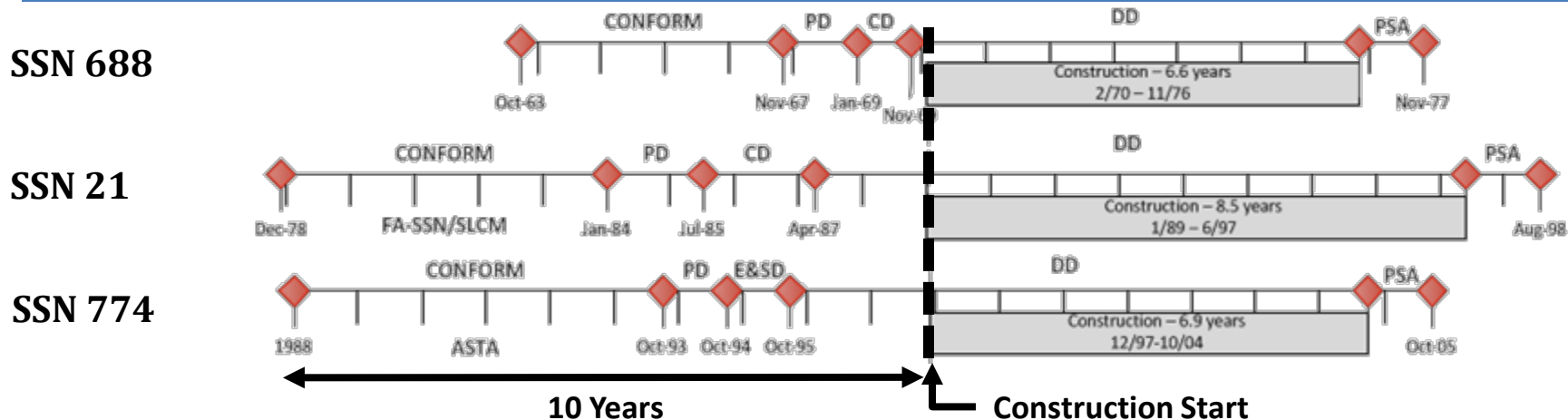


Engineered Resilient System Design: Submarines in a new Era of Undersea Warfare

Presented by Dr. Joseph T. Arcano
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18th Annual NDIA Systems Engineering Conference
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Springfield, VA

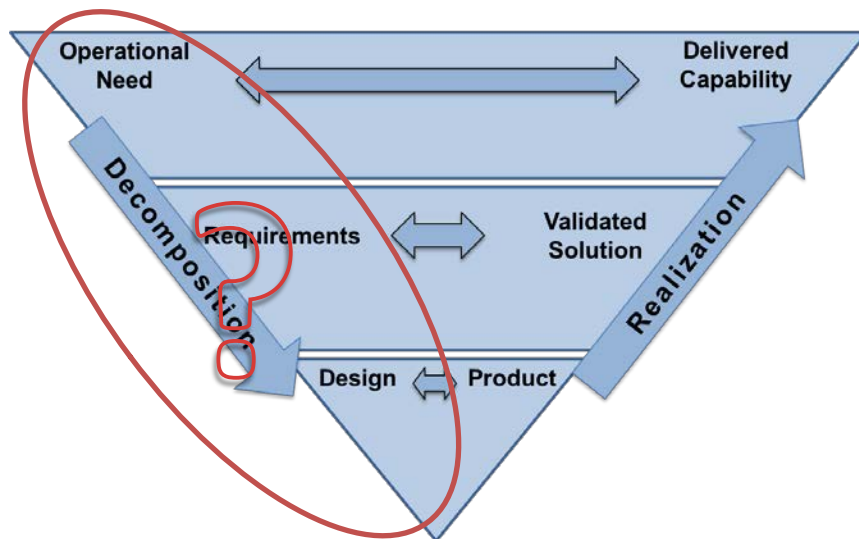
Preparing for the Next Generation Submarine



