Feasibility of an immersive digital twin:

The definition of a digital twin and discussions around the benefit of immersion.

CATAPULT
High Value Manufacturing

September 2018

A report by the High Value Manufacturing Catapult Visualisation and VR Forum.

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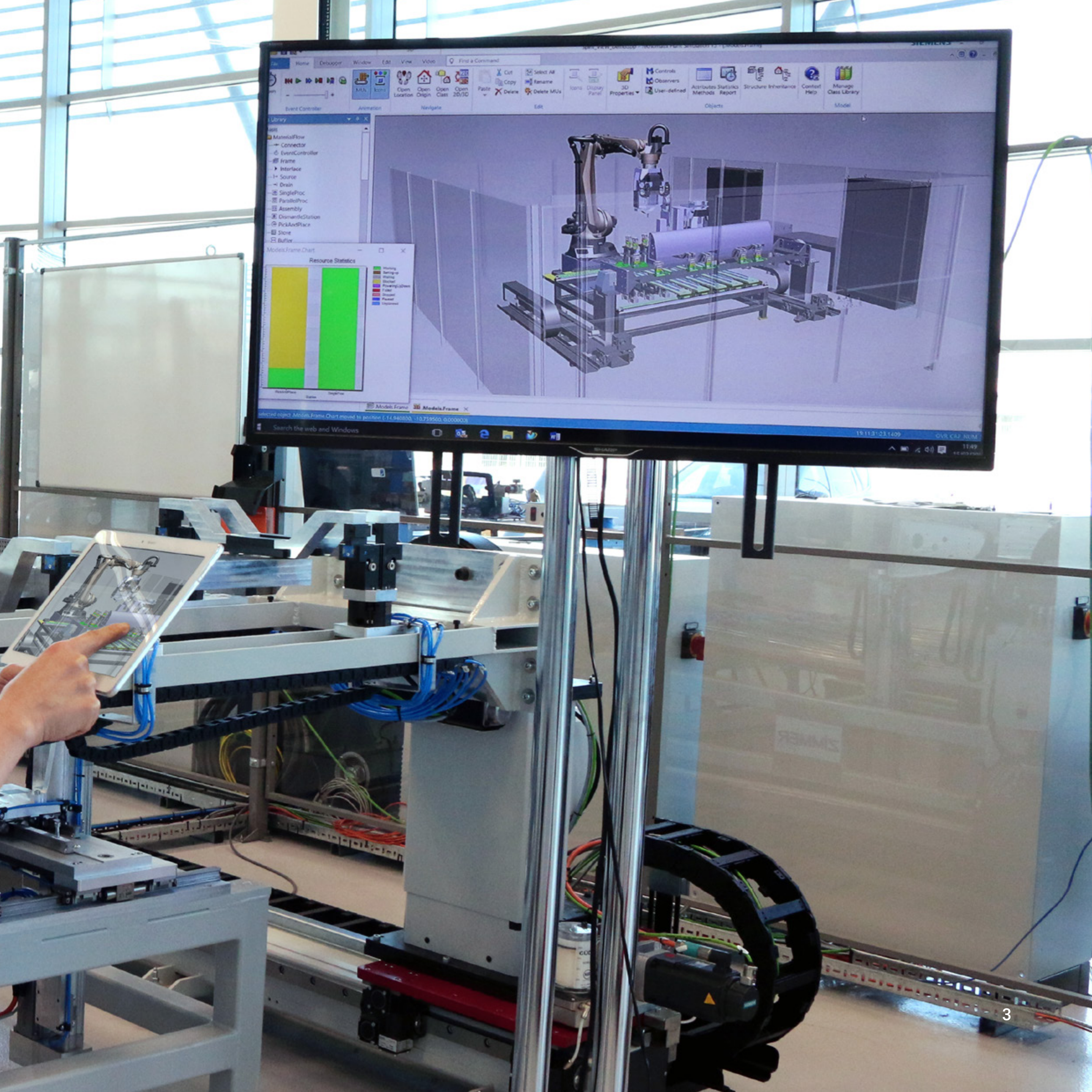

SIEMENS
Find a Command
Home
Debugger
Window
Edit
View
Video
Library
MaterialFlow
Connector
EventController
Frame
Interface
Source
Drain
SingleProc
ParallelProc
Assembly
DismantleStation
PickAndPlace
Store
Buffer
Resource Statistics
Search the web and Windows

Foreword

According to research, the digital twin market is set to grow to over $15B by 2023.

Much of this growth is expected to be in the field of manufacturing as the number of pieces of manufacturing equipment that are connected though the industrial internet grows. This will open up massive opportunities for new business models with remote monitoring of equipment driving a move towards servitisation. It is also expected to speed up the rate of new product introduction, as better insights into how equipment is being used become more accessible.

But the answers to some fundamental questions still remain unclear. As a follow on to our report Immersive Technologies in Manufacturing, this latest study provides answers to at least some of those questions – what do people think a digital twin is, what is needed to make a digital twin and is there any value for the use of immersion in a digital twin?

