Total Ship Systems Engineering

CAPSTONE DESIGN PROJECT

Naval Postgraduate School

Team 2001

Presentation Outline

Introduction

Requirements

Analysis of Alternatives

Hull

Propulsion/Electrical

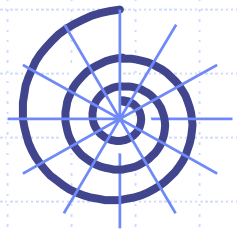
Aviation Systems

Combat Systems

Damage Control/ Habitability

Total Ship Evaluation

Conclusion



Total Ship Systems Engineering Team

Team Leaders
LT Joe Keller, USN
LCDR Rabon Cooke, USN

Damage Control/Habitability
LTJG Mersin Gokce, TN
LTJG Orhan Barbaros Okan, TN

Aviation Systems
LT Scot Searles, USN

Combat Systems
Mr. Ivan Ng, Singapore DSTA

Hull
CDR(sel) James Ivey, USN
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Manning/Cost
LT Peter LaShomb, USN

Propulsion/Electrical
LT Ryan Kuchler, USN
LT Brad Stallings, USN

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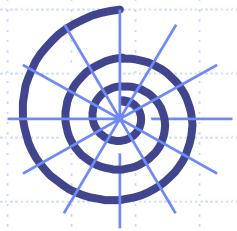

Mission Needs Statement

- **REQUIREMENTS**
  - Ability to "knock down the door"
  - Deny enemy's targeting sequence through speed, maneuver, stealth, and distributed counter-targeting
- **MISSIONS**
  - Operate primarily in the littoral environment as a complement to the Carrier Battle Group (CVBG)
  - Operate independent of the CVBG during certain Military Operations Other Than War (MOOTW)
  - Provide a credible force to harass and suppress enemy forces, while awaiting CVBG arrival
  - Operate UCAVs, UAVs, and manned aircraft.

Mission Needs Statement
(continued)

- **GUIDELINES**
  - Significantly increased distribution of aviation assets
  - Higher sustained and maximum speeds
  - Total ship, aircraft, and weapons system engineering approach
  - Technology through 2012, IOC 2021
  - Significant manpower reductions

Operational Requirements

Key Performance Parameters

Parameter	Threshold	Objective
Speed	40 kts	60 kts
Manning	150	120
Range	4000 nmi	4500 nmi
Sortie Rate	80 sorties/day	120 sorties/day
Sustainability	7 days Sustained rate ops	7 days Surge rate ops

Ship Design Philosophy

- Survivability
- Automation
- Reduced Manning
- Upgradeability
- Maintainability
- Reliability
- Manufacturability
- COTS
- Affordability

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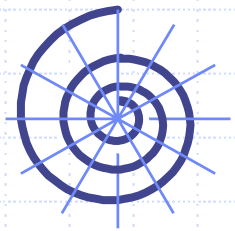

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- Requirements
- Analysis of Alternatives
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- Propulsion/Electrical
- Aviation Systems
- Combat Systems
- Damage Control/ Habitability
- Total Ship Evaluation
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Analysis of Alternatives

- Consider ship designs to support following options:
  - 1 or 2 Squadrons of aircraft with SEA ARROW
  - 1 or 2 Squadrons of aircraft with JSF replacing SEA ARROW
  - 1 or 2 Squadrons of aircraft with SEA ARROW but w/o SEA QUIVER Support
- 1 Squadron consists of :

Aircraft Type	# of Aircraft
SEA ARROW or JSF	8
Helicopters	2
UAVs	10
Maneuver Air Support (MAS)	3

Ship Alternatives
(first estimates)

	1 Squadron			2 Squadron		
	w/SEA ARROW	w/JSF	w/o SEA QUIVER	w/SEA ARROW	w/JSF	w/o SEA QUIVER
Total Payload (mT)	**1900**	3865	2280	3250	7170	3630
Length (m)	**160**	180	163	175	206	186
Breadth (m)	**39**	44	40	44	52	47
Displacement (mT)	**10500**	15100	11100	13600	22100	14500

Design Reference Mission

- Transit legs of 4000 nmi @ 50 kts
  - Refuel 2 SEA LANCEs at 2000 nmi
  - 20% fuel remaining
- 7 days combat operations
  - 2 refuelings of SEA LANCEs
  - Normal sortie rate operations
  - 2 days @ 20 kts
  - 1 day @ 25 kts
  - Remaining time at loiter speeds (10-15 kts)

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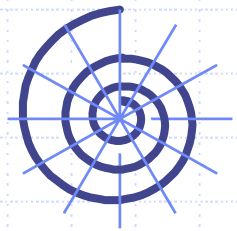
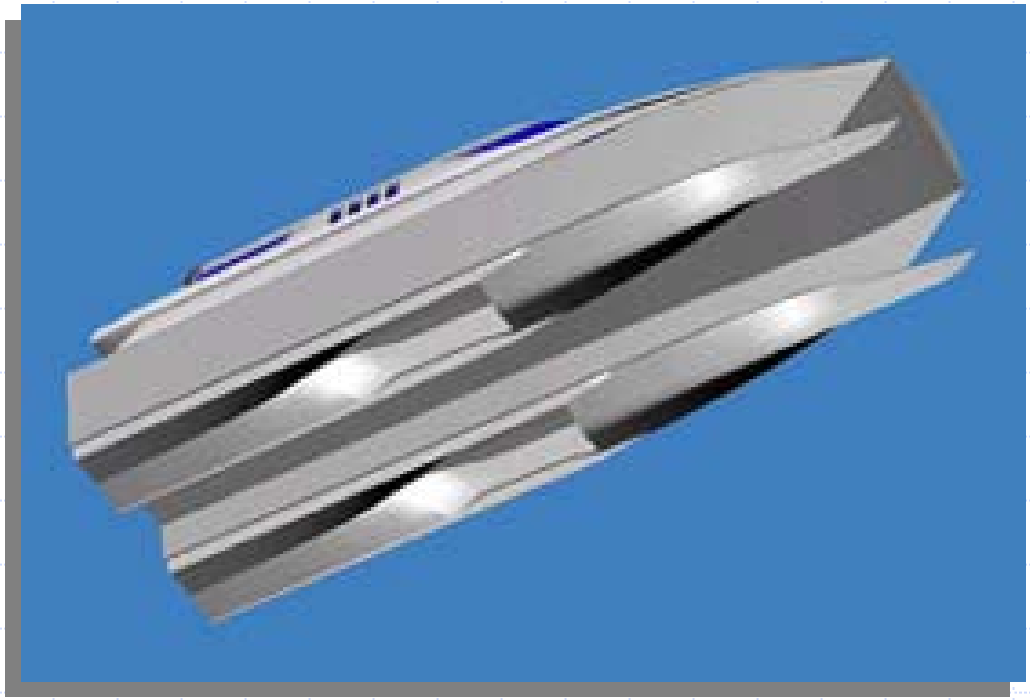


Hull Form-Harley SES



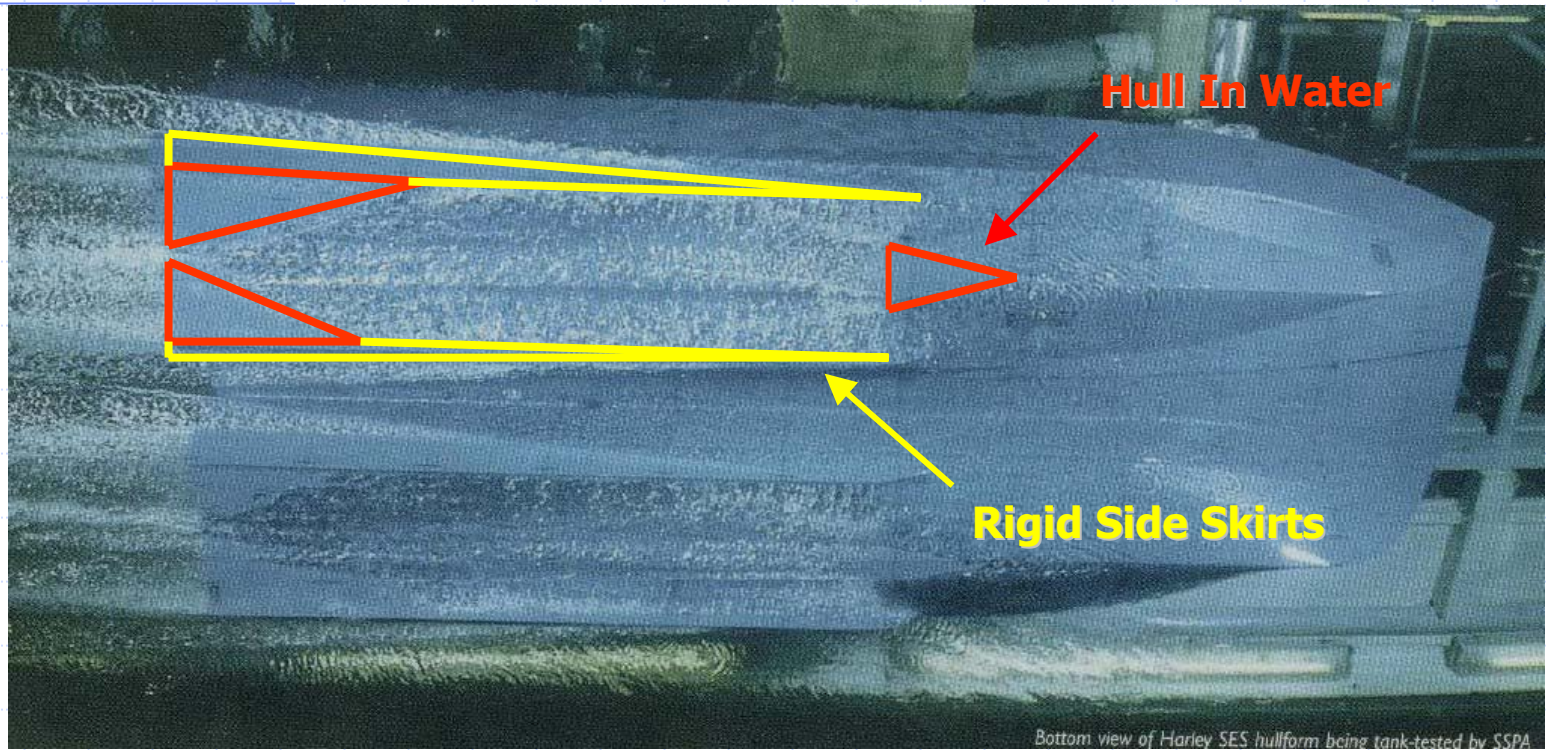
An Air Assisted Catamaran

Hull form uses pressurized air to support 85% of the weight

Results in only a small portion of Hull in contact with water thereby

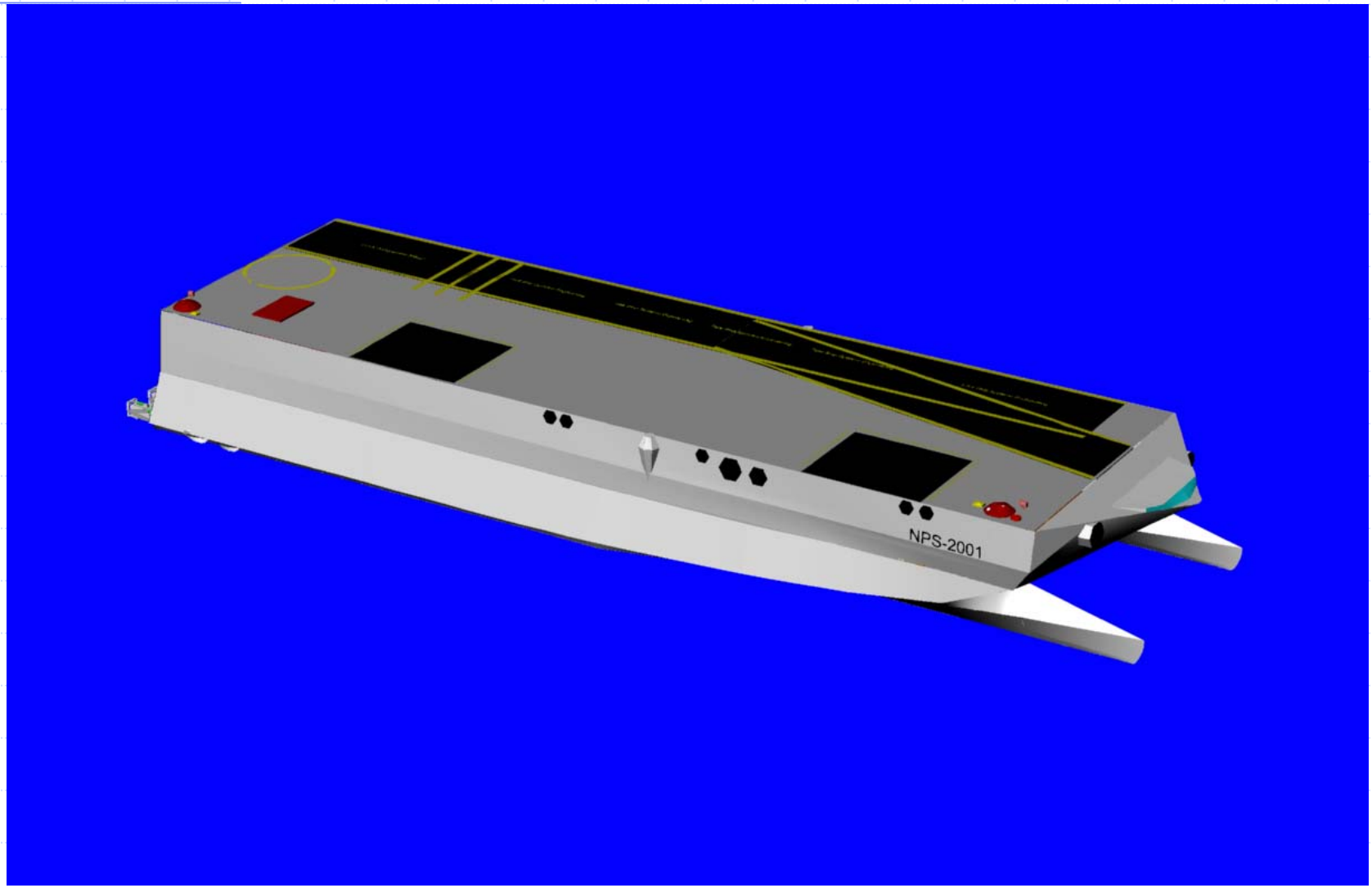
Reduces overall power requirement

Hull Form-Harley SES



***Fisheye view of Vibtech model being tested**

SEA ARCHER



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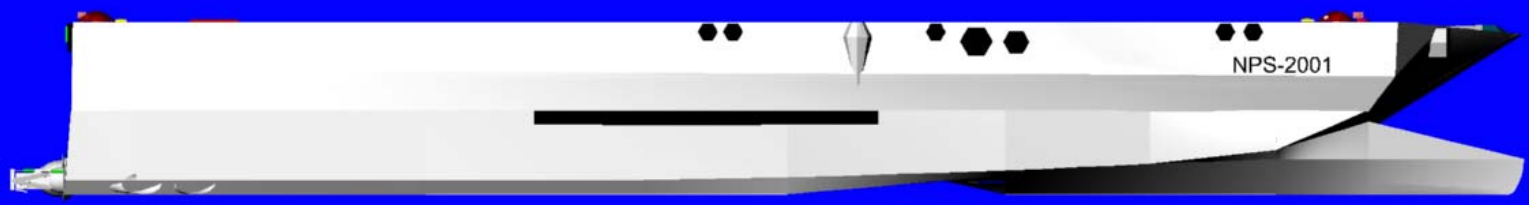


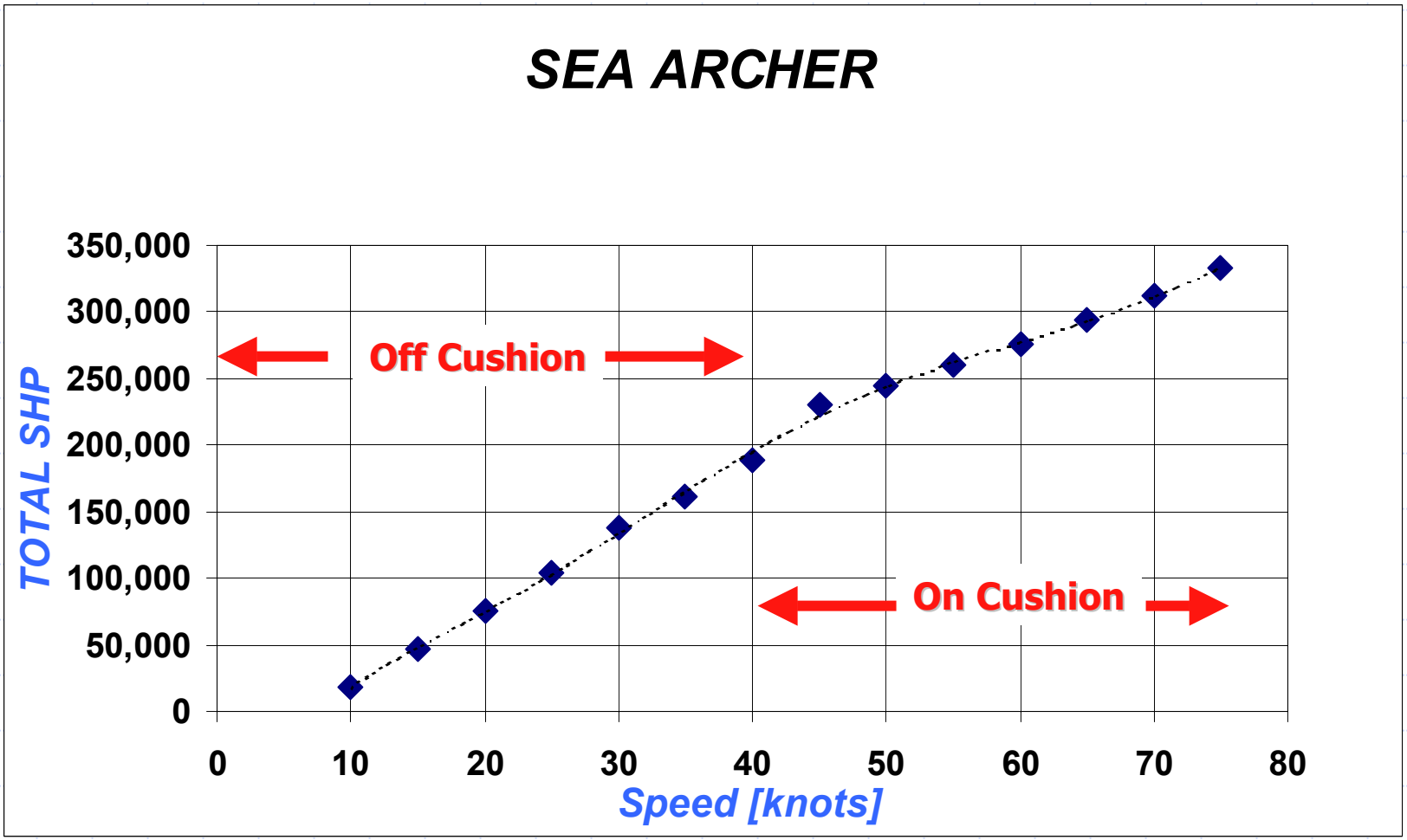
SEA ARCHER Characteristics

Displacement:	13,500	mT
Length:	181	m
Beam:	59	m
Side-hull Beam:	22	m
Range (50 Knots):	4,000	nmi
Draft On/Off Cushion	2 / 4	m
Construction:	Carbon Fiber	

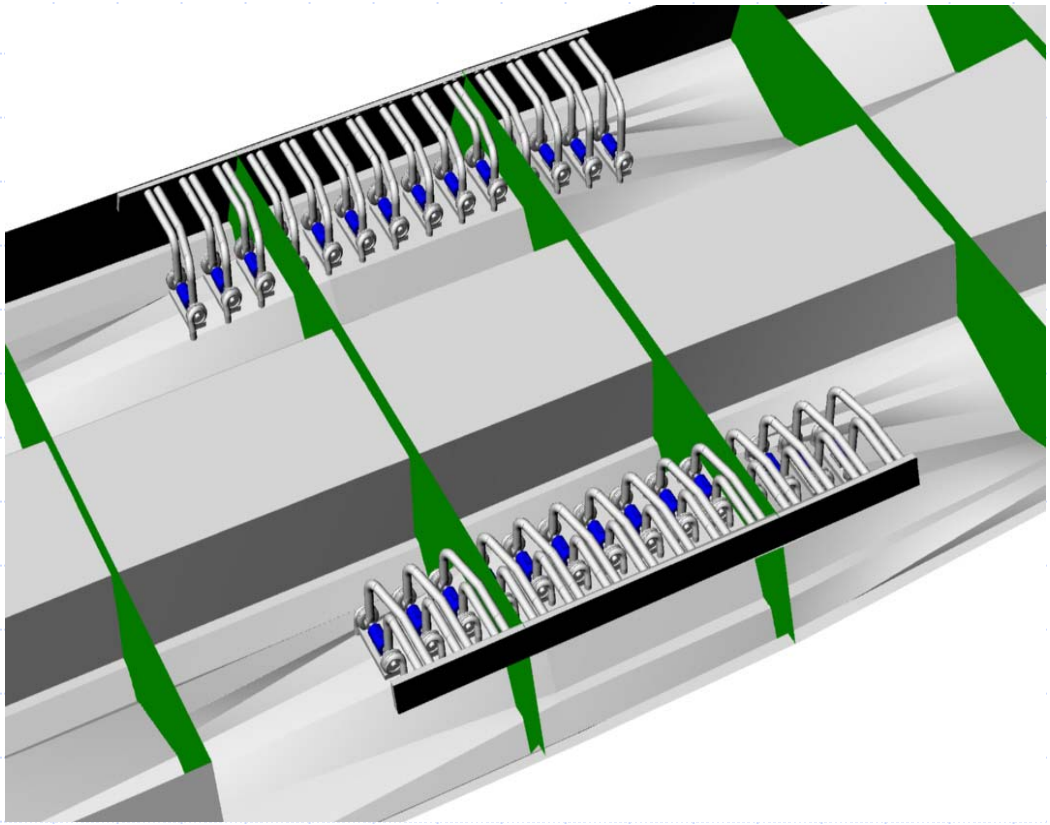
SEA ARCHER Weight Fractions

Structural (SWBS 100):	20	%
Machinery (SWBS 200):	11	%
Electrical (SWBS 300):	13	%
Comms (SWBS 400):	<1	%
Auxiliary (SWBS 500):	7	%
Outfit (SWBS 600):	3	%
Armament (SWBS 700):	3	%
Payload :	12	%
Fuel :	31	%

SEA ARCHER Speed/Power



Lift System Requirements



Each sidehull has 14 fan modules

Each fan module consist of a pair of two-stage centrifugal blowers driven by a single AC motor

