



Collaborative Systems Engineering & Design Symposium at The Georgia Institute of Technology

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Early Stage Evaluation of Navy Ship Machinery Systems using SeaQuest

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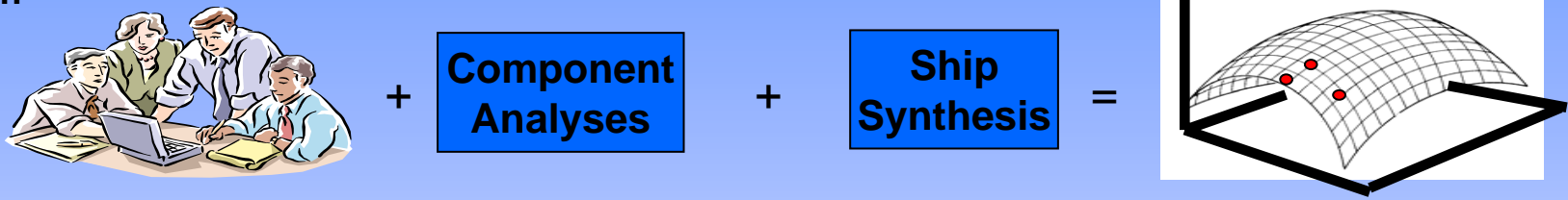


Agenda

- Background
- SeaQuest Process
- SeaQuest Applications
 - Alternative Propulsion Study
 - DDG-51 Energy Efficiency Study
- Current Status and Future Development

Background

Point Design Approach



Piece together individually optimized components to create subsystems/systems
Force the subsystems/systems into the ship

Family of Designs Approach

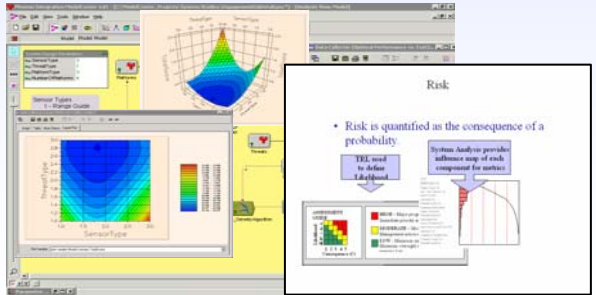
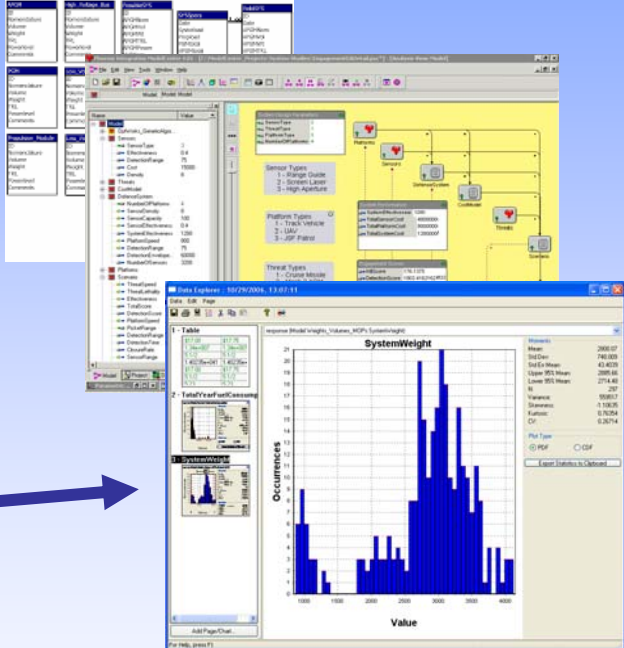
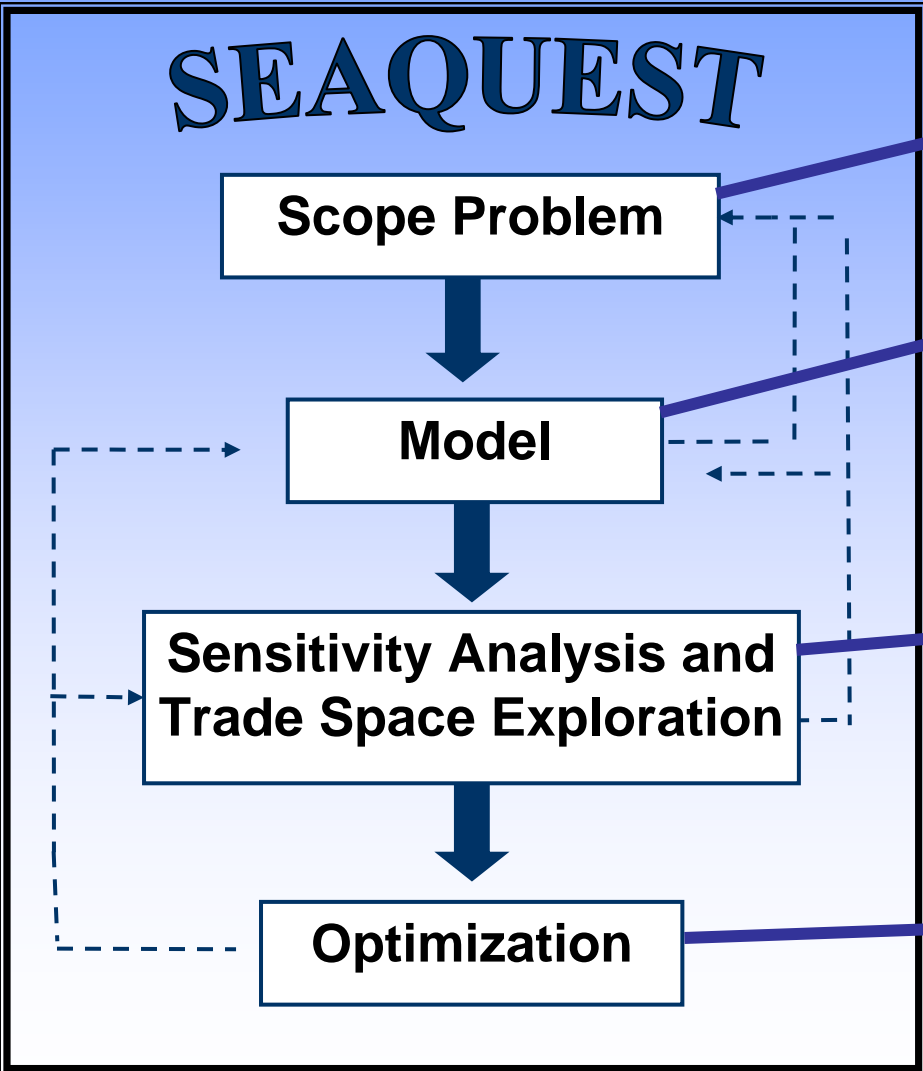


