Navy Platform Digital Twin

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Digital Twin History

- First presented during executive product lifecycle management (PLM) courses at the University of Michigan in early 2002. Referred to as “Mirrored Spaces Model.” (Grieves)

- AFRL began investigating a digital twin approach to predict aircraft structural life around 2009. Recent discussion with the AFRL lead indicates they see it as a 30+ year objective.(Tuegel)
  - Advertised 2011 SBIR to integrate measured data with physics-based models.

- NASA began exploring digital twin for CBM around 2010.

- IBM and GE’s interest in digital twin appears to be focused on exploiting the internet-of-things as a framework for connecting equipment sensors, data, and models.

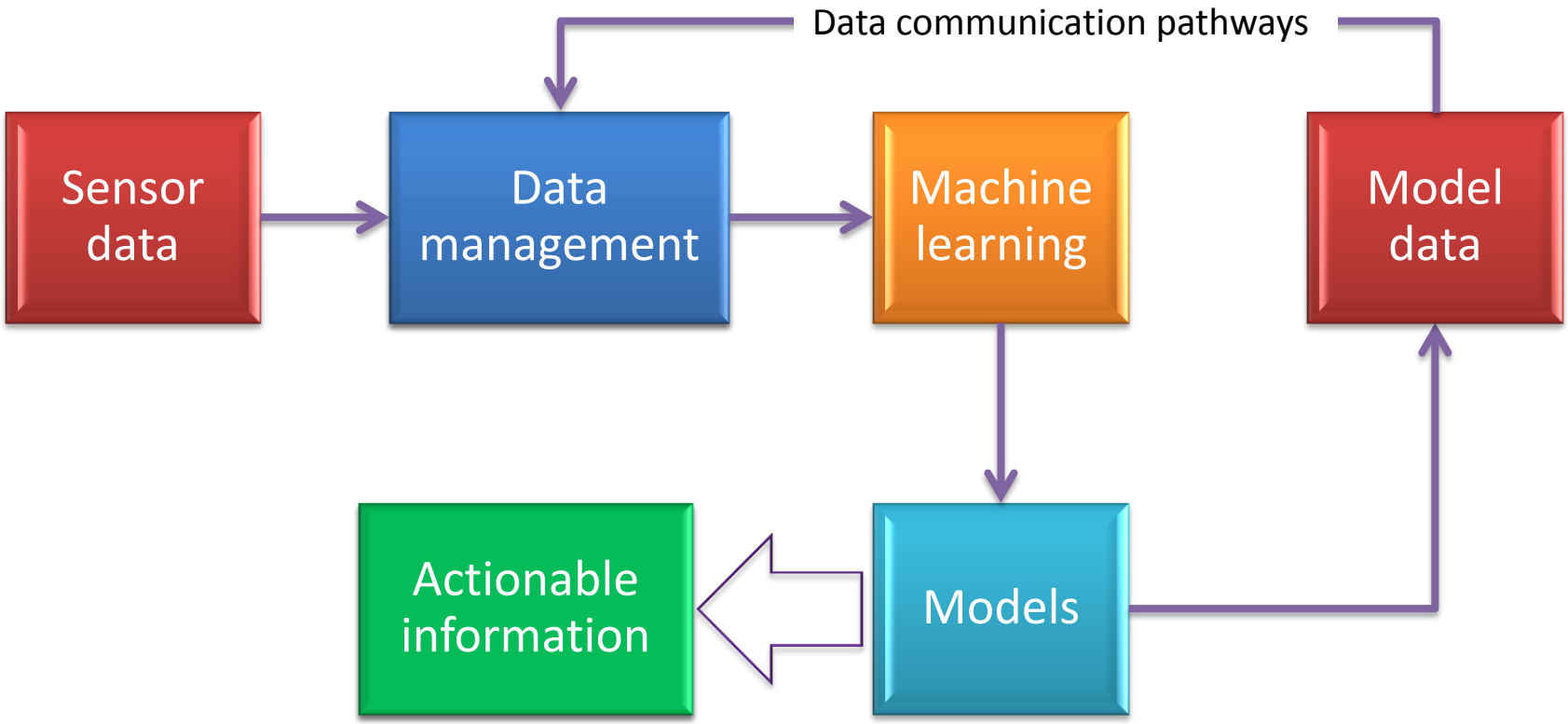
Description of Digital Twin

- Grieves and Vickers
  - "The premise driving the model was that each system consisted of two systems, the **physical system that has always existed and a new virtual system that contained all of the information about the physical system**. This meant that there was a mirroring or twinning of systems between what existed in real space to what existed in virtual space and vice versa." (emphasis added)
