SEA-10 RIVERINE 2010
Integrated Project

Systems Engineering and Analysis Cohort 10:

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LT Jennifer Free, SWO
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Faculty Advisors:

RDML Richard Williams (RET)
Professor Eugene Paulo

December 1, 2006

Agenda

0800	Introduction
0815	Systems Engineering Design Process
0830	Modeling & Analysis
0845	Data Outputs, Process, Assumptions & Limitations
0900	Cost Estimation & System Reliability
0915	Data Analysis
0930	Conclusions & Recommendations
0945	Questions

BULLARD HALL 100B

1000	Breakout Session & Model Demonstration

Primitive Need

"…our Navy is missing a great opportunity to influence events by not having a riverine force."

- Admiral Mike Mullen, Chief of Naval Operations, speech to the Naval War College in August 2005

"…I want the biggest bang for the buck."

- RADM Donald Bullard, Commander NECC, meeting with SEA-10

"The biggest tactical limitation inherent in operating on the water is not being able to see very far beyond the banks. "

- Mr. Joshua Iverson, Staff Sergeant, USMC (RET), assigned to Small Craft Company in Iraq, Meeting with SEA-10 at Special Mission Training Center

RIVGRU ONE Feedback

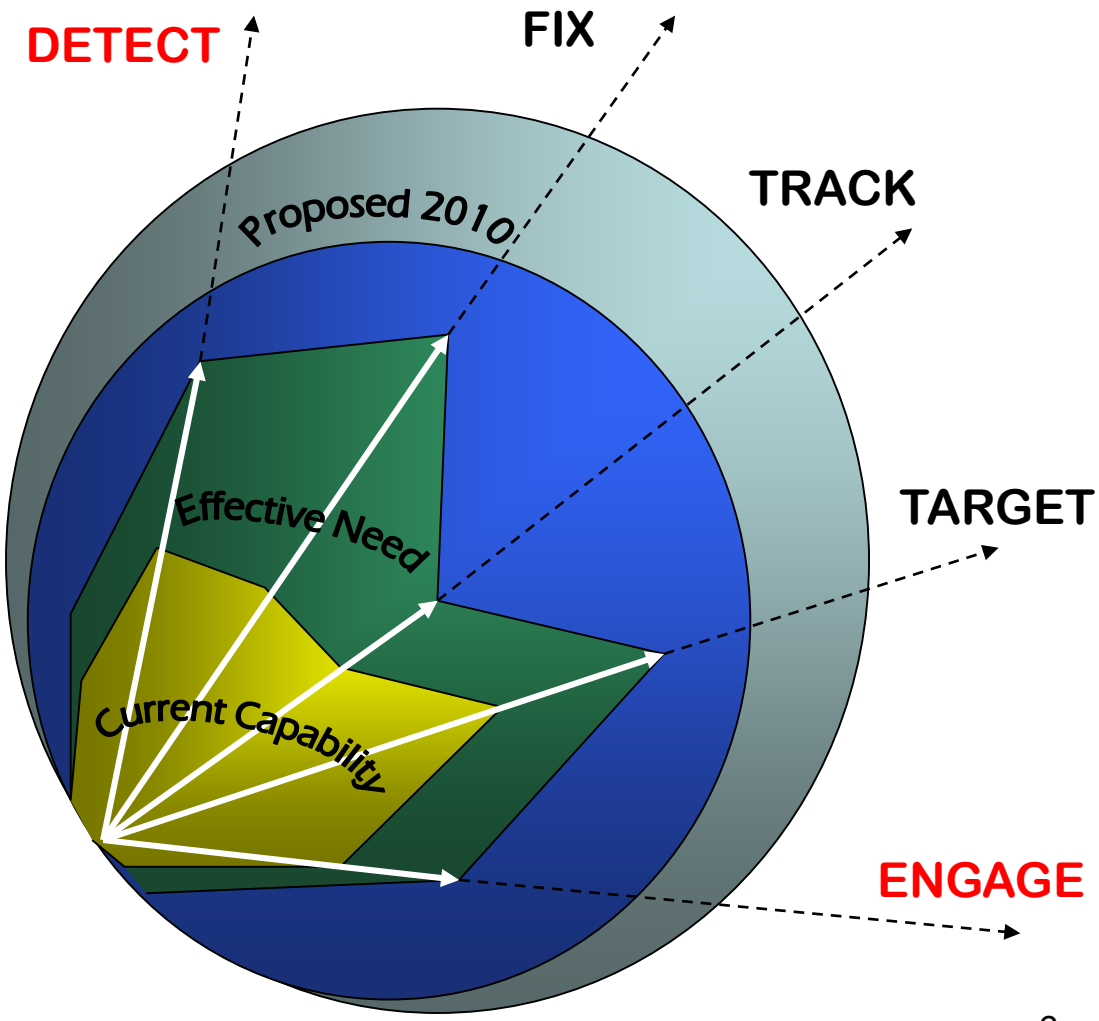
- VTC 30 November 2006
  - Value of single sensor versus networked sensors
  - UAV cost numbers too high
  - Further use of SEA-10 MANA model
  - USV dwell time and automation
  - Verified and validated reliability numbers
  - Perceived USV reliability low, UAV plug and play reliability better
  - Further study of sustainment/logistics

Riverine Operations

- Riverine Area Control/Protect Critical Infrastructure
- Interdiction of Riverine Lines of communication
- Fire Support
- Insertion / extraction of conventional ground forces
- Theater Security Cooperation

Initial Tasking

- Capture the Baseline.
- Identify the effective need/capability gaps.
- Propose a cost-effective follow on system to meet projected operational requirements.



Research Focus

- “Most bang for the buck”
- Alternatives
- Unmanned systems
- Organic indirect fires
- Ground combat element
- Dedicated helicopter support

Modeled Alternatives

Baseline Force:

Composition

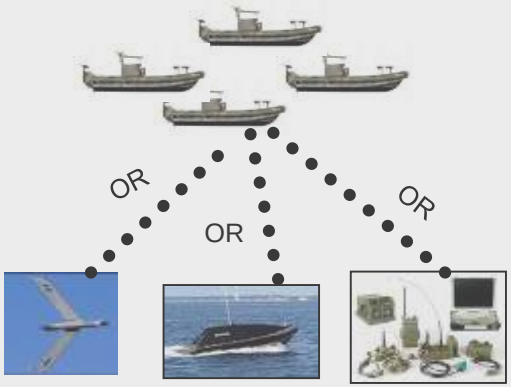
3 Divisions of 4 SURCs (12 total)

- (1) M 240G Medium machine gun
- (1) GAU 17 Electric powered gatling gun
- (1) .50 cal
- (1 per person) M -16

Disposition

SURC employment

- (1) C2 SURC
- (2) Force Protection SURC
- (1) SURC with 7 man VBSS team



ALT 1: Baseline + Sensors:

Extend Sensor Range

Enable SURCs to bring superior firepower to bear at maximum range

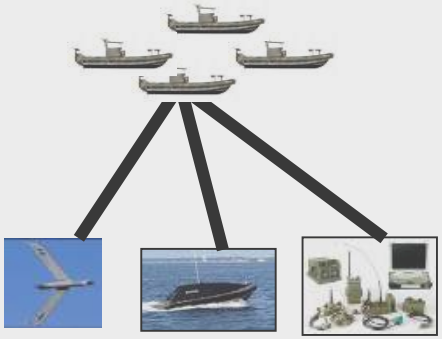
ALT 2: Baseline + Engagement

Increase Engagement capability of RF

GCE

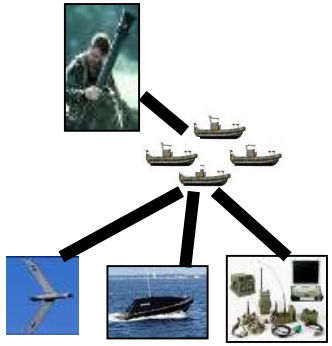
(2) 12 man assault force

M-16 & Squad Automatic Weapon



ALT 3: Baseline + Network Sensors

Extend sensor range using networked sensors



ALT 4: Baseline + Network Sensors + Indirect Fire

81mm Mortar

Mortar Barge

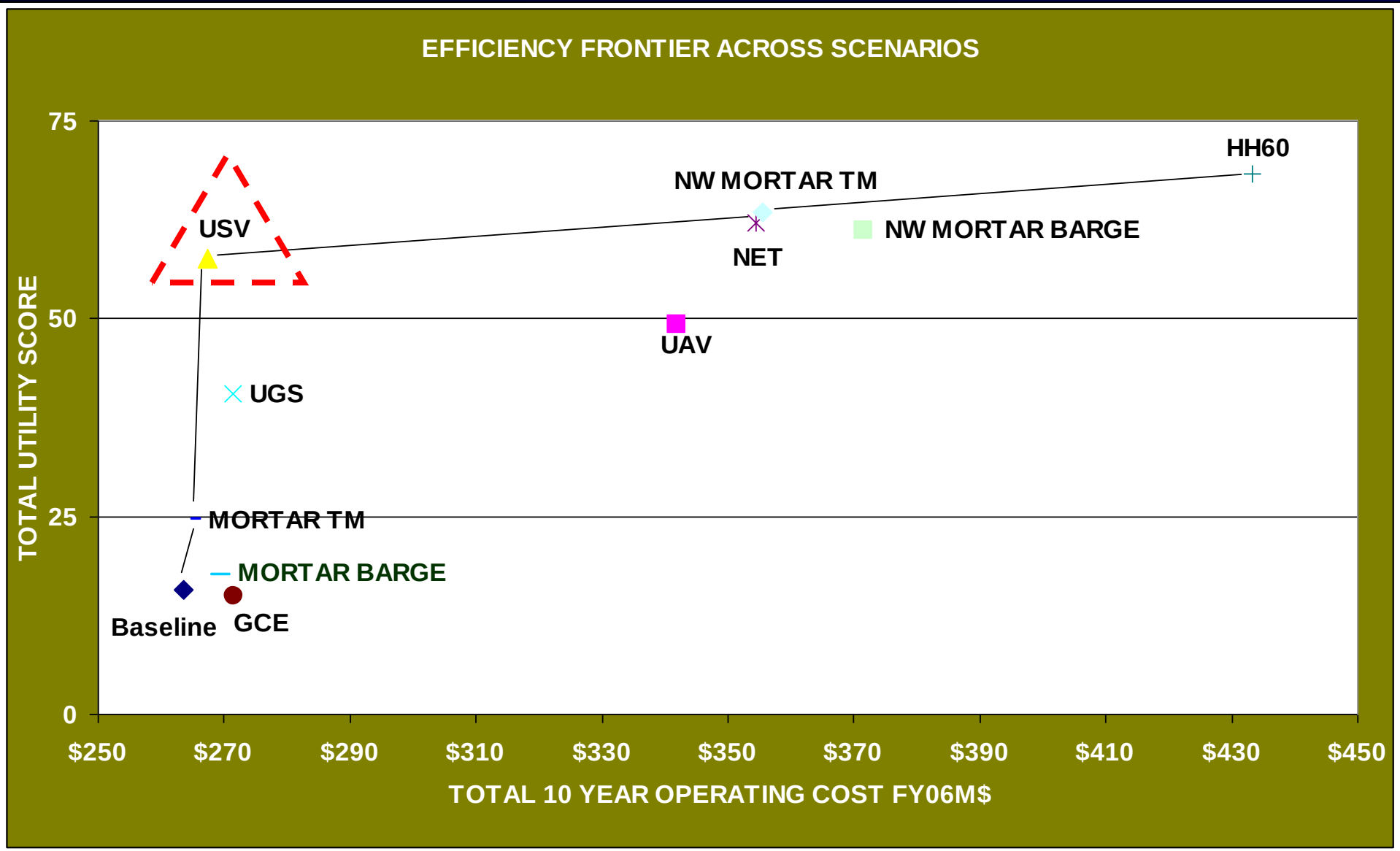
ALT 5: Baseline + Dedicated Helo Support

