

Advances in Early-Stage Resilient Submarine Design Capability

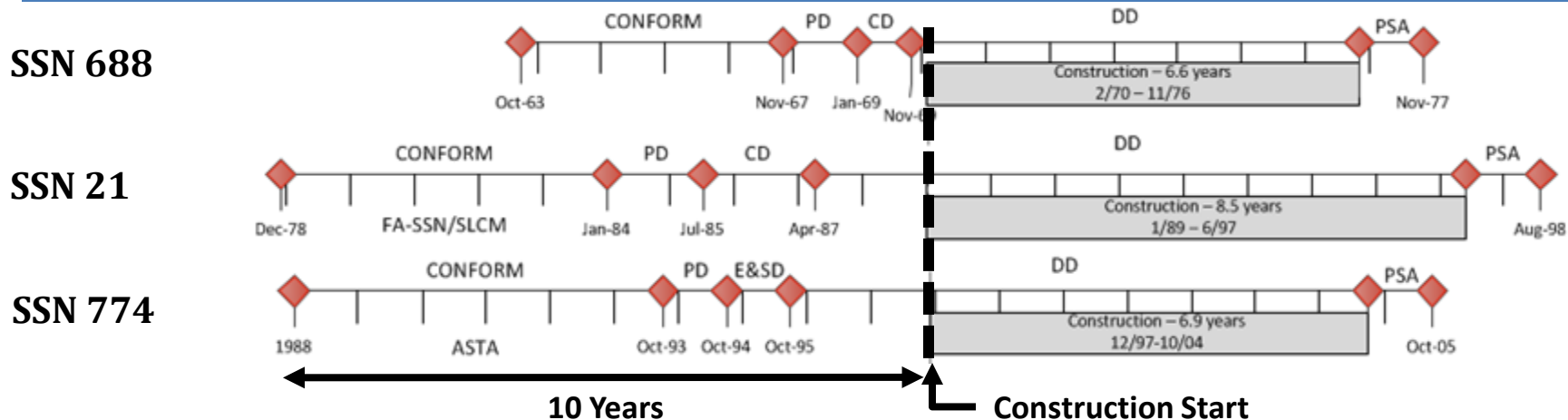
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19th Annual NDIA Systems Engineering Conference, 2016

Bottom Line Up Front

- The next generation submarine requirements, technologies, and design are uncertain
- The current submarine design toolset is inadequate to support full set-based requirements, technology, and design trade space exploration
- Significant, stable, and persistent investment is required to close the design tools gap
- FY16 ERS funding has provided an initial step towards reducing the capability gap for both tools and people
- Proposed FY17+ projects will apply the newly fielded capabilities and continue to reduce the tools gap

Preparing for the Next Generation Submarine

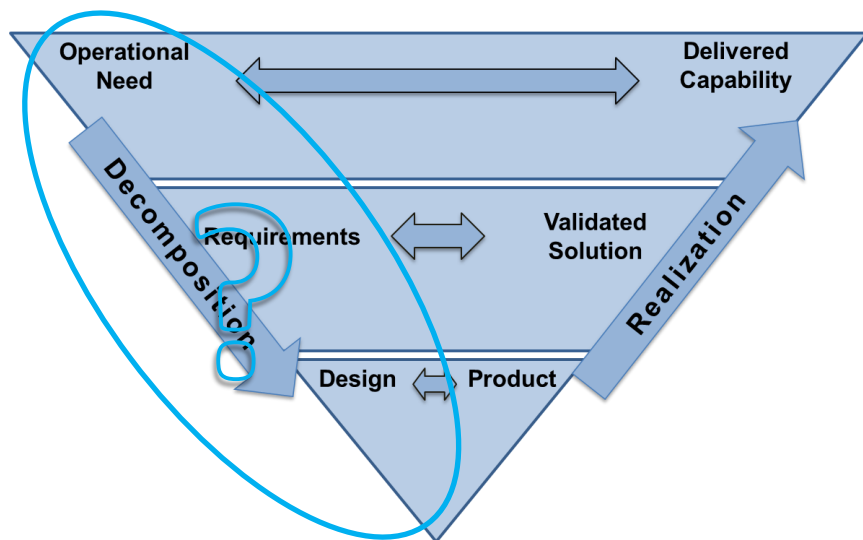


- The U.S. Navy shipbuilding plan has construction of the next generation submarine starting around 2034
- Historical trends show that concept development needs to begin at least 10 years prior to construction start
- Technologies, people, processes, and design tools must be matured now if they are to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