  - "The Digital Twin is a set of virtual information constructs that fully describes a potential or actual physical manufactured product **from the micro atomic level to the macro geometrical level**." (emphasis added)
- Leiva
  - "The digital twin refers to a digital model of a particular asset that includes design specifications and engineering models describing its geometry, materials, components and behavior, but more importantly it also includes the as-built and operational data unique to the specific physical asset which it represents.
- General Electric
  - "A Digital Twin continuously collects sensor data on the asset and applies advanced analytics and self-learning AI to gain unique insights about its performance and operation."
- The attributes of the twin are different depending on where we are in the lifecycle of the physical system; design, prototype, in-service, modernization.

A list of references is provided at the end of the presentation.

Digital Twin Block Diagram

- Basic diagram of primary elements used in most commercial digital twin frameworks.
- Few frameworks include physics-based models/simulations, and many have no models at all
  ⇨ they rely on machine learning output to provide actionable information directly.



Navy Platform Digital Twin Vision

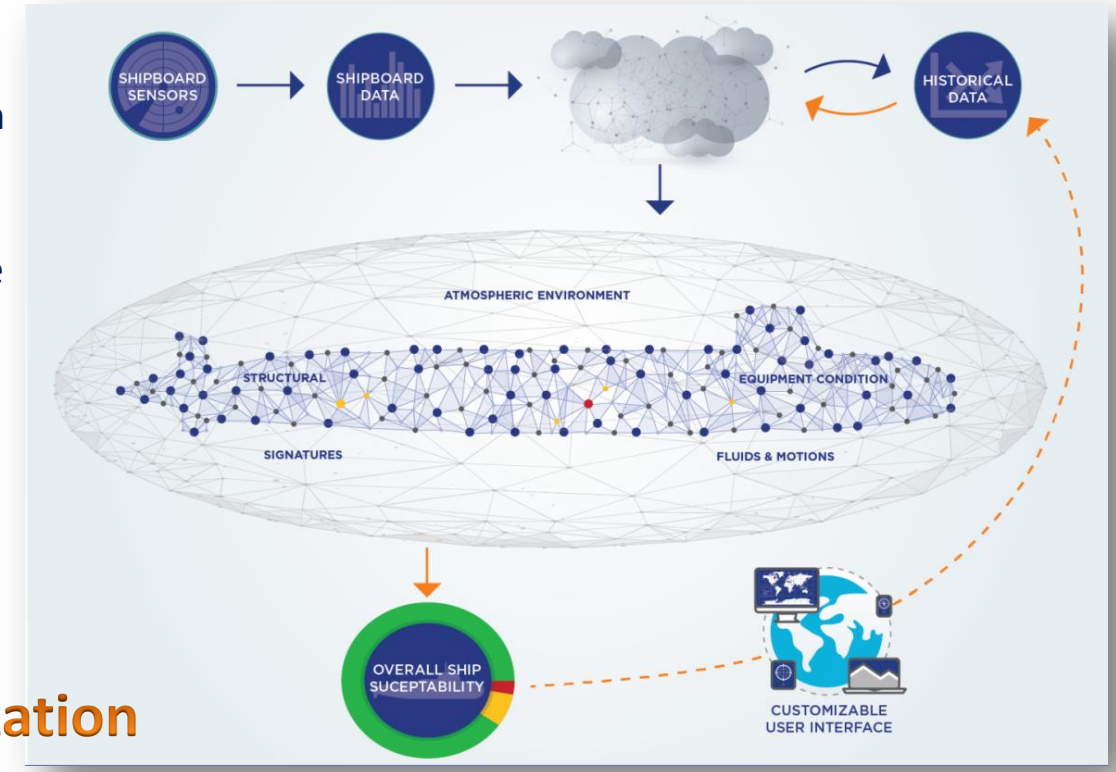
A CYBER-PHYSICAL SUBSTANTIATION THAT TIGHTLY INTEGRATES DATA AND PHYSICS TO OPTIMIZE PLATFORM BEHAVIORS.