System is designed to deliver

27,000 m^3/min

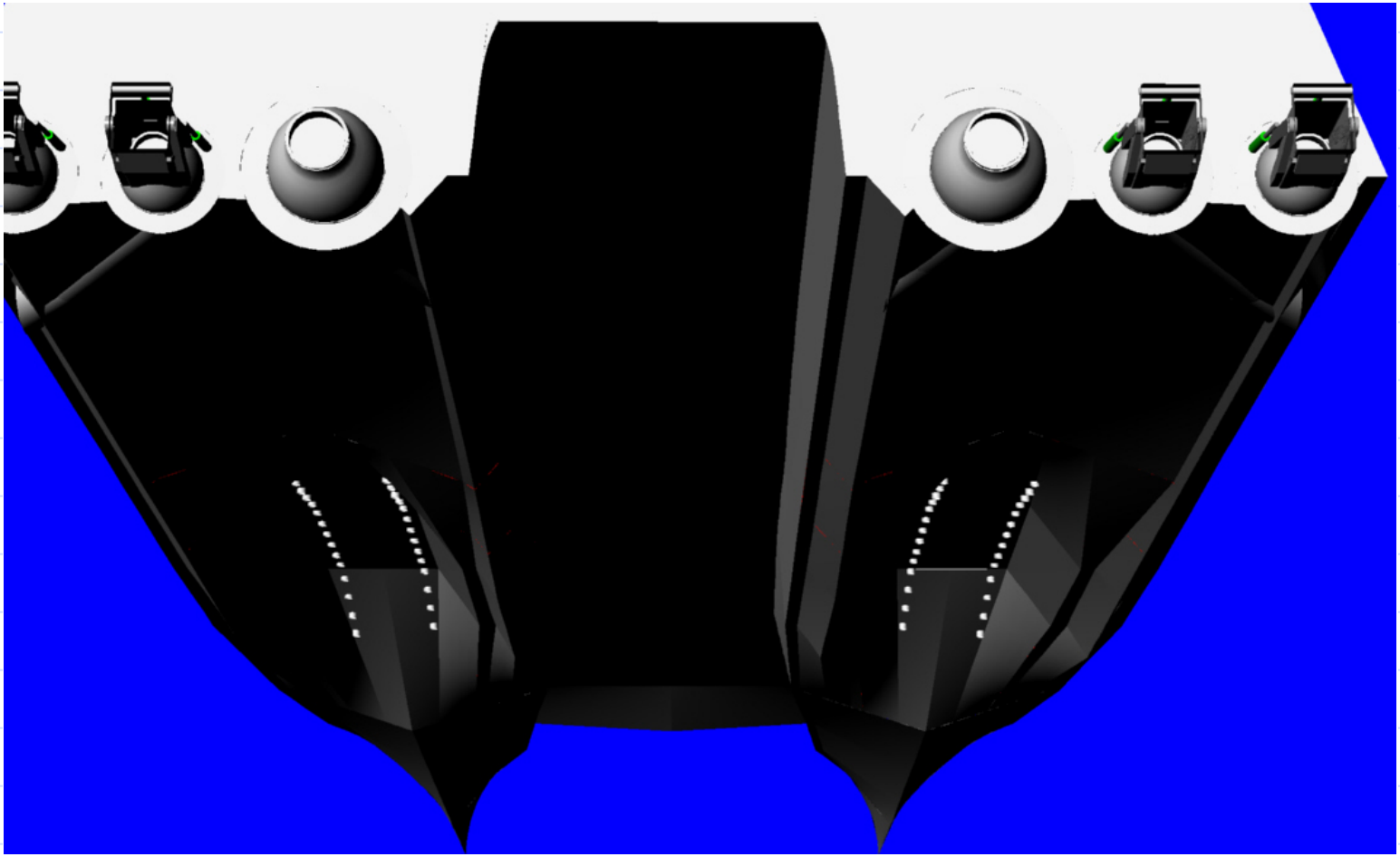
at 42 KPa

Requiring

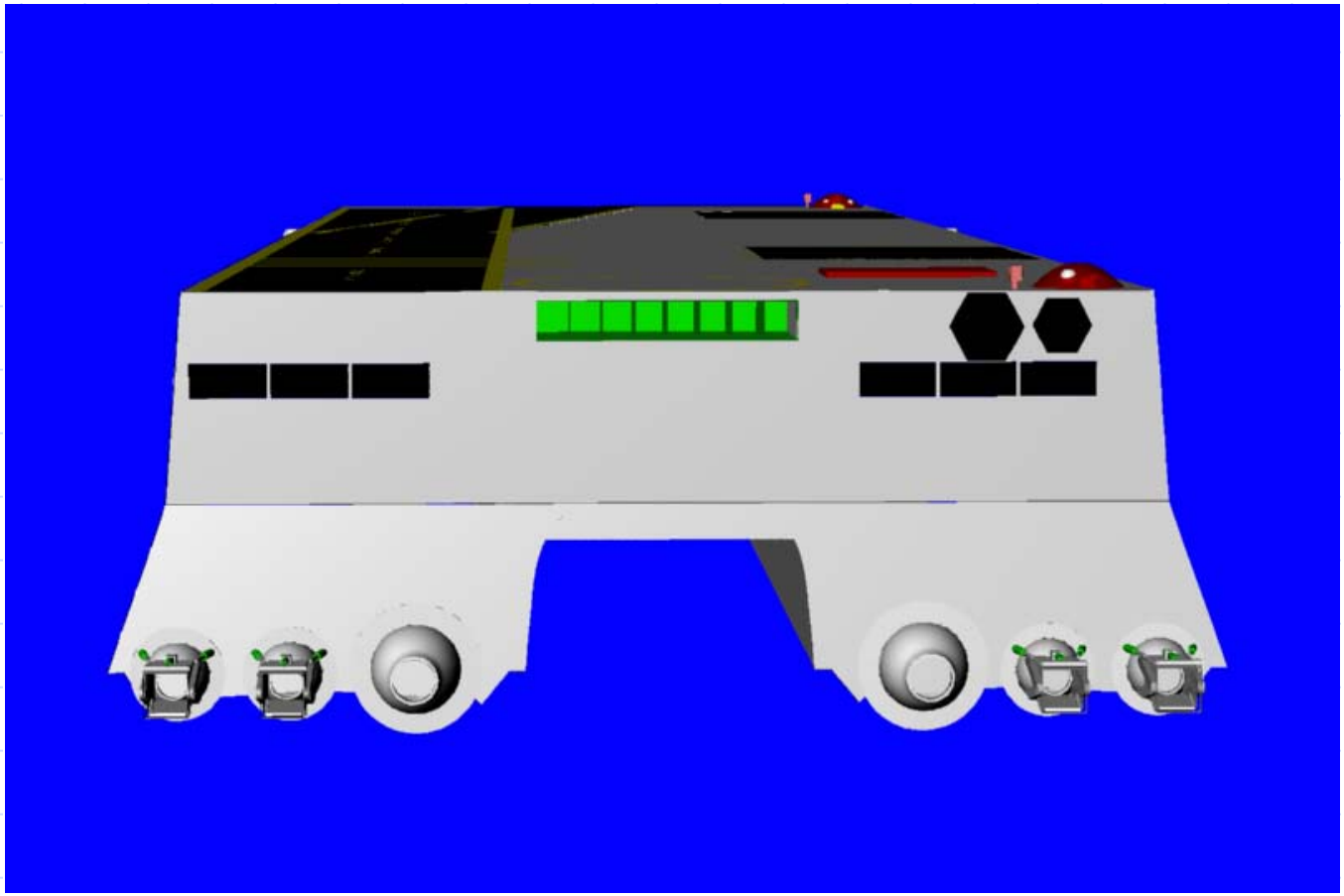
25,920 HP

Two fan modules in each sidehull are for redundancy and maintenance

SEA ARCHER Air Cavity



Qualitative Maneuvering Assessment



Does not need assistance when entering port

Qualitative Maneuvering Assessment

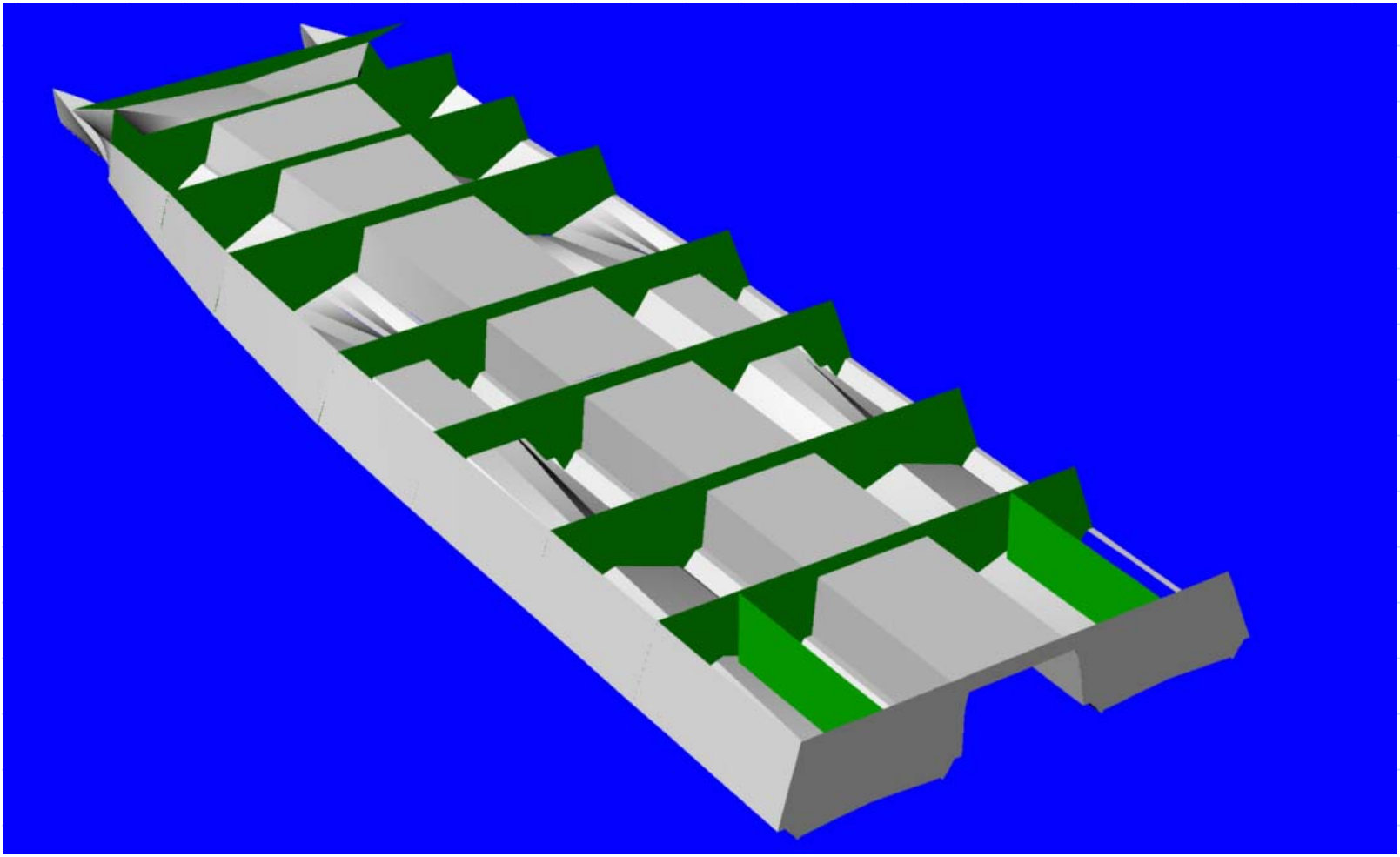
Reduced Wake Signature

Monohull Chase Boat

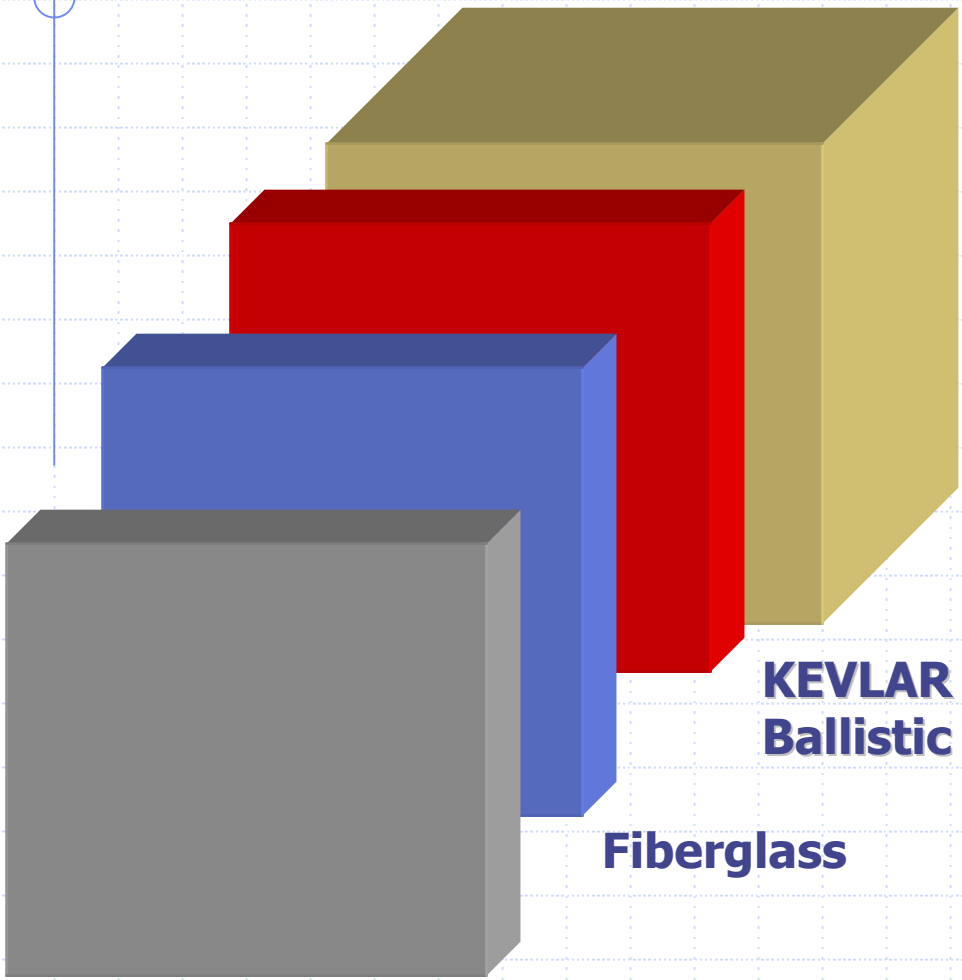
High L/B SES XR-5

Low Wake - reduced detectability

Survivability



Carbon Fiber Construction



Carbon Fiber for Structural Strength

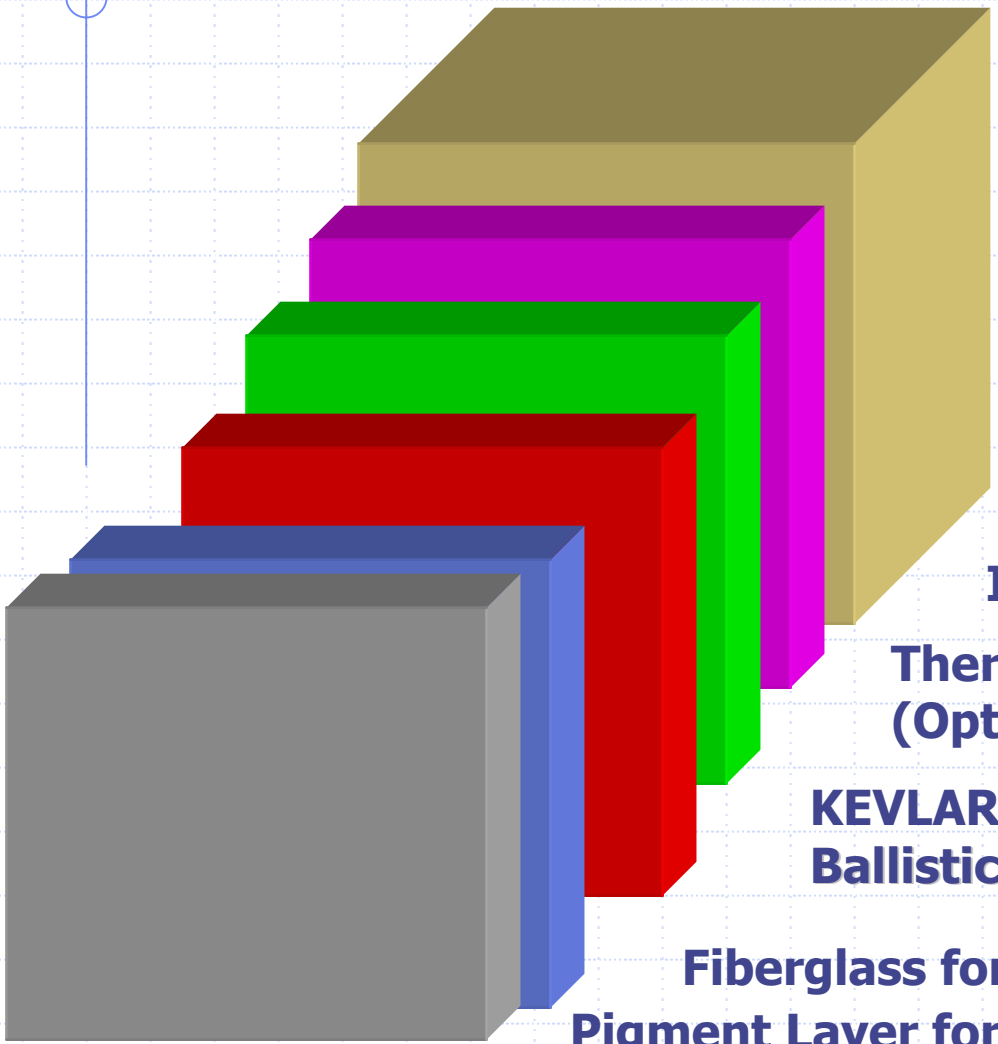
- 1/5 weight for same volume
- 3X stronger for same volume
- Highly corrosive resistant
- Safety factors of 3

KEVLAR for Impact Resistance and Ballistic Protection (Optional)

Fiberglass

Pigment Layer

Carbon Fiber Construction



Carbon Fiber for Structural Strength

- 1/5 weight for same volume
- 3X stronger for same volume
- Highly corrosive resistant
- Safety factors of 3

Insulator (Optional)

Thermal Shield - Silicon Based Polymer (Optional)

KEVLAR for Impact Resistance and Ballistic Protection (Optional)

Fiberglass for Carbon Fiber UV Protection

Pigment Layer for Life of Ship Color

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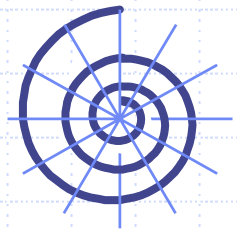


Propulsion

- Determine power requirements
- Research Specific Fuel Consumption (SFC) improvement
- Select prime movers
- Select propulsors
- Calculate weight and volume requirements
- Calculate fuel consumption (based on different speed profiles)
- Lay out plant

Power Requirements

Speed (kts)	Propulsion Horsepower	Power (MW)
10	16,400	12.2
15	42,300	31.5
20	68,200	50.9
25	94,100	70.2
30	125,300	93.4
35	146,700	109
40	171,000	127
45	210,000	156
50	222,400	166
55	236,200	176
60	251,000	187

Ship service power required

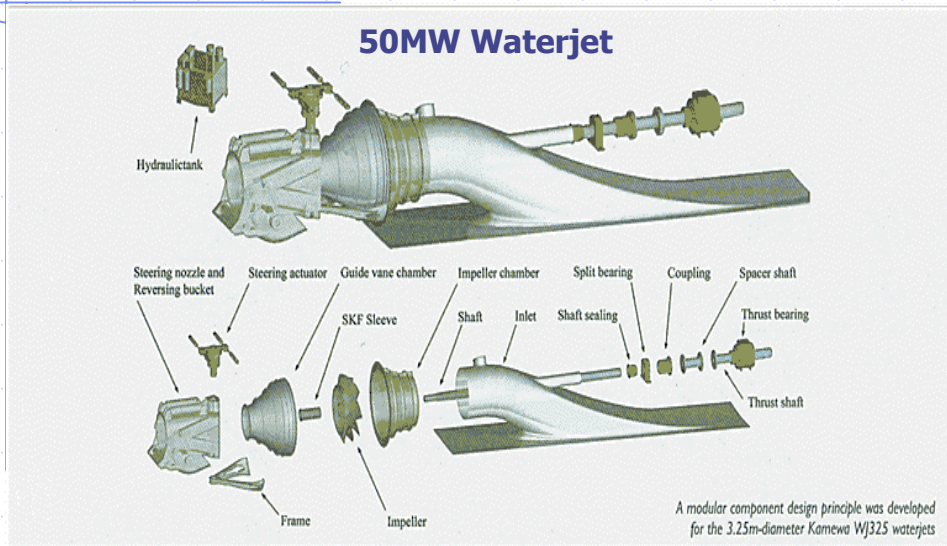
34MW (~46,000HP)

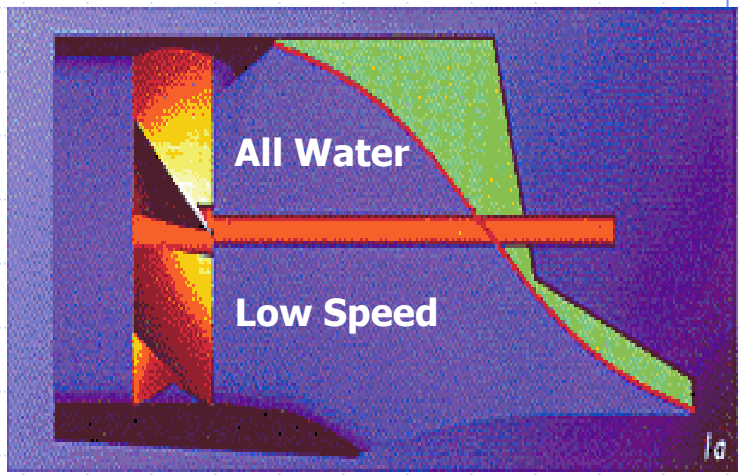
Total power required (~297,000HP)

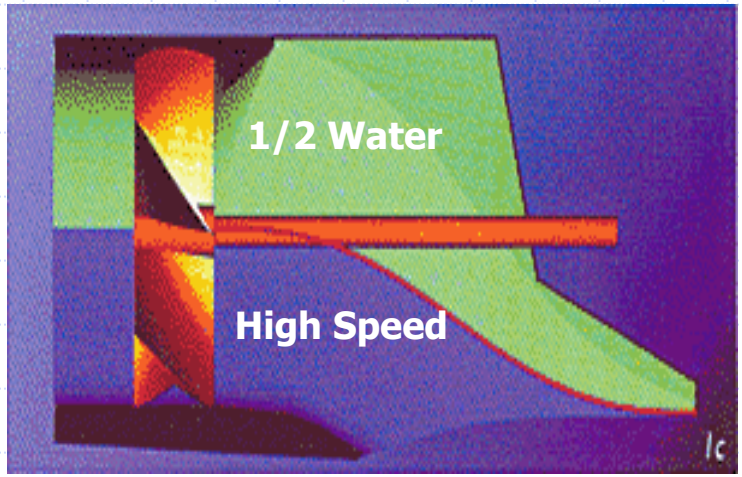
Equipment Selection

- **Engines**
  - **Trent 50 =>50MW (67,000HP)/eng;**
  - **Trent 30 =>36MW (48,000HP)/eng;**
- **Motors**
  - **36 MW Induction motor by Alstom**
- **Gears**
  - **36 MW Rolls-Royce**
  - **50 MW Philadelphia Gear**
- **Propulsors**
  - **36 MW Waterjet/Hydro-Air Drive**
  - **50 MW Waterjet/Hydro-Air Drive**

