"Understanding your Digital Twins"

Digital Twin TRUST, Validation & Verification Guidance

NSRP Business Technologies and Ship Design & Material Technologies Joint Panel Meeting

April 30- May 2, 2024 Suffolk, VA

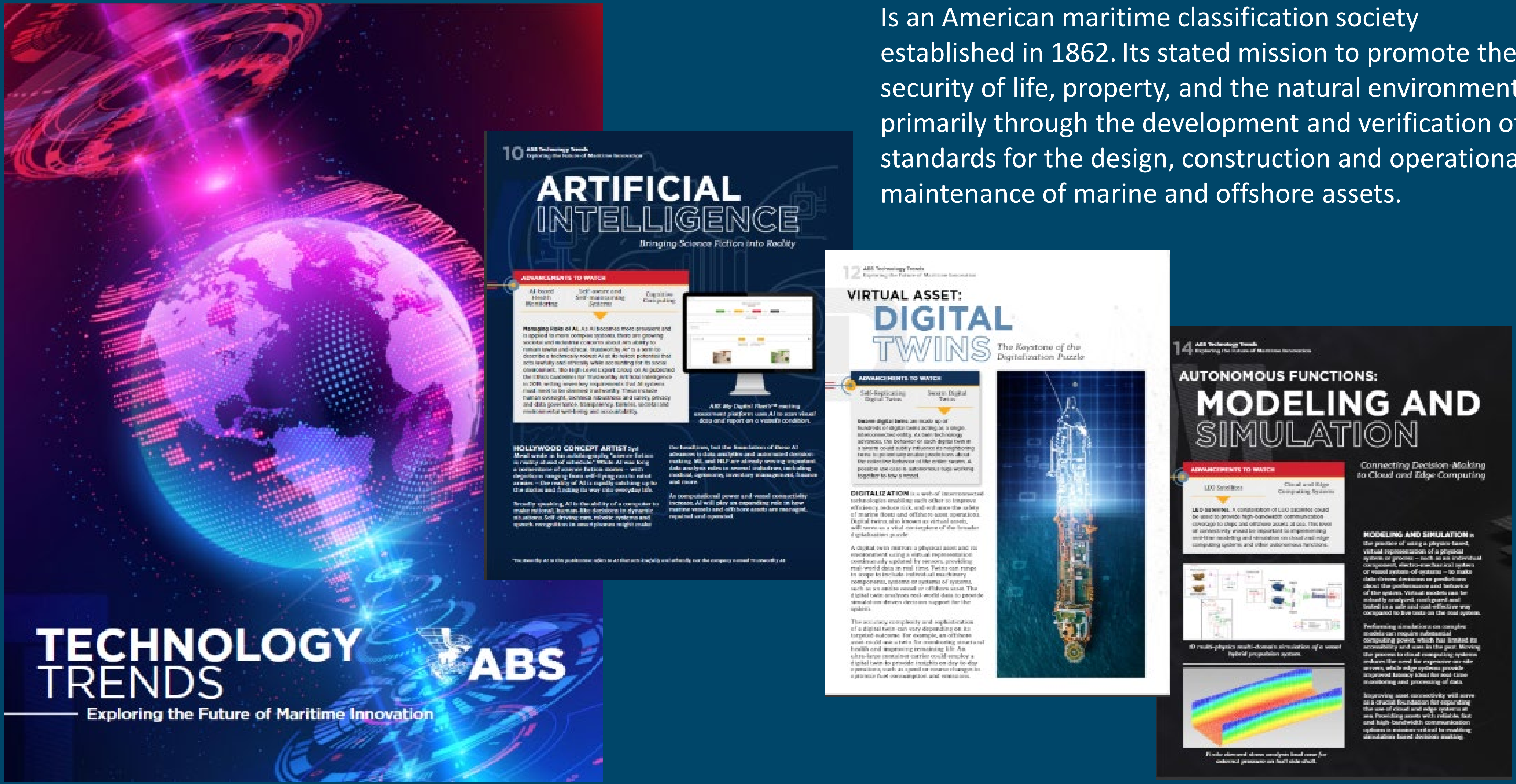
Presenters:

Mark Debbink; HII-Newport News Shipbuilding

Christopher Peters; HII-Newport News Shipbuilding

The **American Bureau of Shipping** (**ABS**)

Is an American maritime classification society established in 1862. Its stated mission to promote the security of life, property, and the natural environment, primarily through the development and verification of standards for the design, construction and operational maintenance of marine and offshore assets.



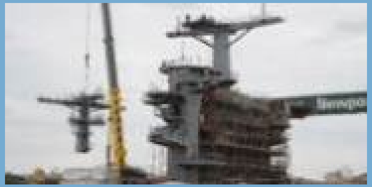
HII

Divisions

NEWPORT NEWS SHIPBUILDING

***Ford*-Class**
Aircraft Carrier Programs

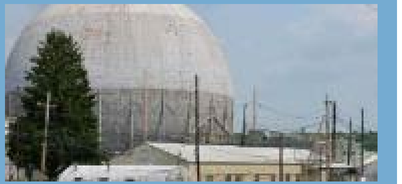
Submarine Programs
New Construction



Aircraft Carrier Refuelings
(RCOH) & Inactivation

Submarine Onsite and
CVN Offsite Fleet Support Programs

Engineering and Planning Yard
Programs



Kenneth A. Kesselring
Site Operations

INGALLS SHIPBUILDING

***America*-class**
Large Deck Amphibious Assault Ships

***San Antonio*-class**
Amphibious Transport Dock Ships

***Arleigh Burke*-class**
Aegis Guided Missile Destroyers

***Legend*-class**
National Security Cutters

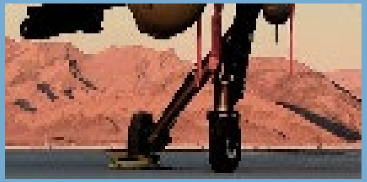
MISSION TECHNOLOGIES

Cyber & Electronic Warfare

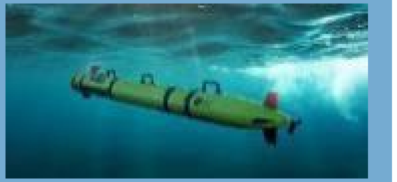
Live, Virtual, Constructive Solutions

Fleet Sustainment

Nuclear & Environmental Services



Intelligence, Surveillance & Reconnaissance



Unmanned Systems

Digital Twin “TRUST” Verification & Validation (V&V) Guide

NSRP RA 2023-07

Classification Sociaty-Project Lead
American Bureau of Shipping (ABS)

