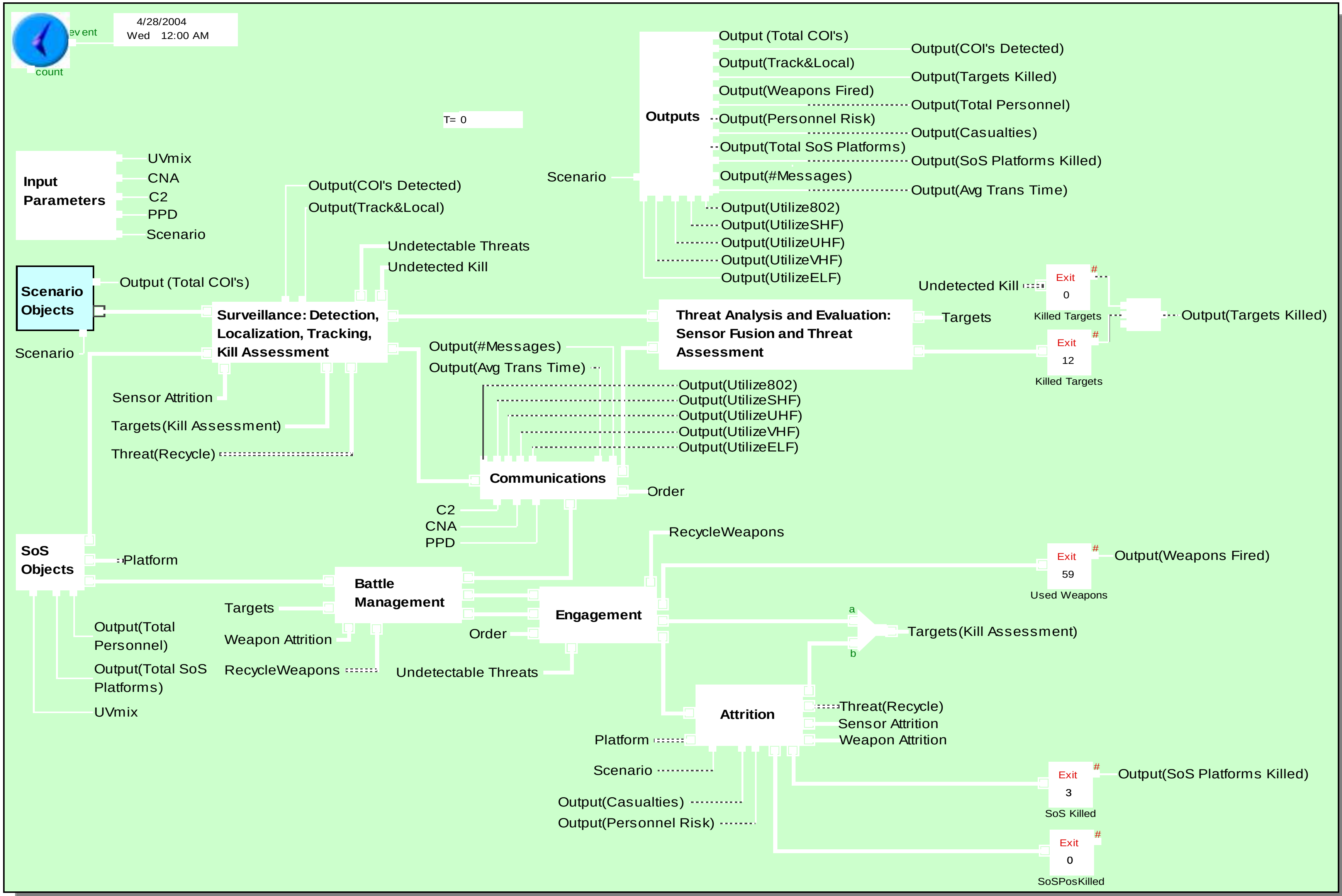




Extend™ Model Design

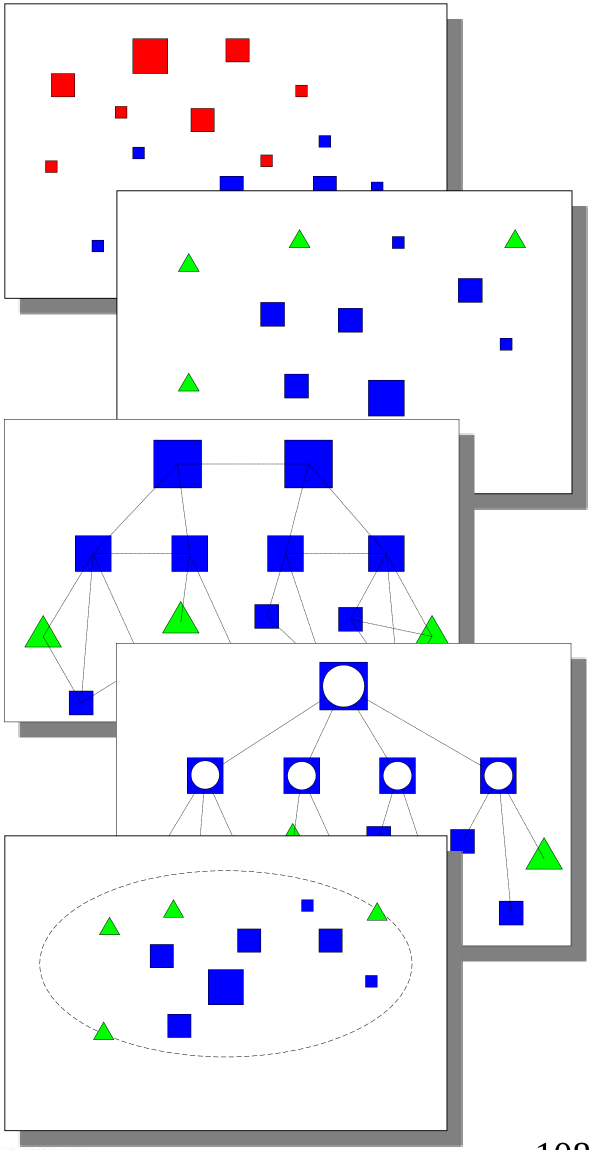


Top-Layer Extend™ Model



Experiment Design

- Full-Factorial Design With Configurations For All Combinations of Design Variables
  - 3 Scenarios (Benign, Nominal, Stressing)
  - 3 Architectures (Manned Only, Balanced Hybrid, Primarily Unmanned)
  - 3 Communications Network Architectures (Enclave, Hybrid, Distributed)
  - 2 C2 Structures (Centralized, Decentralized)
  - 2 Physical Platform Distributions (Small, Medium, Large)
- Run Matrix (162 Configurations with 50 Monte Carlo Runs Each) – 8100 Runs



Inputs

Attributes

- SoS Objects
  - Platform Types
  - Sensor/Weapon Capabilities
  - Sensor Performance
  - Communications Capability
  - Mission Area
- Scenario Objects
  - Threat Types
  - Mission Area
  - Arrival Times

Mission Area (ref)	Mission
1	Surface
2	Air
3	Subsurface
4	Mine
5	Land

Threat Type (ref)	Threat
1	DDG
2	FFG
3	3 x PGM
4	MIG-31 (Fighter)
5	SU-30 (Bomber)
6	Missile Swarm
7	Diesel Sub
8	Nuc Sub
9	Mini Sub
10	Mine Field
11	ASCM Launcher

Link Type (ref)	Comm Link
1	802.11
2	SHF
3	UHF
4	VHF
5	ELF

Process Model Parameters

- Surveillance/Threat Analysis & Eval
  - ALWSE-MC Time To Detect Data
  - Sensor Availability
- Battle Management
  - Weapon Availability
- Communications
  - Network Architecture
  - Link Availability
  - Link Data Rates
- Engagement
  - $P_{SoS}(K)$
  - Time To Engage
  - $P_{enemy}(K)$

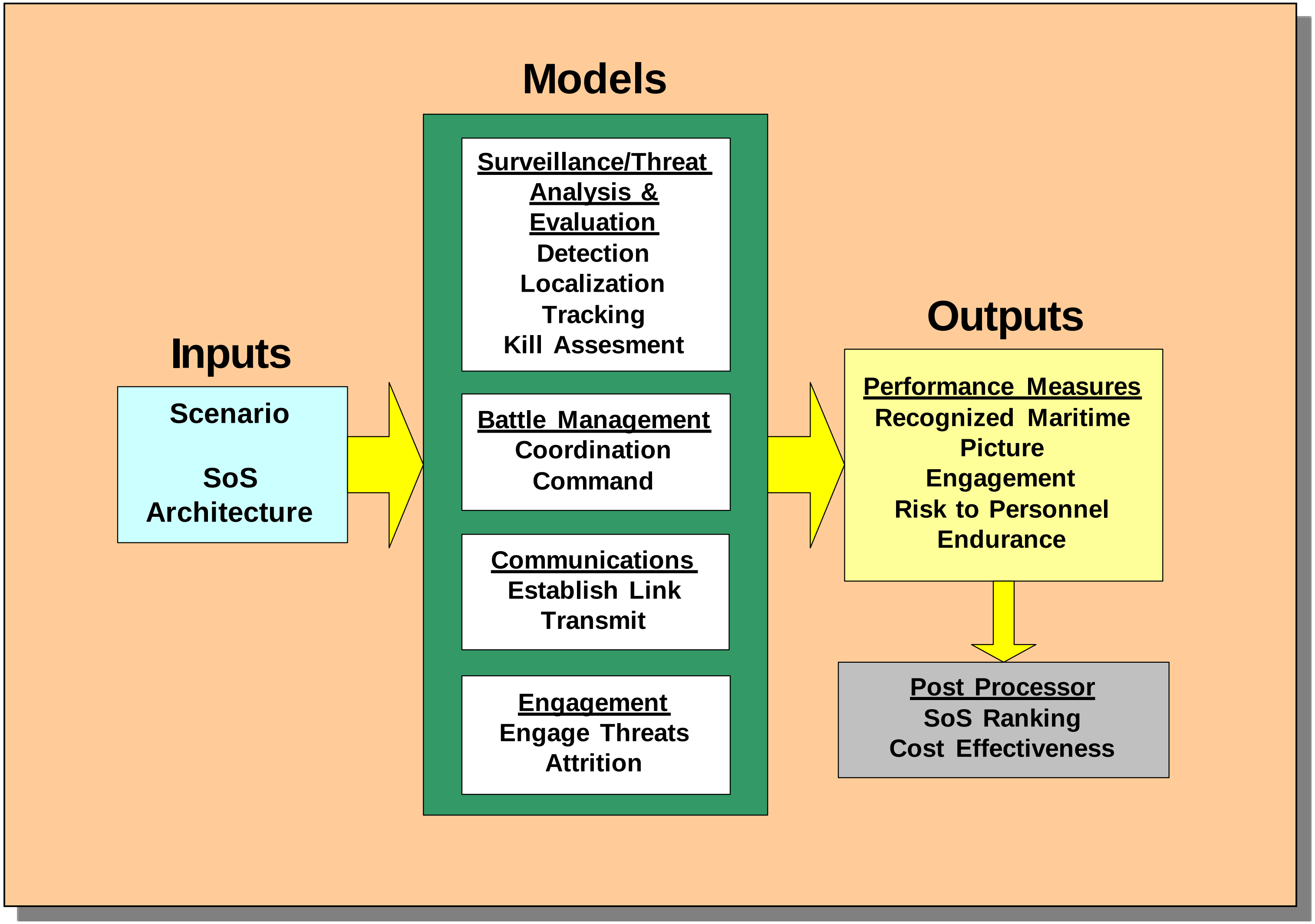
Simulation Outputs – Performance Measures

Config	SoS Arch (1,2,3)	CNA (1,2,3)	C2 (1,2)	PPD (1,2,3)	Scenario / Hostility (1,2,3)	Total COIs	COIs Detected	COIs Localized &	Enemy Targets Killed	Weapons Fired	Total Personnel	Personnel Exposed to Risk	Casualties	Total SoS Platforms	SoS Platforms Killed	Time to Max RMP Ratio (hrs)	Max RMP Ratio
1	1	1	1	1	1	5	5	5	3	5	9755	0	0	106	0	0.569	1
2	1	1	1	1	2	133	133	133	10	36	9755	129	455	106	3	28.905	1

- **Recognized Maritime Picture**
  - Time to Develop RMP
- **Engagement**
  - Targets Killed / Targets Engaged
  - Targets Killed / Total Targets

- **Risk to Personnel**
  - Number of Personnel Exposed to Risk
  - Number of Casualties
- **Combat Endurance**
  - Number of Surviving SoS Platforms

Simulative Study Design

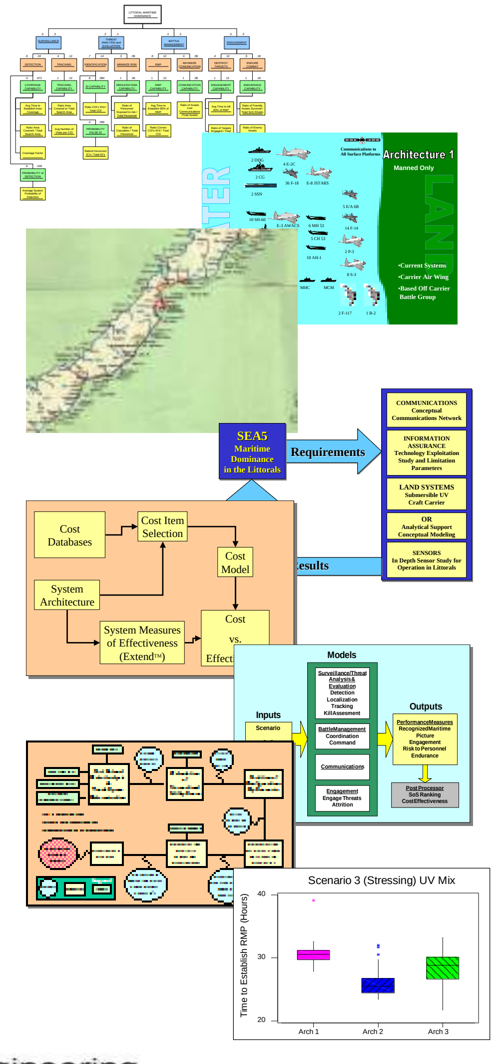


Architecture Ranking

LT Chad Graham

SoS Development

- Functional Analysis
- Value Systems Design
- Architectures
- Threats & Scenarios
- TDSI Integration
- Cost Analysis
- Simulative Study
- Architecture Ranking
- Configuration Validation



Topics

- Data Analysis
- Architecture Ranking Process
- Architecture Ranking Results
- Configuration Ranking Process
- Configuration Ranking Result

Data Analysis

Extend Outputs

- Total Contacts of Interest
- Enemy Targets Killed
- Avg Time to Establish RMP
- Sos Platforms Killed
- Casualties
- Personnel Exposed to Risk
- Avg Message Transmission Time
- Total Personnel

Extend Processed Data Output

Evaluation Measure	Global Weight	Configuration Number					
		1	2	3	4	5	6
Surveillance	0.3	1.039331	28.772294	30.59990644	1.0379031	28.556723	30.461997
Risk Exposure	0.08	14.2	2189.62	0	2.58	1872.56	0
Casualties	0.12	0	716.38	7334.36	0	356.78	7317.66
RMP Capability	0.12	1.1164263	0.0348017	0.032721644	1.1647954	0.0350882	0.0328582
Communication Capability	0.08	0.4060147	0.293401	0.217374375	0.4042391	0.3062207	0.214317
Combat Effectiveness	0.02	0.7435079	0.5926398	0.523884607	0.7864524	0.6084756	0.5387256
Engagement Capability	0.1	0.6712812	0.0498008	0.014249879	0.6898679	0.0541287	0.0183736
[illegible]	0.09	1	0.9892453	0.713773585	1	0.9911321	0.7226415
[illegible]	0.09	0.3	0.4933835	0.731748252	0.3	0.5085714	0.7223776