Evaluate the ship-level impact of combinations of components
Provide several levels of comparison
Filter less attractive options prior to investing in detailed analyses/development

SeaQuest

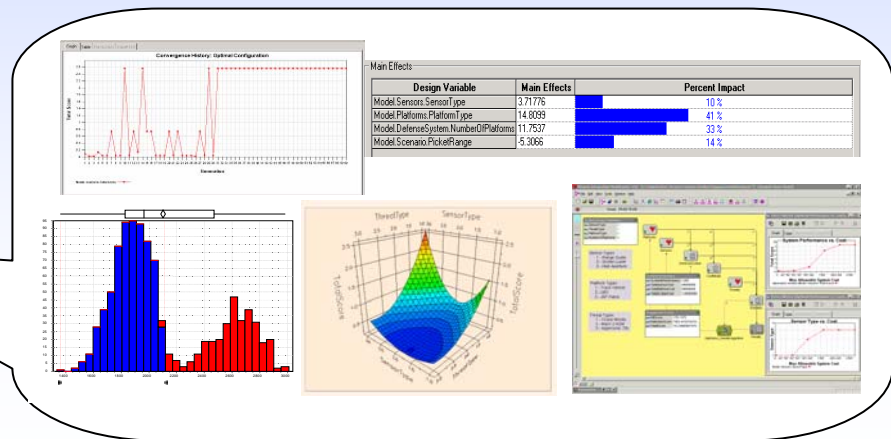
Systems Engineering Application for Quick Evaluation of Shipboard Technologies

Requirements

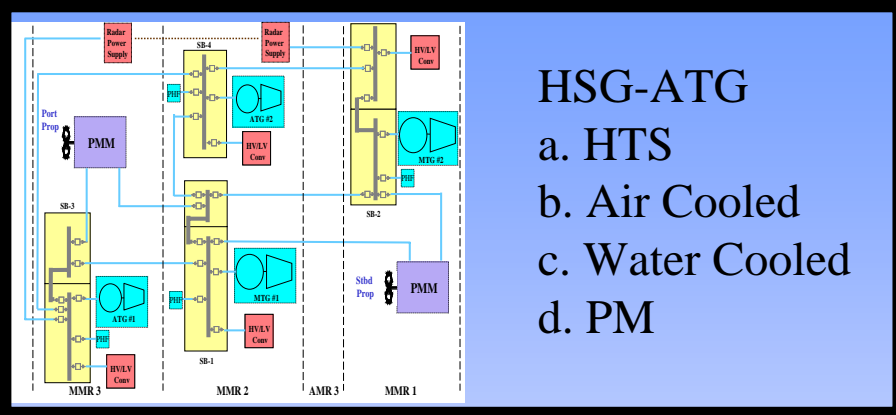


SeaQuest Features & Capabilities

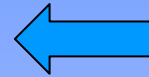
- Ship Impact Assessments of Alternative Architectures, Systems and Components
- Comparison of Competing Architectures, Systems and Components
- Optimization of Design Solutions
- Rapid Recalculations to Accommodate Parameter Changes
- Define Design Space and Trade Space for Technology Investment
- Parametric Studies
- Probabilistic Analysis
- Optimization: Genetic Algorithm; Gradient-Based
- Sensitivity Studies: Main Effects and Interaction Effects
- Design Space Exploration: Design of Experiments; Prediction Profiler



Evolution of SeaQuest



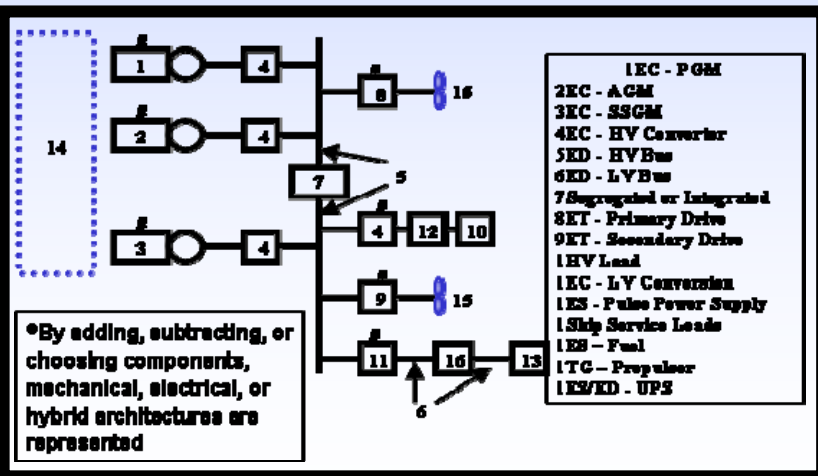
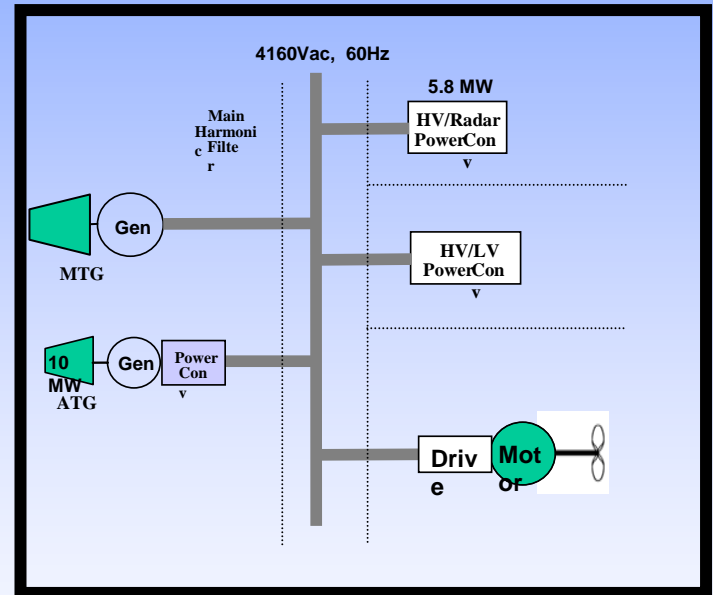
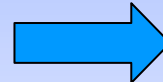
FY05