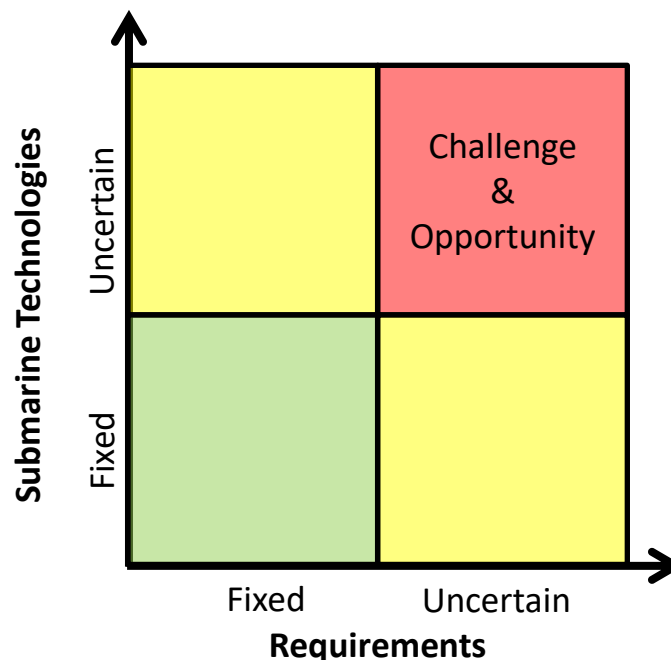
“Engineered Resilient System Design: Submarines in a new Era of Undersea Warfare”, presented by Dr. Joseph T. Arcano at the 18th Annual NDIA Systems Engineering Conference, Springfield, VA 2015.

A New Era in Undersea Warfare

- Future requirements and technologies are yet to be defined
- The global pace of technology development is accelerating
- The Submarine Concept Team is addressing this challenge



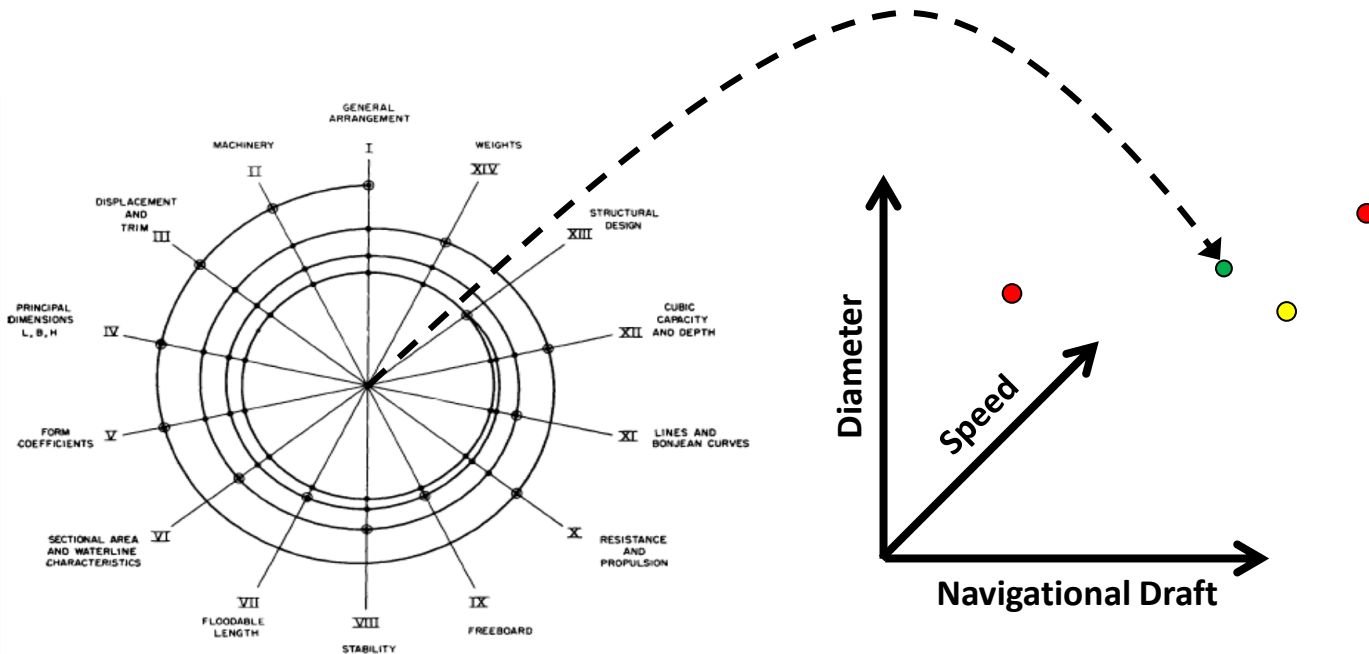
Defense Acquisition Guidebook - <https://acc.dau.mil>