- The stored data represents the past of the physical system and the physical substantiation only exists at this moment in time. The ***cyber-physical NDT exists*** right now as ***both its past substantiations*** and its ***future ones***, plus ones it may never realize.
- NDT is a continuous analytical fusion of data, physics-based models, and machine learning to prescribe ***multiple future instantiations*** of the ship and its environment, which enables the user to readily identify the optimum choices.

Heuristic

Data driven

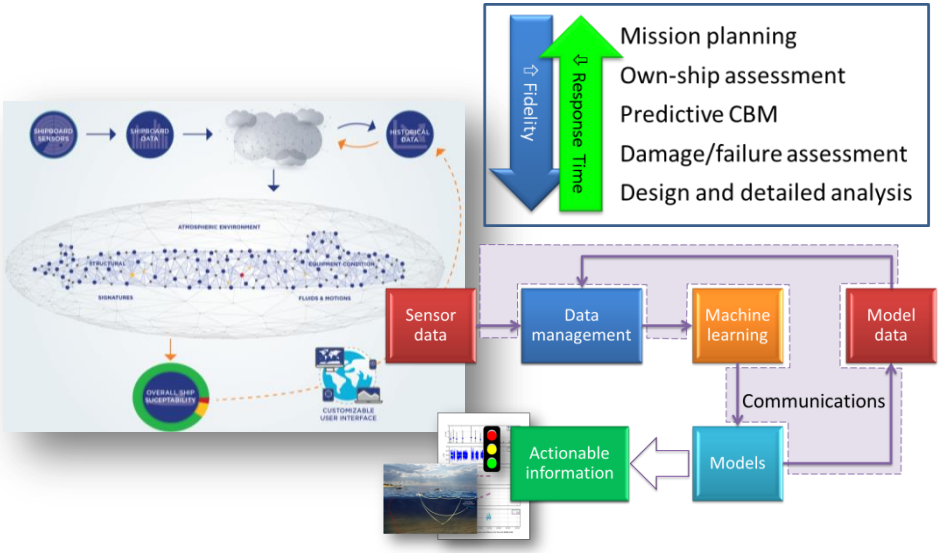
Multivariable optimization



Navy Platform Digital Twin

Objective: Develop a cyber-physical substantiation of Navy platforms that seamlessly ***fuses measured data and physics-based models*** to ***predict optimum platform performance***, ***material condition***, and ***battlespace susceptibility***. The Navy Digital Twin (NDT) will create a data-constrained model-driven framework to provide probabilistic prescriptive information to ***enhance resource allocation, logistics planning, and in-situ decision-making***.

Heuristic
Data driven
Multiobjective optimization



Key Technologies:

- Distributed analytics
- Machine learning
- Compressed sampling
- Digital sensor networks
- Multi-physics solvers
- Multi-objective optimization

Challenges:

- Cybersecurity
- Reduced-order approaches for multi-physics solvers
- Ship-to-shore data transfer
- Expressing prognostic data as prescriptive information

Research Partners:

- Warfare Centers
- Rochester Inst. Technology
- NRL-Monterey/Stennis
- Cornell University
- University of Michigan
- University of Connecticut

Transition:

- TEAM SUB
- MSC
- PEO Ships
- Platform ISEAs

Initial Efforts:

Technical Focus	FY17	FY18	FY19	FY20	FY21	FY22
Est. framework						
Signature						
Structural Life						
Effectiveness						
Availability						