This report is the first to canvas the manufacturing user base on such a scale and will better inform policy makers, guide funding bodies and investors and maintain the UK in a thought leadership position for the use of digital twins in manufacturing.

Dr Sam Turner,
CTO High Value Manufacturing Catapult.

“Is there any value for the use of immersion in a digital twin?


37.36

Executive Summary

The term digital twin is appearing more and more often in media, academic journals and online. And yet, it is still unclear what a digital twin actually is. This report provides an insight into the current perception of aspects of the digital twin and the value of immersion in a digital twin.

Over 150 engineers from across the High Value Manufacturing Catapult and associated companies were surveyed. Of these, nearly 80% had heard the term digital twin, but there was no common understanding of what a digital twin was, with the most agreed definition being ‘a virtual replica of the physical asset which can be used to monitor and evaluate its performance’.

The part of the manufacturing lifecycle in which it was perceived to offer the greatest value was in the operational phase, with the second greatest value being in manufacturing.

The report identifies that the components of a digital twin system which were considered absolutely necessary included a physical asset and a data set, although there was disagreement around the need for real time data. Other components that were essential, nice to have and not required were identified and discussed. Feedback from those surveyed then indicated their opinions on those business processes which could be considered under threat from a digital twin and where the business value could be extracted.

Those surveyed were then given a number of scenarios and asked to consider whether or not they were digital twins. This highlighted the fact that there is still a wide variety of situations which could be described as digital twins, but which would not get widespread agreement.

The architectures of a number of digital twin systems is then described. This, yet again, highlights the fact that there is no consistent architectural model because the model will depend on the use case – and that the use cases can differ widely.

Finally, the discussion moves to the perceived value of immersion in a digital twin. While many respondents suggested that an immersive digital twin would add value, the precise use cases were not clearly defined.

The report concludes with an in-depth interview with a representative of a leading company in this field – PTC.

Introduction

The concept of creating a high fidelity, real-time, remotely accessible virtual representation of a real-world product (or 'immersive digital twin') is often spoken about in the context of manufacturing. Currently there are very few complete and accessible exemplars of such a system, so developing the plans for one would help to demonstrate both the challenges and opportunities available for future manufacturing systems.

This report provides an overview of the term digital twin, how it is being characterised in manufacturing and how the use of immersion can add value to the concept. Showing not only how the technologies are currently being used, but also how they might be used in the future. This report is one component of a larger project entitled Business Engagement in Immersive (BEiI) carried out by the Digital Catapult, Immerse UK and the High Value Manufacturing Catapult (HVM Catapult), with funding from Innovate UK. The high-level ambition of this project is to advance the UK in the development and commercial use of immersive technologies and content.

The report draws on three sources of data collected and analysed in the first quarter of 2018. The first was in the form of workshop discussions with thought-leaders within the HVM Catapult network. The second was an online survey which asked users specific questions regarding their preconceptions around the term digital twin and the value of immersion as part of that experience. Finally a one-to-one interview was held with a leading industrialist and digital twin advocate to provide deeper insight into the concept and where its development and application might lead.

The results are presented on the following pages, with insights and use cases provided along the way.


TROAX
Total Today
141,713
69.3%
Total Yesterday
206,688
This Hour
2,727
Best Hour Today
12,937
Production by Hour
Effectiveness By Hour
Categorisation
Stop Distribution
Rate Distribution
Today's Stoppages
SAMSUNG
SIEMENS
AMRC
BOEING

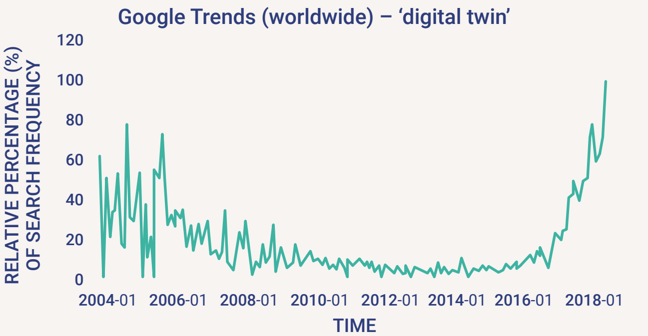
A brief history of digital twins

The first mention of the phrase digital twin occurred in 1998 and refers to a digital counterpart of Alan Alda's voice in Alan Alda meets Alan Alda 2.0.

In the context of digital twins being discussed here in manufacturing, this did not appear in the literature until 2005[1]. This paper even alludes to the area of the Internet of Things, referring to it as the 'Web of Augmented Physical Objects'. Grieves in 2016 discussed the origins of the digital twin[2]. The author claims that their representation of the 'Conceptual Ideal for PLM' was in essence the original digital twin concept, just without the name. He referred to it as the 'Mirrored Spaces Model' and did not refer to it as a 'digital twin' until the year 2011. However the 'different name' argument could be made for other similar terms. (e.g. Cyber-Physical Systems).

In 2011 and 2012, NASA and the US Air Force published two papers on digital twins[3,4]. They discussed the concept of a digital twin on a structural level to help predict fleet maintenance. These papers are two of the most highly cited documents on the topic, and are recognised as being the first time the phrase was taken seriously by both industry and academia. This was partly due to the organisations involved, and partly due the paper's connection to predictive technologies, and the value of the use case being presented.