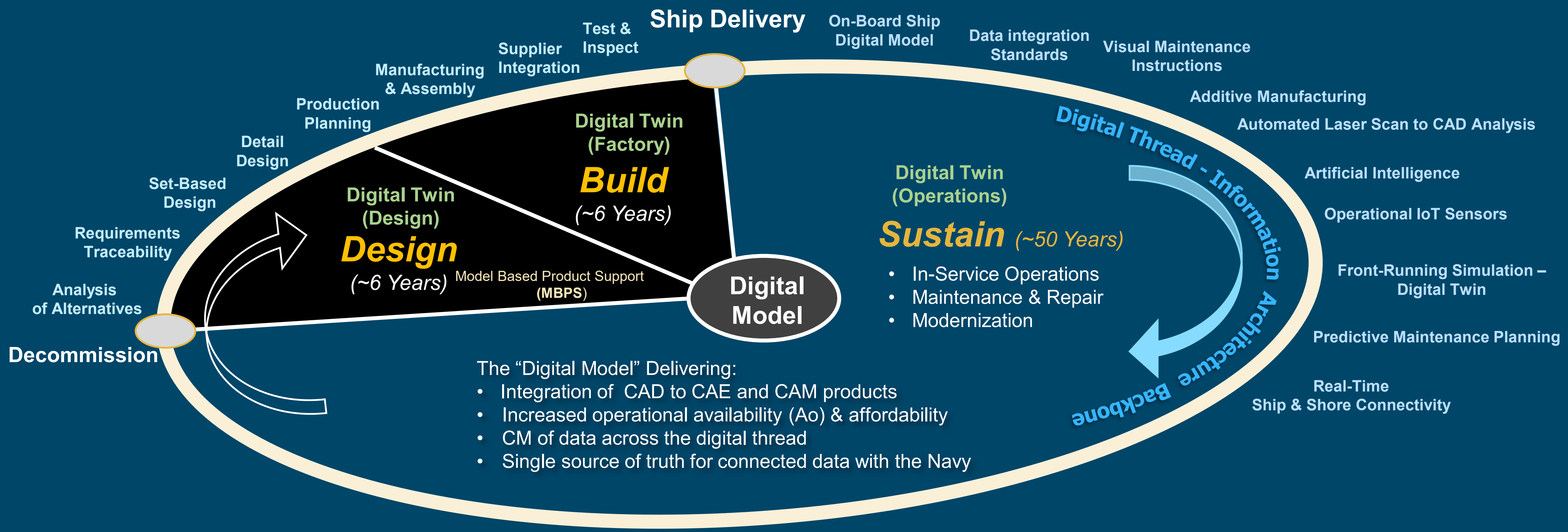
Shipyards
Newport News Shipbuilding (HII-NNS)
Ingalls Shipbuilding (HII-Ingalls)
HII Unmanned Systems Group (HII-UXS)

Government
NAVSEA 05Z with NSWC Philadelphia
NSWC Carderock

“Understanding your Digital Twins”

Advancing Digital Twin Ontology and Qualification **“TRUST”** for the Maritime Industry

The Shipbuilding *Digital Thread* will require Advanced *Digital Twin* Capabilities



DT's are Advancing Digital Data Management through the Ship's Lifecycle

Digital Twin “TRUST” Verification & Validation (V&V) Guide

PROJECT GOAL
Provide a method to Ensure TRUST in Digital Twins for the Design, Build, and Sustainment of our Nation’s Ships

- Build a common Digital Twin ontology and use cases
- Develop a Verification and Validation (V&V) framework for Digital Twin models and applications
- Demonstrate the V&V framework in a digital test environment using existing Digital Twin demonstration cases from project participants
- Publish and promote an ABS Guide for Verification & Validation of Digital Twin Technology Applications

