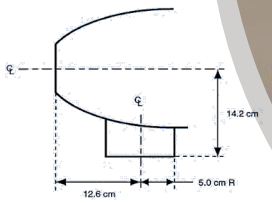
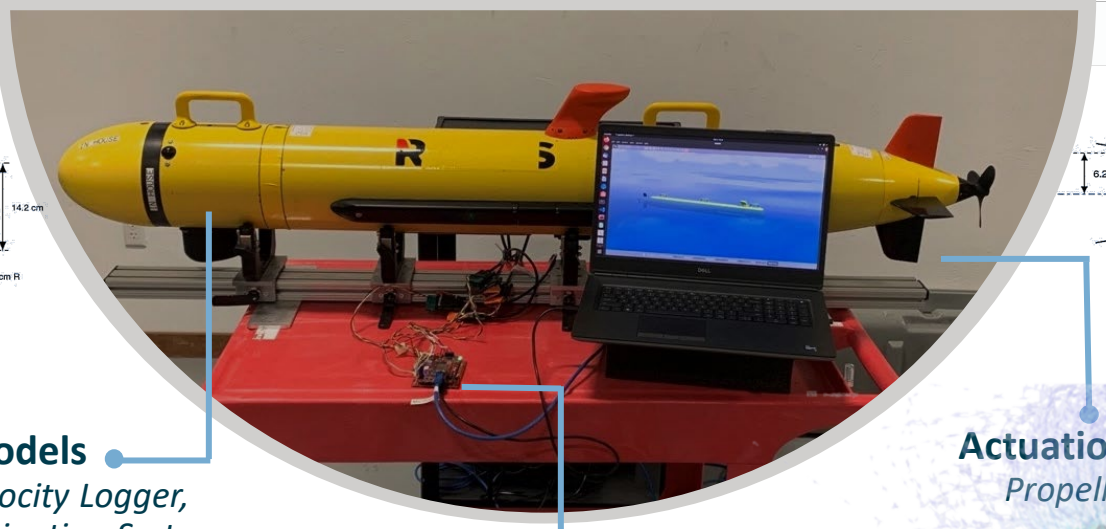
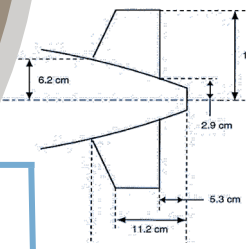
UUV Digital Twin Capability
MT UxS' s Simulation Environment







About the Digital Twin:

Simulation environment to emulate UUV sensors and capture vehicle forces and dynamics operating in realistic ocean environments with software and hardware in the loop capability.

Applications:
- Reduce schedule and cost for development, test, and verification
- Advance state of the art autonomy solutions
- Interactive tool for mission planning and training

Machinery and Control:

Create true models of ships systems and subsystems – Propulsion, Navigation, Situational Awareness, Power and support systems. Provide live continuous communication to/from vessel.

Efficacy:
- Improve and expedite vessel designs
- Strengthen innovation
- Increase vessel readiness
- Reduce emissions and fuel consumption

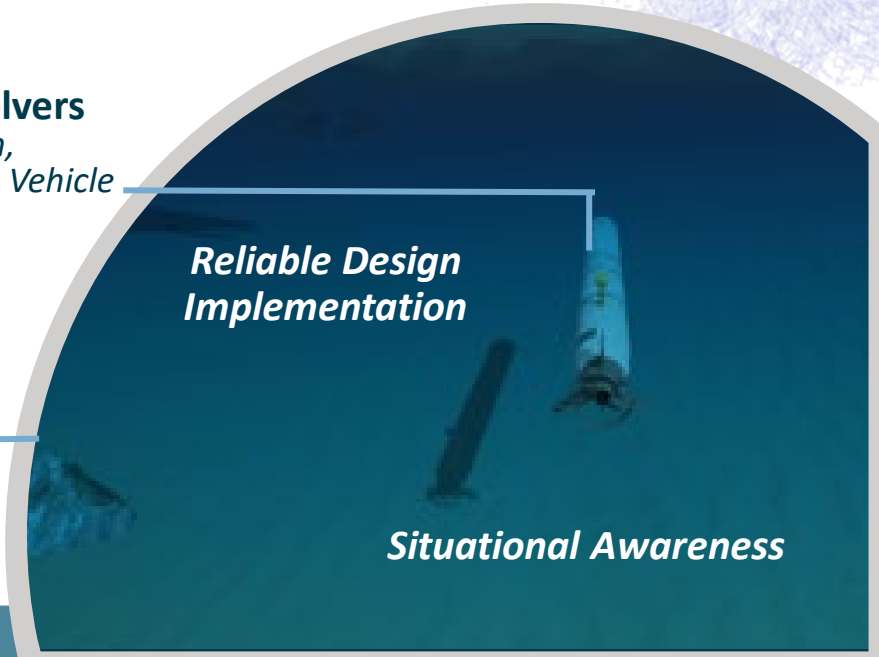
Sensor Models
Doppler Velocity Logger, Inertial Navigation System, Depth, Conductivity and Temperature, Global Positioning System

