Digital Twins: Enhancing Subsea Asset Integrity
It is no secret that maintaining subsea asset integrity cost-effectively is tough. But there is good news. Advances in technology, particularly digital technologies, have given rise to new tools that offer extraordinary benefits to integrity engineers, helping to drive down the total cost of asset ownership. One of these is the ‘digital twin’, a much talked-about – yet often misunderstood – digital integrity management tool.

**What is a digital twin?**

The term ‘digital twin’ seems to be a popular buzz phrase in today’s oil and gas industry. But it means different things to different people. One company that is embracing and actively developing digital techniques to enhance subsea asset integrity is the Acteon Group, which specialises in the critical dynamic subsea infrastructure. Its branded service company, Acteon Field Life Services (FLS), is helping clients reduce costs by maintaining the integrity of the infrastructure that supports the production fluid vein. One of the primary ways this is achieved is by using a range of digital tools, including the digital twin.

A digital twin is broadly defined as a virtual representation of an entire physical asset or a critical element of it. With its dedication to subsea infrastructure integrity, the company’s primary focus is on maintaining risers, flowlines, pipelines, moorings, platform well conductors, subsea equipment, and foundations. Its member companies build and use digital twins of, for example, risers and wellheads to continually monitor ‘hot spots’ that are vulnerable stress and fatigue locations.

The analysis of the data provided by the digital twin helps improve operations, as well as reduce downtime and maintenance costs.

**Three primary types**

Digital twins can be very simple or more complex, offering unique benefits that were not previously available. For example, the technology makes it possible to test asset response to common subsea stimuli. This is useful as it allows integrity engineers to reliably predict how the asset, or critical portions of it, will respond in the future. Alternatively, the digital twin can be a computer visualisation of the remote, difficult-to-access asset. Regardless of the digital twin employed, it helps reduce costs and risks in some fashion, whether during planning, construction, operation, life extension, or decommissioning.
Acteon classifies digital twins into three primary types:

**Type 1 – spatial twinning**
A Type 1 digital twin is a virtual visual representation of a physical asset. It is typically a 3D spatial model that represents all or part of an asset (Figure 1). It is particularly useful for providing information and insight regarding remote assets that are difficult or costly to visit, and for superimposing various features or information upon for analysis during design, construction, maintenance, and repair phases (Figure 2).

Acteon's digital twin technology is currently in use around the world. For example, the company's subsidiary, UTEC, has used its web-based iSITE™ software tool to host a 360° point-cloud and photographic visualisation – digital twin – of the topsides of a floating production storage and offloading (FPSO) vessel. The FPSO, more than 290 m long, 45 m wide, and 18 stories high, operates offshore Newfoundland and Labrador. The Canadian operator’s team can now remotely visualise the FPSO facilities via the digital twin to tour the vessel for risk management, operational and maintenance planning, safety review, and site inductions, without an offshore visit (Figure 3). As a result, offshore travel to the vessel has dropped significantly, delivering reduced operating costs and risks and enhanced productivity.

As further illustration, UTEC has also produced a series of 3D datasets to create digital twins of a client’s subsea assets to support future construction and maintenance projects. To help the client pinpoint the location and position of a subsea structure, the end of a pipeline flange and termination points of four neighbouring pipelines, the company carried out multiple 360° subsea laser scans. Drawing upon this data, digital twins of the flanges and pipelines were produced that revealed their respective orientations and positions, allowing the client’s integrity engineers to proceed efficiently with necessary remediation planning.

**Type 2 – localised response twinning**
A Type 2 digital twin focuses on twinning the physical response characteristics on specific critical locations of an asset. That response characteristic could be structural or process-related.

For example, integrity engineers at Acteon companies 2H Offshore have begun developing digital twins for critical parts of a subsea riser to offer more insight into their historical and future responses. Subsea risers are dynamic structures that can be susceptible to fatigue damage due to the regular cyclic loading from vessel motions, waves, loading, and the effects of ocean currents. While designed to endure these for the anticipated service life of the asset, often there are unforeseen changes in the metocean conditions or the presence of corrosion anomalies that can potentially significantly increase fatigue damage beyond that desired, risking their long-term integrity. Furthermore, assets can be required to remain in service beyond their original design life, again potentially increasing fatigue damage beyond that anticipated. In both cases, obtaining accurate riser response data at critical locations is needed. Whilst permanently instrumenting the riser with sensors at these locations would be the ideal approach, this may be cost prohibitive for every riser on the platform throughout its entire service life, while accessibility issues faced when placing sensors pose further complications.