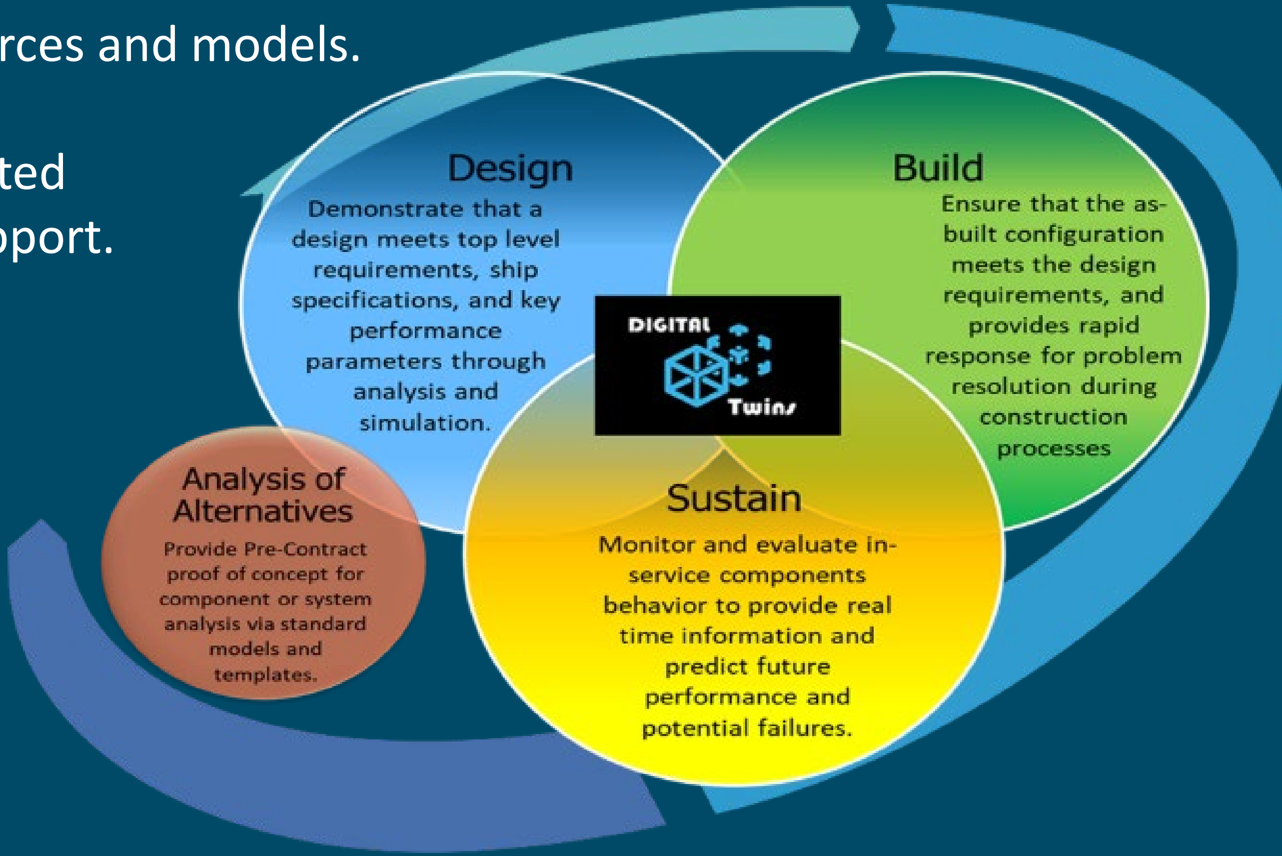
Project Objectives

- >10% reduction in the learning curve costs for organizations in launching or upgrading their Digital Twin technology applications
- >10% reduction in the development costs of specific Digital Twin technology applications using the project guidance
- >25% reduction in costs and >25% reduction in the approval cycle time for completing V&V of Digital Twin technology applications
- Adoption of the ABS Guide across NSRP shipyards and government agencies (Navy, USCG, MSC, MARAD, NOAA, USACE, etc.) and the broader commercial shipbuilding and repair enterprises

Digital Twin Definition

A virtual representation of a physical system, along with its environment and processes, that is updated through the periodic or live exchange of information.

- Comprised of a fusion of multiple data sources and models.
- Complexity and fidelity are driven by targeted outcomes and level of decision-making support.



HII Digital Twin (DT) Infrastructure Framework

Process STEPS

1 Digital Twin (DT) required?

Design
- Is a DT a Ship Spec requirement?
- Failure has a serious consequence?
- Does software control motion?
- Are there any significant hardware/software issues with the legacy or modified design?
- Does the component present significant cost, schedule, or development Risk?
- Will the prototype be used for software verification?
- Is the unit acquisition cost and/or quantity above a set threshold level?

Build
- Is the component required for System Integration Testing?
- Does prototype schedule support the integration testing schedule?
- Can a DT be used to demonstrate Top Level Requirements or Key Performance Parameter Requirements?
- Is this a major component / system in the build critical path?
- Does software control motion?

Sustain
- Does system have a high refresh rate?
- Are there known reliability problems with component, manufacturer / vendor?
- Would rapid remote support from Design Agent be required?
- Does it impact the overall availability of the ship?
- Will Sustainment lifecycle phase require component monitoring?
- Does the component have long lead time for replacement, limited or no spares? (managed obsolesces)
- Requires Analyze for End-Of-Life component performance?

DT Decision Tree

2 What type of DT is required?

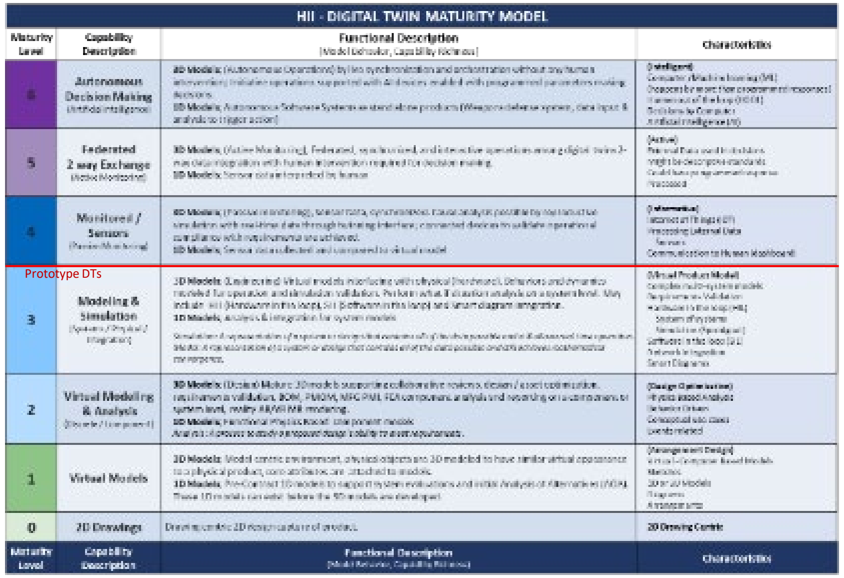
Design
- Analysis of Alternatives (AoA) – Pre-Contract proof of concept for component or system
- Demonstrate that the design meets Top Level Requirements, Key Performance Parameters, and Ship Specifications.
- Ensure the design includes the necessary features (sensors, data collection, etc.) to support Digital Twin use in the Build & Sustain phases
- Provides Customer interface/ participation
- Demonstrate ability to test & verify future technology components
- May replace large scale land based mock-ups which have been traditional method of evaluation
- Reduce risk and support design development efforts

Build
- Provide feedback to validate the DT simulation models
- Prove reliability of design
- Optimize the construction schedule
- Minimize system integration and testing problems
- Ensure the as-built configuration meets the performance requirements (KPPs, TLRs, etc.) Prove reliability of design
- Problem resolution during construction processes

Sustain
- Monitor and evaluate in-service components behavior to provide real time information and predict future performance and potential failures.
- Optimize ship performance by varying component lineups based on operating conditions
- Optimize ship Availability (Ao)
- Enable rapid remote support from Design Agent
- Support Long lead time to replace this component; limited / no spares
- Manage obsolescence
- Enable Artificial Intelligence Steps
- Uncertainty of System conditions is minimized