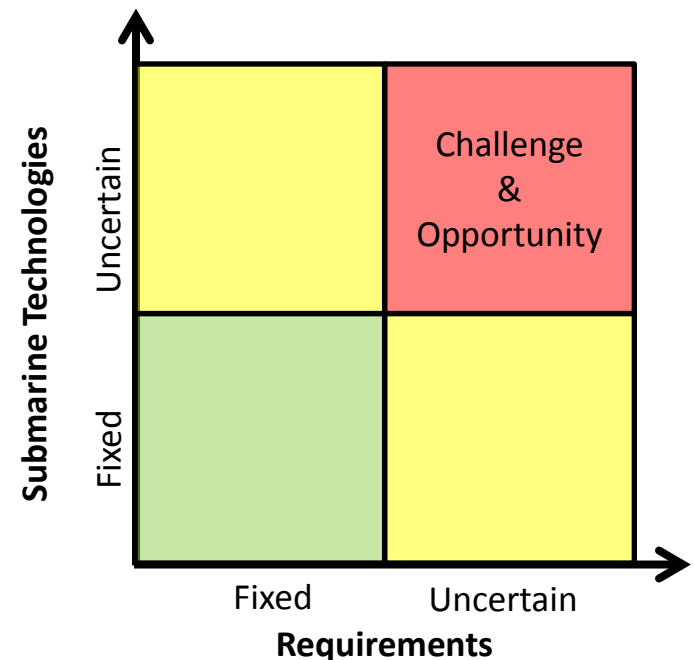
- The U.S. Navy shipbuilding plan starts construction of the next generation submarine in 2034
- Historical trends show that concept development needs to begin at least 10 years prior to construction start
- Technologies, people, processes, and design tools must be matured now if they are to support the future program

A New Era in Undersea Warfare

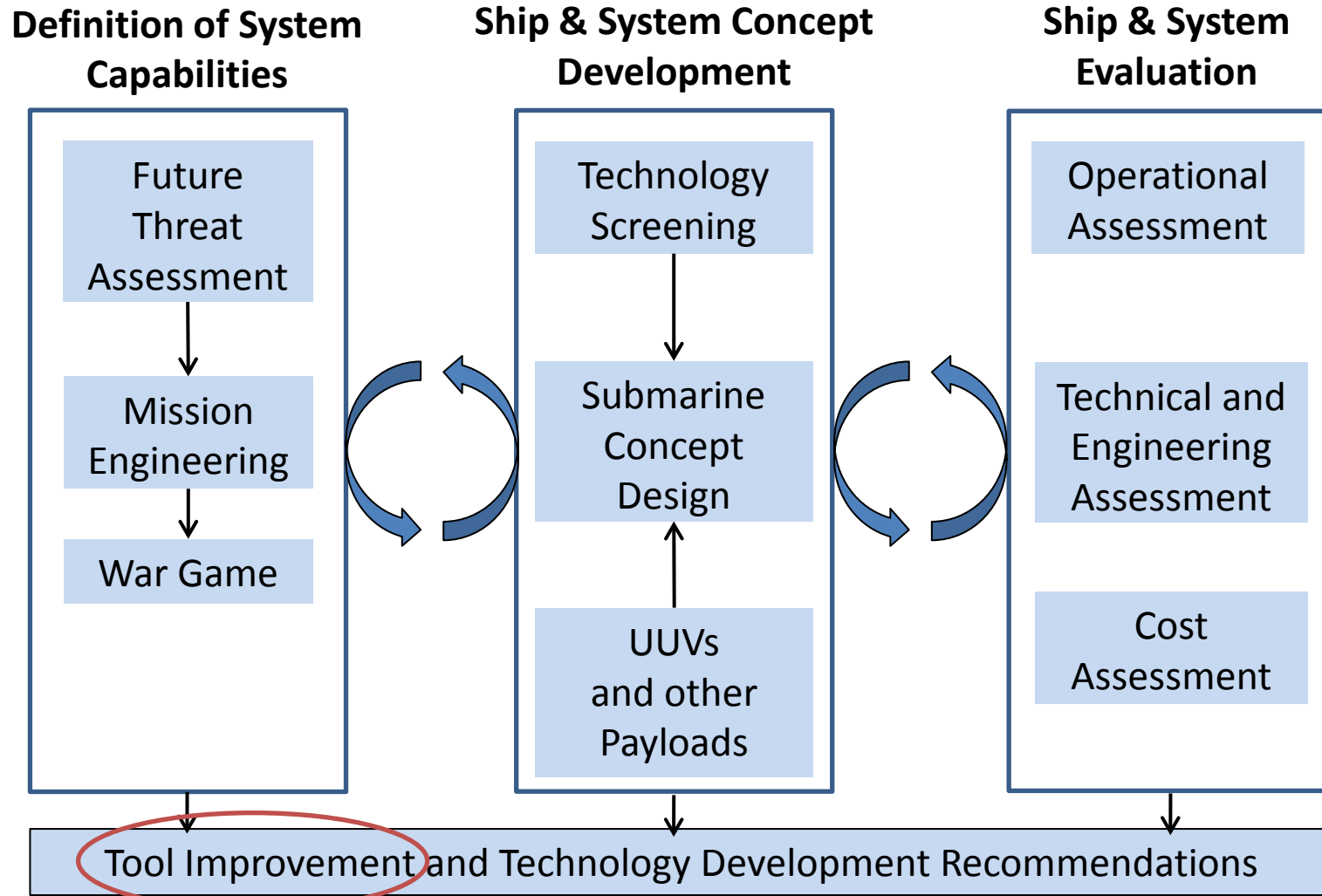
- Future concepts of employment and technologies are yet to be defined
- The global pace of technology development is accelerating
- A Submarine Concept Team, with guidance from a PEOSUB chartered Flag Oversight Board, is using a systems engineering approach to address this challenge and prepare for an Analysis of Alternatives



