Naval Postgraduate School
Systems Engineering Department
Monterey, CA

Defining a Model-Based Systems Engineering Approach for Technical Reviews

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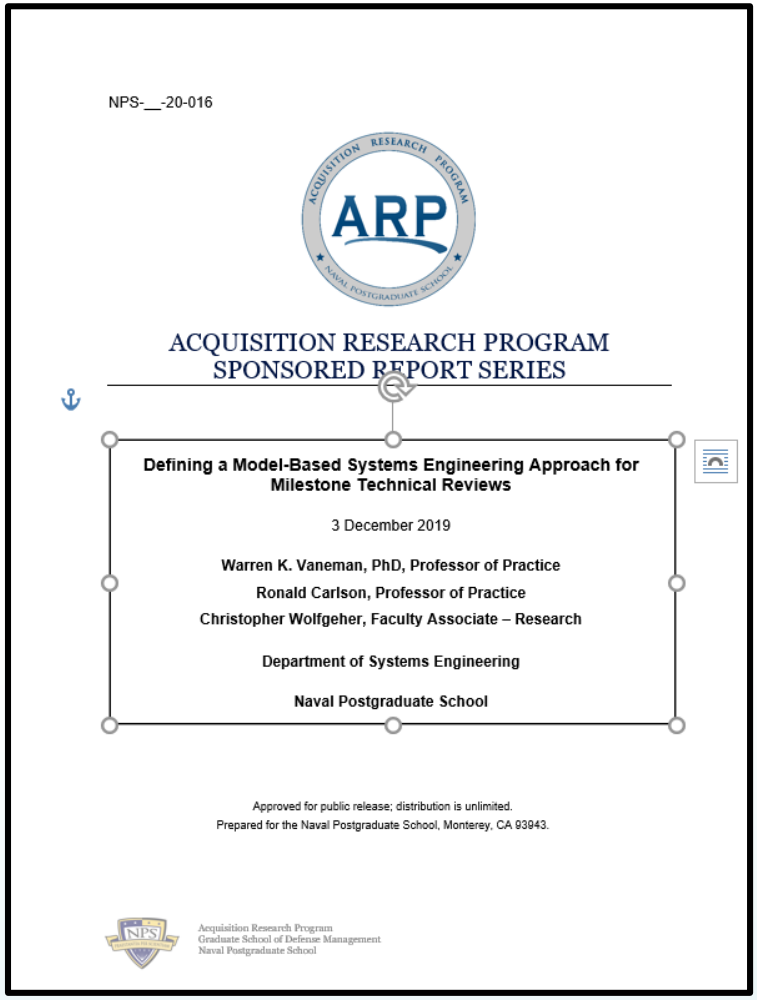
Background

- FY19 Acquisition Research Program project focused on Technical Reviews in a Model-Based Systems Engineering (MBSE) environment.
- Two project phases:
  - Define a systematic processes for developing the virtual model of the system, as the program progresses through the acquisition lifecycle.
  - Evaluate existing review criteria, and determine the suitability of current MBSE visualization models to address that criteria.



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Defining a Model-Based Systems Engineering Approach for Milestone Technical Reviews

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Acquisition Research Program
Graduate School of Defense Management
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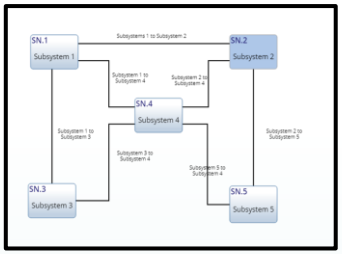
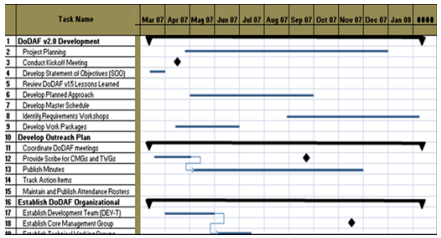
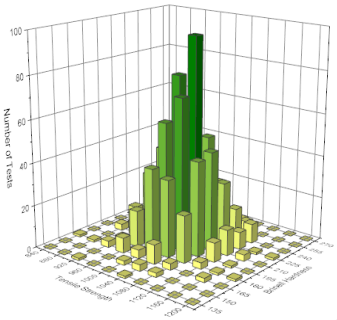
Background

