"SYSTEMS ENGINEERING APPLICATIONS IN NAVSEA-CARDEROCK'S INNOVATION CENTER"

Presentation to Naval Postgraduate School

Systems Engineering & Analysis Program

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(Code 011)

Outline

- ***I*nnovation Center Overview**
- **Systems Engineering Application Philosophy**
- **Example of Application in “Surface Combatant Optimized for Unmanned Vehicle Operations (SCOUVO)”**
- **Summary**
- **Discussion**

The Innovation Center Defined

- **"Innovation" = Creativity + Implementation**

- **NAVSEA-Carderock *I*nnovation Center Charter:**

  "Provide a mechanism to have 3-to-6-member, full-time, multi-disciplined, dedicated teams investigate high risk/high payoff solutions to Navy engineering and R&D challenges or problems and perform accelerated exploration of new ideas"

Innovation Center Project Record (24)

1. Unmanned Underwater Vehicle (UUV) [‘89]
2. Semi-Submerged Surface Ship [’89]
3. “Tipjet” Vertical Launch & Recovery (VLAR) Sensor Platform [‘89]
4. Quiet Surface Ship Propulsor/Hull Concepts [’90]
5. Automated Ship Hull Husbandry Vehicle [‘91]
6. Advanced Submarine Stern Cluster [’92]
7. Advanced Submarine Sail Cluster [’92]
8. 21st Century Destroyer Technology Drivers [‘92]
9. System Technology Assessment Resource (“STAR”) [’93]
10. “Autonomic” Ship [‘93]
11. Maritime Pre-positioning & Sustainment Ship System [’94]
12. Dual Use and Commercialization of Technologies(“DUCT”) [’94]
13. Small Combatant [’95]
14. Littoral Warfare Fire Support Ship & Reduced Manning [’95]
15. Concurrent Engineering of Layered Systems (“CELS”) [’96]
16. Leading Edge Advanced Prototyping for Ships (“LEAPS”) [’96]
17. Integrated Hull & Deck Topside Design (“DeckOps 2020”) [’97]
18. Low Signature Options for Future Submarines (CLASSIFIED) [’98]
19. Low Maintenance Surface Ships [’98]
20. “Carrier Islands” [’99]
21. Project “Blackjack” (Mobile Forward Expeditionary Operating Base/Craft) [’00]
22. Unmanned Surface Vehicle [’01]
23. Advanced Logistics Delivery System (ALDS) [’02]
24. Surface Combatant Optimized for Unmanned Vehicle Operations (SCOUVO) [’03]

AHMV Field Test on USS CAPE ST GEORGE

Systems Engineering Application Philosophy

- **"Defining the Problem" = Team Restatement of Initial Charter absolutely vital first step ("Requirements Definition")**
- **Must establish valid & measurable (within project time & resource constraints) metrics**
- **"Divergence/Convergence" fundamental to IC Process**
- **"Brainstorming" key tool in Divergence Phase**
- **After convergence to most promising alternatives, standard systems engineering process applied**

"CV Islands" Project - Finalized Charter and Evolution

Final: **Develop and Assess Integrated Aircraft Carrier Island Concepts and Corresponding Implementation Plans Capable of Significantly Advancing Naval Warfare at Reduced Total Ownership Cost**

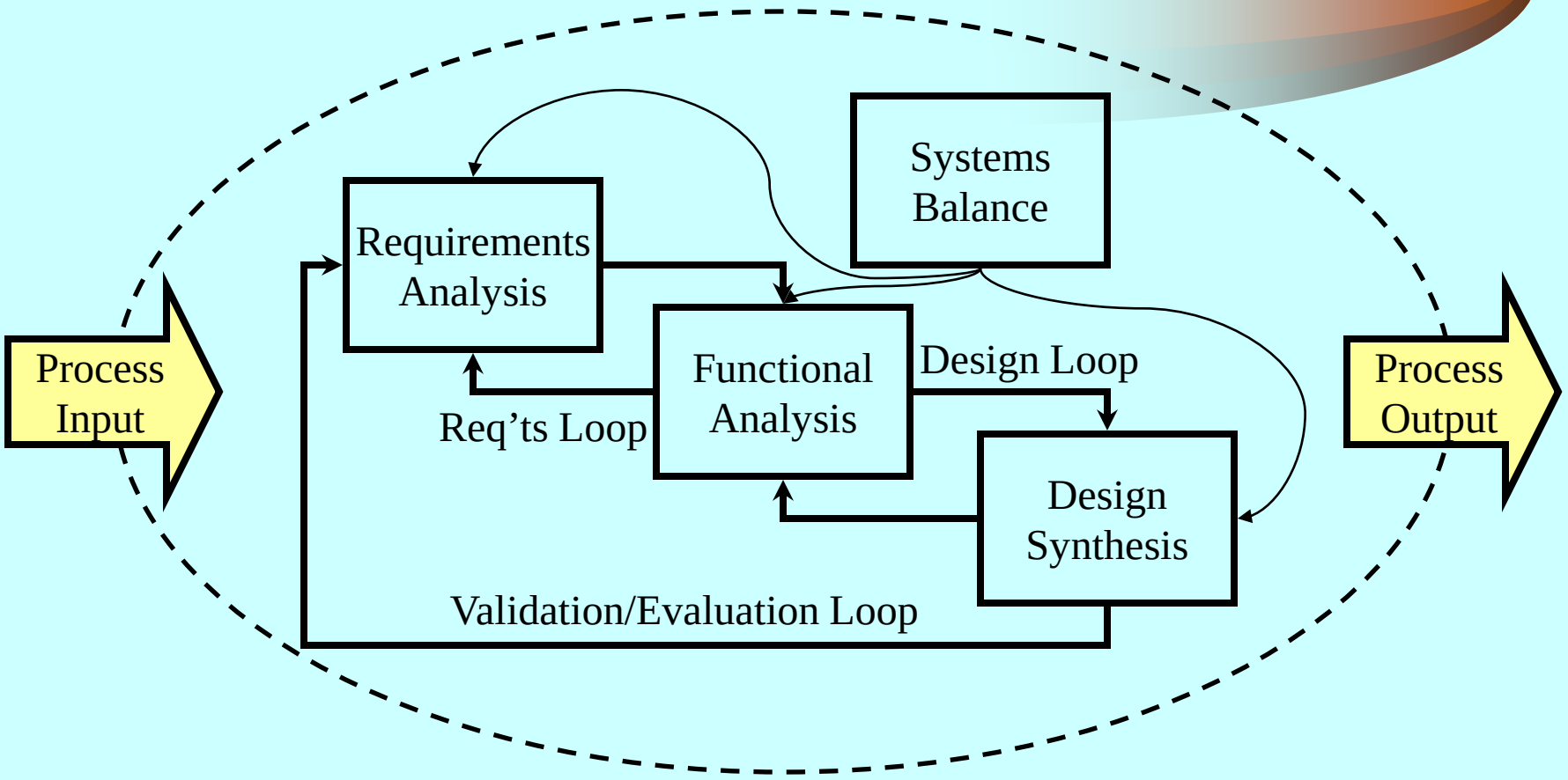
Original: Develop integrated aircraft carrier island & topside design system concepts capable of meeting future aircraft carrier requirements envisioned for the CVNX which can be progressively incorporated in hulls beginning with CVN 77 and corresponding technology development plans

High Risk / High Pay-Off

"CV Islands" Metrics ("Success Criteria")

- Reduced Total Ownership Cost (TOC)
- Positive Impact on Sortie Rate
- Enhanced Survivability (Susceptibility, etc.)
- Minimize Flight Deck Impact
- Reduced Accident Rate
- Increased Flexibility of Aircraft Operations
- Minimize Weight
- Upgradeability

Systems Engineering Process



Surface Combatant Optimized for Unmanned Vehicle Operations (SCOUVO) - Team Charter

" Develop alternative design concepts for a near term[1], relatively small[2], high speed[3], littoral warfare surface combatant that optimally integrates the operations of unmanned vehicles[4] with the ship platform and the network-centric operational environment "