Google trends analysis shows there was occasional use of term over 2004/2005 when it first appeared in the academic community. Subsequently the use of the term declined before making a comeback in 2016. More recently, the term has seen a marked increase in search activity, most likely due to the general adoption of the term by industry and marketing teams.



1 - "The Web of augmented physical objects - IEEE Conference Publication." http://ieeexplore.ieee.org/document/1493630/. Accessed 23 Mar. 2018.

2 - "Origins of the Digital Twin Concept (PDF Download Available)." 9 Mar. 2018, https://www.researchgate.net/publication/307509727_Origins_of_the_Digital_Twin_Concept. Accessed 23 Mar. 2018.

3 - (n.d.). The Digital Twin Paradigm for Future NASA and U.S. Air Force Vehicles. Retrieved March 23, 2018, from https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20120008178.pdf

4 - (n.d.). Reengineering Aircraft Structural Life Prediction Using a Digital Twin. Retrieved March 23, 2018, from https://www.hindawi.com/journals/ijae/2011/154798/


94.23
41.62
48.12
29.87
59.55
74.84

Data collection

A questionnaire was developed internally by the HVM Catapult and distributed online to collect high-level data regarding the term digital twin.

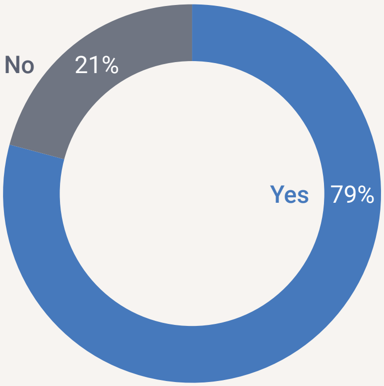
The survey was anonymous and the target demographic for the questionnaire was a range of engineers, across numerous disciplines and seniority from within the High Value Manufacturing Catapult's network.

Questions were chosen to get a baseline understanding of the term digital twin and how it applies to the manufacturing sector today. A variety of areas of interest were considered, including components, value (ROI), impact business systems and where implementation is most likely to occur.

An interview enabled us to further explore some of the themes that became apparent from the first survey. The interviewee was selected based on criteria consisting of exposure, understanding and leadership in the manufacturing world. Paul Haimes – PTC's vice-president of technical sales in Europe, was chosen and interviewed by Jonathan Eyre, technical lead for digital twin at the AMRC.

Survey Results

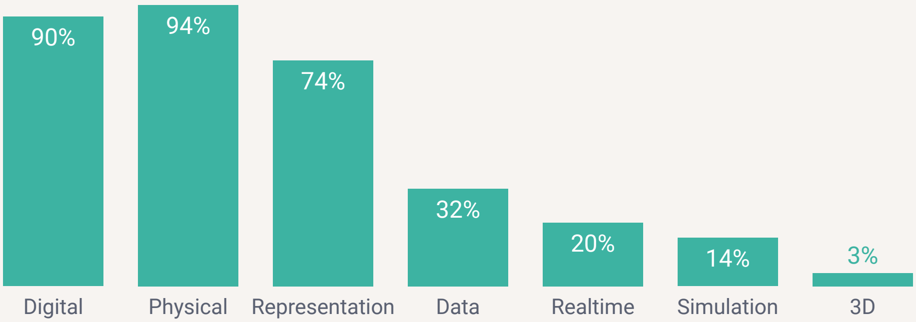
Are you aware of the phrase ‘digital twin’?



Digital twin… probably around 80% will know the term. They will have heard of it, they might not know exactly what it is.
– Paul Haimes, PTC