(4) Helicopter detachment

(4) Hellfire missiles

(2) 7.62mm machine gun

Bang for the Buck



Research Insights

- The **Unmanned Surface Vehicle** provided the greatest overall improvement system performance for the cost

- Dedicated **helicopter** support generated the best performance, but was the most costly alternative

Research Insights

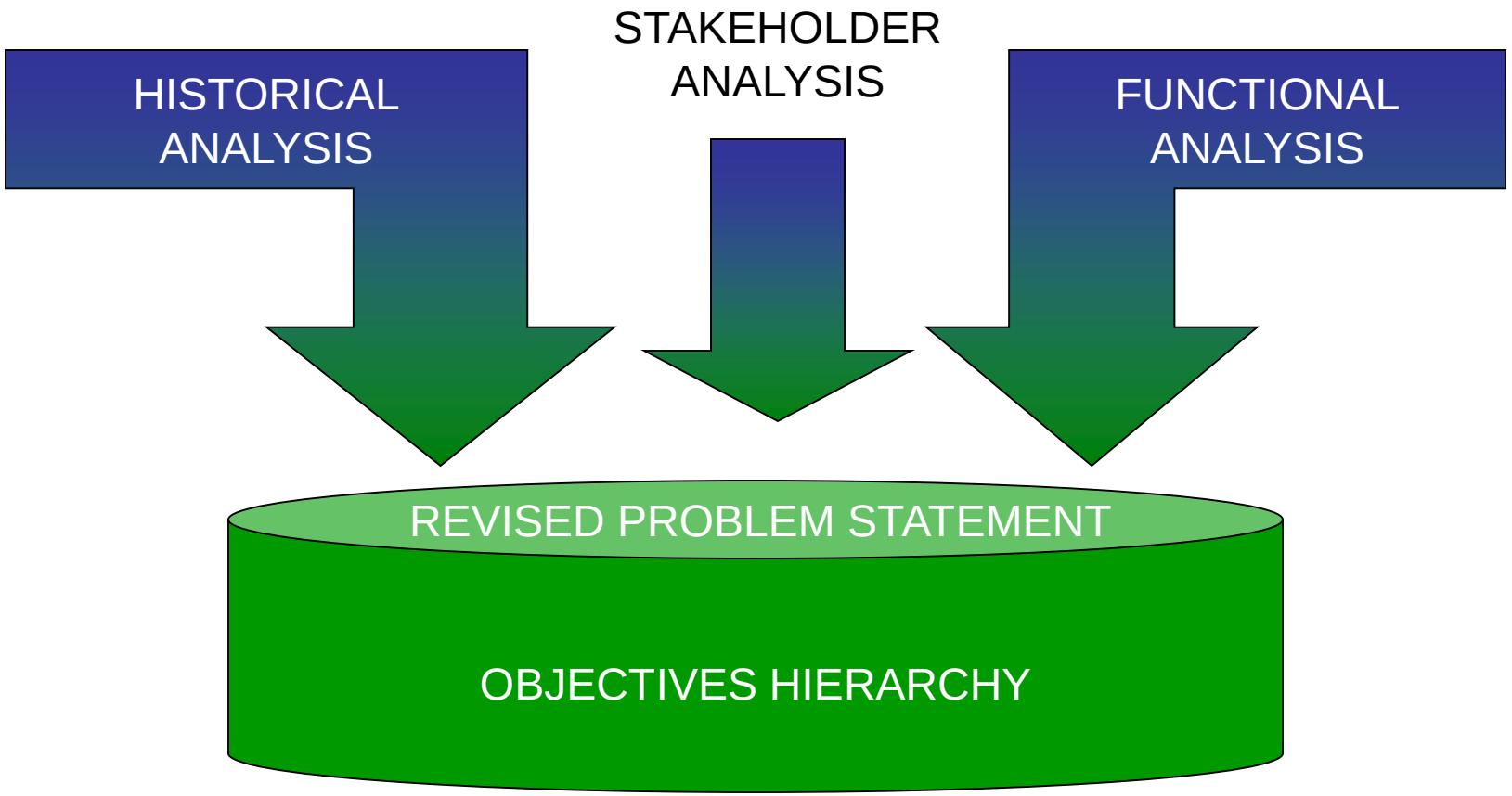
- Improved **sensor capability** had the greatest effect on overall system performance for the associated cost

- A **single unmanned sensor** enhanced baseline force performance and the networked sensor alternatives

Research Insights

- The **ground combat element** performance was scenario dependent
- **All modeled alternatives** improved battle space awareness and/or situational responsiveness over the baseline force.
- **All alternatives** are fractional cost increases to the baseline

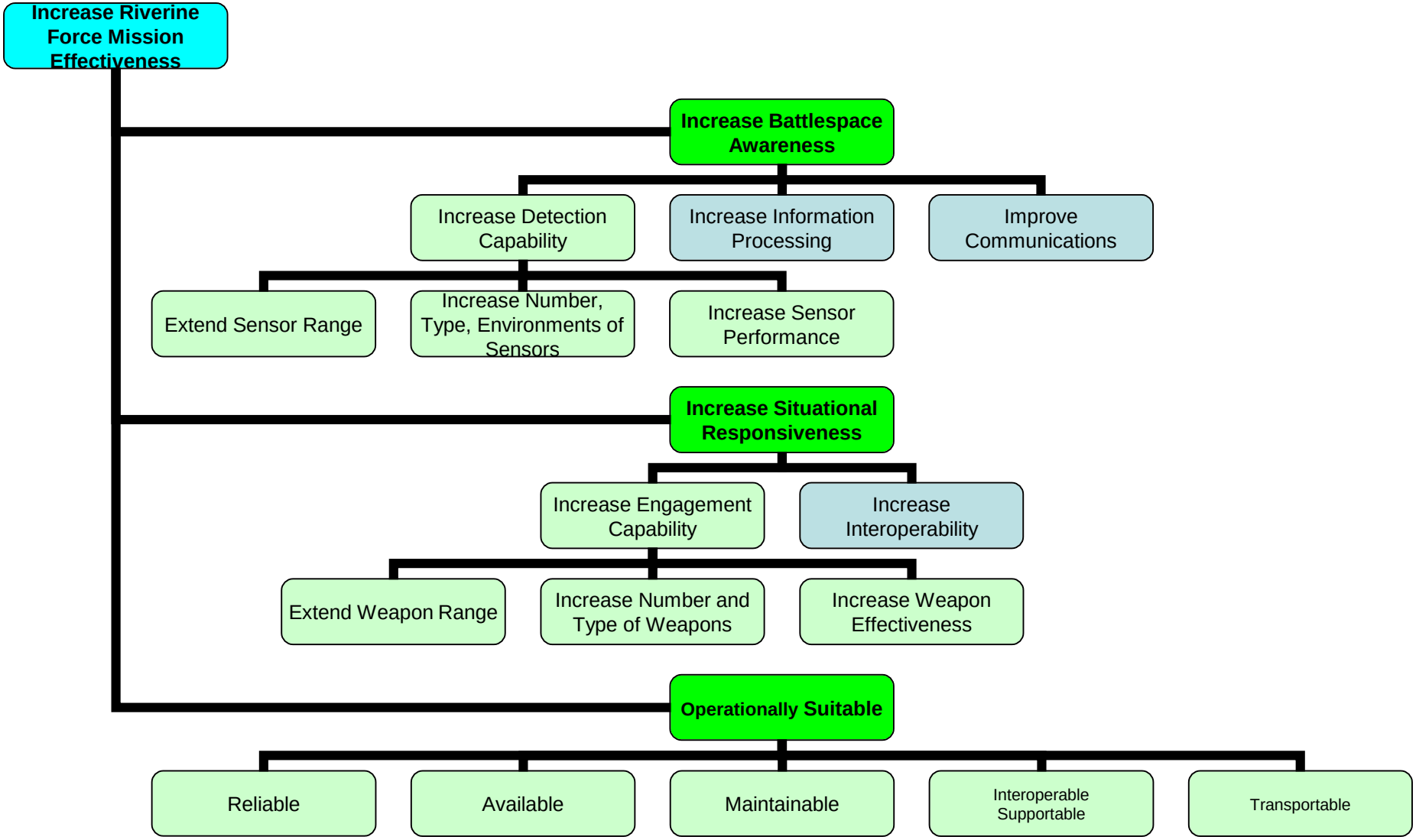
SEDP Process



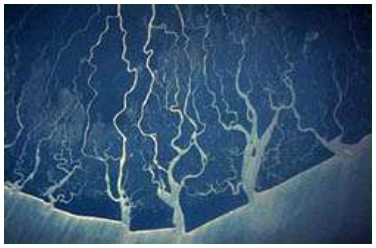
Revised Problem Statement

Define, analyze, and recommend a cost effective alternative from competing architectures that ***increases*** the US Navy's proposed riverine force's ***battle space awareness and situational responsiveness*** utilizing technologies currently in use or available for use by 2010

Objectives Hierarchy



Operational Setting



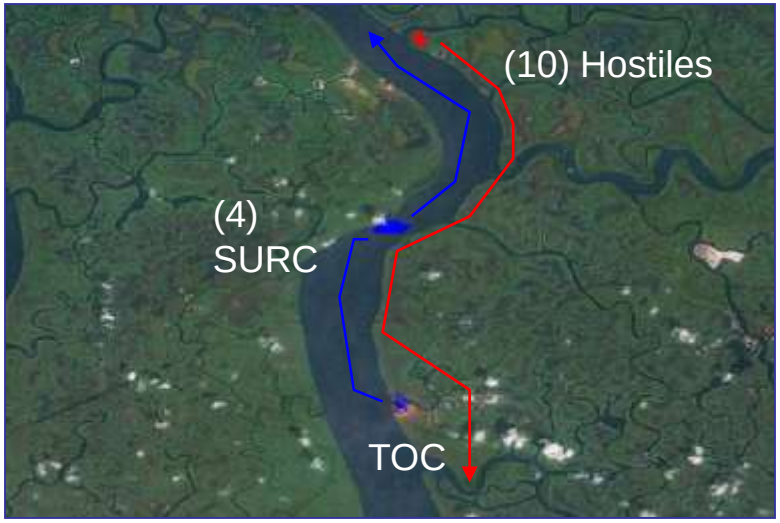

- **Niger River Delta**
  - Densely populated
  - 200,000 live in cities
  - Length: 4350 km
  - Width: 1 km to 150 meters
  - AVE LOS: up to 150 meters (can be as little as 50 meters)
  - Jungle canopy, mangroves and brackish water

