HYDROGRAPHIC SERVICES REVIEW PANEL

A federal advisory committee, advising the NOAA Administrator

Digital Twin

A Cornerstone for NOAA's Coastal and Ocean Mapping Programs and Coastal Resilience

The concept of the Digital Twin originated in the manufacturing industry around 2002, and it has been gaining momentum in many engineering and geospatial sectors since 2016. Digital Twin at its simplest means a dynamic, up-to-date digital replica or representation of a physical object, asset, or system. Digital Twin is the environment where a complete collection of all data is represented in one place that evolves with the flow of new real-time data input from sensors and data feeds. Digital Twin offers the ability to incorporate data and information from other systems and to adapt over time to support all facets of an asset or ecosystem, from planning through operations. In addition, Digital Twin can be coupled with Artificial Intelligence (AI) and deep learning to help managers, policy makers, facility engineers, or vessel captains to increase access to accurate data, forging connections for improved and defensible decision-making. Due to this dynamic capability, Digital Twin applications have reproduced quickly over the last few years, with industries from manufacturing to supply chain to health care capitalizing on the value of this geospatial tool. One of the most promising applications is in the multifaceted operation of vessel navigation controls and assets management.

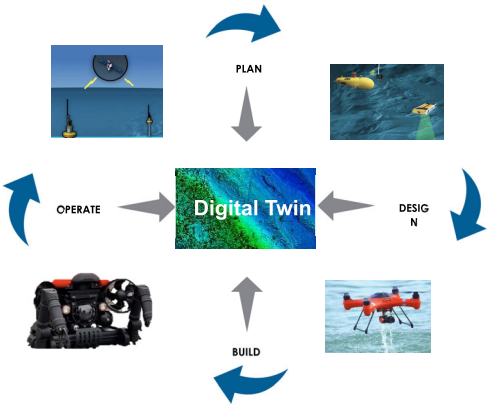


Image illustrates the life cycle of Digital Twin, Credit: Woolpert, Inc.

The National Oceanic and Atmospheric Administration (NOAA) has witnessed overarching digital transformation in the data and services it provides. NOAA and its contractors collect a tremendous amount of scientific data, environmental monitoring logs, digital aerial imagery, and three-dimensional sonar and lidar data. Digital Twins and 3D models have complementary applications in the coastal setting. A 3D model, whether for the coastal areas or the ocean bottom, is the best platform for presenting a realistic environment for the interpretation of integrated data. The model then provides a base layer that can incorporate historical and engineering designs, real-time environmental measurements, and daily operation data to make it a living, breathing accurate Digital Twin (model).

Immense amounts of data are collected daily by existing NOAA sensor technologies to support various maritime community and stakeholders who use such data for planning and operations. The Physical Oceanographic Real-Time System (PORTS) program is a good example of the strategic services that NOAA offers to deliver vital information to mariners for navigation safety. This data supports maritime navigation, coastal resilience, infrastructure management, and disaster response and recovery. This data is often siloed in different databases. If integrated into a Digital Twin, NOAA officials and their stakeholders gain access across different offices to make individual and collaborative decisions. This not only helps realize synergies to advance each office and service, but also provides the framework to identify opportunities to improve NOAA's overall operations, research, planning, resilience and emergency response.

A Digital Twin can help NOAA and its stakeholders enhance their ability to process, monitor, perform quality-control, consolidate, fuse, and assimilate navigation and environmental observations with streamlined data processing and dissemination to users and applications. One of the pressing issues facing humanity is global warming and deteriorating air quality. NOAA can play a crucial role in a structured decarbonization-focused approach to reduce the carbon footprint of commercial fleets and maritime industry operations. The Digital Twin concept plays a leading role in achieving positive outcomes for a decarbonizing strategy that aims at achieving net zero emission to improve different aspects of life including sustainability, resilience, human health, climate risk mitigation, and future challenges.

The Digital Twin concept can benefit from the three-dimensional digital representation of the earth and our oceans, and for applications within the United States, it should be based on the forthcoming geometrical datum of 2022, to assure seamless transition between land and sea using the unified geometrical datum that the National Geodetic Survey National Spatial Reference System (NSRS) modernization program offers.

