Supporting the Industry 4.0 Transformation
ESI calls for a new paradigm: the Hybrid Twin™

What makes you so sure you want to be the owner of a new car? Some of us crave the feeling of driving and stand in awe before the curves of the latest convertible, but for an increasing number of people a car is just a means to get from A to B. With rent-a-bikes, public transportation and taxi app enabled ride sharing and, very soon, arrays of self-driving autonomous vehicles, getting from A to B no longer means owning a car. As author **Joe Barkai** asserts in his book **"The Outcome Economy"*, today's consumers are not after products anymore, they want solutions to their needs.** In fact, customers of all types are after an "outcome" and we see this transformation happening across all industry sectors. For example, GE (General Electric) has ceased to sell aircraft engines and offers instead hours in flight (what they refer to as "Power by the Hour"). **The product or tool has become irrelevant**. The experience of the product and its outcome are what the customer pays for.

Products are designed to meet predefined specifications. Prototypes of these products are built and tested in an effort to confirm their behavior in standardized, well defined conditions. Thanks to the power of computing available today, such prototypes can be virtual. Consequently, tests can be done earlier and quicker to support the re-engineering loops that lead to an optimized product. Furthermore, virtual manufacturing anticipates the actual fabrication and assembly

processes and then predicts the consequences for the product when it is subjected to a standard set of pre-certification tests.

In today's "Outcome" economy we can't stop at certification testing; we have to understand how the product is really used and whether it delivers the expected benefit, or outcome. Here, newly available technologies, including Big Data Analytics and the Internet of Things (IoT), come to bear. Inconceivably large volumes of data can now be captured, processed and interpreted as products are fitted with myriads of sensors that stream live data about use, environment, and condition. **Harnessing this data and updating the Virtual Prototype to a "*living*" virtual product *in-operation* gives life to a whole new solution for industrials: the Hybrid Twin™**.

With the Hybrid Twin™, the product is managed in its live ecosystem. As illustrated in the graphic for a wind turbine, the Hybrid Twin™ matures and gains real-life experience; it becomes possible to manage life expectancy by planning preventive maintenance to optimize performance and minimize risk of failure. Such action can include physical intervention and/or over-the-air live updates that adjust the equipment and operational parameters. Moreover, the fact that the Hybrid Twin™ has associated physics-based models makes it possible to examine the consequences of

Foresight vs Hindsight

Actionable !
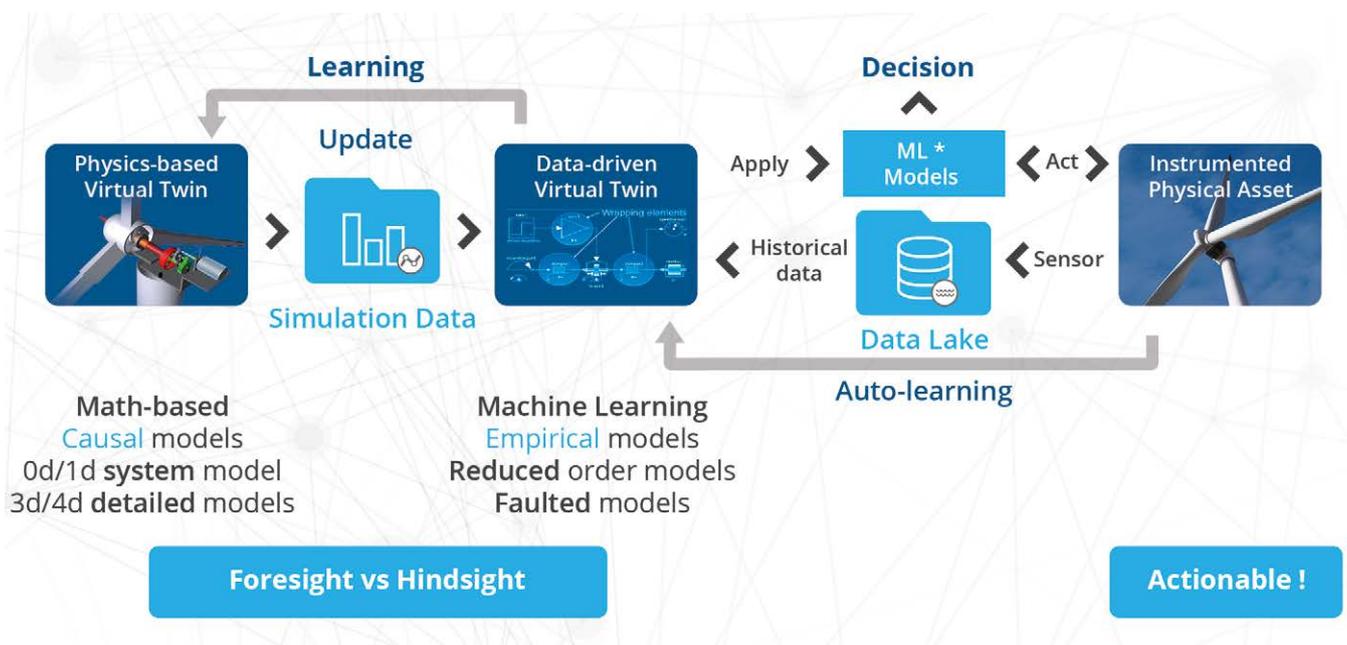
the actual operating conditions – which can be vastly different from the certification conditions – by simulating the interaction between the product and its in-operation environment.