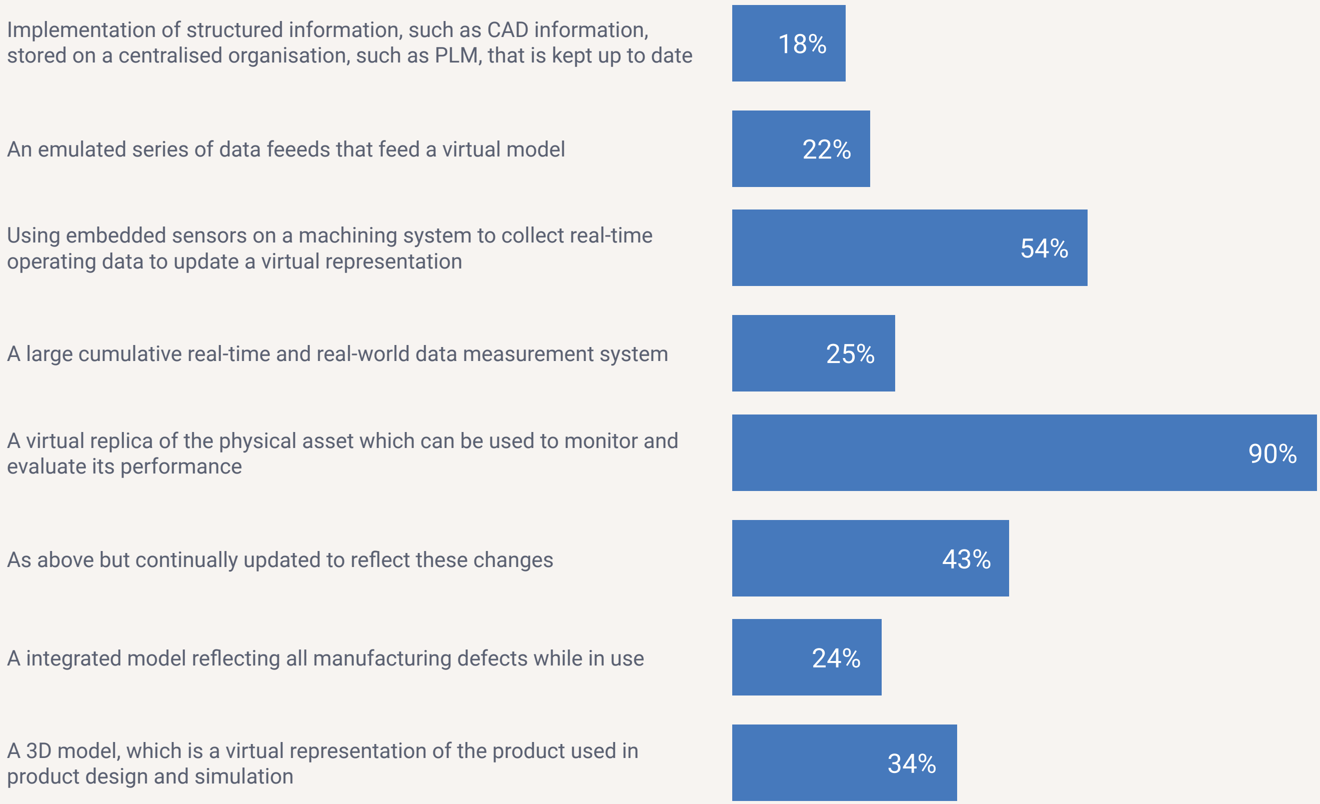
Describe what inputs constitute a digital twin?

Percentage of responses including terms from the identified groups

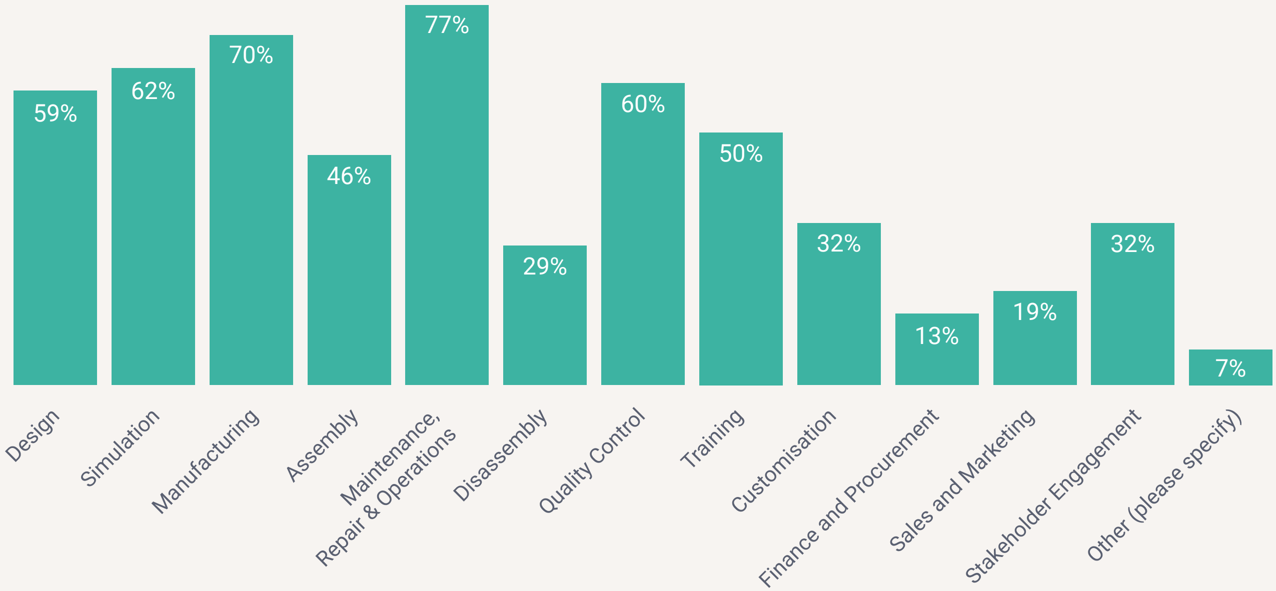


The above suggests that whilst the majority were in agreement around core requirements, some participants also believed that real-time (data) and simulation were necessary, suggesting that there may be baseline requirements to reach a basic twin as well as more ‘complex’ twins.

Which of the following best describes a digital twin?