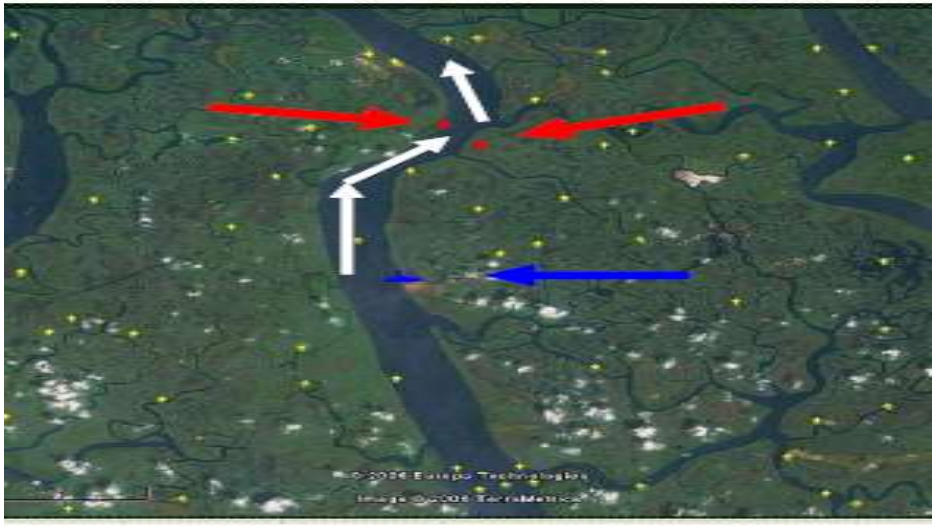
- **Red Forces**
  - Level II threat
  - Can operate at or near company strength
    - Automatic weapons
    - RPGs
    - Crew served weapons
    - Small boats
    - Technicals
  - "Networked Comms"
    - Cell phones
    - PRC-117 equivalent

Scenario and Modeling

Patrol

Level II Threat Ambush



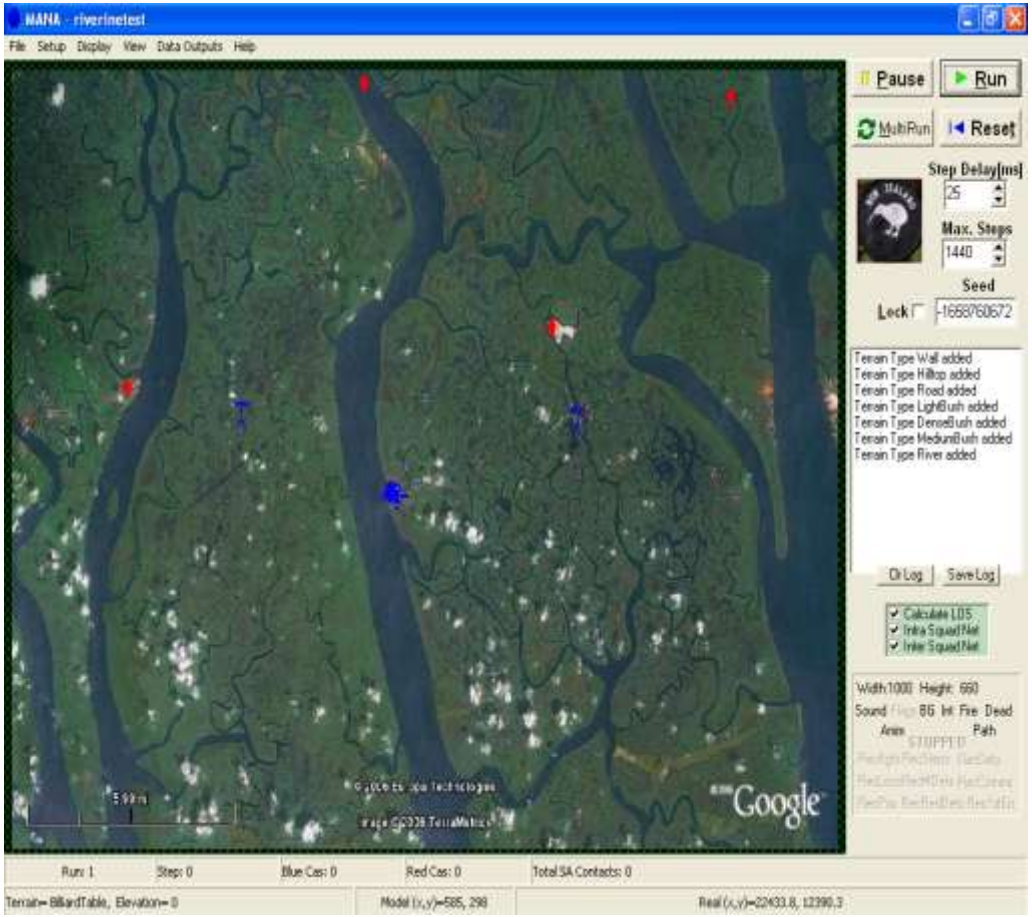


LT Rich Byers

SEA-10 Modeling

MANA

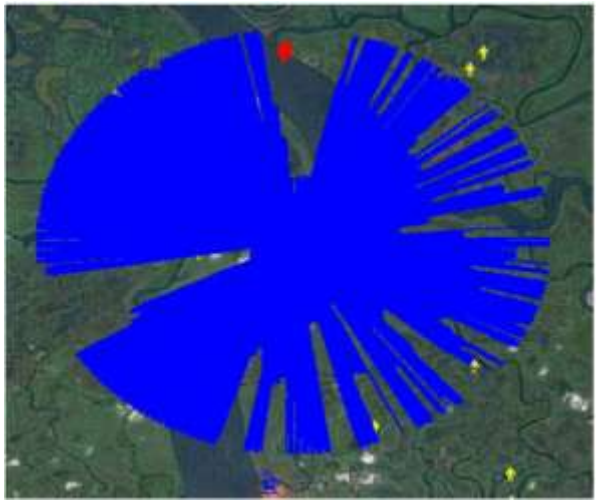
- **Map Aware**
  - agents at individual and squad level are aware of and respond to the geographic characteristics of their surroundings.
- **Non Uniform**
  - “Global” behavior of the system “emerges” as the result of many local interactions.
  - Provides feedback that is not present in top-down models.
  - Cannot be decomposed into simple independent parts.
  - Agents interact with each other in non-linear ways (Adapt)
- **Automata**
  - Scaleable
  - Iterative
  - Quantifiable



Battlefield

- Specifications
  - Real World
  - 24 x 15 mile
  - 38m/grid x 36 m/grid
  - Conversion to 8 bit palletized version

Terrain Effects



	Going	Cover	Conceal	Red	Green	Blue
BilliardTable	1.00	0.00	0.00	0	0	0
Wall	0.00	1.00	1.00	178	178	178
Hilltop	0.90	0.10	0.95	46	46	25
Road	1.00	0.00	0.00	255	255	0
LightBush	0.75	0.10	0.30	102	102	51
DenseBush	0.20	0.30	0.90	51	95	96
MediumBush	0.43	0.20	0.60	53	94	53
River	1.00	0.00	0.00	50	50	105

- RGB Table
- Cover and Concealment
- Movement Rates
- Impacts Detection Capability
  - Range to detection
  - Time to detection
- Realism

Behavior and SA

	Agent SA																	Squad SA							Inorganic SA					
AGENT and STATE	Enemies	Combat	Enemy Threat 1	EnemyThreat 2	EnemyThreat 3	Ideal Enemy	En. Class	Uninjured Friends	Injured Friends	Cluster	Neutrals	Next Waypoint	Advance	Alt. Waypoint	Easy Going	Cover	Concealment	Line Center	Enemy Threat 1	EnemyThreat 2	EnemyThreat 3	Squad Friends	Other Friends	Neutrals	Unknowns	Enemy Threat 1	EnemyThreat 2	EnemyThreat 3	Friends	Neutrals	Unknowns
TOC	100		100	75	50	100	0	100	50		0	0		0	10	100	10	0	100	75	50	100	50	0	0	75	50	15	50	0	0
SURC	100		100	75	50	100	0	0	0		0	75		0	10	10	10	10	100	100	50	30	0	0	0	100	100	50	0	0	0
VBSS	100		100	75	50	100	0	0	0		0	75		0	10	10	10	10	100	100	50	0	0	0	0	100	100	25	0	0	0
TRSS	100		0	0	0	0		0	0		0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UAV	100		100	100	100	0		0	0		0	20		0	0	0	0	0	100	100	100	0	0	0	100	100	100	100	0	0	100
USV	100		100	75	50	100	0	0	0		0	75		0	0	0	0	0	100	100	50	30	0	0	0	100	100	50	0	0	0
GCE Default	0		0	0	0	0		0	0		0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GCE Fuel Out	0		0	0	0	0		0	0		0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GCE Refuelled by Anyone	100		100	75	50	0		100	50		0	75		0	10	30	30	10	100	75	50	50	25	0	100	75	50	25	25	0	75
Mortar Team Default	0		0	0	0	0		0	0		0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mortar Team Fuel Out	0		0	0	0	0		0	0		0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mortar Team Refuelled by Anyone	100		100	75	50	0		100	50		0	0		0	10	30	30	10	100	75	50	30	0	0	0	75	50	25	25	0	100
Mortar Barge	100		100	75	50	100	0	0	0		0	75		0	10	10	10	10	100	100	50	30	0	0	0	100	100	50	0	0	0
HH-60	100		100	100	100	0		0	0		0	20		0	0	0	0	0	100	100	100	0	0	0	100	100	100	100	0	0	100
Red RifleRPG-22	100		100	75	50	100	0	100	50		0	50		0	10	30	30	10	100	75	50	25	0	0	100	75	50	25	15	0	75
Red RifleRPG-22 AMB Default	100		100	75	50	100	0	100	50		0	50		0	10	30	60	10	100	75	50	25	0	0	100	75	50	25	15	0	50
Red RifleRPG-22 AMB Squad EN Contact	100		100	100	50	100	0	100	50		0	50		0	10	30	30	10	100	100	100	50	25	0	20	75	50	25	15	0	50
Red RifleRPG-22 AMB IO SA Enemy Contact	100		100	75	50	100	0	100	50		0	50		0	10	30	30	10	100	75	50	50	25	0	100	75	50	25	15	0	50
NEUTRAL	-100		0	0	0	0		100	50		0	10		100	100	0	0	0	-100	-100	-100	0	0	0	0	-100	-100	-100	0	0	0

Weapons

Kinetic

	Meters			Grids										
Name	Min	Effective	Max	Min	Effective	Max	Shot Radius (m)	Shot Radius (grids)	Max Targets/ min	Max Targets / Step (MANA)	{High Rate of Fire / min}	Carried Rounds	Penetration (mm)	Notes
AK-47/AKM	0	300	2500	0	8	65	0	0	40	1000	600	120	0	7.62mm Assault Rifle
AK-74	0	500	800	0	13	21	0	0	40	1000	600	300	0	5.45mm Assault Rifle
RPK-74	0	800	1000	0	21	26	0	0	50	1000	600	320	0	5.45mm Light Machine Gun
SVD	0	1300	3800	0	34	99	0	0	30	1000	30	40	10	7.62mm Sniper Rifle
PKM	0	1000	3800	0	26	99	0	0	250	1000	650	600	8	7.62mm GPM
NSV	0	2000	7850	0	52	205	0	0	100	1000	680	300	20	12.7mm Heavy Machine Gun
M-16A2/A3	0	550	3600	0	14	94	0	0	45	1000	800	1250	0	7.62mm Assault Rifle
M240B	0	800	3725	0	21	97	0	0	100	1000	200	1200	0	7.62mm Heavy Machine Gun
M249	0	1000	3600	0	26	94	0	0	100	1000	750	1000	0	5.56mm Heavy Machine Gun
M60	0	800	3725	0	21	97	0	0	100	1000	550	900	8	7.62mm Heavy Machine Gun
GAU-17/A	0	400	1000	0	10	26	0	0	2000	1000	4000	5000	0	7.62mm Mini Gun
M2	0	2400	6770	0	63	177	0	0	200	1000	550	600	11	12.7mm .50 cal Machine Gun