In the questions answered below by Dr. Soua of TWI, you can read of ESI's leadership in the "WindTwin" project, a collaborative R&D project co-funded by "Innovate UK". The project will develop a comprehensive Hybrid Twin™ solution dedicated to support the Wind Energy sector, in particular providing onshore/offshore wind farm operators with the capacity to intelligently plan preventive maintenance. If we reflect a little we can see that the ideas behind that project are equally applicable to the plant and factory that produce products. When the whole equipment in a manufacturing plant

communicates its status **in real time and we are able** to flexibly adjust parameters based on actual production results, providing alerts and remedial action when there is a batch of non-standard materials or components, or warning of the imminent need of predictive maintenance, then we can truly manage the factory "outcome". That principle is at the heart of the **Smart Factory**, or **Industry 4.0, and is emerging as industrials are willing to wager that the investment in that future is well worth the return. Indeed the digital transformation is upon us and the Hybrid Twin™ is truly at its foundation**!

* Joe Barkai: The Outcome Economy; How the Industrial Internet of Things is Transforming Every Business (May 25, 2016)

Partners in the WindTwin project

3 Questions for...

Dr. Slim Soua

Section Manager - Condition and Structural Health Monitoring,
Structural Integrity Group
TWI

ESI and TWI are expanding their collaboration program. Can you tell us more about the expansion and why now?

ESI and TWI have been collaborating for several years, focusing mainly on typical applications of Computer-Aided Engineering (CAE) in the domain of Materials and Welding Processes. The collaboration has included utilizing existing software capabilities for our in-house research: such as investigating challenging metallurgical & mechanical issues encountered during welding with ESI SYSWELD[1]; or leveraging the crash & strength models in ESI Virtual Performance Solution[2] to develop new concepts for increasing the safety of structures fabricated in composites. We have also worked together on developing new and innovative solutions through large scale collaborative R&D projects, for instance the EU project SIMUTOOL[3] which required a simulation platform for manufacturing Composites via Microwave Heating.

Over the last 40 years, TWI has grown significantly and diversified its expertise well beyond materials and joining technologies, including the development of world-leading capabilities in structural integrity management. The Integrity Management Group (IMG) now offers state-of-the-art monitoring solutions, which is helping hundreds of companies worldwide manage the life of their asset, avoid engineering failure, improve safety and reliability, reduce inspection & maintenance costs, ensure regulatory compliance, and optimize operating expenditure.

Thanks to the ongoing collaboration, we at the IMG team became aware of ESI's strategic plan to expand their solutions beyond Virtual Prototyping to cover the entire Product Performance Lifecycle™ (PPL). To us, a move like this means that ESI is no longer only providing solutions to address issues for the design and manufacturing communities but will now need to assist customers with the challenges associated with the product "In Operation" as well. This creates a clear synergy between ESI's vision and TWI's capabilities. Additionally, the role the Industrial Internet of Things (IIoT) will play in shaping the future of business is overwhelming. The Industry 4.0 initiative, which started in Germany in 2012, is now a global phenomenon and ESI and TWI are set to be a part of it.

