Digital Twin "TRUST" Verification & Validation (V&V) Guide
for
Ship Design, Construction, Delivery & Sustainment

NSRP All Panel Meeting

Charleston, SC

March 28, 2023

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ABS
HII-NNS
HII-Ingalls
HII-UXS
NAVSEA 05Z & NSWC PHILI.
NSWC Carderock

This project will provide a method to Ensure TRUST in Digital Twins for Design, Build, and Sustainment of our Nations Ships.

We will develop and demonstrate a V&V framework for Digital Twin models.

NSRP NATIONAL SHIPBUILDING RESEARCH PROGRAM™ Taking Shipbuilding and Repair to the Next Level

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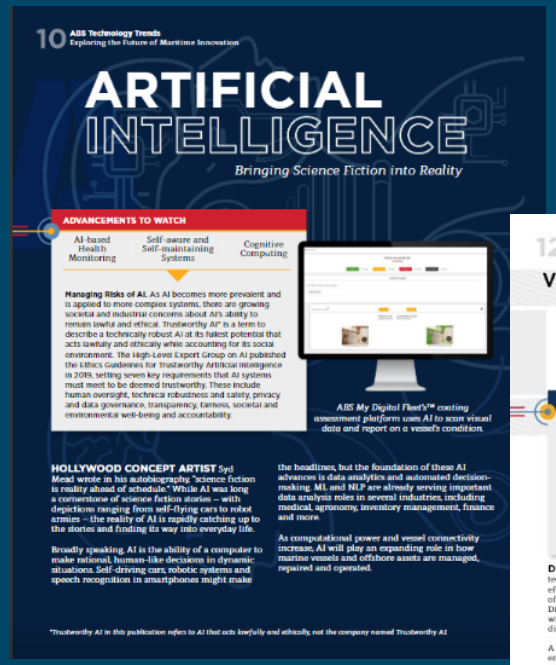

10 ABS Technology Trends
Exploring the Future of Maritime Innovation

ARTIFICIAL INTELLIGENCE

Bringing Science Fiction into Reality

ADVANCEMENTS TO WATCH

AI-based Health Monitoring | Self-aware and Self-maintaining Systems | Cognitive Computing

Managing Risks of AI. As AI becomes more prevalent and is applied to more complex systems, there are growing societal and industrial concerns about AI's ability to remain lawful and ethical. Trustworthy AI* is a term to describe a technically robust AI at its fullest potential that acts lawfully and ethically while accounting for its social environment. The High-Level Expert Group on AI published the Ethics Guidelines for Trustworthy Artificial Intelligence in 2019, setting seven key requirements that AI systems must meet to be deemed trustworthy. These include human oversight, technical robustness and safety, privacy and data governance, transparency, fairness, societal and environmental well-being and accountability.

ABS My Digital Fleet's™ coating assessment platform uses AI to scan visual data and report on a vessel's condition.

HOLLYWOOD CONCEPT ARTIST Syd Mead wrote in his autobiography, "science fiction is reality ahead of schedule." While AI was long a cornerstone of science fiction stories – with depictions ranging from self-flying cars to robot armies – the reality of AI is rapidly catching up to the stories and finding its way into everyday life.

Broadly speaking, AI is the ability of a computer to make rational, human-like decisions in dynamic situations. Self-driving cars, robotic systems and speech recognition in smartphones might make the headlines, but the foundation of these AI advances is data analytics and automated decision-making. ML and NLP are already serving important data analysis roles in several industries, including medical, agronomy, inventory management, finance and more.

As computational power and vessel connectivity increase, AI will play an expanding role in how marine vessels and offshore assets are managed, repaired and operated.

*"Trustworthy AI in this publication refers to AI that acts lawfully and ethically, not the company named Trustworthy AI


12 ABS Technology Trends
Exploring the Future of Maritime Innovation

VIRTUAL ASSET:
DIGITAL TWINS
The Keystone of the Digitalization Puzzle

ADVANCEMENTS TO WATCH

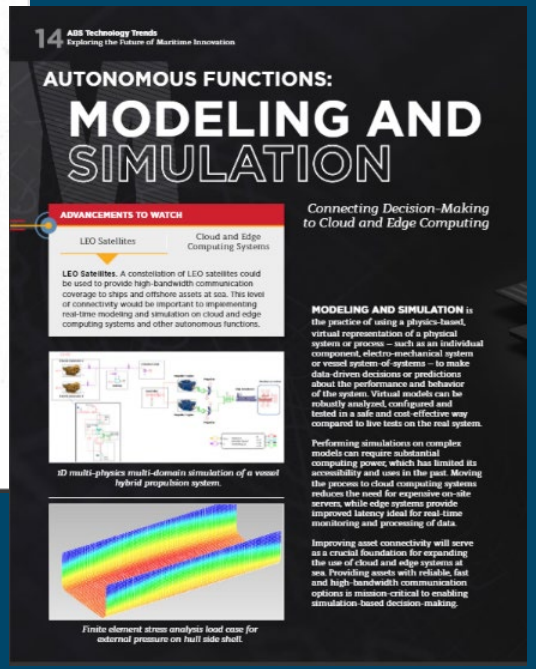
Self-Replicating Digital Twins | Swarm Digital Twins

Swarm digital twins are made up of hundreds of digital twins acting as a single, interconnected entity. As twin technology advances, the behavior of each digital twin in a swarm could subtly influence its neighboring twins to potentially enable predictions about the collective behavior of the entire swarm. A possible use case is autonomous tugs working together to tow a vessel.