Propulsor Selection





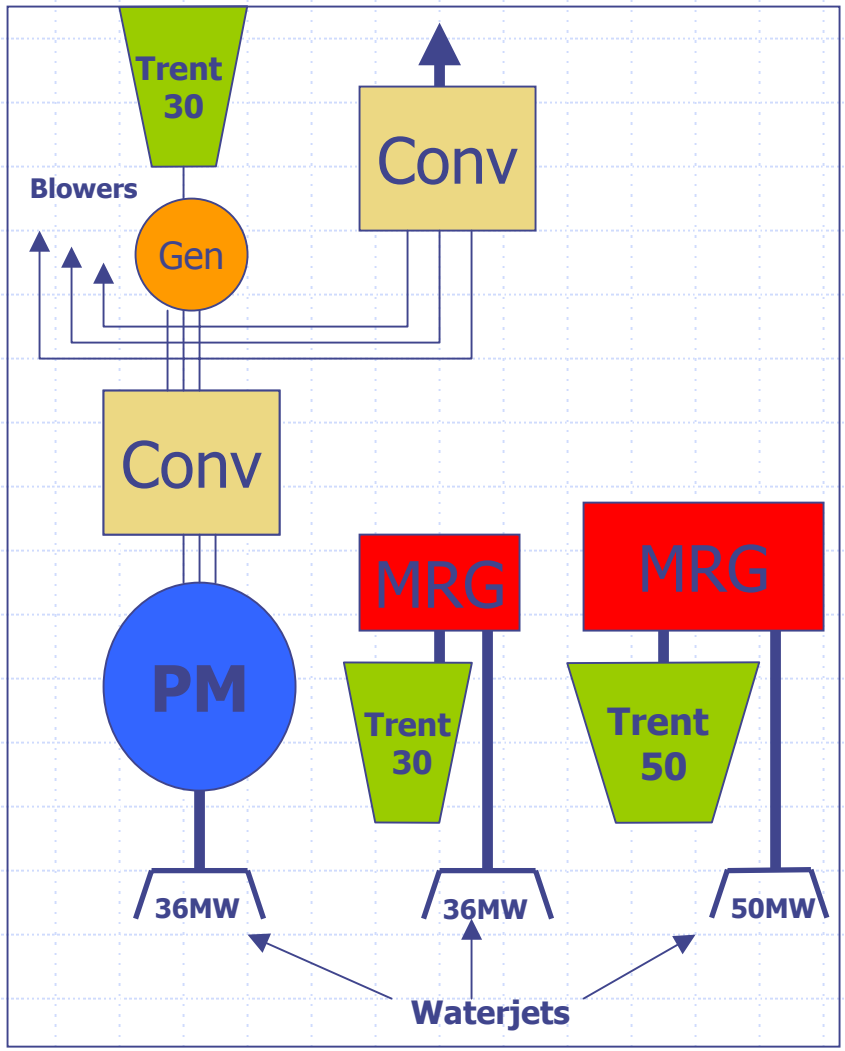


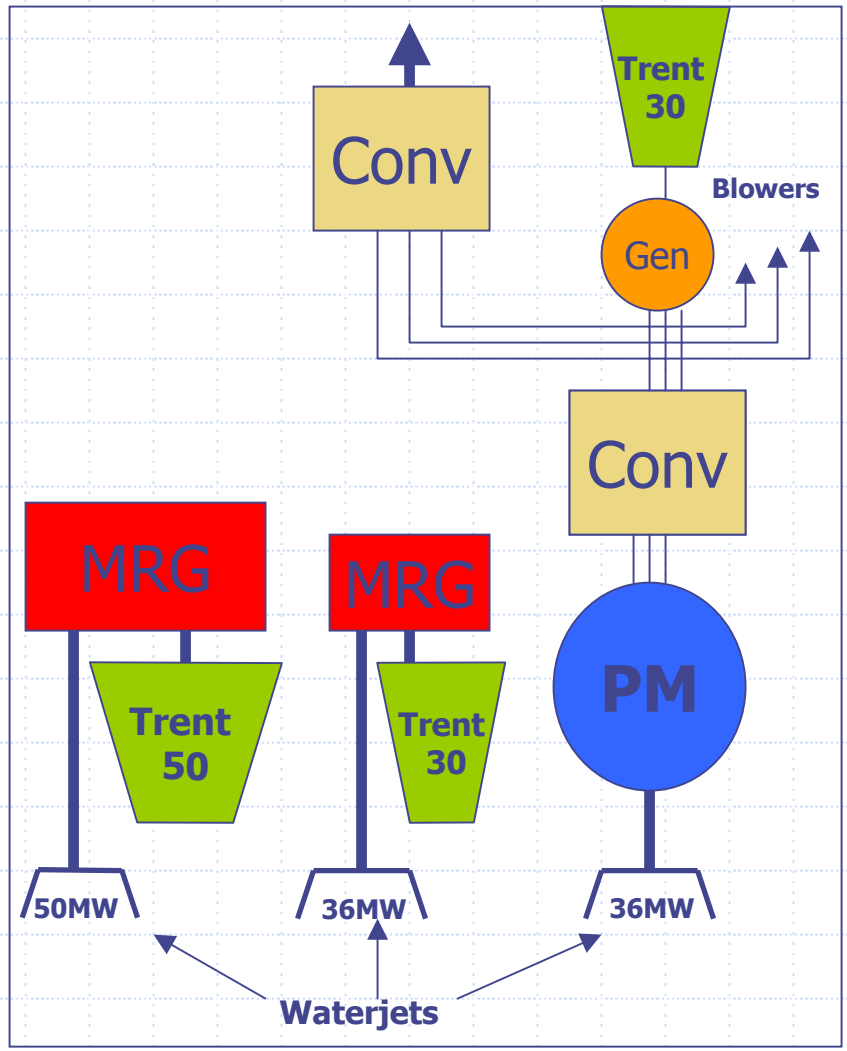
Weight/Volume Requirements

Device	# req'd	Weight (mT)	Volume (m^3)
Trent 50	2	76	490
Trent 30	2	52	245
Motor (36 MW)	2	210	221
Reduction Gear (36MW)	2	50	82
Reduction Gears (50MW)	2	91	117
Waterjets (36MW)	4	464	377
Waterjets (50MW)	2	604	220
Totals		**1547**	**1752**

Final Propulsion Option

Total Rated Power available 327,209 SHP (244MW)



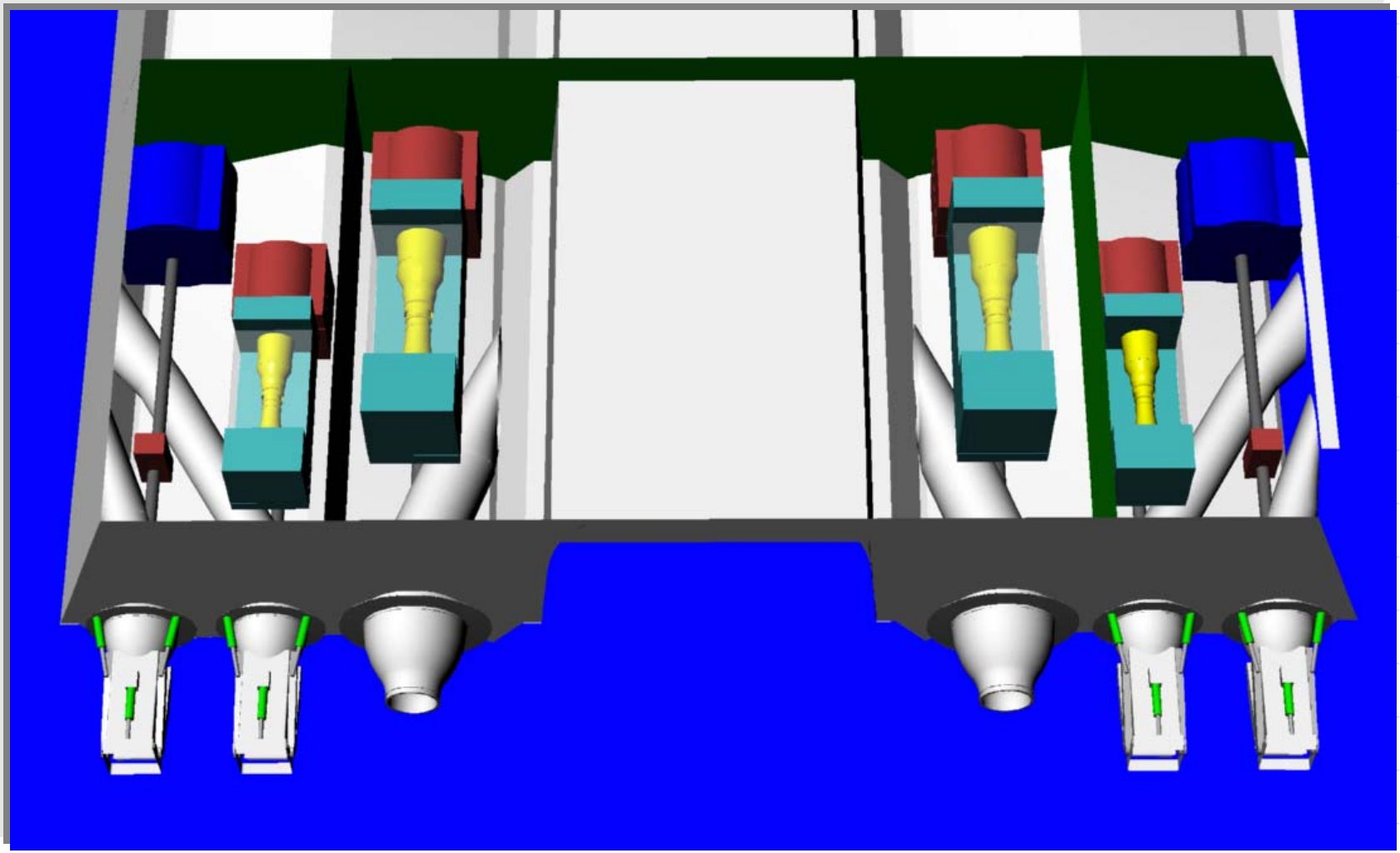


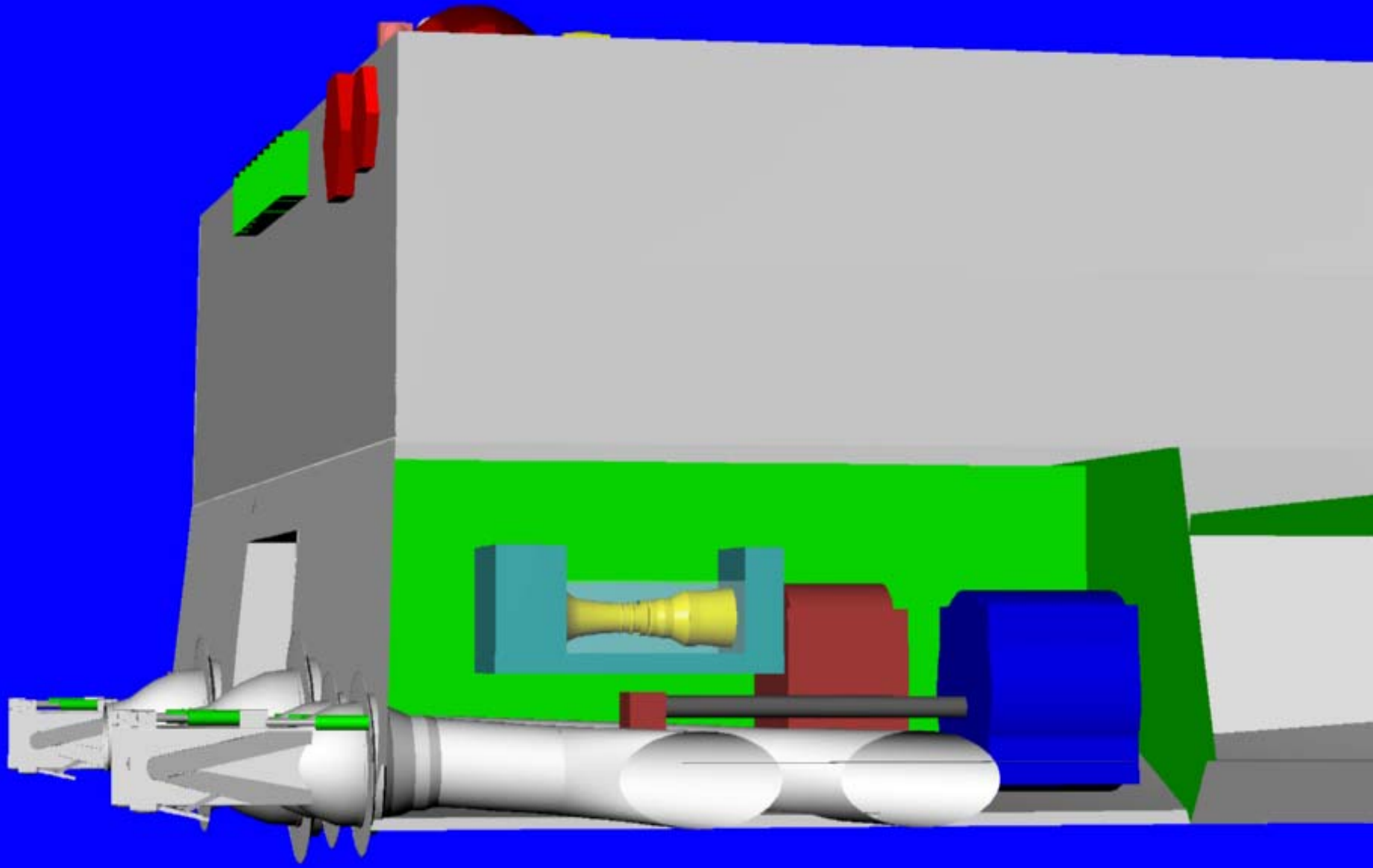
Fuel Requirements

Note: fuel calculations assume constant 34MW ship service load

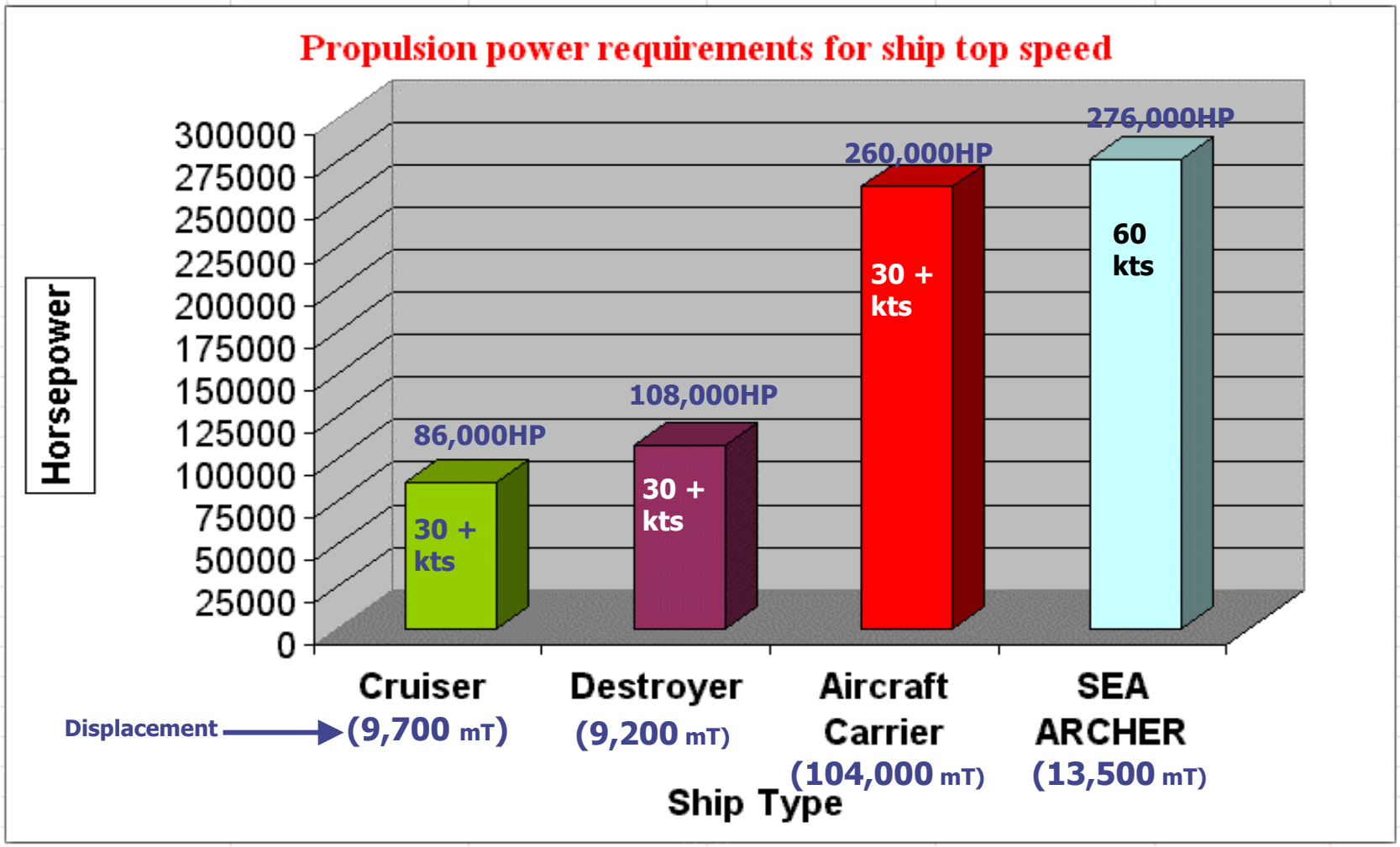
Speed Profile	Transit Fuel (mT) @ 40kts (threshold)	Transit Fuel (mT) @ 50kts (objective)	Oparea Fuel (mT) @ 15 kt loiter
Fuel burn @ 40kts for 94 hours	2585		
Fuel burn @ 50kts for 94 hours		3198	
Sea Lance Refuel	346	346	692
Refuel @ 20kts for 2 hours	29	29	
Fuel burn @ 20kts for 48 hours			694
Fuel burn @ 25kts for 24 hours			426
Fuel burn @ 60kts for 6 hours			226
Loiter @10 kts for 90 hours			
Loiter @15 kts for 90 hours			1004
Totals Fuel Burn	2960	3573	3042
Total Capacity with 20% remaining	3551	4288	3650

3-D Engine Room





Cost to Go 60 kts



CG

CVN

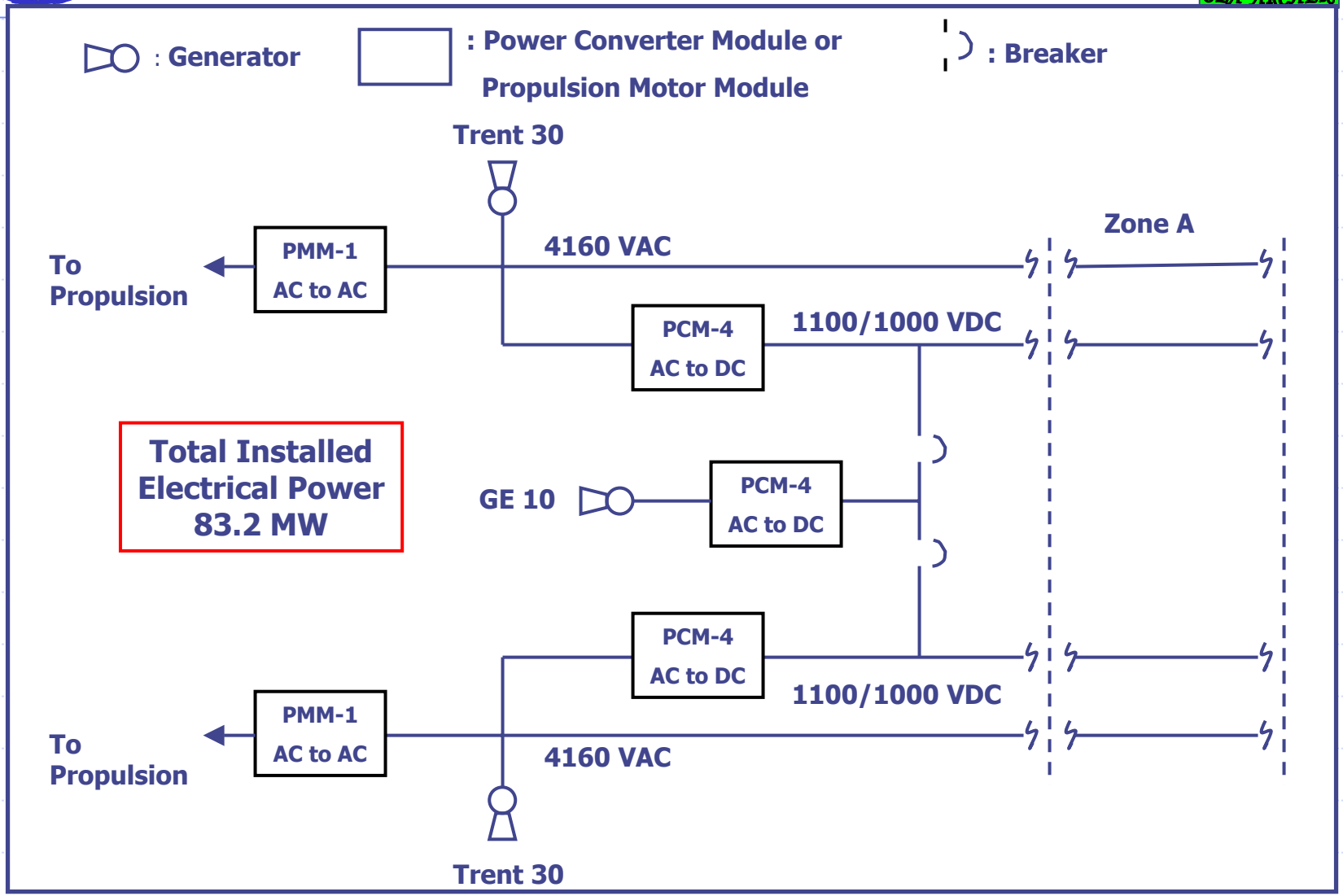
DDG

SEA ARCHER

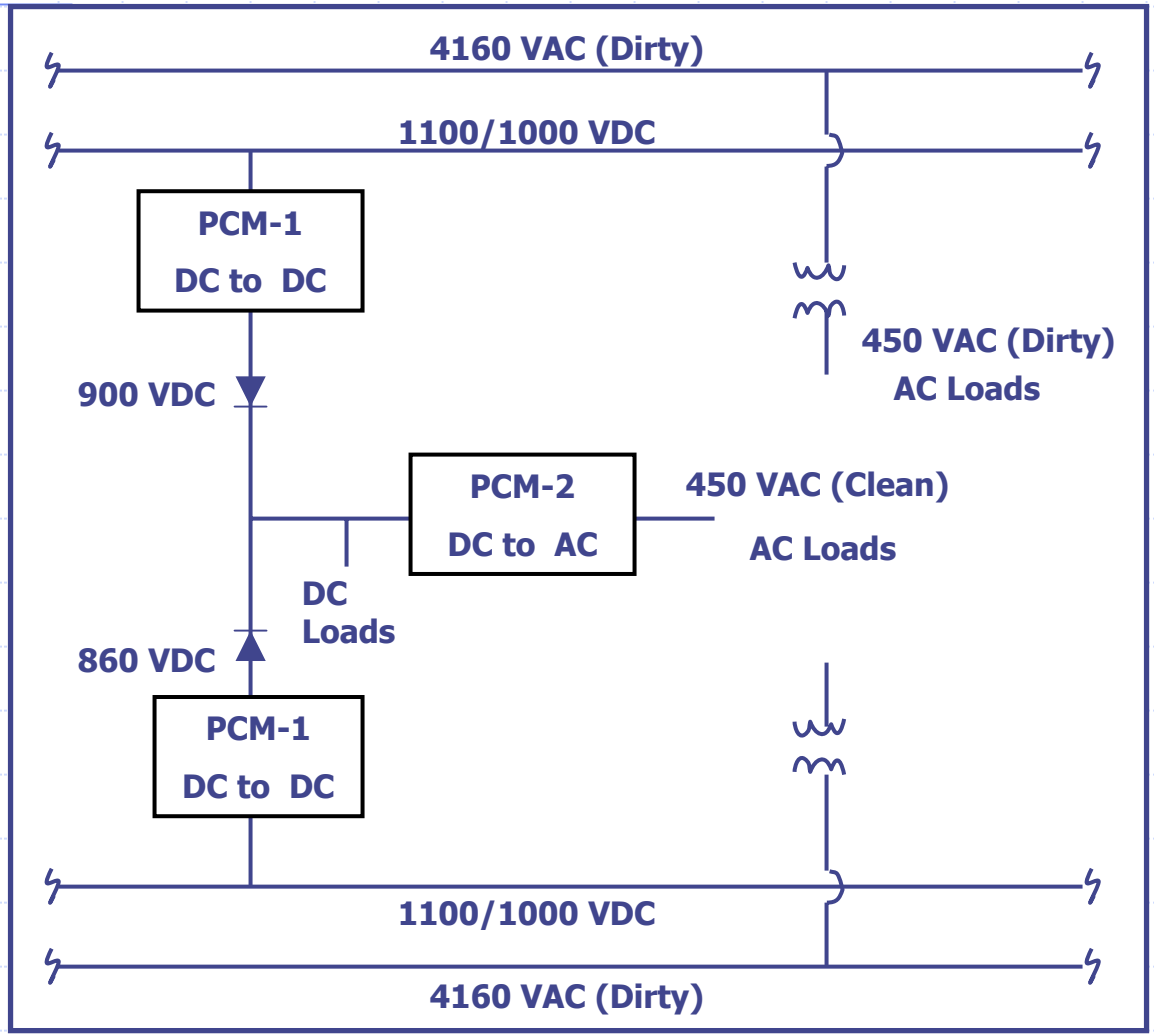
Electrical Overview

- Installed Electrical Power: 83.2 MW
  - 2 Trent 30s: 36 MW each
  - 1 GE-10: 11.2 MW
- Electrical Load: 34 MW
  - Up to 46 MW with intermittent loads
  - Excludes propulsion motor power requirements
- Modified AC & DC Zonal Architecture
  - Weight Savings
  - Ship may be fabricated and tested in zones
  - Fault detection simpler and faster/able to be zone isolated
- Hybrid Integrated Electric Drive (Hybrid-IED)
  - 2 of 6 propulsors are electric drive
- Superior Electrical/Propulsion Casualty Response
  - Can lose any 2 propulsion engines and still achieve 40 kts