Provides one architecture for trades, 4 different ATGs. Database of only several components allows only a few possible combinations.

Provides multiple architectures and several components to provide system trade-off. Database of over 30 components allows > 1K combinations.

FY06



FY07



Provides multiple architectures and multiple components to provide system trade-off. Database of over 100 components allows > 1B combinations.



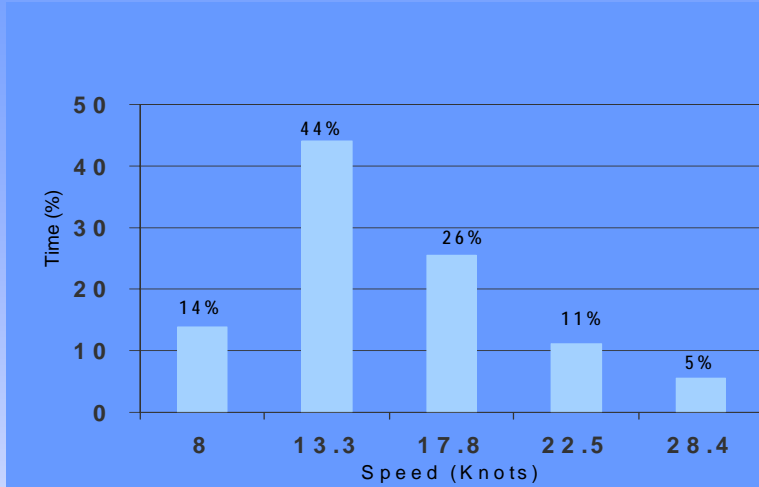
Alternative Propulsion Study Scope Problem

- Determine impact of various propulsion and power architectures and components on variants of
 - Small surface combatants
 - Medium surface combatants
 - Amphibious warfare ships
- Key Performance Parameters
 - Lifetime Fuel Consumption
 - Risk (Technology Readiness Level)
- Design Reference Mission: More realistic basis for comparison
- Speed-State-Time profile vs. Speed-Time profile
- Model Architecture

Note: There were other items investigated as part of the Alternative Propulsion Study, but outside of the SeaQuest methodology.

Alternative Propulsion Study

Scope Problem cont.



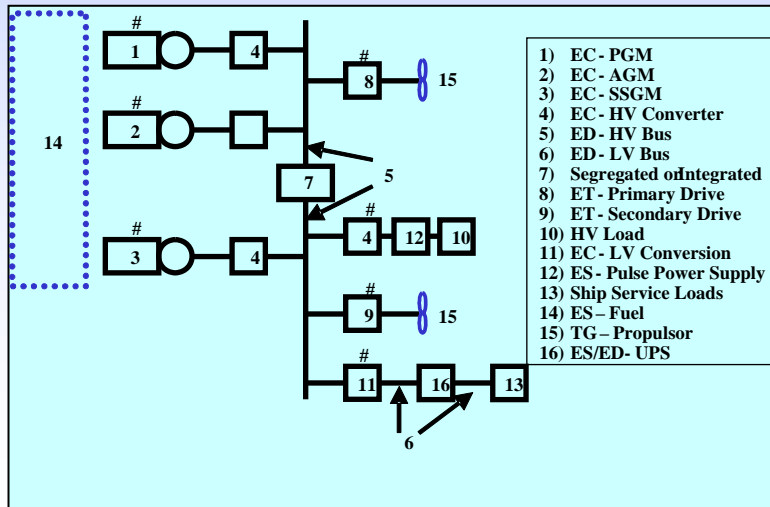
Speed-State Time Profile - 2814.3 hours/year at sea

Speed	% Time at Cold Iron	% Time at Anchor	% Time at Condition 3 Alone	% Time at Condition 3 Networked	% Time at Condition 2 Alone	% Time at Condition 2 Networked	% Time at Super Battle
Cold Iron	63.34%						
Anchor		4.54%					
6			0.67%	9.74%	1.93%	1.63%	0.15%
10			0.00%	1.57%	2.57%	1.95%	0.15%
15			4.41%	0.00%	0.87%	0.50%	0.15%
20			0.00%	0.00%	1.79%	1.23%	0.15%
MC			0.00%	0.00%	1.28%	1.24%	0.15%

State determines equipment line-up → ship service electric loads

Percent Total =

100.0%



16 node Generic Model Architecture can represent Mechanical, Electrical or Hybrid Drives by eliminating nodes and swapping out components

Alternative Propulsion Study

Build Model

The screenshot shows the Phoenix Integration ModelCenter 7.0 interface. The main workspace displays a hierarchical model diagram with components like 'electrical_plant_components', 'TRL_Calculator', 'Fuel_Calculator', and 'Weights_Volumes_MOPs'. A 'Component Tree' on the left lists various system requirements and components. The interface includes a menu bar, toolbars, and a 'Quick Help' panel on the right.

