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Industry 4.0:

Demystifying Digital Twins

Foreword by the Author

Industry 4.0 is moving from the hype-cycle to the investment phase, with manufacturing firms launching innovative development projects to future-proof their competitive position. Digital twins may be the key to the success of these projects, but what are they and how should they be used?

I've seen many organisations that are already experimenting – for example, some of my customers have implemented machine sensors, IoT middleware and analytical technologies in search of new insights and a couple are now using augmented reality to assist operator training. However, these initiatives, often pitched as proof-of-concept, have been implemented as a technology trial rather than from a solution perspective. This has severely limited the overall business value, mostly in terms of achieving a future-proof competitive position.

How do you escape this technology-first approach, bottom-up experimentation and vendor hype? After all, Industry 4.0 is a business strategy that involves complete value chain transformation, which means stakeholders need to understand the impact that technology has on the connected business as a whole.

The answer for many companies is to commission a digital twin and use technology as a means to develop a digital roadmap. While the term 'digital twin' was coined relatively recently, the concept isn't new. Different forms of digital twin have been used across different industries for decades to de-risk and optimise major decisions, and to increase operational efficiency. They just weren't termed as such!

The digital twin is now a recognised core component of the Industry 4.0 journey, helping organisations understand their data, complex processes and resources to drive business insight and operational optimisation. But a digital twin still means different things to different people.

In this paper, I discuss different implementations and levels of scope at which digital twins have been deployed, illustrating use cases and benefits in an attempt to bring clarity on what digital twins are, what they do, how they contribute to successful digital transformation and how you should use them to drive real business value.

Andrew Aitken
Chief Operating Officer
Lanner

Digital Twin Defined

Today's digital world encompasses a wide spectrum of technologies and market needs, so there have been many interpretations of the digital twin concept. Digital twins gained initial momentum within high-value product manufacturing industries such as automotive and aerospace, but the concept is increasingly being found across many others including in FMCG, food and beverage, construction, retail and energy.

General Electric (GE) defines 3 levels in which the Industrial Internet of Things (IIoT or Industry 4.0 or 4IR, depending on your preferred nomenclature) aims to digitally create a performance impact:

- Level 1: Asset
- Level 2: Operational Process
- Level 3: Enterprise

Some researchers and industry commentators have made statements that relate digital twins solely to physical objects like products and machines, confining them to the asset level. These definitions are unnecessarily restrictive (in many cases, they're influenced by the commentator's specialist background).

We get a more concise yet holistic description of a digital twin from Marc Thomas Schmidt, Chief Architect at GE Predix. In his presentation at Minds & Machines 2017, he defined digital twins as:

"Dynamic digital representations that enable companies to optimise the performance of their assets, processes and business."

It's important to note that at the operational and enterprise levels, digital twins will necessarily be process-based rather than asset-based. Logically, this means they must incorporate some form of dynamic logic emulation and predictive simulation across the end-to-end process to best provide analytical value.

The higher the level, the more the game moves away from product life-cycle management (asset-based) domain thinking and towards the business process management domain. Crucially, the digital twin concept can therefore be tailored to fit organisational needs, meaning there's no one-size-fits-all solution.