DIGITALIZATION is a web of interconnected technologies enabling each other to improve efficiency, reduce risk, and enhance the safety of marine fleets and offshore asset operations. Digital twins, also known as virtual assets, will serve as a vital centerpiece of the broader digitalization puzzle.

A digital twin mirrors a physical asset and its environment using a virtual representation continuously updated by sensors, providing real-world data in real time. Twins can range in scope to include individual machinery components, systems or systems of systems, such as an entire vessel or offshore asset. The digital twin analyzes real-world data to provide simulation-driven decision support for the system.

The accuracy, complexity and sophistication of a digital twin can vary depending on its targeted outcome. For example, an offshore asset could use a twin for monitoring structural health and improving remaining life. An ultra-large container carrier could employ a digital twin to provide insights on day-to-day operations, such as speed or course changes to optimize fuel consumption and emissions.


14 ABS Technology Trends
Exploring the Future of Maritime Innovation

AUTONOMOUS FUNCTIONS:
MODELING AND SIMULATION

Connecting Decision-Making to Cloud and Edge Computing

ADVANCEMENTS TO WATCH

LEO Satellites | Cloud and Edge Computing Systems

LEO Satellites. A constellation of LEO satellites could be used to provide high-bandwidth communication coverage to ships and offshore assets at sea. This level of connectivity would be important to implementing real-time modeling and simulation on cloud and edge computing systems and other autonomous functions.

3D multi-physics multi-domain simulation of a vessel hybrid propulsion system.

Finite element stress analysis load case for external pressure on hull side shell.

MODELING AND SIMULATION is the practice of using a physics-based, virtual representation of a physical system or process – such as an individual component, electro-mechanical system or vessel system-of-systems – to make data-driven decisions or predictions about the performance and behavior of the system. Virtual models can be robustly analyzed, configured and tested in a safe and cost-effective way compared to live tests on the real system.

Performing simulations on complex models can require substantial computing power, which has limited its accessibility and uses in the past. Moving the process to cloud computing systems reduces the need for expensive on-site servers, while edge systems provide improved latency ideal for real-time monitoring and processing of data.

Improving asset connectivity will serve as a crucial foundation for expanding the use of cloud and edge systems at sea. Providing assets with reliable, fast and high-bandwidth communication options is mission-critical to enabling simulation-based decision-making.

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

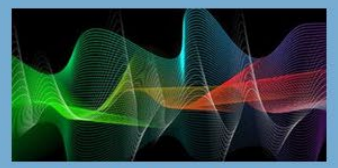
***America*-class**
Large Deck Amphibious Assault Ships