Phoenix Integration ModelCenter™

Component Database Link

TRL Calculator

Fuel (Energy) Calculator

Component Database Inputs

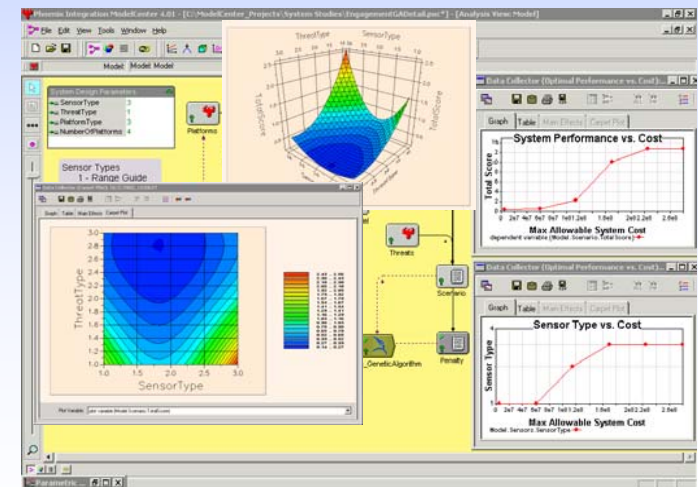
System Requirements

Cable Weights

Power & Propulsion System Weight, Volume and Measure of Performance Calculator

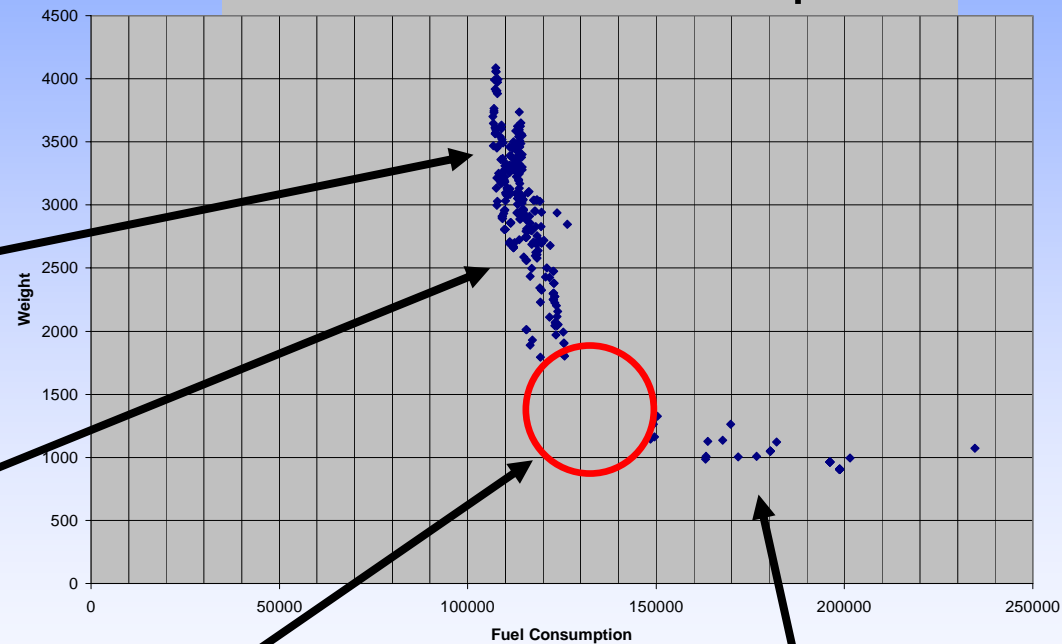
Alternative Propulsion Study Sensitivity Analysis and Trade Space Exploration

- Design of Experiments (DOE)
 - Over 250 engine combinations
 - 81 data points for Speed-State-Time profiles
- Measures of Performance (MOP)
 - 3 MOPs based on
 - Yearly fuel consumption
 - Machinery weight
 - Shaft horsepower
 - Ship speed



Alternative Propulsion Study Sensitivity Analysis and Trade Space Exploration cont.