High Explosive

	Meters			Grids										
Name	Min	Effective	Max	Min	Effective	Max	Shot Radius (m)	Shot Radius (grids)	Max Targets/ min	Max Targets / Step (MANA)	{High Rate of Fire / min}	Carried Rounds	Penetration (mm)	Notes
RPG-7	0	500	800	0	13	21	5	0	6	600	6	5	330	40mm ATGL
RPG-22	0	150	250	0	4	7	5	0	1	100	1	1	390	72mm Disposable ATGL
SA-16	600	3500	5000	16	91	131	5	0	1	100	1	2	0	Manportable SAM
82mm Mortar	1000	4000	4000	26	104	104	15	0	4	400	65	10	0	40mm ATGL
GP-30	40	400	400	1	10	10	6	0	4	400	5	10	0	40mm Grenade Launcher
M203	31	350	400	1	9	10	5	0	5	500	7	36	330	40mm Grenade Launcher
M-72	10	200	1000	0	5	26	5	0	1	100	1	1	300	66mm Disposable ATGL
M224	44	1930	1930	1	50	50	4	0	8	800	30	20	0	62mm Mortar
M252	83	5608	5608	2	146	146	40	1	15	1000	30	60	0	82mm Mortar
AGM-114K	500		8000	13		209	10	0	4	4	4	4	500	Hellfire Missile
MK19	18	1500	2550	0	39	67	15	0	40	1000	60	164	51	40mm Grenade MG

Process

- **Mana Processes:**
  1. Situational awareness maps are updated by squad number.
  2. Randomly selected Agents (one turn per time step) carry out the following tasks:
     a. Detection and Communication Prep
     b. Weapons Engagement
     c. Refuel
     d. Movement
  3. Each squad is selected once in random order to process its communications queues.
  4. Simulation Halted upon 1440 Time steps or termination of opposition

Limitations

- Movement
  - MANA limits velocity ratio to 1000 grids per 100 time steps
    - Modern vehicles exceed this by a factor of 100
    - Limits all vehicles to 22 kph
- Disembarking Forces
  - Transportation load/unload unavailable
  - Simulated via prestaging and refueling

Limitations

- Erratic USV/UAV Movement
  - USV / UAV would follow erratic search patterns based upon behavior
  - Given Patrol waypoints to simulate operator control
- SURC Damage Mitigation
  - Cannot model cover provided by vessel
  - Increased SURC Hits to Kill
    - models cover afforded
    - models Vessel Durability

$$7 \text{ crew } (.60 \text{ armor}) + 7 \text{ crew (total)} = 11 \text{ Hits to Kill}$$

Limitations

- Geography
  - Mana can model elevation but not water depth
    - Mobility of platforms was not limited by water depth
  - Terrain on billiard table
- Agents
  - Swarm behavior
    - Attack focused vice maneuver

Clutter

- Military forces do not operate in a vacuum
- Large civilian population may yield;
  - False Targets
  - Distraction
  - Limits Engagement
- Neutral population assigned by taking mean of MFMD against Total Population of the region
- 8 Neutrals for every red agent

Country	Total Population	Men Fit For Military Duty	Ratio
Ghana	22409572	3011081	7.44:1
Togo	5548702	696933	7.96:1
Benin	7862944	749774	10.48:1
Nigeria	131859731	15052914	8.75:1
Cameroon	17340702	1946767	8.90:1
		Mean	8.7:1
		Reduced Mean	8:1

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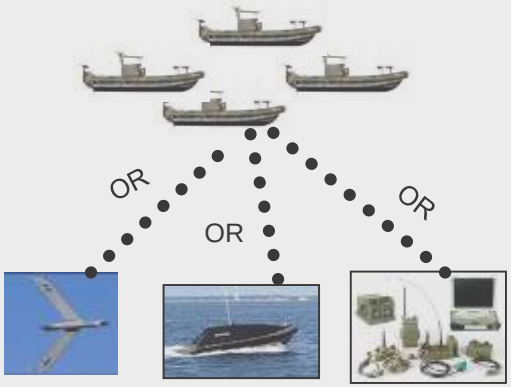

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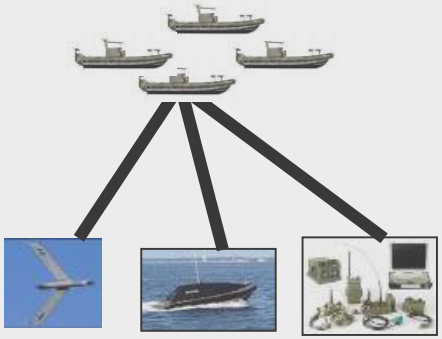

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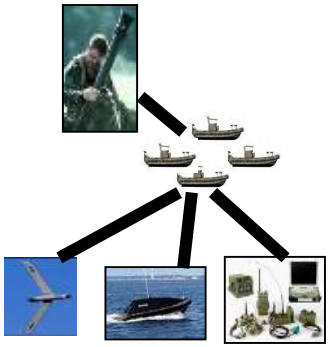

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81mm Mortar

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ALT 5: Baseline + Dedicated Helo Support

(4) Helicopter detachment

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LT Jen Free

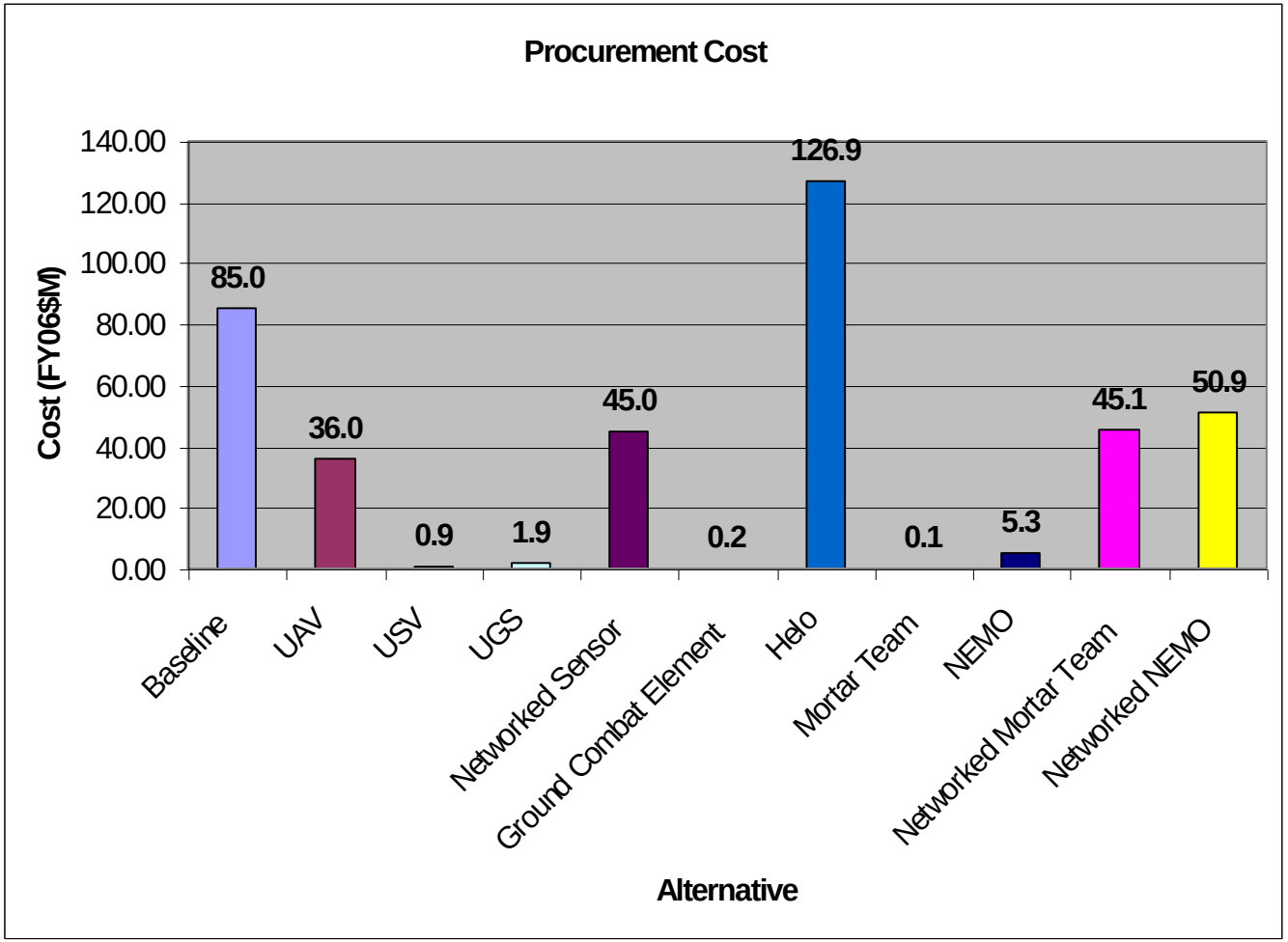
Cost Estimation

Cost Estimation Caveats

- All cost data obtained from open source
- All costs in FY06$
- Cost estimation data is provided for comparison of alternatives
- Determining military significance is the goal