Defense Acquisition Guidebook - <https://acc.dau.mil>

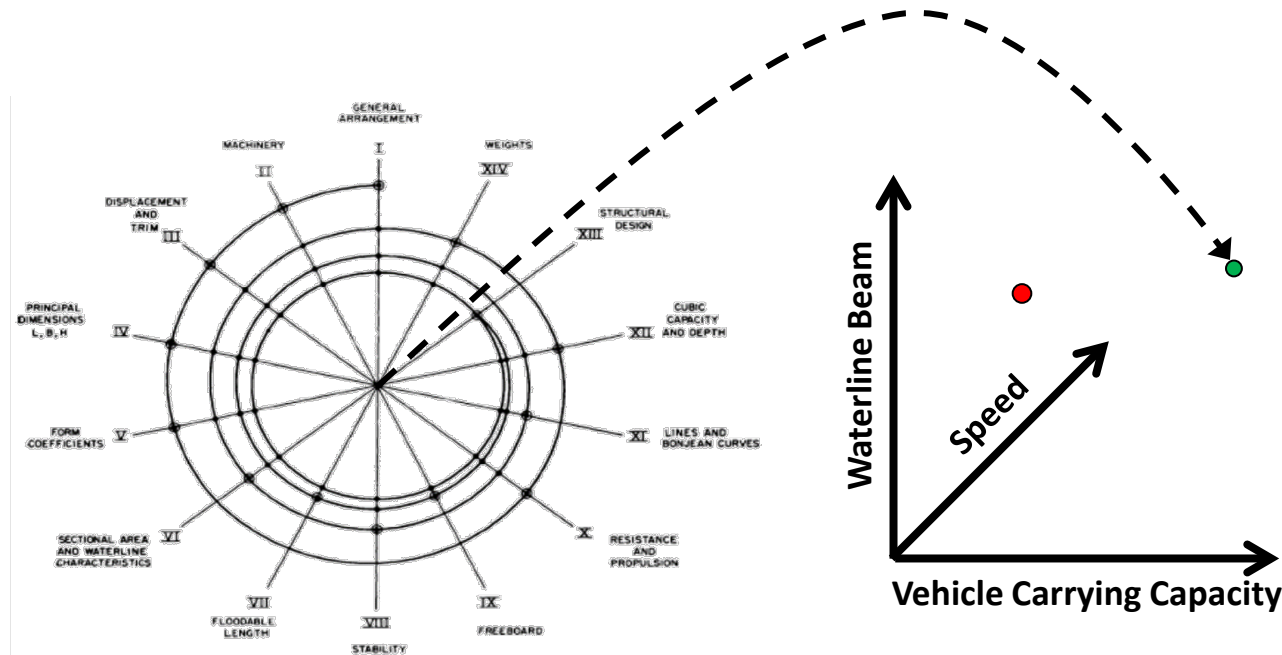


Submarine Concept Team Design Process



The Classic Design Paradigm

- A manual point-based design spiral approach is flexible and accurate, but very slow and manpower intensive
- Few design points can be evaluated, meaning limited understanding of requirement impacts
- Not ideal when requirements are uncertain or coupled

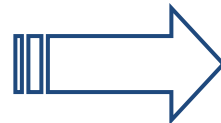
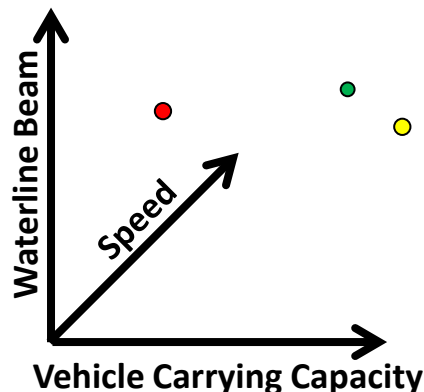


Evans, J.H., "Basic design concepts,"
Naval Engineers Journal, Vol. 21, pp. 671-679, 1959.

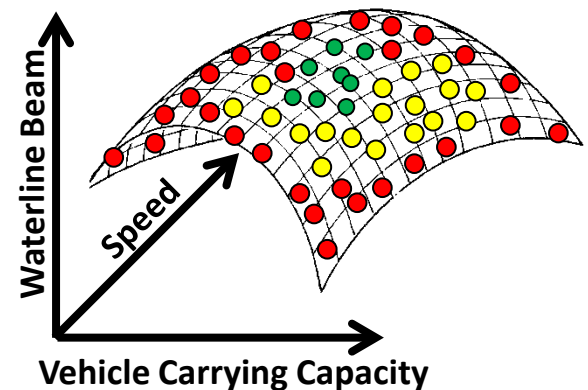
Moving Toward Design Space Exploration

- The goal of Design Space Exploration is to define a broader design trade space
- Increasing knowledge early reduces risk and cost
- Design Space Exploration requires a significant investment in tools, especially with regard to automating design synthesis