Hardware Components
Actuation motor, Acoustic Communication, Core board

Actuation Models
Propeller and Fins

Hydrodynamic Solvers
6 Degree of Freedom, Nonlinear dynamics, Vehicle models

Realistic Ocean Environments
Bathymetry, Wave effects, Turbulence, Current, Salinity & Temperature Profiles



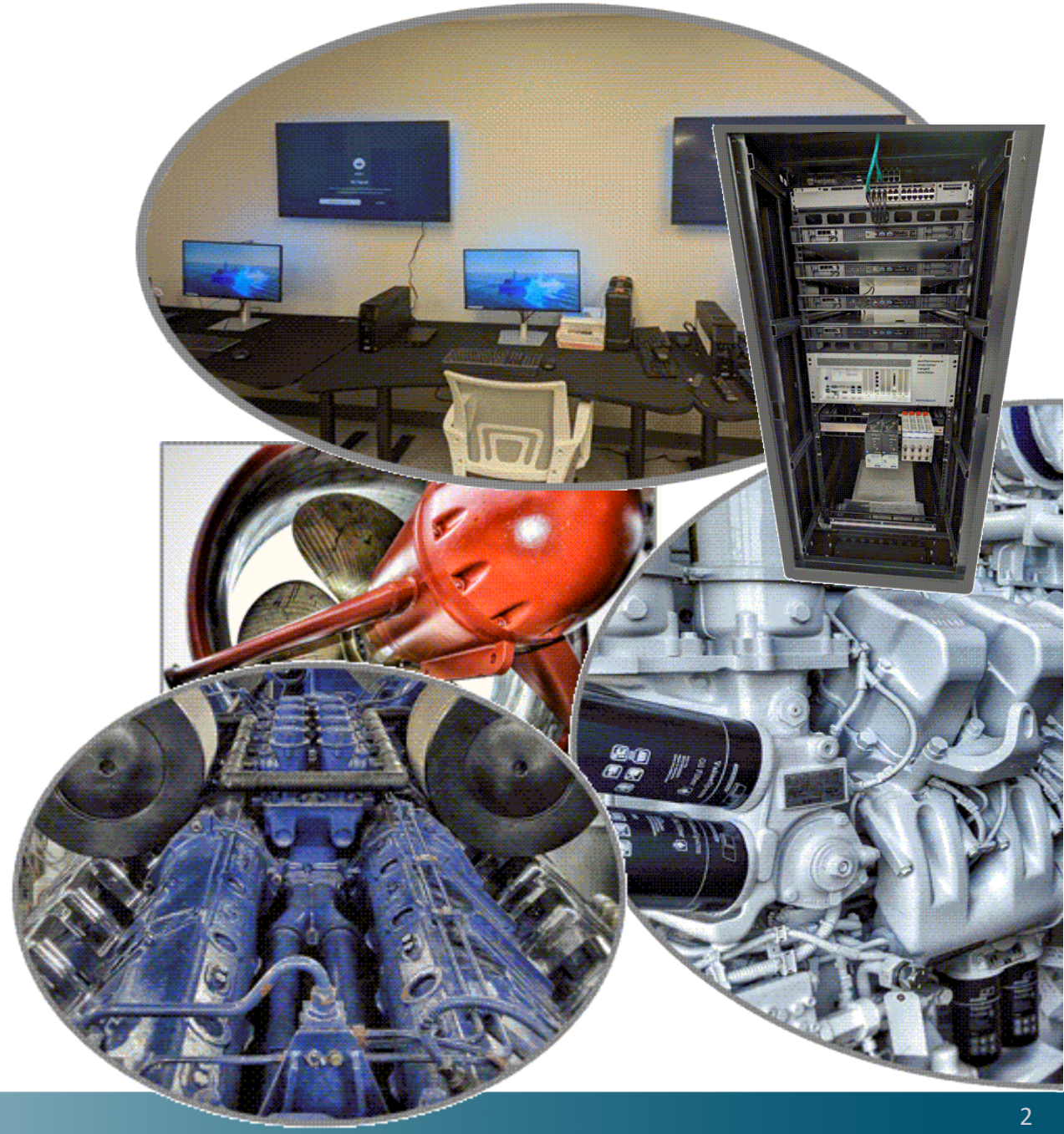
USV Digital Twin Implementation
MT UxS' s Environments