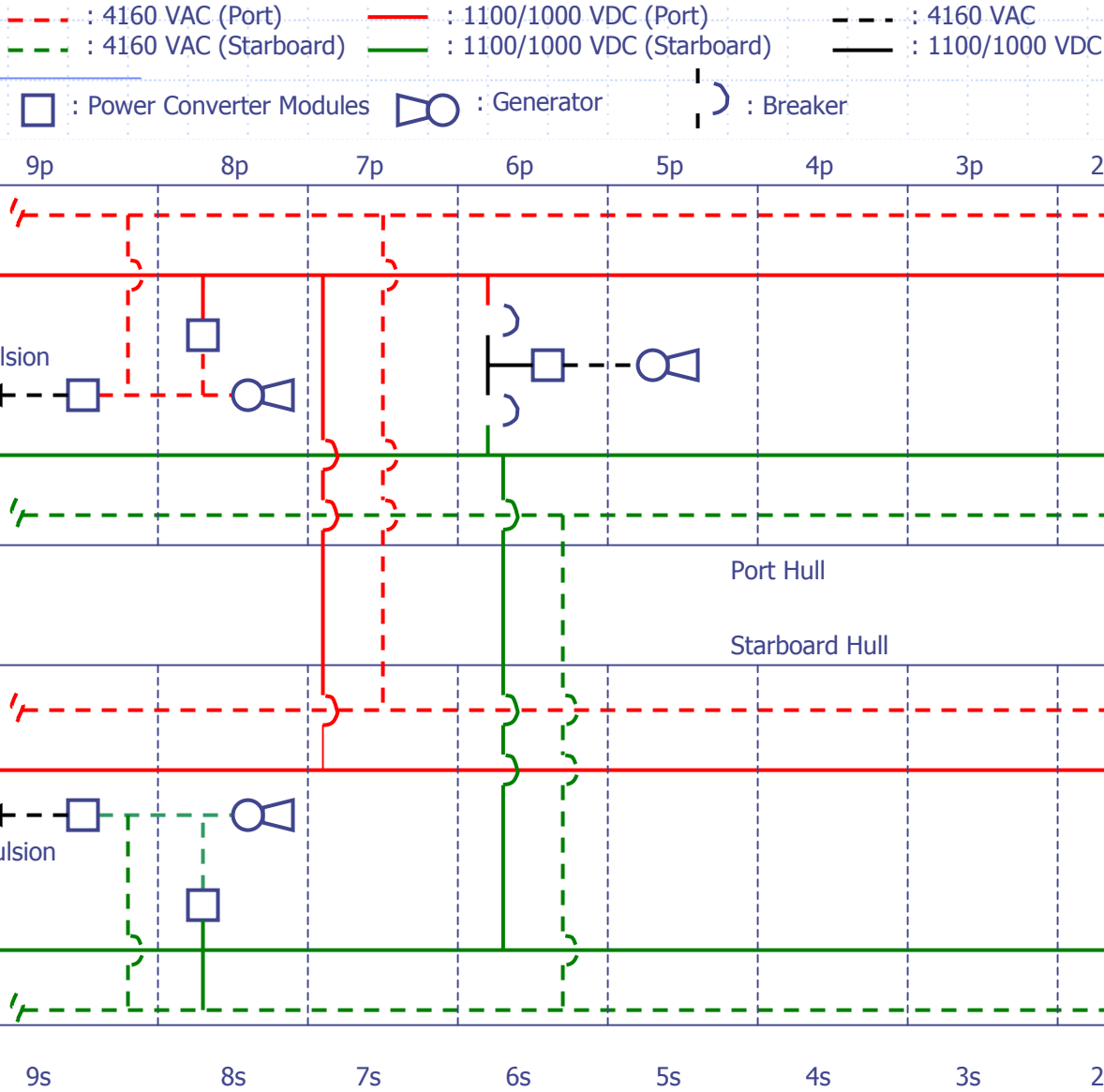
Source Configuration

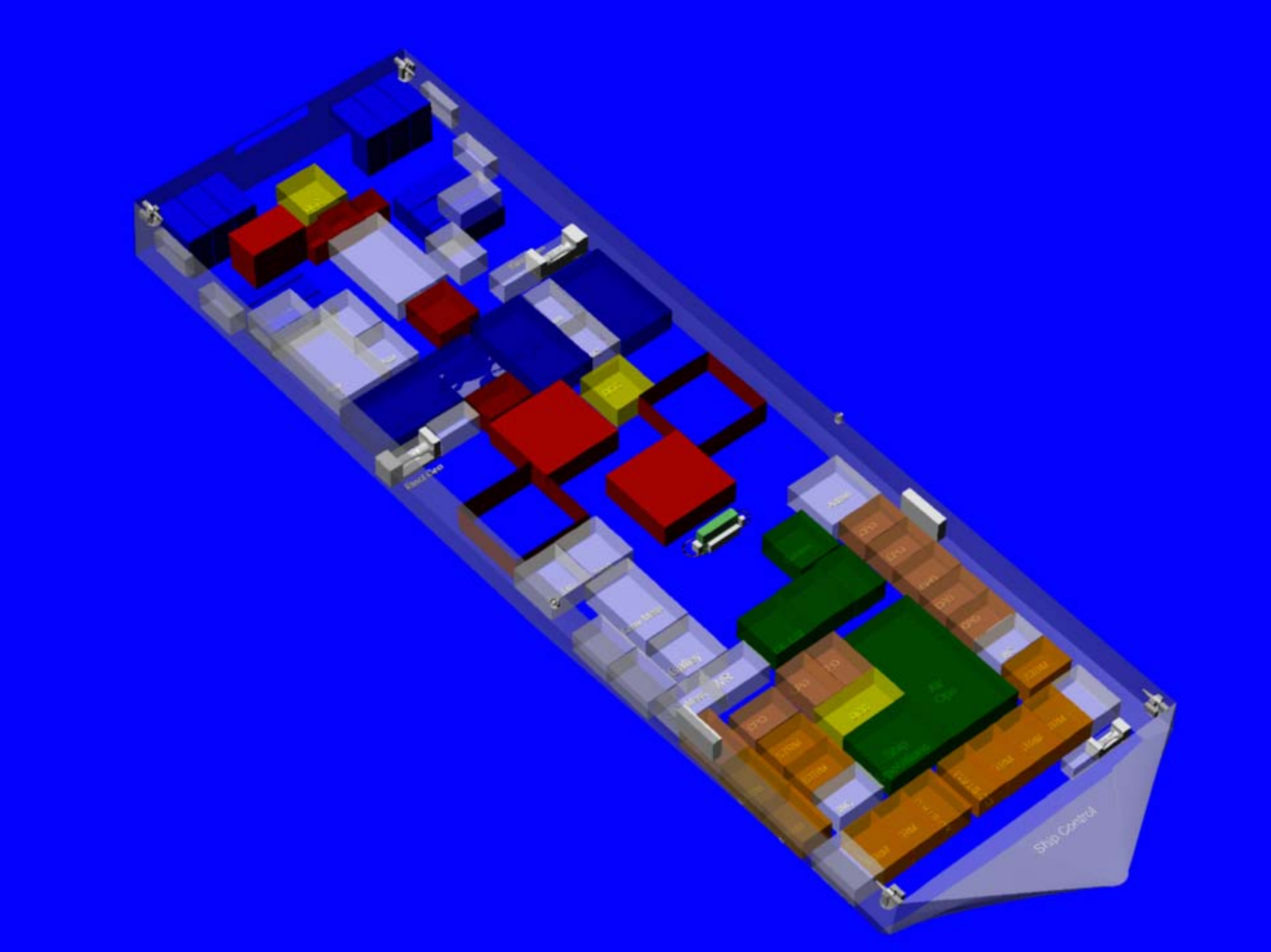


Zonal Configuration



Electrical Layout




Ship Control

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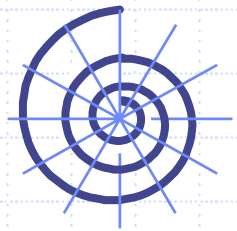
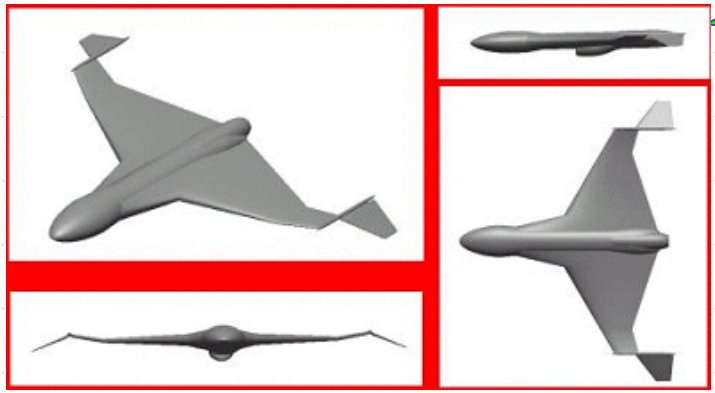


Aviation Assets

- 8 - SEA ARROW UCAVs
  - Weight - 15,000 lbs
  - Range – 465 nm
  - Payload – 1,500 lbs

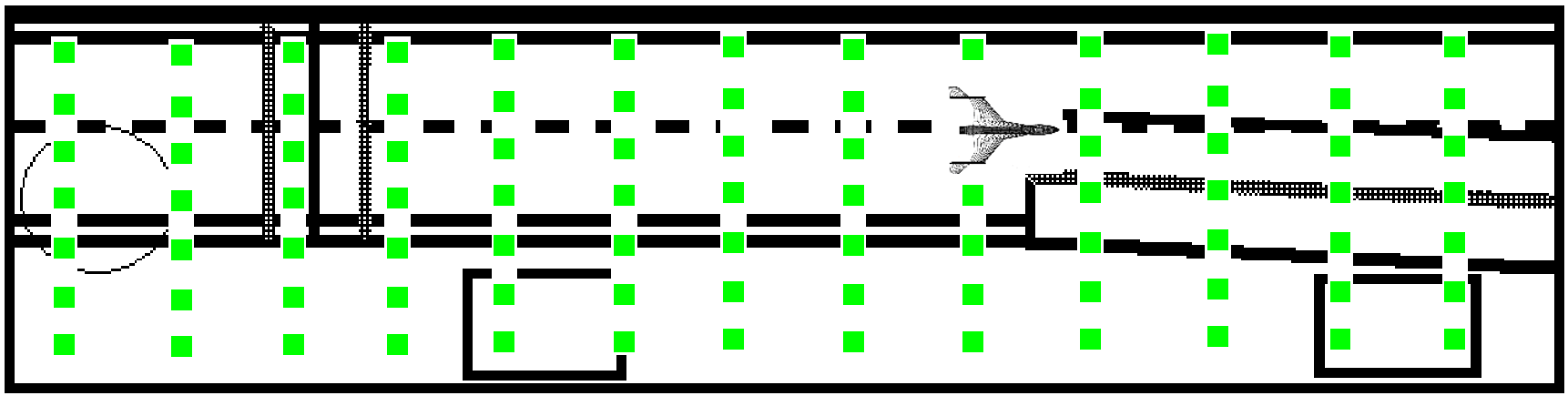


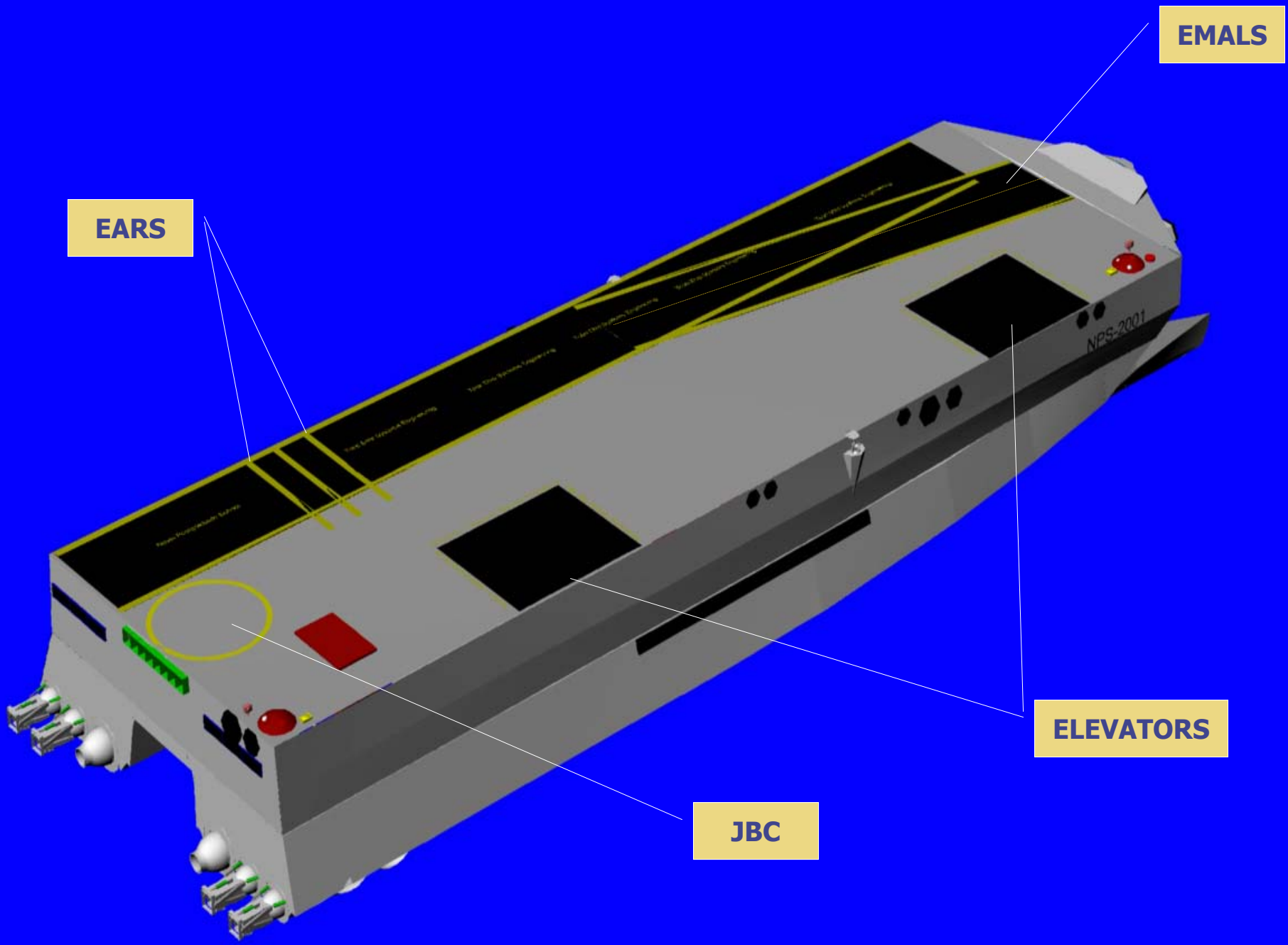
- 10 - Reconnaissance UAVs
  - Weight 5,000 lbs
  - Range – 1200 nm
  - Payload – 500 lbs

- 2 - SH-60 Helos
  - Weight – 23,500 lbs
  - Range – 380 nm
  - Payload – 4,100 lbs

Flight Deck Layout

- One EMALS catapult
  - Unassisted a/c launch for wind over deck > 40kts
- Two EARS wires, barricade
- Two aircraft elevators
- Jet Blast Collector (JBC)



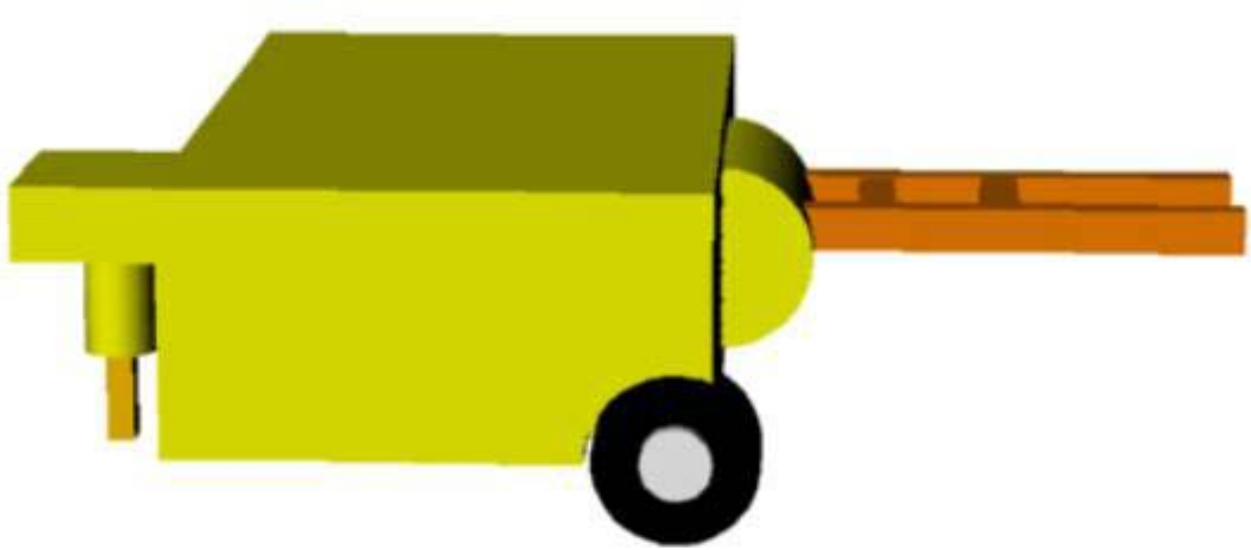

EMALS
EARS
NPS-2001
ELEVATORS
JBC

Towbot – Topside A/C Movement

- Four towbots onboard
- Diesel-powered, 730 kg
- Computer-controlled
- Electromagnetic tie-down capability

Trackbot – Hangar Bay A/C Movement

- 22 Trackbots onboard
- Electric-powered through track, 460 kg
- Same computer-control & tie-down capability as Towbots