***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

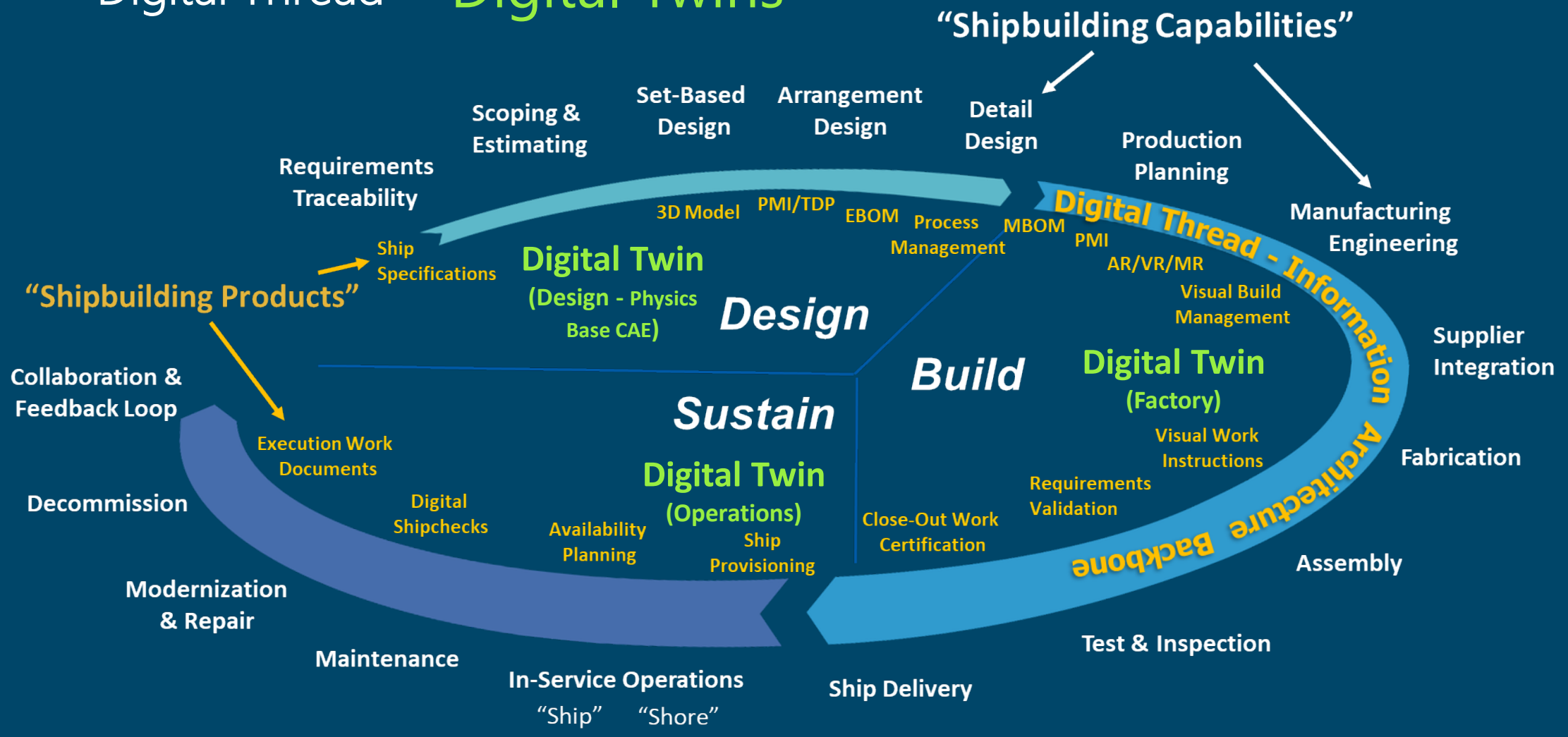
Nuclear & Environmental Services

Intelligence, Surveillance & Reconnaissance

Unmanned Systems
USV &UUV's

Enabling the Navy the Nation Needs
Using Digital to Design, Build & Sustain our Navy's Fleet

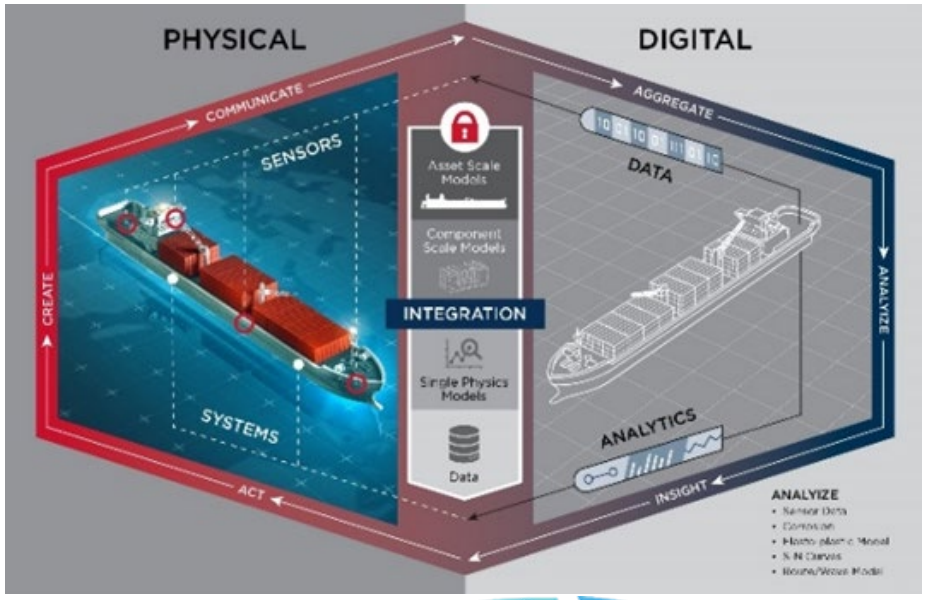
Digital Thread – Digital Twins



Digital Technology In the Future of Shipbuilding and Sustainment

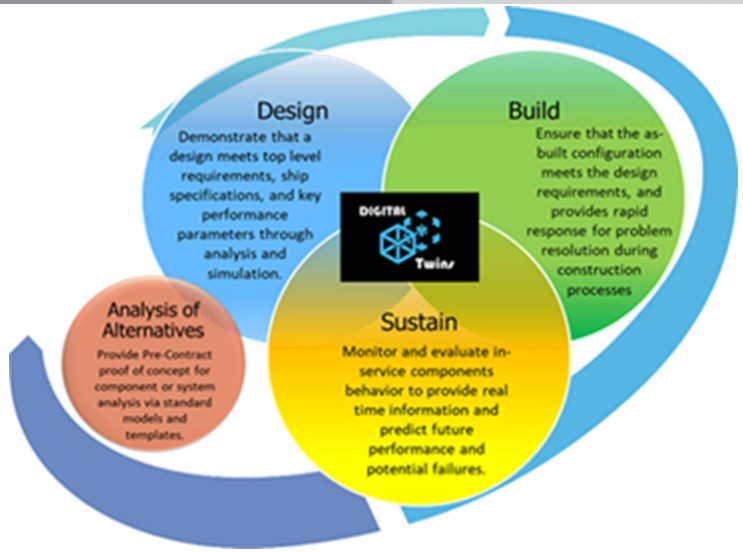
A **digital twin** is:

- Is a virtual representation of an asset (e.g., a component, a system, a ship, or a factory) or of a process (e.g., an assembly sequence)
- Is a tool for analyzing and specifying requirements, understanding the asset and optimizing its behavior, interfacing with the asset and managing its configuration, and forecasting its future performance
- Exists in all phases of the digital thread – Design, Build, or Sustain.