From limited investigation of relatively few design points

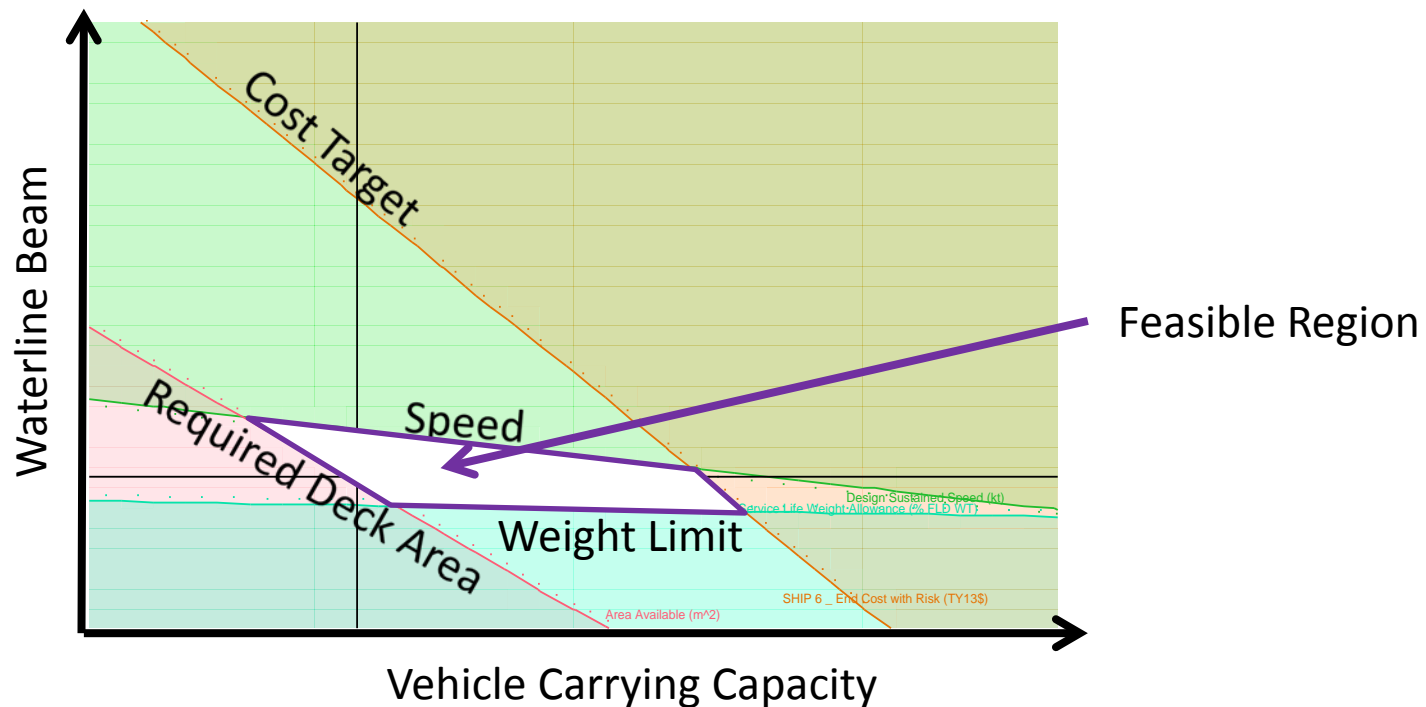


To robust investigation