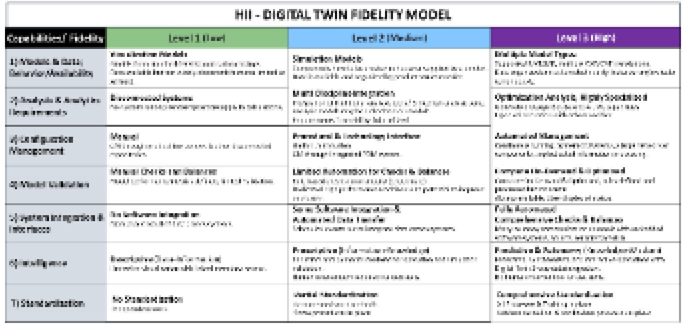
DT Use-Cases & Benefits across the Digital Thread

3 What DT Maturity Level is needed?



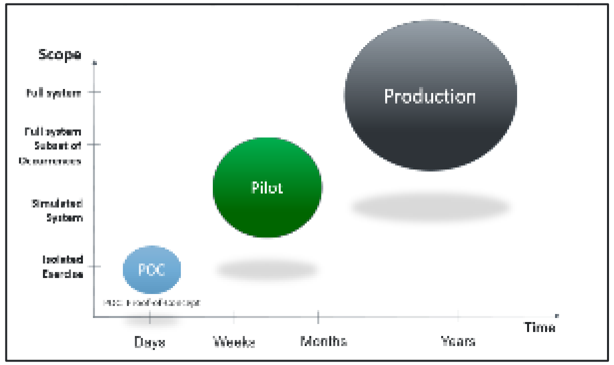
DT Maturity Levels

4 How Complex is the Model?



DT Complexity / Fidelity Levels

5 Design Phase Status?



DT Needs change with development phases

This framework will provide a strategy for Digital Twin evaluation, development, and planning.

HII - DIGITAL TWIN MATURITY MODEL

This Model will provide a Standard for Digital Twin categorization and communication.

Physical Asset - Sensors

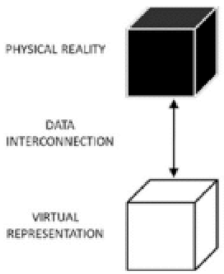
Virtual Prototype DT's

Maturity Level	Capability Description	Functional Description (Model Behavior, Capability Richness)	Characteristics
6	**Autonomous Decision Making** (Artificial Intelligence)	**3D Models**; (Autonomous Operations) by live synchronization and orchestration without any human intervention; Initiative operations supported with AI devices enabled with programmed parameters making decisions. **1D Models**; Autonomous Software Systems as stand alone products (Weapons defense system, data input & analysis to trigger action)	**(Intelligent)** Computer /Machine learning (ML) (happens by more than programmed responses) Human out of the loop (HOOL) Decisions by Computer Artificial Intelligence (AI)
5	**Federated 2 way Exchange** (Active Monitoring)	**3D Models**; (Active Monitoring), Federated, synchronized, and interactive operations among digital twins 2-way data integration with human intervention required for decision making. **1D Models**; Sensor data interpreted by human	**(Active)** External Data used in decisions Might be descriptive standards Could have programmed response Processed
4	**Monitored / Sensors** (Passive Monitoring)	**3D Models**; (Passive monitoring), Sensor Data, synchronized. Cause analysis possible by reproductive simulation with real-time data through twinning interface; connected devices to validate operational compliance with requirements are achieved. **1D Models**; Sensor data collected and compared to virtual model	**(Informative)** Internet of Things (IOT) Processing External Data Sensors Communication to Human (dashboard)
3	**Modeling & Simulation** (Systems / Physical / Integration)	**3D Models**; (Engineering) Virtual models interfacing with physical (hardware). Behaviors and dynamics modeled for operation and simulation validation. Perform what if situation analysis on a system level. May include HIL (Hardware in the loop), SIL (Software in the loop) and Smart diagram integration. **1D Models**; Analysis & integration for system models *Simulation: A representation of a system or design that contains all of the data possible and still allows real time operation.* *Model: A representation of a system or design that contains all of the data possible and still achieves mathematical convergence.*	**(Virtual Product Model)** Complex multi-system models Requirements Validation Hardware in the loop (HIL) System of systems Simulation (Speedgoat) Software in the loop (SIL) Network Integration Smart Diagrams
2	**Virtual Modeling & Analysis** (Discrete / Component)	**3D Models**; (Design) Mature 3D models supporting collaborative reviews, design / asset optimization, requirements validation, BOM, PMOM, MFG PMI, FEA component analysis and reporting on a component or system level, reality AR/VR MR rendering. **1D Models**; Functional Physics Based component models *Analysis: A process to study a proposed design's ability to meet requirements.*	**(Design Optimization)** Physics Based Analysis Behavior Driven Conceptual use-cases Events related
1	**Virtual Models**	**3D Models**; Model centric environment, physical objects are 3D modeled to have similar virtual appearance to a physical product, core attributes are attached to models. **1D Models**; Pre-Contract 1D models to support system evaluations and initial Analysis of Alternatives (AOA). These 1D models can exist before the 3D models are developed.	**(Arrangement Design)** Virtual - Computer Based Models Sketches 1D or 3D Models Diagrams Arrangements
0	**2D Drawings**	Drawing centric 2D design capture of product.	**2D Drawing Centric**
Maturity Level	Capability Description	Functional Description (Model Behavior, Capability Richness)	Characteristics

Digital Twin V&V Guide

Digital Twin Principal Components

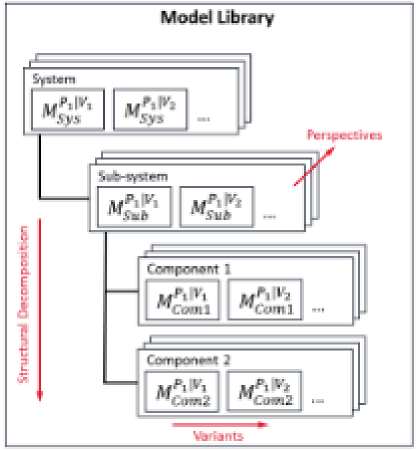
1. **Physical System**
   - Scope
     - Selected based on intended use cases/solution domain(s)
2. **Virtual Representation**
   - Digital Infrastructure/Administration
     - Models
     - Visualizations
     - Data Management
3. **Interconnection of Data**