In which stages of the product life cycle do you see the digital twin offering greatest value?



Answers to 'Other':

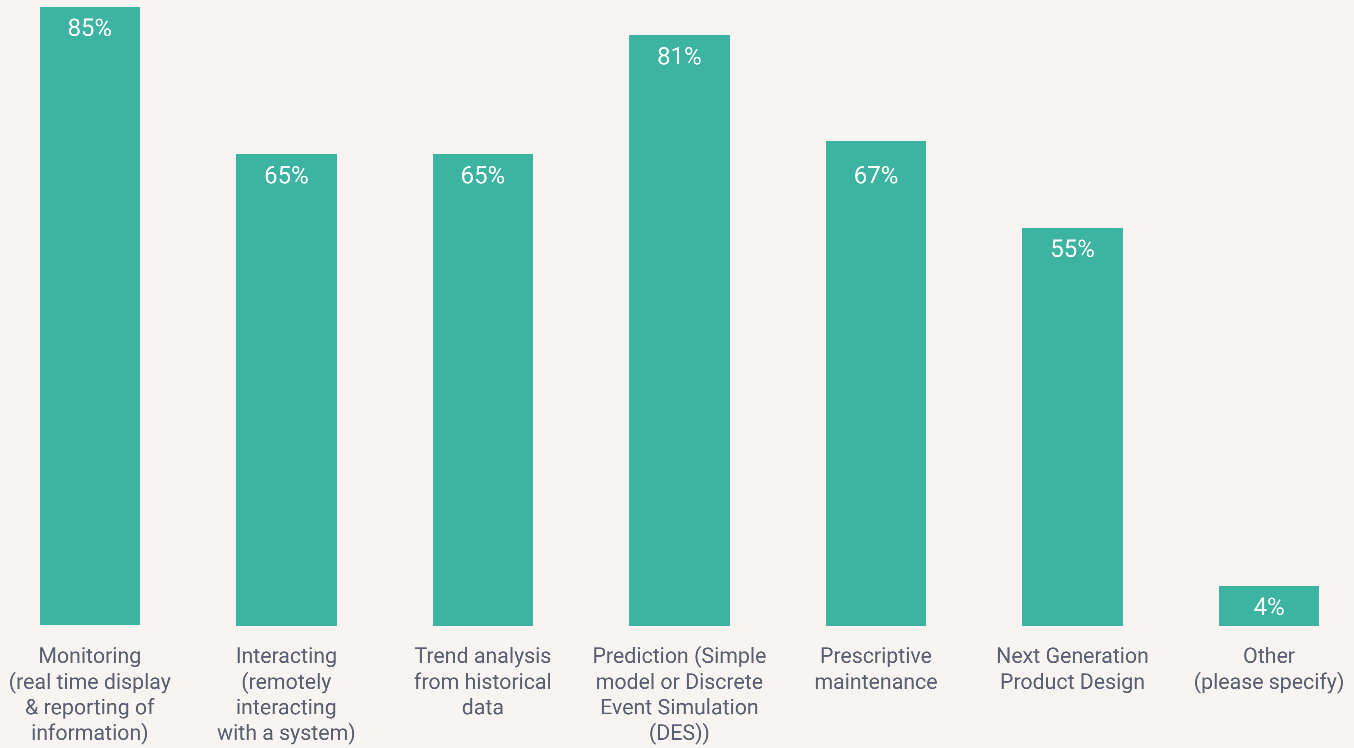
– Commissioning
– Remote trouble shooting
– Recreation of in-service failure
– Traceability, RCA, PFMEA
– Ramp up
– Continuous Improvement
– Metrology

What components do you think are necessary for a digital twin?

The findings endorse the view that it is essential for a digital twin to have both a live data set and a physical asset, in-turn confirming the need for ‘real time’ data (although the definition of ‘real-time’ can vary dependant on use-case). The results also show that a 2D or 3D graphic is not necessary, which suggests the ‘digital’ representation must be anything that gives the data context in a digital environment – e.g. a labelled data field.

Whilst the above are the baseline requirements for a digital twin, the analysis also highlights that digital twins can be more complex with the use of offline datasets, detailed graphics, simulations and prediction.

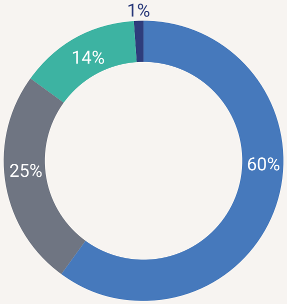
Which business systems could you see a digital twin either replacing or complementing?