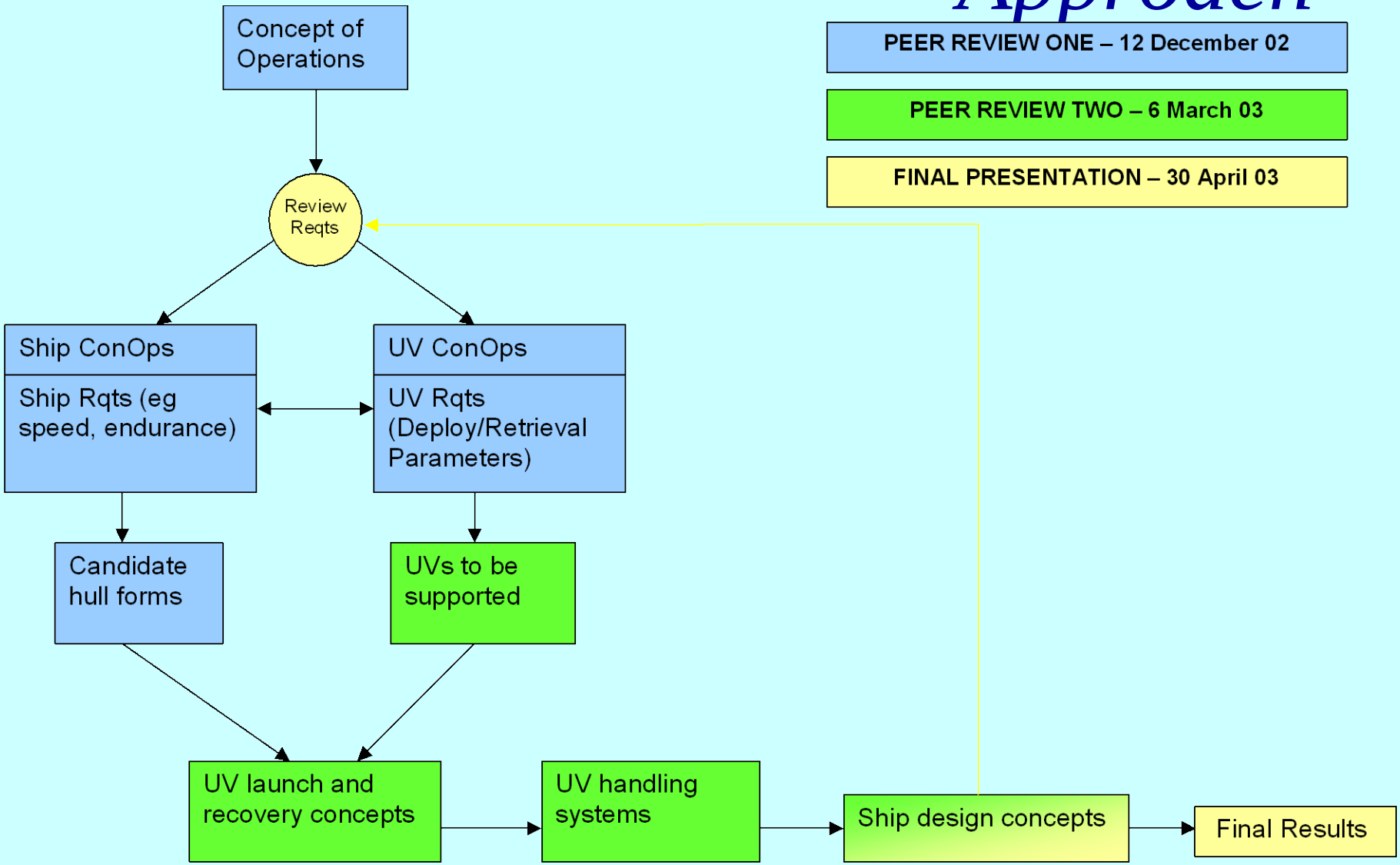
1. 2015
2. Less than 5000 tons
3. Greater than 45 knots
4. UAVs, USVs, UUVs, and UGVs

Approach

PEER REVIEW ONE – 12 December 02

PEER REVIEW TWO – 6 March 03

FINAL PRESENTATION – 30 April 03



Mission Scenario

- Four primary missions for SCOUVO
  - Intelligence, Surveillance and Reconnaissance (ISR)
  - Shallow Water Anti-Submarine Warfare (ASW)
  - Mine Warfare (MIW)
  - Small Boat Defense (SBD)
- MIW chosen as reference mission
  - High degree of interaction between ship and UVs
  - Most taxing on the entire system
  - Widest range of types and sizes of UVs
- Near-term UVs used as examples
  - Future UVs assumed similar or smaller

MIW Mission Loadout

Mission Bay Vehicles	Quantity	Footprint (sqm)	Weight (tons)	Support Containers	Footprint (sqm)	Weight (tons)
LMRS	2	12	2	4	60	1
RMS	1	36	13	2	30	11
BPAUV	4	6	NA	1	15	6
SPARTAN w/ Klein or AQS-14	2	143	20	2	30	5
11-M RHIB w/REMUS/SCULPIN	1	72	10	2	30	5
VSW w/ 6 Crawlers	1	1	NA	1	15	7
OWL (+EO/IR Pkg) (ISR)	2	NA	NA	1	15	5
totals	13	270	46	13	195	39
				TOTAL	**465**	**85**

Hangar Vehicles	Quantity	Footprint (sqm)	Weight (tons)	Support Containers	Footprint (sqm)	Weight (tons)
MH-60S	1	126	9	3	45	
ALMDS		NA	NA	1	15	8
AQS-20A		NA	NA	1	15	7
AMNS		NA	NA	1	15	5
RAMICS		NA	NA	1	15	7
COBRA		NA	NA	1	15	5
totals	1	126	9	8	120	31
				TOTAL	**246**	**40**