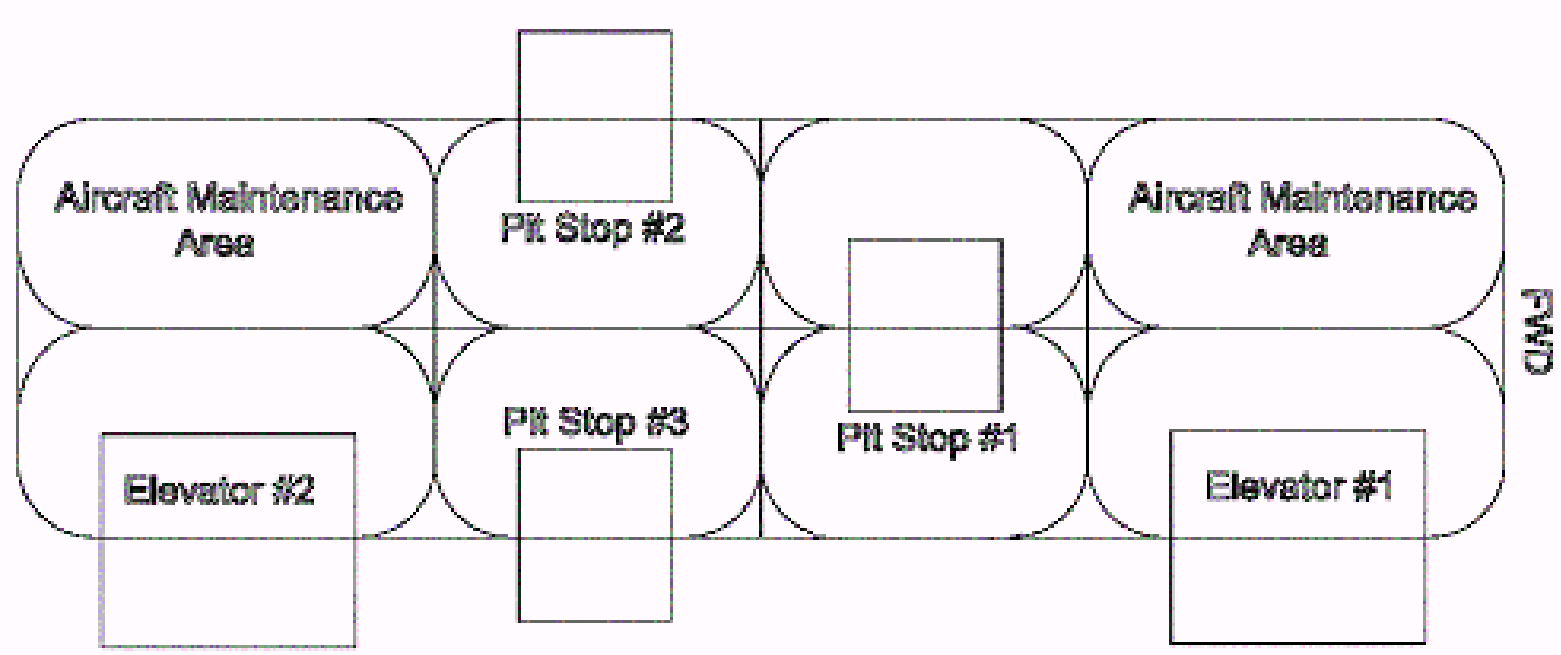


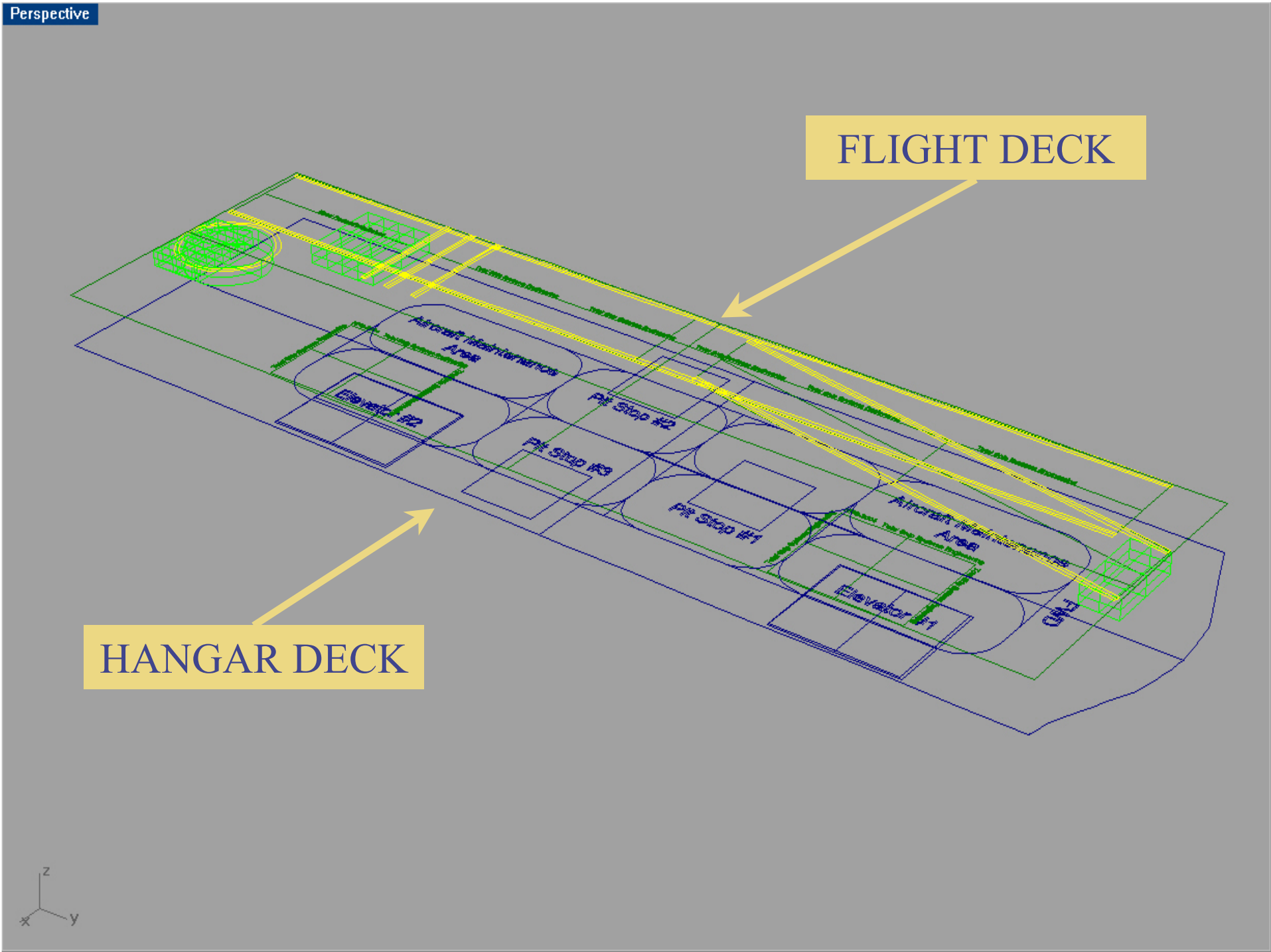
Other Robots

- Chainbots--secure main gear
  - 44 Chainbots onboard
  - Battery-powered, 115 kg
- Flight Deck Firefighting Robot
  - One onboard
  - Diesel-powered, 1600 kg
  - Water cannon & 760-liter AFFF tank
  - Bulldozer-type blade on front

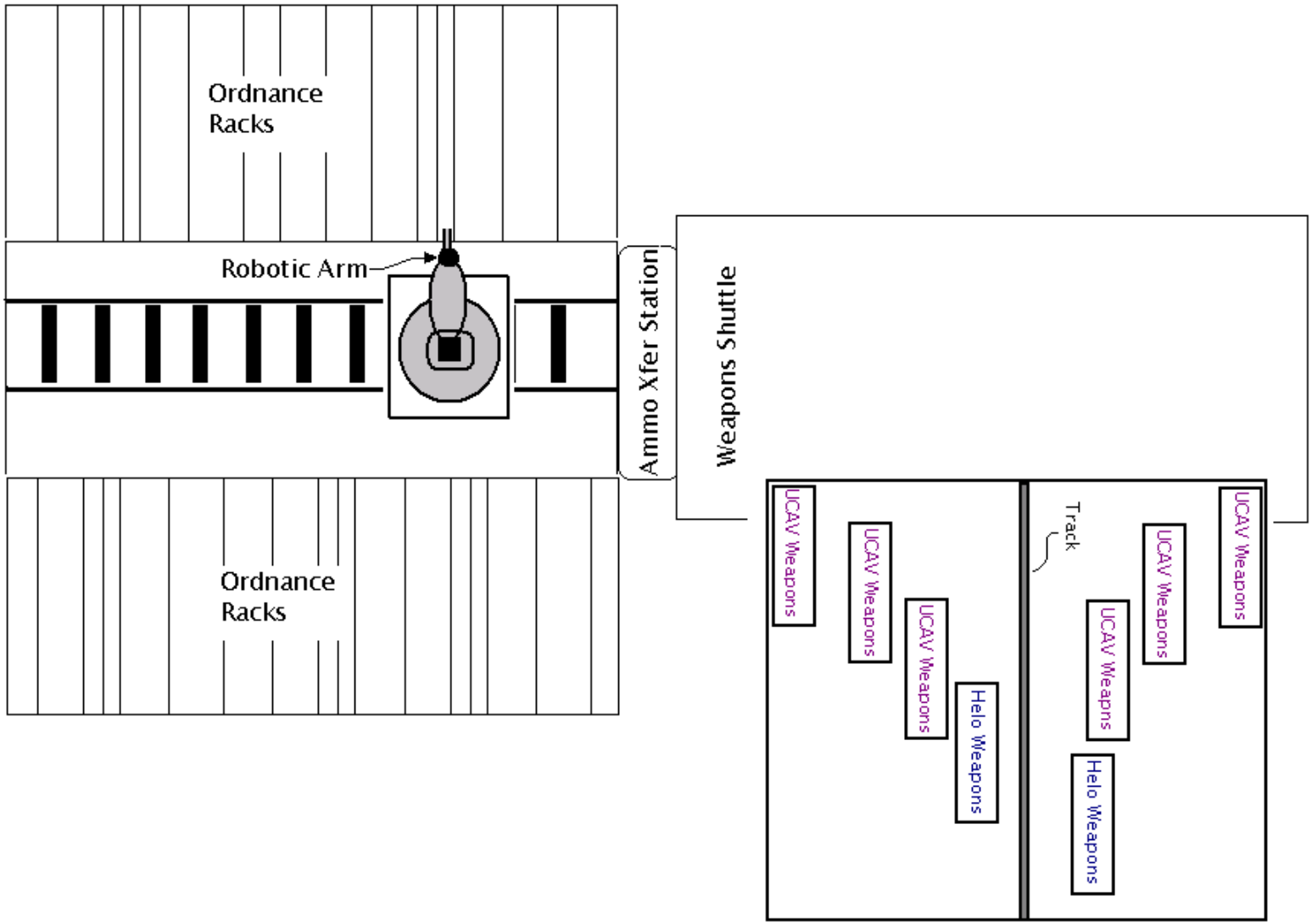
Hangar Bay Layout

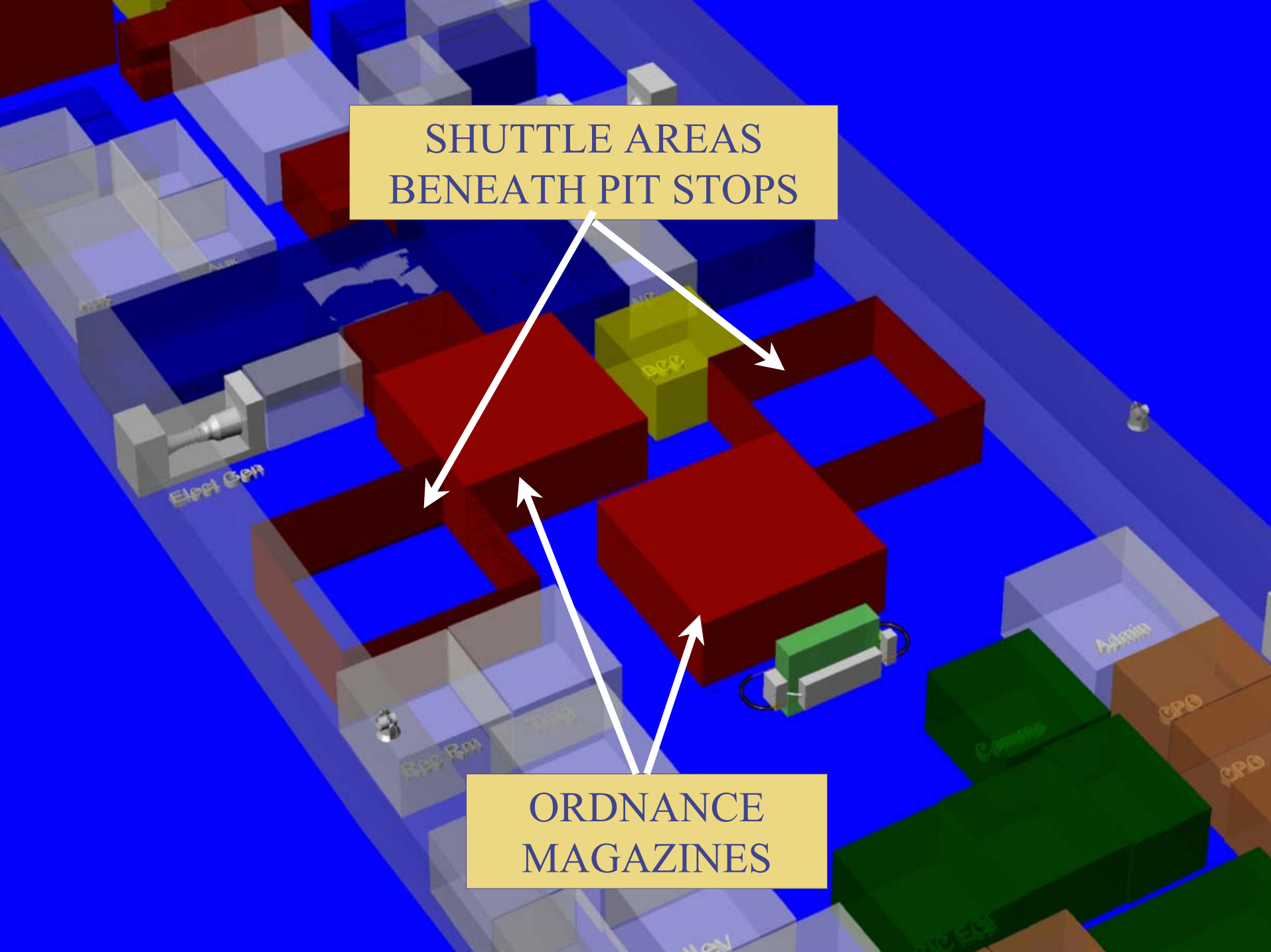
- Totally enclosed
- 3 pit stops
  - Overhead refueling rig
  - Automated ordnance mounting from below
- 2 Maintenance Areas




Perspective
FLIGHT DECK
HANGAR DECK
Aircraft Maintenance Area
Elevator #2
Pit Stop #2
Pit Stop #3
Pit Stop #1
Aircraft Maintenance Area
Elevator #1
z
x
y

Ordnance Handling System




SHUTTLE AREAS
BENEATH PIT STOPS
ORDNANCE
MAGAZINES
Elect Gen
DCC
Admin
CPO
CPO

Ordnance Payload –118 mT

% of Missions	Type of Mission	% Ordnance Expended
25%	Multipurpose	75%
20%	Battlefield Interdiction	100%
20%	Suppression of Enemy Air Defenses	100%
15%	Close Air Support	100%
10%	Combat Air Patrol	25%
10%	Marine Patrol	25%

Presentation Outline

Introduction

Requirements

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Hull

Propulsion/Electrical

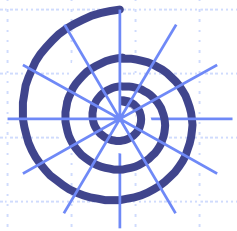
Aviation Systems

Combat Systems

Damage Control/ Habitability

Total Ship Evaluation

Conclusion



Combat Systems

"***Connectivity*** *must include* ***seamless integration*** *of both* ***organic*** *and off-ship* ***sensor inputs*** *for power projection actions….. In a fully* ***Network Centric Warfare*** *(NCW) enviornment."*

- Enhanced Cooperative Engagement Capability
- Enhanced Ship Self Defense System
- Integrated Weapons Control System

Shipboard Sensors

*"Central to the threat's defensive plan is the early **identification** and rapid **denial** in the littorals"*

- **Volume Search Radar**
  - 3-D L-Band
  - Search, detect and track aircraft, missiles and UAVs
  - Air traffic control for UCAV
  - Provide target cueing to the MFR.
  - 250 km detection range for aircraft
- **Multi-Function Radar**
  - Scaled SPY 3
  - 3-D X-Band optimized for air & surface
  - Fire control radar capability
  - Missile uplink and midcourse guidance
  - 70 km detection range for missile

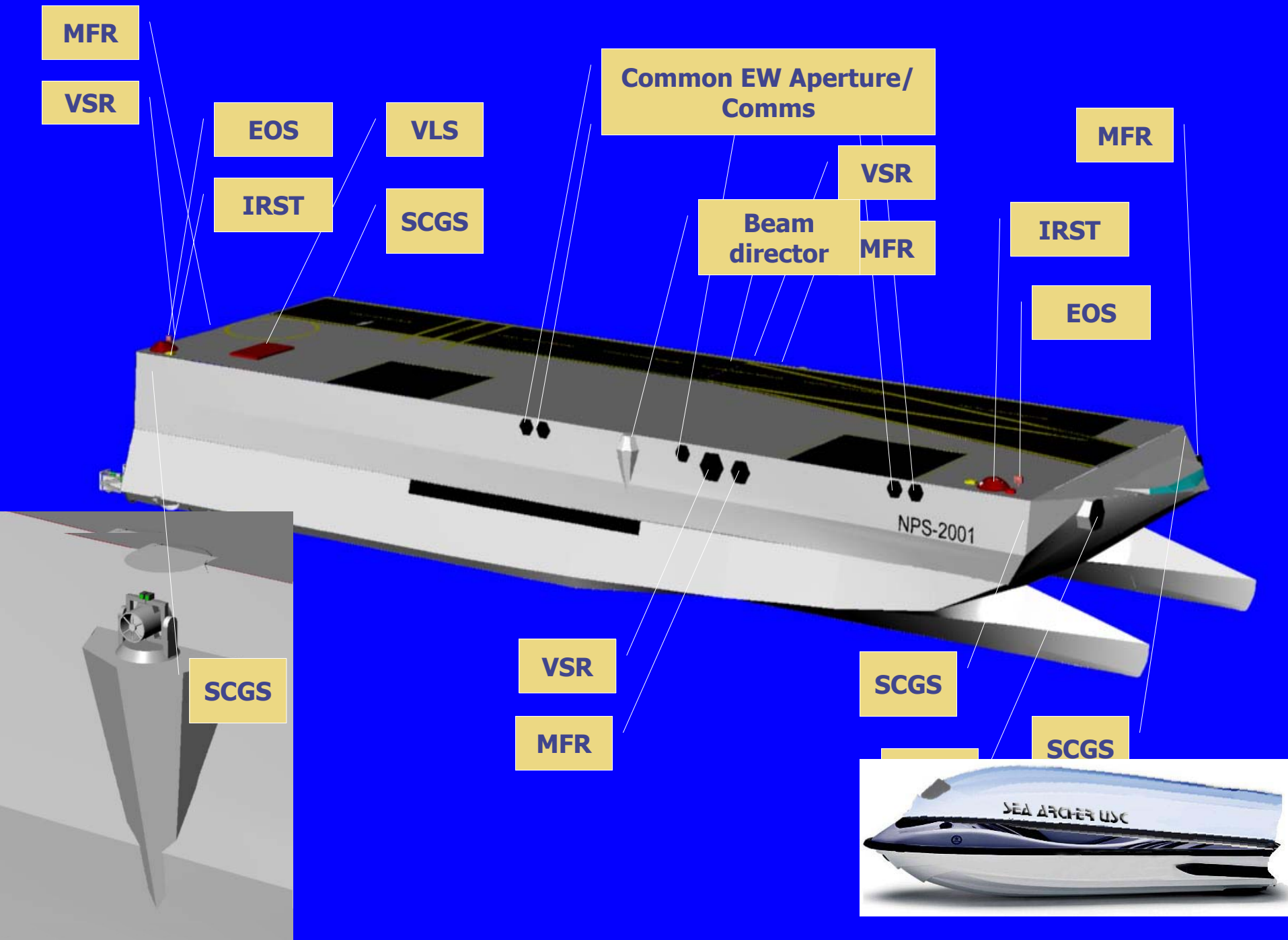
Shipboard Sensors

- **SLY-2 Advanced Integrated Electronic Warfare System (AIEWS)**
  - Integrates softkill & decoys
  - Active jammer
- **Infra Red Search & Track System (IRST)**
  - Early warning for Anti-Ship Cruise Missiles (ASCM)
  - Dual band

- **Electro Optical Systems**
  - Night & day capable
  - TV/thermal imager/LRF
  - Secondary weapon director

Offboard Sensors

- **UAV / SEA ARROW**
  - Radar
  - Electro Optical Systems
- **Helicopters**
  - Light Detection & Ranging (LIDAR) – Mine Detection
  - Towed sonar suite
- **Unmanned Surface Craft (USC)**
  - Mine detection suite
  - Electro optical sensors


MFR
VSR
EOS
IRST
VLS
SCGS
Common EW Aperture/ Comms
Beam director
VSR
MFR
MFR
IRST
EOS
NPS-2001
SCGS
VSR
MFR
SCGS
SCGS
SEA ARCHER USC

Shipboard Weapons

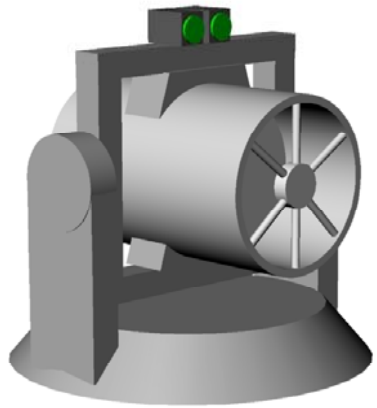
"Denying enemy's targeting sequence through.. ***Enhanced Anti-Ship Missile Defense (ASMD), Cruise Missile Defense, Anti-Submarine Warfare (ASW), and Mine Counter Measure (MCM)."***

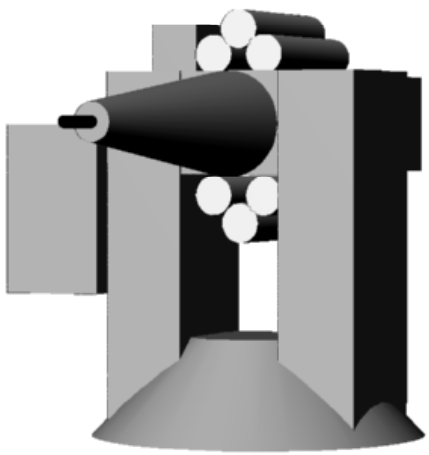
- **Vertical Launch System**
  - 16 cell launcher
  - Provide 360 coverage
- **Super Sea Sparrow Missiles**
  - Quad pack per cell (total 64 missiles)
  - Anti-Surface & Anti-Air capable
  - 30 km range
  - Multimode seeker
    - Active Radar, IR, Home on Jam (HOJ), Laser Guided
  - Dual mode fuse – proximity, delayed impact
  - Selectable target point

Shipboard Weapons

"Operate primarily in the littoral environment "

- Free Electron Laser
  - 1 μm wavelength
  - 1.5 MW beam
  - Maximum effective range 5 to 8 km
  - 2 beam directors (port & starboard)
  - Up to 20 targets before recharging