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The Classic Design Paradigm

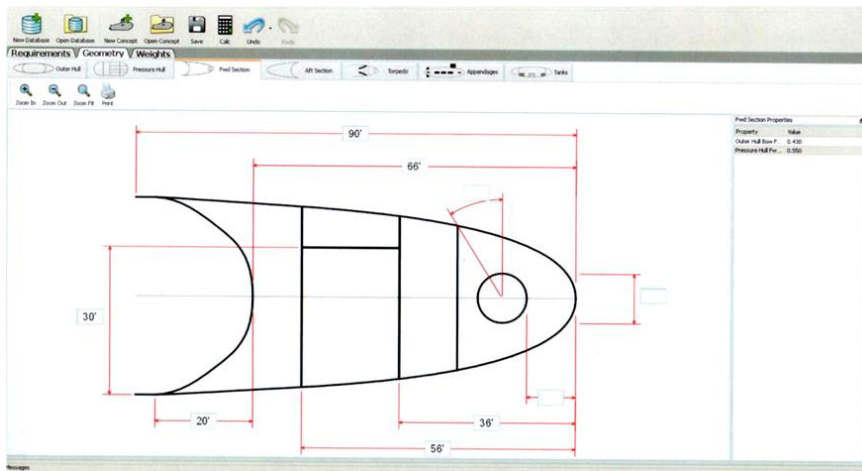
- A manual point-based design spiral approach is flexible and accurate, but very slow and manpower intensive
- Few points can be evaluated, meaning limited understanding of requirements, technologies, or designs
- Not ideal when requirements are uncertain or coupled



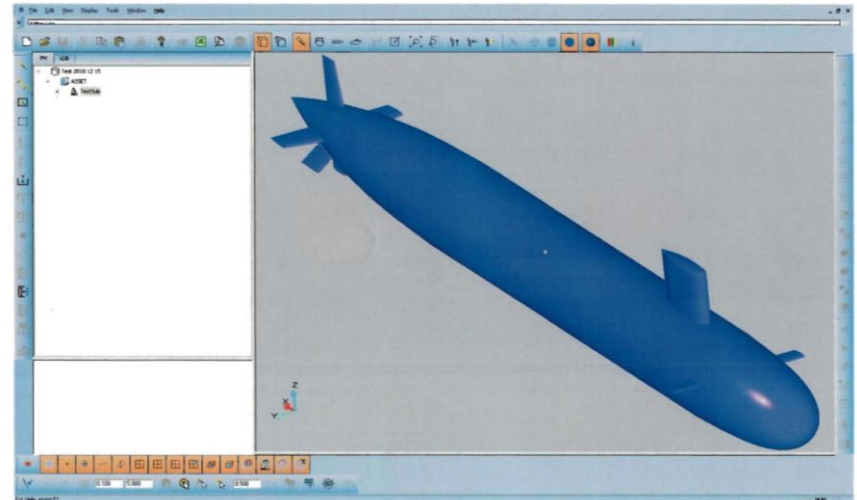
Evans, J.H., "Basic design concepts,"
Naval Engineers Journal, Vol. 21, pp. 671-679, 1959.