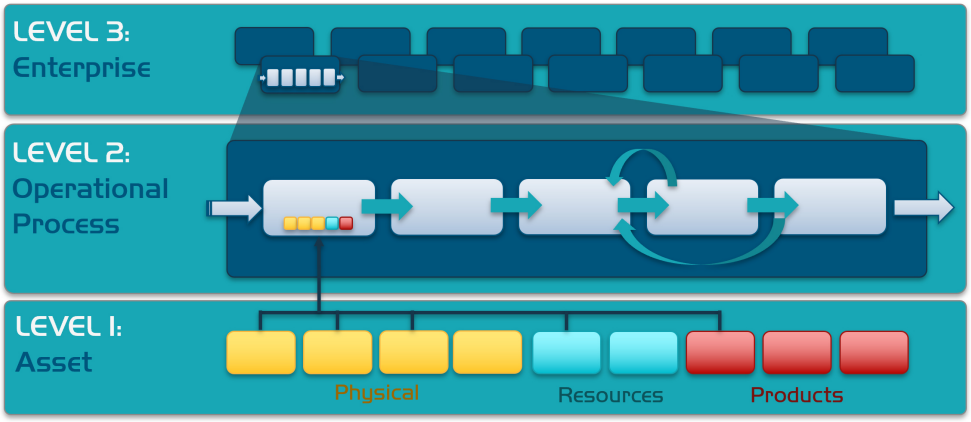


Figure 1. The Interconnected Ecosystem of Business Digital Twins and their Scope

3 Levels of a Digital Twin

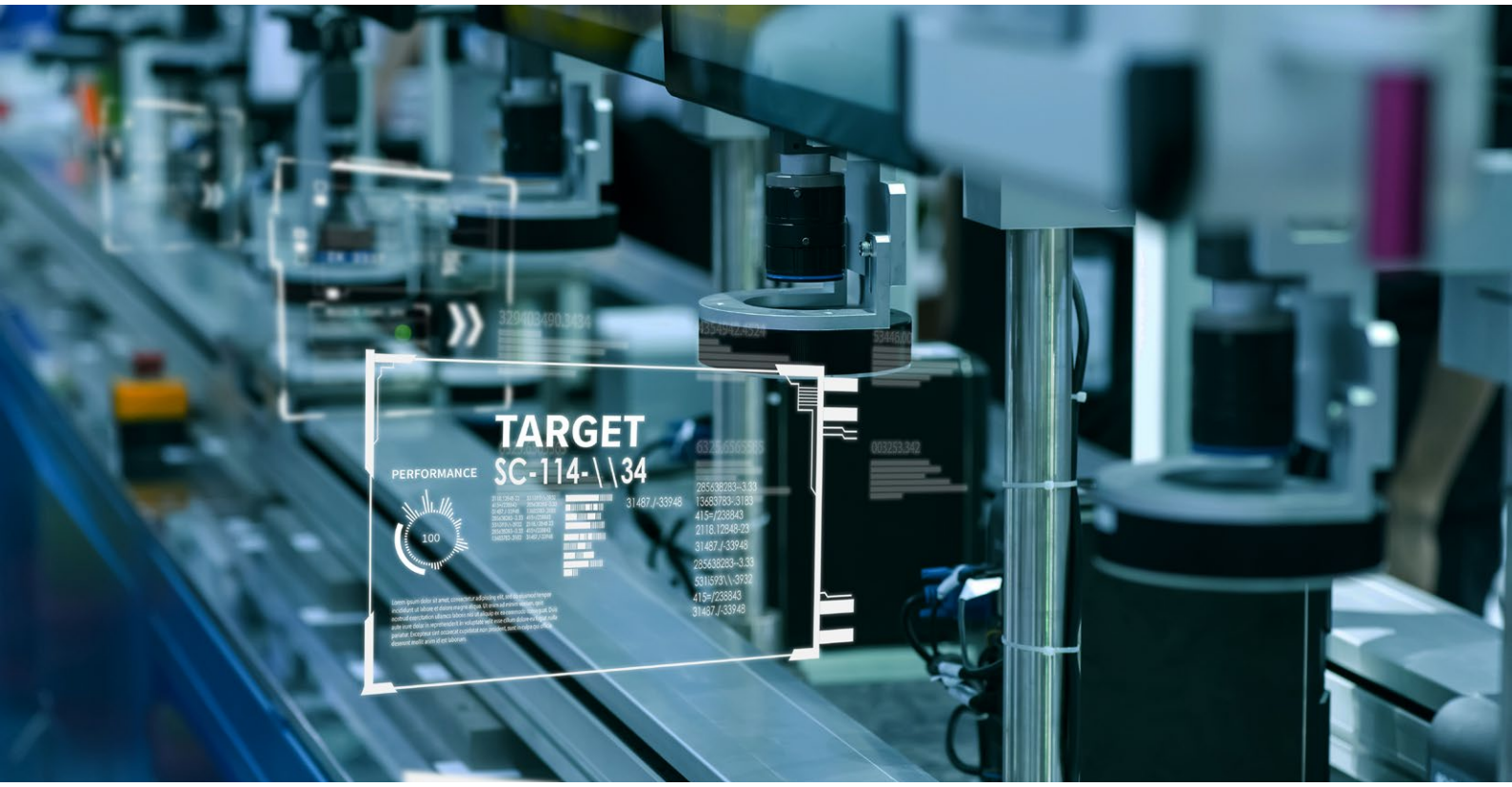
LEVEL 1 Asset Digital Twin

What it is:

An asset digital twin is an extension of the expertise traditionally covered by CAD/CAE and product life-cycle management (PLM). It focuses on optimising the life-cycle design and manufacture of more complex assets, usually at a product or machine level.