IDEAL MISSION SPACE

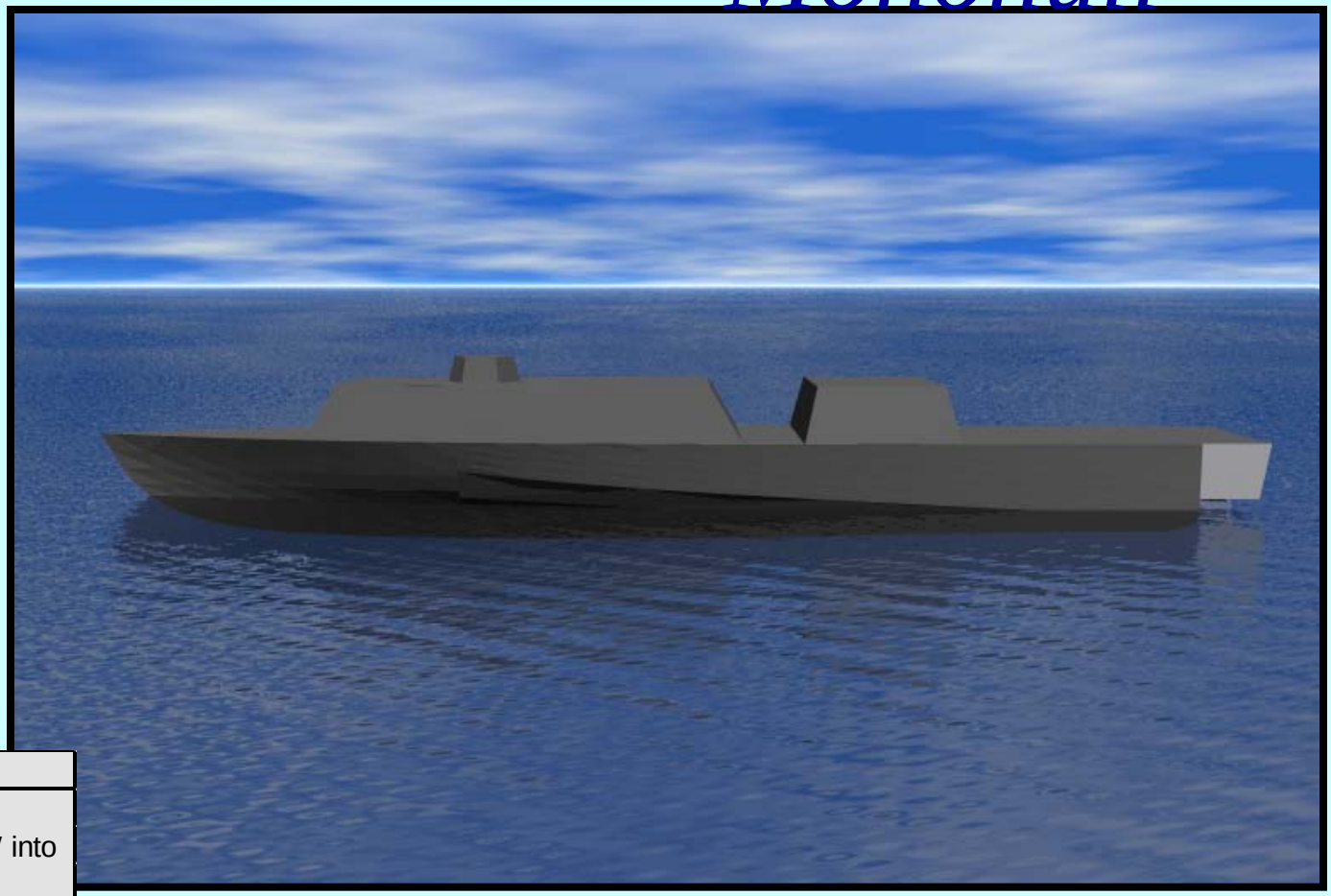
Mission Bay: 465 sqm

Hangar: 246 sqm

Surface Combatant Optimized for Unmanned Vehicle Operations (SCOUVO) – Hull Form Options

- **Advanced Monohull**
- **Catamaran**
- **Trimaran**

Monohull



Hull Characteristics	
Length - LWL (m)	120.5
Beam (m)	17.2
Draft (m)	4.4
Depth (m)	12.0
Mission Bay Area (sqm)	560
Light Ship w/margin (mt)	3770
Fuel (mt)	740
Mission Payload (mt)	85
Total Loads (mt)	930
Full Load Disp. (mt)	4700
Hull Material	AL

Power Systems
Propulsion System (CODOG): (3) Rolls Royce Trent GT @ 50.0 MW into (3) 50 MW Axial Flow waterjets and (2) MTU Diesels @ 7.2 MW into (2) 50 MW Axial Flow waterjets
Ship Services: (3) Diesel Gen Sets @ 3.2 MW

Speed and Endurance	
Endurance Speed (kts)	18
Endurance Range (n mi)	4000
Sust. Speed @ 80% power (kts)	43
Max. Speed @ full power (kts)	48

Catamaran

Hull Characteristics	
Length - LWL (m)	90.0
Beam-Overall (m)	25.0
Beam-Demihull (m)	7.5
Draft (m)	4.8
Depth (m)	15.0
Mission Bay Area (sqm)	575.0
Light Ship w/margin (mt)	3455
Fuel (mt)	640
Mission Payload (mt)	85
Total Loads (mt)	830
Full Load Disp. (mt)	4285
Hull Material	AL

Power Systems
Propulsion System (CODOG): (4) MT30 GT @ 36.0 MW into (4) 35 MW Axial Flow waterjets and (2) MTU Diesels @ 6.5 MW into (2) 35 MW Axial Flow waterjets
Ship Services: (3) Diesel Gen Sets @ 3.2 MW

Speed and Endurance	
Endurance Speed (kts)	18
Endurance Range (n mi)	4000
Sust. Speed @ 80% power (kts)	45
Max. Speed @ full power (kts)	50

Trimaran

Hull Characteristics	
Length - LWL (m)	168.0
Beam-Overall (m)	24.7
Draft (m)	4.3
Depth (m)	12.0
Beam-Center Hull (m)	12.0
Beam-Side Hull (m)	2.4
Length - Side Hull (m)	43.2
Mission Bay Area (sqm)	465.0
Light Ship w/margin (mt)	3890
Fuel (mt)	460
Mission Payload (mt)	85
Total Loads (mt)	650
Full Load Disp. (mt)	4540
Hull Material	AL

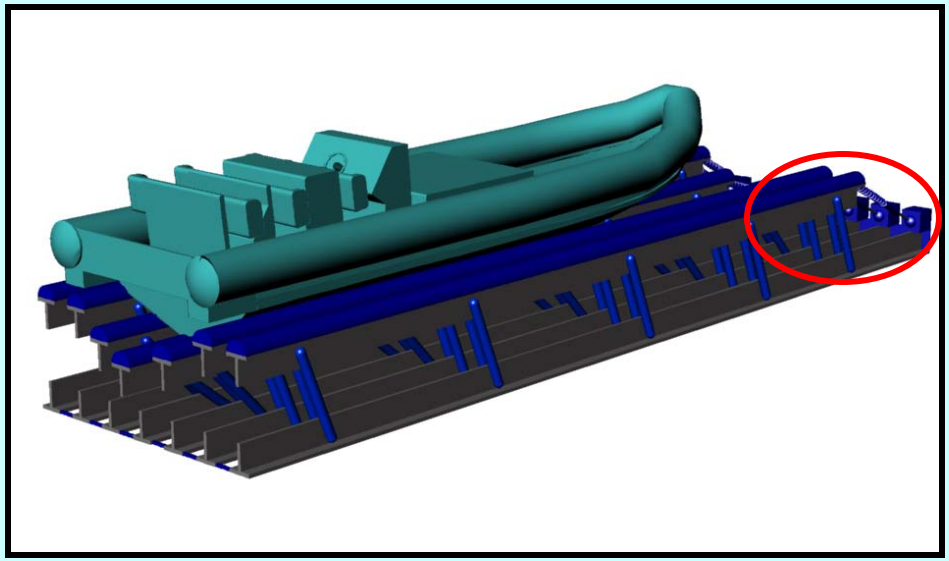
Power Systems
Main Propulsion System (CODOG): (3) GE LM 6000 GT @ 42.0 MW into (3) 45 MW Axial Flow waterjets and (2) MTU Diesels @ 3.9 MW into (2) 45 MW Axial Flow waterjets
Aux. Propulsion System -In Side Hulls (For UV Operations): (2) 3 MW electric motors. (2) 3 MW Waterjets
Ship Services: (3) Diesel Gen Sets @ 3.2 MW

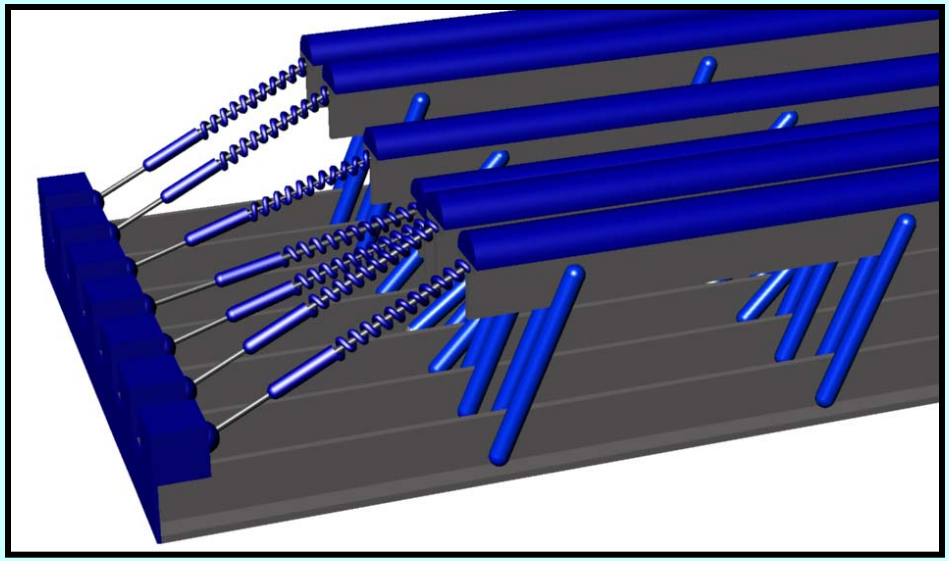
Speed and Endurance	
Endurance Speed (kts)	18
Endurance Range (n mi)	4000
Sust. Speed @ 80% power (kts)	47
Max. Speed @ full power (kts)	50