Lab Environment (Simulation)

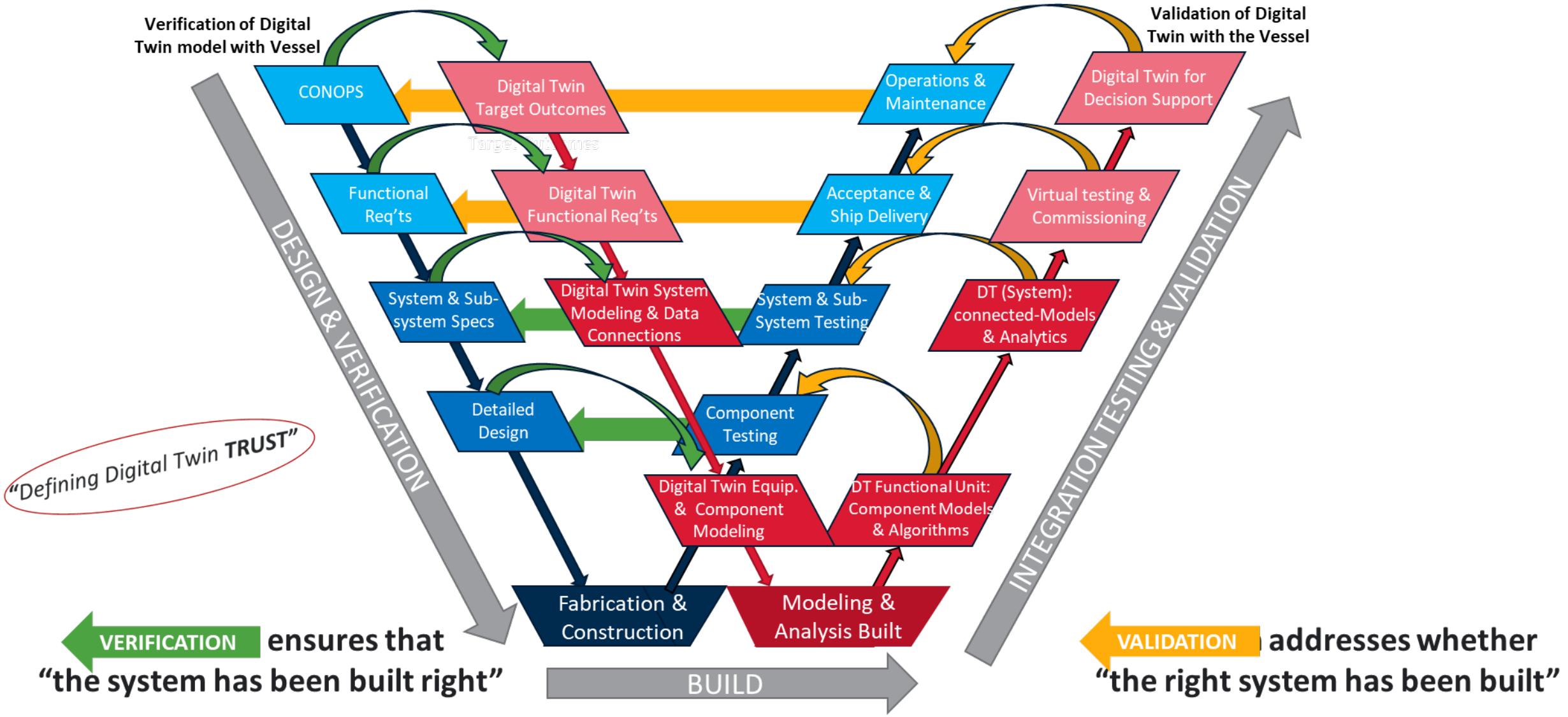
- Speedgoat Real-time Simulators
- PLC based I/O simulation
- Autonomy and Supervisory servers
- Matlab/Simulink simulation software
- Vessel Simulator
- Navigational Simulator
- Radar Simulator
- EO/IR Simulator

Vessel Environment (At Sea)

- Sensor suites for machinery and systems
- Secure vessel to shore data links
- System health monitor
- Predictive maintenance processing



DT Verification & Validation



VERIFICATION ensures that "the system has been built right"

VALIDATION addresses whether "the right system has been built"

Models must be clearly defined, account for all aspects of V&V, and easy to use with automated tools.

