THE INTERNET OF BIG THINGS

DIGITAL TWINS AT WORK IN MARITIME AND ENERGY

Tackling real world costs, tight margins and safety challenges with virtual tools

By Øyvind Smogeli

2017 is a milestone year for DNV GL, with our sights now set on creating 'virtual sister ships' that allow designers, builders, operators and other stakeholders to collaborate on reducing costs, improving efficiency, and boosting safety through-out the vessel's lifecycle.

It's not just in maritime that my data and engineering expert colleagues at DNV GL are advancing the concept of a cloud-based digital twin. It's an approach that could revolutionize projects – from concept design right through to decommissioning – across all the industries we serve. The company believes that data smart asset solutions are a key to improved business performance and risk management, and the digital twin approach is central to this next-generation offering.

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Virtual assets

A digital twin is a digital representation of a physical object, asset or system: a ship, a car, a wind turbine, a power grid, a pipeline, or a piece of equipment such as a thruster or an engine.

It can contain various digital models and collections of information and processes related to this object. Data can be in the form of graphical 3D-models, dynamic and discrete simulation models, virtualized control systems and communication networks, analytical models, data models, sensor data, relationship data, process data, as well as digital information such as documentation and reports.

DNV GL BELIEVES ITS ROLE AS AN ADVISOR OFFERS ADVANTAGES BECAUSE IT DOES NOT HAVE A VESTED INTEREST IN SELLING ANY ASSOCIATED PROPRIETARY ENGINEERING PRODUCTS.

The digital twin combines all available information and models of the object throughout its lifecycle. Within the digital twin environment, a theoretically endless variety of operations can be performed, including system design, efficient assurance and verification services, simulator-based testing and virtual system integration, and the generation of deep insights and predictions.

A digital twin fuelled with sensor data allows decision makers to react, if not in real-time, then within a decision interval that enables actions that still have value. Also, as more empirical evidence from real-world operation accumulates, the model becomes more predictive, which enables greater proactivity to avoid risks and maximize profitability.

A leap in ambition

I believe that DNV GL's proposition is completely novel in the maritime industry. The leap in ambition is the combination of a digital twin for system integration and testing with insights from sensor data. This will propel the industry into a future where model-based simulation, data analytics and visualization software connect in the cloud with data from physical sensors.

We are now in discussions with potential industry partners for a proof-of-concept programme to launch in 2017. It follows the success of *Nauticus Twinity*, a DNV GL innovation project which modelled how a virtual sister ship might be created.

The rise of digital twins

Digital twins are not a new idea. The US Air Force and many car makers such as Maserati have used them to reduce cost and time all the way from design, through sourcing of equipment and components, to manufacturing and operation. Equipment manufacturers like GE are increasingly relying on them in their core business processes. Lawmakers also see their potential. German regulations oblige pre-installation simulation of a wind turbine's operation in a wind farm grid and mandate the use of digital twins in the country's wind farm certification process.

I see great potential for digital twin models in our processes for demonstrating that customers' technologies and processes comply with international and national standards and regulations, as well as for technical assurance of new or modified technologies.

This applies also to verification and classification. As part of the digital revolution, industries such as maritime have become increasingly reliant on software-driven cyber-physical systems. In the extension of this development we also see the drive towards autonomous functions – from self-driving cars in the automotive industry to unmanned ships in maritime. For these cyber-physical systems, you cannot verify key properties such as safety, reliability or availability as a paper exercise only, or by analysing individual components and subsystems and then aggregating results.

The emergent properties that arise when components and subsystems are integrated to become systems and systems-of-systems require new methods. In short, what we propose is a systems approach combined with extensive testing and verification in a simulated environment, all driven by the digital twin.

In the next two to three years, my colleagues in the DNV GL research will develop something called the 'Probabilistic Twin' – an extension of the Digital Twin concept. According to Andreas Havfer from DNV GL's Oil & Gas and Energy Systems team, while the latter is a digital copy of the physical asset, the probabilistic twin is a forecasting tool to support effective risk management in operations, coupling the digital twin to risk models which are continuously updated based on actual conditions and new knowledge. Preliminary work on coupling risk models with data analytics has already been carried out.

A wider digitalization strategy

As a trusted, neutral party, DNV GL is currently developing an open industry data platform enabling the sharing of data, algorithms and transactions between industry players.