SCOUVO Unmanned Vehicle Launch, Recovery & Handling (LR&H) Subsystems

- **Variable Cradle**
- **Towed Body**
- **“Chinese Lantern”**
- **Homing Crane**
- **Paravane**

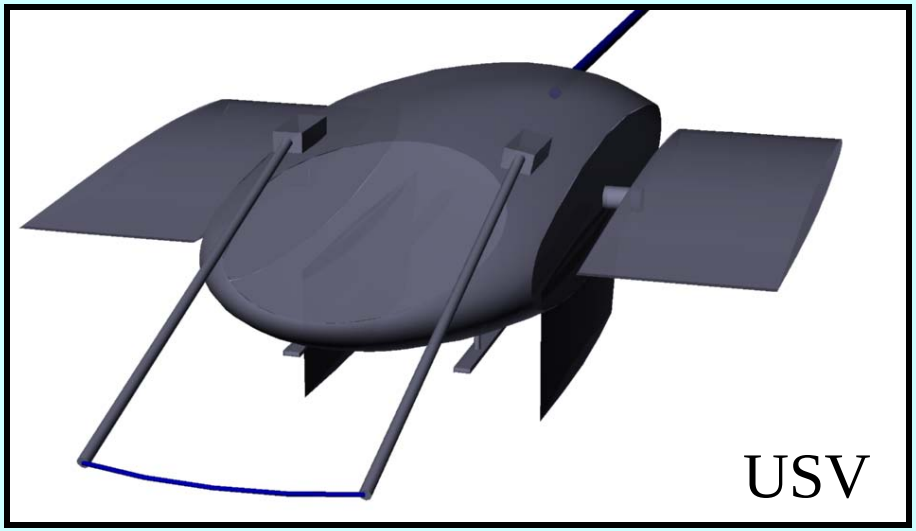
Variable Cradle

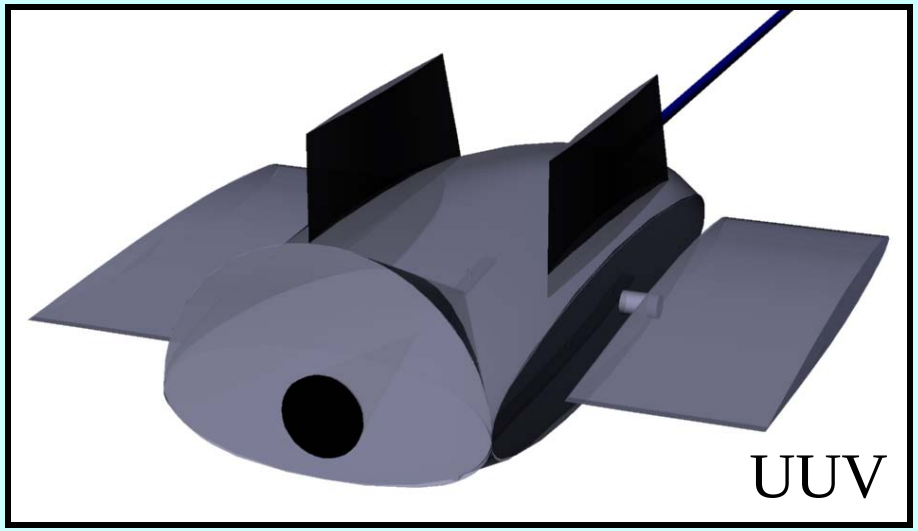




- Landing area for USVs and UUVs on stern ramp
- Cradle configuration programmable for various UUVs/USVs
- Individually adjustable shock absorbing rails
- Inflatable cushioned rail covers
- Clearances for hull appendages
- Open frame for water flow-through

Towed Body

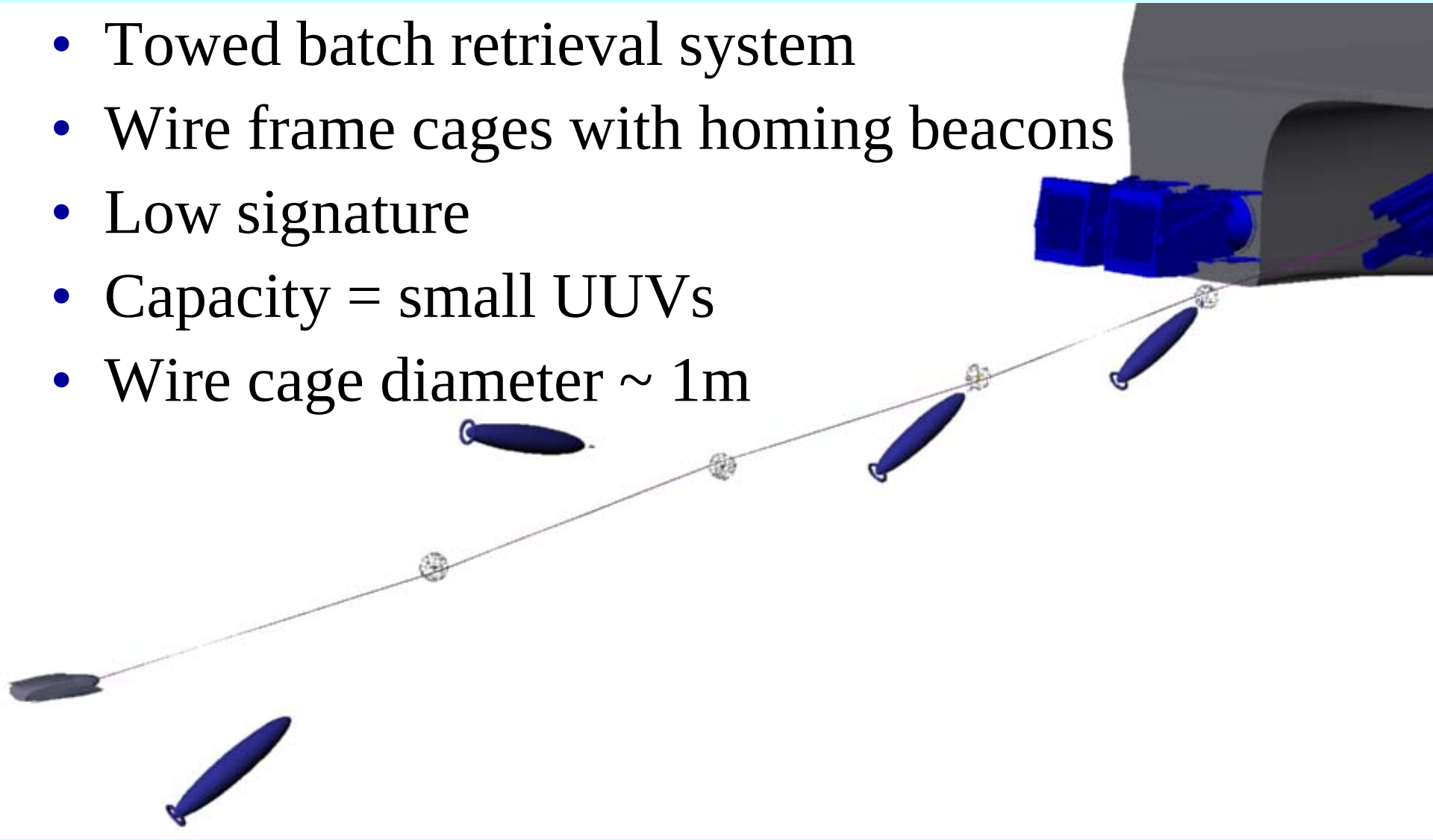




- Towed maneuvering body for USV/UUV retrieval
- Optical homing guidance system
- Towing, fuel, power and data connections
- Low signature
- Wingspan ~ 1m

