Ireland's Digital Transformation: Building a Digital Twin of the Ocean

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Background

The concept of a Digital Twin has advanced significantly in recent years, offering a virtual representation of the real world that enables modelling, simulation and visualisation of complex systems. When applied to the ocean, this technology has the potential to help stakeholders and decision makers, providing access to vast datasets collected over decades and supporting the protection of the environment and sustainable development of marine related activities.

Offshore developments, climate change adaptation, environmental conservation, and the planning of developing coastal urban areas all rely on effective, evidence-based decision-making. Embracing strategic and legislative frameworks such as the European Union's Maritime Spatial Planning Directive, Ireland is actively developing digital strategies and planning initiatives in its marine environment. Digital Twins of the Ocean (DTOs) can leverage insights into current conditions and predictive scenarios, supporting better informed decision-making for a range of stakeholders.

Situated at the western periphery of Europe and responsible for a vast maritime area (cf. The Real Map of Ireland) Ireland is focusing on digital innovation in marine sciences. Building on decades of expertise in marine data collection, management, and analysis, underpinned by established data acquisition programmes and rigorous process flows, the Marine Institute is driving Ireland's digital transition by advancing the development of a **Digital Twin of the Ocean**, transforming how we understand, manage and protect our marine environment

Enabling an ocean of data

In hosting Ireland's National Oceanographic Data Centre (NODC) and contributing to key European initiatives, the Marine Institute plays an important role in integrating and disseminating high-quality marine data. Marine observations data is often collected for a single purpose, and not necessarily re-used. This data collection can be expensive and complicated; thus, it is crucial to work with existing products: **repurposing the wheel, not reinventing**. To that effort, building on the knowledge gained through international collaboration, the Marine Institute has worked towards becoming a data centre of excellence, and as a result has been awarded IODE accreditation for its Quality Management Framework and the CoreTrustSeal certification for trusted data repositories. This enables the development of services built on trustworthy data, flowing through a robust infrastructure composed of established pipelines, consolidated databases architecture and homogeneous publication pathways (e.g. OGC spatial services, ERDDAP), alongside rich metadata. Having properly documented processes and quality metadata is key to building authoritative and re-usable services, encouraging uptake and enabling one of the key drivers: build once, re-use many times (or publish once, re-use in many services). As a result, several services are being developed, such as those supporting the development of Ireland's first Designated Maritime Area Plan (DMAP): a first step towards better informed decision making.

Building the foundation of a DTO

In line with Government policy, the Marine Institute is adopting a "cloud first approach" as a core design principle driving the digital transformation and a national and international shift towards

integrated digital services. The increased adoption of cloud-based storage and services enables more data to be available and as such, more integrable. Thanks to cloud technology, it is now easier to consolidate applications and services architecture, leveraging data analytics SaaS and data spaces (through projects like FAIR-EASE), whilst still relying on a solid foundation of on-premises infrastructure and keeping security as a core design constraint. This approach is now being applied to a new secure spatial infrastructure, underpinning services and enabling Marine Institute initiatives such as upgrades to the Marine Atlas and Digital Ocean Portal, and the integration of new visualisation capabilities.

Towards innovative services

Benefiting from these enterprise-grade foundations, the focus of the roadmap for the future can now be on advanced data exploration, visualisation and modelling, whilst ensuring continuous improvements of processes and underlying services. 3D visualisation R&D has already started and is promising great opportunities for immersive data exploration and augmented reality, making the data more accessible and opening new ways of outreach to the public. Coupled with real-time and modelled data integration, this would lead the way towards better scenario predictions and decision support tools, such as the recent DMAP and Sea Sensitivity Studies.

Connectivity has improved in recent years and as such, allowing more data to flow in near real-time. It is then important to maintain and optimize the underlying systems. Indeed, data pipelines can potentially be streamlined across the different in-situ instruments, eventually consolidating the acquisition chain and simplifying collection from new sources. With more data becoming accessible, a strong focus will be put on leveraging AI and Machine Learning capabilities to optimize storage and allow advance data analysis, transitioning work from various projects into an operational information processing chain.

Delivering good quality and informative data, through engaging user experience and supported by reliable data flows will streamline the transition from Data Viewers to fully functional DTOs.

Conclusion

Ireland's digital transformation strategy prioritizes Digital Twins as key to the future of marine and coastal management. The Marine Institute has aligned its vision with this strategy, leveraging its experience in data processing, building trusted, scalable, and interoperable digital services to support Digital Twins of the Ocean. By harnessing cloud computing, AI-driven analytics, and high-quality marine data, the Marine Institute is bridging the gap between data and decision-making. Delivering DTO services is at reach, enhancing accessibility, cross-sector collaboration, and evidence-based policymaking.

As DTO development progresses, the Marine Institute remains committed to innovation, data integrity, and integrating new capabilities; paving the way for a future where Ireland's marine data infrastructure is not only fit for purpose but also an enabler of sustainable ocean governance, climate resilience, and economic growth.

While acknowledging many challenges lie ahead, it is important to recognise that fundamental building blocks and efforts already exist that can be built upon by **bringing it all together**. Driven by end user needs, leveraging expertise and connecting recent progress in digital capabilities adds to the existing momentum for delivering on the promise of Ocean Digital Twins.