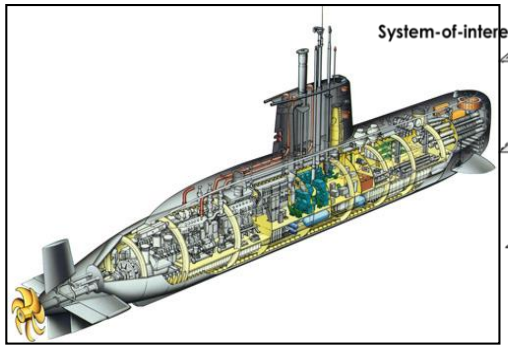
Traditional Systems Engineering Technical Reviews

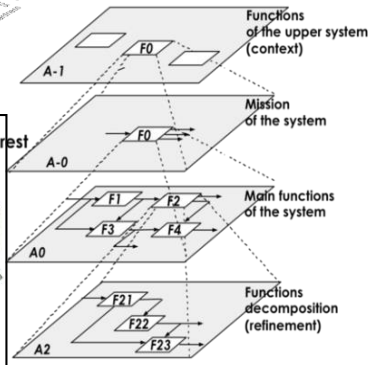




Model-Based Systems Engineering Technical Reviews

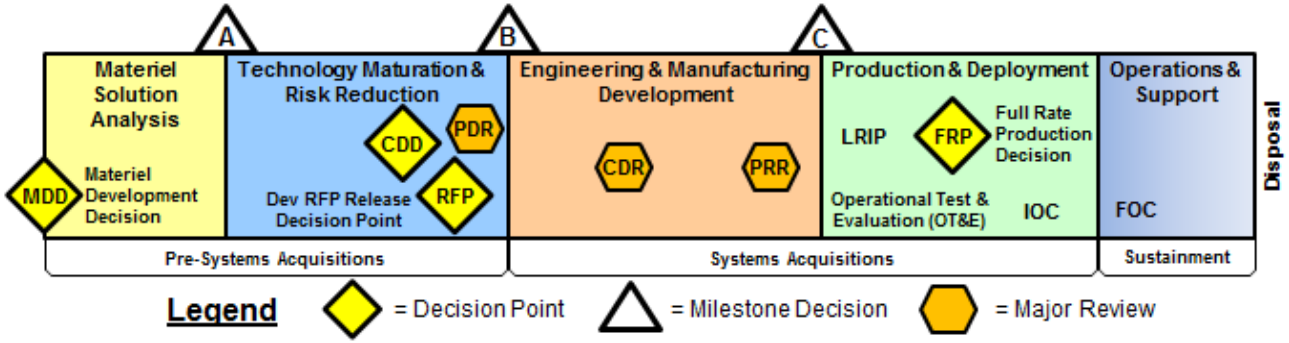






Model-Based Systems Engineering was envisioned to transform systems engineering from a document-based to model-based discipline.

