



# Digital Twins of the Ocean

## Digital Twins of the Ocean Defined

The **Vision** of the Digital Twins of the Ocean (DITTO) Programme is a world where digital twins are used to support ocean science, ocean protection, ocean governance and a sustainable ocean economy. The **Mission** of DITTO is to develop and share a common understanding of digital twins of the ocean, to establish best practice in their development, and to advance a digital framework to empower ocean professionals from all sectors around the world to effectively use digital twins.

DITTO will promote co-design of twins with targeted end users, raise awareness of their uses and applications, and demonstrate their potential for decision making across multiple sectors including ocean governance.

## Characteristics of Digital Twins

**Digital twins** are virtual representations of physical objects and systems - the physical or real twin (in this case the ocean or a part of it) - which have been widely applied in the engineering realm for tasks such as engine optimization and port management. Digital twins include predictive and data-driven models that users can interact with to support their needs. Digital twins thus provide the ability to make informed operational, management, and policy decisions for the real twin. This connection between the digital twin and the real one requires a well-formulated interface between the digital twin, environmental data, and the user. User interaction is therefore an essential function that is embedded in the design of digital twins, including visualisation, user-driven data transformation and data-science tools.

## Why Digital Twins of the ocean?

A **Digital Twin of the Ocean (DTO)** is a virtual representation of the real ocean that has a two-way connection with it. Observations from the real ocean, in combination with models, data science and artificial intelligence, are used to create a digital twin that adapts as the real world changes. Manipulating the twin to address 'what if' scenarios can provide information for decision-making and highlight regions of the real ocean in need of better or different observations. A well-constructed digital twin of the ocean will enable a wide range of users to interact with ocean data and information to improve understanding and inform decisions and can support ocean literacy and ocean understanding. They can be used to explore ways in which the ocean will respond to a changing set of conditions, providing a powerful tool for decision making. DTOs will provide ocean researchers, professionals, citizen scientists, educators, policymakers, and the general public alike with the capability to visualise and explore ocean knowledge, data, models and forecasts.

## The Opportunity

The **UN Decade** of Ocean Science for Sustainable Development offers a once-in-a-generation opportunity to make transformative advances in our capacity to observe and understand the ocean. Digital twins of the ocean are tools that allow us to integrate the research innovations and new ocean knowledge of the Decade directly into user-defined decision-making tools to empower society for sustainable development and ocean protection.



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## The fundamental building blocks to support a Digital Twin of the ocean:

### 1) An **Observing** system.

A co-design between users and developers of the observing networks needed for digital twins of the ocean will create a positive and continual feedback loop between both where information from the digital twin can be used to inform and optimise the observing network whilst benefiting from it.

### 2) A **Data Space** that provides access to ocean observations through data communication and management in a timely way following common data principles.

The Data Space includes tailored computing capacity (often cloud based), an information management framework, a forum for setting data standards and protocols, and a system for data mapping architectures and data lineage to track data transformations.

### 3) A **Data Analytics and Prediction Engine** to maximise the understanding and value from these data.

The Prediction Engine provides tools to add value to ocean observation through predictive modelling, emulation, and artificial intelligence / machine learning to create, manipulate and analyse marine information. Digital twins incorporate the additional capacity for the user to modify the prediction engine to explore options, scenarios, and consequences.

### 4) An **Interactive and Provisioning layer** allowing users to visualise, interact with and tailor the data, scenarios and models to meet their needs.

This layer provides a powerful interface to the information and tools in the data engine that is easy to adapt and use, and represents one of the characteristic features of digital twinning. These provisioning layers are tailored towards human users and are often visually pleasing front-end interfaces with easy, intuitive access. Machine-to-machine provisioning is also common, in which case the provisioning layer is tailored to enable federating with other twins or systems.

### 5) An **Outreach and Training** capability to train developers, experts and users of digital twins respecting the capabilities and realities of the diverse international communities.

Digital twins are not new. However, their application to the earth system and ocean domains is relatively recent. Support to develop international capacity and capabilities is needed to ensure that observations and other data are accessible through appropriate Data Spaces, that models and analytics systems are available and usable to all and that DTO information can be developed and applied to serve diverse international communities' user needs.