Model-based Systems Engineering (MBSE) and **digital twin** technology applications are critical to the future of Government and Commercial shipbuilding and sustainment:

- Core to the entire digital thread for the lifecycle of ship
- Foundation for collaborative analysis and decision making among the stakeholders driving ship design, construction, and sustainment
- Tools that transition across lifecycle phases just like the physical assets themselves
- Critical for technical authority verification, validation, and certification of increasingly **complex and novel** ship designs and shipbuilding/sustainment processes



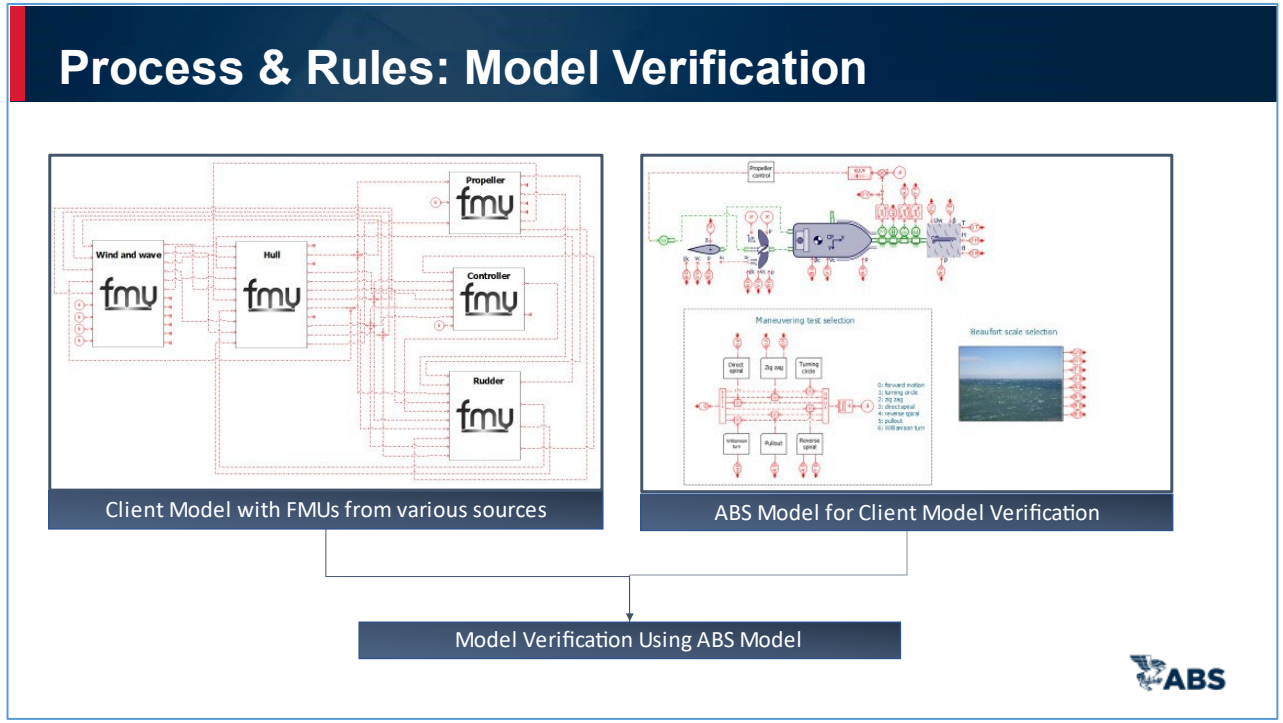
The Need for Application and V&V Guidance

Digital twin technology applications are only useful when they have the **TRUST** of all applicable stakeholders. This includes meeting the following criteria:

- Can be developed and used cost-effectively
- Address a well-defined and understood scope/purpose
- Have clearly defined assumptions, limitations, and maturity levels
- Have undergone appropriate V&V to satisfy all applicable technical authorities

Current Challenges:

- Interest and requirements for digital twin applications is growing rapidly with digital shipbuilding initiatives (>19%)
- Growth in development and use of digital twins is outpacing the guidance, tools, and resources for validating their use
- Lack of consensus industry guidance is affecting:
  - Startup and management costs for digital twin programs
  - Costs of developing specific digital twin applications
  - Costs for internal V&V by developers
  - Costs for external V&V by Technical Authorities



Project Objectives – Vision of Results: We envision that clarity of expectations for qualification and use of digital twin technology will provide great benefits for all stakeholders:

- **For the Shipbuilding and Ship Repair Industry**
  - ***Common reference terminology*** internally and in exchanges with Government Agencies when describing types and maturity levels of digital twin technology, promoting better definition of contract deliverables and associated pricing
  - ***Defined process and criteria*** for measuring the suitability/quality of digital twin technology applications for intended purposes before use in critical decisions for ship design, construction, and sustainment
- **For Government Agencies**
  - Same benefits as for the shipbuilding and ship repair industry for internally developed digital twin applications
  - ***Ability to reference*** *a collaboratively developed reference document* when building digital twin requirements into ship specifications and associated solicitations
  - ***Clear expectations*** about how digital twin applications should undergo V&V before use on shipbuilding programs and/or delivery to the Government
- **For Both Stakeholder Groups**
  - ***Ability to manage risk*** by leveraging independent, third-party V&V using clearly defined processes and acceptance criteria to support ultimate acceptance and use in government programs
  - ***Reference material*** that can be used in the development and *training* of technical staff involved in the development, V&V, and use of Digital Twin technology applications
  - ***Trust in Digital Twin technology*** **for decision-support** throughout the digital thread lifecycle of the ships during design, construction and sustainment, resulting in greater adoption.