Data Analysis Process

- Averaged 50 Runs of Output Data Per Configuration
- Extracted Averages for Every MOE for 162 Configurations
- Imported Averages Into Excel Data Sheet for Further Manipulation
- Processed Data Output to Match Total Utility Inputs

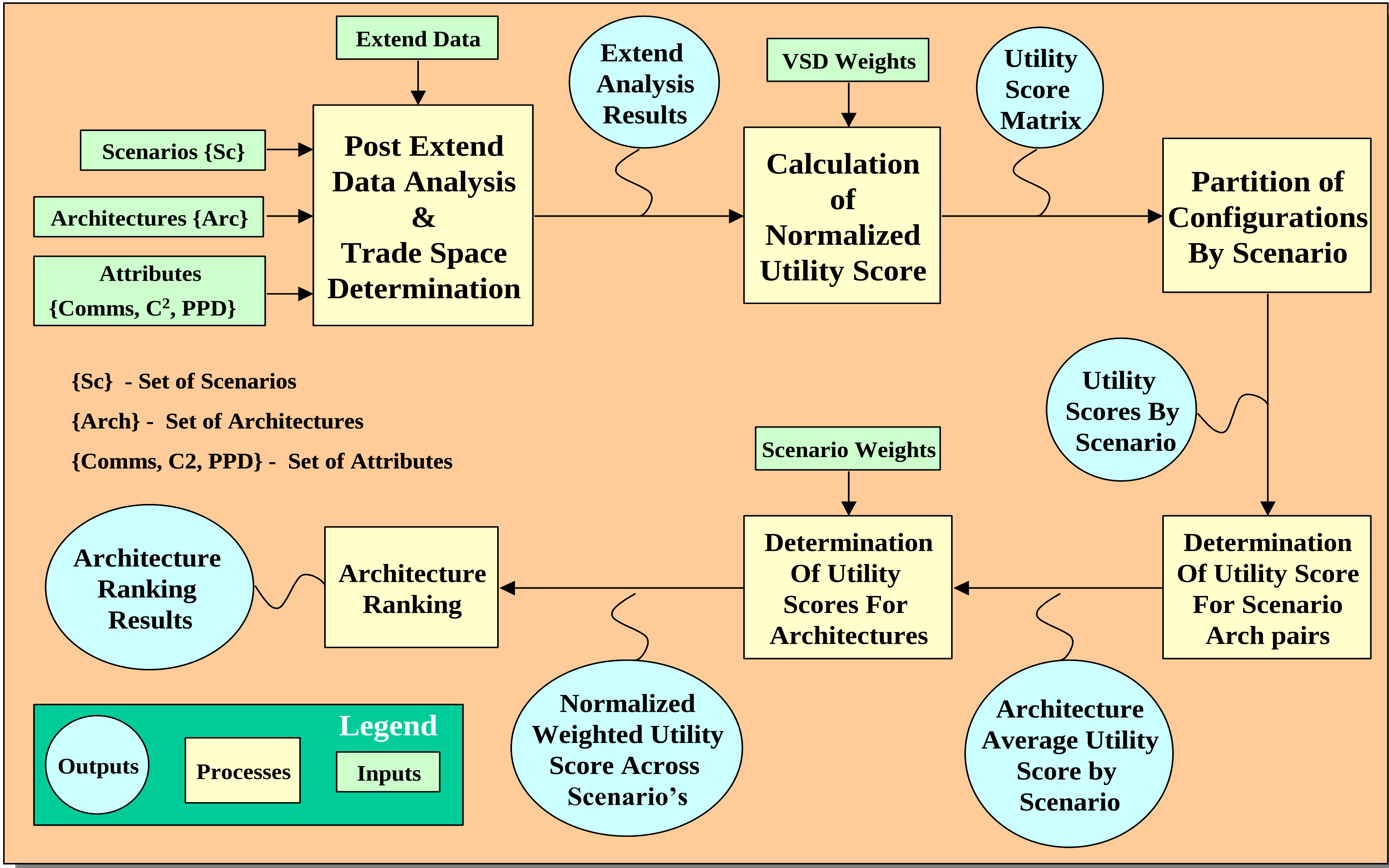
Extend Data Table

Run#	Config	SoS Arch (1,2,3)	CNA (1,2,3)	C2 (1,2)	PPD (1,2,3)	Scenario / Hostility (1,2,3)	Total COIs	COIs Detected	COIs Localized &				
1	1	1	1	1	1	1	5	5	5	4	7	9755	129
2	1	1	1	1	1	1	5	5	5	4	4	9755	0
3	1	1	1	1	1	1	5	5	5	4	5	9755	0
4	1	1	1	1	1	1	5	5	5	4	4	9755	0
5	1	1	1	1	1	1	5	5	5	3	4	9755	0
6	1	1	1	1	1	1	5	5	5	3	4	9755	0
7	1	1	1	1	1	1	5	5	5	3	5	9755	0
8	1	1	1	1	1	1	5	5	5	4	4	9755	0
9	1	1	1	1	1	1	5	5	5	4	6	9755	0
10	1	1	1	1	1	1	5	5	5	3	4	9755	0
11	1	1	1	1	1	1	5	5	5	3	4	9755	0
12	1	1	1	1	1	1	5	5	5	4	4	9755	0
13	1	1	1	1	1	1	5	5	5	4	8	9755	129
14	1	1	1	1	1	1	5	5	5	4	4	9755	0
15	1	1	1	1	1	1	5	5	5	4	4	9755	0
16	1	1	1	1	1	1	5	5	5	4	4	9755	0
17	1	1	1	1	1	1	5	5	5	3	4	9755	0
18	1	1	1	1	1	1	5	5	5	4	5	9755	0
19	1	1	1	1	1	1	5	5	5	2	4	9755	0
20	1	1	1	1	1	1	5	5	5	3	6	9755	0
21	1	1	1	1	1	1	5	5	5	5	7	9755	0

Data Outputs

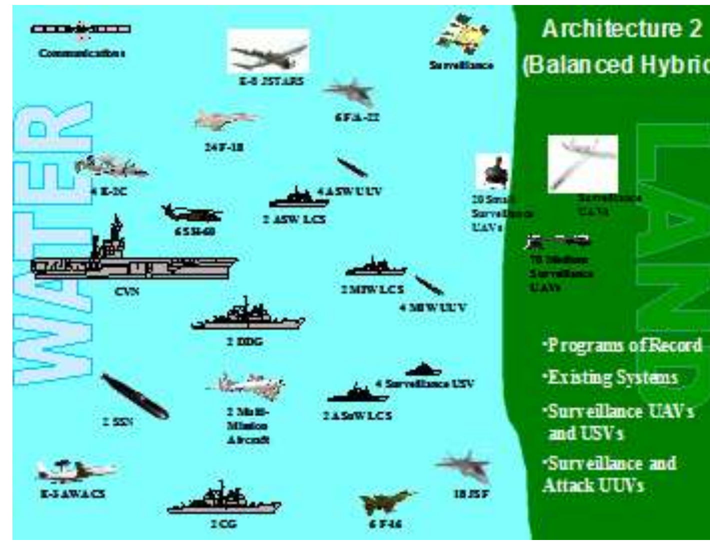
- Surveillance
- Risk Exposure
- Casualties
- Communication Capability
- Combat Endurance
- Engagement Capability
- Recognized Maritime Picture Capability

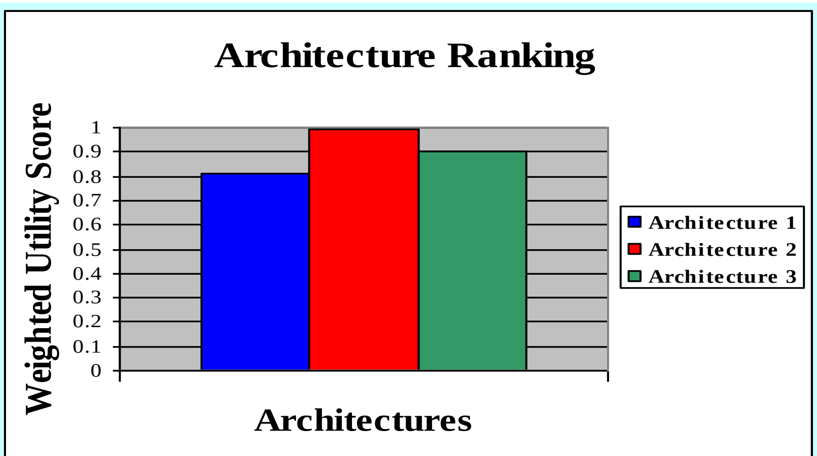
Architecture Ranking Process



Architecture Ranking Summary

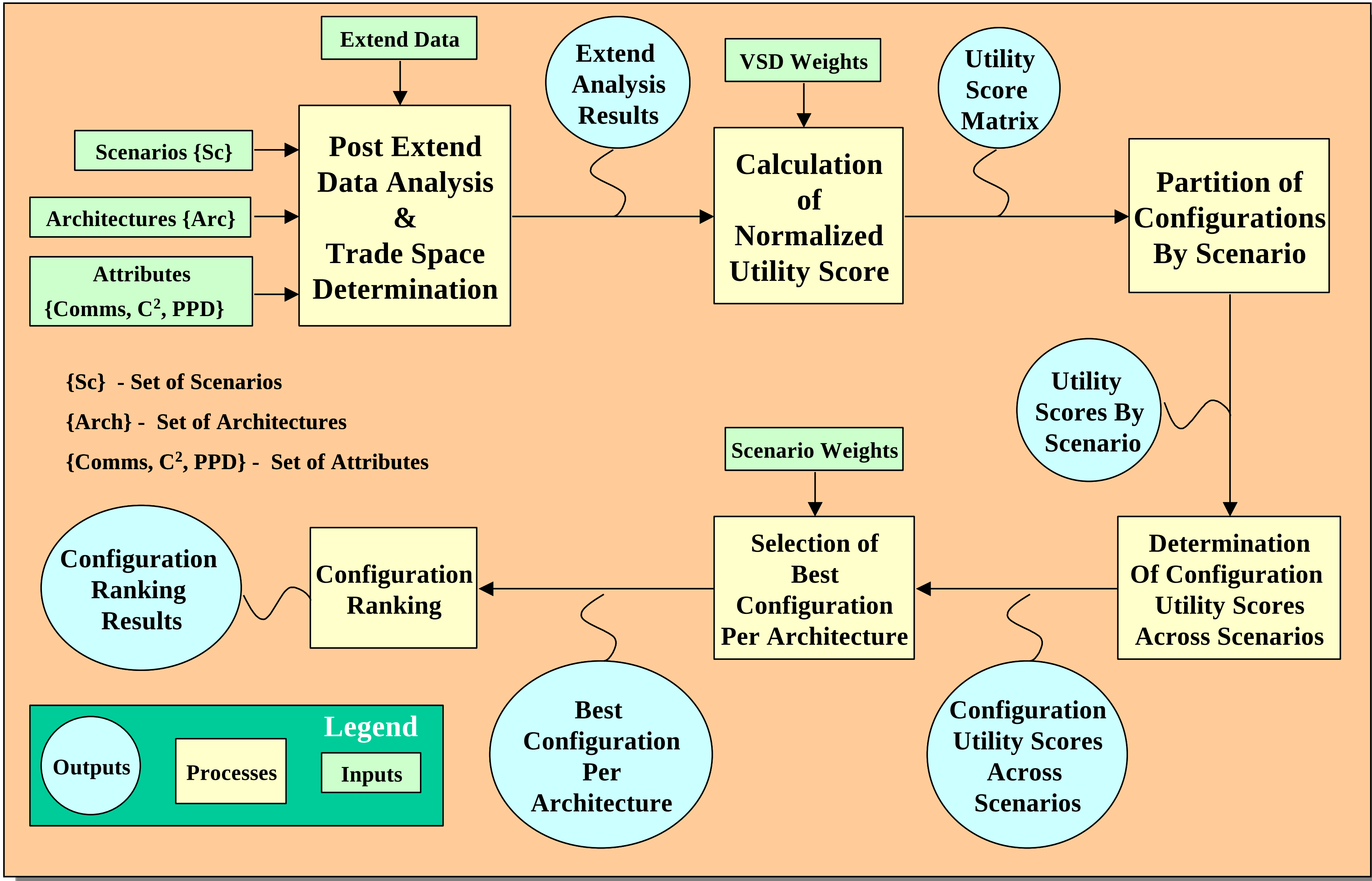
- **Balanced Hybrid Architecture With Unmanned/Manned Ratio of 1.5:1 is Selected Based on Overall Performance**
- **UV to Manned Ratio Greater Than 1.5:1 Decreases Overall SoS Performance**





- These Results Are Based on Defined Scenarios With Weights Provided by Primary Stakeholder
- Architecture Ranking is Insensitive to Scenario Weights

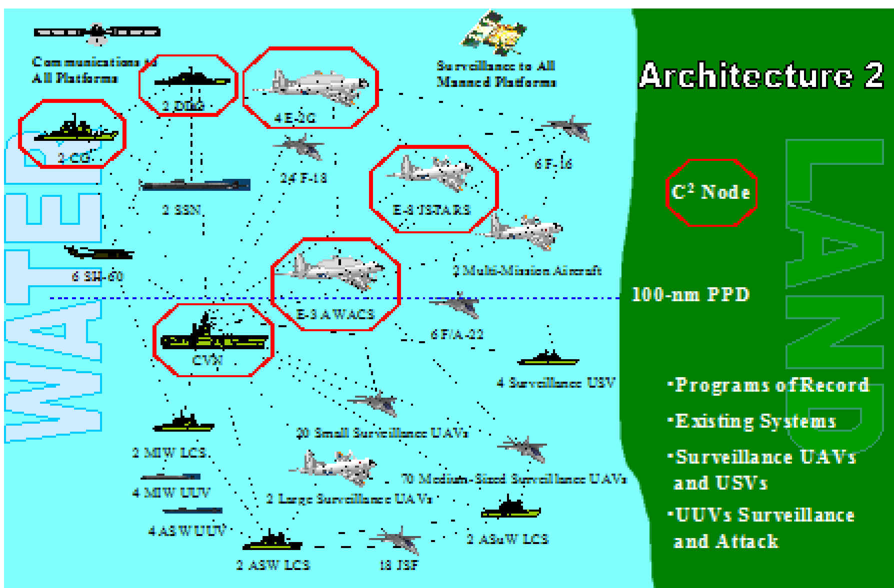
Configuration Ranking Process



Configuration Ranking Results

Best Configuration

- **Balanced Hybrid Unmanned/Manned Architecture (Architecture 2)**
- **Distributed Communication**
- **Decentralized Command & Control**
- **100-nm Platform Distribution**