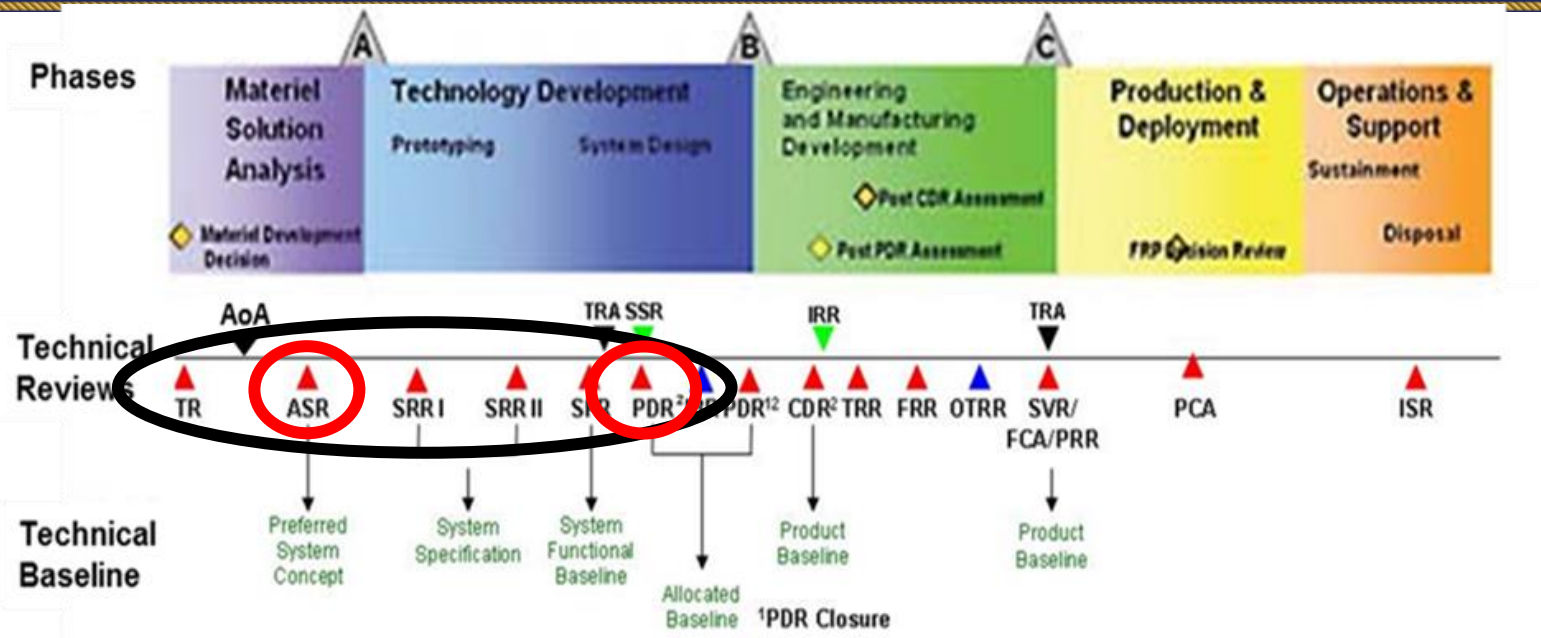
Modeling with the System Acquisition Lifecycle



- The System Acquisition Lifecycle Model identifies five primary phases which take the system from concept develop and material solution analysis through operations and support.
  - The first three phases (prior to Milestone C) are where the most significant engineering occurs.
  - Each phase contains one or more Systems Engineering Technical Reviews (SETR).
  - Current SETRs focus “static artifacts” to demonstrate criteria satisfaction.
- MBSE focuses on model development of the “virtual system” throughout the lifecycle, and away from artifacts produced exclusively for technical reviews.

Use models to support engineering activities and decision making across the lifecycle. - *DoD Digital Engineering Strategy, Goal 1.3*