NOAA should play a more proactive leadership role to develop the Digital Twin concept by providing its services and data availability to connect with its stakeholders and communities.

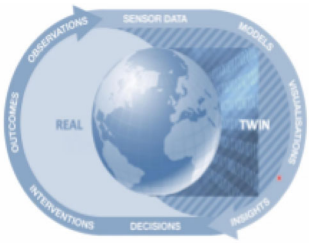
NOAA's National Ocean Service will benefit from crossing the digital divide and applying Digital Twins as assets to increase services and to help the recreational and commercial maritime industry with:

1) Increasing safe, efficient, and weather-optimized transportation and commercial navigation data.
2) Resilience, preparedness, and risk reduction for coastal communities.
3) Protecting and promoting access to special coastal and marine locations used for recreation and tourism.
4) Streamlining public services through efficient cloud-based and nearly real-time updated electronic charts.
5) Utilizing the AI revolution to help the public mine the data that NOAA provides and convert such data into knowledge.
6) Helping ports or waterways quantify and manage emissions for air quality and health (as shown in Vancouver, BC).

NOAA can also benefit from the concept of Digital Twin to manage its geographically scattered assets and vessels, including the two new survey vessels being constructed.

Recommendations for NOAA Action:
Working with its federal, state and industry partners, NOAA should prioritize the following:

1. Support and expand NOAA's initiatives in big data, digital transformation, and AI. Similarly, ensure that the data NOAA stewards and disseminates are truly interoperable and fully adherent to FAIR (Findable, Accessible, Interoperable, Reusable) data principles particularly within NOAA navigation services offices. This will be the foundation for the development of Digital Twin.
2. Form a task force to evaluate the Digital Twin role in managing NOAA's foundational data, optimizing economic activity at the ports, improving safety protocols in port operations, supporting coastal resilience, coastal and ocean mapping, modeling-based predictions, and managing NOAA assets. Other mandates include implementation requirements definition (financial and IT infrastructure) and roles and responsibilities within NOS and across NOAA.
3. Based on a positive outcome of the task force report:
   a. Work with industry and academia to develop a strategy for a performance-based Digital Twin model. Focus on a small but quick platform development.
   b. Working with industry and academia, take the necessary steps to build the Digital Twin enterprise for U.S. coastal areas, commercial U.S. navigation routes across the Pacific and the Atlantic oceans, inland waterways, fixed assets such as buildings and structures, NOAA fleet of vessels, natural marine resources.
   c. For the physical and environmental data gathering and disbursing, focus on the larger portfolio approaches rather than project perspective. This way, building a Digital Twin can be easily achieved. As it exists today, NOAA maintains many valuable databases that can be the foundation for a Digital Twin, but it needs to be aligned to an overall digital platform infrastructure that supports Digital Twin.
   d. As prototypes, NOAA can partner with industry and academia to build Digital Twins in specific ocean and marine environments. Examples could be related to precision navigation with the Port of Long Beach being extended to incorporate the shore-based facilities and operations and better integrate tide, swell, and current services. Additional prototype examples are supporting pilotage on the Mississippi River with integrated 3D/4D visualization of bridge air gaps, or supporting the full life cycle of a wind farm development. Prototyping is essential to assist in assessing and optimizing the digital infrastructure by identifying weaknesses, if any, and explore the needed requirements.
4. As a prerequisite for the Digital Twin development, continue precise height determination surveys as it is crucial to seamlessly connect land and sea.
5. Continue to support the modernization of the NSRS for its role in building national Digital Twin for inland and coastal environments.
6. Increase collaboration with national and international agencies who are in the business of mapping the earth surface and/or collecting marine environmental data. NOAA needs to first ensure it can support the needs of other agencies and industry needs with all the data and services to be incorporated in a Digital Twin.
7. Increase funding for research and development internally or through academia and external research institutes to support NOAA Digital Twin and AI initiatives.



Digital Twins of the Ocean

Image Credit: DITTO, ditto-oceandecade.org

In October 2003, Secretary of Commerce Don Evans established the HSRP as directed by the Hydrographic Services Improvement Act of 2002, Public Law 107-372. Panel members, a diverse field of experts appointed by the NOAA Administrator, serve to advise on NOAA navigation services programs.

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