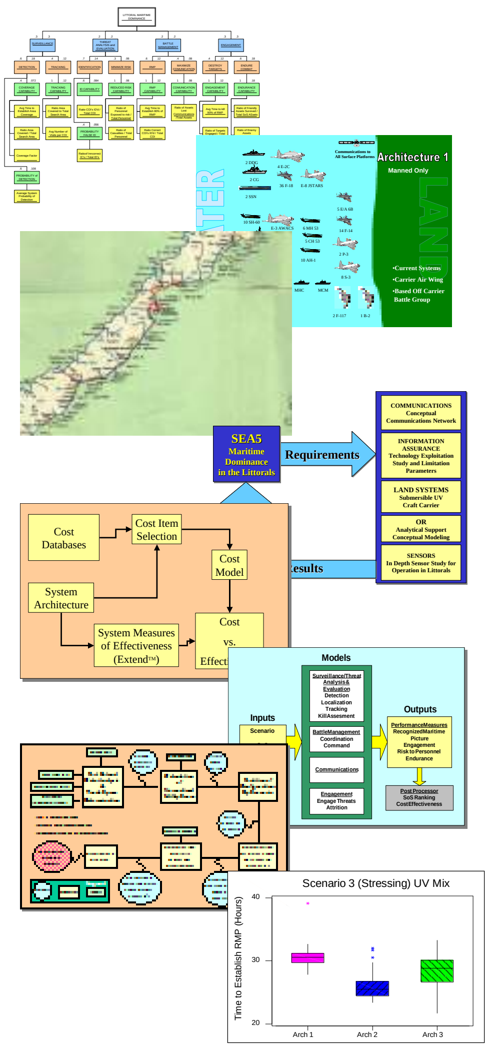
- **Distributed Communications**
  - Faster Dissemination of Information
    - Average Message Delay 1/10th Hybrid's & 1/100th Enclave's
  - Minimum Impact on Throughput with Node Failures
- **Decentralized Command and Control**
  - Faster Dissemination of Command Messages
    - Average Message Delay 1/10th Centralized C2's
  - Faster Reaction Times
  - Less Network Demand
  - Reduced Single C2 Node Workload
  - Single C2 Node Failure Avoidance
- **Platform Distribution**
  - 100-nm Platform Distribution Exhibiting Superior Performance Albeit Statistically Insignificant

Configuration Selection Validation

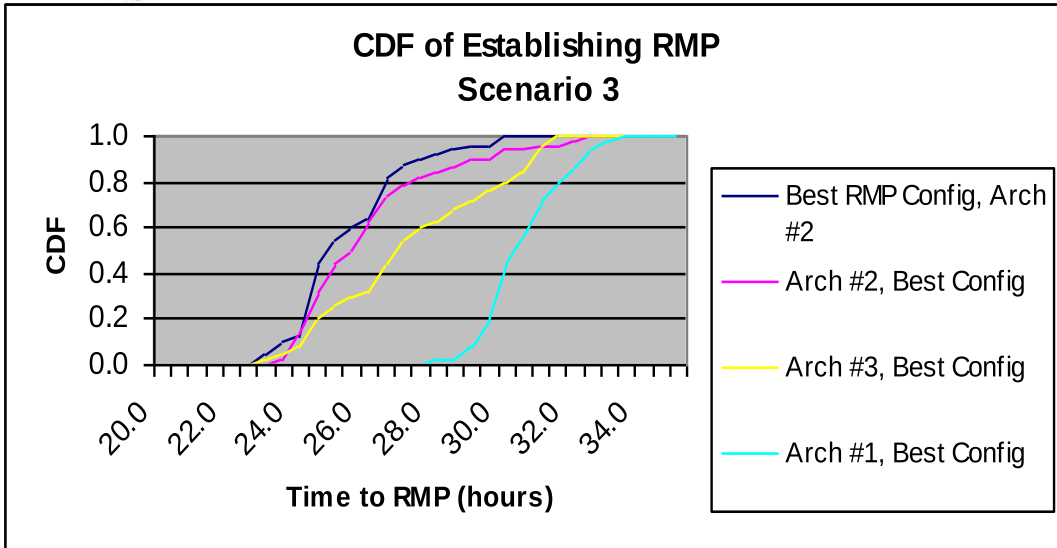
LT Jeff Winslow

SoS Development

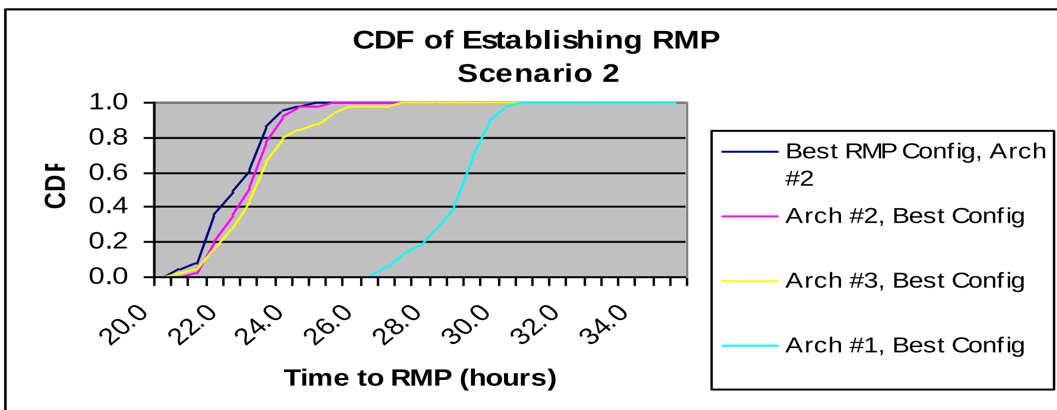
- Functional Analysis
- Value Systems Design
- Architectures
- Threats & Scenarios
- TDSI Integration
- Cost Analysis
- Simulative Study
- Architecture Ranking
- Configuration Validation

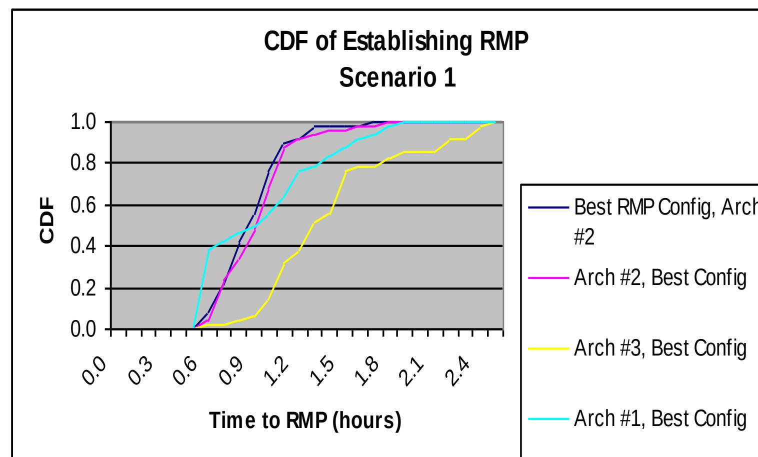


Selected Configuration Validation



- Comparison of CDF for Time-to-RMP for Best Configuration from 162 Configurations to CDFs for Selected Configurations
- Excellent Agreement between Best-Configuration CDF and CDF for Selected Architecture 2-Best Configuration Thus Validating Chosen Configuration
- Comparison of CDFs for Other MOEs Also Validating Chosen Configuration

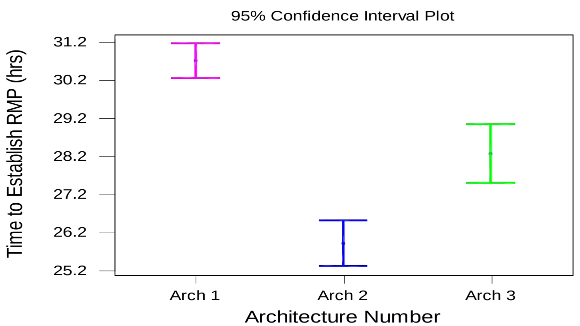


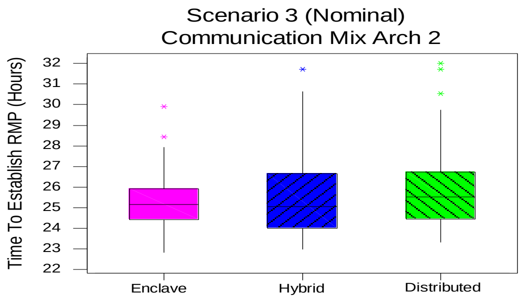


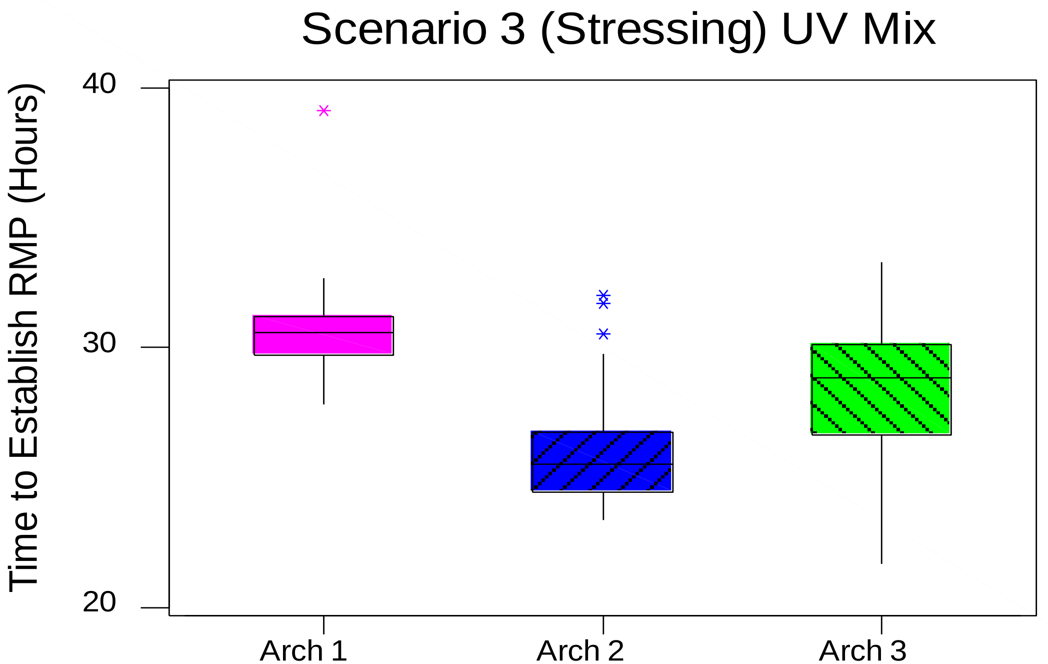
CDF: Cumulative Distribution Function

Effects of Configuration Attributes On RMP

- Significant Effects of Unmanned/Manned Ratio on Time-to-RMP
- Insignificant Effects of Command and Control Structure & Communication Network Architecture

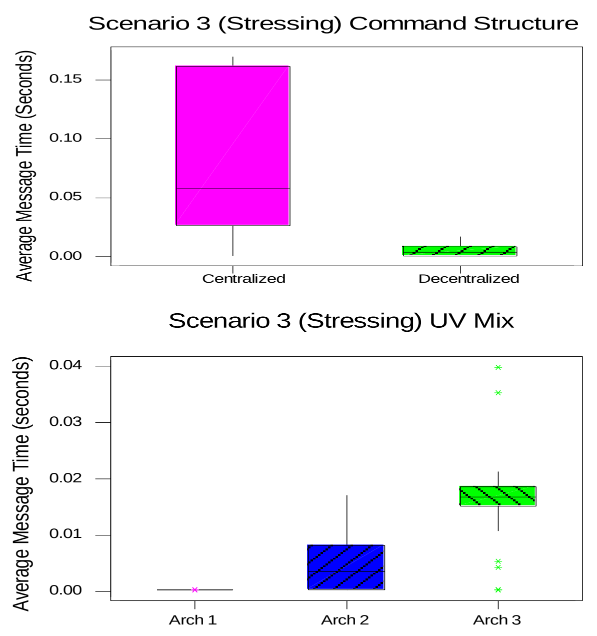


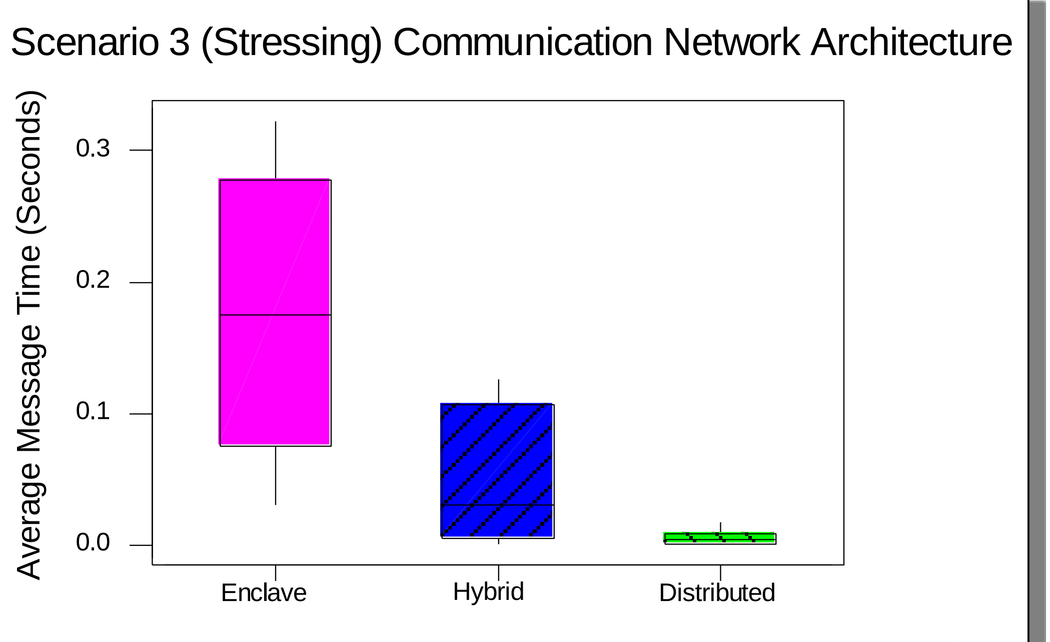




Effects of Configuration Attributes On Communications Performance

• Significant Effects of Unmanned/Manned Ratio, Command & Control and Communication Network Architecture on Communication Performance (Message Delay)