of concepts throughout the design space



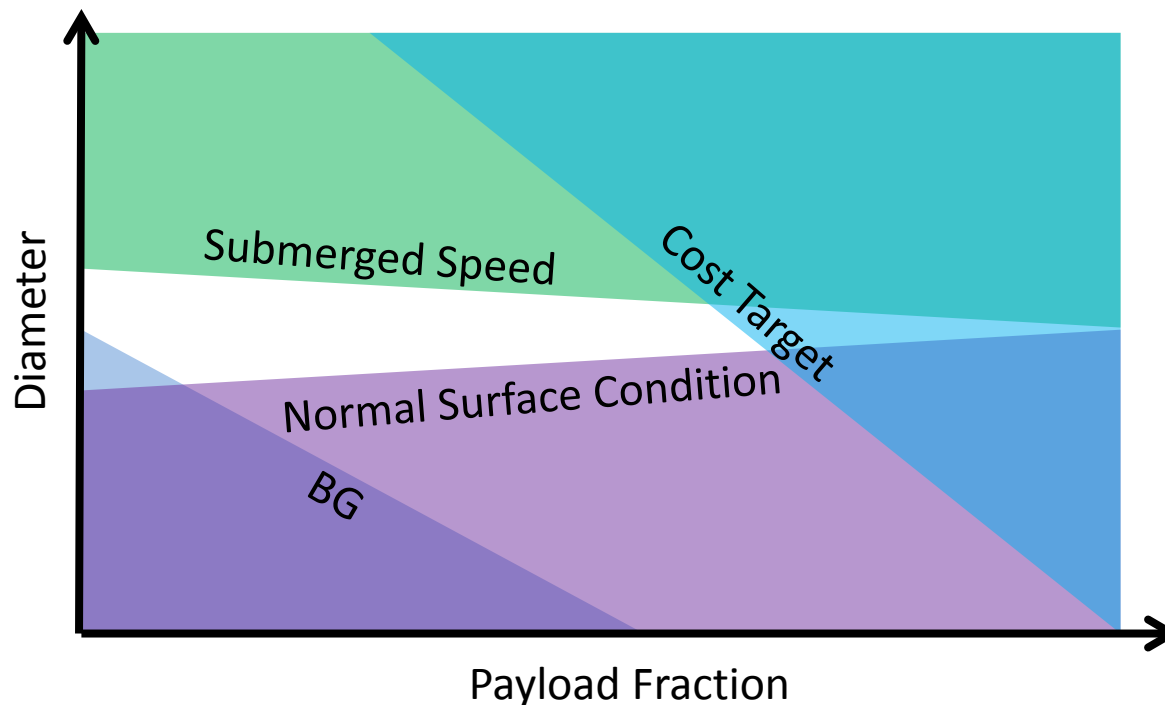
The Rapid Ship Design Environment (RSDE)