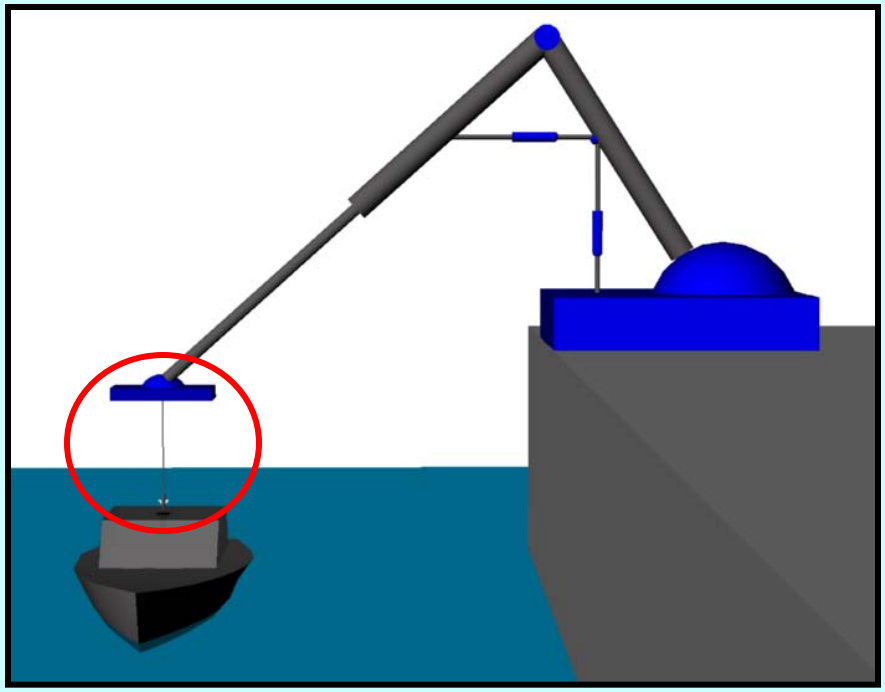
"Chinese Lantern"

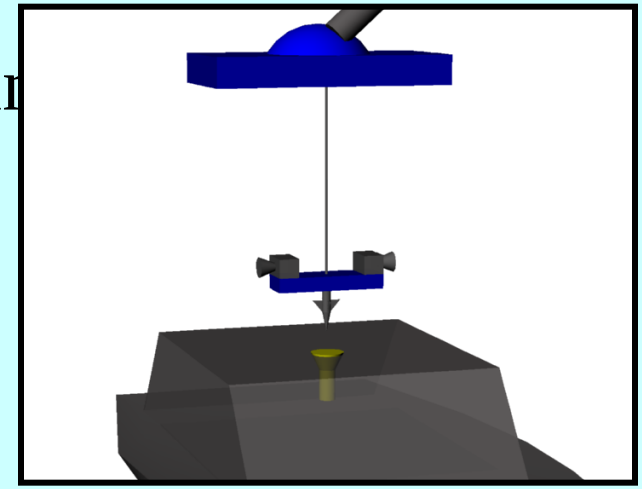
- Towed batch retrieval system
- Wire frame cages with homing beacons
- Low signature
- Capacity = small UUVs
- Wire cage diameter ~ 1m



Homing Crane

- Motion controlled crane with maneuvering pickup fixture
- Waterjet thruster steered
- Optical homing control
- Launch and recover UUVs and USVs
- On-load & off-load equipment
- Flight deck handlin





Paravane

- Derived from A/N37U-1 Mine Clearing Set
  (NSWCCD POC D. Pickett, Code 5300)

- Towed Paravane and UV retrieval line

- Engages stopped UV and pulls UV close to ship for crane pick up

- Low signature

- Fully automated

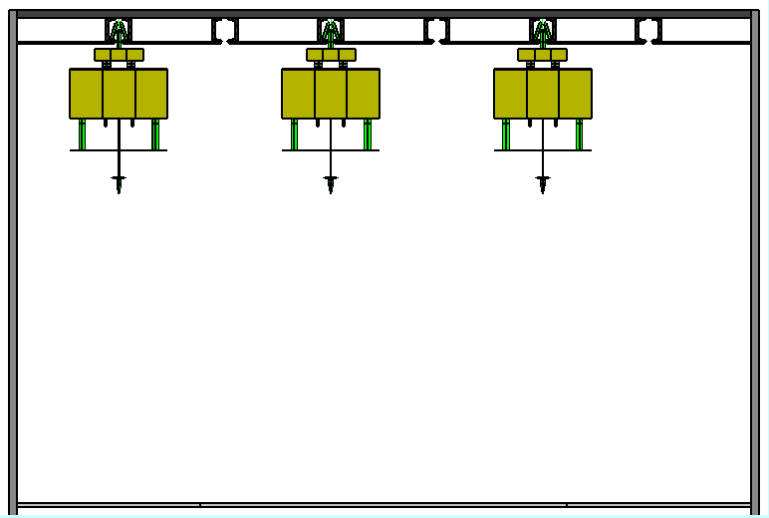
- ~ 60 meter outreach

On-Board Handling

- Goals
  - Flexibility
  - Reconfigurability
  - Single storage/maintenance/prep space

- Assumptions
  - Max single-object weight = 9 mt (20,000 lbs)
  - Water launch, max length = 11 m
  - Air launch, max length = 16 m

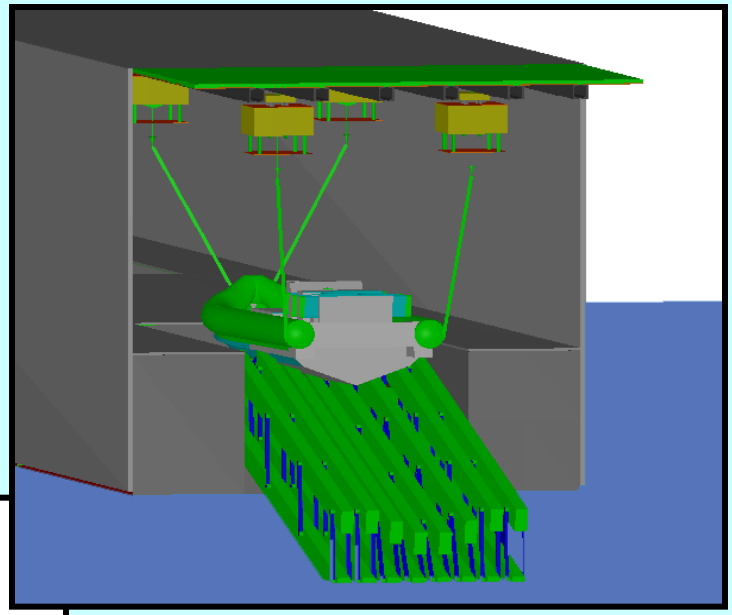
Overhead Hoist Array System

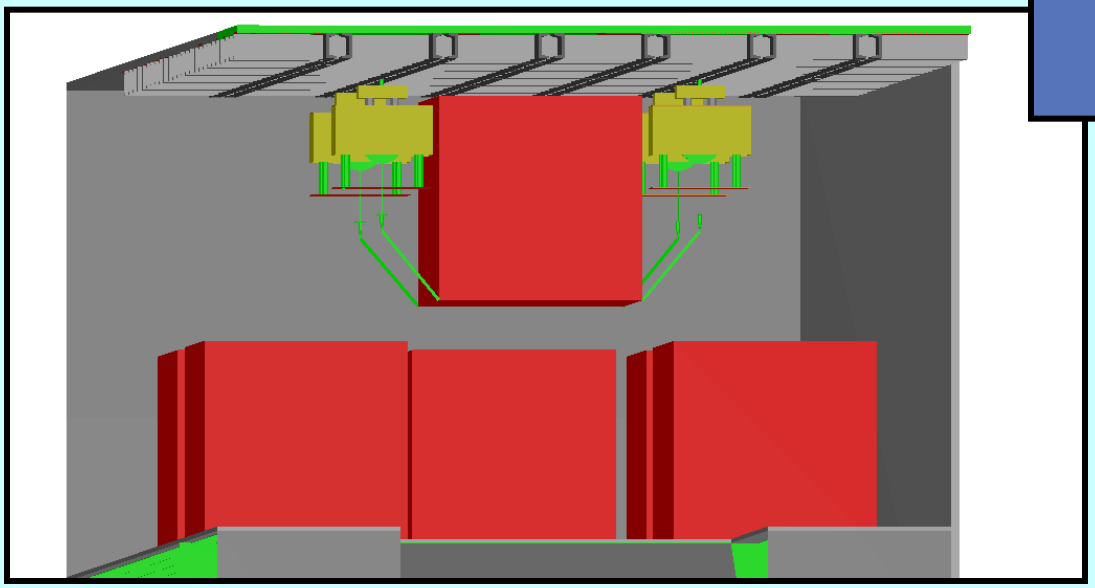


- Multiple self-powered hoists under central computer control
- Ride on grid of overhead rails
- Operate singularly or collectively
- Possible automated hookup
- Capacity (each) = 4000 lbs (1.8 mt)
- Ship embarks 10-12 hoists
- Duty cycle time = 8 hours