Current Design Tool Capability

- **ASSET-Submarine** is the current submarine concept design tool
 - A manual tool currently limited to small excursions from the Block I VIRGINIA



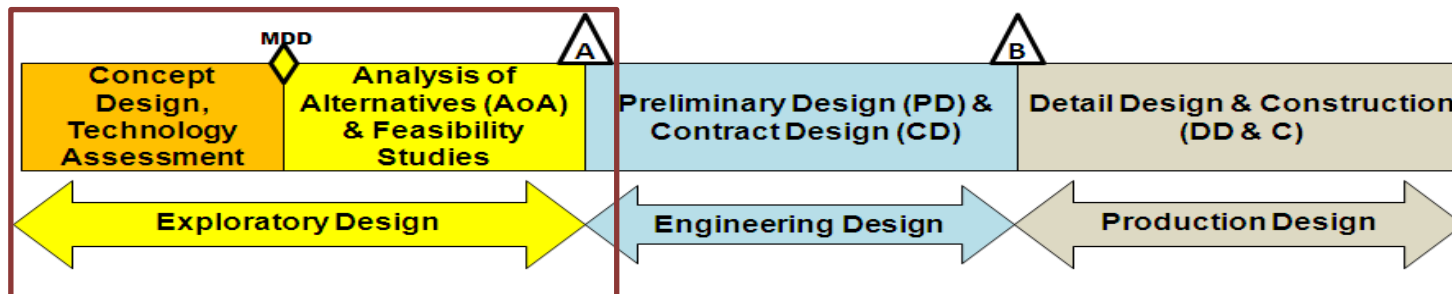
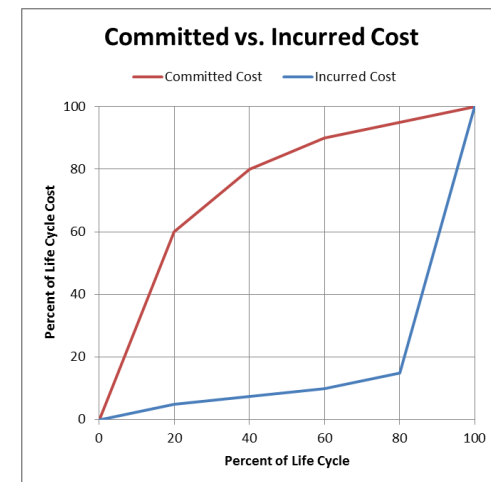
ASSET-Submarine v1.4



LEAPS Editor

Motivation for Set-Based Design

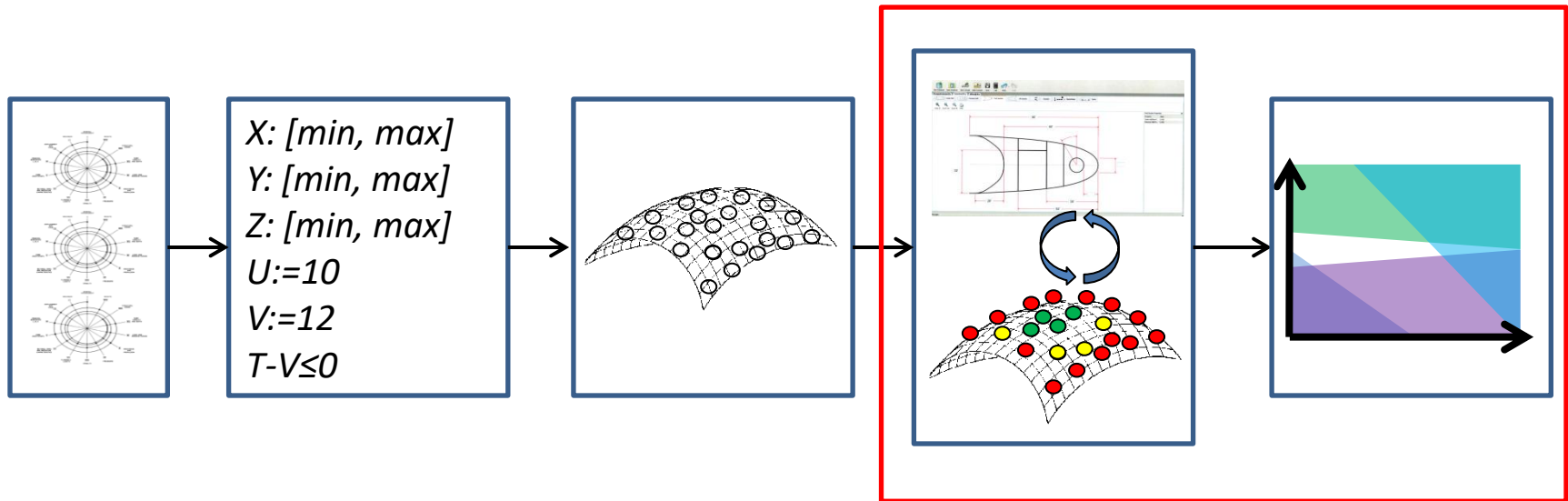
- Pre-Milestone A decisions are very influential
- Set-Based Design (SBD) is a proven methodology to make the right decision the first time by understanding tradeoffs prior to commitment, SBD applies to:
 1. Requirements development
 2. Technology development
 3. Design development
- The output is tradeoff information, e.g. between cost, capability, and performance