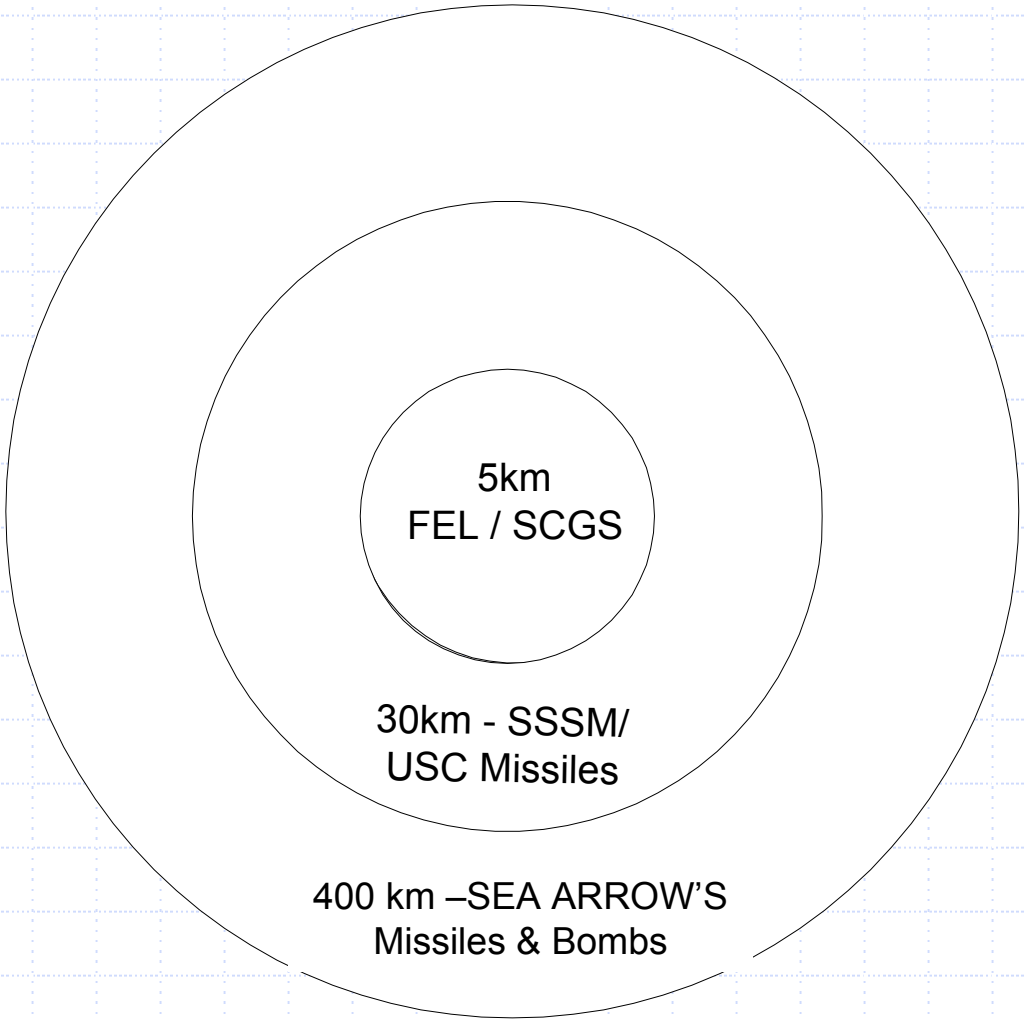


- Small Caliber Stabilized Gun System
  - 30mm Chain Gun
  - 200 ready to fire rounds
  - Stabilized with auto target tracking
  - Decoy launchers attached – Nulka, Chaff, IR
  - Electro Optical Sights night & day operation

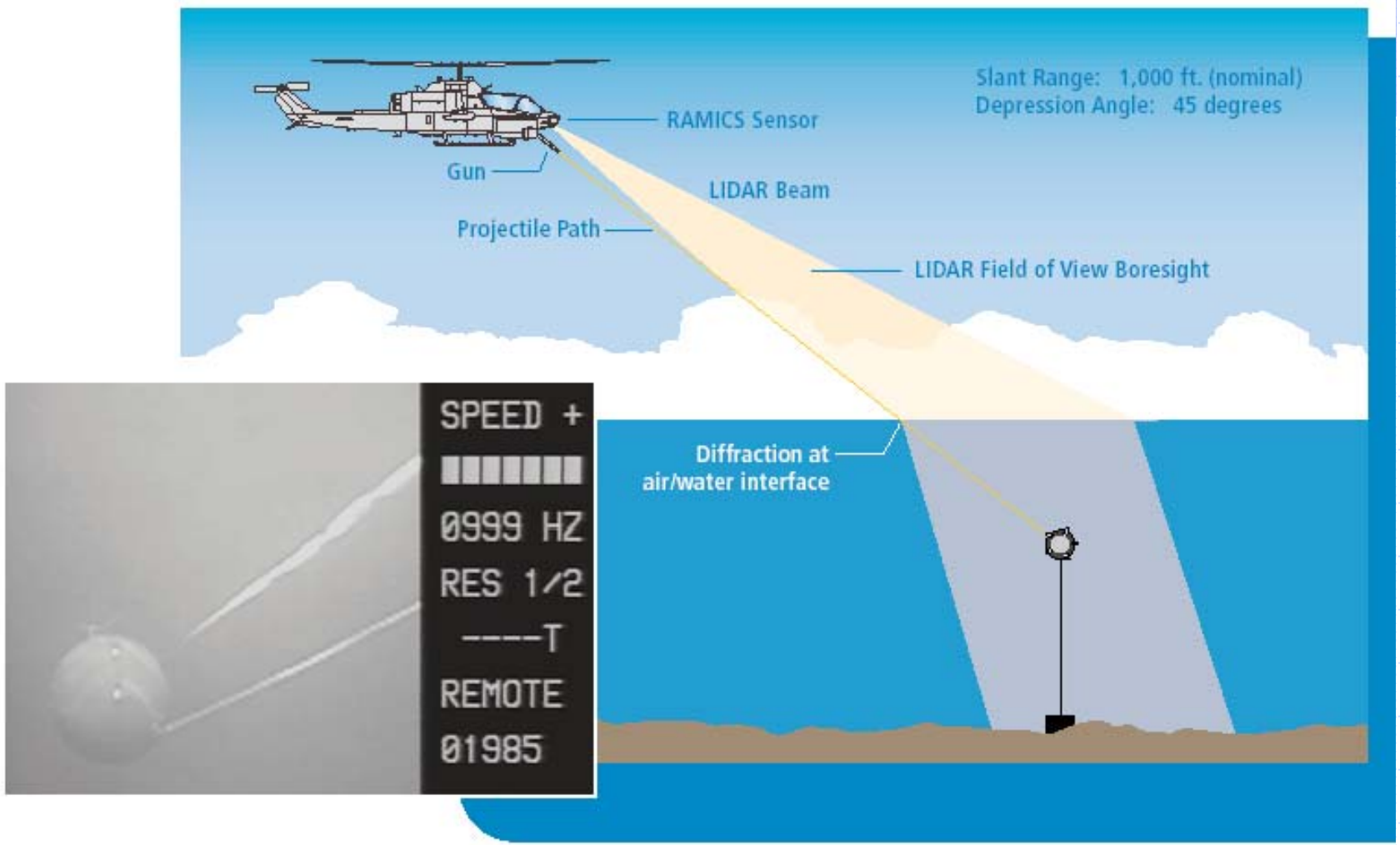
Offboard Weapons

- SEA ARROW
  - Air to Air Missiles
  - Laser guided bombs
  - Anti-Ship missiles
- Helicopters
  - Rapid Airborne Mine Clearance System (RAMICS)
  - Torpedoes
  - Penguin Missiles
- Unmanned Surface Craft
  - Anti-Surface/Air capable Stinger missiles

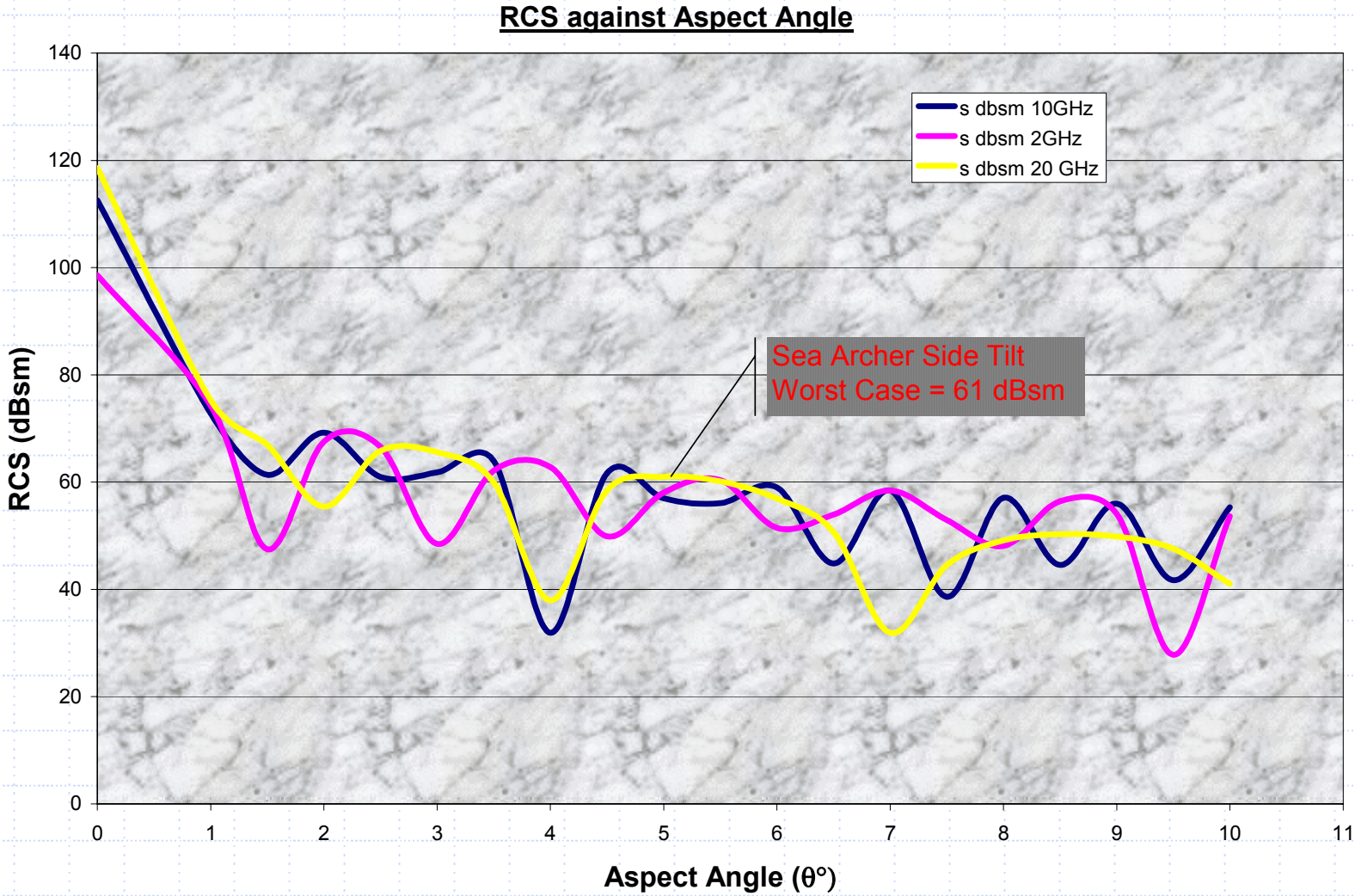
Layered Defense for SEA ARCHER



RAMICS Concept



Radar Cross Section



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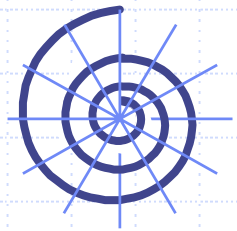


Damage Control

Automated Damage Control System (ADCS) for reduced manning

- Detection System
- Data Network, Processing Centers, and Evaluation Tools
  - Personal Locator Device Network
- Control Station Display and Interface
- Isolation System
- Reactive System

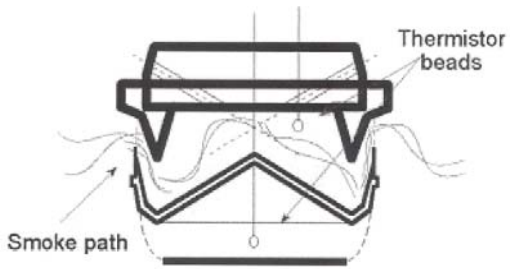
Detectors

- Triple Wavelength Infra-Red Detectors (3IR) for flame detection
- Closed Circuit Television (CCTV) system for smoke and flame detection
- Smart Microsensors for determining the composition of the air, gases

Detectors (continued)

- Humidity detectors
- Liquid level detectors
- Fiber Optical (FO) and High Performance Optical (HPO) detectors for heat detection

High Performance Optical Detector



Detectors Onboard

Compartment	3IR	CCTV	HPO	FO	Smart	Humidity	Liquid Level
Machinery spaces	X	X	X	-	X	-	X
Engine enclosures	X	-	X	-	X	-	-
Magazine areas	-	-	-	X	X	X	X
Electronics equipment rooms	X	-	-	X	X	X	-
Hangar	X	X	-	-	X	-	-
Flight deck	-	X	-	-	-	-	-
CIC	X	-	-	X	X	-	-
Bridge	-	-	X	-	X	-	-
Accommodations	-	-	X	-	X	-	-
Kitchens&Galley	-	-	X	-	X	-	-
Offices	-	-	X	-	X	-	-
Passageways	-	-	-	-	X	-	-
Paint lockers	-	-	-	-	X	-	-
Pump rooms	-	-	-	-	X	X	X
A/C&Refrigeration rooms	-	-	-	-	X	X	-

Fire Suppression Systems

- FM-200 Fire Suppression System
- Carbon Dioxide Fire Suppression System
- Water Mist System
- Aqueous Film Forming Foam (AFFF) System

Fire Suppression Systems Onboard

Compartment	FM 200	CO_2	Water Mist	AFFF
Machinery spaces	--	--	X	X
Engine enclosures	--	X	--	--
Magazine areas	--	--	--	--
Electronics equipment rooms	X	--	--	--
Hangar	--	--	X	X
Flight deck	--	--	--	X
CIC	X	--	--	--
Bridge	X	--	--	--
Accommodations	X	--	--	--
Kitchens&Galley	X	--	--	--
Offices	X	--	--	--
Passageways	X	--	--	--
Paint lockers	--	X	--	--
Pump rooms	--	X	--	--
A/C&Refrigeration rooms	--	X	--	--

Personnel Locator Device

- PLD
  - Bracelet
  - Electronic device
  - Transmits the identity of the crewmember
  - Personnel location
  - Personnel paging
  - Emergency notification

Damage Control

- Habitability deck is the DC deck
- Three damage control zones
- One DC party for each DC zone and a flight deck damage control party
- Two fire-resistant curtains in the hangar bay
- Safety area on the flight deck
- Fire suppression robot
- Flooding control and dewatering systems

Probable Fire Fighting Scenario

- FIRE
- Fire detection by the detectors
- Display on the monitors
- Reroute the ventilation and electric power
- Check if there is any personnel in the compartment via PLD network
- Open/close the hatches within the fire/smoke boundary
- Fire suppression by the automated fire suppression system
- Power the fire main pumps in that zone
- DC party engagement

Probable Damage Control Scenario

- Incoming missile detection by the sensors
- Reroute the ventilation and electric power
- Close/open the hatches within the fire/smoke boundary
- Fire suppression by the automated fire suppression system
- HIT
- DC party engagement
- Detect which equipments are lost

Chemical Biological and Radiological System (CBR)

- Capable to launch and recover the aircraft in all types of CBR contaminated environments
- Long-range detection systems
- Portable detection systems
- CBR protective clothes at each damage control locker and hangar bay
- Collective protection system for the manned areas
- Decontamination of the aircraft in the elevators

Auxiliary Systems

Will provide:

- Improved reliability/maintainability of fluid, electrical, and mechanical systems
- Support for reduced manning through automation of operation and maintenance

Innovation Examples

Magnetic sensor

- On all electrical equipment
- Detect the power consumption
- Provide information if there is any other failure, whether the equipment is damaged or not

Variable speed pumps

- Reduce the weight
- Reduce maintenance
- Reduce power
- Increase efficiency

Habitability

Food service

- Cook/chill technology
- One galley for food preparation
- Reduce trash maintained onboard
  - Biodegradable meal containers

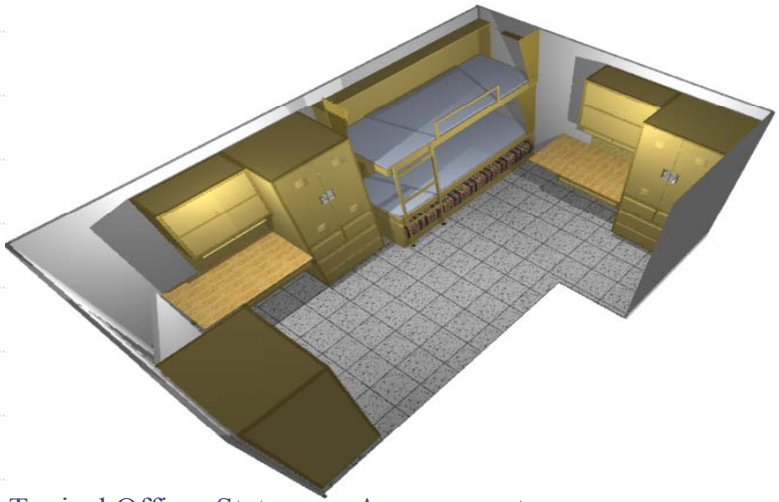
Habitability

- Shipboard Wide Area Network (SWAN)
  - All staterooms have LAN (classified access)
- Self-service crew services
  - Laundry
  - Ship's store, etc.

Accommodations

- Accommodations for mixed-gender crews at sea
- Workload reductions
  - Wax-less floors
  - Endurance paints
  - Paint-less surfaces

Habitability



Typical Officer Stateroom Arrangement

Sit-up Berth

Typical CPO Stateroom Arrangement

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Total Ship Evaluation

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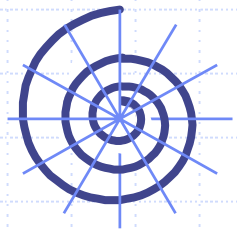
Combat Systems



