Early Stage Design and Evaluation of Shipboard Machinery Systems

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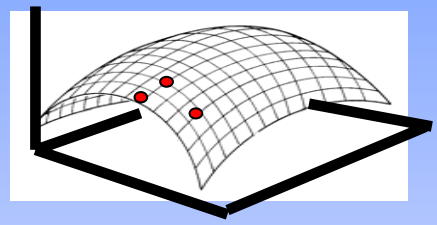
Point vs. Family of Designs

Point Design Approach

+ **ASSET/ LEAPS** =



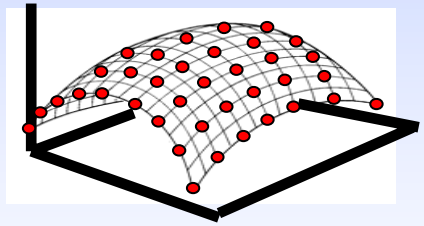
→ Additional Analysis $

Family of Designs Approach

+ Additional Analysis +

+ **ASSET/ LEAPS**

SeaQuest =



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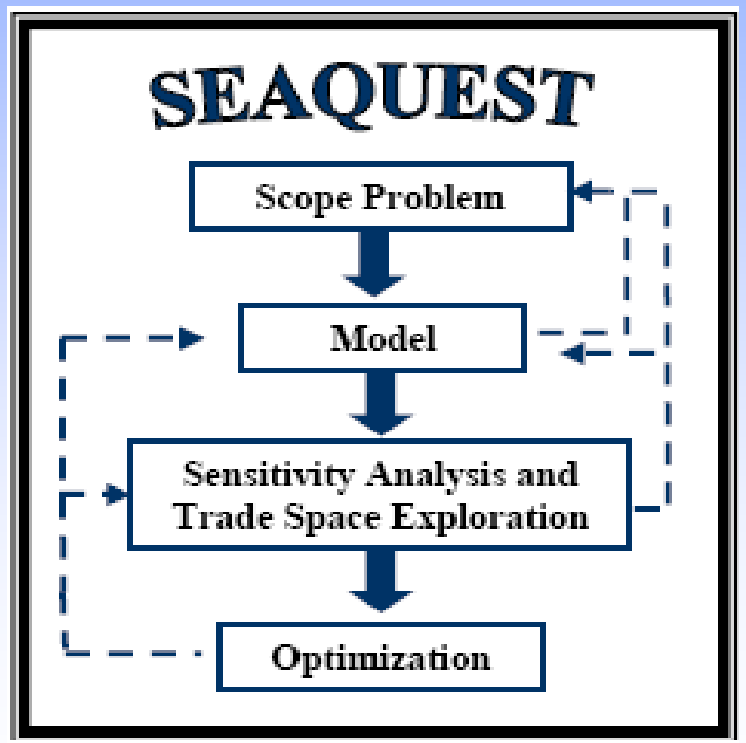
SeaQuest

- ***S***ystems ***E***ngineering ***A***pplication for ***Qu***ickly ***E***valuating ***S***hipboard ***T***echnologies

- **SeaQuest is a two part philosophy for systems design and analysis.**
  - » **Sea is the process**
  - » **Quest is the toolset**