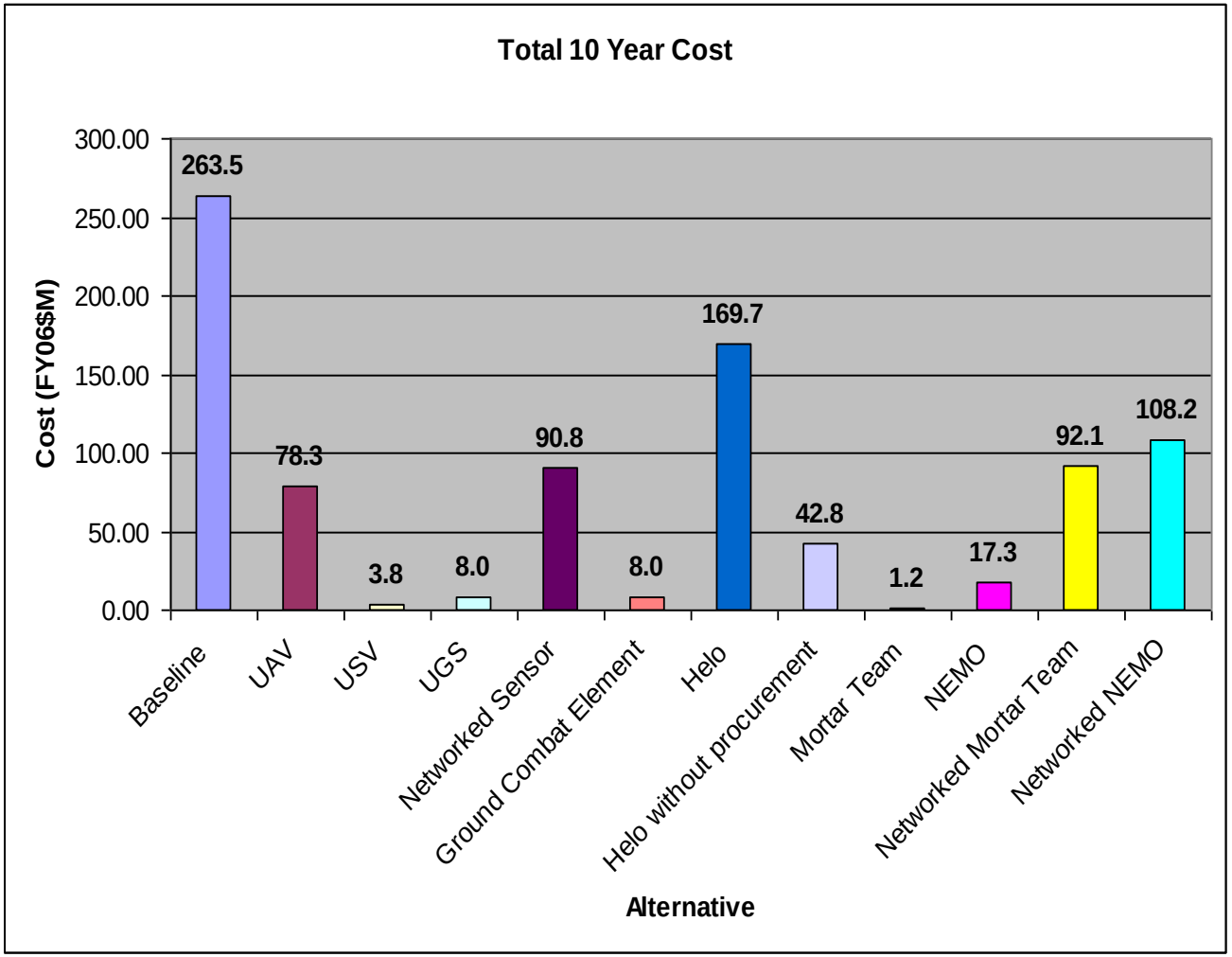
Procurement Cost Summary

- Procure all capabilities in 2010
- Personnel not included in procurement costs



Total 10 Year Cost

- Includes procurement and O&S cost
- All alternatives are marginal to baseline



Cost Estimation Summary

Alternative	Description	Average Operating Cost per Year (FY06$M)	Procurement Cost (FY06$M)	Total 10 Year Cost (FY06$M)
	Baseline	16.31	85.00	263.54
I	UAV	3.90	36.00	78.32
	USV	0.26	0.90	3.77
	UGS	0.38	1.90	7.96
II	Ground Combat Element	0.74	0.19	8.03
III	Networked Sensor	4.58	45.01	90.85
IV	Mortar Team	0.10	0.09	1.20
V	Networked Mortar Team	4.69	45.10	92.05
VI	NEMO	1.15	5.33	17.31
VII	Networked NEMO	5.73	50.87	108.16
VII	Helicopter	3.89	126.90	169.71
	Helicopter without procurement	N/A	N/A	42.81

LCDR Jim Beaver

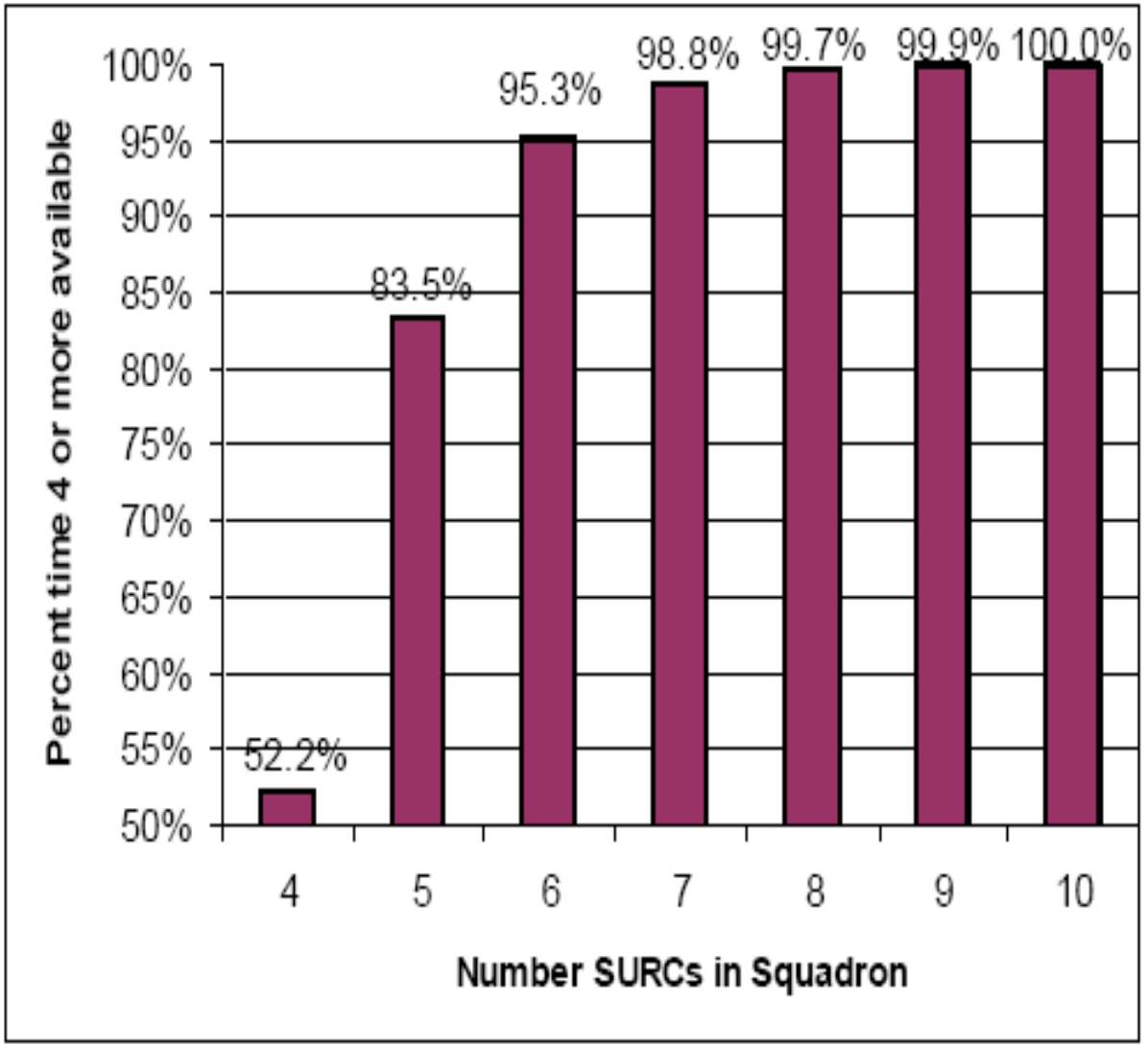
Reliability

System Reliability

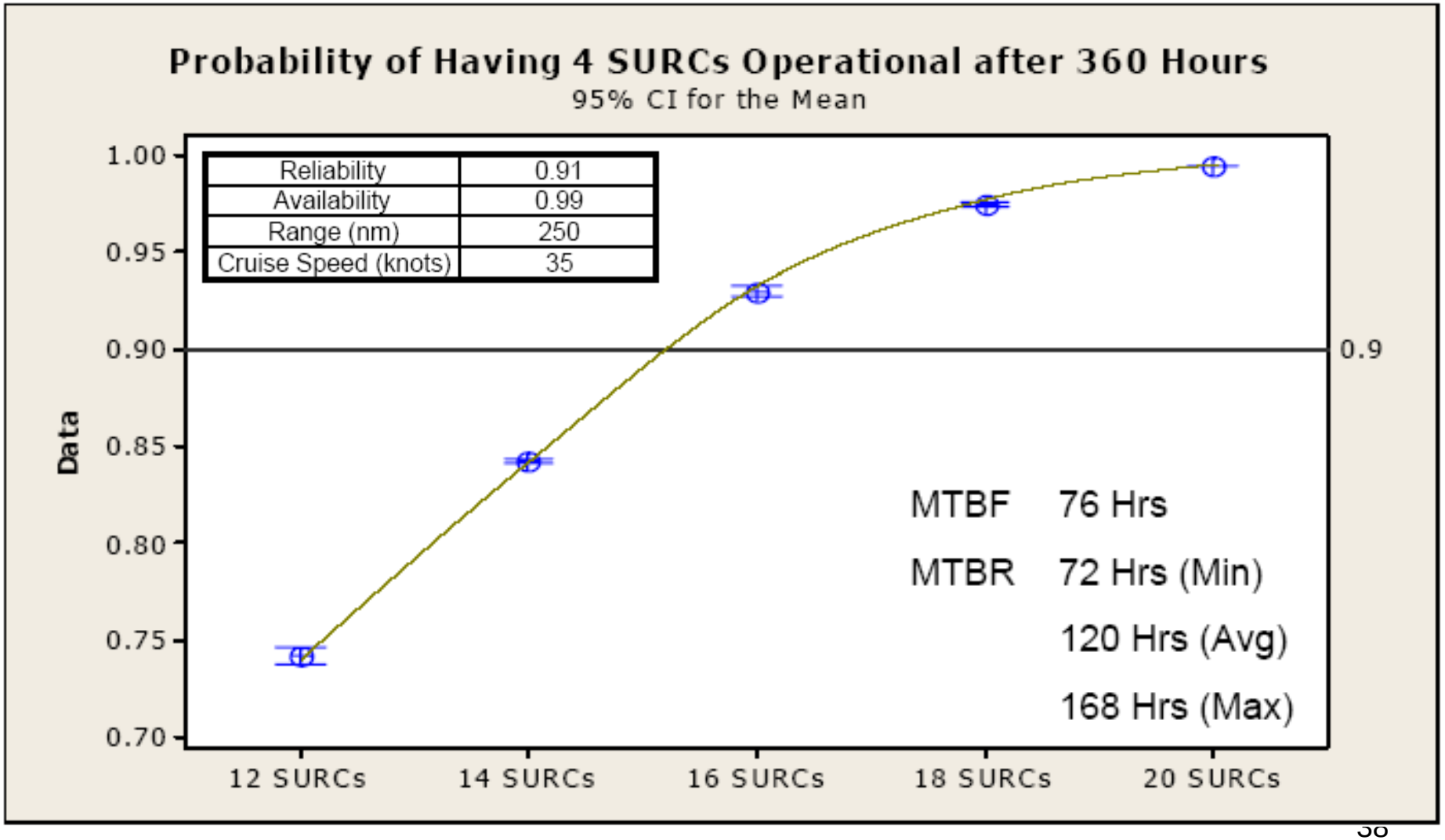
- SEA-10 analyzed <u>operational suitability component</u> reliability of the networked system to help make a cost-benefit determination.
- Critical to support of combat and operational readiness.