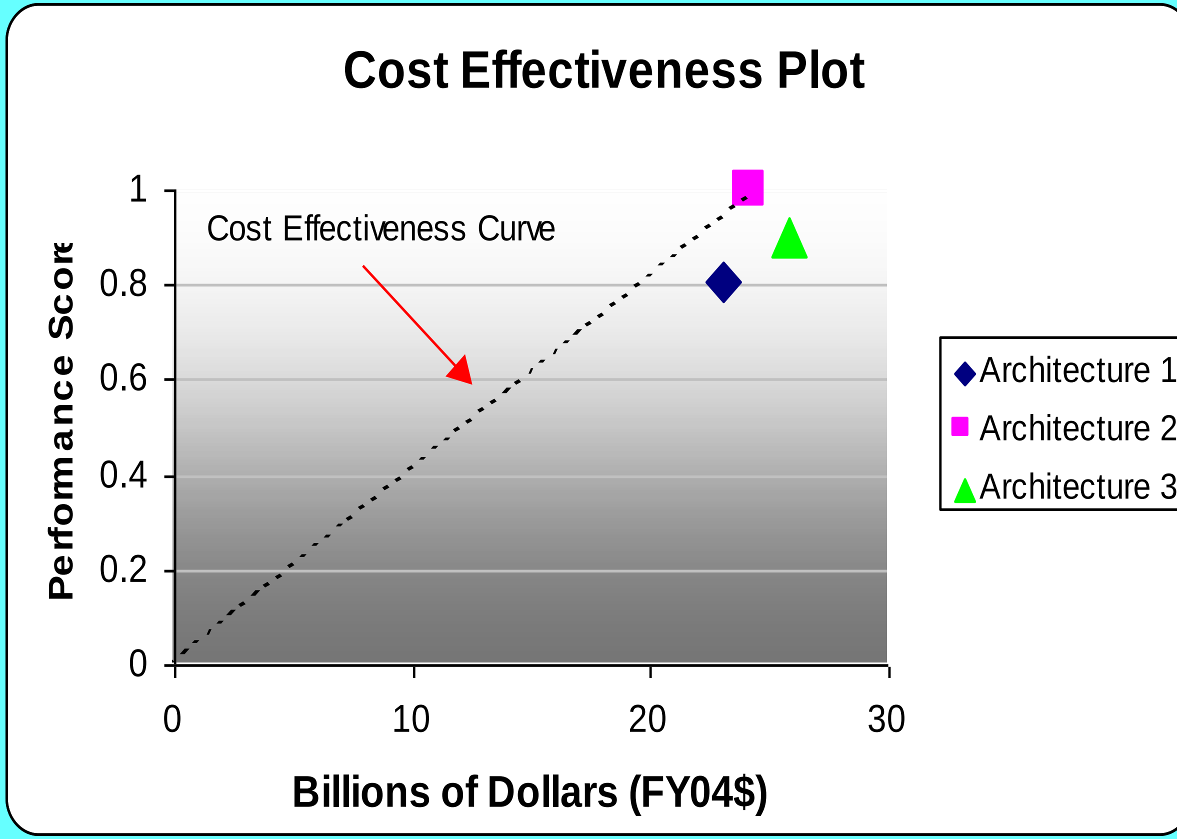




Cost Effectiveness Curve

for Architecture Recommendation

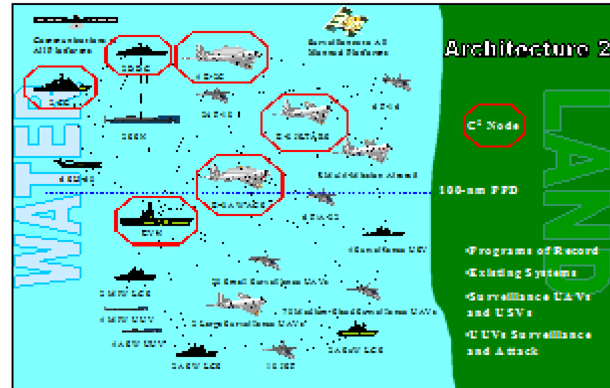
- Balanced Hybrid (Architecture 2) Cost Effective & Cost Efficient
- Manned Only (Architecture 1) Cost Effective Not Cost Efficient
- Primarily Unmanned (Architecture 3) Dominated (Neither Effective or Efficient)

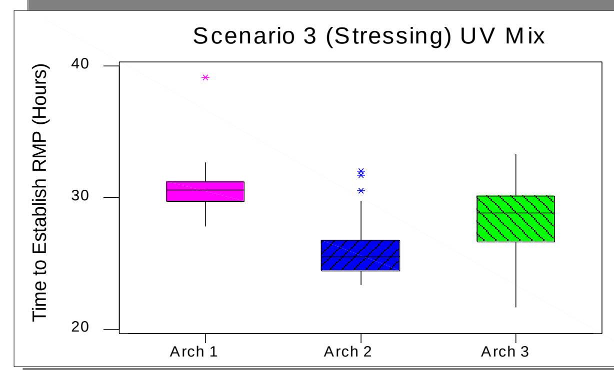


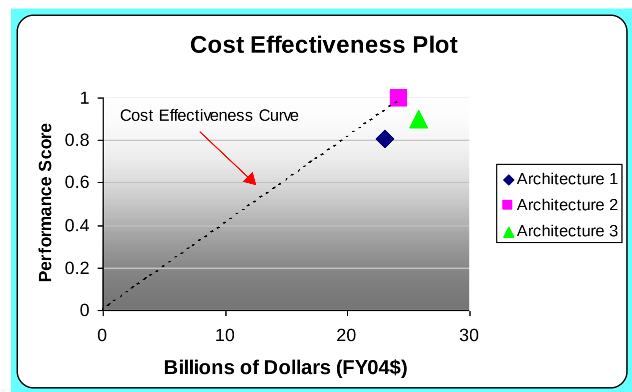
Architecture 2 Recommended Based on Cost & Performance

Recommended SoS Configuration

- **Recommended SoS Configuration**
  - **Balanced Hybrid Unmanned/Manned Architecture (Architecture 2)**
  - **Distributed Communication**
  - **Decentralized Command & Control**
  - **100-nm Platform Distribution**
- **Recommended Configuration Validated**
  - **Based On Independent Statistical Analysis**
  - **Involving All MOEs**
- **Balanced Hybrid Unmanned/ Manned Architecture Recommended Based on Cost & Performance**
  - **Cost Effective and Cost Efficient**







Project Conclusion

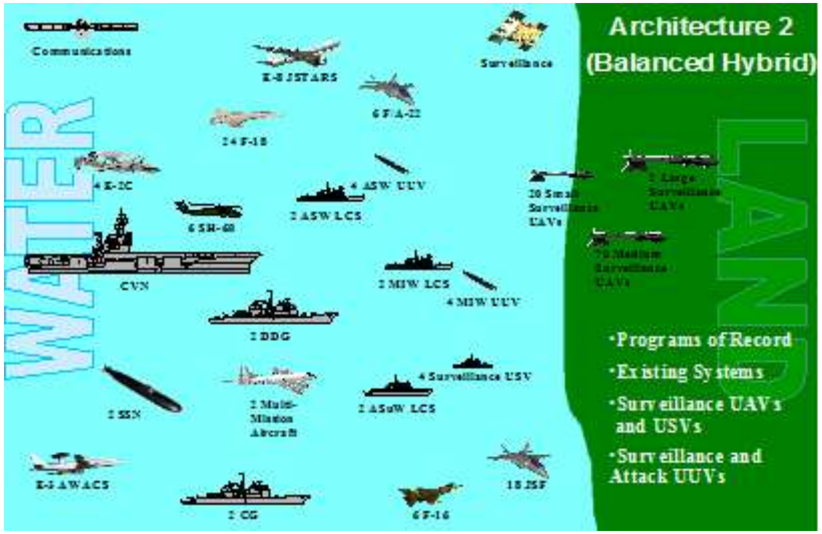
LCDR Quoc Tran

Project Overview

- Tasked With A Complex Problem of Maritime Dominance in the Littoral
- Developed a Project Management Plan
- Executed The Plan Using Systems Engineering Design Process
- Generated Conceptual SoS Architecture Alternatives
- Used Modeling and Simulation to Assess Architecture Performance
- Ranked SoS Architecture Alternatives

Recommended System of Systems for Maritime Dominance in Littorals

- **Unmanned Vehicles Complement But Cannot Replace Manned Platforms**
- **Recommended System of Systems Enabling SEA BASING and SEA STRIKE in 200 nm by 200 nm Littoral Operation Area in 2020 Timeframe**
  - **Consists of Unmanned/Manned Vehicle Ratio of Approximately 1.5 to 1**
  - **Utilizes Distributed Communications with 100nm Physical Platform Distribution**
  - **Employs Decentralized Command & Control Structure**
  - **Is Cost Effective Relative to Other Alternatives**



- **Distributed Communications**
  - Faster Dissemination of Information
  - Minimum Impact on Throughput with Node Failures
- **Decentralized Command and Control**
  - Shorter Reaction Times
  - Less Network Demand
  - Single C2 Node Failure Avoidance
- **100 nm Platform Distribution**
  - Superior Overall Performance

Acknowledgments

- Family and Friends
- Project Advisor – Dr. Huynh
- Military Advisor– CAPT Kline
- Supporting Temasek Defense Systems Institute Teams
- Department of Defense Organizations and Defense Industry
- Professors

Questions and Answers

Questions May Be Reserved for the Break Out Session at 1300 in the Bullard Hall Computer Lab (If So Desired)

- Report and Presentation Will Be Available After 18 June 2004

http://www.nps.navy.mil/SEA/MaritimeDominance

Backup Slides

Differences in Architectures

Architecture 1	Architecture 2	Architecture 3
CVN	CVN	CVN
SH-60	SH-60	SH-60
E-3 AWACS	E-3 AWACS	E-3 AWACS
CG	CG	DDX
DDG	DDG	CGX
SSN	SSN	Insertion UUV
E2-C	E2-C	Multi-Mission USV
F/A-18	F/A-18	Strik UAV
E-8 JSTARS	E-8 JSTARS	Medium-Sized Multi-Mission UAV
P-3	LCS	LCS
CH-53	MIW UUV	MIW UUV
MH-53	ASW UUV	ASW UUV
F-14	JSF	JSF
S-3	Large Surveillance UAVs	Large Surveillance UAVs
E/A-6B	Medium-Sized Surveillance UAVs	Medium-Sized Surveillance UAVs
AH-1	Small Surveillance UAVs	Small Surveillance UAVs
B-2	F-16	
B-52	F/A-22	
F-117	Multi-Mission Aircraft	

All Architectures

Arch1 and Arch 2

Arch 2 and Arch 3

TDSI Inputs to Integrated Project

		CONOPS	Simulative Study
COMMUNICATIONS	MANET Parameters Link Capacity 24 Mb/s Range 60 km Delay 4.37*10-3 s Sea web Parameters Link Capacity 600bps Range 10 km Delay 6.7 s Advantages/Disadvantages of MANET And SDR Performance Security Details		√
INFORMATION ASSURANCE	Threats to UAVs Means to Mitigate Threats	√	
OPERATIONS RESEARCH	Fusion Model Description of Quality vs. Quantity for Search/Detection with UAVs Optimization of Search Patterns Effects of Increasing # of UAVs Optimization # of Communications Nodes for Underwater UV Network	√	

TDSI Inputs to Integrated Project

SENSORS

Surveillance Gaps
Recommended Sensors to fill specific Gaps
Parameters of FOPEN/SAR
- Center Frequency 440 MHz
- BW 19.38 MHz
- Peak Power 1000 W
- Average Power 19 W
- Azimuth 3dB Beam Width 19°
- Elevation 3dB Beam Width 38°
- Nominal Gain 14 dB

LAND SYSTEMS

Parameters of UV craft carrier
- Length 11.08 m
- Width 2.286 m
- Height 2.238 m
- Weight <15,000 kg
- Max Depth 50 m
- Range 150 nm
- Average Speed 6 kts
- Endurance 72 hrs
- Deployment methods
  - LPD well deck
  - Helo drop
  - Submarine launch
- Number/type of UVs carried
  - 5 Golden Eye UAVs
  - 20 iSTAR UAVs
  - 4 REMUS UUVs
  - 6 TALON Robots UGV

	CONOPS	Simulative Study
SENSORS		√
LAND SYSTEMS	√	

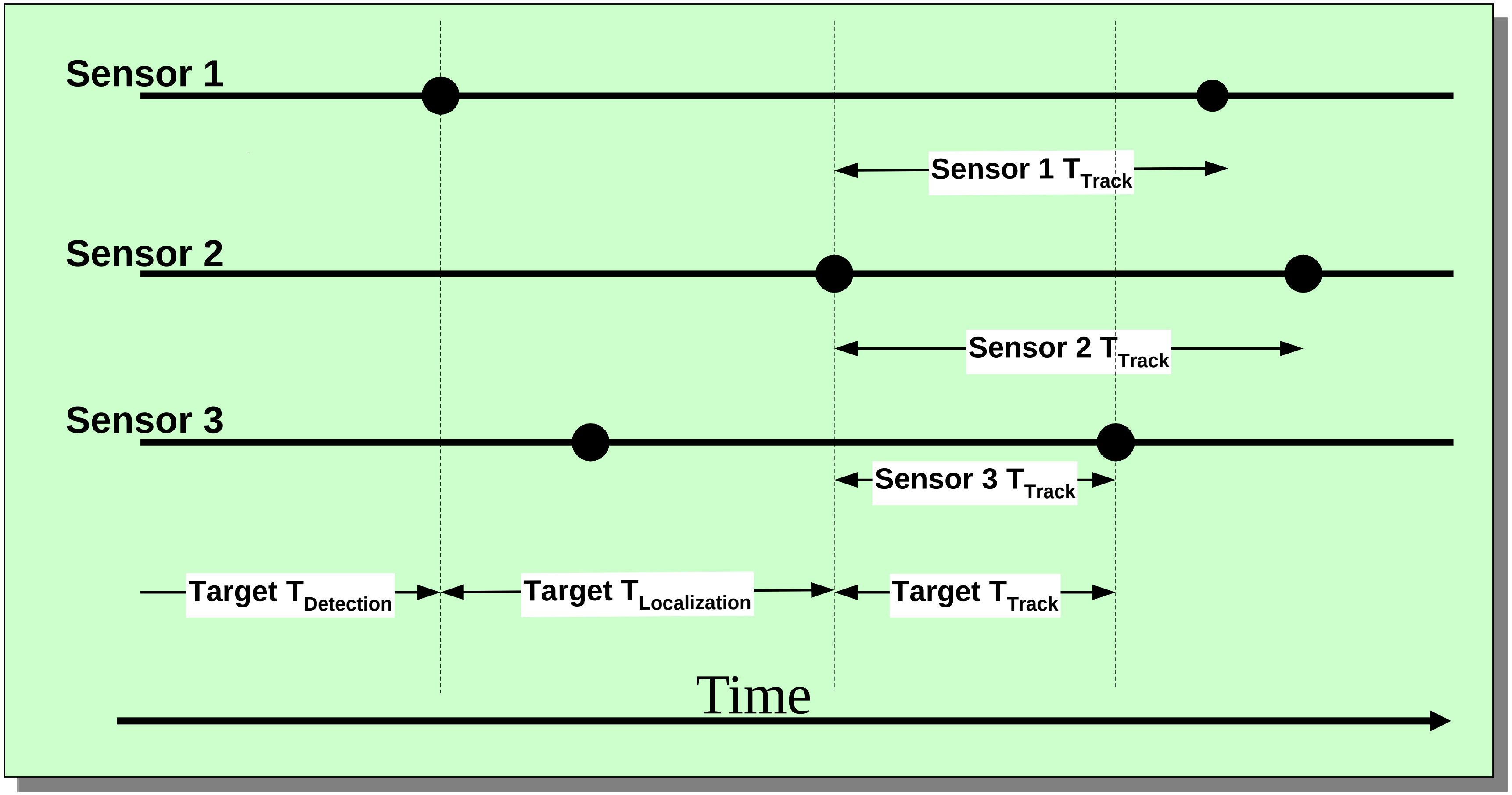
Cost Analysis Databases

- Visibility and Management of Operating and Support Costs (VAMOSC) Database from NCCA
- Air Force Total Ownership Cost (AFTOC) Database from AFCAA
- Operating and Support Management Information System (OSMIS) Database from USACEAC
- Jane's Online
- Navy and Air Force Online Fact Files
- Federation of American Scientists (FAS)
- Defense Automated Cost Information System (DACIMS) Database from DCARC