Digital Twin "TRUST" Verification & Validation (V&V) Guide

Solutions Produced: The work will produce the following outputs:

- Publication of an ABS Guide on Verification & Validation of Digital Twin Technology Applications, incorporating best practice information from the project, including the Digital Twin ontology and recommended V&V process with associated methods and tools
- ABS webinar for Government and Industry on the ABS guidance publication
- Final report documenting the research process and the demonstrations of the recommended V&V approach/criteria on real Digital Twin technology

Benefit Metrics: We propose the following benefit metrics for the project:

- >10% reduction in the learning curve costs for organizations (government or commercial) launching or upgrading their Digital Twin technology application development and use initiatives
- >10% reduction in the development costs of specific Digital Twin technology applications using the project guidance
- >25% reduction in the costs and >25% reduction in the approval cycle time for completing V&V of Digital Twin technology applications (for both the developers and for the approving Technical Authorities)
- Adoption and use of the ABS Guidance Publication across the NSRP shipyards and government agencies (Navy, USCG, MSC, MARAD, NOAA, USACE, Army Watercraft, etc.) as well as broader use among the many stakeholders in the naval and commercial shipbuilding and repair enterprises

PEOPLE AND ORGANIZATIONAL IMPACTS

This project focuses on addressing the people and organizational impacts needed to institutionalize trust in Digital Twin technology applications in shipbuilding and sustainment:

- **Organizational Change/Cultural Change:** The project provides the ontology and V&V approach, methods, tools, and examples to enable a culture of TRUST among the many stakeholders working with Digital Twin technology applications being developed and used across the naval shipbuilding enterprise (and the maritime industry more broadly).
- **Human Resources:** By encouraging the expanded use of Digital Twin technology, the project supports the growth of high technology jobs in developing, validating, and using these applications across all of the organizations participating in the naval shipbuilding enterprise (Government and commercial).
- **Workforce Development:** The guidance developed in this project will be a valuable tool for supporting training and skill development of workers who will be developing, validating, and using Digital Twin technology (Government and commercial workers across the naval shipbuilding enterprise).

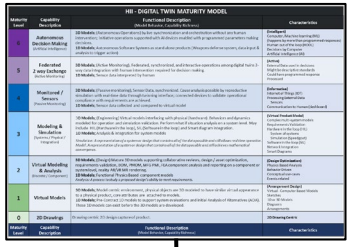
Work Product Use Cases & Technology Dissemination

Work Products

- Ontology
- Maturity Models
- V&V Methodology
- V&V Tool & Test Environment Inventory
- Best Practice Recommendations

DT Maturity Model

ABS *Guide on Verification & Validation of Digital Twin Technology Applications*



ABS Webinar for Government & Industry

Final Report on Research Process and Demonstrations

- Research Process/Results
- V&V Demonstration Results (Company-specific and Non-proprietary Versions for Sharing)
- V&V Test Environment Recommendations

Technology Dissemination

Project Observers (Yards & Gov)	NSRP Reporting	ABS Industry Outreach	ABS Publications Management	ABS Webinars	Conference Papers & Presentations	Government Specification/ Reference

Use Cases

Digital Twin Developers

Shipyards, System Integrators, OEMS, Service Providers, Government Agencies, Other

Efficient initiation and/or enhancement of Digital Twin programs within organization

More efficient development of specific digital twin technology applications

Reference to support workforce development in digital twin technology

Government Program Offices

Navy, MSC, USCG, MARAD, USACE, Army Watercraft, NOAA, NSF, Etc.

Commercial Marine

Owner/Operators, Ship Management Companies, Etc.

Reference publication for specifying digital twin requirements and/or expectations in ship design, construction, and sustainment contracts

Clear expectations about how digital twin applications should undergo V&V before acceptance (e.g., at delivery with physical assets)