System Weight vs.
Total Fuel Consumption



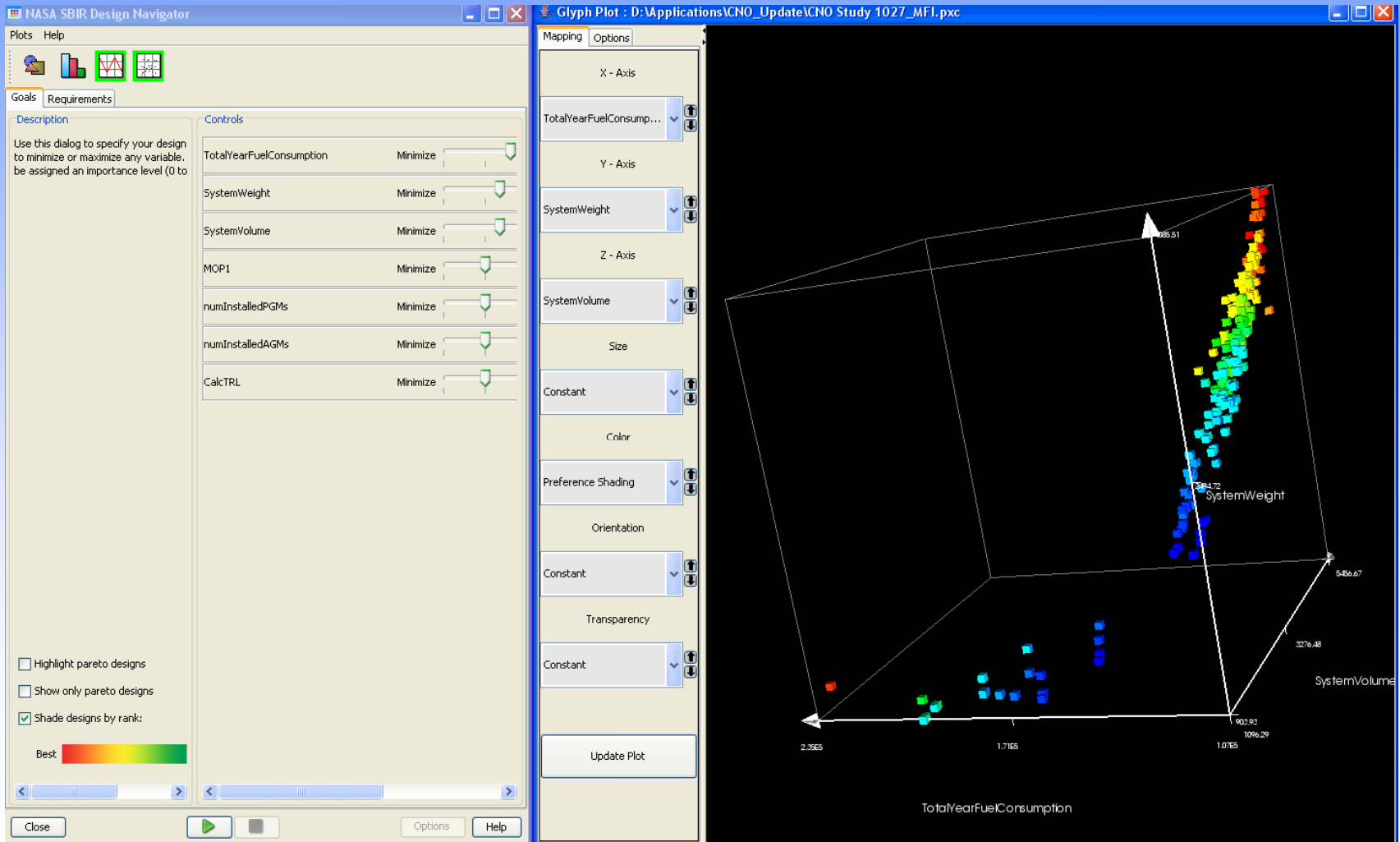
Diesel -Diesel Combos

Gas Turbine –
Diesel Combos

Knee in the Curve –
Technology Gap Analysis

Gas Turbine –
Gas Turbine Combos

Alternative Propulsion Study Sensitivity Analysis and Trade Space Exploration cont.

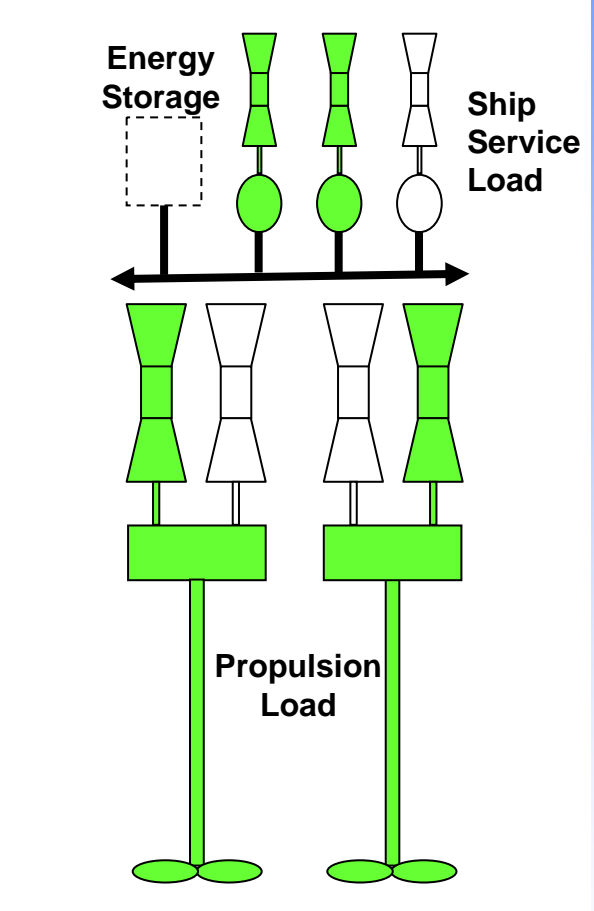


DDG 51 Energy Efficiency Study Scope Problem

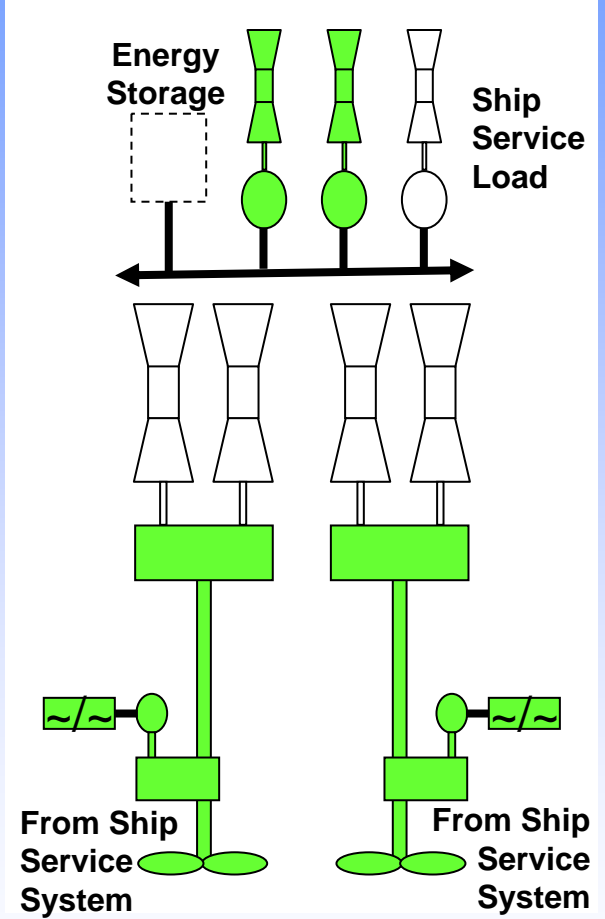
- BAA Request for Proposal Fuel Efficient and Power Dense Demonstrator for the USS Arleigh Burke (DDG 51) Flight IIA Class Ship
 - Improve fuel efficiency
 - Increase available power generation
- Key Performance Parameters
 - Return on Investment (ROI)
 - Lifetime Fuel Consumption
 - NRE Cost
 - Impact on Availability
- Model Architecture
 - Mechanical Drive
 - Hybrid Drive
 - Electric Propulsion System (EPS)
 - Propulsion Derived Ship Service (PDSS)