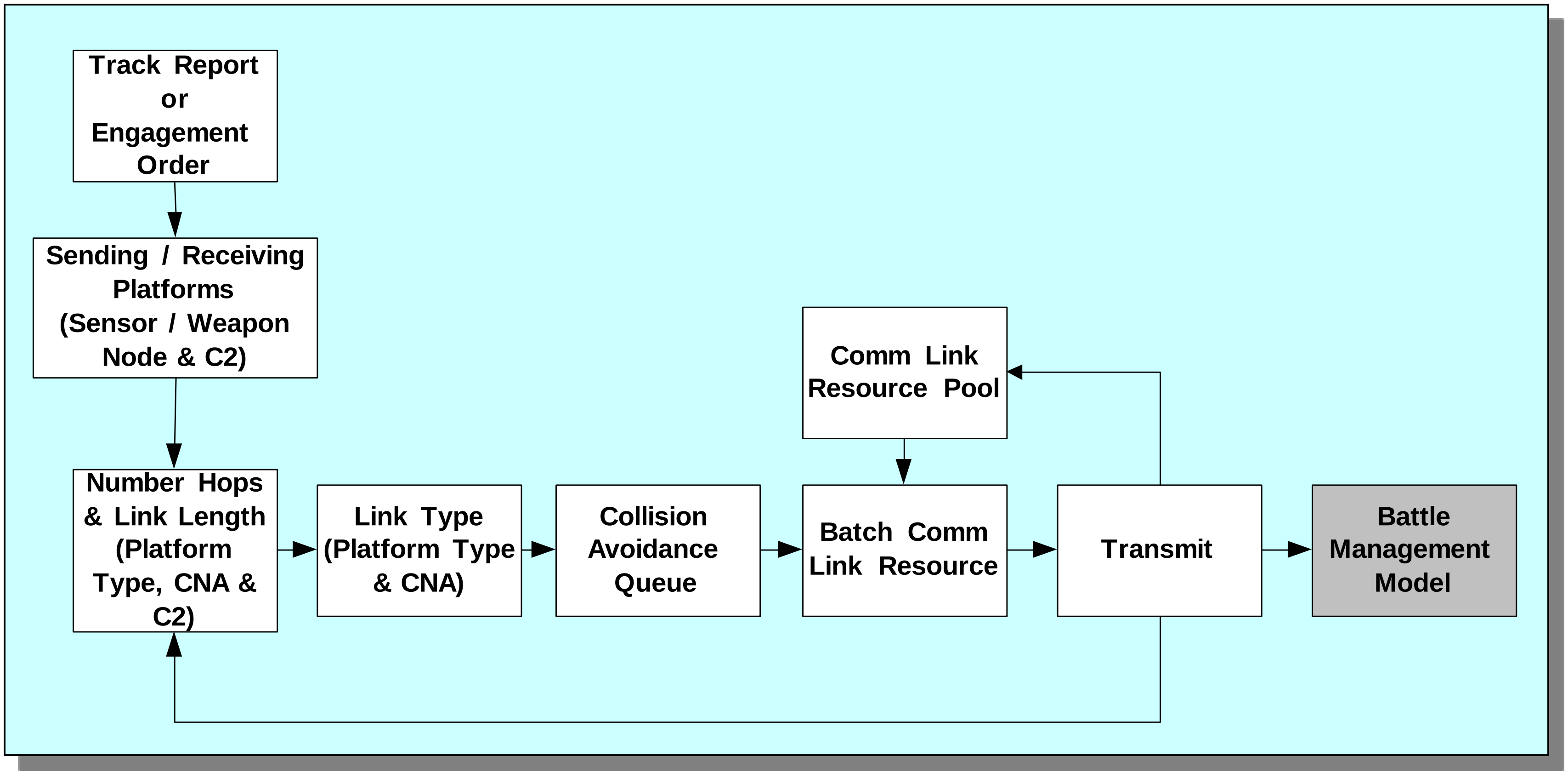
Platform Cost Assumptions

- O&S Costs for USVs and UUVs Not Available
- Total Ownership Costs (TOC) Based on 10 year Service Life

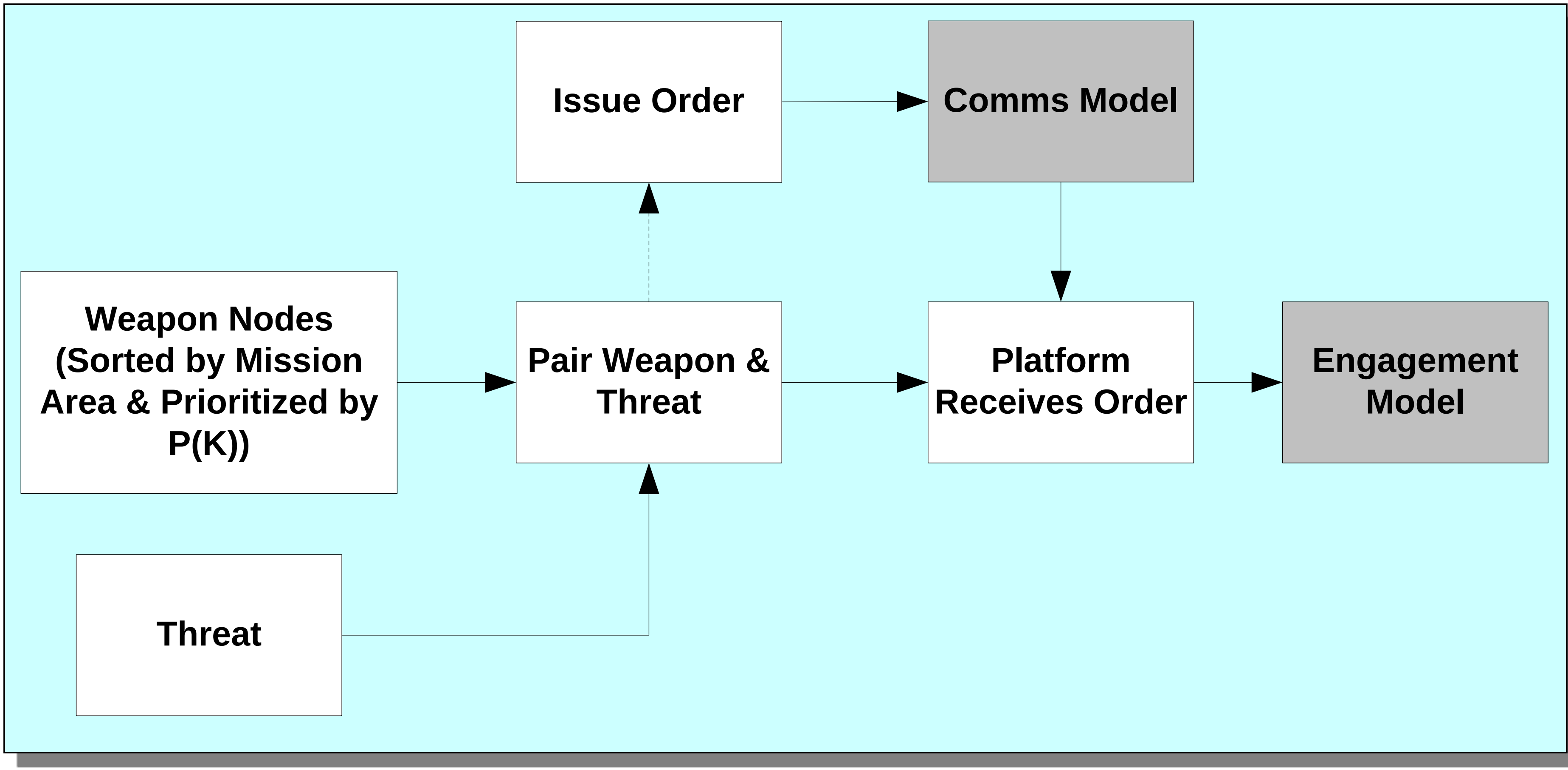
Surveillance Algorithm



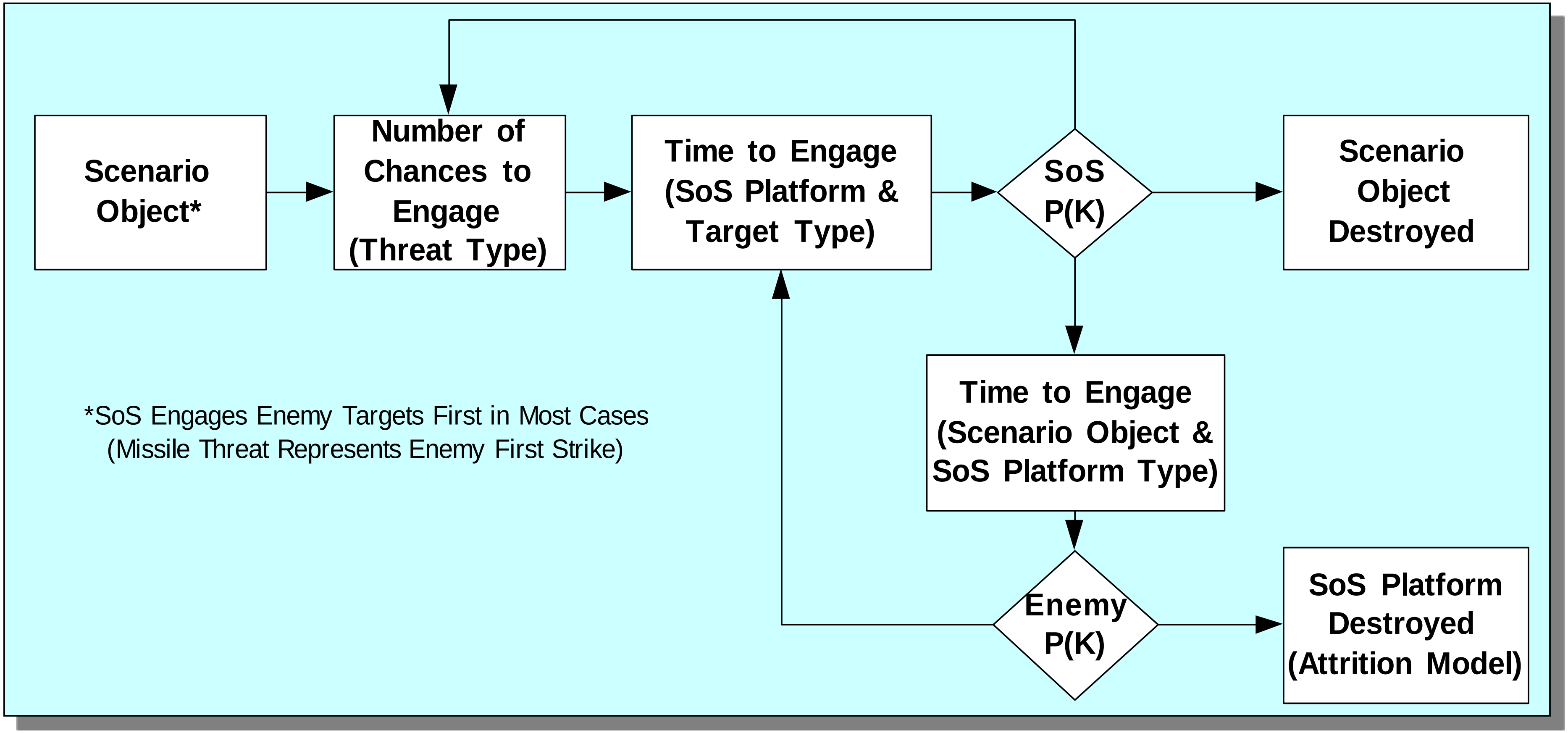
Communications Algorithm



Battle Management Algorithm



Engagement Algorithm



Bounded and Weighted VSD

1. Maritime Dominance
   a. Surveillance (.3)
      i. Detection (.6 / .18)
         1. Coverage Capability (.4 / .072)
            a. Average Time to Establish Complete Area Coverage
            b. Ratio Area Covered / Total Search Area
            c. Coverage Factor (Confidence)
         2. Probability of Detection (.6 / .108)
            a. Average System Probability of Detection
      ii. Tracking (.4 / .12)
         1. Tracking Capability (1 / .12)
            a. Ratio Contacts of Interest (COI) tracked / Total COI
            b. Average Number of Visits per COI
   b. Threat Analysis and Evaluation (.2)
      i. Identification (.7 / .14)
         1. ID Capability (.6 / .084)
            a. Ratio COI's ID'd / Total COI
         2. Probability of False ID (.4 / .056)
            a. Ratio of Incorrect ID's / Total ID's
      ii. Minimize Risk (.3 / .06)
         1. Reduced Exposure to Risk Capability (1 / .06)
            a. Ratio of Personnel Exposed to Risk / Total Personnel
            b. Ratio of Casualties / Total Personnel
   c. Battle Management (.2)
      i. Recognized Maritime Picture (RMP) (.6 / .12)
         1. RMP Capability (1 / .12)
            a. Average Time to Establish 80% of RMP
            b. Ratio Correct COI's ID'd / Total COI
      ii. Maximize Communication (.4 / .08)
         1. Communication Capability (1 / .08)
            a. Ratio of Number of Assets Lost Communications / Total Assets
   d. Engagement (.3)
      i. Destroy / Disable Targets (.4 / .12)
         1. Engagement Capability (1 / .12)
            a. Average Time to Kill 80% of Targets
            b. Ratio of Targets Engaged / Total Targets
      ii. Endure Combat (.6 / .18)
         1. Endurance Capability (1 / .18)
            a. Ratio of Friendly Assets Survived / Total SoS Assets
            b. Ratio of Enemy Assets Survived / Total Enemy Assets

Assumptions and Constraints

- Calculations were done by approximating relative sizes of the UAVs to the manned systems they would be replacing.
- The calculations on the number UAVs capable of fitting on a carrier is based off the size of the predator UAV.
- We assumed that it would be possible to fold the wings in 2020 and that they would be capable of launching off and landing onto a carrier

UV Calculations

Arch 3								Arch 2				
		Wingspan	Length	Area	Total					Wingspan	Length	Area
25	Med Surveillance	40	25	1000	25000			58	Med Surveillance	40	25	1000
25	Med Strike	50	30	1500	37500			14	JSF	30	45	1350
25	Med Multi	48	27	1296	32400			4	E-2	42	60	2520
14	JSF	30	45	1350	18900			7	Sh-60	15	50	750
4	E-2	42	60	2520	10080			24	FA 18	29	55	1595
7	Sh-60	15	50	750	5250							
					129130	sq ft						
Current Carrier												
				Area	Total							
8	S-3	39	53	2067	16536							
36	F/A-18 E/F	29	55	1595	57420							
4	E-2	42	60	2520	10080							
14	F-14	38	62	2356	32984							
5	EA-6B	30	59	1770	8850							
7	Sh-60	15	50	750	5250							
					131120	sq ft	Approx. Carrier space					
Assume that with Wing Fold the wingspan is approxamatly 2/3 the size												
Arch 3								Arch 2				
		Wingspan	Length	Area	Total					Wingspan	Length	Area
30	Med Surveillance	32	27	864	25920			70	Med Surveillance	30	27	810
30	Med Strike	32	27	864	25920			14	JSF	30	45	1350
50	Med Multi	32	27	864	43200			4	E-2	42	60	2520
14	JSF	30	45	1350	18900			7	Sh-60	15	50	750
4	E-2	42	60	2520	10080			24	FA 18	29	55	1595
7	Sh-60	15	50	750	5250							
					129270	sq ft						
			26.66667	17.77777778								

Changes In Sub & Surface Vessels

Arch 1

- 1 CVN
- 2 CG
- 4 DDG
- 2 FFG
- 2 SSN
- 1 MHC
- 1 MCM
- 1 LHA

Arch 2

- 1 CVN
- 2 CG
- 2 DDG
- 6 LCS
- 2 SSN
- 2 SSGN
- 4 USV
- 4 MIW UUV
- 4 ASW/ASUW UUV

Arch 3

- 1 CVN
- 2 CGX
- 2 DDX
- 6 LCS
- 4 Multi-Mission USV
- 4 MIW UUV
- 4 ASW/ASUW UUV
- 1 Long Range UV Insertion Platform

Changes In Air Assets

Arch 1

- 4 E2-C
- 10 SH-60
- 36 F/A-18
- 2 P-3
- 5 CH-53
- 2 MH-53
- 14 F-14
- 8 S-3
- 5 E/A-6B
- 10 AH-1
- 1 E-3 AWACS
- 1 E-8 JSTARS
- 1 B-2
- 2 B-52
- 2 F-117