By combining our customer's asset data with industry-wide data sets, DNV GL aims to unlock data silos and provide a frictionless, quality-assured data market place that truly releases value. The platform is open in the sense that it will profile and quality assess data, allowing customers either to perform their own analytics or invite others, including DNV GL, to perform analytics on their assured data.

With this collaborative data platform, the trust that we have established over decades advising clients and managing joint innovation projects is critical. As a colleague recently remarked, we are effectively making our analogue role digital.

That said, DNV GL has of course long been entrusted to handle customers' data. As a legacy of decades of experience in this space, we already have the modelling and data analytics capabilities as well as solutions for data-smart customer interfaces.

Enabling digital twin approaches thus sits within our wider strategy at DNV GL to evolve further and faster as a data smart company.

Digital twins at work across DNV GL

The COSSMOS solution, for example, has been implemented successfully to model, simulate and optimize complex, integrated ship machinery systems. COSSMOS models are effectively virtual engine rooms connected to cost data and the vessel's operating parameters to generate valuable insights. DNV GL now builds on solid experience from running a range of commercial COSSMOS-based applications with more than 60 vessels worldwide.

Another example is the Marine Cybernetics Advisory team that I lead, where we connect control system software on ships and offshore units to a digital twin, a Hardware-In-the-Loop (HIL) simulator that models the vessel, its machinery and various equipment and systems. We have done this successfully for more than 150 vessels, and the technology can easily be adapted to any ship or asset type.

The new Digital Assurance programme in DNV GL's Group Technology and Research division is now building on the proven HIL technology and insights from the *Nauticus Twinity* project to establish the framework for a more comprehensive cloud-based digital twin platform.

In the renewable energy field, DNV GL is already providing online SCADA-based condition monitoring services for wind assets, utilising innovative algorithms to analyse the large amounts of SCADA data streamed from operating turbines in the field in order to predict health issues in drive train components. But this is just the start.

With years of HIL testing and modelling of wind assets behind it, the company sees its ongoing development of digital twins for wind as an evolutionary process. My colleague Graeme

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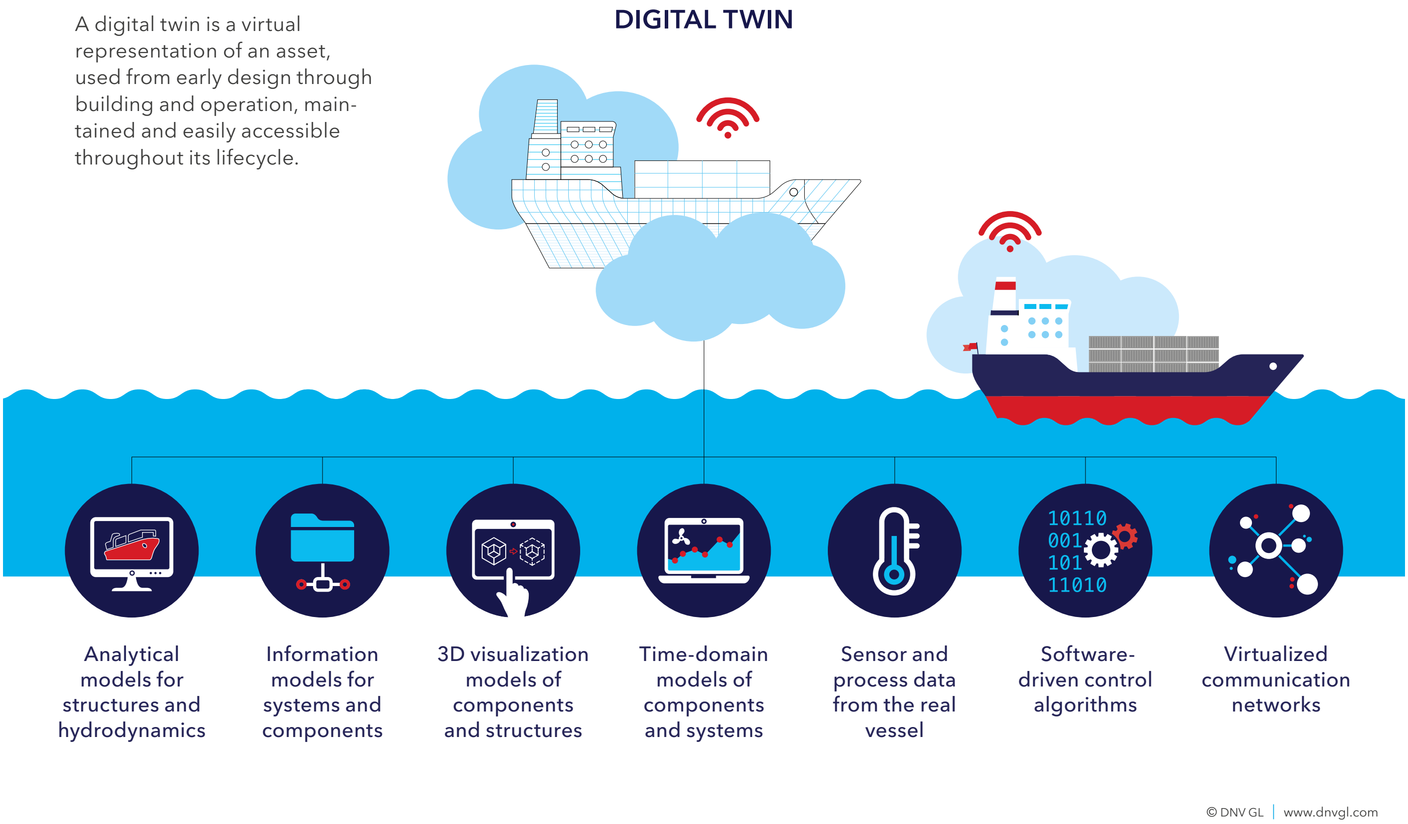
A digital twin is a virtual representation of an asset, used from early design through building and operation, maintained and easily accessible throughout its lifecycle.