DDG 51 Energy Efficiency Study

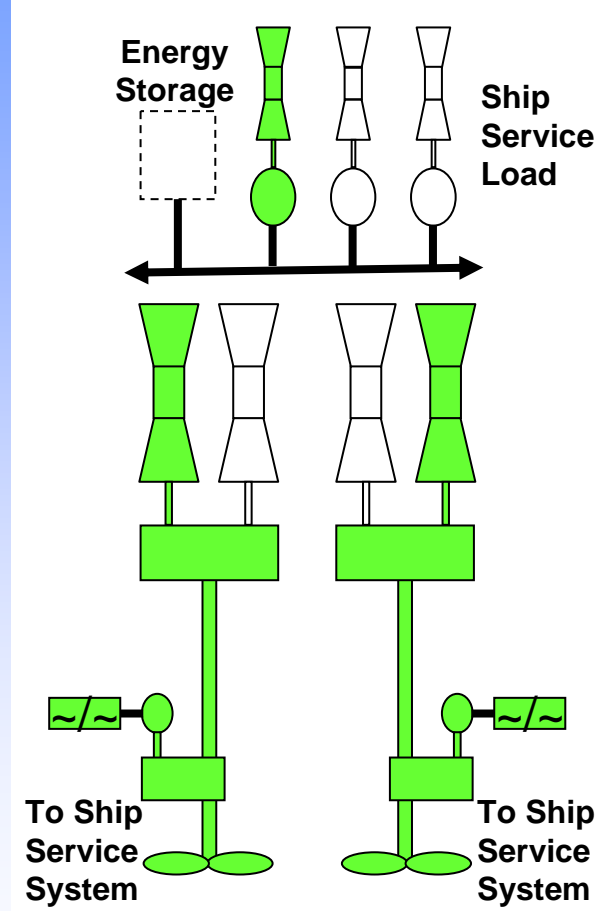
Scope Problem cont.