Study Focus

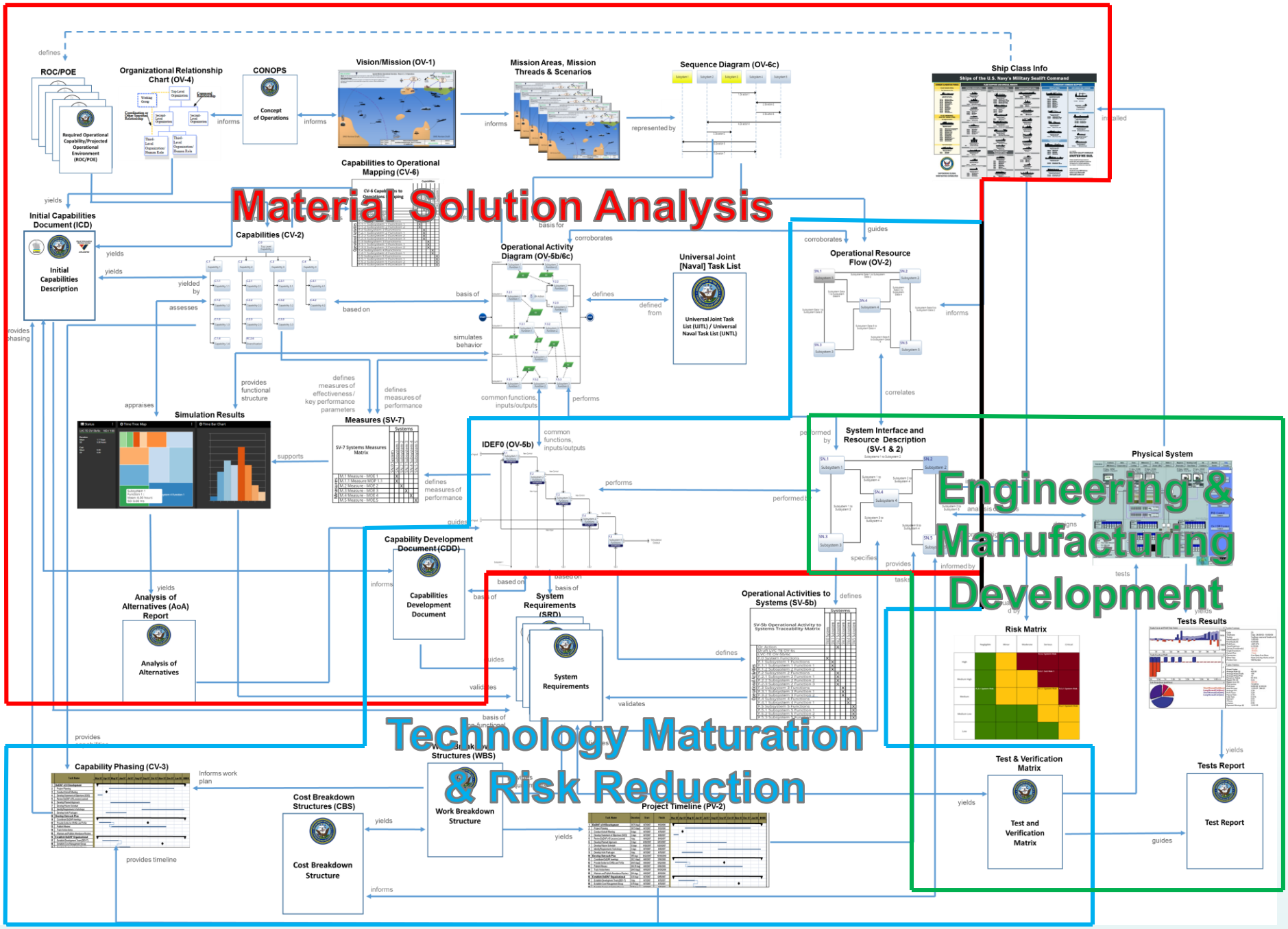


- Evaluate existing review criteria, and determine the suitability of current MBSE visualizations to address that criteria.
- Focused on the reviews from project inception to Preliminary Design Review.
- Analysis focused on:
  - Alternative System Review (ASR)
  - Preliminary Design Review (PDR)

Applicability of Systems Engineering Visualizations within the Acquisition Lifecycle