- RSDE is a Design Space Exploration tool for surface ships developed with long-term support from CREATE and ERS
- RSDE played a key part in the Small Surface Combatant Task Force and Analysis of Alternatives for the LX(R) amphibious assault ship



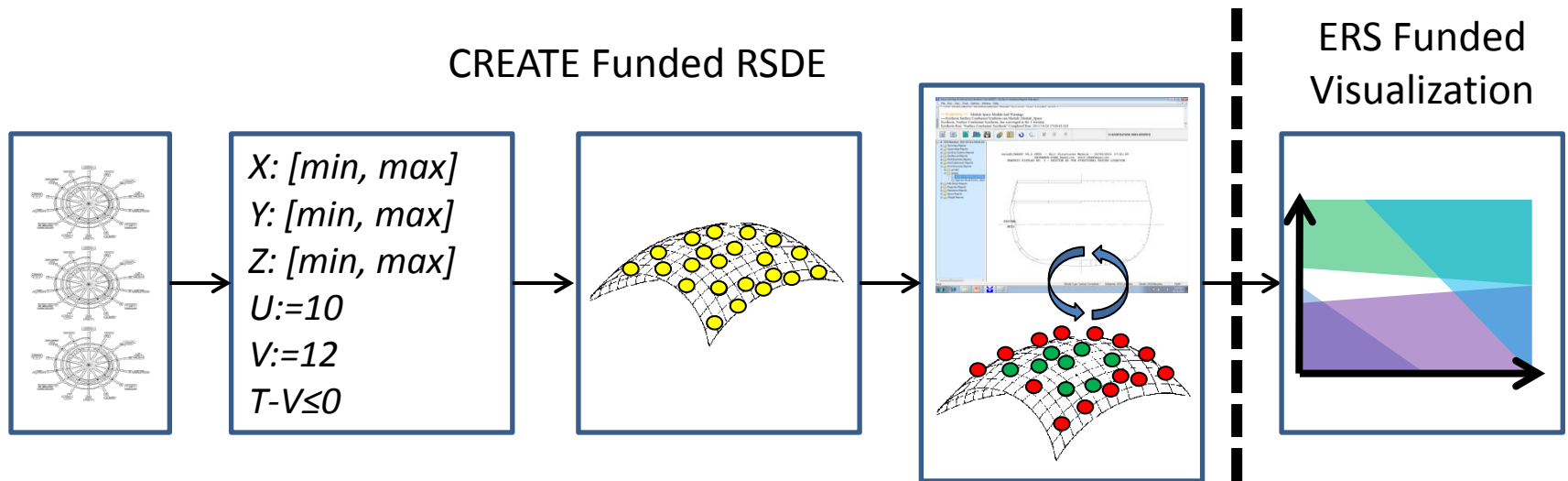
The Submarine Rapid Design Environment (SRDE)