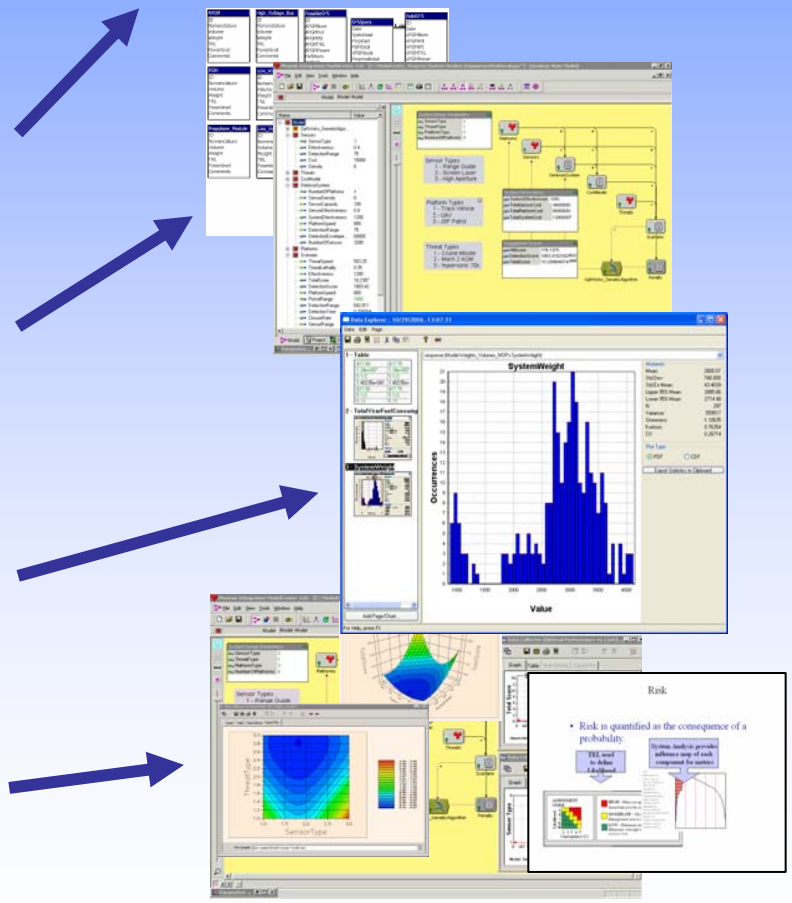


Enabled by Design Integration Software

Requirements

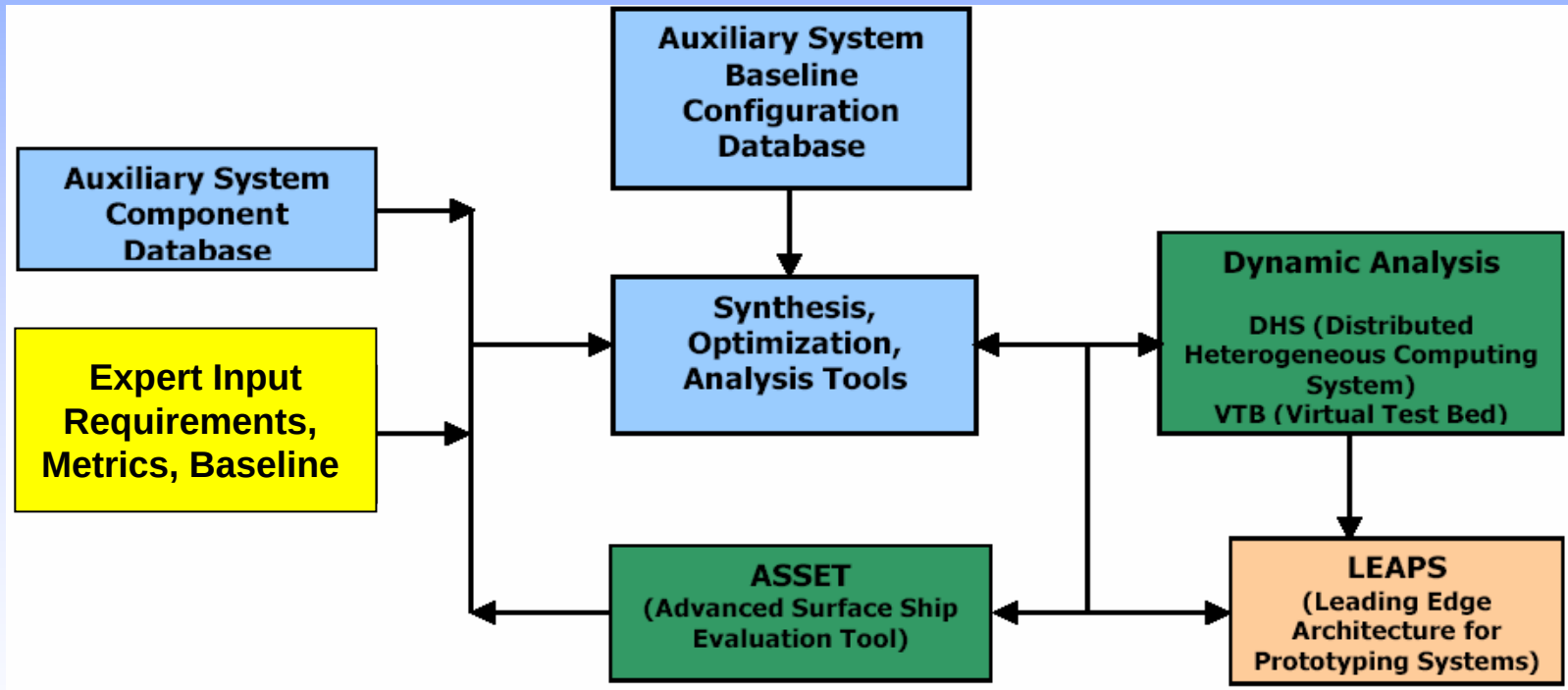
SEAQUEST

- Scope Problem
- Model
- Sensitivity Analysis and Trade Space Exploration
- Optimization



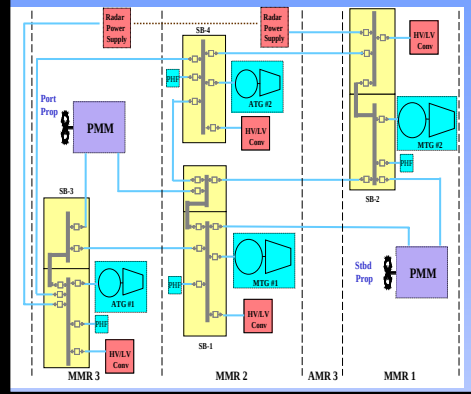
Integrates New and Existing Models

Using advanced system engineering and analysis tools, determine the optimized HM&E system and total ship system impact of a proposed system design.