	Materiel Solution Analysis			Technology Development				Engineering and Manufacturing Development			Documents			
Systems Engineering Views	Analysis of Alternatives (AoA)	Alternative Systems Review (ASR)	Milestone A	System Requirements Review (SRR)	System Functional Baseline (SFB)	Preliminary Design Review (PDR)	Milestone B	Critical Design Review (CDR)	Test Readiness Review	Milestone C	Initial Capabilities Document	Capability Development Document (CDD)	System Requirements Specifications	Test Report
CV-2	x	x		x							x	x		
CV-3	x	x		x							x	x		
CV-6		x		x							x	x		
OV-1	x	x		x							x	x		
OV-2	x	x		x								x	x	
OV-4		x		x							x	x		
OV-5b	x	x		x	x	x						x	x	
OV-5b/6c	x	x		x	x	x					x	x	x	
OV-6c	x	x		x	x	x					x	x	x	
PV-2					x	x		x						
SV-1	x	x		x	x	x		x	x			x	x	x
SV-2					x	x		x	x				x	x
SV-5b				x	x	x		x	x			x	x	x
SV-7	x	x		x	x	x		x	x			x		x
Cost Esttimate	x			x				x						
Risk Matrix	x	x			x	x		x						
Similation Results	x			x		x		x	x				x	x
Test and Verification Matrix						x		x	x					x
Test Results								x	x					x
Work Breakdown Structure					x	x		x						

- Current model-based visualizations were related to SETRs by correlating the generic criteria for each review, or content of the major documents, to the data in each visualization.
- A generic criteria was used for widespread applicability.
- The visualizations were also related where they are developed within the systems engineering lifecycle.


Material Solution Analysis
Technology Maturation & Risk Reduction
Engineering & Manufacturing Development
ROC/POE
Required Operational Capability/Projected Operational Environment (ROC/POE)
Organizational Relationship Chart (OV-4)
CONOPS
Concept of Operations
Vision/Mission (OV-1)
Mission Areas, Mission Threads & Scenarios
Sequence Diagram (OV-6c)
Ship Class Info
Capabilities to Operational Mapping (CV-6)
Initial Capabilities Document (ICD)
Initial Capabilities Description
Capabilities (CV-2)
Operational Activity Diagram (OV-5b/6c)
Universal Joint [Naval] Task List
Universal Joint Task List (UJTL) / Universal Naval Task List (UNTL)
Operational Resource Flow (OV-2)
Simulation Results
Measures (SV-7)
IDEF0 (OV-5b)
System Interface and Resource Description (SV-1 & 2)
Physical System
Capability Development Document (CDD)
Capabilities Development Document
Analysis of Alternatives (AoA) Report
Analysis of Alternatives
System Requirements (SRD)
System Requirements
Operational Activities to Systems (SV-5b)
Risk Matrix
Tests Results
Capability Phasing (CV-3)
Work Breakdown Structures (WBS)
Work Breakdown Structure
Cost Breakdown Structures (CBS)
Cost Breakdown Structure
Project Timeline (PV-2)
Test & Verification Matrix
Test and Verification Matrix
Tests Report
Test Report
defines
informs
yields
represented by
installed
basis for
corroborates
guides
yielded by
assesses
based on
basis of
simulates behavior
defined from
provides phasing
appraises
provides functional structure
defines measures of effectiveness / key performance parameters
defines measures of performance
common functions, inputs/outputs
performs
performed by
correlates
supports
specifies
provides task
informed by
tests
Informs work plan
provides timeline