McCann, Head of Turbine Engineering at DNV GL, says that, "As currently envisaged, a digital twin would cover the complete project lifecycle by integrating a virtual representation of the entire wind plant with continuous data streams from the asset's SCADA system, operations and maintenance records, inspections data and other sources."

In DNV GL – Software, another aspect of the digital twin concept is high on the agenda. Their analytical asset models have already been around for decades, but now they are taking the step into a cloud-based digital twin solution.

Innovation in digital asset ecosystems

The Director of Digital Transformation in DNV GL – Software, Tormod Svensen, comments: "We are not building a new mother-of-all-models for digital twin applications. Our customers are already modelling their assets with our software, and we are working hard to integrate these models and get them talking together seamlessly.

"In our digital asset ecosystems we are integrating our existing applications and data models and using the cloud, big data and the Internet of Things to create exciting opportunities that will harness the power of advanced predictive analysis to optimize performance, improve information integrity and deliver business critical results that you can trust."

"We are not starting from scratch. We are working today with clients on our digital asset ecosystems for ships, pipelines, process plants, offshore structures and electric grids. All of these solutions revolve around the digital twin concept. Our innovation is driven by continuous customer interaction."

Enhanced security and safety

Digital twins can also help to address the high level of concern about cyber security threats as cyber-physical systems and connectivity multiply. Corporate IT and OT systems are being exposed to ever more external networks and devices through the Industrial Internet of Things, and as more assets become remotely supervised, controlled and maintained.

I view the kind of digital twins we are developing as a way to help manage both external cyber security threats such as intentional cyber-attacks, and the internal cyber safety threats that reside within the integrated systems due to their complexity and emergent properties. We want to manage risk at an early stage, uncovering hazards before they manifest during new-build and operation, so a systems approach combined with simulation-based testing and verification is the only viable solution.

Where are we going with all of this? DNV GL is definitely a pioneer in this space and we are working with what might be termed 'early adopters'. But it seems fairly certain that it will not be long before the digital twin concept becomes mainstream, with players in many industries clamouring for virtual *doppelgängers* of their critical plants, equipment, control systems and processes.

BETTER DESIGN AND OPERATION IN MARITIME

Within 10 years, virtual ships could become the standard method for commissioning, designing, operating and maintaining vessels and whole fleets. This is the view taken by Bjørn Johan Vartdal, head of the Maritime Transport research programme at DNV GL.