Mechanical Propulsion

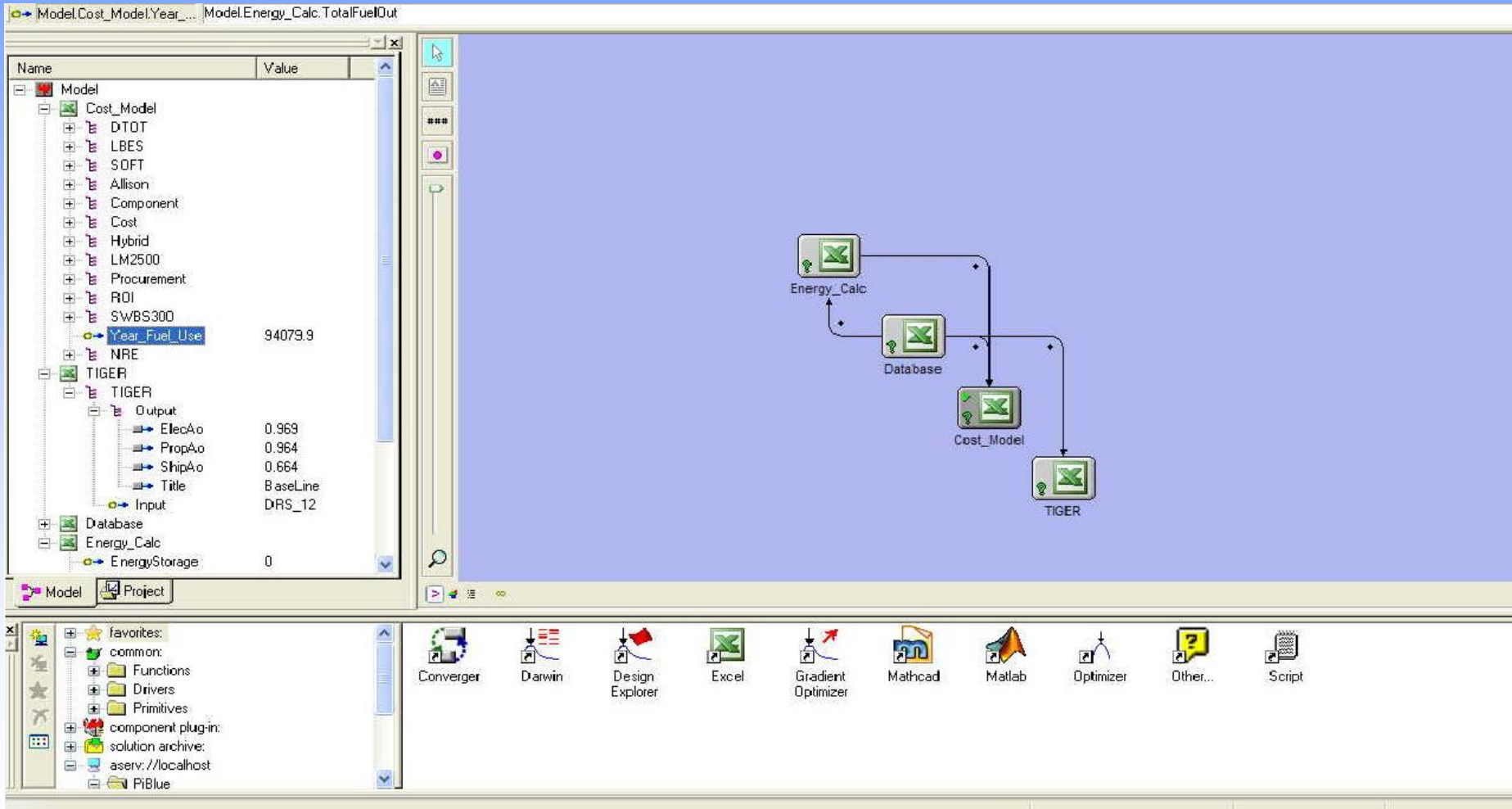


Electric Propulsion



Propulsion Derived Ship Service

DDG 51 Energy Efficiency Study Build Model



The screenshot displays a software interface for building a model. On the left, a tree view shows the model structure:

Name	Value
Model	
Cost_Model	
DTOT	
LBES	
SOFT	
Allison	
Component	
Cost	
Hybrid	
LM2500	
Procurement	
ROI	
SWBS300	
Year_Fuel_Use	94079.9
NRE	
TIGER	
TIGER	
Output	
ElecAo	0.969
PropAo	0.964
ShipAo	0.664
Title	BaseLine
Input	DRS_12
Database	
Energy_Calc	
EnergyStorage	0

On the right, a flow diagram illustrates the model's data flow:

- Energy_Calc** feeds into **Database**.
- Database** feeds into **Cost_Model**.
- Cost_Model** feeds into **TIGER**.
- Energy_Calc** also feeds into **TIGER**.

The bottom of the interface shows a taskbar with various application icons: Converger, Darwin, Design Explorer, Excel, Gradient Optimizer, Mathcad, Matlab, Optimizer, Other..., and Script.

DDG 51 Energy Efficiency Study

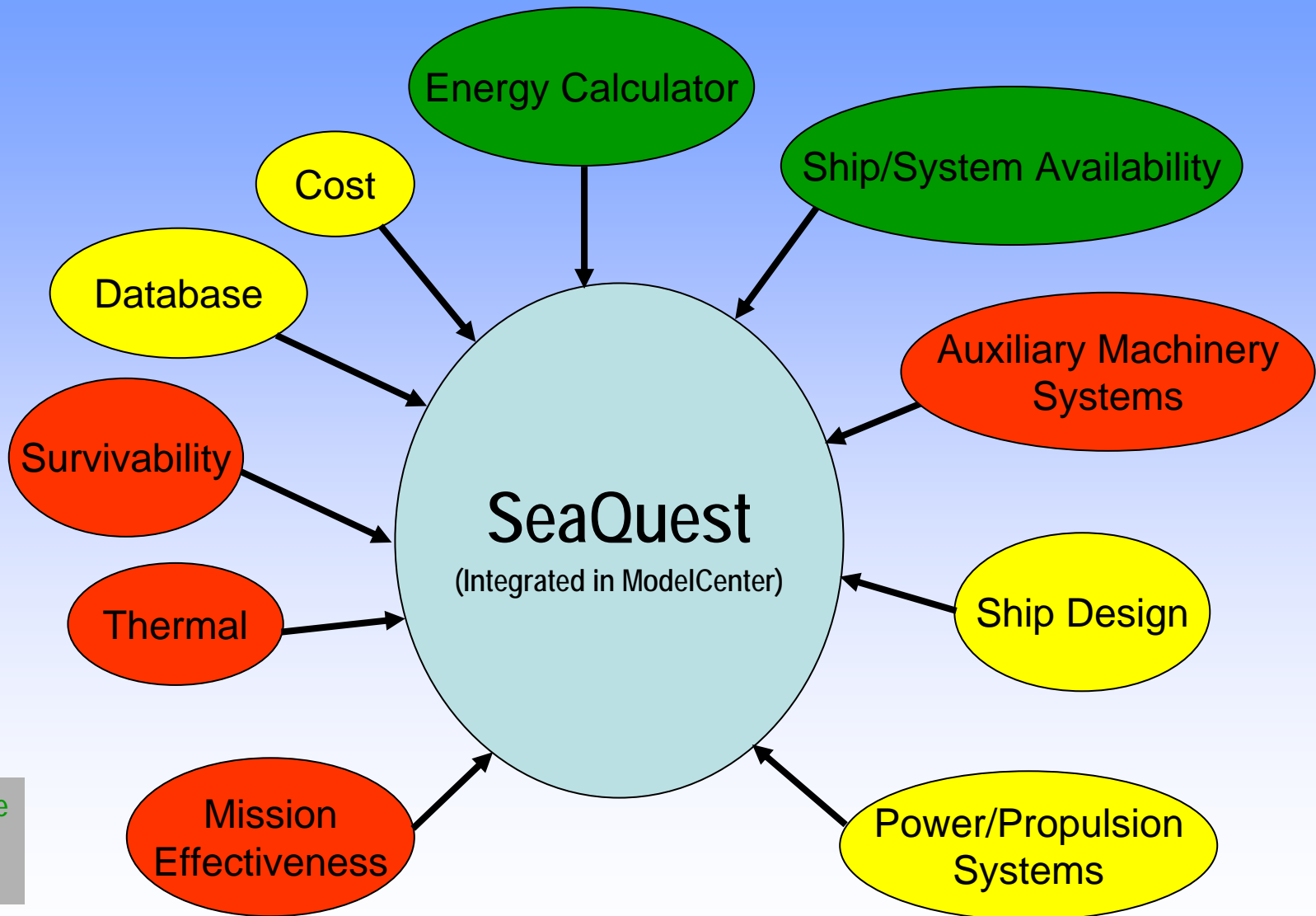
Sensitivity Analysis and Trade Space Exploration