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Moving Toward Set-Based Design

- Fully exploring submarine requirements, technologies, and the design trade space requires a significant investment in tools, especially with regard to automating design synthesis and visualizing results



Capability Gaps

1st Step: ASSET-Submarine v1.5

- **VIRGINIA Class Block III and Block V models**
 - Funded by ERS
 - Demonstrated the current tool capability, and increased the design experience base
 - Provide the analytical base for Block VI and VII concept studies



SSN 784 - <http://www.navy.mil>

1st Step: ASSET-Submarine v1.5

- **Documentation**

- Funded by ERS
- Engaged the user community for required tool capability upgrades
- Leveraged the experience of developing match models
- Identified desired flexibility enhancements
- Workforce development and knowledge capture

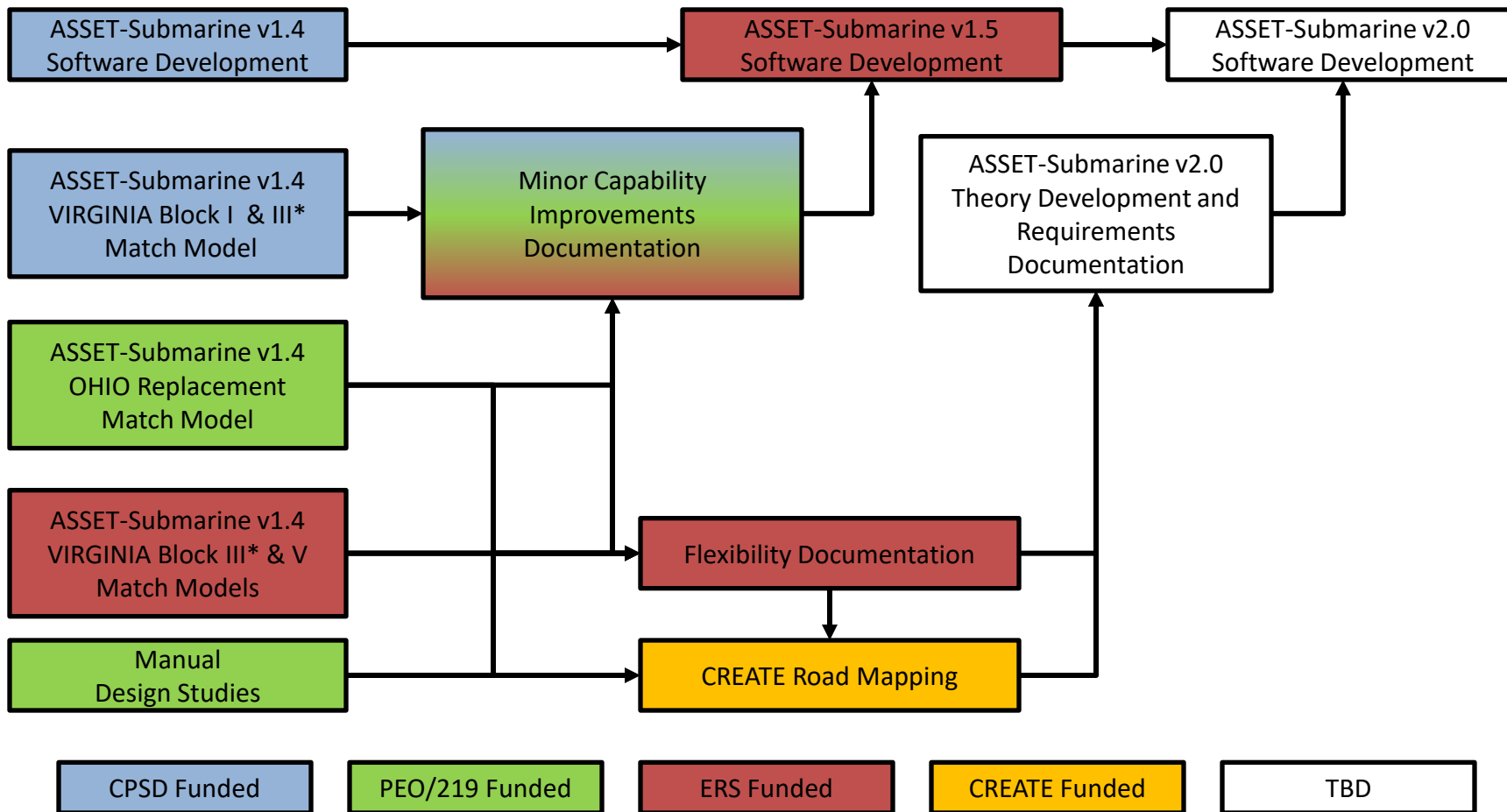
- **Software development**

- Funded by ERS
- Implemented “quick-win” needed capability improvements
- Enabled ASSET-Submarine for use in CY16 and CY17 concept design studies
- Re-engaged developers for work on submarine design software
- Delivered in September 2016
- Immediate benefit to submarine concept design teams at NAVSEA 05U, NSWC-Carderock Division

1st Step: ASSET-Submarine v1.5

- **Enhanced Design Capability**
 - Now model additional evolutionary concept designs, *beyond VA Class*
 - Model *all* current attack submarines in the fleet
 - Previously could only model VA Class
 - Capabilities enabled by updates to:
 - Geometric modeling: addition/subtraction of key submarine features
 - Automatic update of weights and volumes as a result
 - Improved weights & volumes tracking

ASSET-Submarine Funding History



*The CPSPD funded VIRGINIA Block III match model was completed prior to finalization of the Block III design. The ERS funded VIRGINIA Block III Match Model used the final design and was a necessary step to complete the Block V match model.