Analysis of Alternatives

Aviation Systems

Hull

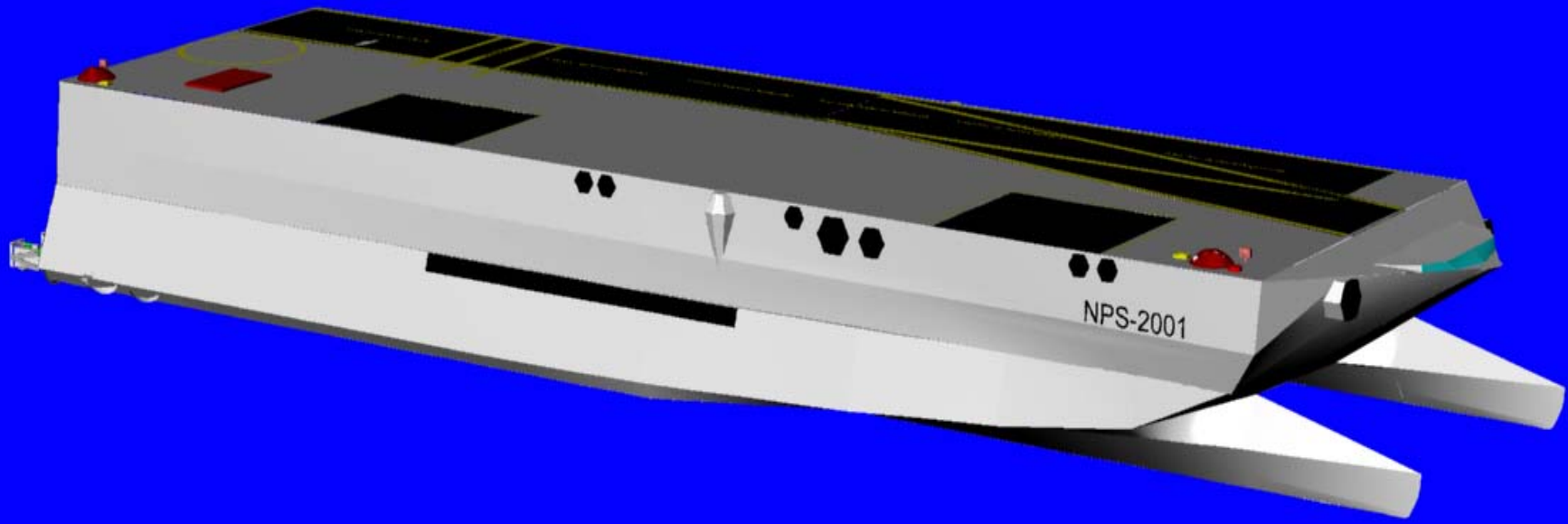
Propulsion/Electrical

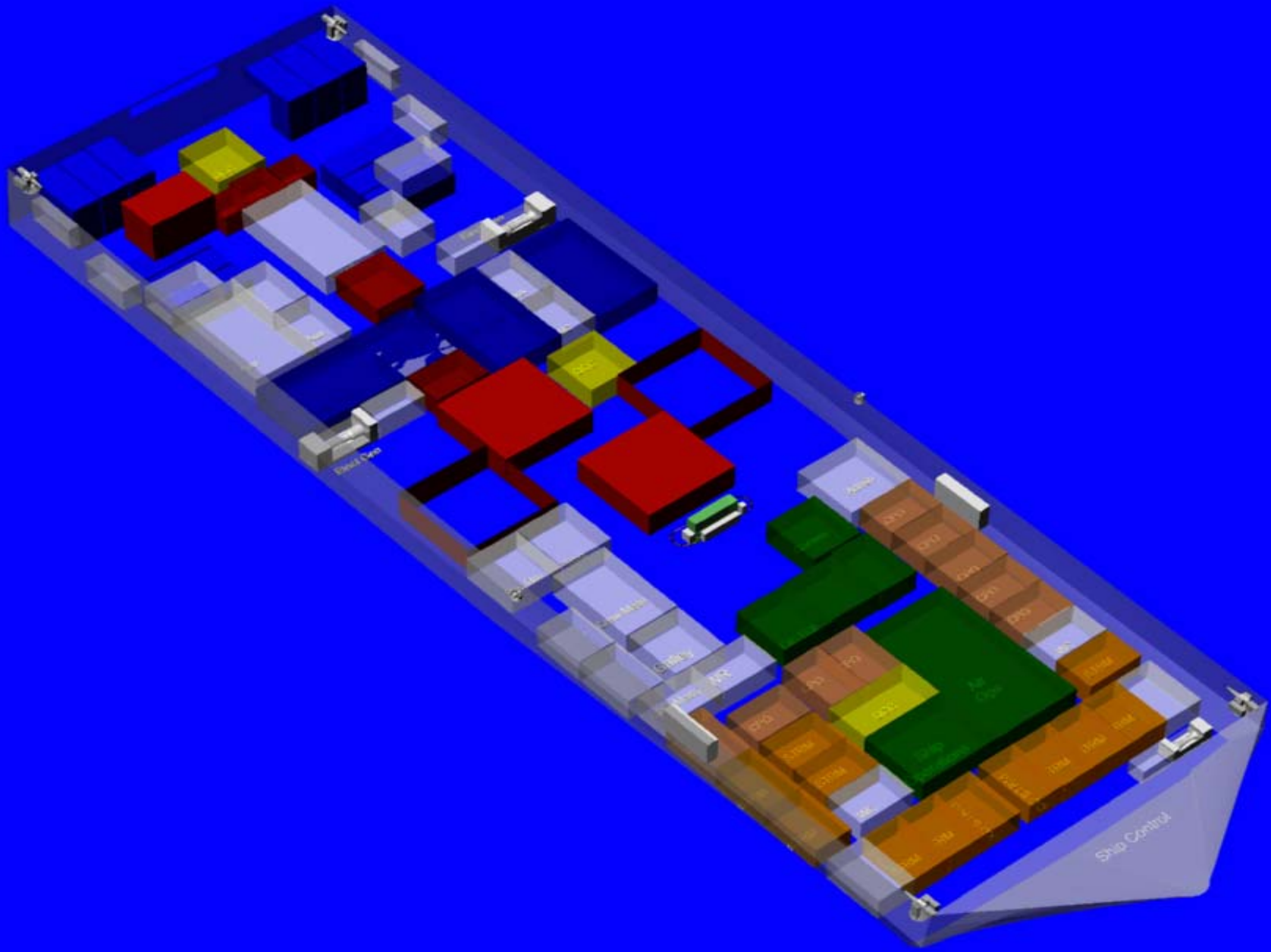
Ship Systems Integration

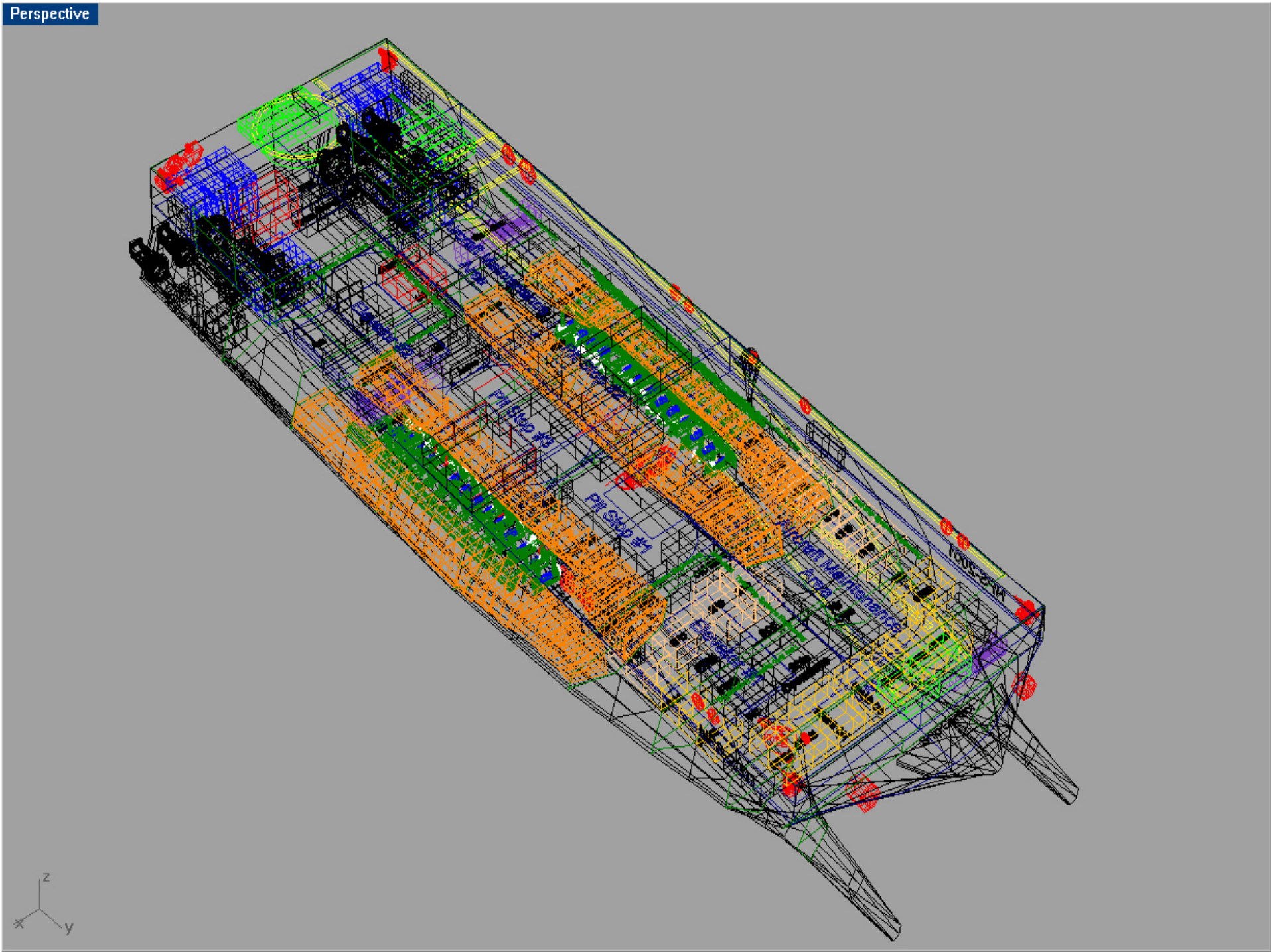
- Manning
- Maintenance
- Logistics
- Operational functionality
- Upgradeability
- Survivability
- Cost

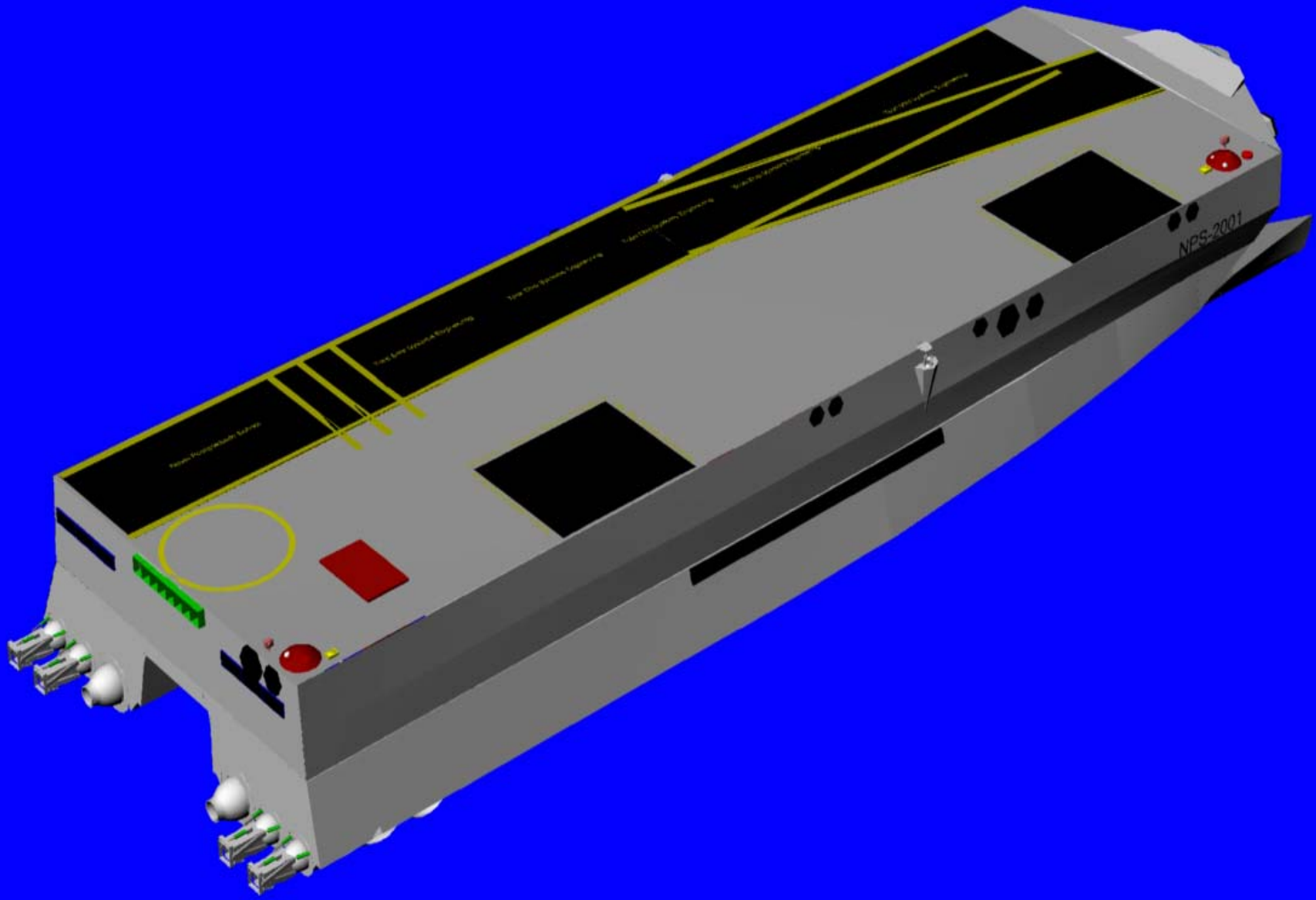
Ship Design Philosophy

- Survivability
- Automation
- Reduced Manning
- Upgradeability
- Maintainability
- Reliability
- Manufacturability
- COTS
- Affordability


NPS-2001


Ship Control


Perspective
Pit Shop #1
Pit Shop #2
Pit Shop #3
Accident Maintenance
Area
z
x
y


NPS-2001

Manning

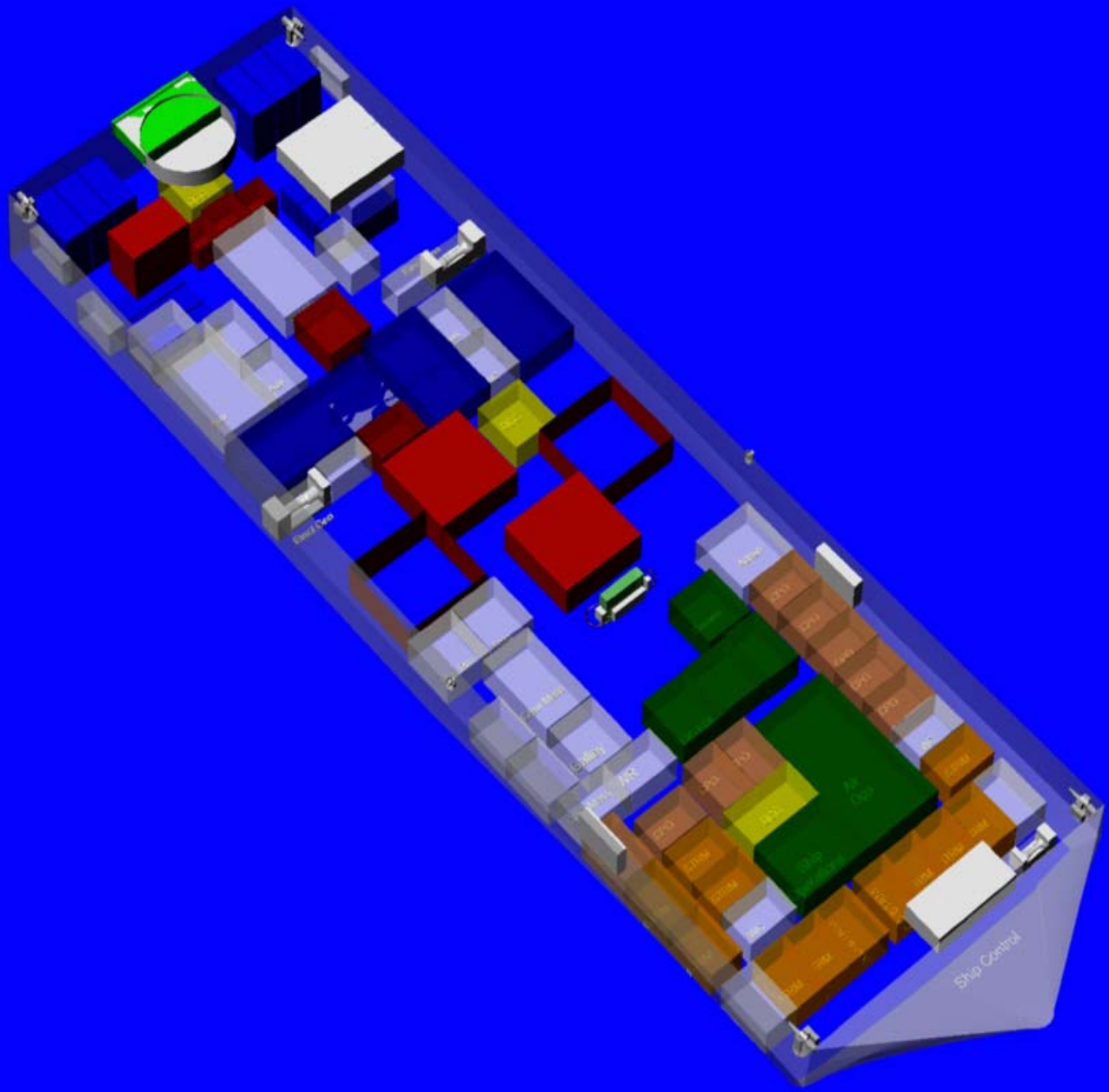
- Manning
  - [Total – 128; Ships Force – 75; Aviation - 53]
  - Officers – 27; CPO – 27; Enlisted – 74
- Watch
  - [Total – 26; Ships Force – 17; Aviation – 9 (O/C/E)]
  - Ops/Combat Systems - 3/3/2
  - Engineering – 1/1/4
  - Aviation – 2/5/2
  - Logistics/Galley – 0/1/2

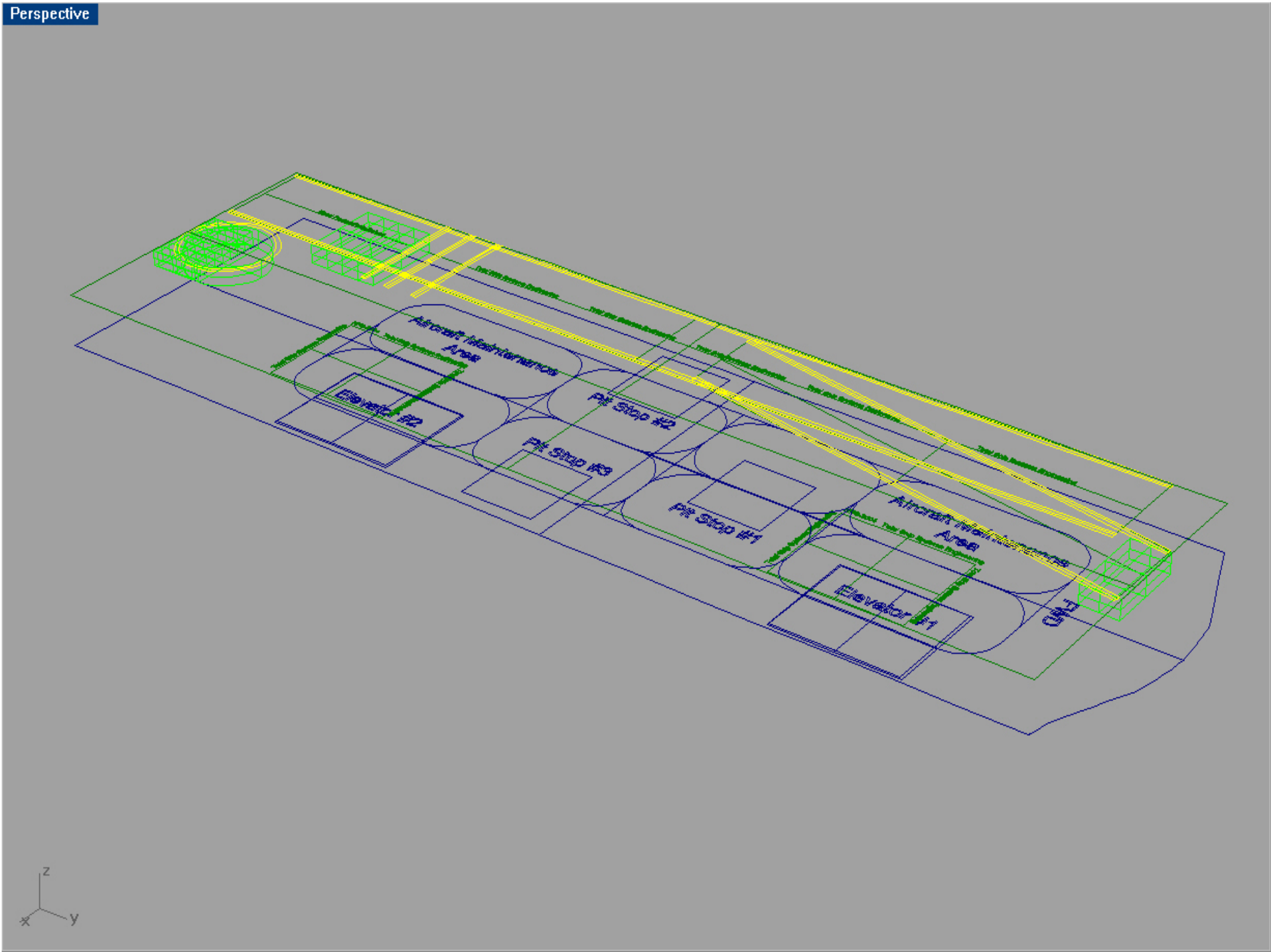
Maintenance & Logistics

- Maintenance
  - Ship's force provide operational level maintenance
  - Ship shops available for limited repair
  - Tiger teams of 50 personnel every 30 days provided from CV, IMA or dedicated tender (ADX)
- Logistics
  - Provisions for:
    - Personnel - 90 days
    - Ship ordnance – 30 days
    - Aviation ordnance – 7 days
  - Compatible with present and future fleet UNREP assets
    - Vertical replenishment for stores
    - Traditional alongside replenishment for fuel

Operational Functionality

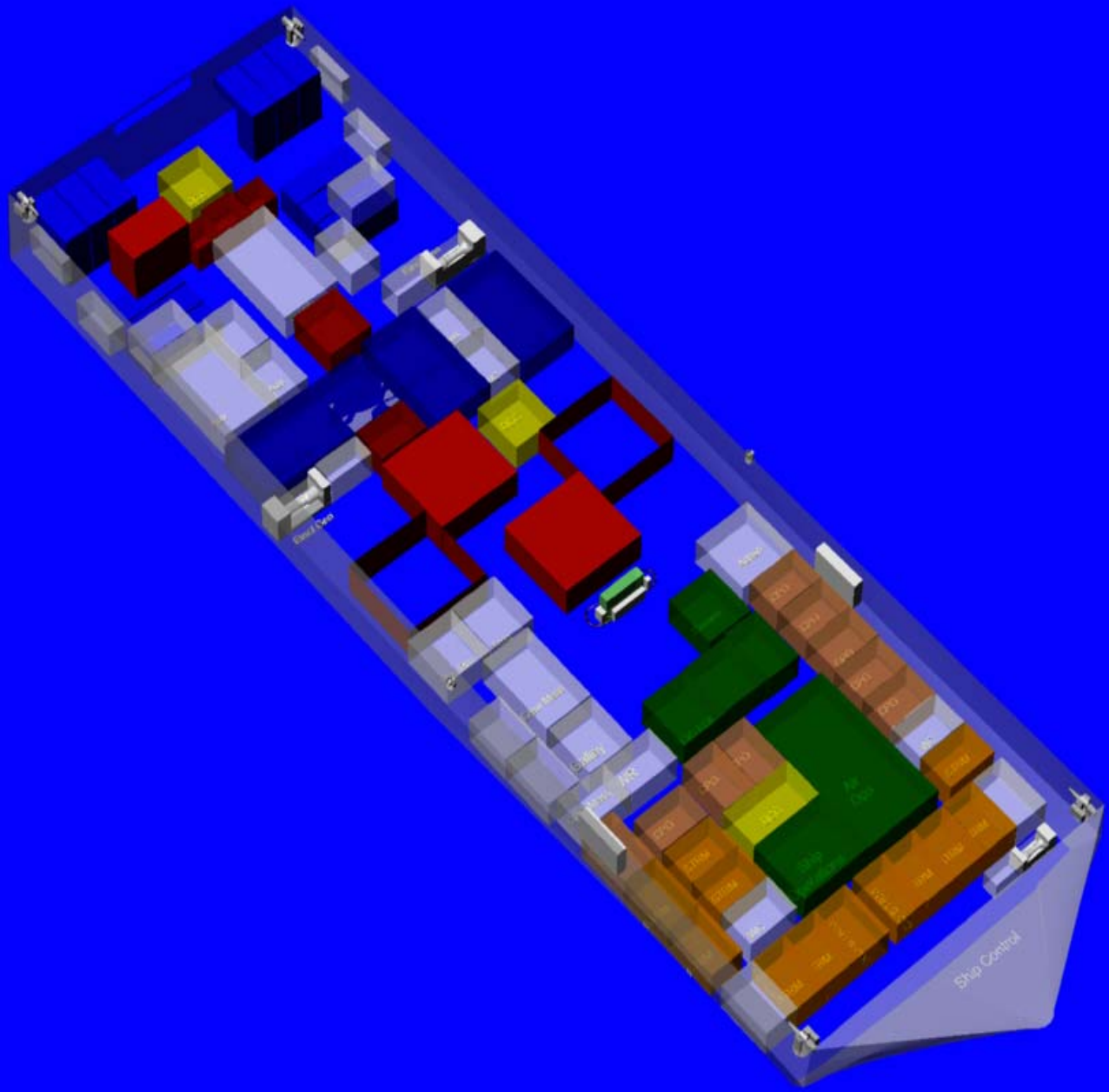
- Distributed aviation capability
- Crew spaces centrally located
- All operational spaces collocated along the centerline of the ship
- Ship control available from either the bridge or the combat operations center