Alternate System Review Analysis

Criteria	Satisfied by Traditional Review?	Satisfied by MBSE?	Views
Is the initial CONOPS updated to reflect current user position about capability gap(s), supported missions, interfacing/enabling systems in the operational architecture?	Partial	Yes	CV-2, CV-6, OV-1, OV-6c, OV-5b/6c
Are the required related solutions and supporting references (ICD and CDDs) identified?	Partial	Yes	CV-2, CV-3, CV-6, OV-4, OV-5b, OV-5b/6c
Are the thresholds and objectives initially stated as broad measures of effectiveness and suitability (e.g., KPPs)?	Yes	Yes	CV-2, OV-5b, OV-5b/6c, SV-7
Is there a clear understanding of the system requirements consistent with the ICD?	Yes	Yes	CV-2, CV-3, CV-6, OV-4
Are high-level description of the preferred materiel solution(s) available and sufficiently detailed and understood to enable further technical analysis in preparation for Milestone A?	Partial	Yes	OV-2, OV-5b, SV-1
Are interfaces and external dependencies are adequately defined for this stage in lifecycle?	Partial	Yes	OV-2, SV-1
Are system requirements are sufficiently understood to enable functional definition?	Partial	Yes	OV-5b, OV-5b/6c
Is a comprehensive rationale available for the preferred materiel solution(s), based on the AoA?	Partial	Yes	CV-2, CV-3, CV-6, OV-2, OV-4, OV-5b, OV-5b/6c.
Can the proposed material solution(s) satisfy the user needs?	Partial	Yes	CV-2, CV-3, CV-6, OV-2, OV-5b, OV-5b/6c.
Have cost estimates been developed and were the cost comparisons across alternatives balanced and validated?	Partial	Yes	OV-2, OV-5b, SV-1
Have key assumptions and constraints associated with preferred materiel solution(s) been identified?	Partial	Yes	OV-2, OV-5b, SV-1

ASR Analysis

- Partially satisfied results do not suggest that ASRs have not been performed properly in the past, rather, given the absence of concordance in document-based reviews, the criteria requiring different types of data using different artifacts is extremely difficult to achieve efficiently and effectively.
- All of the criteria satisfied in a MBSE environment because of the concordance.

In a MBSE-environment **CONCORDANCE** the ability to represent a single entity such that data in one view, or level of abstraction, matches the data in another view, or level of abstraction, when talking about the exact same thing.

Preliminary Design Review Analysis

PDR Criteria Category	MBSE Ability to Satisfy Criteria
Schedule Planning	↑
Program Critical Path	→
Cost / Schedule / Performance / Key Performance Parameters (KPP)	↑
Latest Cost Estimate	→
Production Costs Estimates	↓
Operating and Support (O&S) Costs Estimate	→
Earned Value Management (EVM)	→
Work Breakdown Structure (WBS) review	↑
Software Metrics	→
Program Management	↑
Configuration Management (CM)	↑
Systems Engineering Processes	↑
Acquisition Logistics Support Management and Staffing	↓
Automated Information Technology (AIT)	↓
Risk Management (RM) Processes	↑
Logistics Budgeting and Funding	↓
Test Processes (TEMP, T&E Strategy, etc.)	→
Production Processes (ISO 9000, etc.)	↓
Software	→
Producibility	↓
Human System Safety	↓
Aeromechanics	↓
Structures	↑
Materials	↓
Mass Properties	↓
Human Systems Integration Engineering	↓
Environmental Regulations	↓
Safety and Health	↓
System Safety	↓