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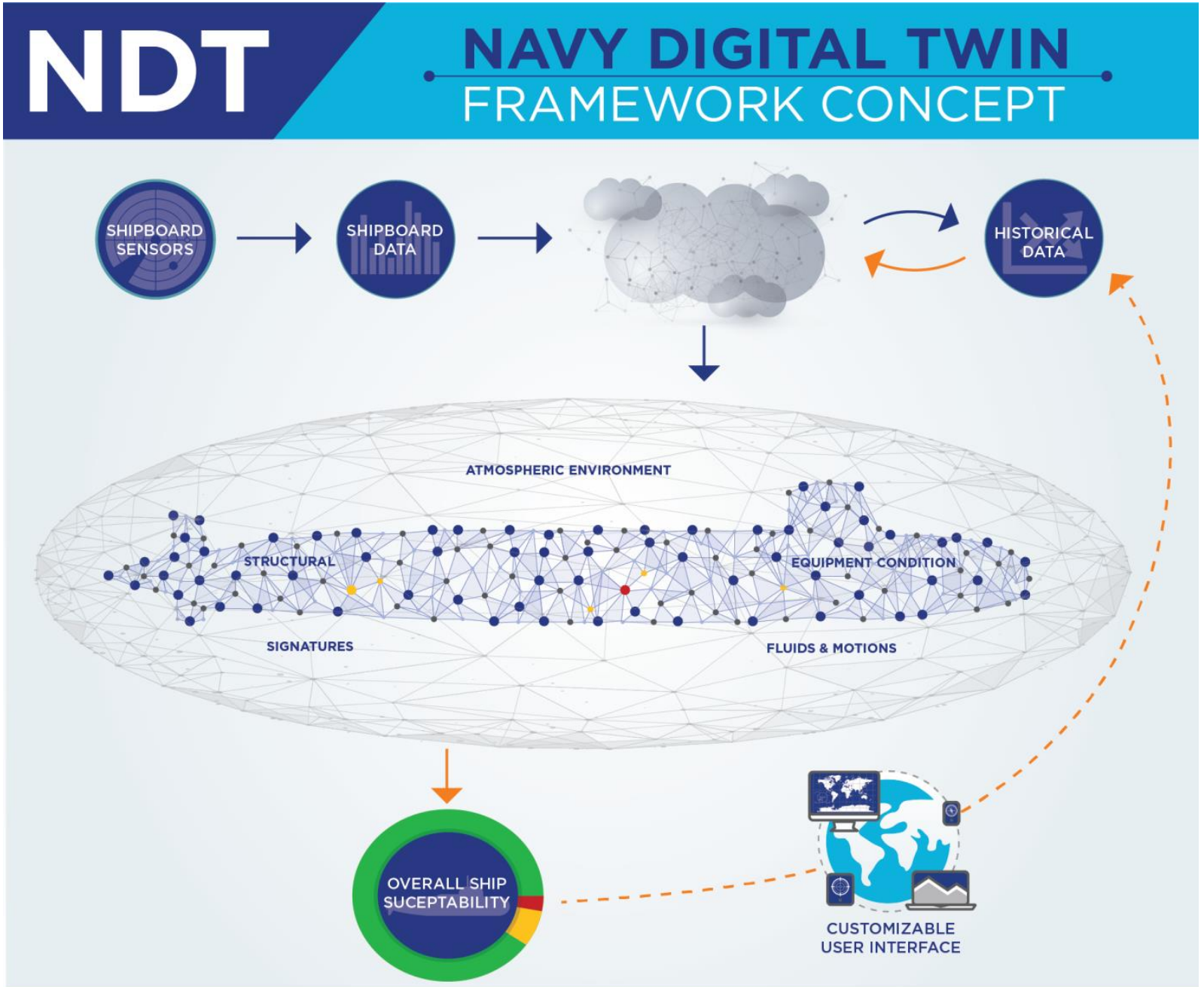

FIGURE 1. The Navy Digital Twin (NDT) framework will allow data sharing between simulations of a variety of physics and levels of fidelity. All models in the NDT framework will exploit current and historical data to arrive at optimal descriptions of ship susceptibility.