To provide an alternative solution, 2H Offshore is developing data-driven virtual sensors, based on a digital twin of each these critical riser sections. The digital twins are analytical response models often built with machine-learning techniques that estimate fatigue damage at each specific hot spot along the riser (Figure 4). The twin is then stimulated by measured past and future vessel motions and environmental loads, just like the real riser. By using this method, the integrity engineer has access to much more accurate estimates of actual past fatigue damage and future response, allowing for more informed decisions on replacement or mitigations measures, avoiding unnecessary risks and reducing costs.

To give deeper insight, 2H Offshore partners with sister company Pulse Structural Monitoring to provide targeted physical sensor-based monitoring to deliver further enhancement of the digital twin through calibration and additional response inputs. By adopting this approach, even greater understanding can be gained and potential conservatism removed.

**Type 3 – global response twinning**
A Type 3 digital twin is Acteon’s emerging vision for a tool to support future operational and integrity activities based around access to a complete digital representation of large elements of critical dynamic subsea infrastructure. This would likely consist of a digital twin of all significant subsea assets, often coupled together, that allows integrity engineers to immediately establish up-to-date responses for multiple locations. This offers greater flexibility and insight than the Type 2 twin, which relies on pre-determining a small number of critical locations. Type 3 twin systems are likely based around
In-depth understanding of the ‘real-world’

Pictured is a digital twin generated from laser scan data acquired from an offshore platform. The measurements illustrate the distance between pipework points. The inset (upper left) provides asset navigation within the iSite solution. Image credit: UTEC Survey.

Building a digital twin
Every digital twin is unique and is customised to reflect the asset or targeted section of it. When building, for example, an analytical model, more advanced machine-learning models and kept calibrated by carefully chosen physical sensors and measurements.

This type of model also provides much more opportunity to input a greater number of variables and stimuli, for example, a coupled riser, mooring and vessel response to actual wind, wave and current conditions at varying degrees and frequencies throughout service life.

The digital twin can also be updated with asset operating data gathered regularly or even in real time. Integrity engineers can then review the digital twin to assess how the asset is functioning by calibrating and measuring the activity against historic performance data. By doing so, they can identify patterns and adjust operation and maintenance plans, if necessary. Over time, the level of accuracy achieved by a digital twin can also be improved.

In the not-so-distant future, operators could be employing a digital twin that is based on many years of operational data and mirrors the entire critical subsea infrastructure; one that features multiple risers, wellhead foundations, moorings, and pipelines.

The future is now
Having made great strides in developing digital twin technology, Acteon actively supports clients with digital integrity management solutions. Digital twin technology is integral to the company’s service lines. For example, drilling riser digital twins are embedded in Pulse Structural Monitoring’s drilling integrity services and software products. They also form a central element of the company’s subsidiary Clarus Subsea Integrity’s web-based integrity management portal iCUE. Development and implementation of digital twins can also be delivered for integration into clients’ systems.

Looking ahead, the digital twin will become a standard asset integrity management tool that accelerates automation, exponentially increases speed, and significantly improves the accuracy of engineering analysis, monitoring, and inspection. Already, it provides more accurate assessments of the status of current equipment and assets and how they will perform in the future. These capabilities are giving integrity managers the ability to prevent anomalies, operate assets more efficiently, and extend asset life, where feasible.

The ability to more accurately predict future performance is also significant for design engineers. Armed with these insights, which are based on deeper historic data and asset response to a wide range of stimuli, designers will have greater confidence, and be less inclined to continue to develop overly-conservative designs that underperform.

It will free them to create more innovative designs that must be customised to withstand, for example, the effects of pre-tested subsea stimuli, such as fatigue caused by waves repeatedly impacting the structure. As a result, operators can commission infrastructure designs that will help them realise greatly reduced operational risks and costs.

By employing digital twins, efficiencies and decision-making will be enhanced, improving the operator’s ability to predict asset behaviour throughout the asset lifecycle from design and construction, through to operation, and into life extension and eventual decommissioning.

Figure 3. This illustration of a Type 2 analytical response model from 2H Offshore estimates fatigue damage at specific hot spots along the riser and predicts future responses. Image credit: 2H Offshore.

Figure 4. This illustration of a Type 2 analytical response model from 2H Offshore estimates fatigue damage at specific hot spots along the riser and predicts future responses. Image credit: 2H Offshore.