Arch 2

- 4 E2-C
- 7 SH-60
- 24 F/A-18
- 18 JSF
- 1 E-3 AWACS
- 1 E-8 JSTARS
- 6 F-16
- 6 F/A-22
- 2 Large Surveillance UAVs
- 70 Medium Surveillance UAVs
- 20 Small Surveillance UAVs
- 2 Multi-Mission Aircraft (MMA)

Arch 3

- 6 SH-60
- 14 JSF
- 1 E-3 AWACS
- 8 Large Surveillance UAVs
- 30 Medium Surveillance UAVs
- 20 Small Surveillance UAVs
- 30 Medium Strike UAVs
- 50 Medium Multi Mission UAVs

Land Forces Estimate in JAOA

- Estimate of PRC forces
  - 3 Infantry Divisions = 45K
  - 1 Arty Division = 15K
  - Total = 60K
- Estimate of JUMPVISA Coalition forces
  - 1 MEB = 17K
  - 1 OFB = 3K
  - 1 Airborne Division = 12K
  - 1 Infantry Division = 11K
  - Total = 43K

Game Theory Definitions

IMPACT Table Breakdown

Mission Area Def

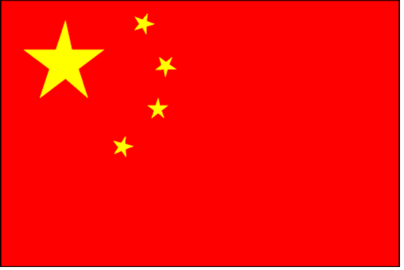
1	**TBMD**
2	**AAW**
3	**Land Warfare**
4	**SUW/USW**
5	**LOC**

Probability of Kill:

Non-selective

	Displacement	Multiple	Number	Wt Mult	P9H)	Hits to Kill	P(k)
LPD-17	25000	24.57	6.00	147.43	0.669261	5	0.223087
CVN	97,000	27.71	1.00	27.71	0.125811	5	0.041937
CG	9,000	2.57	4.00	10.29	0.046693	2	0.006226
DDG	8,500	2.43	9.00	21.86	0.099222	2	0.01323
LCS	3,500	1.00	13.00	13.00	0.059014	1	0.003934
Totals:	204,000	58.28571	33	220.2857	1	15	0.288413
P(MA) =	0.85						
P(MH) =							
	P(SHMK) :						
Ex-War	0.0061						
CVN	0.0054						
CG	0.15						
DDG	0.15						
LCS	0.365						

P(MA) =	Probability of Missile Acquire
P(MH) =	Probability of Missile Hit ; standard measure of missile accuracy
P(SHMK) =	Probability of Single Hit Missile Hill (per ship class)
Multiple =	The number of times that a ship is more likely to be targeted than an LCS positioned near it based on size difference
Number =	Number of ships in that class that are in the targeting area simultaneously
Wt Mult =	Likelihood that a particular ship class will be target based on the number of ships in that class that are present
P(H) =	Weighted probability of hit for each ship class based on the numbers of that ship class in the area
Hits to Kill =	Number of hits required per class of ship to achieve mission kill
P(k) =	Weighted total probability, adjusted by number of ships per class present, of mission kill per class



Game Theory Calculations:

POA 1 – Repeated 150-200 missile raids (A/C)
POA 2 – Coordinated raid attacks at key assets
COA 1 – US waits for Chinese first strike
COA 2 – US first strike → reduce Chinese 50%

China is 96% likely to adopt POA 1; Weaken US AAW

CHINA

US	**POA 1**	**POA 2**
COA 1	US wins; No WFA losses **0.0**	China wins; Loss 2 WFA **2.0**
COA 2	US wins; China @ 55% **-1.5**	US wins; China @ 40% **-2.0**

US 76.78% likely to use some form of COA 2.

*Table is viewed from the Chinese perspective

END RESULT: US is unable to defend vs. ASM threat after 2 raids/SAG

Modeling Tools Description

Higher Level Models Build on Lower Level Models

Excel/SWAT

- Based on Physical Laws
  - High Fidelity
  - Limited Breadth
- Establishes Fundamental Physical Characteristics for all Other Models

ALWSE-MC

- Implements Concepts of Operation
  - Less Depth
  - Consideration of "Real World" Effects
  - Application of Tactical Environment
- Provides Performance Characteristics for Higher Level Models

Extend™

- Implements Process Algorithms to Provide
  - Increased Breadth
  - Abstraction
  - Assessment of Multiple Configurations of Variable Parameters
- Produces Comprehensive and Quantitative Results for Decision Making

Modeling Outputs

Excel/SWAT

- Engineering Physics Based Modeling Performed to Create Database Tables and Lateral Range Detection Curves for Sensors/Threats Pairs

ALWSE-MC

- Platform/Combat System Modeling Performed to Incorporate Operational Implementation of Sensors/Threats Pairs and Produce Time to Detection Data

Extend™

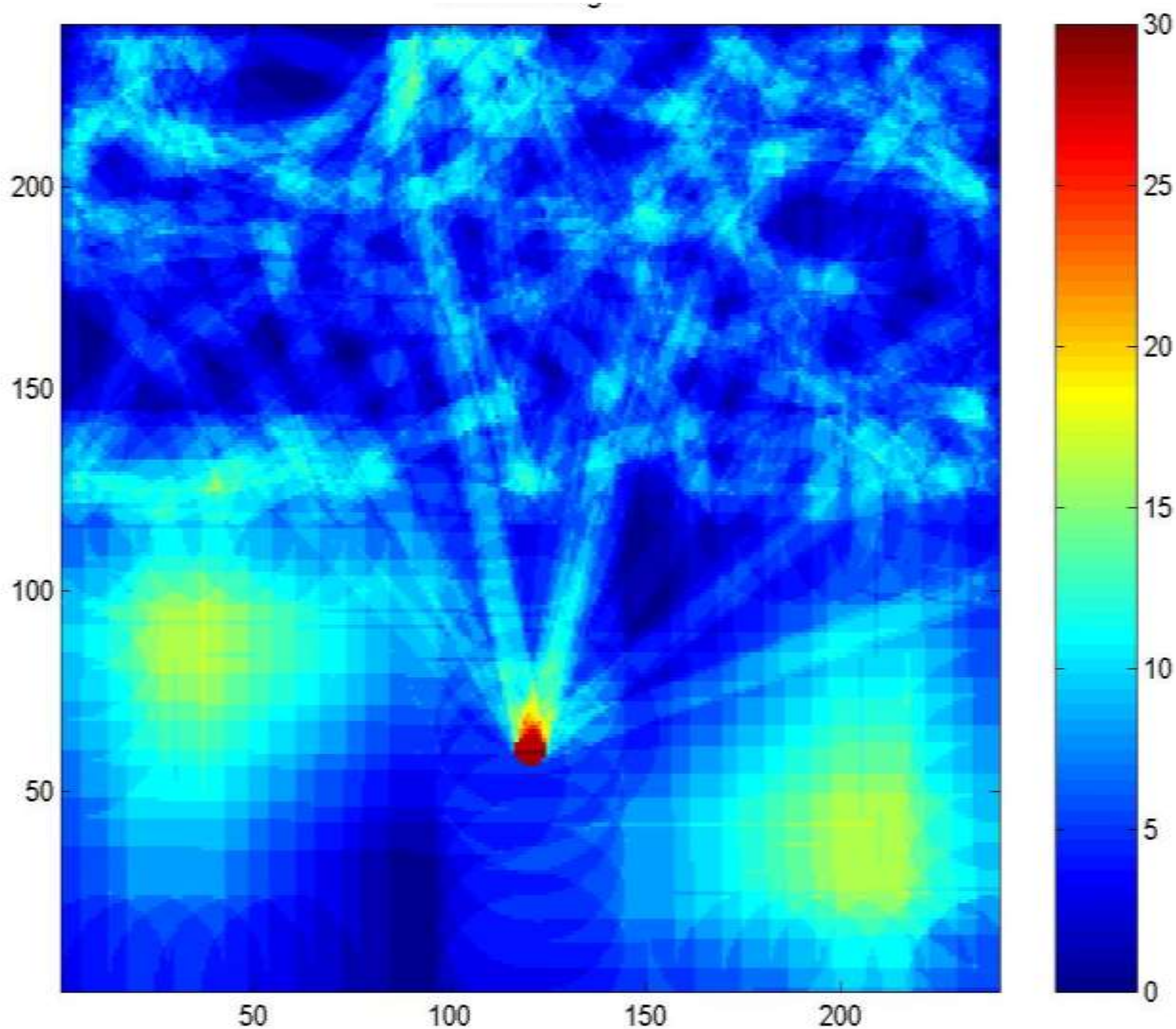
- Force/Theater Modeling Performed to Incorporate Multiple Architectural and Scenario Parameters and Provide the Necessary Outputs to Fulfill the Simulative Study Objectives

Land Systems Unmanned Vehicle Carrier Analysis

- Used ALWSE-MC to evaluate the area coverage by payload of the TDSI Land Systems Unmanned Vehicle Carrier
- 10 nm x 10 nm
- 4 UUV (search speed 3 kts)
- 5 Crawler UGV (search speed 1.3 ft/sec)
- 20 iStar UAV (search speed 30 kts)
- 6 Goldeneye UAV (search speed 30 kts)
- Area split horizontally between water and land
- UUVs conducted ladder search of area, UAVs/UGVs conducted random search patterns

Area Covered

- Area divided into 25 ft x 25 ft squares
- Color scheme scaled according to number of times square was visited
- 98.43% area covered in 22 hrs (maximum endurance of UV)



Results

- Significant littoral surveillance capability can be achieved at distance with reduced risk to personnel
- Rapid, Modular Deployment options
- 150 nm operating range of Unmanned Vehicle Carrier
- 98.43% area (10 nm x 10 nm) covered in 22 hrs of operation

Engineering Models – Threat Signature Tool

Mach Conversion Table

km/hr	m/s	Mach	km/hr	m/s	Mach
720	200	0.6061	1,098	305	0.9242
738	205	0.6212	1,116	310	0.9394
756	210	0.6364	1,134	315	0.9545
774	215	0.6515	1,152	320	0.9697
792	220	0.6667	1,170	325	0.9848
810	225	0.6818	**1,188**	**330**	**1.0000**
828	230	0.6970	1,206	335	1.0152
846	235	0.7121	1,224	340	1.0303
864	240	0.7273	1,242	345	1.0455
882	245	0.7424	1,260	350	1.0606
900	250	0.7576	1,278	355	1.0758
918	255	0.7727	1,296	360	1.0909
936	260	0.7879	1,314	365	1.1061
954	265	0.8030	1,332	370	1.1212
972	270	0.8182	1,350	375	1.1364
990	275	0.8333	1,368	380	1.1515
1,008	280	0.8485	1,386	385	1.1667
1,026	285	0.8636	1,404	390	1.1818
1,044	290	0.8788	1,422	395	1.1970
1,062	295	0.8939	1,440	400	1.2121
1,080	300	0.9091	1,458	405	1.2273

Reflectance = 0.0100
Emissivity = 0.9900
Pi = 3.14
TA Radians = 0
Sensor Freq(M) = 3.0E+09

Reqd CNR 0.69
Power (watts) 3.0000E+09
Aperture Diameter (m) 4.000
Bandwidth (Hz) 1.00E+08
Freq (Hz) 3.00E+09
Noise figure 1
Antenna Temp (K) 300

Generic Threat Categories

Threat	Length (m)	Diameter (m)	Reflectivity	RCS (m^2)
ASCM-1	3.75	0.42	0.1	0.0138474
ASCM-2	8.9	0.67	0.1	0.03523865
ASCM-3	11.6	0.92	0.1	0.0664424
Ambient temp (K)	300			

$$R = \left[\frac{\pi P_T D^4 \sigma}{64 \lambda^2 kTBF(CNR)} \right]^{1/4}$$

Pi = 3.14
Pt (W) = 100
Sigma =
T = 299.7
TBF =
CNR = 0.79
BW = 1.05E+08

Reflect = 0.0100
Noise Fig. = 1

TA (Rad) = 0
Ant F (Hz) 3000000000
Ant Ap = 0.003

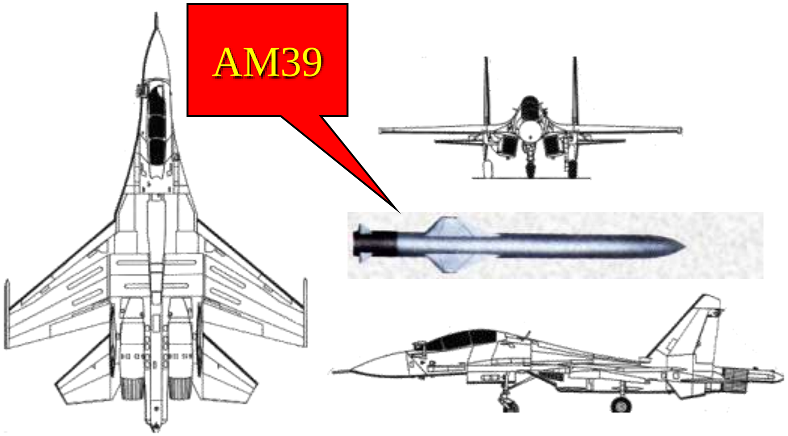
RCS (m^2) Diameter	Length (m) ASCM 7.34	Detection Range (m)	Detection Range (nm)	Length (m) A/C 10.00	Detection Range (m)	Detection Range (nm)
0.01	7.9E-07	1.6E-01	9.0E-05	7.9E-07	1.6E-01	9.0E-05
0.02	3.1E-06	2.3E-01	1.3E-04	3.1E-06	2.3E-01	1.3E-04
0.03	7.1E-06	2.8E-01	1.6E-04	7.1E-06	2.8E-01	1.6E-04
0.04	1.3E-05	3.3E-01	1.8E-04	1.3E-05	3.3E-01	1.8E-04
0.05	2.0E-05	3.7E-01	2.0E-04	2.0E-05	3.7E-01	2.0E-04
0.06	2.8E-05	4.0E-01	2.2E-04	2.8E-05	4.0E-01	2.2E-04
0.07	3.8E-05	4.3E-01	2.4E-04	3.8E-05	4.3E-01	2.4E-04
0.08	5.0E-05	4.6E-01	2.5E-04	5.0E-05	4.6E-01	2.5E-04