- RSDE capability needs to be extended to submarine design
- The Design Space Exploration method will remain unchanged, but the design synthesis, constraints and parameters will be different



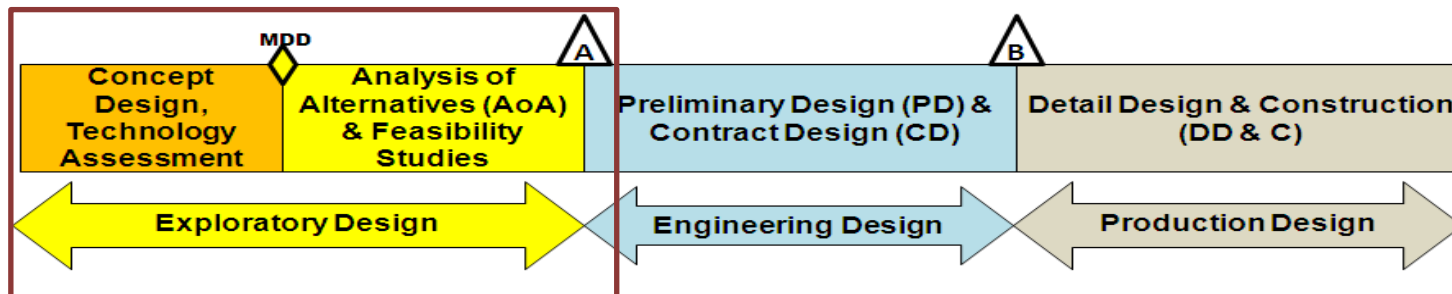
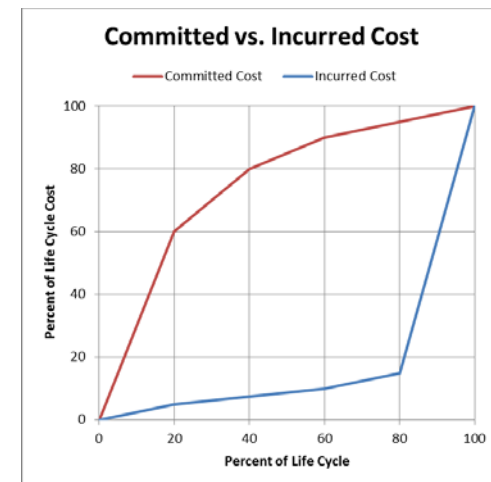
How RSDE Works

1. Design several baselines as starting points for Design Space Exploration
2. Determine design requirements and ranges for parameters, creating the bounds of the design space
3. Pick design points to evaluate using Design of Experiments
4. Run automated design synthesis and analysis tools to determine the feasibility and characteristics of the sampled points
5. Conduct trade off analysis using design space visualization tools



DSE's Role in Acquisition

- Pre-Milestone A decisions are very influential
- Increased knowledge of the trade space from Design Space Exploration enables well-informed early decisions and reduces risk regarding:
 1. Requirements
 2. Ship architecture
 3. Concepts of employment
 4. Military effectiveness
 5. Technology selection and investment
 6. Cost



Defense Acquisition Guidebook - <https://acc.dau.mil>

Submarine DSE Presents Unique Challenges

- Never been attempted before
- No established automated design synthesis method
- Compared to surface ships, submarine Design Space Exploration will require:
 - Different priorities, technologies, and science
 - Different design constraints
 - Tighter coupling of design constraints
 - Higher minimum required fidelity levels



http://www.navy.mil/navydata/our_ships.asp

An Excellent Opportunity for the DoD

- High level visibility
- Large return on investment
- Demonstrable successes
- Design decision aid that can be used by decision makers

The Navy is moving forward to develop this capability