Full Name	ROI.OneShip	ROI.OneShip.Cost	NRE.TotalCost	Fuel Savings	TIGER Output Electrical Ao
	Years	Dollars	Dollars	Barrels/Year	Percent Deviation from Baseline
Single Generator Ops - No Technology Added	0	\$ -	\$ -	7,500	-13%
Hybrid Drive and Energy Storage	4 - 5	\$9 - \$12.5M	\$39 - \$55M	14,500	0%
Energy Storage (Chemical)	6 - 10	\$5 - \$12.5M	\$13 - \$73M	7,500	0%
Hybrid Drive	7 - 9	\$9 - \$12.5M	\$43 - \$60M	8,400	0%
Energy Storage (Flywheel)	11 - 19	\$14 - \$32M	\$44 - \$62M	7,500	0%
Bottom Cycle	15 - 17	\$58 - \$82M	\$100 - \$140M	22,000	0%
High Speed Generator with Energy Storage	24 - 26	\$36 - \$48M	\$70 - \$98M	7,500	-1%

Status

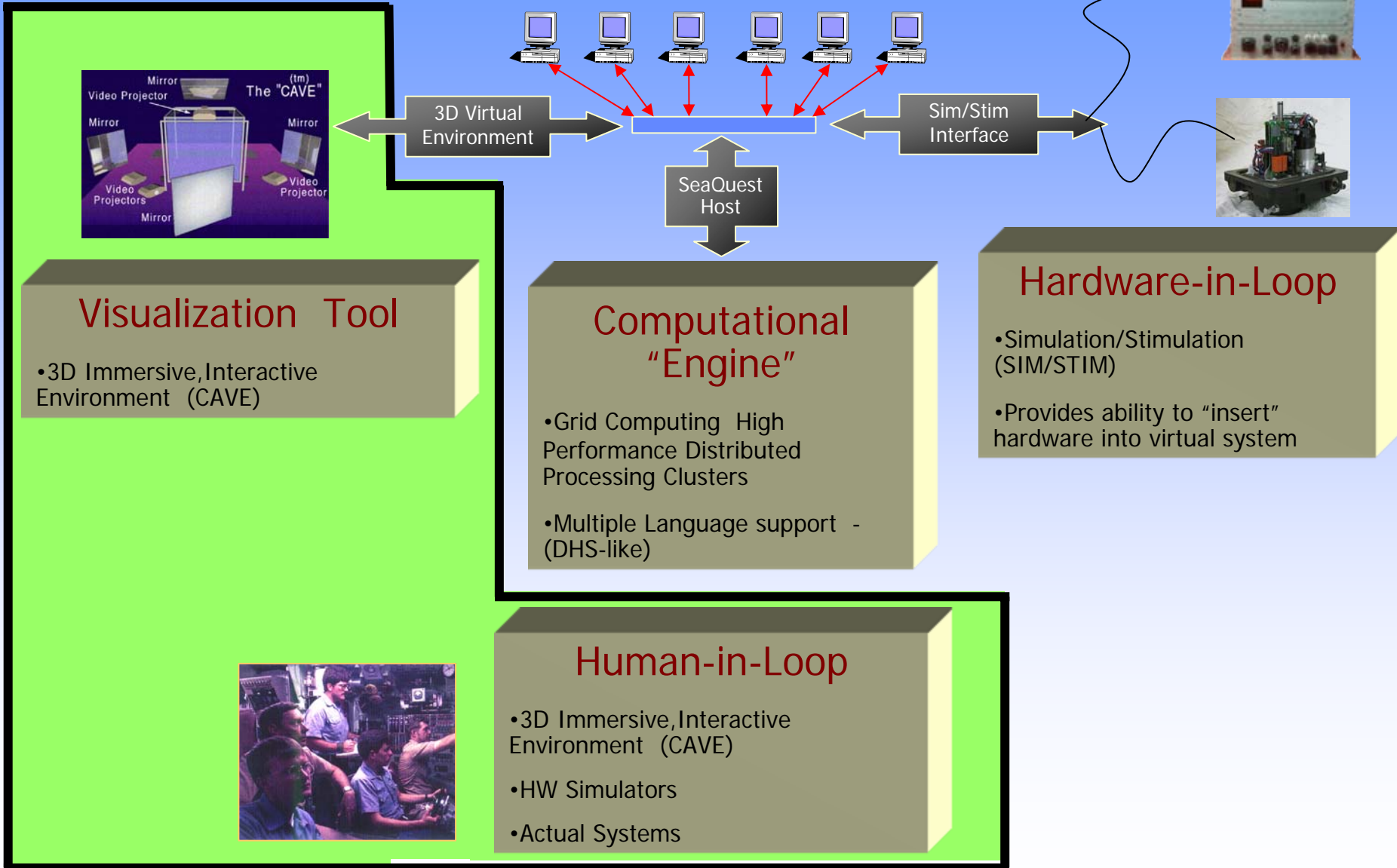
- Scoping studies
 - CGX studies (power & propulsion architecture studies)
 - Compact Power (ship impact studies)
- Refining, improving models & database
 - SWBS based database
 - Power quality models (e.g. THD)
 - System cost interactions (e.g. denser electronics -> more cooling)
 - Automate Reliability Block Diagrams
- Adding & developing new models/components
 - Thermal loading
 - ASSET (i.e. ship design)
 - MySQL wrapper
- Implementing process controls (e.g. standard variable naming conventions, configuration management)

SeaQuest Model Development & Integration



Complete
Ongoing
Planned

Future Development



Questions

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