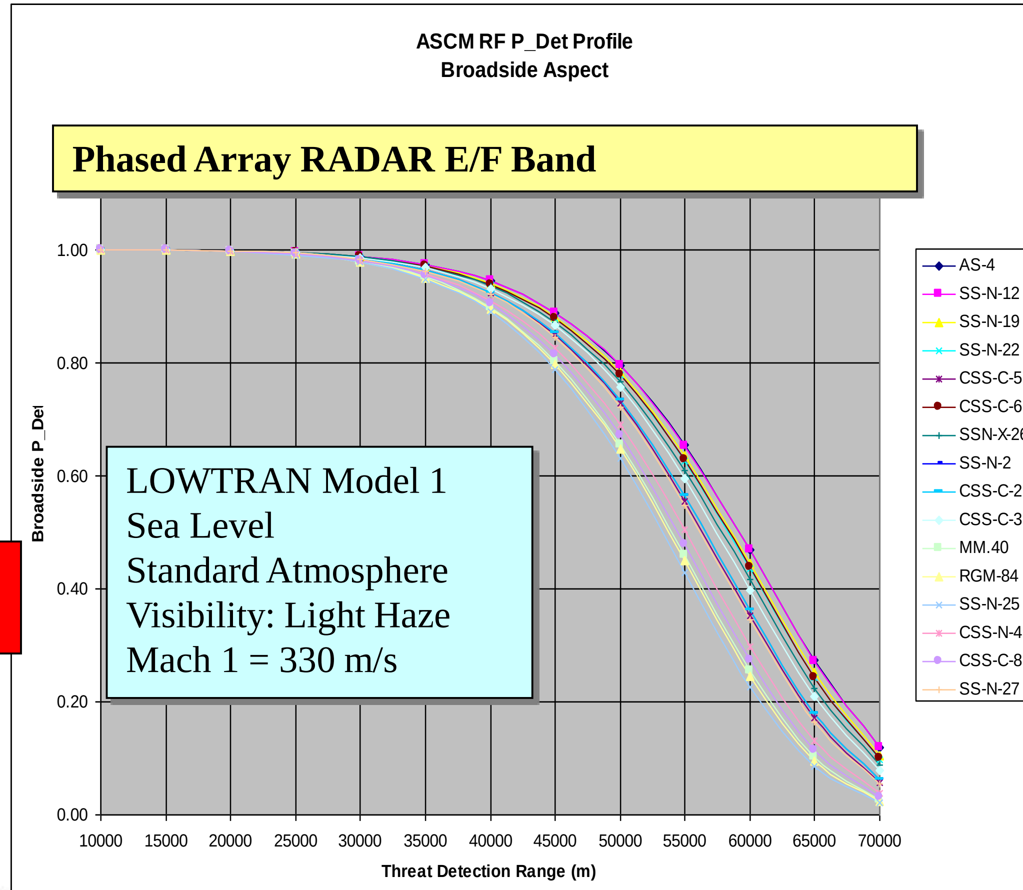
Assumptions:

- Broadside Aspect
- Reflectance 1/0.1
- Ogive/Cylinder
- Ships: Displacement
- Raleigh Atmospherics
- Johnson’s Criteria (IR Resolution)

Engineering Models – Representative P_det Curves

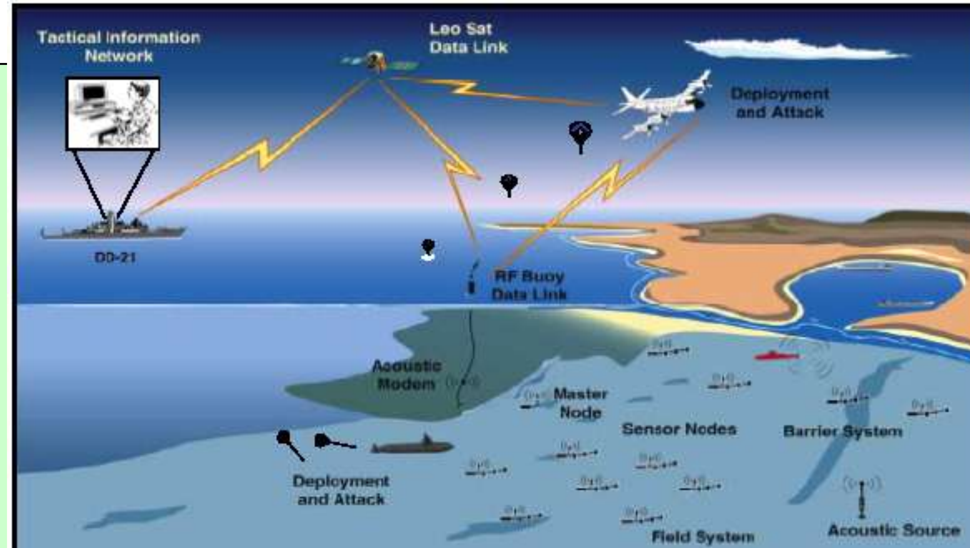
- Acoustic/RADAR/EO-IR Longitudinal Probability of Detection Curves
- SA/SS/AS Envelopes Characterized By Unclassified Physics Models
- Swerling II Detection Model / NVESD ACQUIRE Algorithm





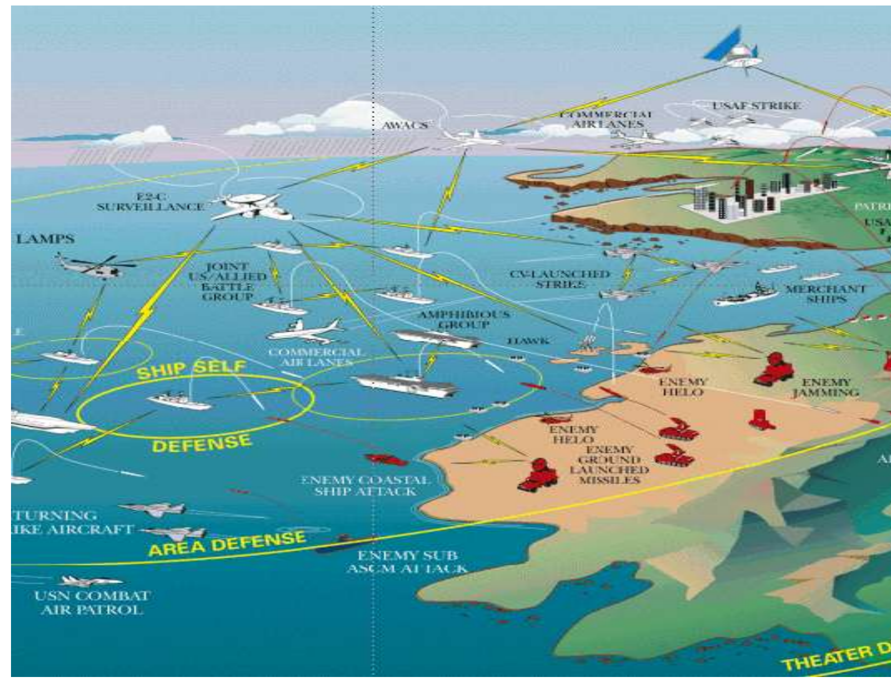
Concept of Operations 1

- Employment of UV Assets
  - Introduce Less Capable/less Costly Assets First
  - More Advanced Assets Follow
- Search Pattern
  - Alternating Waffle Search



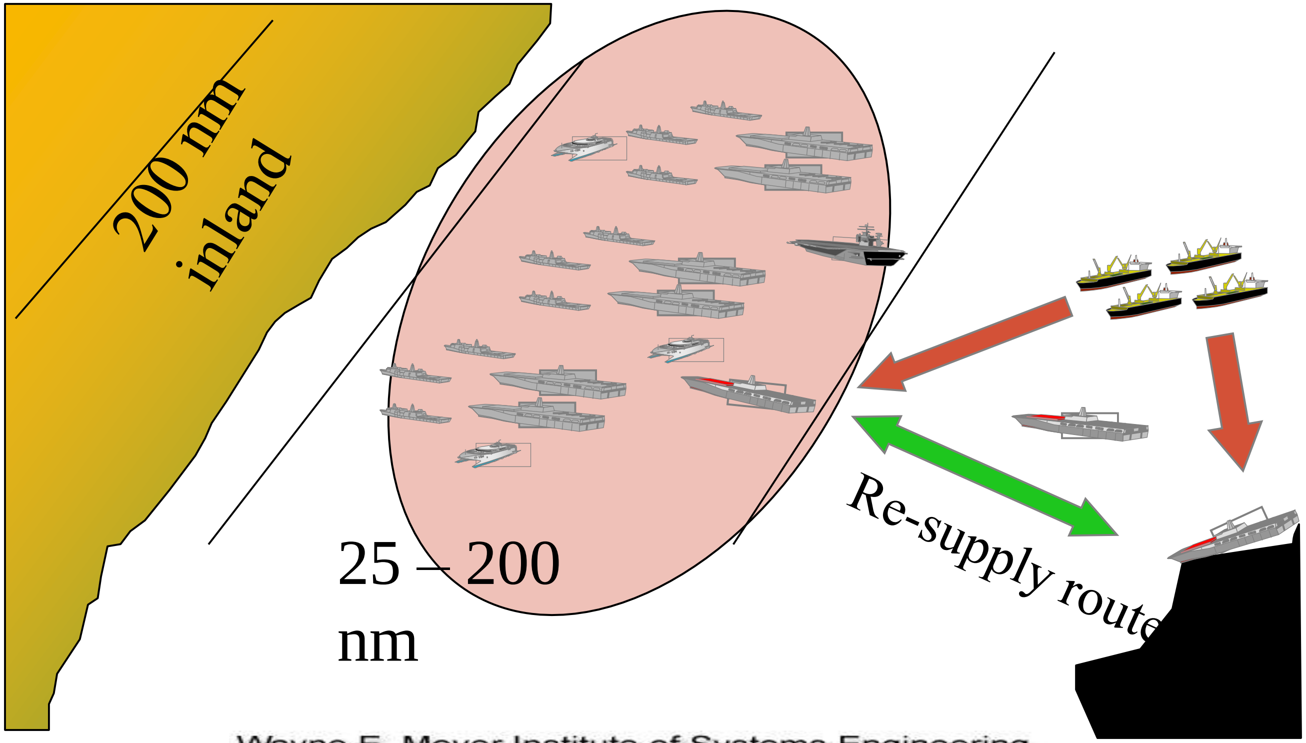
Concept of Operations 2

- Distributed Communications
  - All Platforms Have Communication Capability
- Decentralized Command and Control
  - Performed by Manned Platforms



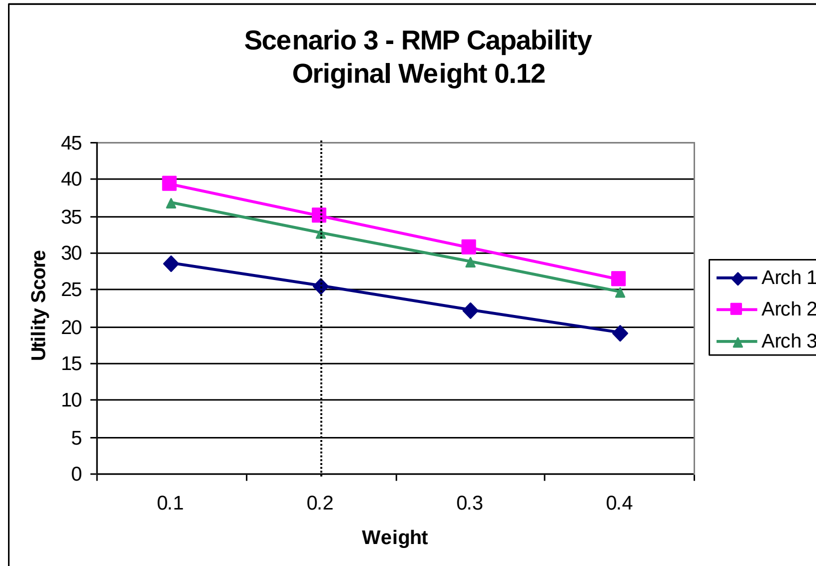
Concept of Operations 3

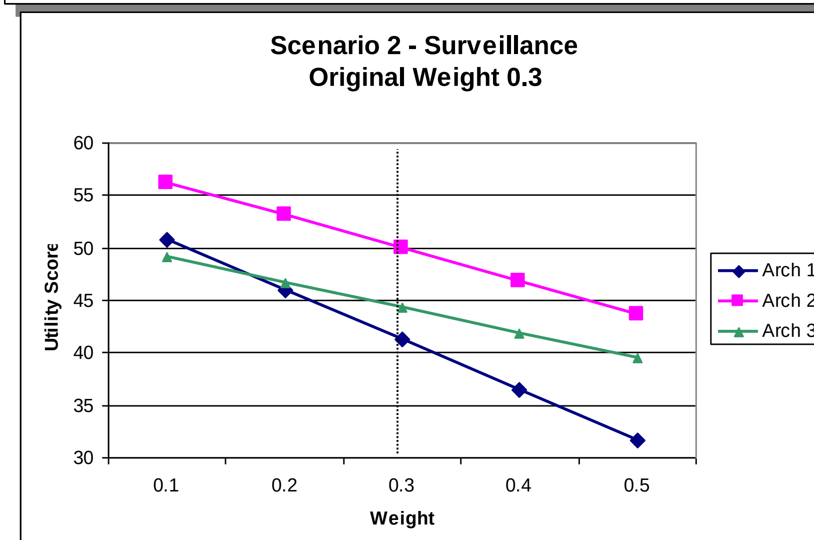
- Medium Platform Distribution
  - 150 Nautical Mile Distance



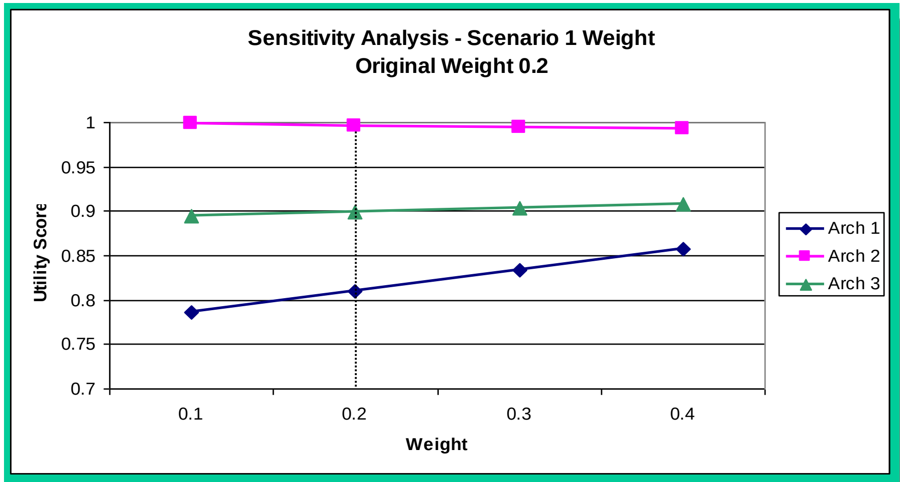
Global Weight Sensitivity Analysis BU

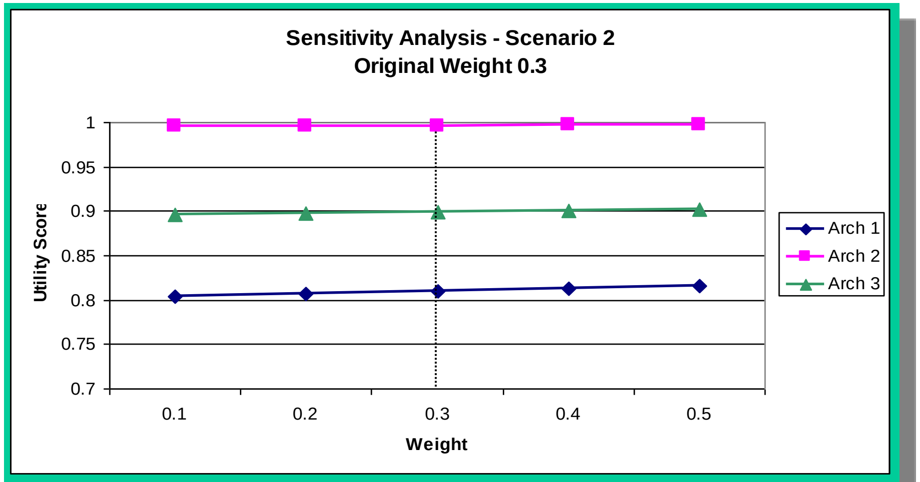
- Insensitivity of Global Weights within Measures of Effectiveness
- Measures of Effectiveness Were Within Insensitivity Range