Leverage ongoing projects in system optimization and integration of design databases.

Evolution of SeaQuest



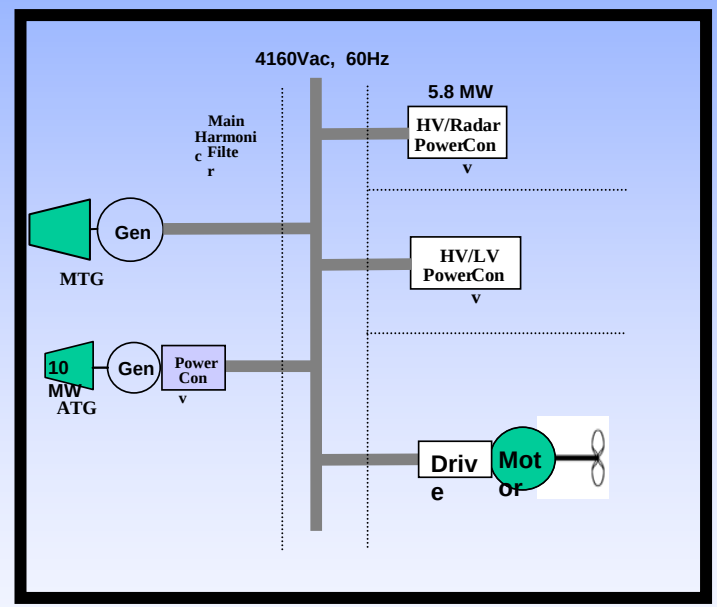
HSG-ATG
a. HTS
b. Air Cooled
c. Water Cooled
d. PM