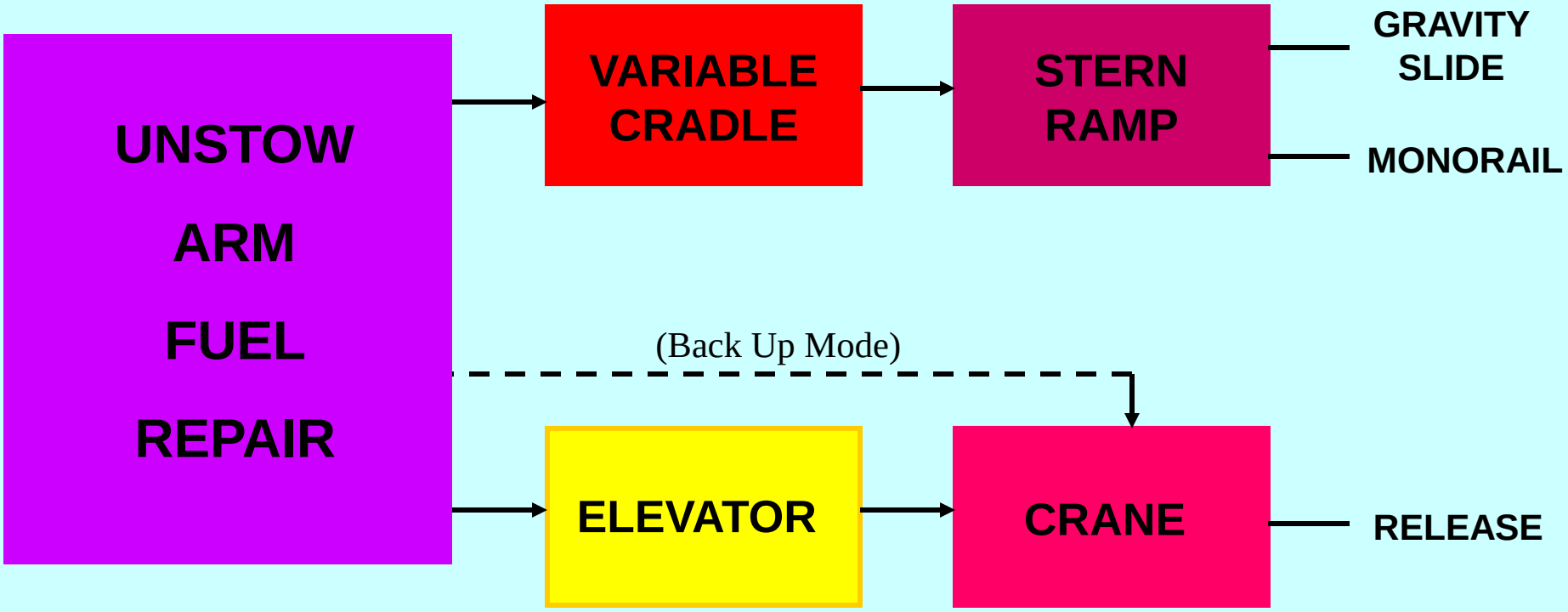
Overhead Hoist Array System

- Position hoist(s) over equipment
- Possible auto-attachment
- Lift as high as possible
- Reposition for launch or storage