A few more points:
- Digital twins are dynamic (general expectation of periodic updates)
- Digital twins are updatable/manipulable/interrogable
- Better thought of as a spectrum, rather than binary classification

HII ABS Distribution A 13

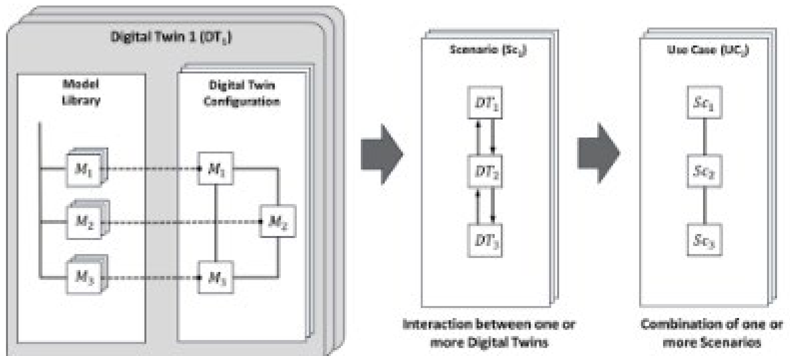
Digital Twin Model Library



- **Model Types**
  - Stored Representations
    - [Data Definition/Schema/Storage]
  - Computational Representations
    - [Physics, Data-driven, Hybrid]
- **Model Hierarchies, Variants & Perspectives**
  - *Hierarchies*: alignment of models with physical system hierarchies, such as structural decomposition
  - *Variants*: different model fidelities/details/assumptions/etc. (multi-scale)
  - *Perspectives*: different physical domains, e.g., mechanics, thermodynamics, controls, etc. (multi-physics)
- **Other model type categorizations**
  - Deterministic vs. Stochastic Models
  - Surrogate and Reduced Order Models

HII ABS Distribution A 15

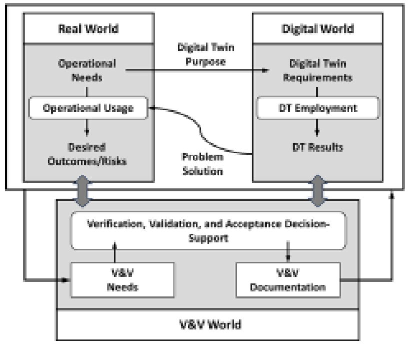
Modular Framework for Digital Twin Ontology



HII ABS Distribution A 14

Digital Twins are used for Problem Solving

- **A Digital Twin's purpose should align with a real-world operational need.**
- **A good Digital Twin's purpose statement leads to:**
  - Capability Requirements (Function and Fidelity)
  - Accuracy Requirements (Software, Data, Output)
  - Usability Requirements (Awareness of human error?)
  - Acceptability Criteria (What are the metrics?)
- **V&V activities are a risk mitigation function (not risk elimination)**



Verification: "Did we build the digital twin system right?"
Validation: "Did we build the right digital twin system?"

HII ABS Distribution A 16

Digital Twin V&V Guide

Digital Twin Criticality

DT Result Integration Level (RIL)	
0	Informative DT results
1	Decision recommendations based on DT results (Human-in-the-loop)
2	Fully autonomous decision-making based on DT results

+

Supplementary Information Availability (SIA)	
0	No data from actual or similar system. --AND-- No other credible MS&DT or analysis data.
1	Limited data from actual or similar system used in decision-making apart from MS&DT. --OR-- Credible results from another model, simulation, or DT are available and used in decision-making.
2	Ample data from actual or similar system used in decision-making apart from MS&DT. --AND-- Credible results from another model, simulation, or DT are available and used in decision-making.

2*RIL + (2 – SIA)

	Effects of Failure of Decision-Making Process
L	Failure will not lead to dangerous situations for human safety, safety of the asset, and/or threat to the environment.
M	Failure could eventually lead to dangerous situations for human safety, safety of the asset, and/or threat to the environment.
H	Failure could immediately lead to dangerous situations for human safety, safety of the asset, and/or threat to the environment.

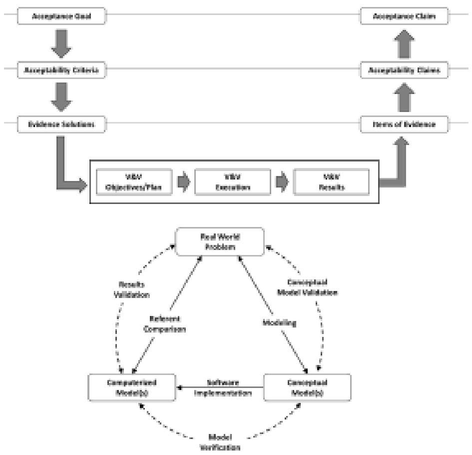
Digital Twin Influence Level	*Decision Consequence Level*		
	L	*M*	*H*
L	L	L	M
M	M	M	H
H	M	H	H

Conceptual Model Validation

Conceptual Model Validation: The evaluation of whether the theories and assumptions underlying the conceptual model are correct and whether the model representation of the real-world problem is reasonable for the intended purpose.

1. Model objectives: The model objective(s) should be stated. This evidence should be assessed based on its alignment with the intended use.
2. Model inputs/outputs: The inputs of the model should be identified in both their source and collection frequency. This should establish the outputs of the model which can be assessed in relation to the identified problem parameters of interest.
3. Model Content: The model content describes the mathematical approaches and formulas to be used. The validity and context of these formulas must be justified with consideration to their intended use.
4. Assumptions and simplifications: Any assumptions and limitations of the model should be stated. This evidence may be used in conjunction with results validation in the determination of the applicability of the system results.

Verification & Validation Framework



- Goal-Claim network provides logical flow for identifying, gathering, and interpreting evidence to support acceptance of DT for intended purpose
- This process is often highly iterative, and the result is not necessarily a binary yes/no
- For an acceptance claim to hold value, it should be developed in a structured manner where the reasoning is traceable, reproducible, and explicit
- Key V&V activities:
  - Conceptual Model Validation
  - Verification
  - Results Validation

Digital Twin Verification & Validation

Verification Activities

The process of determining the extent to which a Digital Twin is compliant with its requirements and specifications as detailed in its conceptual models, mathematical models, or other constructs.
"Did we build the digital twin system right?"