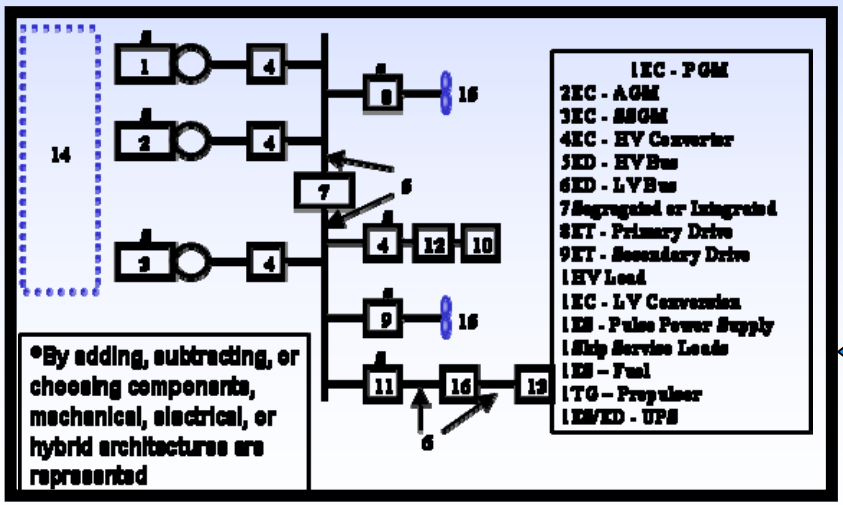
FY05

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

FY06

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





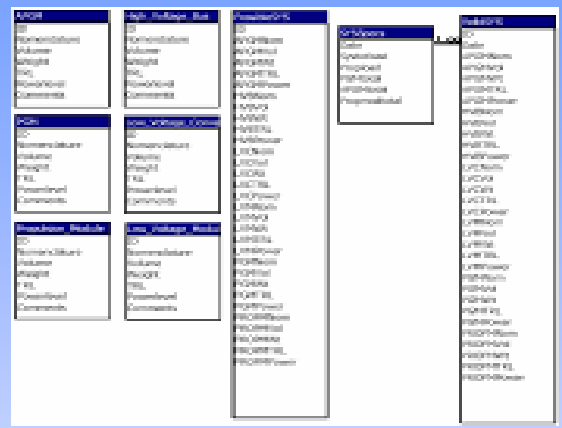
FY07

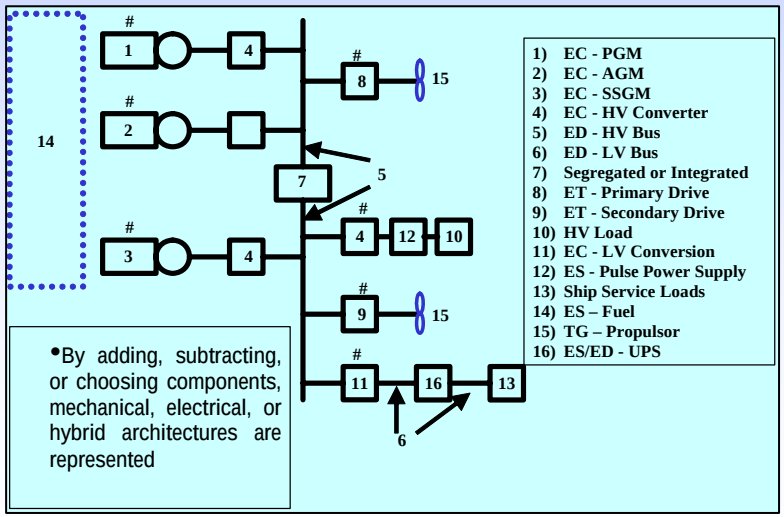
Provides multiple architectures and multiple components to provide system trade-off.. Database of over 100 components allows > 1B combinations.

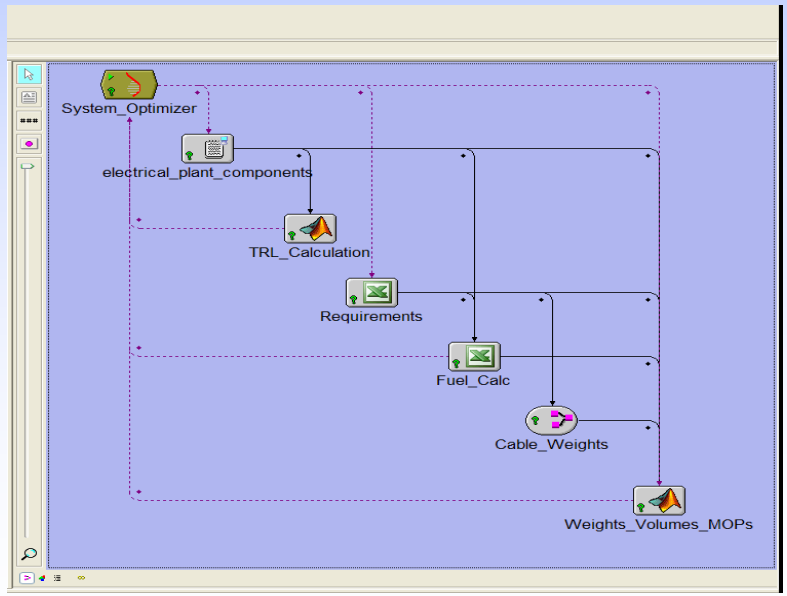
Alternative Propulsion:
Synthesis Modeling and Trade Tool Task