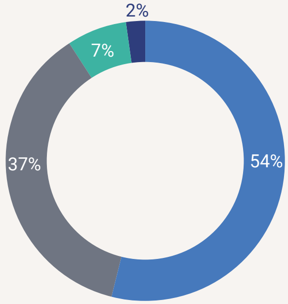
Answers to 'Other':

- Training
- Condition-based maintenance
- Predictive maintenance
- Inspection

How much business value do you see for the following sections by implementing a digital twin? (4 high and 1 low)

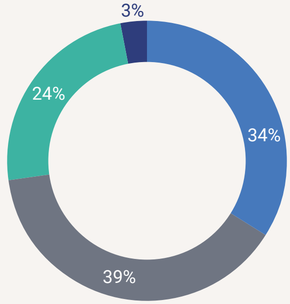


Remote Monitoring



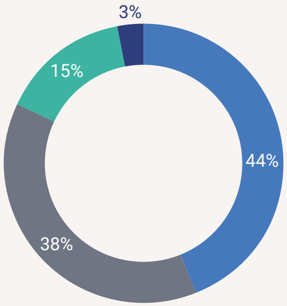
Quality

(predict and detect quality trend defects sooner)



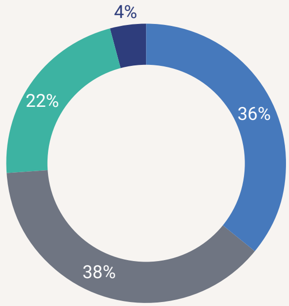
Warranty cost and services

(understand current configuration of equipment in the field to be able to service more efficiently)



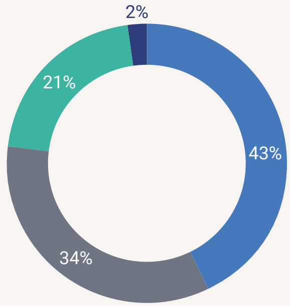
Operations cost

(improve product design and engineering change execution)



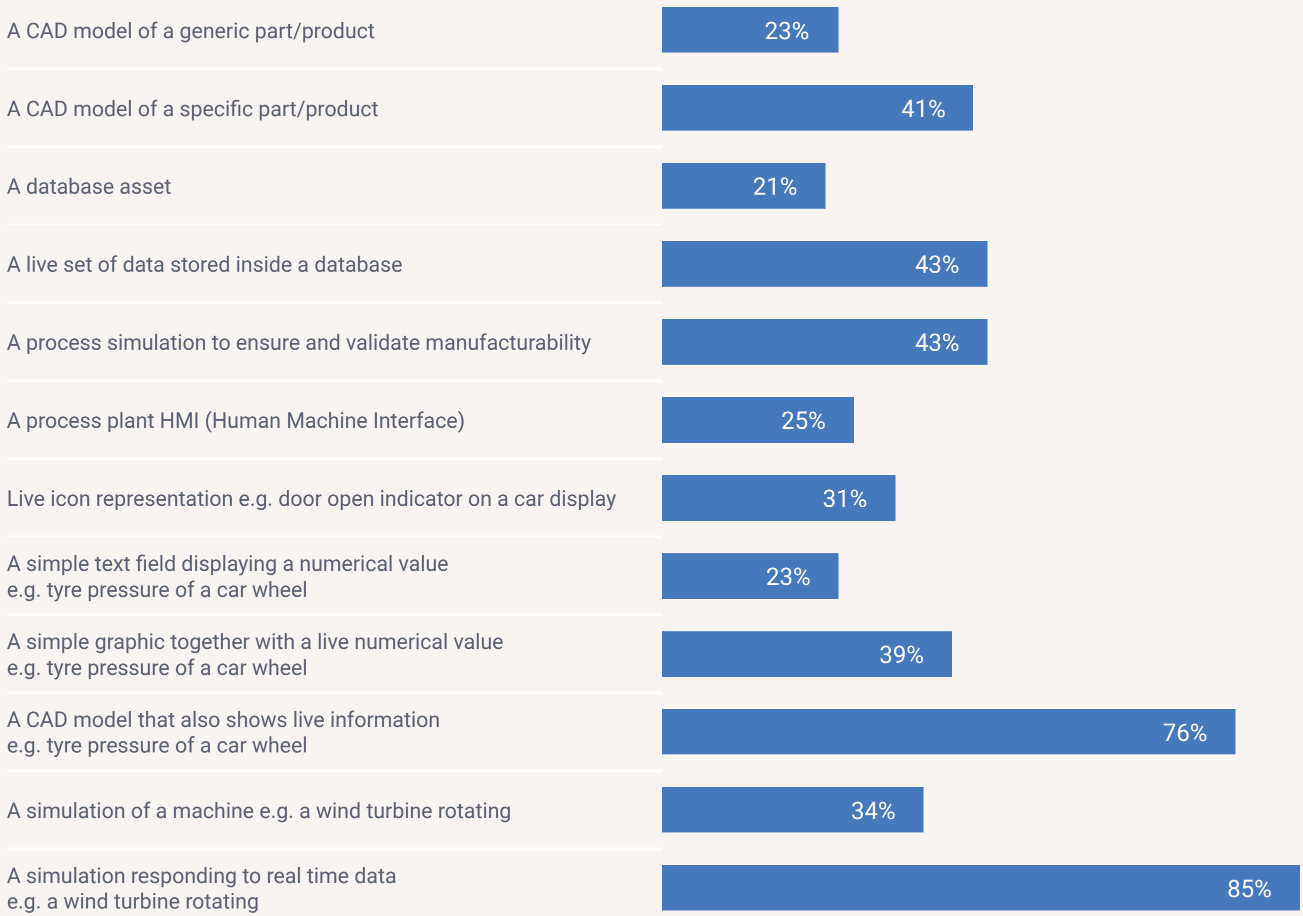
New product introduction cost and lead time