Verification Category		*Focus*	*Responsibility*	*Methods*
Code Verification	Software Quality Assurance	Reliability, robustness, and security of the software	Software development team & DT developer	Configuration management, static analysis, dynamic testing, formal testing
	Numerical Algorithm Verification	Correctness of the numerical algorithms implemented in the code	DT developer	Analytical solutions, benchmark problems, etc.
Calculation Verification	Numerical Error Estimation	Estimation of the numerical accuracy of the given solution to the governing equations	DT developer	Grid convergence, recovery methods, Richardson extrapolation, etc.

Validation Activities Results

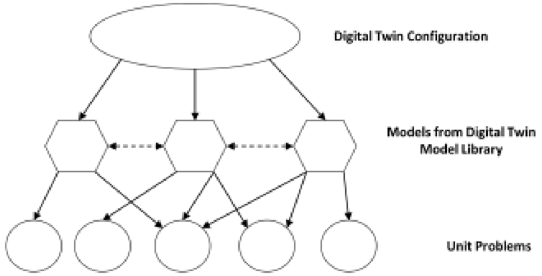
The process of determining the degree to which a Digital Twin is an accurate representation of the real world from the perspective of the intended use.
"Did we build the right digital twin system?"

Validation	*Observable System*	*Unobservable System*
Subjective Approach	• Animation • Event Validity / Op. Graphics • Turing Tests	• Face Validity • Extreme Condition Tests • Degenerate Tests • Internal Validity • Comparisons w/ Benchmarks
Objective Approach	• Predictive Validation • Historical Data Validation	• Comparisons w/ Benchmarks

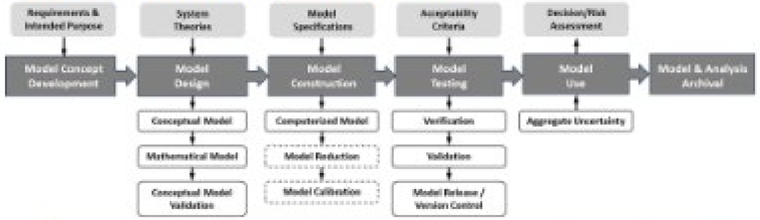
Digital Twin V&V Guide

Digital Twin Special Considerations

- **Digital twin V&V requires a hierarchical approach**
  - Digital Twin as a model administration unit
  - V&V of individual models and simulations
  - V&V of the integrated DT configuration
- **Digital twins are constantly updating over time**
  - Process required to consider re-validation schedule or triggers



Alignment with Model Development Processes



Phase	Pre-A	A	B	C	D	E	F
MS&OT Phase Name	Model Initiation	Model Concept Development	Model Design	Model Construction	Model Testing	Model Use	Model & Analysis Archival
Sargent Circle Phases		Problem Formulation & Analysis		Model Implementation	Depiction of RWS		
V&V Concurrent Activity Name		• Conceptual Model Validation		• Verification	• Verification • Result Validation	• Result Validation (optional)	• V&V Archival
V&V Post-Hoc Activity Name					• Conceptual Model Validation • Verification • Result Validation	• Result Validation (optional)	• V&V Archival

Digital Twin Credibility

Category	*Credibility Factor*	*Description*
Digital Twin Development	**Data Pedigree**	Is the pedigree (and quality) of the data used to develop and validate the digital twin adequate or acceptable?
	Verification	Was the digital twin implemented correctly, per their requirements/specifications?
	Validation	Did the digital twin results compare favorably to the referent data, and how close is the referent to the real-world system.
Digital Twin Use	**Input Pedigree**	Is the pedigree (and quality) of the data used to setup and run the digital twin adequate or acceptable?
	Uncertainty Characterization	Is the uncertainty in the current digital twin results appropriately characterized? What are the sources of uncertainty in the results and how are they propagated through to the results of the analysis?
	Results Robustness	How thoroughly are the sensitivities of the current digital twin results known?
Supporting Evidence	**Digital Twin Model History**	How similar is the current version of the digital twin to previous versions, and how similar is the current use of the digital twin to previous successful uses?
	Digital Twin Management	How well managed were the digital twin processes and products? This can also include organizational maturity, digital twin maintenance, and other quality control and documentation practices.

ABS

GUIDANCE NOTES ON

VERIFICATION AND VALIDATION OF MODELS, SIMULATIONS, AND DIGITAL TWINS

JANUARY 2024

American Bureau of Shipping
Incorporated by Act of Legislature of the State of New York 1862

NSRP Project Deliverable.

ABS Plaza
16855 Northchase Drive
Houston, TX 77060 USA

NNS Digital Twin V&V Guide Evaluation Findings

- **The ABS V&V Guide document requires user instructions to be effective.**
  - ***HII created a V&V user spreadsheet with process step defined to achieve the desired level DT credibility.***
- The technical contents of ABS V&V guide are adequate to specify digital twin requirements for certification.
- Use of the NNS V&V spreadsheet; for evaluation of a current NNS production MS DT, showed the need for more rigorous artifact documentation and archival/traceability.
- In the NNS DT developed without use of the guide, some of the V&V steps such as criticality were skipped resulting in difficulty to assign criticality activities to the development process.
- NNS initial evaluation was conducted on a production MS DT (TLTA). Additional evaluations are planned for an operational DT where alignment of sensor feedback and DT MS behavior can be addressed.
- NNS user response to the V&V guide and process spreadsheet is positive and if available shows effectiveness to improve processes and achieve documentation traceability.
- HII Newport News, Ingalls, and MT divisions each conducted evaluations of the ABS V&V Guide and plan on sharing their results to share information and form a standardized baseline DT process.
- Our intended use for the ABS DT V&V guide and NNS spreadsheet is to provide technical certification framework for both internal and customer use and reference.