This digital twin captures detailed engineering data to visualise, simulate and analyse asset functions. Capable of capturing asset and field performance data across a variety of operating contexts and geographies – for example, for wind turbines, heavy mining machinery or aero-engines, asset digital twins help close the design-to-operations loop by monitoring performance, detecting issues and identifying improvements for product or manufacturing performance. A good example of this is collecting reliability data to better understand failures, so they can be managed more predictably.

Often the end goal of an asset digital twin is insight that powers new product-as-a-service (PaaS) business models through efficient product life-cycle management.



LEVEL 1

Extending the relevance of predictive maintenance

Predictive maintenance concepts such as condition-based monitoring are not new, however asset digital twins and predictive analytics are encouraging more widespread adoption by providing more visually meaningful predictive maintenance foresight.

Interest in predictive maintenance strategies has increased in line with other predictive analytics technologies, so it's not surprising that automation, PLM and OEM vendors are focusing their marketing efforts on asset digital twins. Asset digital twins can go further to add substantially more value in situations where multiple asset populations are deployed across different geographies and/or operating conditions. Twins enable you to harvest even greater insights to enable cost reductions from more effective organisation and scheduling of field service and engineering resources.

What you can do with it:

- Mimic the functionality of existing products and machine assets
- Capture and Visualise real-time sensor information
- Gain a better understanding of product/ machine interface characteristics
- Use data to improve design for manufacturing performance
- Speed up product and equipment design cycles and time to market
- Gain early insights that improve right-first-time asset performance and reduce quality costs

When to use it:

Asset level digital twins can be used to represent hardware (devices, machines, vehicles), resources (people, finances, energy, water) or even products in order to maintain a functional view of that asset.

Any business strategy that requires robust asset management, either to provide product performance monitoring, distributed field services and training or connected services will see significant value in this level of digital twin. Asset level digital twins provide the cornerstone of any Product-as-a-Service (PaaS) business model.

LEVEL 2.1 Operational Process Digital Twin – Supervisory Capability

What it is:

A Supervisory Digital Twin mimics the running of real-life processes, either at the operational or business level. At its most basic, it offers visual emulation (or animation) to support the understanding of static or dynamic operational characteristics and how they relate to performance outcomes.

Some commentators have called this an Emulation Twin, while this paper sides with the term Supervisory Twin, as used by the Advanced Manufacturing Research Centre (one of the UK High Value Manufacturing Catapult Centres).

These twins can inform (or train) users in how to best design, operate and maintain their processes and assets.

Many companies talk about their need for real-time data and analytics. In reality, some form of intermediate data processing (e.g. data buffering or synthesis) is usually necessary to facilitate the link between the physical and digital world.

The supervisory twin's purpose and specific operational context will dictate how important speed is. You can develop it with data links to collect key process state information on an agreed time-based frequency, delivering an appropriately accurate level of synchronisation. That way you benefit from valuable insights you can only get by more dynamically capturing data from the physical world and synthesising it digitally.

What you can do with it:

- Secure a better understanding of new operational or business processes
- Optimise new product and process designs, while identifying and eliminating operational errors
- Ensure consistent operational and ongoing standards
- Plan and test the impact of key business scenarios
- Visually test new conceptual designs and business models
- Communicate and educate stakeholders and clients on process dynamics

When to use it:

If you need the digital twin for either macro-level design and monitoring, or detailed operator or maintenance training support purposes, then a supervisory (or emulation) twin may meet your needs.

This can be the case at the concept design stage, however it's worth thinking about future diagnostic and decision making requirements up front to avoid future limitations of solely a supervisory twin approach.

LEVEL 2.2 Operational Process Digital Twin - Diagnostic and Control Capability

What it is:

This digital twin gives you dynamic diagnostic capabilities, so you can analyse end-to-end process performance in real time. It links sensor data from the physical world to analytical and data-mining algorithms to better understand and manage process performance. The use of real-time PLC devices and PID process control loop systems is obviously not new – these automation concepts were implemented across many manufacturing sites during Industry 3.0.

However, Industry 4.0 is unlocking a wider opportunity to apply these technologies at scale in a cost-effective way – which is essential given the increasing market urgency.