Reference to support workforce development in digital twin technology

Technical Authorities

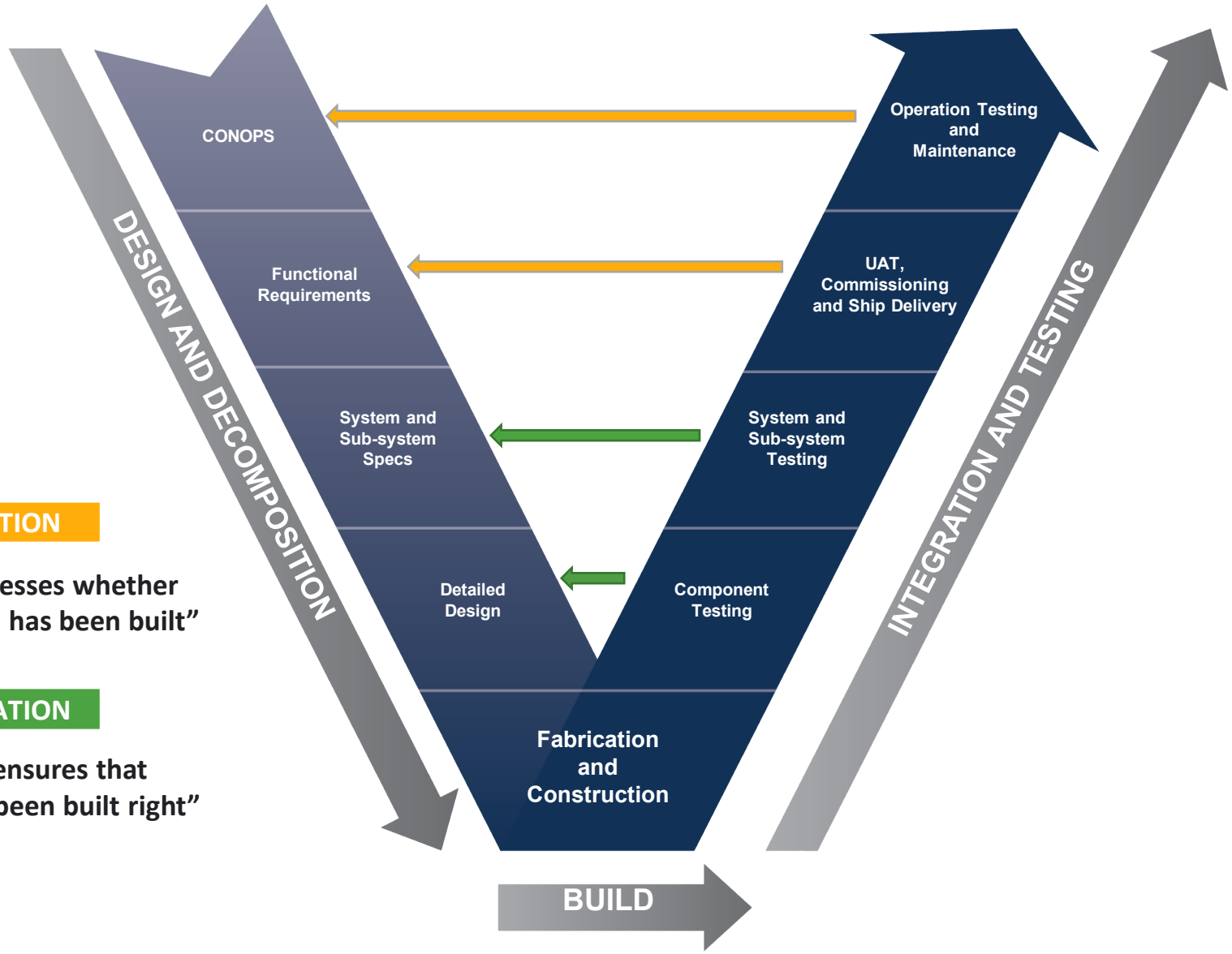
Internal QA Organizations, Government Technical Authorities, Class Societies

Methodology and tools for executive efficient V&V of digital twin technology applications

Establishing test environments for digital twin V&V activities

Reference to support workforce development in digital twin technology

Digital Twin Verification & Validation



VALIDATION

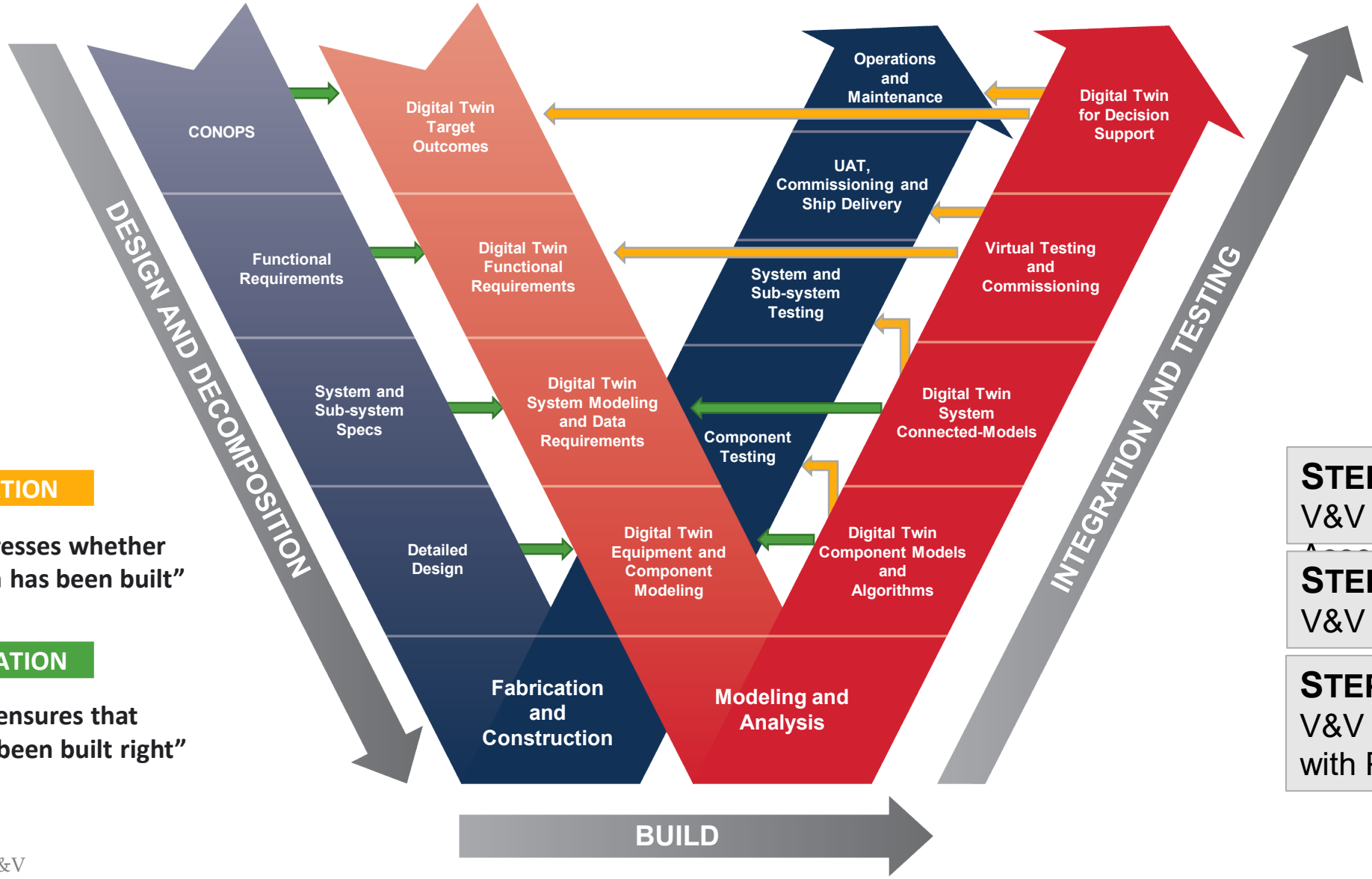
Validation addresses whether "the right system has been built"