How to Specify Digital Twins

Digital Twin Next Steps Forward

(Addressing Contracts)

Step 1 – Necessity Review

Require that HII perform a Digital Twin "Necessity Review" of a design via contract.

Step 2 - Approval

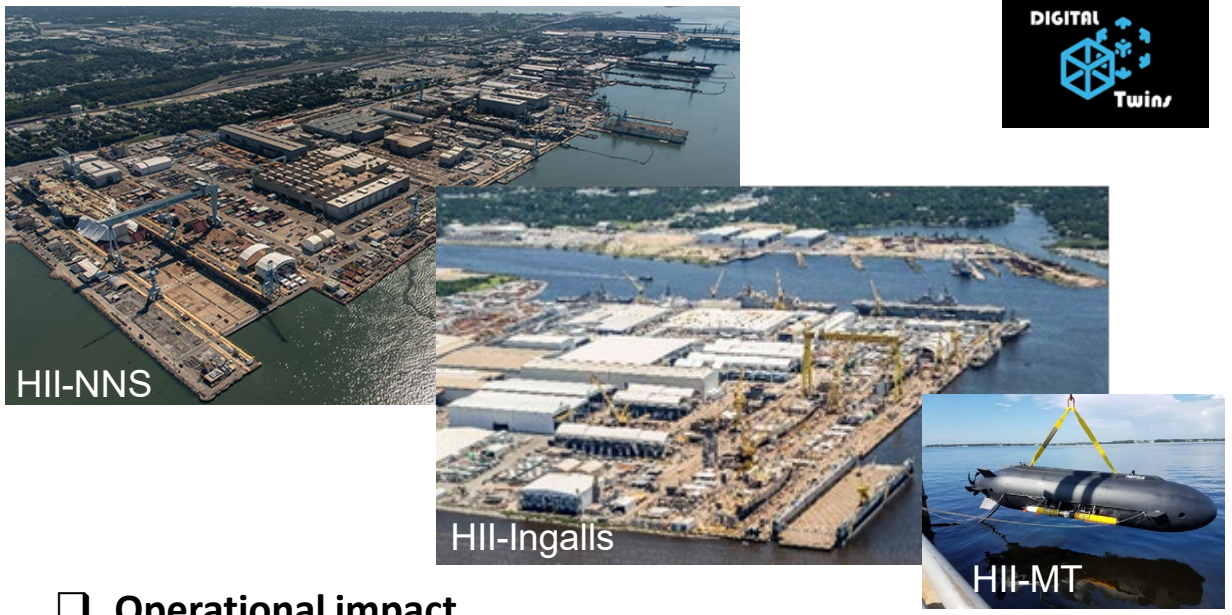
For each "Approved" Digital Twin development, require milestone products and reviews.

Step 3 – Specify Terms

Specify the Acceptance/Delivery "Terms" for Digital Twin if Applicable.

What is the plan for Turnover or long term ownership of a Digital Twin?

Enterprise Impact of Digital Twins at HII



- **DT's are an increasing part of HII's processes**
  - Digital Thread Integration
  - Pro-active vs reactive development policies
  - Model Based System Engineering – Requirements Link

- **Address complexity of emerging systems & technology**
  - Provides reliability in complex multi-system designs
  - Deeper Integration of Systems of Systems
    - Systems can't be analyzed without advance tools
  - Advanced analysis with DT processes & tools
    - New design requirements risk mitigation
    - Simulations before implementation
    - First time build quality / testing / inspection
    - Operational monitoring/predictive behavior

- **Standardization for effective communication**
  - Definition & use-cases
  - Maturity Model levels, Complexity Levels
  - Work Methods & Training

- **Operational impact**
  - Develop DT's for critical components/systems
  - Identifying DT's for new design/modernization work
  - Complex system trouble shooting
  - Align Navy plans for DT Sustainment management
  - On-board crew training

- **New policies and practices**
  - Policy/Plan in place, What & Why to Twin
  - Effective Collaboration with Navy & Suppliers
  - Reduced Manufacturing costs
  - Proactive Sustainment support
  - Organization Structure

The complexity of software driven systems requires new advanced tools & Digital Twin's

DIGITAL Twins

Thank you for your attention. Discussion…

November 2022 Gerald R. FORD Navy commissioned ship returning from Maiden Voyage exercises with Joint NATO Forces.

HII-NNS Digital Engineering for Ships Lifecycles

Closing The Loop…