(reduce overall cost to produce new product)

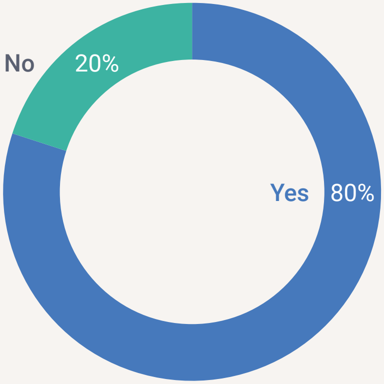


Analysis of historical data sets to understand how previous designs / products performed against expected

Which of the following implementations would you brand a digital twin?



Would you see any value in using immersion (virtual reality or mixed reality) with a digital twin?



> More data means we need to be more efficient in consuming it and the most digestible way to consume this digital information will be through an augmented experience.
>
> **– Paul Haimes, PTC**

Definition of a digital twin

What components are in a digital twin?

Required	A **model** of the physical object or system, which provides context.
	Connectivity between digital and physical assets, which transmits data in at least one direction.
	The ability to monitor the physical system in **real-time**.
Optional / Value Added	**Analytics:** The optional logic for a digital twin may (and often will) include rule engines or complex-event processing that are applied to incoming IoT data. These logic elements may generate alerts or triggers that orchestrate workflows and various forms of descriptive analytics to identify when thresholds are exceeded; they can also drive predictive analytics that provide inputs to enterprise stakeholders.
	Control: Not all digital twins will have the ability to control an object but, when they do, they will connect via the object's specific control system. On-board actuators, electronic switches and other digital-to-analog physical devices make up the control systems.
	Simulation: A sufficiently detailed digital twin may be used by an enterprise to model the current and future behaviour of an object in a variety of conditions and configurations, anticipate failure and optimal operation modes, or identify optimum schedules for operation, refuelling or maintenance.

Technical requirements of a digital twin:

Connectivity: Sensors, data feeds, infrastructure

Analytics: Ability to manipulate data in context

Contextual model: CAD, plan, schematic, text field

Storage: Database etc.

Frame of reference: Spatial and temporal

Simulation: Model.

What is ‘real time’?

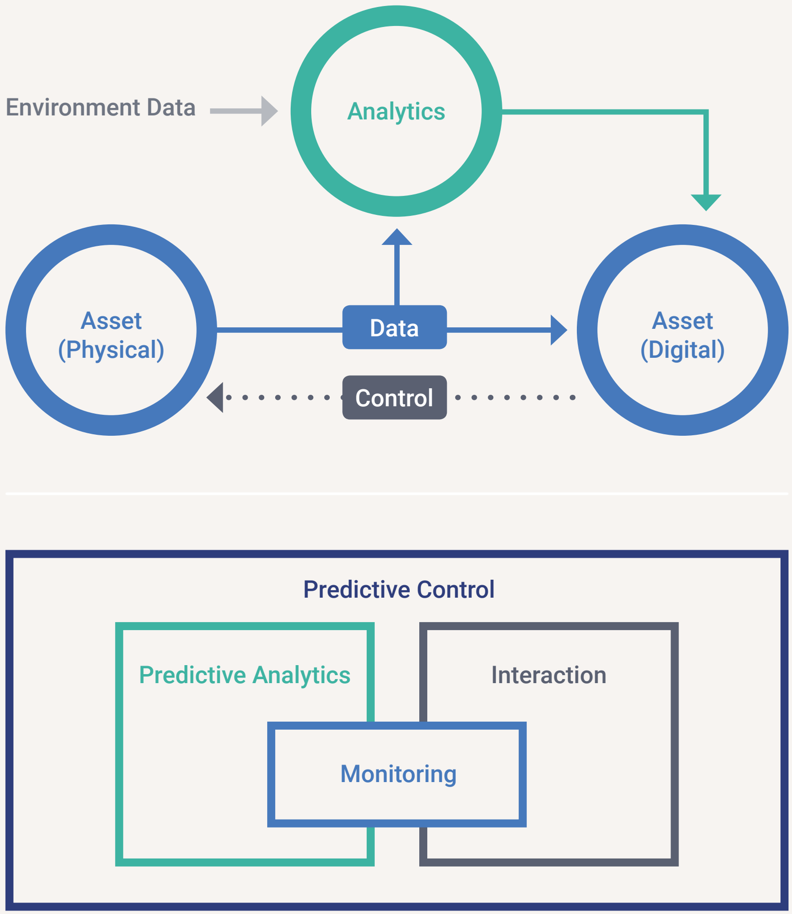
Real time is conventionally thought of as a period of a few milliseconds. For some types of datasets, however, this is not only impossible but also of limited business value. Therefore this real time definition can vary depending on the dynamics of the process and the interaction required. In the case of a digital twin that monitors a chemical process that happens over the period of a minute, millisecond precision may be required. In contrast, in the nuclear industry, where you could have a monitoring digital twin of a radioactive environment for planning purposes, the objects are extremely unlikely to move and an update every few months may be adequate.