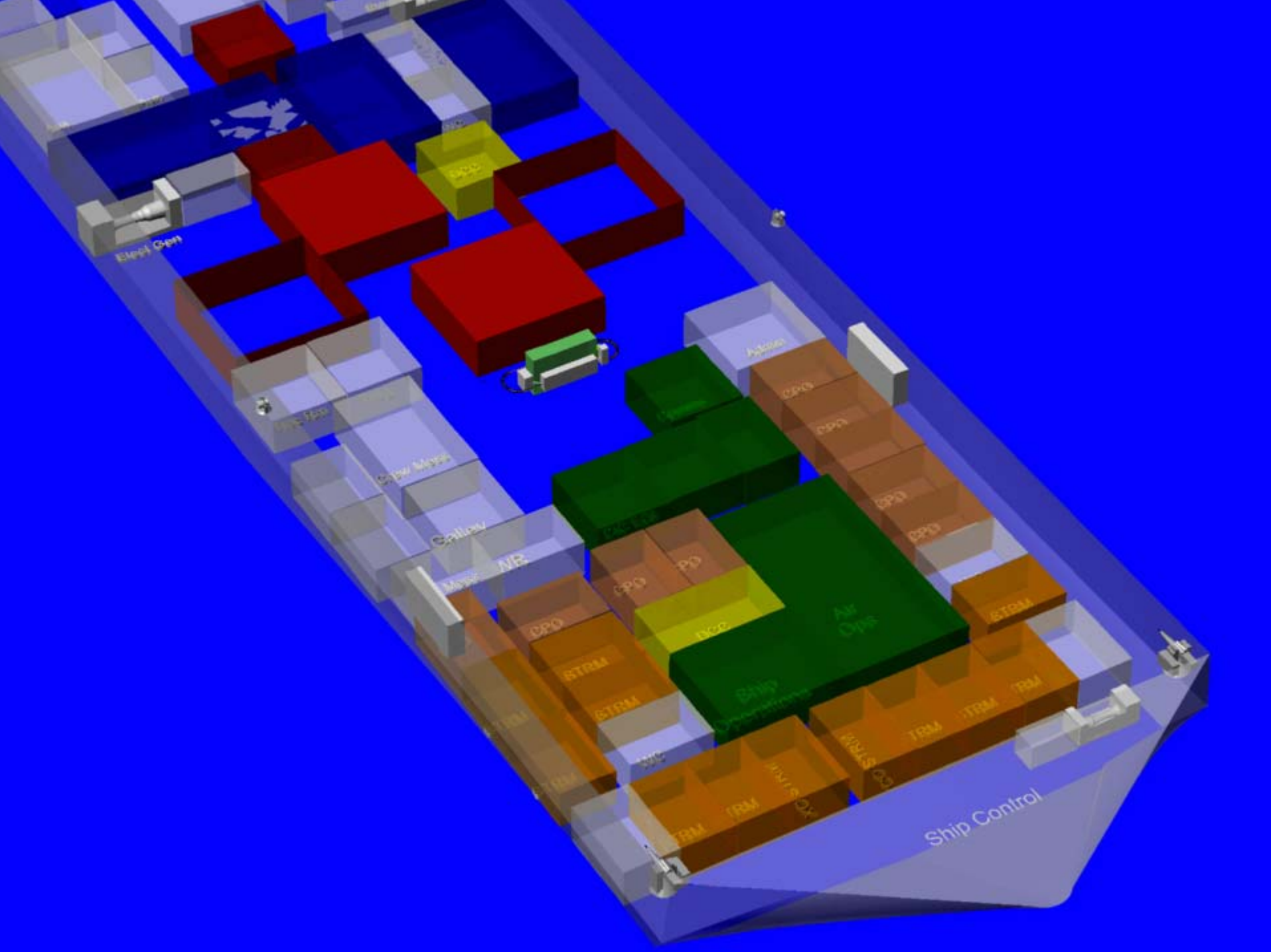

Ship Control

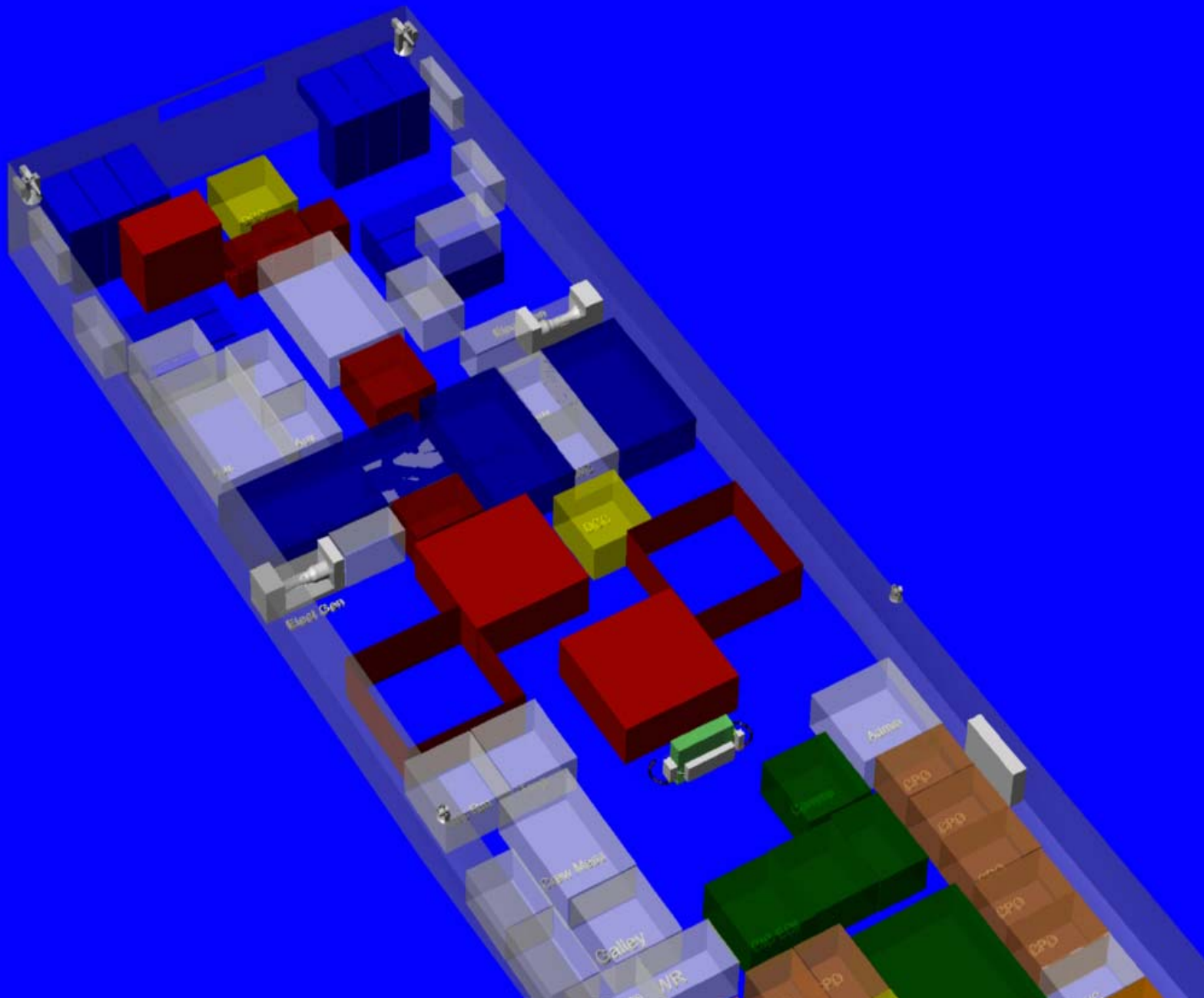

Perspective
Aircraft Maintenance Area
Elevator #2
Pit Stop #2
Pit Stop #3
Pit Stop #1
Aircraft Maintenance Area
Elevator #1
z
x
y

Upgradeability

- Commercial Off the Shelf (COTS)
- Modular construction
- Open access to all systems

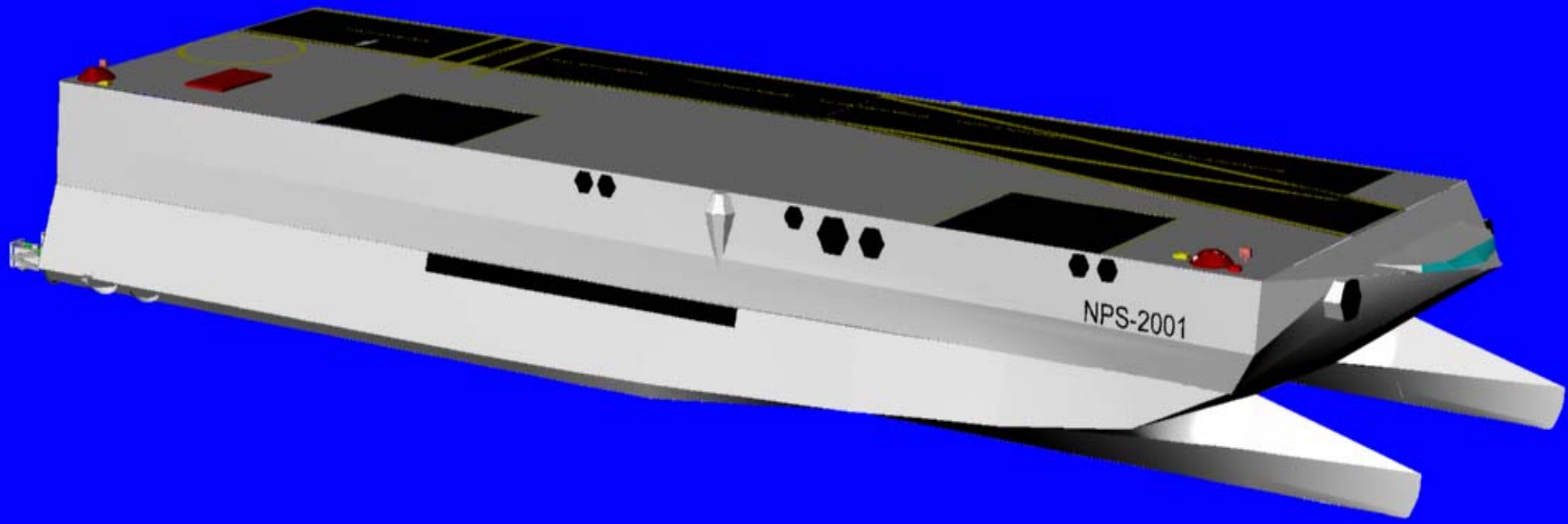

Ship Control


Emerg Gen
Crew Mess
Galley
MR
Ship Control


Elect Gen
Galley
Admin
CPO
CPO
CPO
CPO

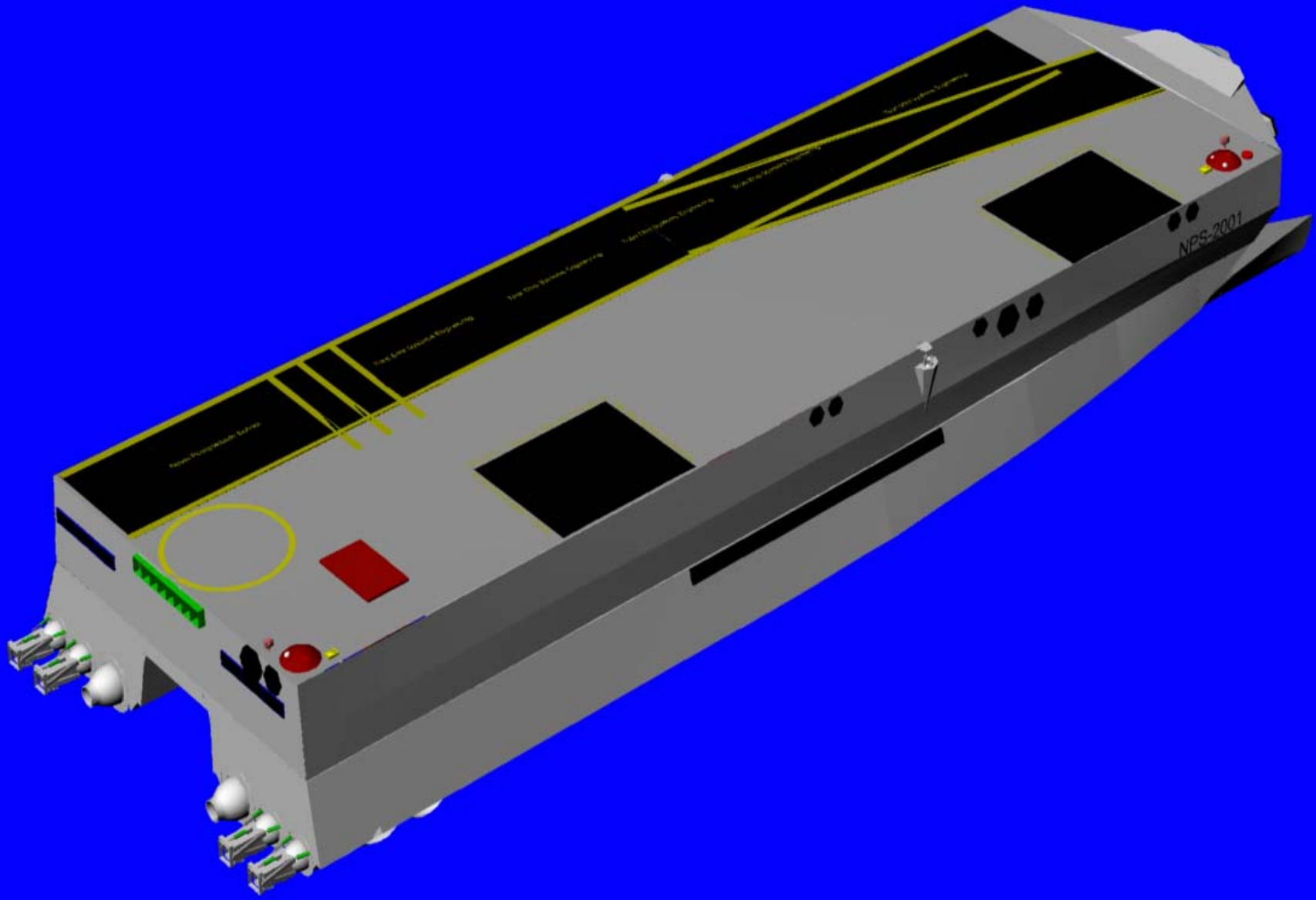
Survivability

- Reduction of infrared signature
- Redundant systems
- Distributed C4I
- Modularity


NPS-2001

Cost

- Acquisition Cost
  - Ship – $1.9B
- Total Ownership Cost (TOC) Reductions
  - Minimum manning
  - Commercial technology
  - Modular construction/outfitting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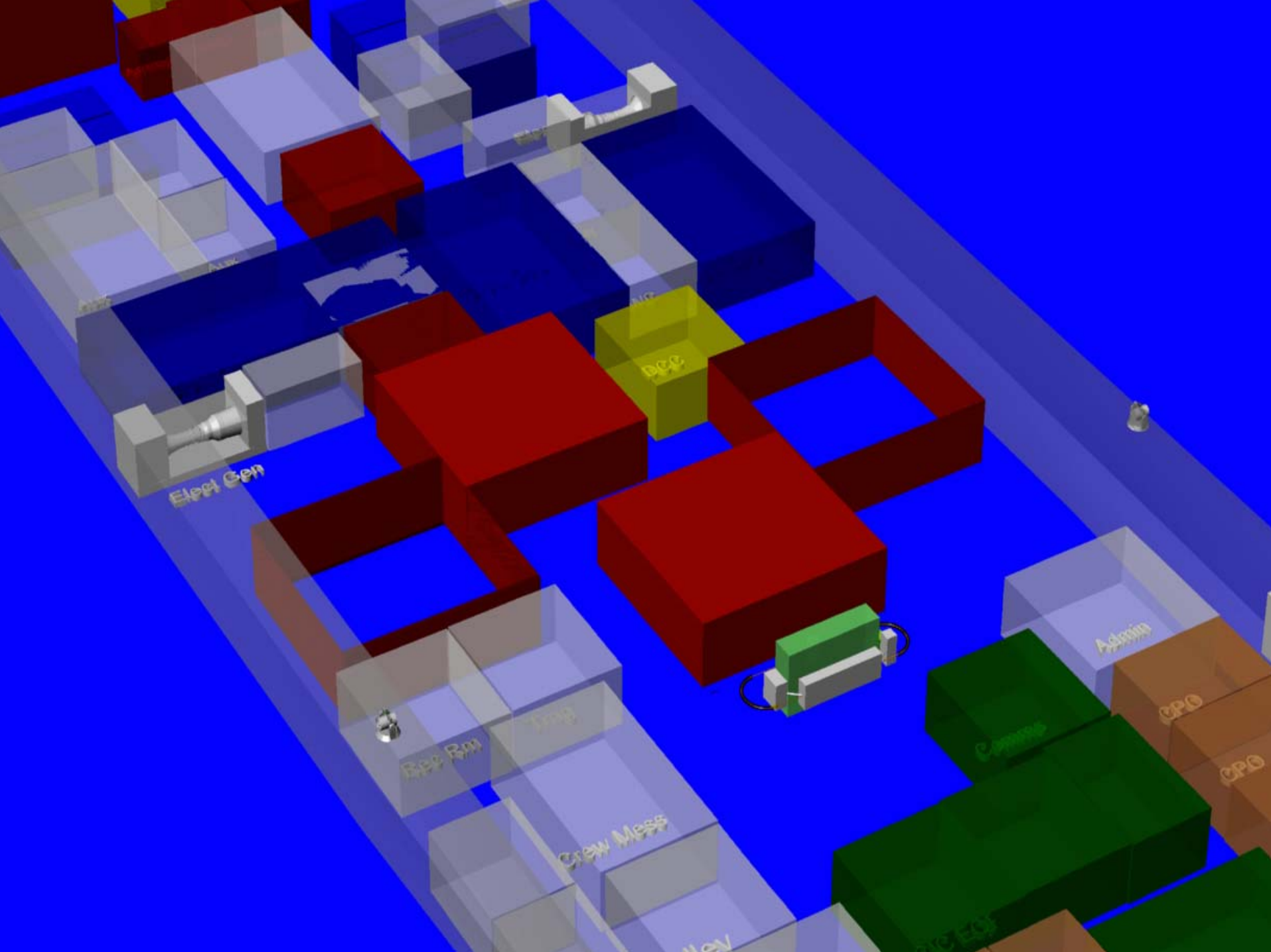
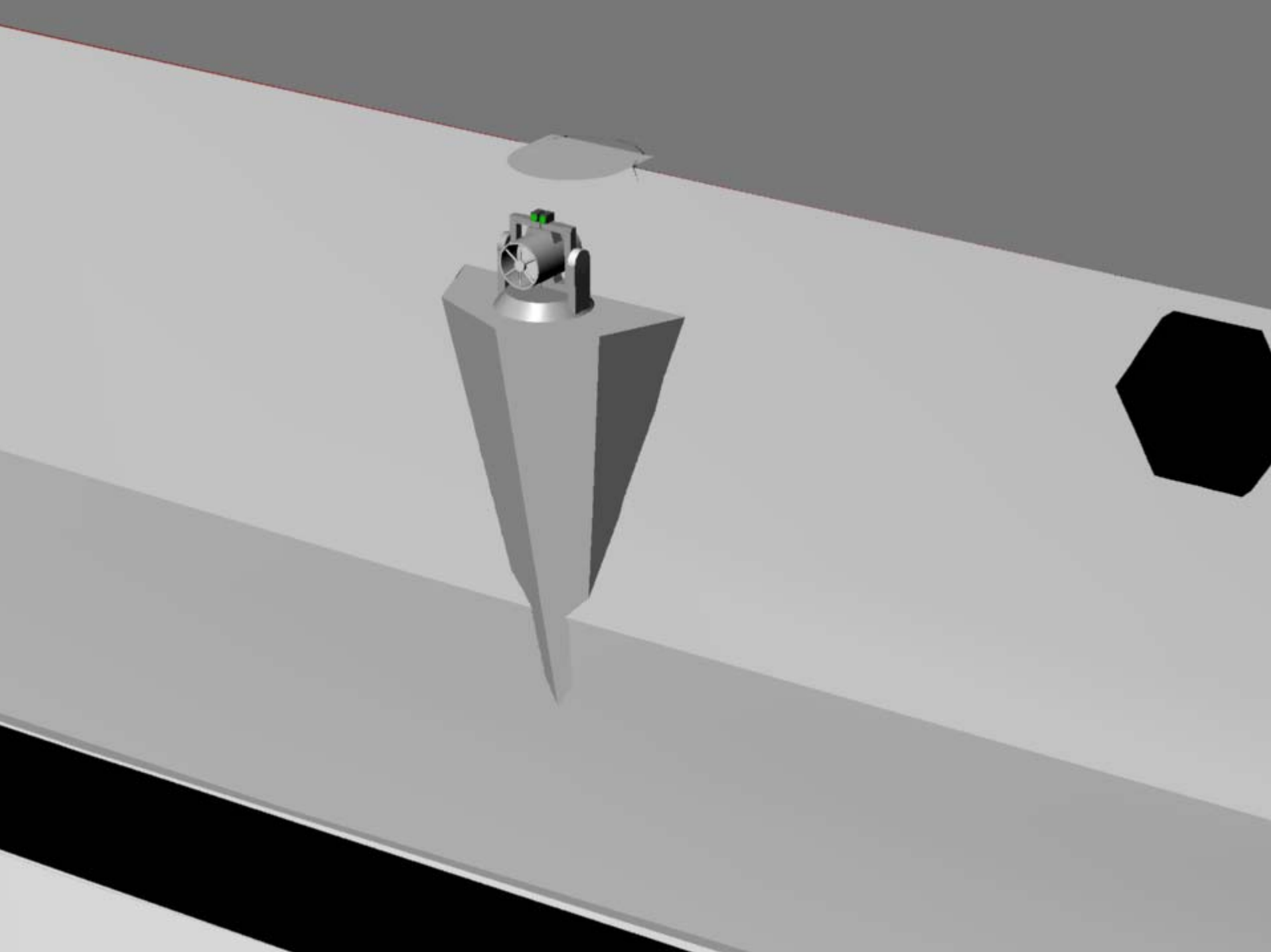

Elect Gen
DCC
Crew Mess
Admin
CPO
CPO



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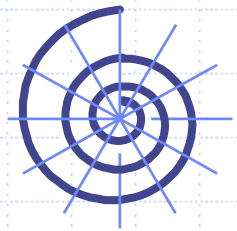

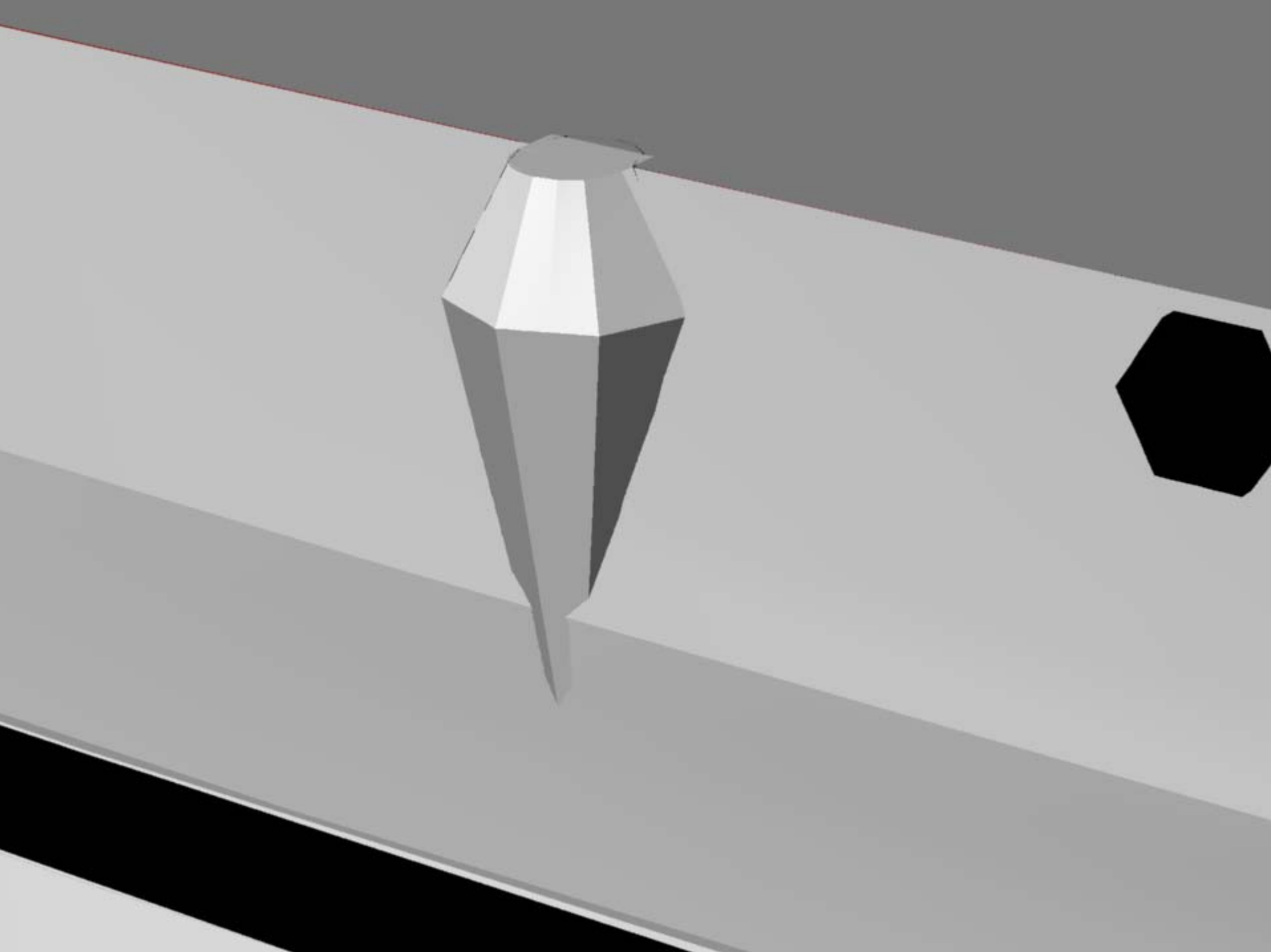

Conclusion

- 1st Iteration Results
  - Speed requirement
  - Large power
  - Large volume
  - Large Costs
- Refine design to improve volume usage
- Further research and development
  - Harley SES hull form
  - Hydro air drive propulsors
  - Automation and robotics
  - Free Electron Laser

Total Ship Systems Engineering

QUESTIONS?