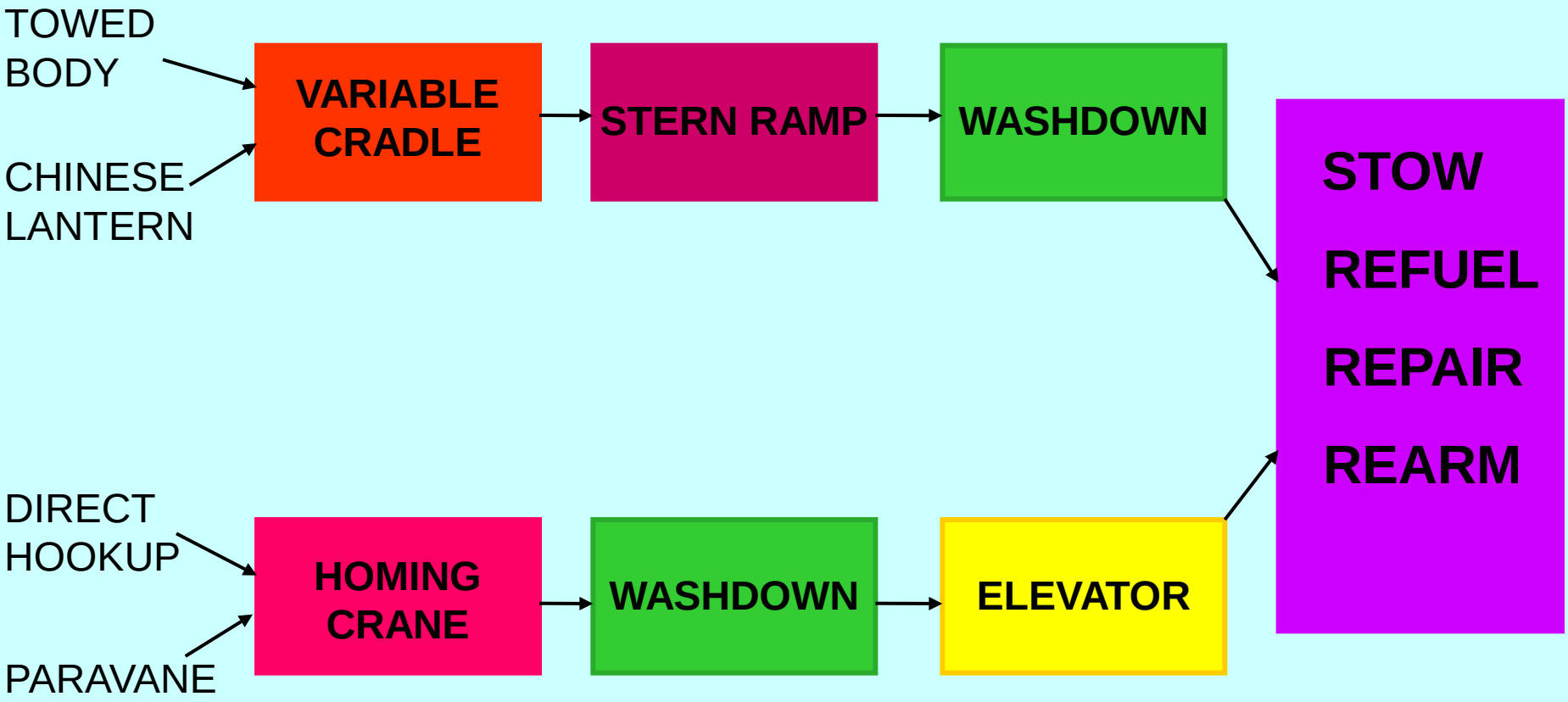




Launch Process



Recovery Process



Recovery "Evolution" Comparison

	Variable Cradle	Towed Body	Chinese Lantern	Homing Crane	Paravane Recovery
Approach	MANNED BOAT DRIVES OR USE TOWED BODY	**UV UNDERWAY, APPROACH ASTERN**	UV UNDERWAY, APPROACH ASTERN	UV UNDERWAY OR DIW, APPROACH ALONGSIDE	UV UNDERWAY OR DIW, APPROACH ALONGSIDE
Capture	MANNED LINE OR TOWED BODY	**UUV SPIKE, USV LOOP**	QUILL TO CAGE	GUIDED SPIKE	GRAPPLING HOOK ONTO LINE
Control	BOW LINE, SELF CENTERING	**LONGITUDINAL SINGLE POINT TOW**	LONGITUDINAL SINGLE POINT TOW	SINGLE POINT HOLD	SINGLE POINT TOW
Remove from Water	CRADLE ON RAMP, TILT RAMP HORIZONTAL	**REELED ONTO VARIABLE CRADLE**	REELED ONTO VARIABLE CRADLE	SINGLE OR MULTI-POINT LIFT	SHUTTLE OR RETRACT LINE, CRANE LIFT
Enter Ship	STERN GATE	**VARIABLE CRADLE INTO MISSION BAY**	VARIABLE CRADLE INTO MISSION BAY	WEATHER DECK	WEATHER DECK
Handle	PICK UP WITH ARRAY HOIST	**TILT RAMP, LIFT WITH HOIST ARRAY**	1 UV UP RAMP, ARRAY HOIST SECURE, DETACH CAGE, NEXT UV	CRADLE TO FORKLIFT OR ELEVATOR	CRADLE TO FORKLIFT OR ELEVATOR
Stow Device	STOWED ON RAMP	**LEAVE ON CABLE, STAY ON RAMP WITH CLAMP**	STOW CAGES IN BOX	RETRACT AND SHELTER	SPECIALIZED SPACE IN SHIP

Retrieval Operational Risks

- Risk at each step of process reviewed

		Variable Cradle	Towed Body	Chinese Lantern	Homing Crane	Paravane Recovery
APPROACH	*power loss*	UV	UV	UV		
	general malfunction			cable tangling	collision	escape, tangling
	fouling	ice	nets/kelp/ice	nets/kelp/ice	ice	nets/kelp/ice
CAPTURE	*general malfunction*	cradle configuration	position/attach	cage structural failure	crane/homing capture	UV device or paravane
	tangling		UV to towed body	UV to cable		UV to paravane
	connnection problem	UV overruns/doesn't seat in cradle	UV overuns body	UV misses cable	homing system malfunction	UV misses cable
	high sea state	UV to cradle slamming	relative motions	relative motions	relative motions	UV motions
CONTROL	*general malfunction*	loss of cradle configuration	winch	winch	crane	winch ,structural
REMOVE FROM WATER	*general malfunction*	stern ramp	winch	winch	crane	crane, release device
	high sea state	relative motions	UV to cradle motions	UV to cradle motions	UV to ship motions	UV to ship motions
	ship effects				heel problems	heel problems
ENTER SHIP	*general malfunction*	ramp	ramp	ramp	crane	crane
	severe weather	operator injury, MB unusable	operator injury, MB unusable	operator injury, MB unusable	operator injury	operator injury
	high sea state	ship motions on operators	ship motions on operators	ship motions on operators	ship motions on operators	ship motions on operators
HANDLING	*general malfunction*	OHA system	OHA system	OHA system	elevator	elevator

SCOUVO L/R&H
Preliminary Risk Assessments

High Risk:

- Homing Crane (water thruster control valves, guidance and control parameters)

Medium Risk:

- Towed Body (maneuvering system performance)
- Array Hoists (control system software, sensors)

Low Risk:

- Chinese Lanterns (towing characteristics)
- Paravane Recovery (automated deploy/retrieve)
- Variable Cradle (actuators, shock absorption system)

Hull Form
Results and Recommendations

General findings :

	PRO	CON
Monohull	•Lowest R&D, construction, acquisition cost	•Stern ramp operations impacted by proximity of waterjets •Least flight deck area / single helo spot
Catamaran	•Flexibility of arrangements •Low RCS signature (stern ramp between hulls)	•Stern ramp operations impacted by mission bay height •Most HP/ton displacement
Trimaran	•Stern ramp operations facilitated by aux. waterjets in sidehulls •Least HP/ton displacement, least fuel weight	•Highest R&D, construction, acquisition cost