The importance of diagnostics and control

At recent technology exhibitions, Microsoft have been demonstrating their internal manufacturing IIoT capabilities, showcasing the business and operational performance tracking they've implemented across their global manufacturing network. They can drill down into performance detail and problem root cause level in real time using live data feeds connected across Microsoft Azure and a customised suite of Microsoft Power BI analytics.

Using this dynamic diagnostic ability, they can more rapidly determine the appropriate corrective action and reduce costs associated with sub-optimal performance. While analytical functionality is in-built within Microsoft's type of diagnostic digital twin, automated corrective control actions aren't yet. For that, you need additional functionality linking analytical results to algorithms driving appropriate methods of process control actuation (such as triggering machine alerts or changing conveyor speed). Machine Learning (ML) and Artificial Intelligence (AI) methods will progressively offer enhanced algorithmic intelligence to support such decisions.

Digital twins delivering diagnostic together with control capability can therefore deliver impressive results by supporting the optimisation of real-world asset and process performance.

LEVEL 2.2

What you can do with it:

- Capture and analyse operational data from assets and processes in real time
- Use that data to present and chart operational statistics
- Trigger alerts to prompt closer monitoring
- Diagnose issues and identify performance improvement actions
- Link physical assets and control systems containing controllogic and algorithms to automatically adjust or optimise process parameters via an actuation loop.

When to use it:

A diagnostic and control digital twin enables more effective execution of an operational plan. It supports increased productivity, improved control and can help drive more stable and reliable operational performance.

LEVEL 2.3 Operational Process Digital Twin - Predictive Capability

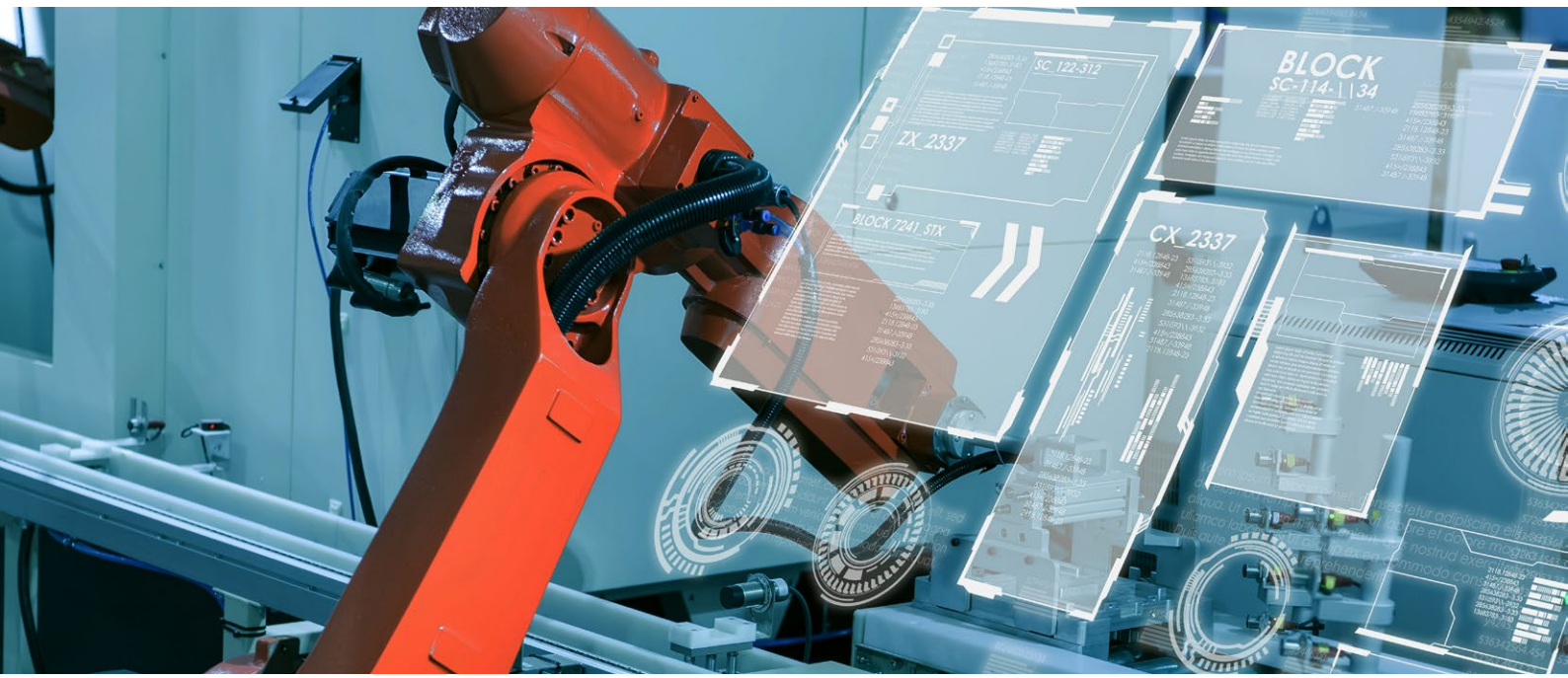
What it is:

A predictive digital twin goes a step further – it unlocks opportunities beyond using current state data to drive asset and operational process performance. It's created using specially designed predictive simulation software and can be used to evaluate planned or potential future scenarios. This allows decision makers to test and understand the impact of each scenario, identifying opportunities and risks, without incurring any cost.

Such foresight is invaluable in de-risking and optimising key business and operational decisions – for example, evaluating digital technology investments, refining resource planning, testing new business process models and improving schedule performance.

Predictive digital twins work by modelling individual events using a time-based engine, considering resources, constraints and interaction with other events. They reflect the process rules and variability affecting the behaviour of the real-life systems and complex operating environments. In this way, they mirror the dynamic processes experienced in actual businesses, be they manufacturing facilities, airports or contact centres.

The level of visualisation deployed within a predictive digital twin should match the intended function. In some cases, a fully immersive virtual reality model of a complete factory is required (e.g. getting investor buy-in for an innovative new factory design concept). In other cases, a high-level, animated ARIS 2D process model may suffice (e.g. when creating an Enterprise Digital Twin for users of an administrative business process who are mainly interested in analytical outcomes).



LEVEL 2.3

Gamify decision making with prescriptive analytics

The predictive digital twin enables decision navigation at a business level by connecting key business questions to the right data sources. You can ask questions like "What if?", "What's best?" and "How do we?'"– and get answers using dynamic models of real business and operational processes.

You essentially gamify decision making with the ability to run different scenarios across the short, medium and long term. This helps you build an informed investment case for technology implementations because they're driven by the business strategy rather than implementing technology-led solutions. As a result, it helps ensure you're designing the business to meet future challenges.

We often speak to stakeholders who want a silver bullet for the business' most complex problems - automated decision making. The hope is that digital twins and artificial intelligence will provide it. While we're not at this point quite yet, we're not as far off as you might think.

Several advanced simulation software packages (like Lanner's WITNESS Horizon) provide optimisation capabilities together with scenario experimentation functionality. This enables a predictive digital twin to hunt for the optimum answer such as balancing the expenditure and resources required to achieve a targeted outcome. This is known as prescriptive rather than predictive analytics.

What you can do with it:

- Ensure strategic business questions drive technology innovation plans
- Facilitate and de-risk new business model testing and planning
- Get answers to questions like "What should our business look like in 5 years?" and "How do we best manage ourselves to meet predicted demand?"
- Validate plans and process changes – "Will our ideas to implement this new business model be successful?"
- Make better decisions earlier by anticipating future opportunities and risks
- Link machine, system and process data to wider business analysis
- Connect OT and IT to the rest of the value chain – facilitating planning and digital transformation
- Justify new digital technology investment plans
- Identify the specific data that must be captured to optimise operational and business performance (rather than collecting and analysing all available data)
- Connect it to your other systems, for example enterprise resource planning (ERP) and manufacturing execution system (MES), to improve scheduling quality