VERIFICATION

Verification ensures that "the system has been built right"

STEP 1
V&V of Physical Asset

Digital Twin Verification & Validation



VALIDATION

Validation addresses whether "the right system has been built"

VERIFICATION

Verification ensures that "the system has been built right"

STEP 1
V&V of Physical Asset

STEP 2
V&V of Digital Twin

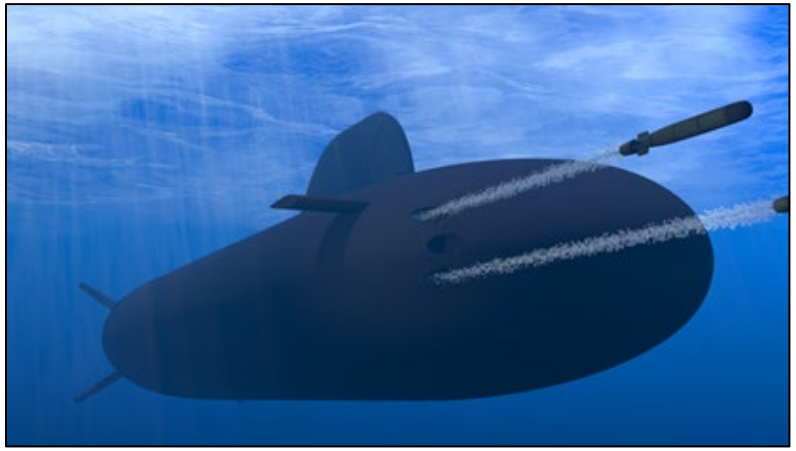
STEP 3
V&V of Digital Twin with Physical Asset

All New Navy Programs Utilize Digital Twin Technology

HII Proteus LDUUV

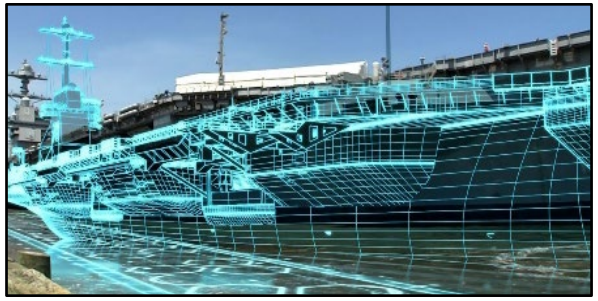
HII-UXS Long Range Unmanned Surface Vessel

HII-UXS Unmanned Under Sea Systems



HII-NNS SSN(X)

ABS Unmanned Commercial Vessels



HII-NNS FORD Class CVN's

HII-Ingalls-UXS LUSV

Deeper Integration of Systems of Systems Cannot Be Analyzed Without Advanced Tools.

Thank you for your attention.
Discussion…

Because of it's widespread Shipbuilding impacts do you have interest in auditing this project?
Sign-up for WebEx and emails? Contact: DWalker@eagle.org or Mark.Debbink@HII-NNS.com