Build Model

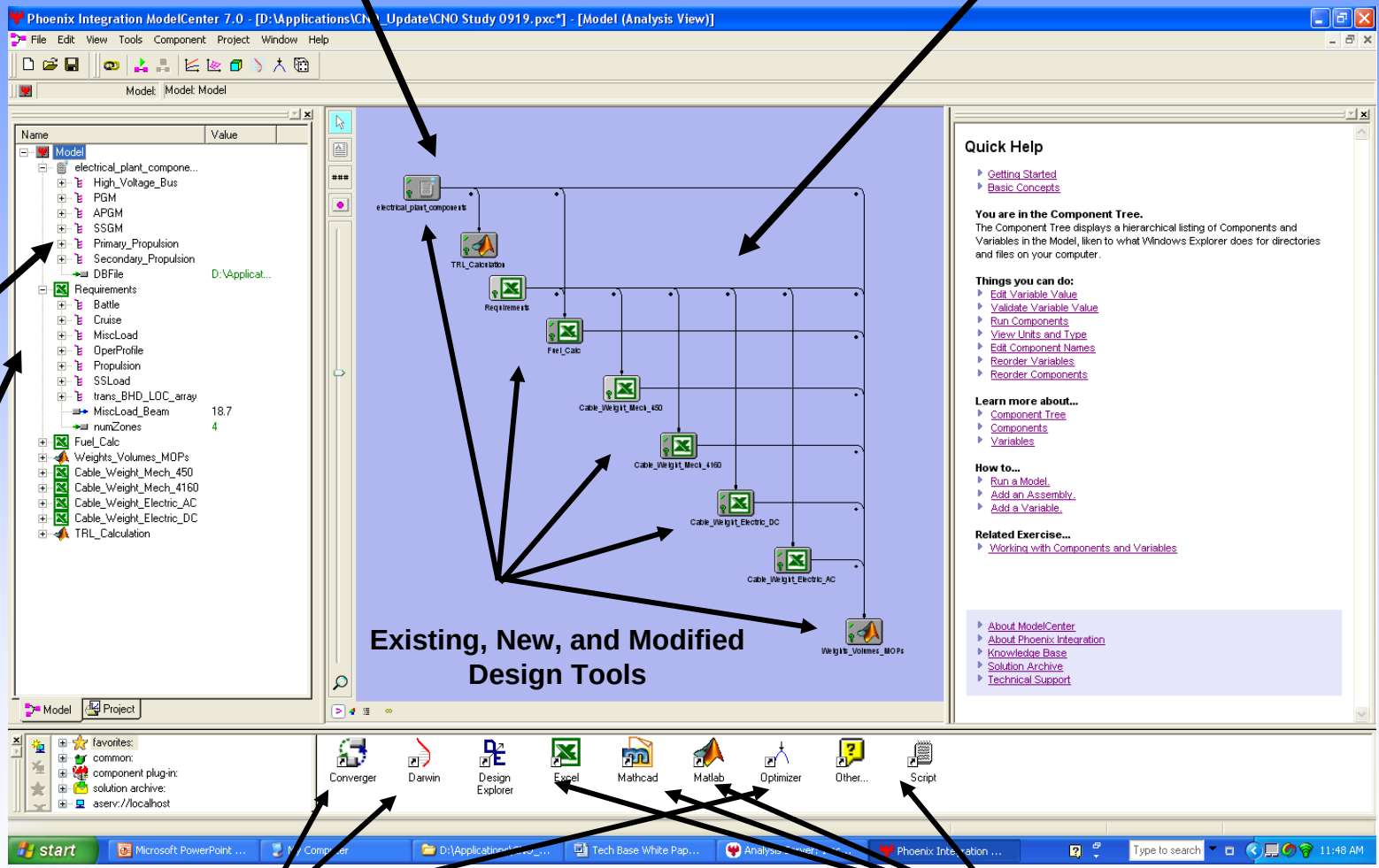
- Fuel calculation module
- Component database module
- System composer module