Ship control systems are one application for digital twins. Actual control system software can be installed in a digital twin vessel for virtual integration, testing and validation. The virtual vessel is a simulator containing all on-board equipment and machinery, networks and control systems; all of it connected up and integrated in cyberspace, just as it would be on the physical vessel. The digital twin's copy of the control system can be tested in simulated conditions identical to those encountered in reality.

"Using digital twins for control system software throughout the lifecycle will help to avoid cost, prevent risk earlier, reduce the time for new systems to enter service in the field, improve systems interoperability, and enable superior system performance," says Vartdal.

Aside from control system software, DNV GL has identified vessel components and machinery systems, and ship hulls, as areas where digital twins could make a valuable contribution, and for which the company already has the building blocks in place.

"Hull sensors sending data to a digital twin would allow you to correlate stress on the hull to weather conditions in which a ship has sailed, for example," Vartdal suggests. "It would let operators improve the way vessels are operated in certain weather condition, or might show why and how operations should be restricted in some cases."

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TWINNING FOR SAFER, SMARTER OFFSHORE OIL & GAS

It is difficult to picture something as big and complex as a 30,000 ton rig rendered perfectly and dynamically in virtual reality. Yet that is becoming a reality. Digital twins offer great benefits to offshore oil and gas for stages starting from development concepts and continuing through design, construction, transportation to location, installation, hook-up and commissioning, operations, and eventual decommissioning.

Analysing sensor data relayed through a corporate Internet of Things, digital twins can provide easy-to-understand dynamic updates on asset condition and operational parameter states.

The virtual rig becomes a single source for all asset information: physical properties, steel mill certificates, construction inspections and acceptance tests, the operational business process state, production demand history and projections, risk levels, remaining life estimate and structural reliability.

Where it includes real-time or near real-time information from many sources, it can enable dynamic barrier management, a step-change improvement to safety management, and help to optimize scheduling of costly inspection and maintenance regimes. It also addresses a common problem in some oil and gas regions: lost or incomplete documentation.

The potential of a digital twin model to prevent losses and boost margins is important in an industry where an unscheduled downtime may cost USD2–5 million per day. Around half of such incidents are due to mechanical failures, for which digital twin's' dynamic tracking, analytical and predictive capabilities can provide an early warning system.

"Poor information management can account for up to a fifth of operational budgets," says Øyvind Endresen, Technology Leader in DNV GL's Environmental Risk Management unit. "With operational margins currently squeezed by low hydrocarbon prices, that can make or break the operational viability of an asset."

The digital twin leverages operators' existing investment in enterprise asset management and design software by linking directly to information from these and running it securely through DNV GL – Software's analytics applications in a consistent manner that ensures the most up-to-date information.

Øyvind concludes, "The Paris Agreement with the high ambitions of emissions reductions requires all industrial sectors to mitigate emissions. Given the wide range technologies available, a digital twin could help to identify and evaluate promising measures and cost-effective reduction strategies. Improving the understanding of GHG emissions through the life time of assets allows companies to better manage GHG related risks."

WINDS OF CHANGE FOR RENEWABLES

Imagine the owner-operator of a global fleet of wind plants sitting in an office and, within seconds, calling up an infographic displaying near real-time performance data from all their turbines and farms.

Digital twins are poised to assist operators increase wind's competitiveness, according to Graeme McCann, head of turbine engineering, DNV GL. "The industry needs to reduce its levelized cost of electricity (LCoE), the average sales price of power needed to break even financially over asset lifecycles," he says. "It also wants to account for the 'quality' of the power it produces, which may be more valuable to customers when it supports the integrity of the electricity grid, for example."

The digital twin paradigm allows asset condition and performance to be tracked dynamically.

"It means operators will be better able to check, share and improve assumptions on which LCoE estimates are calculated," McCann observes.

"As a better real-time management tool, a huge part of its value is the speed with which measurements at the physical asset level can interface with data exchange and analysis. This shortens decision intervals, allowing greater and more timely optimization of decisions in support of asset integrity or technical and financial performance."

Over time, accumulated data allow a digital twin to model a physical asset ever more closely, increasing its value for establishing predictive maintenance schedules, optimizing turbine operations during specific wind conditions, and maybe even forecasting electricity prices, McCann adds.

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