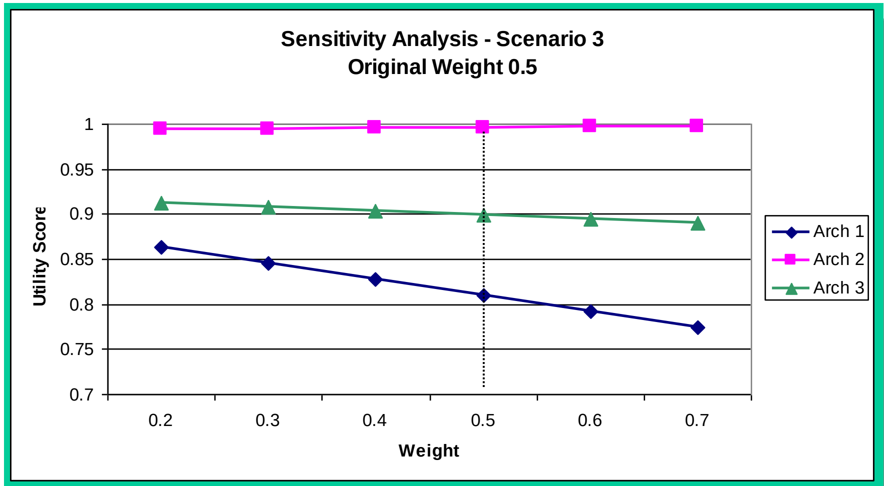




Scenario Weight Sensitivity Analysis BU

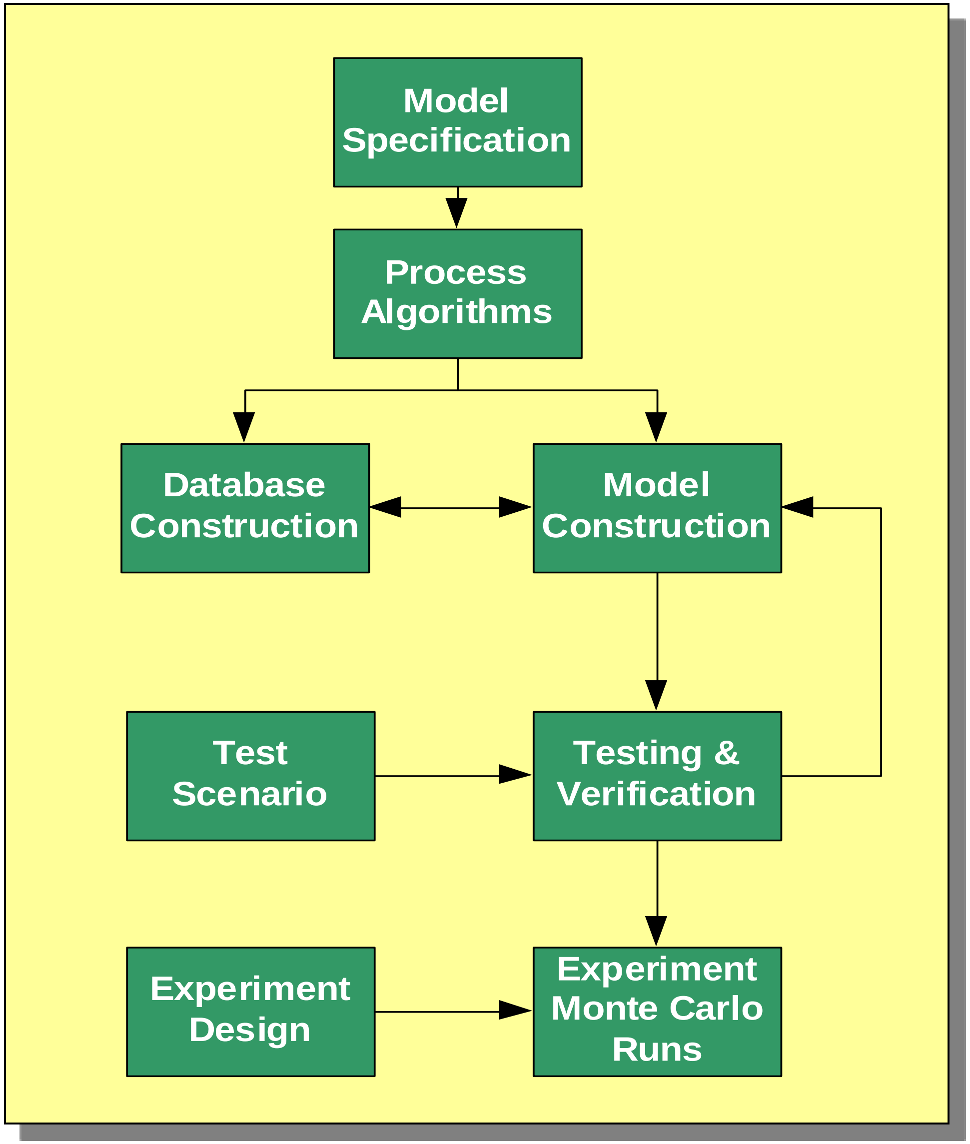






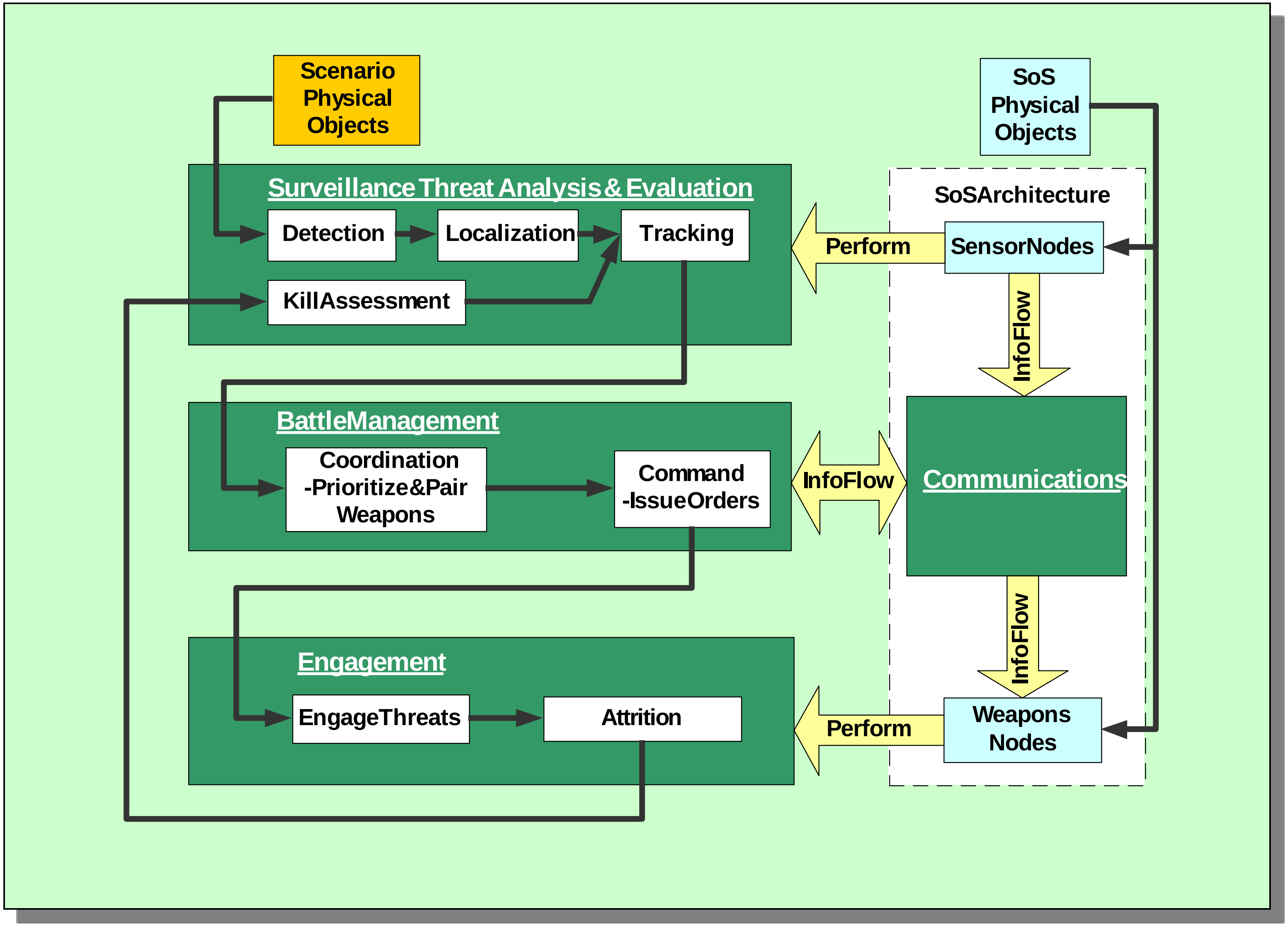
Insensitivity of Architecture Selection to Scenario Weights

Model Development Process



- Allowed Efficient Extend™ Model Development in Compliance with Schedule
- Focused and Standardized Programmer/Modeler Efforts
- Coordinated Modeling Efforts With Data Collectors and Post-Processors

Extend™ Model Design

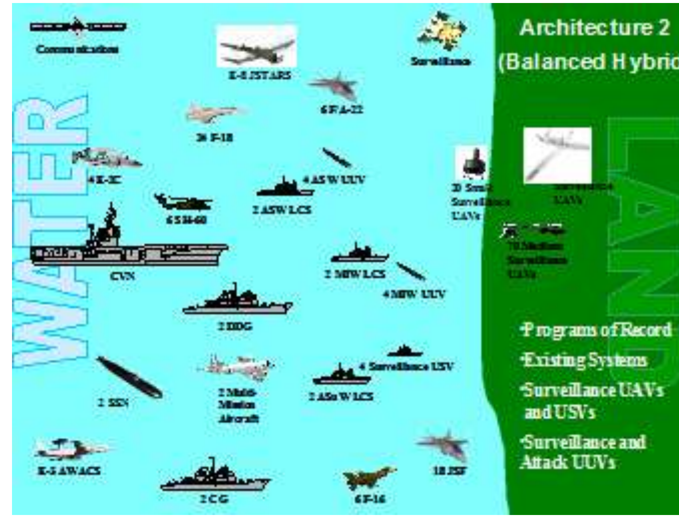


Recommended System of Systems for Maritime Dominance in Littorals

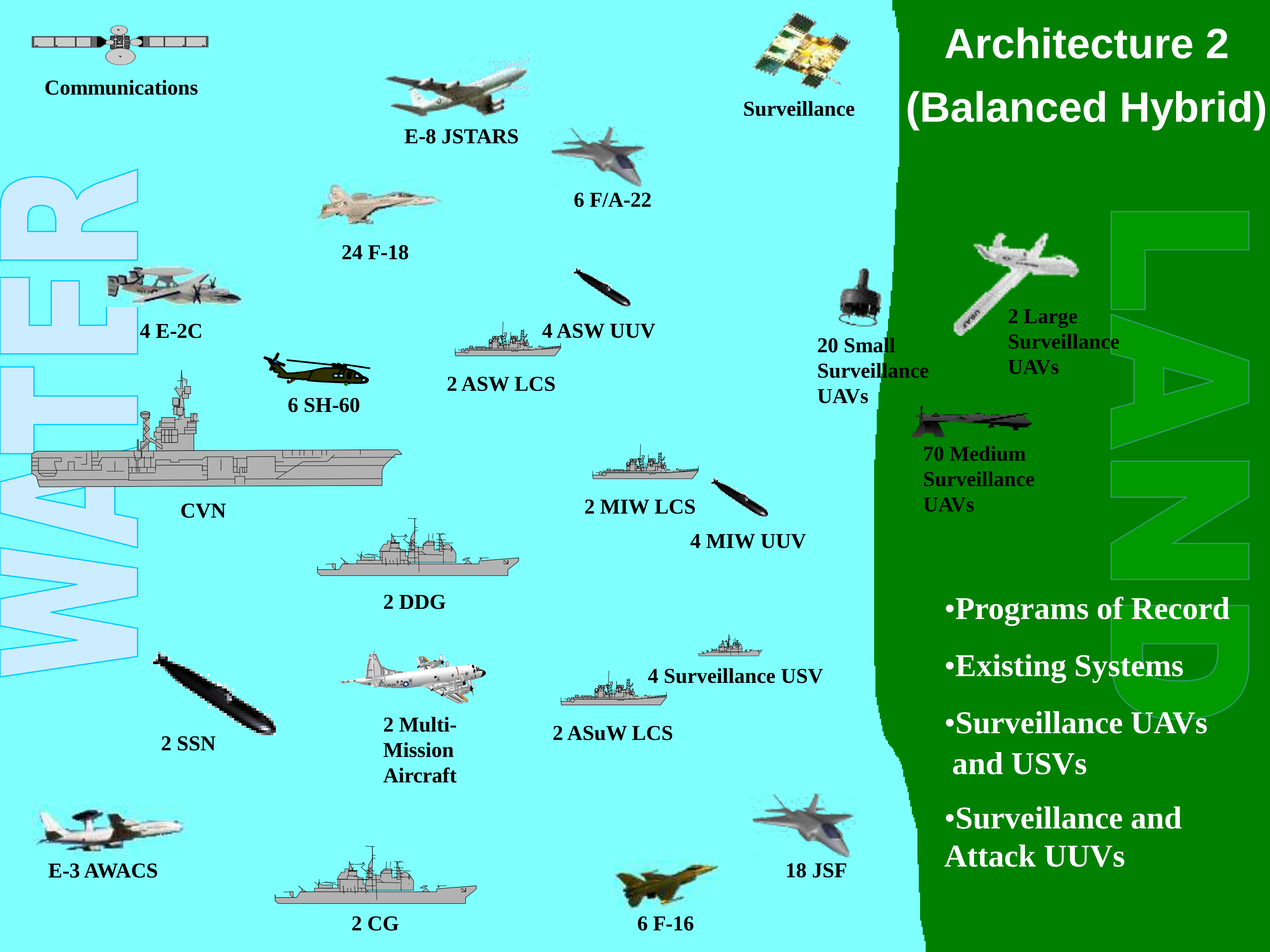
•Unmanned Vehicles Complement But Cannot Replace Manned Platforms

•Recommended System of Systems Enabling SEA BASING and SEA STRIKE in 200 nm by 200 nm Littoral Operation Area in 2020 Timeframe

- **Consists of Unmanned/Manned Vehicle Ratio of Approximately 1.5 to 1**
- **Utilizes Distributed Communications with 100nm Physical Platform Distribution**
- **Employs Decentralized Command & Control Structure**
- **Is Cost Effective Relative to Other Alternatives**



- **Distributed Communications**
  - Faster Dissemination of Information
  - Minimum Impact on Throughput with Node Failures
- **Decentralized Command and Control**
  - Shorter Reaction Times
  - Less Network Demand
  - Single C2 Node Failure Avoidance
- **100 nm Platform Distribution**
  - Superior Overall Performance


Architecture 2
(Balanced Hybrid)
WATER
LAND
Communications
E-8 JSTARS
Surveillance
6 F/A-22
24 F-18
4 E-2C
4 ASW UUV
2 ASW LCS
6 SH-60
20 Small Surveillance UAVs
2 Large Surveillance UAVs
70 Medium Surveillance UAVs
CVN
2 MIW LCS
4 MIW UUV
2 DDG
4 Surveillance USV
2 ASuW LCS
2 SSN
2 Multi-Mission Aircraft
E-3 AWACS
2 CG
6 F-16
18 JSF
•Programs of Record
•Existing Systems
•Surveillance UAVs and USVs
•Surveillance and Attack UUVs