Tool Development: Planning

Step 1: Design Space Exploration to Support Set-Based Design

- Early funding will enable drive towards a submarine design space exploration (DSE) capability to enable set-based design (SBD) methods

Step 2: Further Enable Set-Based Design Method

- Later funding will add additional physics-based analysis capabilities, which are needed to inform and enable the set-based design space reduction.

Funding

- Long-term, steady funding is key to successful software development
 - CREATE-Ships RSDE is an excellent example
 - Frees software development process from the rapidly changing desire-ments of short-term funding sources
- Proposals have been submitted to support FY17 development efforts
 - Focus on: Software and Workforce development

Tool Development: Capabilities

Enabling High Magnitude Design Space Exploration (DSE) FY17-FY19

- Software updates: transition to flexible software design framework
- Expansion of evolutionary design and analysis capability: evolutionary weight, geometry, and displacement calculations to be updated
- Implement hydrostatic balance algorithm
- Integrate into the rapid ship design environment
- Integrate SWAPC capability, implement updates



High Magnitude DSE

Enabling Submarine Set-Based Design (SBD) FY20 & Beyond

- Integrate cost estimation, periodically implement updates
- Develop and implement improved structural design theory
- Develop and implement analysis capabilities: hydrodynamics, susceptibility, vulnerability etc.

Conclusion

- The next generation submarine requirements, technologies, and design are uncertain
- The current submarine design toolset is inadequate to support full set-based requirements, technologies, and design trade space exploration
- Significant, stable, and persistent investment is required to close the design tools gap
- FY16 ERS funding has provided an initial step towards reducing the capability gap for both tools and people
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