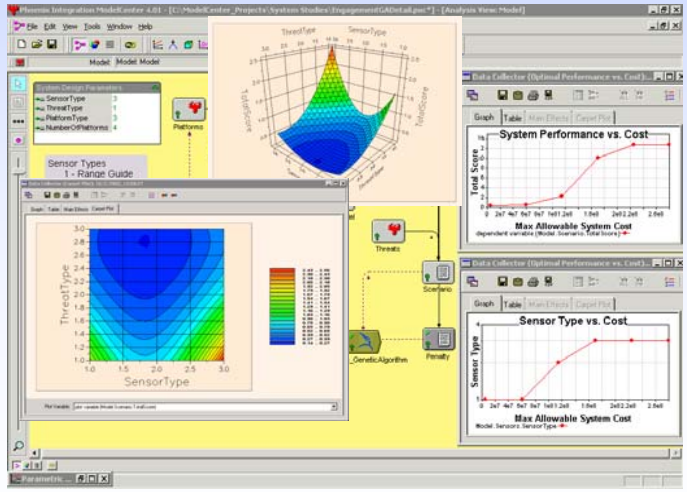
Alternative Propulsion System Model



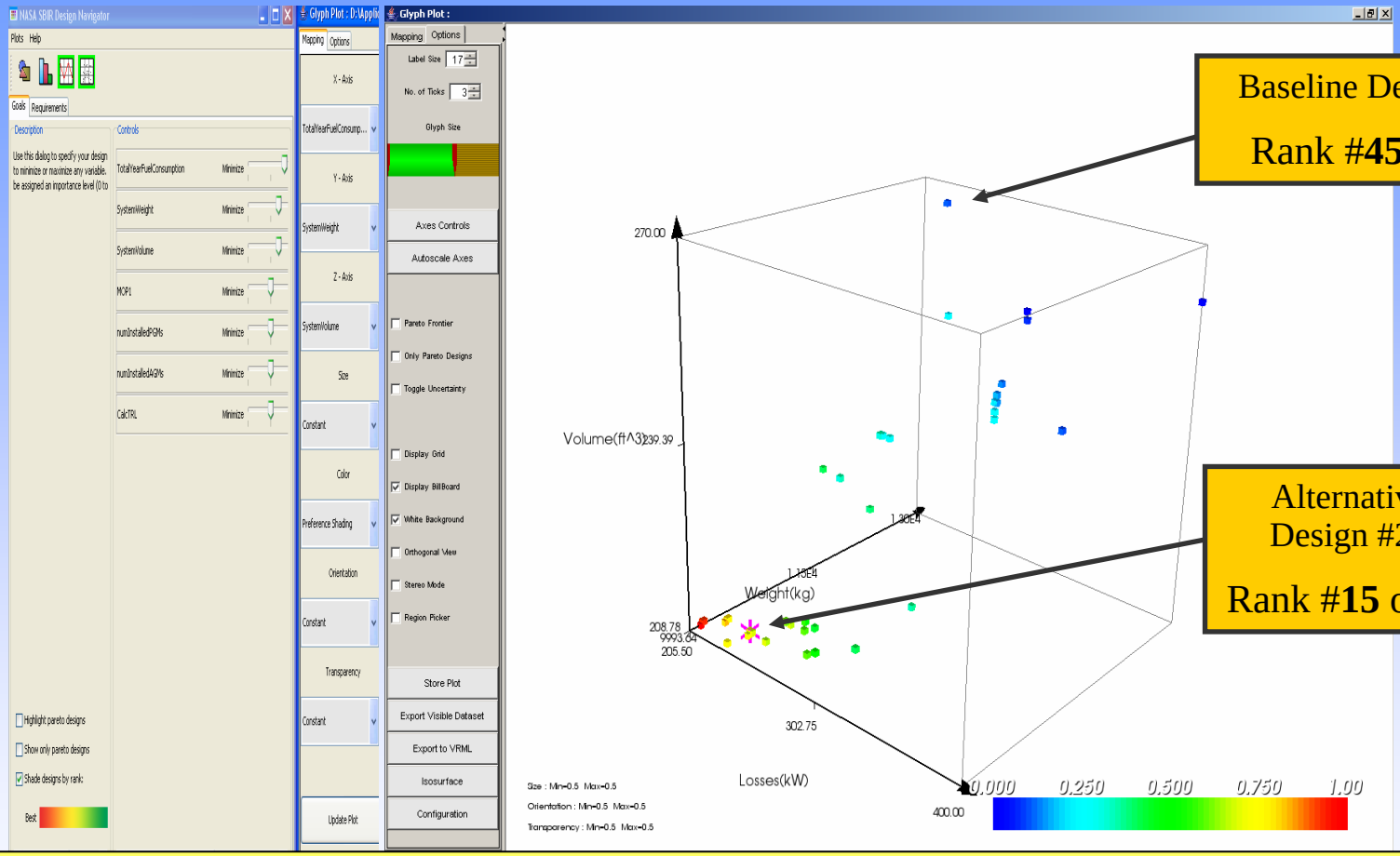
Alternative Propulsion:
Synthesis Modeling and Trade Tool Task