Availability and Readiness

- To demonstrate the connection between availability and readiness consider the following:
  - Assume SURC availability is 0.85 or 85%.
  - 4 SURCs are required to begin a mission.
- As the number of SURCs in a squadron is increased, the probability of having 4 or more SURCs available for the mission is increased.



Modified SEA 9 SARM



Reliability Conclusions and Limitations

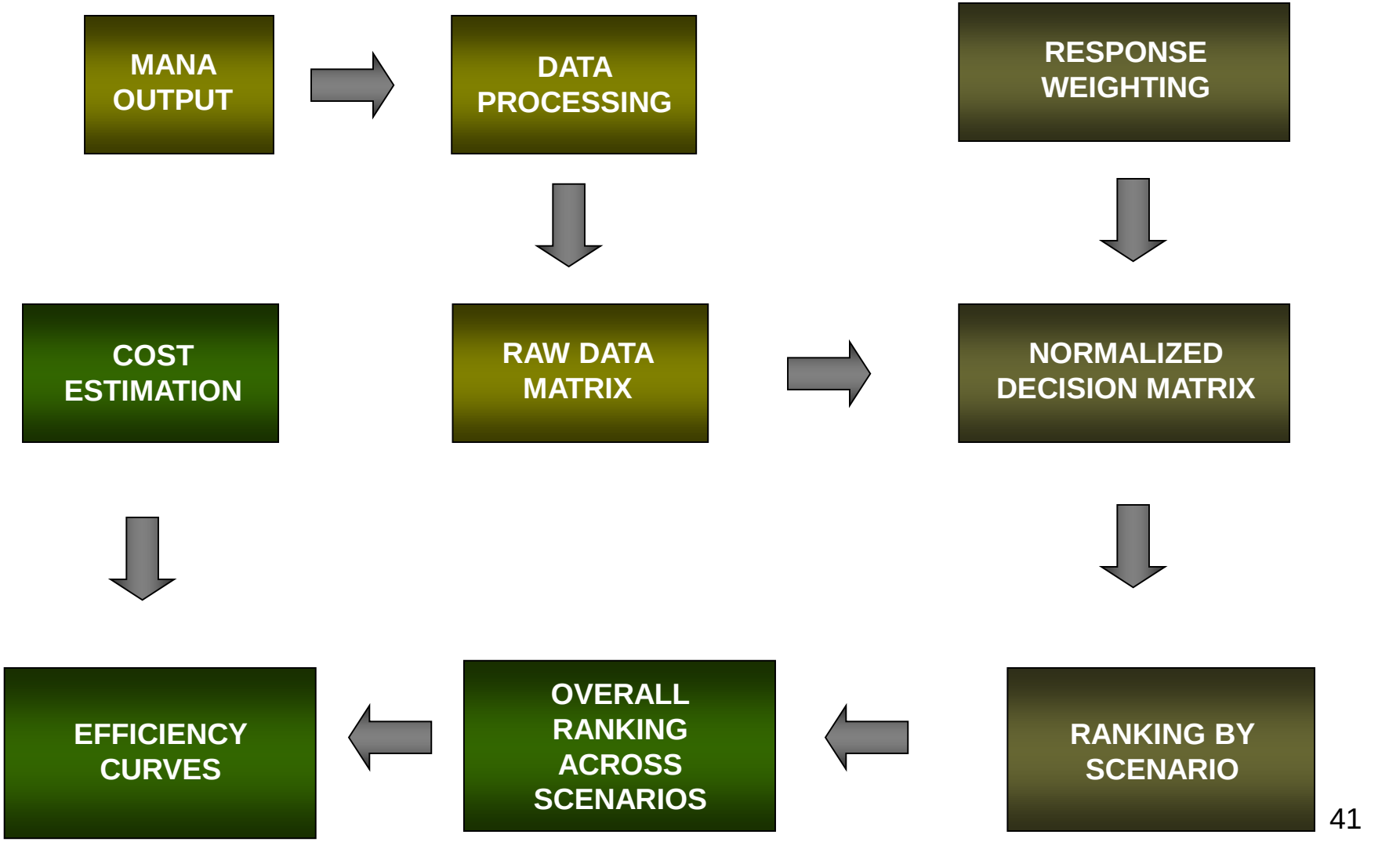
- Unmanned systems MUST have redundancy to augment any low individual component reliability.

- Models for SURC reliability/availability show platform highly reliable, but more hulls needed for extended operations.

LCDR Pedro Mercado

Data Analysis

DATA ANALYSIS PROCESS



MOP Evolution

Increase Battlespace Awareness

Increase Situational Responsiveness

ORIGINAL

Time of Detection
Range of Detection
Proportion of Enemy Detection

Range at Engagement
Length of Engagement
Loss Exchange Ratio

REVISED

Time of Detection
Range of Detection
Detect to Engage Time

% NO HIT / Loss Exchange Ratio
Length of Engagement

MOP Limitations

- Detect to engage time did not fairly represent the battle space awareness gained by the helicopter and networked mortar barge alternatives
- Length of engagement was affected by scenario and modeling limitations
- Detection Range was not a valid indicator of sensor performance and could not be used as a measure of performance

Raw Data Matrix

PATROL						
MOP Alternative	PERCENT OF NO HIT RUNS	LOSS EXCHANGE RATIO (RED/BLUE)	LENGTH OF ENGAGEMENT (IN MIN)	MAX CLASSIFICATION RANGE (GRIDS)	EARLIEST DETECTION TIME (IN MIN)	TIME OF FIRST DETECTION TO FIRST ENGAGEMENT (IN MIN)
Baseline	3%	8.9	3.5	19.6	56.8	0.0
UAV	0%	12.1	21.5	17.9	26.0	20.0
USV	3%	9.6	22.2	126.3	23.8	18.4
UGS	0%	9.9	16.1	17.9	25.3	24.4
UAV+USV+UGS	0%	11.1	10.6	125.7	21.5	23.9
GCE	13%	10.7	4.3	19.9	50.6	0.0
HH60	97%	7.7	9.2	154.8	21.1	0.0
MORTAR TM	3%	8.4	2.2	19.3	41.1	0.0
MORTAR BARGE	7%	8.9	3.5	19.4	56.2	-0.2
NW MORTAR TM	3%	11.4	30.1	123.3	15.5	26.7
NW MORTAR BARGE	87%	11.8	12.7	123.1	23.6	1.9

Data Normalization

Responses where high values were desirable:

$$\left(\frac{AlternativeData - MinDataValue}{MaxDataValue - MinDataValue}\right) \bullet 100$$

Responses where low values were desirable:

$$\left(\frac{MaxDataValue - AlternativeData}{MaxDataValue - MinDataValue}\right) \bullet 100$$

Combining Percentage of no hit runs and Loss Exchange ratio to a single value:

$$(.75) \bullet \left[(PercentageOfNohitRuns) \bullet 100\right] + (.25) \bullet \left[\left(\frac{AlternativeData - MinDataValue}{MaxDataValue - MinDataValue}\right) \bullet 100\right]$$

Decision Matrix

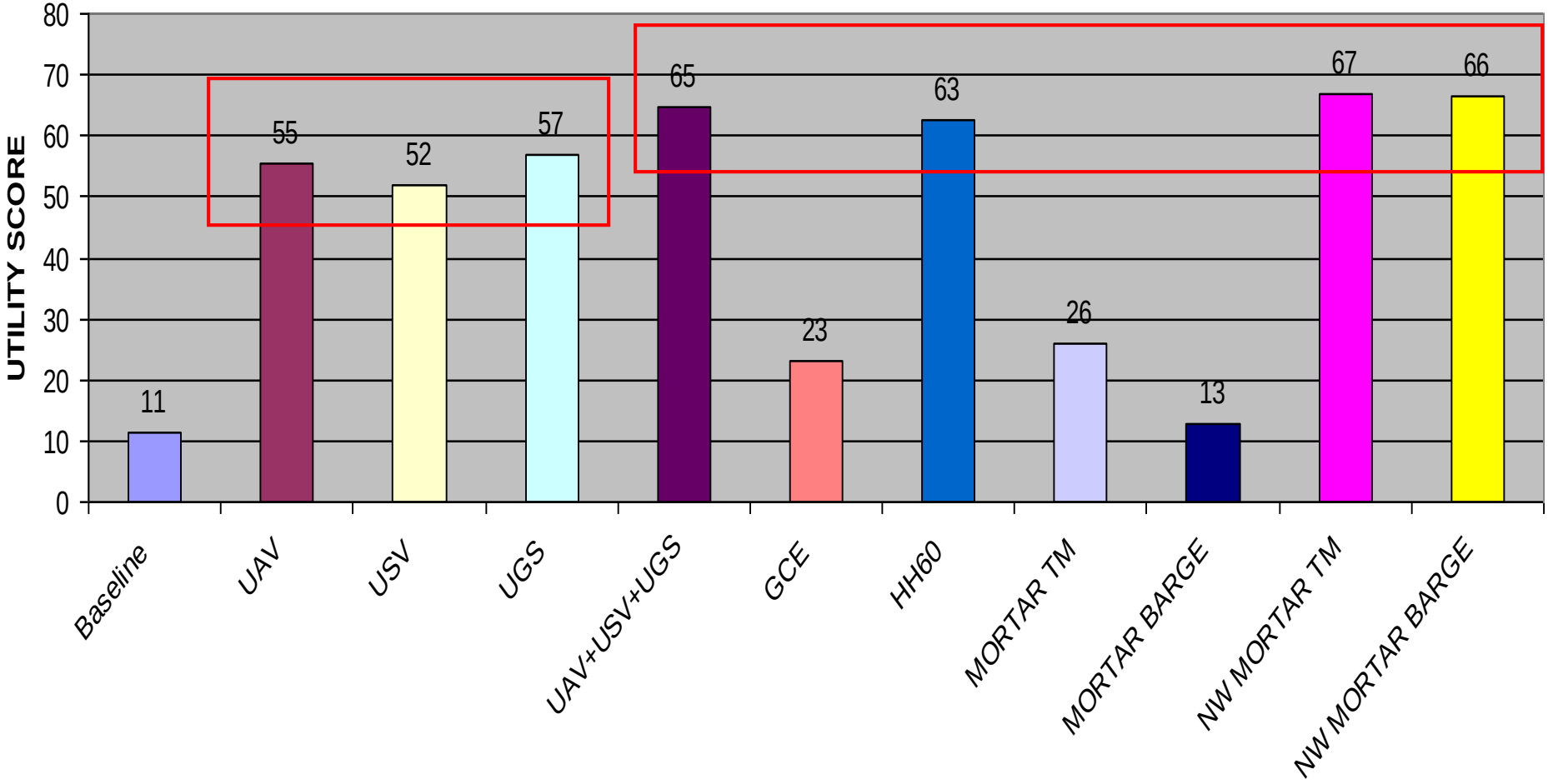
Weighting of measures of performance were determined from interviews with