LEVEL 2.3

When to use it

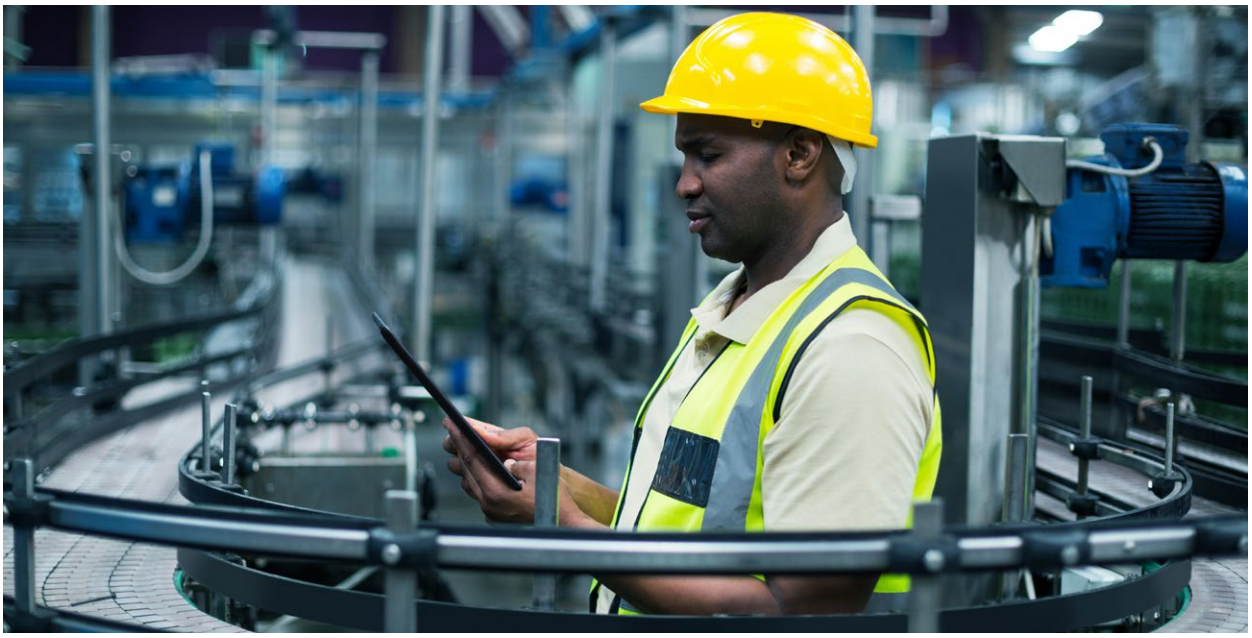
This digital twin supports the testing and optimisation of business and operational planning (as opposed to controlling operational execution). It can also link the business level to operational processes and key asset data feeds to maximise end-to-end business value. That way you ensure your Industry 4.0 technology and data strategies are strategically aligned with the business – turning big data into smart data.

Predictive digital twins in use

Predictive digital twins allow you to evaluate and justify future-state scenarios, and many leading firms in the automotive and manufacturing sectors already mandate the use of this technology for stress-testing business and operational change plans.

As Industry 4.0 momentum increases, companies across many sectors and geographies are increasingly active in using this technology. In Japan, Mitsubishi have created WITNESS Horizon models to interface with MES data feeds to optimise process design. At the other end of the hierarchy, companies like Hayward Tyler and Meggit have linking predictive twins with their business and operational planning systems, such as ERP and MES.

These businesses are connecting their value chains to predictive twins to enable decision navigation at a business level.



LEVEL 3 Enterprise Digital Twin

What it is:

Whilst the Internet of Things (IoT) is driving creation of physical asset and product digital twins that add value for their users, business managers are left with a requirement for digital twins that represent, and support the control of, their areas of responsibility; the processes and resources that allow their business to function.

These higher level, more abstract, business digital twins can utilise lower level asset digital twins to pull data they require to represent the real-world system. They also require an understanding of process and decision logic to add context and insight for those that use them. These are known as "Enterprise Digital Twins" (EDTs). Their main objective is to capture the holistic business operating model for control and management purposes.

Many organisations are now using EDTs to coordinate the critical interdependencies between their resources (people, processes and technology) so that they can understand, manage and optimise complex digital business transformations.

Importantly Enterprise Digital Twins can be linked to Level 1 and Level 2 Digital Twins to maximise their relevance and decision-making value. Increasingly businesses will want to harness the insights and foresights (via predictive digital twins) provided by each and every level of digital twin within a connected digital twin ecosystem.

What you can do with it:

- Make your company more understandable, manageable and able to adapt to business transformation in a co-ordinated manner
- Design and implement digital business transformation roadmaps
- Better manage Digital Business Transformation
- Understand the impact of changes on the customer experience
- Test and de-risk scenarios before changes are implemented across your business
- Track performance against benchmarked or target KPIs
- Optimise the business by balancing resources and performance across end-to-end processes

LEVEL 3

When to use it

Enterprise digital twins should be used to take control of your business when performance is inconsistent with expectations, yet the root causes are either unknown or too challenging to resolve. If you are spending too much time managing exceptions rather than planning strategic improvements, or the level of risk is blocking transformational action, the Enterprise digital twin can resolve this and unblock your route forward.