Digital Twin V&V User Experience

NSRP RA23-07 Digital Twin "TRUST" V&V Guide: NNS Agreement No.: 2022-329-003 **4/2/2024** Ref: ABS Verification and Validation (V&V) Guide

NNS Digital Twin (DT) Evaluation Form

Project No.	Project Name	Engineeer	Verifier	Initial Release Date	Modification Doc. #
		Certified? Yes ☑ N/A ☐ No ☐ Completed			

Digital Twin claims and evidence alignment or approach

Subject	Reviewed			Remarks	Reference Document	Linked Supporting Artifacts	Modifications Made
	Yes	No	N/A				
Process Quality (Use Case Identification)							
DT Definition and Purpose	☐	☐	☐		DT Definiton		☐
Digital Twin Required?	☐	☐		Design Phase	DT Required?		☐
What type of DT needed?	☐	☐	☐		Type of Digital Twin		☐
Maturity Level Determined	☐	☐	☐	0	Maturity		☐
Capability Level Determined	☐	☐	☐		Capability Level		☐
Models & Data; Behavior/Availability		0		Level 1,2, or 3?			☐
Analysis & Analytics Requirements		0		Level 1,2, or 3?			☐
Configuration Management		0		Level 1,2, or 3?			☐
Model Validation		0		Level 1,2, or 3?			☐
System Integration & Interfaces		0		Level 1,2, or 3?			☐
Intelligence		0		Level 1,2, or 3?			☐
Standardization		0		Level 1,2, or 3?			☐
SOW, Customer Review & Feedback	☐	☐					☐
Approval	☐	☐					☐
Ontology							
Ontology Overview	☐	☐	☐		Overview		☐
Review Types of Model Library (Types, Hierarchies, and Variants)	☐	☐	☐		Models		☐
Model Uses in Digital Twins	☐	☐	☐		Model Uses		☐
Simulations/Analysis to be Performed							☐
Ontology Approach	☐	☐	☐		Approach		☐
Criticality Categorization							
Criticality Definition Reviewed	☐	☑	☐		Criticality		☐
Determine decision concequence levels	Low			Input (L, M, or H)	Consequence Levels		☐
Determine DT Results integration levels		0		Could be a 0 or a 1	RIL		☐
Determine levels of supplementary information availability		0		Could be a 0 or a 1. Not fully d	SIA		☐
Digital Twin Influence Levels (Based on RIL & SIA)	2		Low	Input (L, M, or H)	Influence Level		☐
Criticality Matrix Level (Low, Medium, High)	Low			Input (L, M, or H)	Criticality Matrix		☐
Review and Feedback	☐	☐	☐				☐
Is criticality consistent with maturity and complexity levels	☐	☐		Make necessary changes			
Approval	☐	☐					
Verification and Validation							
Verification and Validation Overview Reviewed	☐	☐	☐		V&V Overview		☐
V&V Chart	☐	☐	☐		V&V Guide		☐
Roles Established	☐	☐	☐		Roles		☐
Individual Roles	☐	☐	☐	Have roles been established?			☐
Organizational Roles	☐	☐	☐	Have roles been established?			☐
Claims and Evidence Approach	☐	☐	☐		Claims and Evidence		☐
Conceptual Model Validation Activities	☐	☐	☐		Concept Validation Tasks		☐
Verification Activities	☐	☐	☐		Verification Activities		☐
Solution Verification / Numerical Algorithm Verification	☐	☐	☐				☐
Code Verification / Software Quality Assurance	☐	☐	☐				☐
Results Validation				What methods used?	Validation Methods		☐
Validation Simulation Models							☐
What are the digital twin limitations and caveats?							☐
Results Validation Classification				Observable or Unobservable	Classification		☐
Is and what Model Integration is available?	☐	☐	☐				☐
Operations and Maintenance	☐	☐	☐				☐
Legacy Models Used?	☐	☐					☐
Digital Twins Established?	☐	☐					☐
Customer Review	☐	☐					☐
User Feedback Collected							☐
Lessons Learned Document							
Approval	☐	☐					☐
Credibility Categorization							
Credibility Overview	☐	☐	☐		Crit. Overview		☐
Credibility Factors	☐	☐	☐		Factors		☐
Factors Assessment Level	☐	☐	☐	**If no leave below empty:**	Factor Assessment		☐
Data Pedigree		0		Level 1,2, or 3?			☐
Verification		0		Level 1,2, or 3?			☐
Validation		0		Level 1,2, or 3?			☐
Input Pedigree		0		Level 1,2, or 3?			☐
Uncertainty Charaterization		0		Level 1,2, or 3?			☐
Results Robustness		0		Level 1,2, or 3?			☐
Digital Twin History		0		Level 1,2, or 3?			☐
Digital Twin Management		0		Level 1,2, or 3?			☐
NNS Specific Items	☐	☐					☐
Approval	☐	☐					☐

The NNS Framework Provides Users:

- Process steps
- DT specification
- Guidance on activities
- Checklist for completeness
- Artifact Links
- Certification Report

Digital Twin V&V Guidance: Conclusions & Take - Aways

1. Digital twins are a key technology for supporting the future development and operation of our ships.
2. It is necessary that the decision-maker utilizing these digital twins has sufficient trust in their credibility to employ them for an intended use case.
3. To develop the necessary evidence to gain this trust, a generalizable, scalable, and flexible approach for verification and validation is required.
4. We established a framework for the digital twin concept that recognizes:
    - A virtual representation as a federation of models
    - A structured, multi-layer V&V approach to generate evidence to support a credibility assessment and acceptability
    - A flexible framework can be further tailored by the individual practitioner based on the specifics of their use case.
5. The extent to which a rigorous V&V process should be followed can be based on the identified criticality of the digital twin application:
    - Which includes the level of digital twin integration in the decision-making process,
    - The consequences of a failure or underperformance of the digital twin system or results.
6. The evidence gathered from the V&V activities can then be incorporated into an acceptability decision.
7. Guidance is provided on a minimum set of elements (including V&V evidence) that should be factored into determination of the credibility of a digital twin system or results to be employed for an intended use case.
8. End-Users accept the framework as a standardized process