The British government, like others in the developed world, is investing in large scale R&D funding programs to support new developments based on the IIoT. In response to a recent call from Innovate UK[4] (Emerging and Enabling Technologies Round-1), ESI and TWI have worked together, with two local SMEs (Agility3[5] & Dashboard[6]) and a specialized research group at the Brunel University London[7], to submit a proposal ("WindTwin") for the development of a comprehensive Hybrid Twin™ solution to be used across the Wind Energy sector. Our bid was successful, the Project started recently and is scheduled for completion in December of 2019.

You mention the "Hybrid Twin™". How is that different from a "Digital Twin"?

This is a great question as the field is still in its inception and the terminology can be confusing.

The term Digital Twin is being used to refer to the digital replica of physical assets, derived from real-life data collected using various types of sensors and monitoring technologies of the asset while in operation. It often means that an analytical data-driven model (i.e. the twin) is built to analyse, update, and/or manage the performance of its physical counterpart. It can use a range of tools and advanced algorithms -- such as Machine Learning (ML), decision making, or even Artificial Intelligence (AI) technologies -- to analyze and visualize the "Big Data" collected.

In contrast, the Hybrid Twin™ is associated with solutions where an additional, complementary virtual model is built. This supplementary model is necessarily physics-based and describes cause and effect relationships.

By its own nature, a Digital Twin - based solution is limited by the number and location of available sensors, as well as by the quality of data collected. For example, we know from our preparations for the WindTwin Project that a typical wind turbine may include six to eight strain-sensors per blade, and one or two temperature-sensors in the gearbox, etc. Such sensors provide a 24/7 stream of data, which is indeed very valuable for monitoring purposes and can be utilized to build, validate, and improve data-derived models. On the other hand, wind farm operators are keen to learn more than just the mechanical and thermal behavior at

the locations of these sensors. They also would like to be able to anticipate the full range of potential consequences when any of these sensors starts sending an uncommon pattern of data, and to have a tool that will enable them to investigate potential actions to avoid failure or degraded performance. Ideally, they would like such a tool to recommend the best intervention; one that minimizes the interruption to operation and also the total cost. Here, the role of high-fidelity physics-based models is crucial and the advantages they bring to the Hybrid Twin™ are very clear.

How do you see the impact of the Hybrid Twin™ in relation to the WindTwin project, and beyond?

The WindTwin project aims to streamline the monitoring and maintenance processes for wind farm operators. Addressing the needs of both onshore and offshore farms, the goal is to increase the availability and reliability of wind turbines. A dedicated Hybrid Twin™ based solution will incorporate all relevant physics at the sub-systems level, supported by sufficient degradation models. Through

the solution, operators will be able to use the WindTwin to diagnose performance variations, and deploy condition-based maintenance, instead of pre-determined, schedule-based strategies. This will undoubtedly reduce downtime, inspection & maintenance costs, enabling operators to virtually test maintenance upgrades before deployment. It will also help better control wind turbine settings in order to optimise performance and energy output.

Worldwide, the total number of wind turbines reported by the end of 2016 was just below 250,000. The market size for operation and maintenance is estimated at about 10 billion USD today and is expected to double by 2022. Under normal operation, the annual maintenance cost is about 5% of the capital investment, but it can be as high as 10% in some cases. The potential economic impact of effective use of a Hybrid Twin™ is clear.

Of course, the increasing pressure to eliminate failure, reduce maintenance cost, optimise performance, etc. is not unique to wind turbines. The list of potential applications goes across almost all industry sectors, such as Heavy Machinery, Aerospace, Defense and Marine.

About TWI

TWI is one of the world's foremost independent research and technology organizations, with expertise in materials joining and engineering processes as applied in industry. TWI specializes in innovation, knowledge transfer and in solving problems across all aspects of manufacturing, fabrication and whole-life integrity management. Established in Cambridge, UK in 1946, the organization has gained a first-class reputation for service through its teams of respected consultants, scientists, engineers and support staff.

[1] ESI SYSWELD: www.esi-group.com/sysweld
[2] ESI Virtual Performance Solution (VPS) – Composites: www.esi-group.com/VPS
[3] SIMUTOOL: www.simutool.com
[4] Innovate UK: www.gov.uk/government/organisations/innovate-uk
[5] Agility3: www.agility3.co.uk
[6] Dashboard: www.dashboard.net
[7] Brunel University London: www.brunel.ac.uk

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