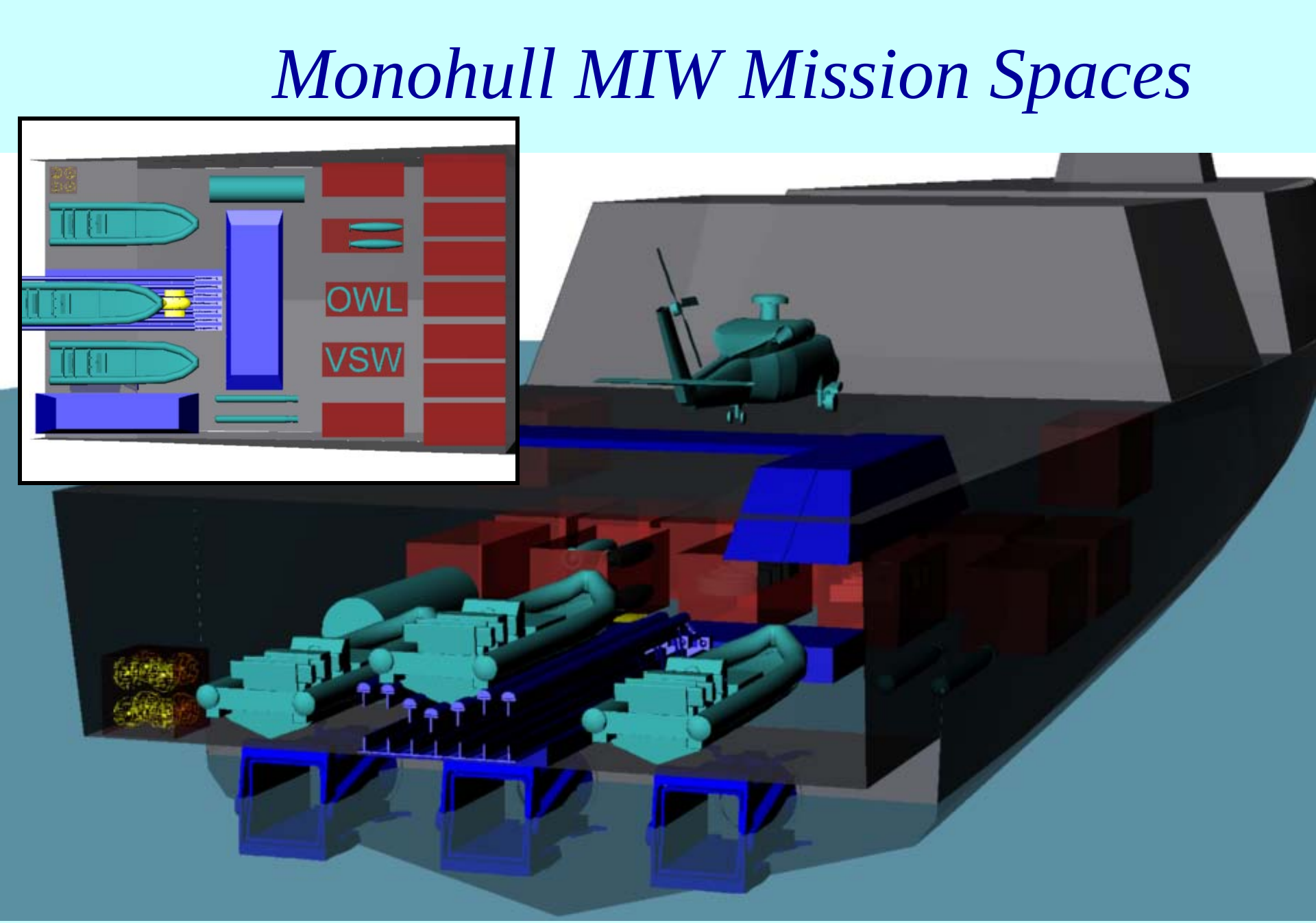
Recommendations

1. 2007 IOC: Catamaran
2. 2015 IOC: Trimaran

MIW Vehicle Operations

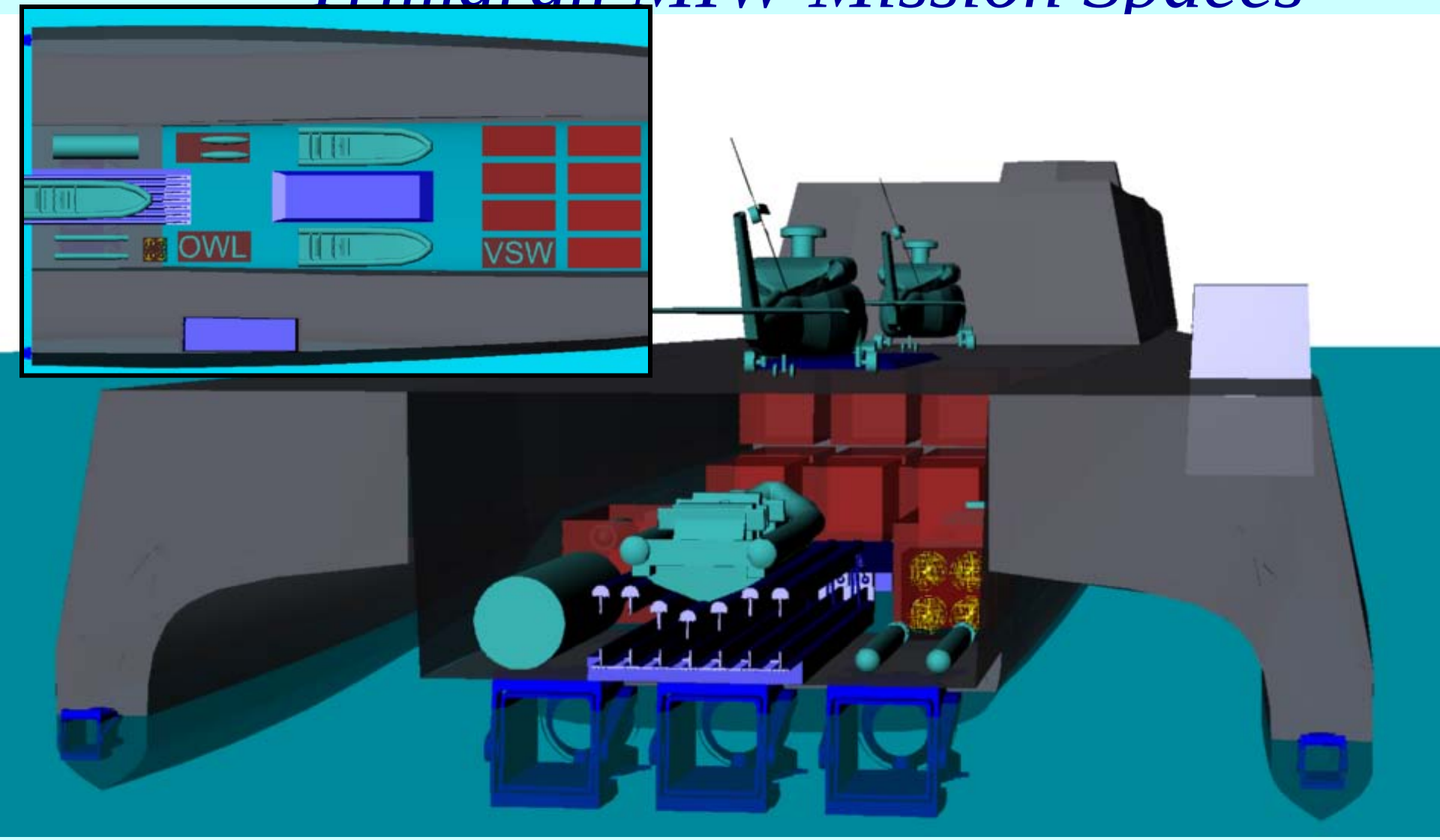
	STORE	MOVE	LAUNCH	OPERATE	CAPTURE	RETRIEVE	MOVE	STORE
LMRS	MISSION BAY ON CRADLE	OVERHEAD HOIST ARRAY	CUSHIONED VARIABLE CRADLE		TOWED BODY	CUSHIONED VARIABLE CRADLE	OVERHEAD HOIST ARRAY	MISSION BAY ON CRADLE
RMS	MISSION BAY ON CRADLE	OVERHEAD HOIST ARRAY TO ELEVATOR	CRANE		PARAVANE	HOMING CRANE	ELEVATOR TO OVERHEAD HOIST ARRAY	MISSION BAY ON CRADLE
BPAUV	MISSION BAY IN ISO CONTAINER	OVERHEAD HOIST ARRAY	VARIABLE CRADLE DOWN RAMP		CHINESE LANTERN	VARIABLE CRADLE	OVERHEAD HOIST ARRAY	MISSION BAY IN ISO CONTAINER
SPARTAN	MISSION BAY ON CRADLE	OVERHEAD HOIST ARRAY	VARIABLE CRADLE DOWN RAMP		TOWED BODY	VARIABLE CRADLE	OVERHEAD HOIST ARRAY	MISSION BAY ON CRADLE
Manned 11-M RHIB	MISSION BAY ON CRADLE	OVERHEAD HOIST ARRAY	VARIABLE CRADLE DOWN RAMP		TOWED BODY	VARIABLE CRADLE	OVERHEAD HOIST ARRAY	MISSION BAY ON CRADLE
VSW w/ 6 Crawlers	MISSION BAY IN ISO CONTAINER	OVERHEAD HOIST ARRAY	VARIABLE CRADLE DOWN RAMP		TOWED BODY	VARIABLE CRADLE	OVERHEAD HOIST ARRAY	MISSION BAY IN ISO CONTAINER
OWL	MISSION BAY IN ISO CONTAINER	OVERHEAD HOIST ARRAY	VARIABLE CRADLE DOWN RAMP		TOWED BODY	VARIABLE CRADLE	OVERHEAD HOIST ARRAY	MISSION BAY IN ISO CONTAINER

Monohull MIW Mission Spaces



Catamaran MIW Mission Spaces

Trimaran MIW Mission Spaces



Conclusions about Mission Bay

- Trimaran and monohull must have telescoping ramp
- Possible for catamaran to have single-piece ramp
- Catamaran provides most accessible space
- With further study, may be able to provide storage in wing structure of trimaran
- In order to pass one ISO container over another mission bay must be 6m high

Conclusions & Recommendations

- **Suite of Recommended L/R&H systems:**
  - **Towed Body**
  - **Variable Cradle**
  - **“Chinese Lantern”**
  - **Paravane**
- **Organic UV Support Systems:**
  - **Homing Crane**
  - **Overhead Hoist Array System**
  - **Stern ramp**
  - **Elevator**
  - **Helicopter hangar**
- **Future USV/UUV Design Features:**
  - **Hardened underside (protected sensors and appendages)**
- **Hull Forms**
  - **2007 IOC: Catamaran**
  - **2015 IOC: Trimaran**

SCOUVO Project Summary

- Established Concept of Operations
- Examined current L/R systems and issues
- Evaluated candidate hull forms, propulsion requirements and mission bay sizing
- Developed 3 alternative ship design concepts
- Explored helicopter and elevator impacts
- Developed multiple L/R&H system concepts
- Identified organic UV support systems
- Identified desirable UV interface attributes
- Recommended hull forms
- Recommended suite of L/R&H systems

Summary of Innovation Center Project Systems Engineering Process Steps

- **Requirements Definition**
- **Establishment of Metrics**
- **Requirements Analysis**
- **Functional Analysis**
- **Design Synthesis**
- **Design Analysis**
- **Feedback/Iteration/Refinement**
- **Assembly of Product**
- **Planning for Follow-On Work**

DISCUSSION