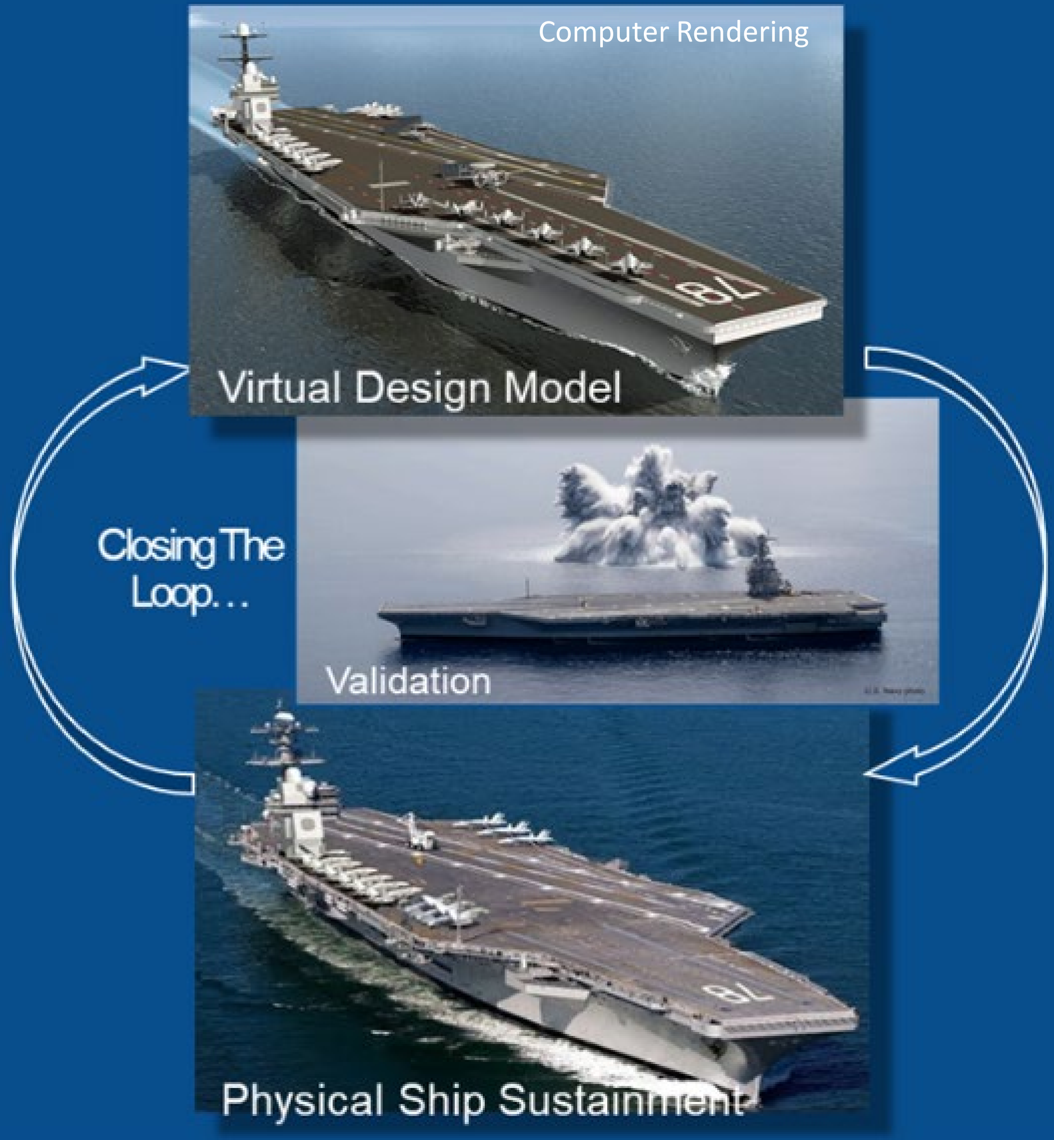
Watch for the ABS Publication

GUIDANCE NOTES ON

VERIFICATION AND VALIDATION OF MODELS, SIMULATIONS, AND DIGITAL TWINS

Thank You for your attention.
Discussion…

Digital Engineering for Ships Lifecycle



Digital Twin V&V Status / Certification Report

HII

INGALLS SHIPBUILDING

Model Creator:				
Model Name:	SSDG_LHA7			
Criticality				**Justifications**
Decision Consequence Level	☐ Low	☒ Medium	☐ High	Model was used in development of shipboard systems
Result Integration Level (RIL)	☐ Low	☒ Medium	☐ High	Decisions recommended based on model results.
Supplementary Information Availability (SLA)	☐ Low	☒ Medium	☐ High	Data from previously used systems were available.
MS&DT Influence Level Based on RIL & SLA	☐ Low	☒ Medium	☐ High	
Criticality Level	☐ Low	☒ Medium	☐ High	
Credibility	☐ Low	☒ Medium	☐ High	
Data Pedigree	☐ Low	☐ Medium	☒ High	Characteristics from a ship service diesel generator set technical manual were used in developing the model. Manufacturer mathematical models were also used for components of the model.
Verification	☐ Low	☐ Medium	☒ High	Model was created in a verified program, with the code being verified based on the accuracy of the simulation outputs
Validation	☐ Low	☐ Medium	☒ High	Model was validated against factory test data from in use equipment.
Input Pedigree	☐ Low	☐ Medium	☒ High	All the input data is tracked to a reputable source and provides enough parameters to recreate the system.
Uncertainty Characterization	☐ Low	☒ Medium	☐ High	The model emulates performance of an "average" production engine, so it is recognized that engines may show variances in performance of any measured parameter in the model.
Results Robustness	☐ Low	☒ Medium	☐ High	
MS&DT History	☐ Low	☐ Medium	☒ High	Model went through various updates based on customer demand.
MS&DT Management	☐ Low	☐ Medium	☐ High	
Conceptual Model Validation				
Model Objectives	This model is intended to provide a dynamic representation of the Ship Service Diesel Generator set when operating in various conditions where the diesel engine and generator can be controlled individually. The model was created to facilitate LHA8 development			
Model Required Inputs	System frequency, diesel engine data, governor settings, actuator settings, generator parameters			
Model Outputs	System Voltage, real power, reactive power, system RPMs, fuel demand, rack position			
Model Content	The model was initially created in MatLab R2013b and later updated in MatLab R2018b. The model block diagrams were developed by using design data (diesel generator), reviewing application software (723+ controller), and reviewing technical manuals (GCU interface)			