- NPS small boat operators
- Marine officers with riverine and combat experience

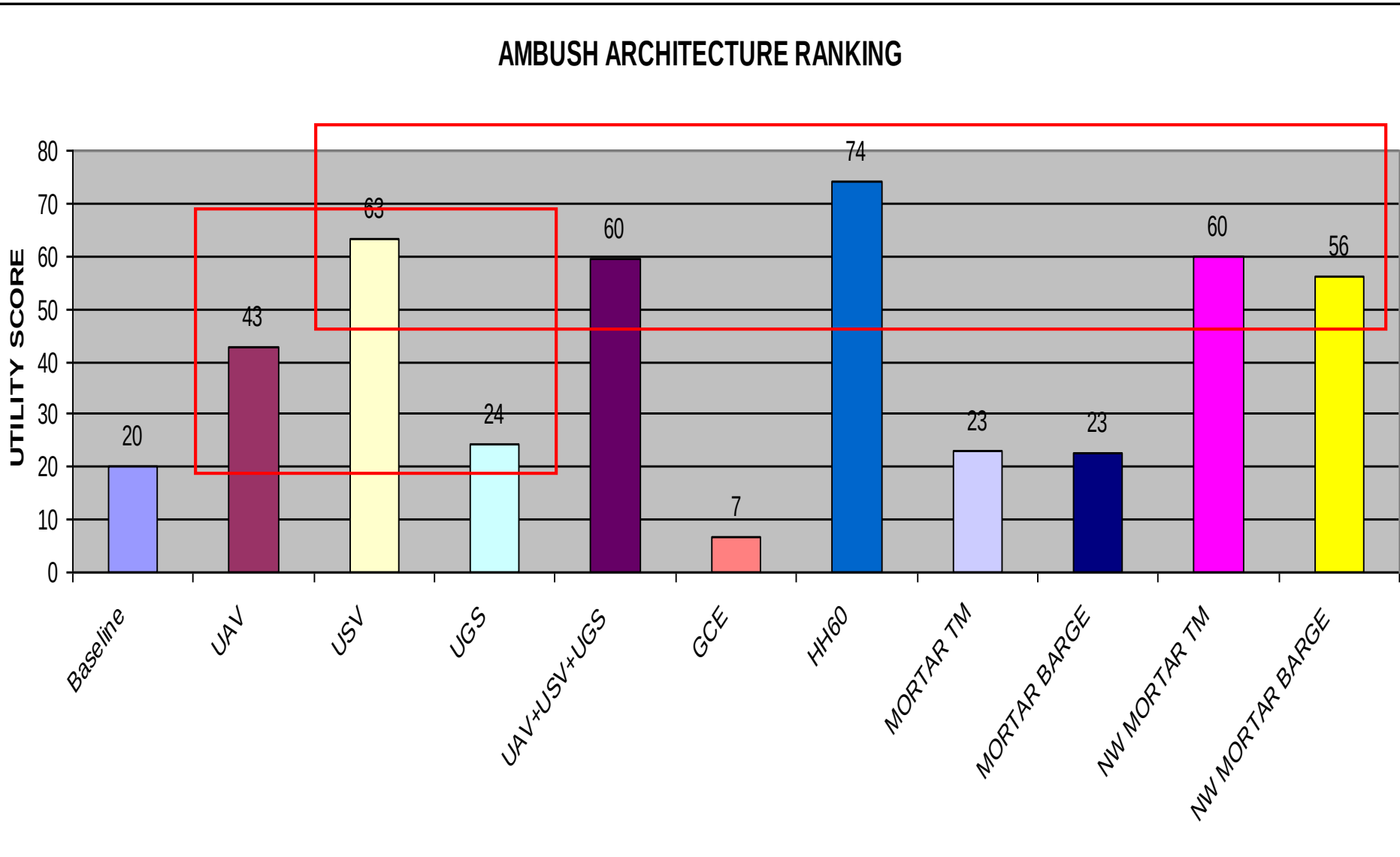
Detailed Sensitivity Analysis conducted in thesis on MOP weighting

	Alternative	Baseline	UAV	USV	UGS	NET	GCE	HH60	MORTAR TM	MORTAR BARGE	NW MORTAR TM	NW MORTAR BARGE
0.3	Percentage of no hit runs/Loss	3	21	8	7	10	18	76	2	5	12	62
0.1	Length of Engagement	88	15	47	67	67	63	68	100	96	38	68
0.4	Time to first enemy detection	15	67	84	55	86	8	93	34	16	94	84
0.2	Time from detection to Engagement	0	72	85	49	88	1	7	1	1	93	11
	WEIGHTED TOTAL	16	49	58	41	62	15	68	25	18	63	61