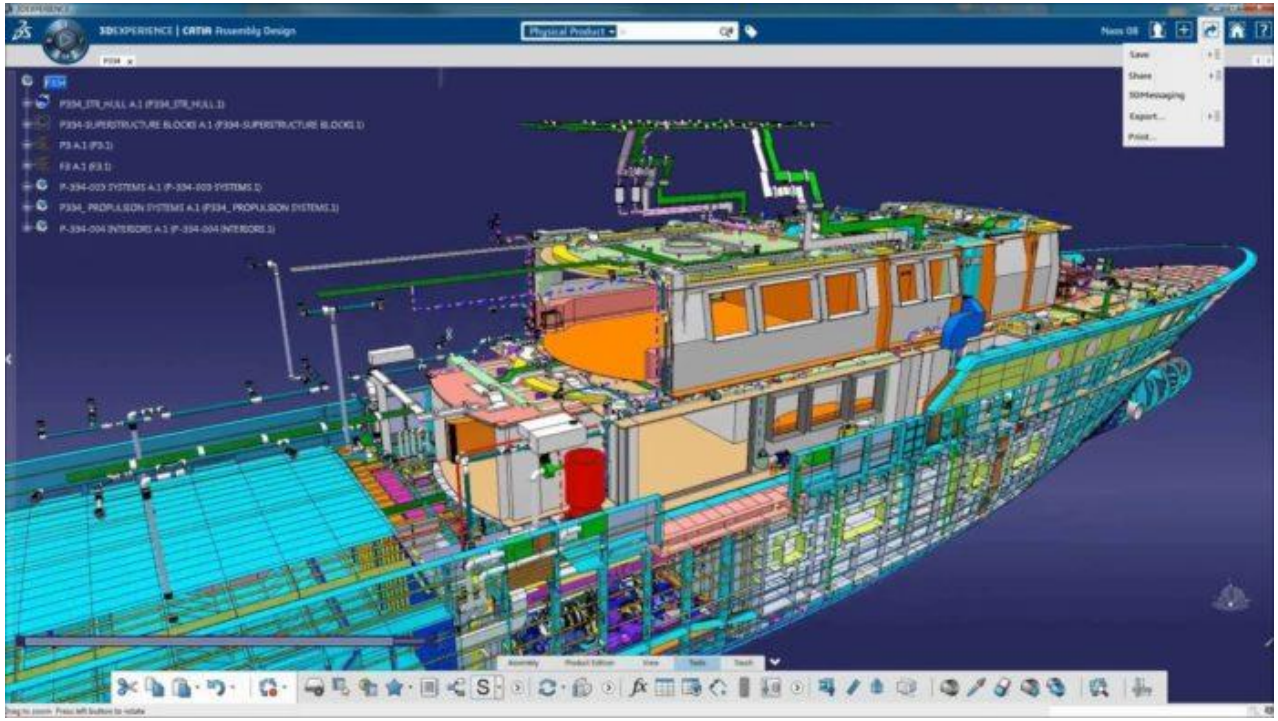
- PDR criteria was evaluated from the Defense Acquisition University and two Navy System Commands.
- 846 PDR questions, in 56 categories, were evaluated for applicability to be addressed by current visualizations.
- Only 80 questions could be adequately addressed with current visualizations.
- Of the 56 categories:
  - 11 categories satisfied
  - 13 partially satisfied
  - 32 not satisfied by visualizations

PDR Analysis

- Only 11% of the 846 PDR questions can be adequately addressed by current models.
- PDR questions have experienced “criteria creep” over the years, and needs a fresh look to ensure they provide value to, and are in the spirit of, the review.
- Many PDR questions are “binary” and offer little insight into the true status of the program.
  - (e.g. Does the program have a risk mitigation plan?)
- New visualizations are needed to capture the essence of PDR.
  - Current systems engineering views are architecture-centric and do not represents the full acquisition lifecycle.
  - ***Note: Current views used in MBSE have origins that are decades old. For MBSE to be effective, new visualizations need to be developed.***