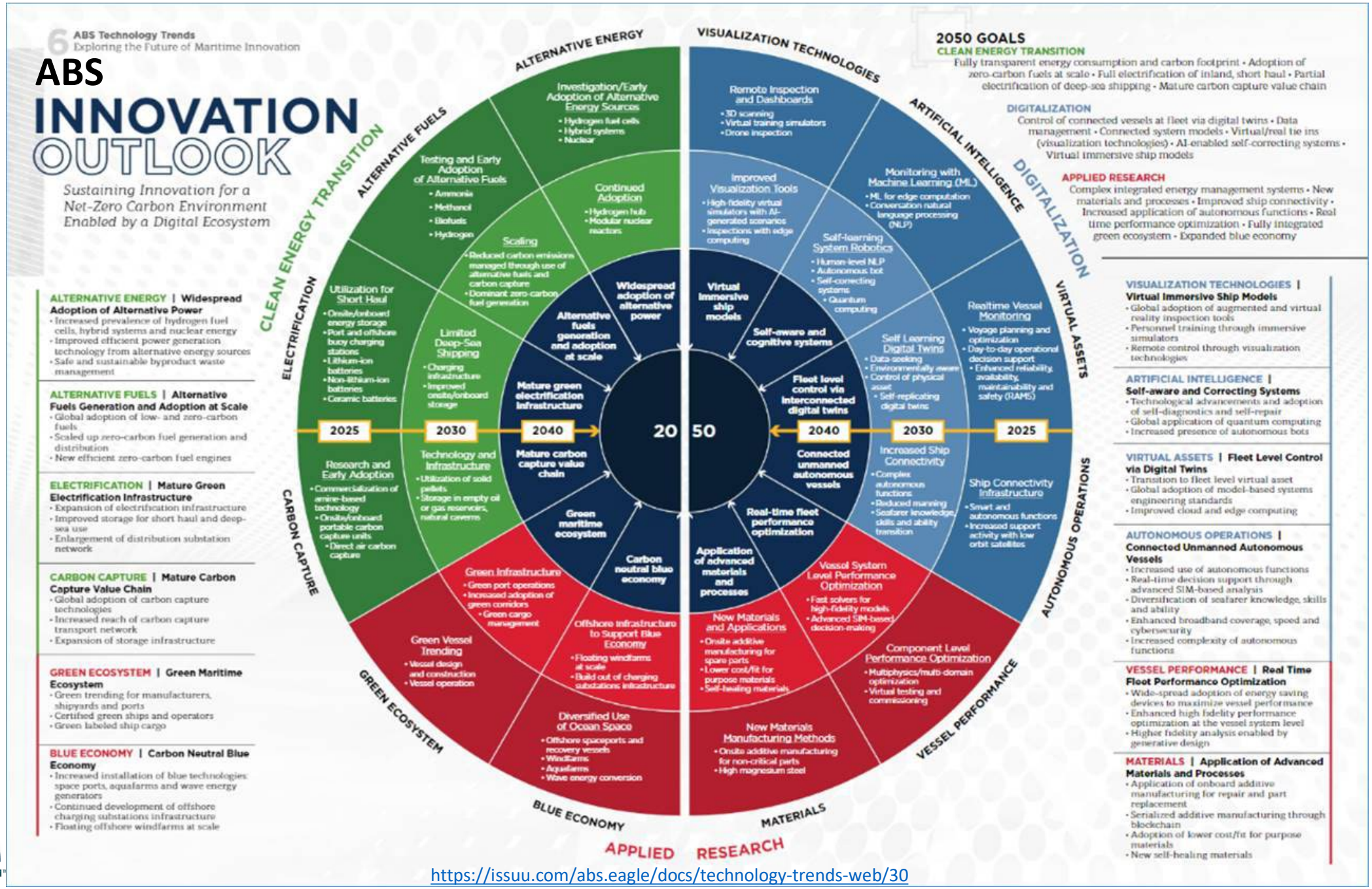
HII-Ingalls Launches, Operates, Recovers LDUUV (2022)
How can manned and unmanned vehicles team up to support the U.S. Navy?
HII's Ingalls Shipbuilding and Mission Technologies divisions demonstrated the critical first step, launching and recovering HII's Proteus large-diameter unmanned underwater vehicle in the Pascagoula River using a prototype platform called Pharos.

NSRP
NATIONAL SHIPBUILDING RESEARCH PROGRAM™
Taking Shipbuilding and Repair to the Next Level

Digital Twin "TRUST" Verification & Validation (V&V) Guide – Project Team

Project Participants	Role and Key Contributions
ABS	Overall project management; Lead research on Digital Twin technology application best practices; Lead development of the V&V approach and associated guidance on methods/tools; Lead the V&V Demonstration applications; Provide the V&V test environment; Develop and publish the ABS *Guide for Verification and Validation of Digital Twin Technology Applications*; Lead production of the final research report
HII-NNS	Serve as the lead NSRP shipyard research partner; Lead key elements of the Digital Twin ontology work, including the Digital Twin Maturity and Complexity Model development; Define requirements for the V&V test environment; Primary source of Digital Twin technology applications for V&V demonstrations; Key contributor to the ABS Guidance publication and final research reports
HII-Ingalls	Serve in an advisory role as a NSRP shipyard stakeholder; Provide technical contribution and advisory support throughout the project; Possible source of Digital Twin technology applications for V&V demonstrations; Review and comment on all work products, including the ABS Guidance document and the final research reports
HII-UXS	Serve as a primary contributor to research work from a technology and service company perspective; Work closely with HII-NNS on key elements of the Digital Twin ontology work, including the Digital Twin Maturity and Complexity Model development; Possible source of Digital Twin technology applications for V&V demonstrations (especially around ship sustainment applications); Review and comment on all work products, including the ABS Guidance document and the final research reports
NAVSEA 05Z & NSWC Philadelphia	Serve in an advisory role as a Government stakeholder for digital shipbuilding and condition-based maintenance strategies and machinery systems; Provide technical contribution and advisory support throughout the project; Review and comment on all work products, including the ABS Guidance document and the final research reports; Coordinate interfaces with NAVSEA 04 and PEO-MLB
NSWC Carderock	Serve in an advisory role as a Government stakeholder for Digital Twin technology applications for ship structures; Provide technical contribution and advisory support throughout the project; Possible source of Digital Twin technology applications for V&V demonstrations (structures); Review and comment on all work products, including the ABS Guidance document and the final research reports

ABS



https://issuu.com/abs.eagle/docs/technology-trends-web/30

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