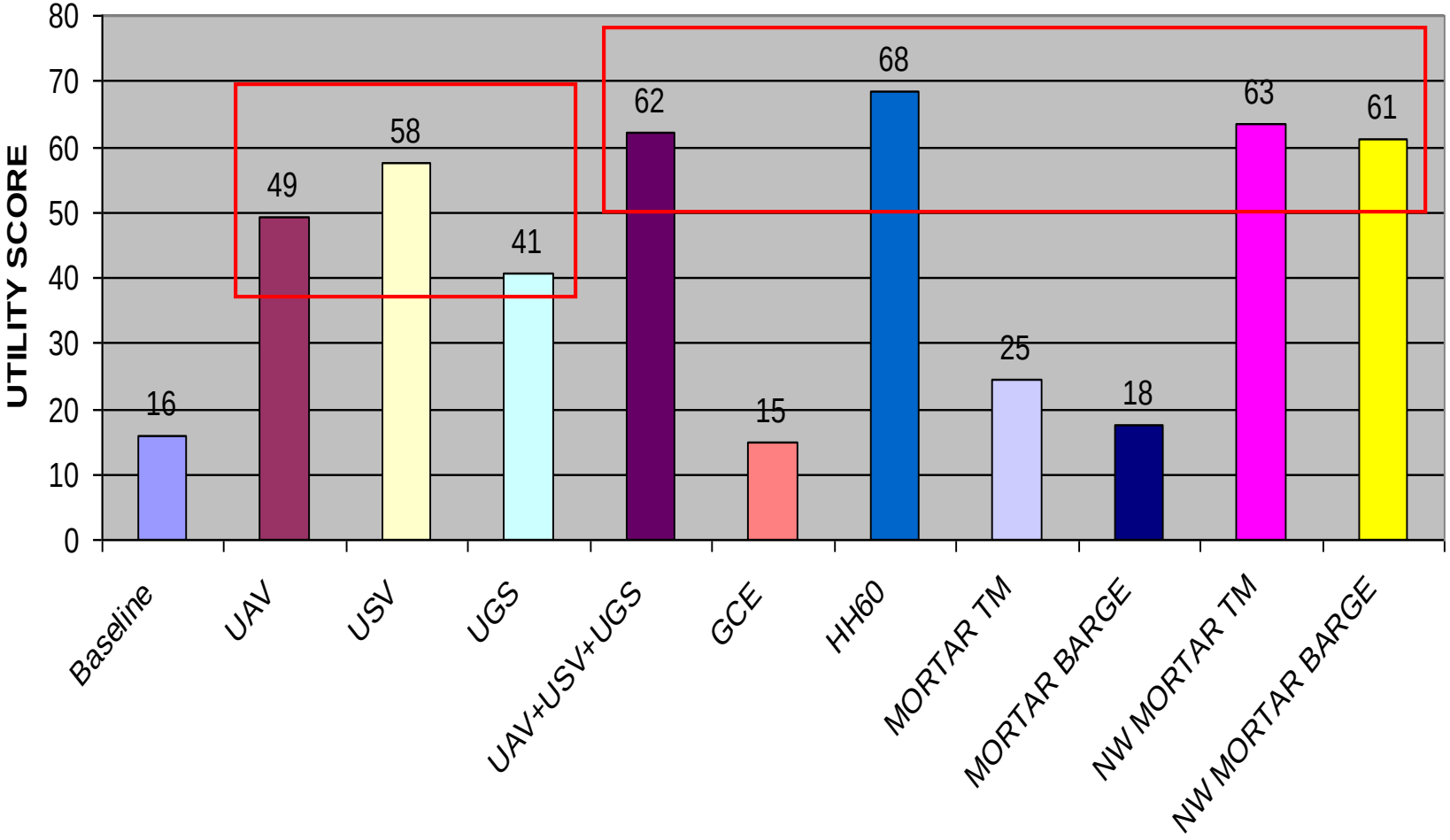
Architecture Ranking Patrol



Architecture Ranking Ambush



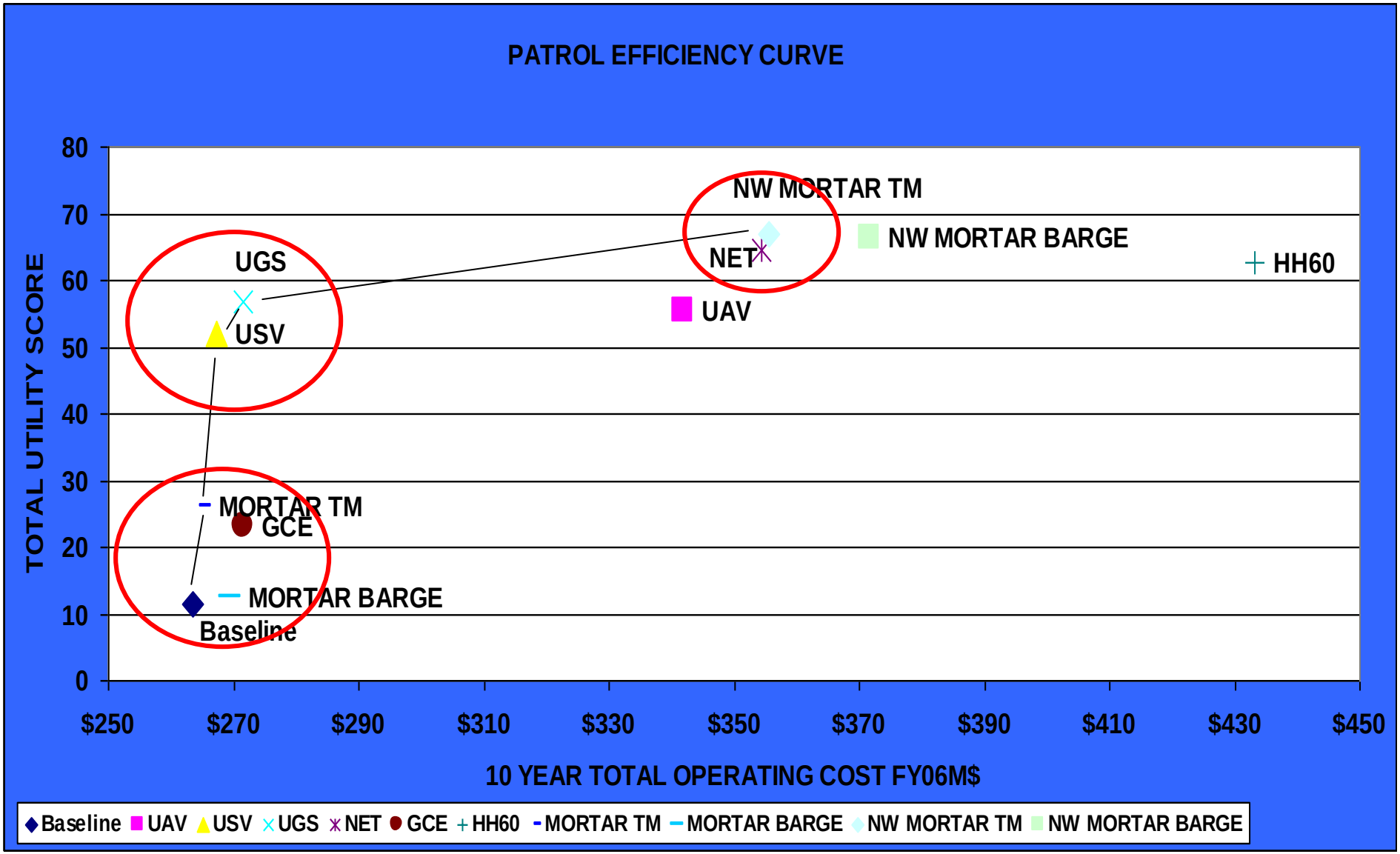
Overall Architecture Ranking



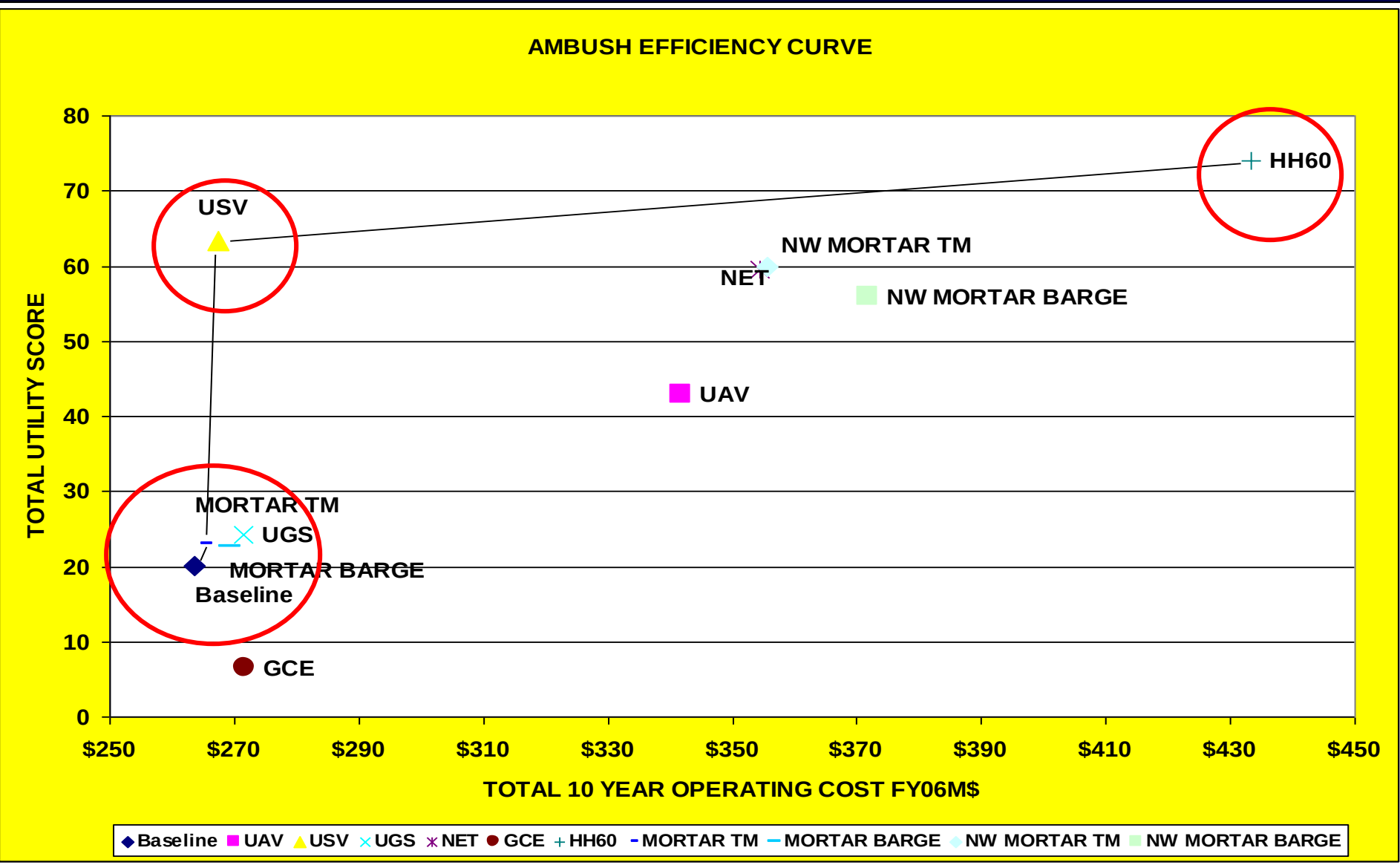
Cost Estimation Summary

Alternative	Description	Average Operating Cost per Year (FY06$M)	Procurement Cost (FY06$M)	Total 10 Year Cost (FY06$M)
	Baseline	16.31	85.00	263.54
I	UAV	3.90	36.00	78.32
	USV	0.26	0.90	3.77
	UGS	0.38	1.90	7.96
II	Ground Combat Element	0.74	0.19	8.03
III	Networked Sensor	4.58	45.01	90.85
IV	Mortar Team	0.10	0.09	1.20
V	Networked Mortar Team	4.69	45.10	92.05
VI	NEMO	1.15	5.33	17.31
VII	Networked NEMO	5.73	50.87	108.16
VII	Helicopter	3.89	126.90	169.71
	Helicopter without procurement	N/A	N/A	42.81

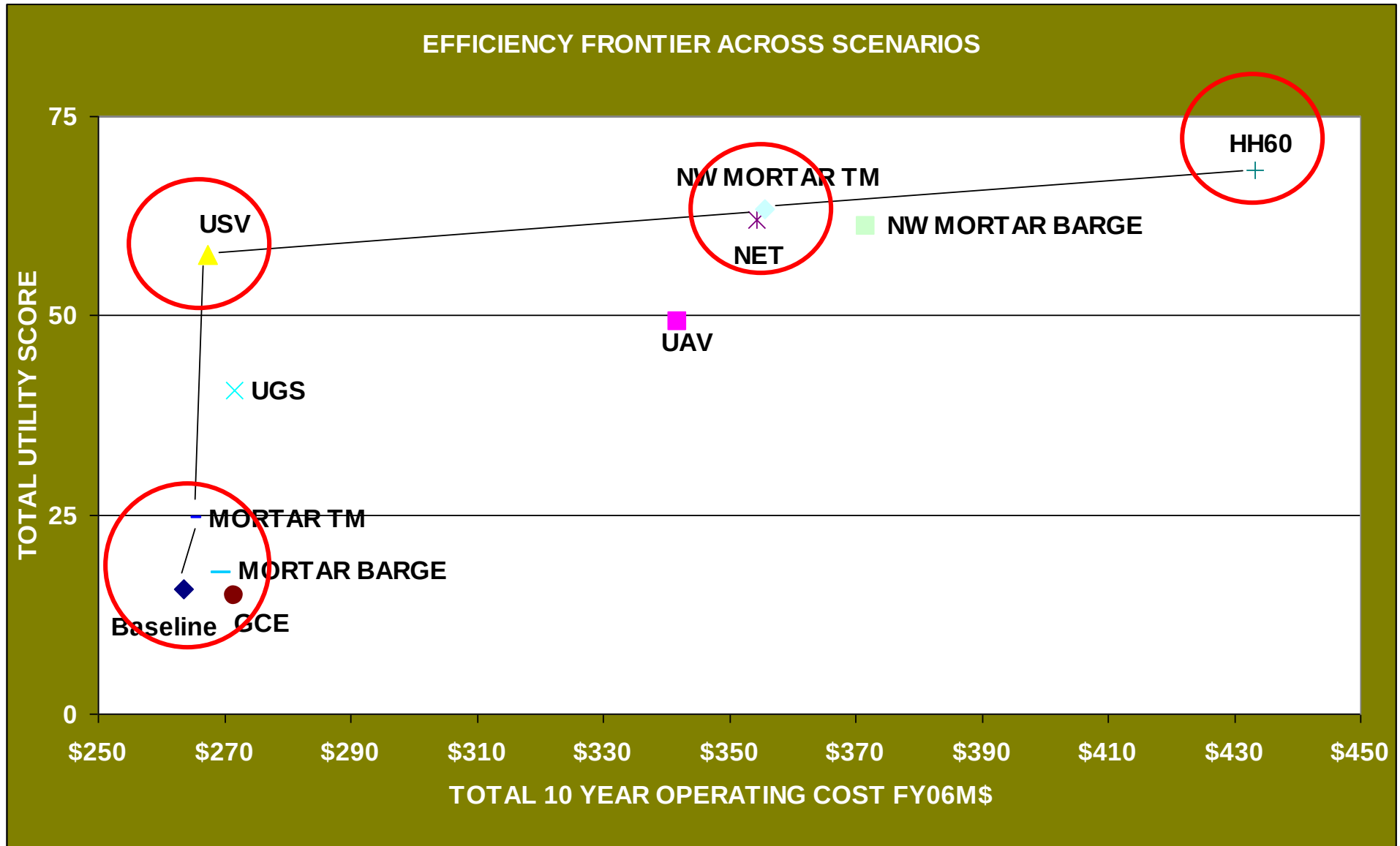
Patrol Efficiency Curve



Ambush Efficiency Curve



Overall Efficiency Curve



Results

- “Most bang for the buck”
  - USV
- Alternatives
  - HH-60 and Networked NEMO best overall
- Unmanned systems
  - Single is as good as networked
- Organic indirect fires
  - Effective only when paired with sensors
- Ground combat element
  - Scenario dependent performance
- Dedicated helicopter support
  - Best performance/highest cost

Other Findings

- The baseline force occasionally achieves parity in performance with upgraded alternatives depending on the response and scenario.
- A single sensor gives the baseline force almost all the benefits of networked sensors.
- In the ambush scenario, upgraded weapons have a significant effect in reducing the length of engagement.
- The combined indirect fire and sensor pairing of the networked mortar barge and the helicopter option dominated all other options across all responses except detect to engage time (only because of model dynamics described previously).

Results

- Consider Unmanned Surface Vehicle as a system that shows potential to improve RF battle space awareness
- Invest in paired sensor and weapon augmentations for the greatest increase in performance
- A helicopter or networked sensor plus indirect fire option consistently outperforms other alternatives

Areas for Further Study

- Sustainment/Logistics
- Communications
- Modeling and Simulation
- Energy
- Movement
- Force Protection
- Mine Countermeasure
- Policy

Softballs for SEA-11

- Sustainment/logistics
- Columbia riverine science symposium
  - MIT infrared study
  - China Lake infrared working group
- USV automation
- Unmanned system reliability analysis

Key Source Documents

- Buede, D.M. *The Engineering Design of Systems: Models and Methods*, John Wiley & Sons, Inc., 2000.
- Naval Expeditionary Combat Command, *Concept of Operations - US Navy Riverine Force (DRAFT)*, 30 August 2006, Naval Amphibious Base, Little Creek, VA.
- US Marine Corps Center for Lessons Learned: Small Craft Company's Deployment in Support of Operation Iraqi Freedom II (OIF II) by Colonel M.E. Dunard, 4 April 2006.
- Others.


SEA X
Riverine 2010

BACKUP