Perform 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

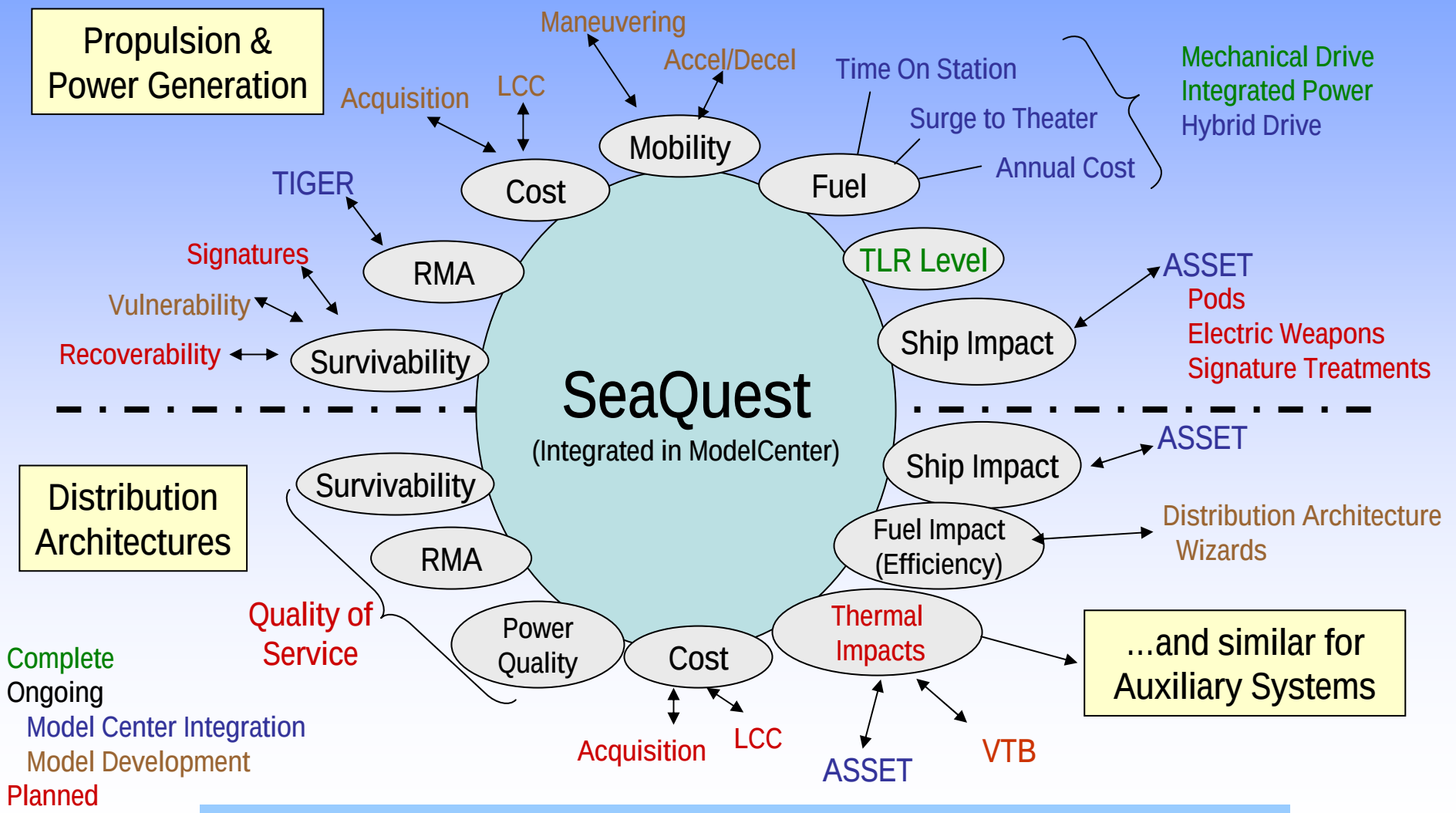


Visualization and Optimization



- Visualization tools used to provide a ranking of multiple components or system configurations with multiple parameters based on user selected metrics
- Optimize using built in tools or manually iterate on select designs

SeaQuest: Propulsion, Power Generation, & Distribution Architecture Tools Development



Summary

- Systems engineering processes and tools such as SeaQuest can help reduce costs and risks while improving performance
  - Single, repeatable process and common toolset
  - Evaluate benefit of evolutionary technology insertions in new and existing ship systems
  - Provides insight where technology development should be headed – where to invest for best ROI
  - Evaluate the potential performance and cost of existing and new technology in future ship systems
  - Aid selection of machinery architectures and components in support of Analysis of Alternatives, and concept/feasibility/preliminary design.

NAVSEA
WARFARE CENTERS
Philadelphia

- **SeaQuest is the process and toolset to provide the insight on methods/technology to address the challenges of life cycle affordability of future Naval ships**

- **Design Integration Software is the enabler for robust system design and analysis.**

Thank you Joe (Jay). I am a Senior Naval Architect in the Machinery Research and Engineering Department at the Naval Surface Warfare Center in Philadelphia. During the past seven years I have been working on systems engineering projects involving system design synthesis modeling and simulation, submarine concept designs, and manned and unmanned submersible vehicle concept designs for the Advanced Machinery Systems Integration Branch.

I have a BS in Ocean Engineering from Virginia Tech, and graduate course work in Systems Engineering and Ocean Engineering from Virginia Tech

Experience:

5 years system design project management

7 years submarine and submersible naval architecture design experience

8 years ship and machinery systems design and evaluation using modeling and simulation

21 1/2 years active duty Navy and submarine nuclear propulsion plant experience.

SLIDE 1

Naval ship design and evaluation methods have typically trailed the aerospace and automotive industries by at least 10 years. Multi-objective trade space evaluation tool use has previously been limited and cumbersome. Design Integration Software has allowed us to close the gap in technology assessments for shipboard machinery systems design.

The increasing complexity of ships due to high power integrated warfare systems, increasing energy demands and fossil fuel costs, and continued budget pressures on Navy programs requires that optimization of machinery plants occur earlier in the ship design cycle.

The decision to fund a technical design concept has typically been done with limited knowledge of its impact to the platform on which it will eventually reside. The constraints of most early concept machinery designs typically focus on operational performance of the components. Only after a design is engineered do cost, risk, and applicability become determining factors in its evaluation. Unfortunately, this approach wastes valuable resources in the technical design of the component when it is later ‘discovered’ the performance of the component when integrated within the system will be too costly or too risky to implement on a naval platform.