The Enterprise Digital Twin

"**A digital twin is** a business operating system that...

...uses a **digital representation** - a twin - of the business operational model to guide planning for how to eceute on digital business transformation."

...**translates the strategy** for digital transformation into targeted business outcomes and business initiatives by assembling measurement schemes [...] which collectively describe the destination and path of the digital transformation journey."

...helps close the **strategy-to-execution** loop by **connecting the business operating model with real-life** data in order to make this model dynamic and to create situational awareness."

Source: Software AG & Marc Kerremans, Gartner Analyst

How to Maximise Value from Digital Twins

It's easy to think of Industry 4.0 as a technology-led initiative, but the goal is to deliver greater customer value and operational efficiency. Using digital twins with various applications and capabilities can help you achieve this – by enabling better, faster and more informed decisions.

1 Be clear on the business value the digital twin must deliver

From the outset, it's crucial you understand the opportunities that exist within your specific business context. As with any technology deployment, this means considering your strategic goals and performance improvement ambitions before you focus on digitising specific processes or assets.

This means you can home in on opportunities where a digital twin can de-risk and improve decision making – and deliver maximum business impact with minimum effort.

2 Consider your visualisation requirements

Once you understand the business questions you want to answer and where you want to focus your optimisation efforts, you can identify the appropriate level of data and visualisation required.

Manufacturing engineers may use a twin to provide asset design diagnostics, while the C-suite may want to explore the impact of implementing a new business model. Analysts may use a twin to help them identify more intelligent ways of extracting smart data from the data lake. Visualisation scope will vary depending on the purpose of the twin so to save time, effort and cost, avoid succumbing to attractive visuals that may not deliver real business value.

If the digital twin is aimed at a detailed asset level, a high-fidelity, dimensionally detailed model, data linked to pre-existing 3D CAD design shapes may be needed. If you're interested in creating digital twins at a factory and supply chain level, you need a lower fidelity approach – it's unlikely to be fit for purpose if created with nut-and-bolt levels of detail.

3 There's a place for multiple digital twins – think big, build small and connect!

Leading businesses are now thinking of digital twin ecosystems in which different twins interact with, and inform, one another. A good example of this is when Lanner worked with a well-known chocolate confectionery manufacturer in North America, utilising a detailed predictive twin of chocolate bar packing lines with a high level of fidelity to streamline performance.

A lower fidelity, factory-level twin was subsequently created and connected to this, drawing key data assumptions from the packing line twin to test investment strategies.

Subsequently, a digital twin of the entire North American supply chain was developed (at an ever-lower level of fidelity) to enable broader production planning and strategic business decisions to be validated.

The 3 digital twins informed different stakeholders and answered different questions, but they integrate to facilitate holistic business and operational performance optimisation.

4 Start your journey with a clear destination in mind

Before creating a digital twin (or digital twin ecosystem), it's important to determine clear scope of detail, functionality and design requirements. Start with a structured scoping study that defines the following for all stakeholders based upon the goals being sought or challenges being solved:

- Asset or process boundaries of the twin
- Required level of data and process fidelity
- Required technology architecture, including essential linkages to real-world data feeds such as sensor and business systems data
- Process logic assumptions and analytics metrics (real-time or future state)

This forms the basis for a detailed specification, meaning your digital twin can be developed cost-effectively, deployed in a rapid time-frame and used for appropriate analysis, control and decision support to realise maximum business value.

Once your digital twin is in place, you'll be in a position to make more confident, better quality business decisions. You will be equipped with effective technologies and processes to convert insight and foresight from the virtual world into actions in the physical world – helping you scale value and future-proof your competitive position.

Lanner develops predictive digital twin software that turns **business data and processes** into business value. For over 20 years Lanner's customers have used predictive simulation technology and predictive digital twins to solve their business challenges and benefit from foresight of their decision outcomes. We can help you to gain insight into your business, make better planning decisions and become more adaptable to today's rapidly shifting business landscape.

Learn more at www.lanner.com or follow us on Twitter @Lanner.

Predictive simulation can provide the missing link to help connect many different elements of your digital strategy. A predictive digital twin can enable a powerful predictive capability that enables you to gamify business scenarios and make important decisions earlier. Early adopters are using these tools to validate, test and optimise their digital plans for long-term competitive advantage.

Companies who continue to make key decisions using either historical data or 'gut-feel' will rapidly find themselves at a disadvantage, or worse.

Contact us to learn more

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