New Visualizations

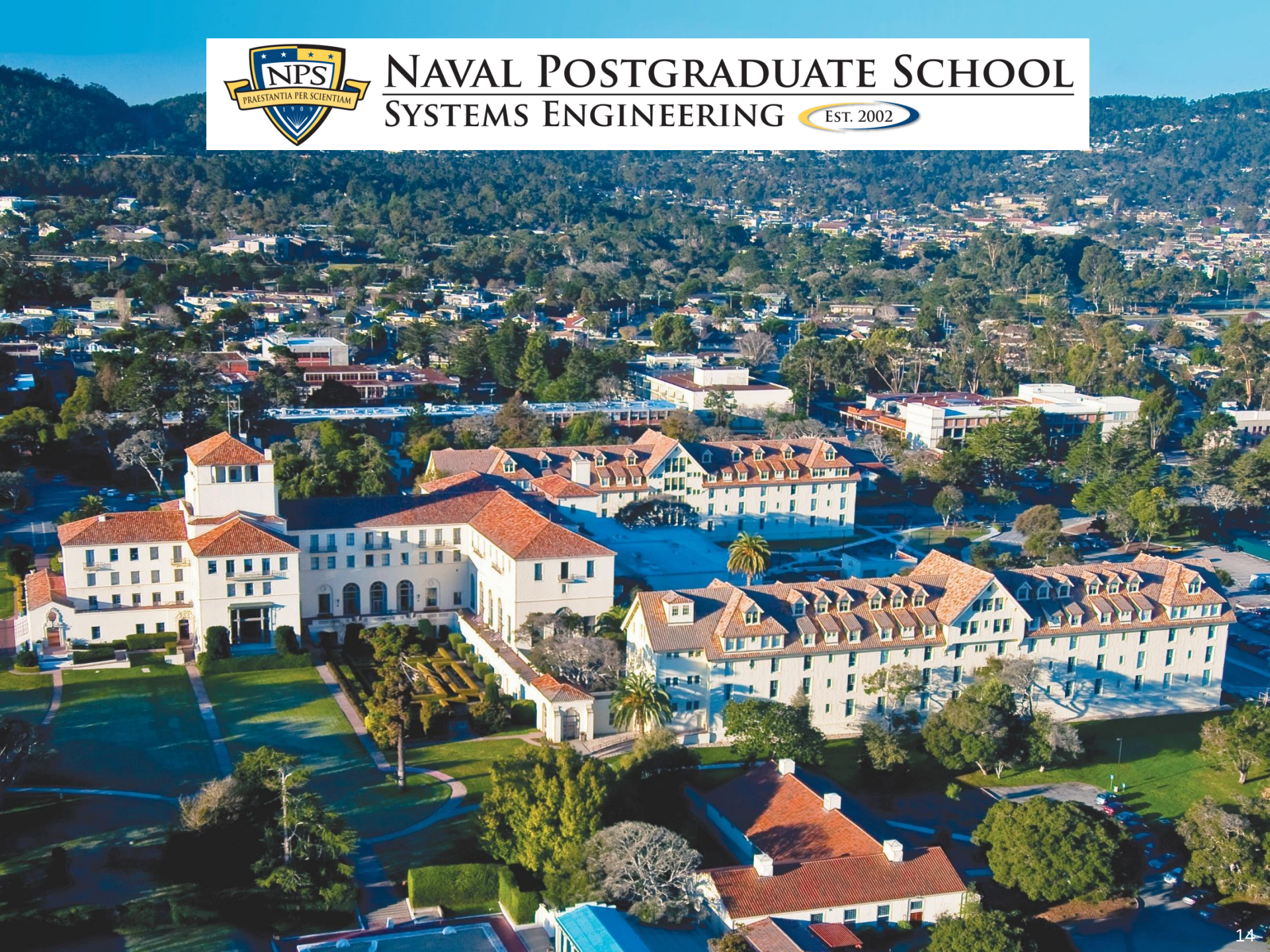
IMAGE SOURCE: https://www.nautechnews.it/files/2017/01/3dexperienceNAOS-696x392.jpg:



- New visualizations must be developed to more efficiently view system data.
- Presentation frameworks should be extended to include data that is relevant across the system lifecycle.
  - (e.g. architectural data, requirements, risk, V&V data, programmatic data)

Summary

- Current model visualizations are well-suited for early reviews prior to PDR.
  - Early reviews are heavily focused on system architectures.
- Model-based reviews allow for complexity to be managed more efficiently because data, not “systems engineering products,” is the commodity that will be used to evaluate the entrance criteria.
- MBSE technical reviews will provide greater insights with faster comprehension for the details across a program’s lifecycle.
- MBSE reviews will not only provide review efficiencies, but will improve the program’s cost and schedule efficiency.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