SLIDE 2

The solution to this problem is to incorporate performance, cost and risk of integration into the early stage design process. This approach can provide the program manager a family of design options with the potential risks associated with each design and the ability to view the effects of changes in design variables on the overall ship design. This approach requires a new process and new toolset.

SLIDE 3

In order to address this need, a system engineering derived process and design synthesis tool has been developed by NSWC Philadelphia. Systems Engineering Approach (SEA) is the process, QUick Evaluation of Shipboard Technologies (QUEST) is the design synthesis tool, and collectively they are SeaQuest.

SLIDE 4

The fundamental enabler for the SeaQuest toolset is the incorporation of various component models, subsystem models, and component databases using Design Integration Software such as Phoenix Integrations Model Center. Design Integration Software enables the performance of shipboard machinery trade studies using various physical, performance & cost models, including system weight and volume, ship level impacts, total fuel consumption, cost (both acquisition and life cycle), time on station, surge to theater, and survivability. It allows the use of Other People's Models to perform machinery trade studies to support early ship design, current fleet technology insertion needs, and research and development decisions.

SLIDE 5

SeaQuest builds on models, created for specific projects which, individually, lack the flexibility or resolution for machinery system and components analysis beyond a high level evaluation. The ability to integrate these independent models results in a design toolset that enables quick and accurate evaluation of a range of propulsion, power, and auxiliary system architectures and components. The toolset allows evaluation of thousands of combinations of architectures and components using multi-objective optimization and advanced visualization tools and facilitates down selection of acceptable solutions based on physical ship requirements and metrics.

SLIDE 6

Previous machinery system projects using Design Integration Software have been progressively more detailed, beginning with a Transformer Capacity Probabilistic Analysis, a High Speed Generator Trade Study for the Advanced Surface Combatant, the Alternative Propulsion Study Report to Congress, a Shipboard Fuel Cell Baseloading study, and most recently, the DDG-51 Hybrid Electric Drive Study and ONR Power Dense Demonstrator for the DDG 51 Flight IIA Ships. The design integration environment facilitated connection of variables from models written in several third party software packages, and provided the tools for data collection, analysis, and visualization.

SLIDE 7

For the Alternative Propulsion Study, SeaQuest was used to determine the impact of various configurations of electrical and propulsion systems on fuel efficiency. Formerly, basic machinery trades were based on achieving maximum speed and the lowest combination of machinery weight plus an endurance fuel load.

SLIDE 8

The Alternative Propulsion study incorporated a speed-state-time profile and robust energy calculator model to increase the accuracy of the machinery design impact and reduce risk in early stage system design.

SLIDE 9

The SeaQuest toolset, as enabled by Design Integration Software, supports Analysis of Alternatives, conceptual and feasibility design efforts, and evaluation of potential machinery research and development initiatives through the use of Design of Experiments, Sensitivity Analysis, Probabilistic Analysis,

SLIDE 10

Optimization Techniques and Visualization Tools all available in a single integrated design environment with relatively easy data pass-through.

SLIDE 11

NAVSEA Philadelphia has ongoing efforts to continue development and integration of new and existing Navy ship machinery evaluation tools including collaborating with Dr. Alan Brown of Virginia Tech, to assist on integration of the Advanced Ship and Submarine Evaluation Tool with SeaQuest, and Phoenix Integration to assist on integration of the TIGER reliability, maintainability, and availability tool with SeaQuest. Issues to date have been primarily with instability in some of the model algorithms, and memory leakage problems with third party software executing thousands of synthesis iterations. Future needs from the Design Integration Software developers are in the areas of simple but robust data management and model configuration management; tools for the evaluation of error, uncertainty, and risk associated with data including integration of models with different levels of fidelity.

SLIDE 12

The benefits of the SeaQuest process and tools are: (1) establishment and recognition of a single, repeatable process and common toolset for machinery design that ties into the Total Ship Systems Engineering effort ongoing in NAVSEA 05D, (2) evaluate the benefit of evolutionary technology insertions in new and existing ship systems, (3) identify areas of research and development of machinery and machinery components that offer the best return of investment, (4) evaluate the potential performance and cost of existing and new technology in future ship systems, and (5) aid in selection of machinery architectures and components in support of Analysis of Alternatives, and concept/feasibility/preliminary design.

SLIDE 13

The advent of weapons systems demanding extremely high power will significantly impact the life cycle affordability of future ships from an energy resource perspective. Methods to evaluate that impact are increasingly more important in the acquisition of future Naval ships. SeaQuest is the process and toolset to provide the insight on methods and technologies to address these challenges, and Design Integration Software is the enabler for robust systems design and analysis.

Thank you for your time.