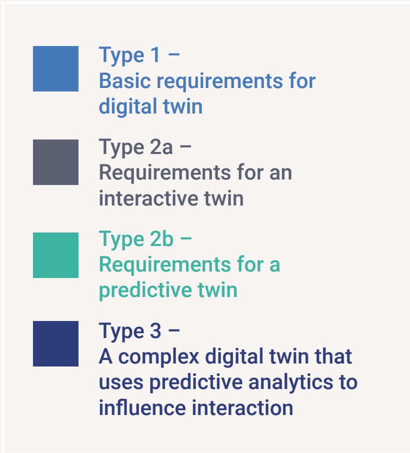
One type of digital twin?

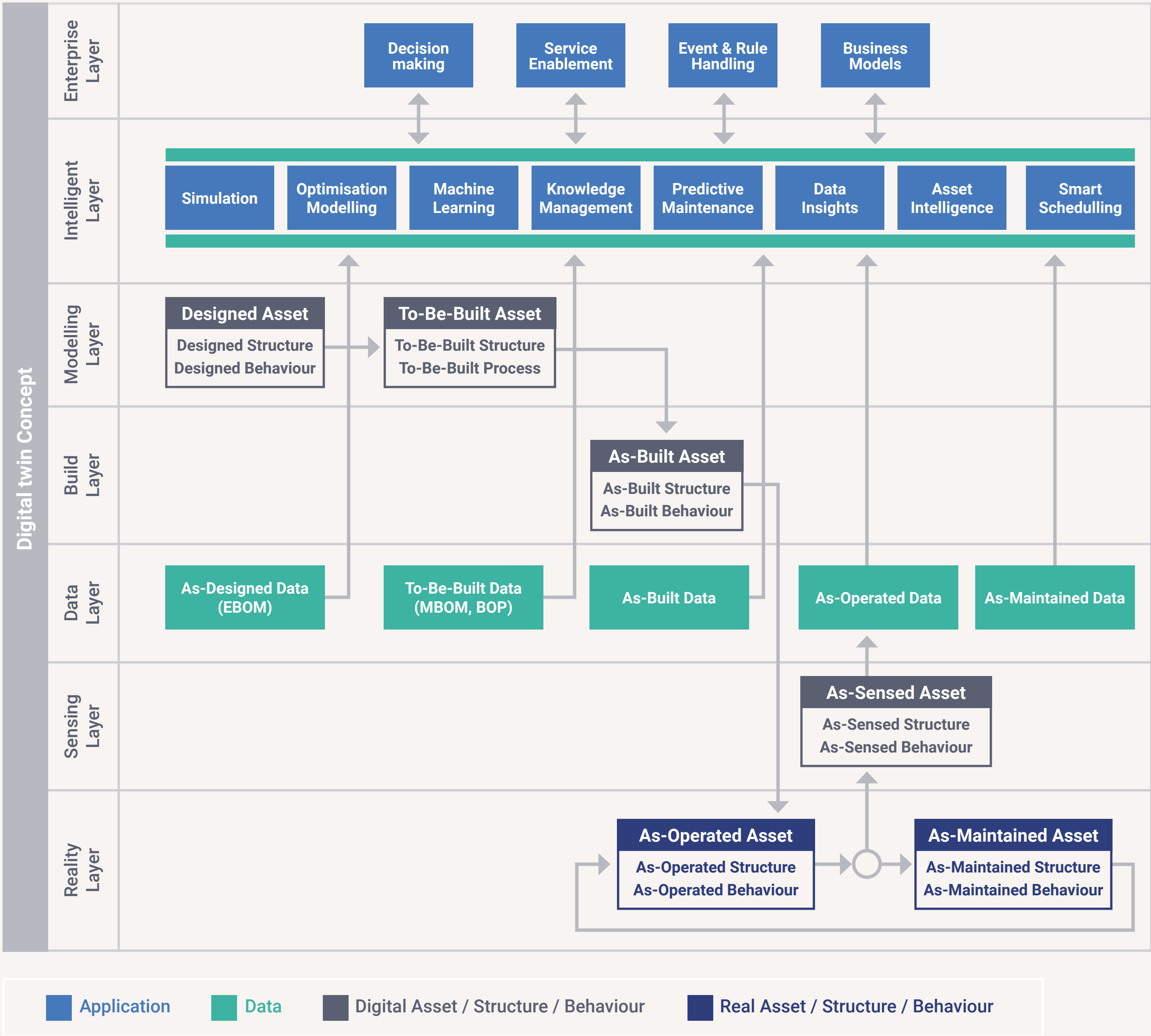
Some components have been highlighted as core and some as optional. However, several participants in the survey expressed that they will not accept a digital twin unless it consists of both the core requirements listed above and one or more of the optional ones. Clearly there is the potential to have multiple ‘types’ of digital twin.

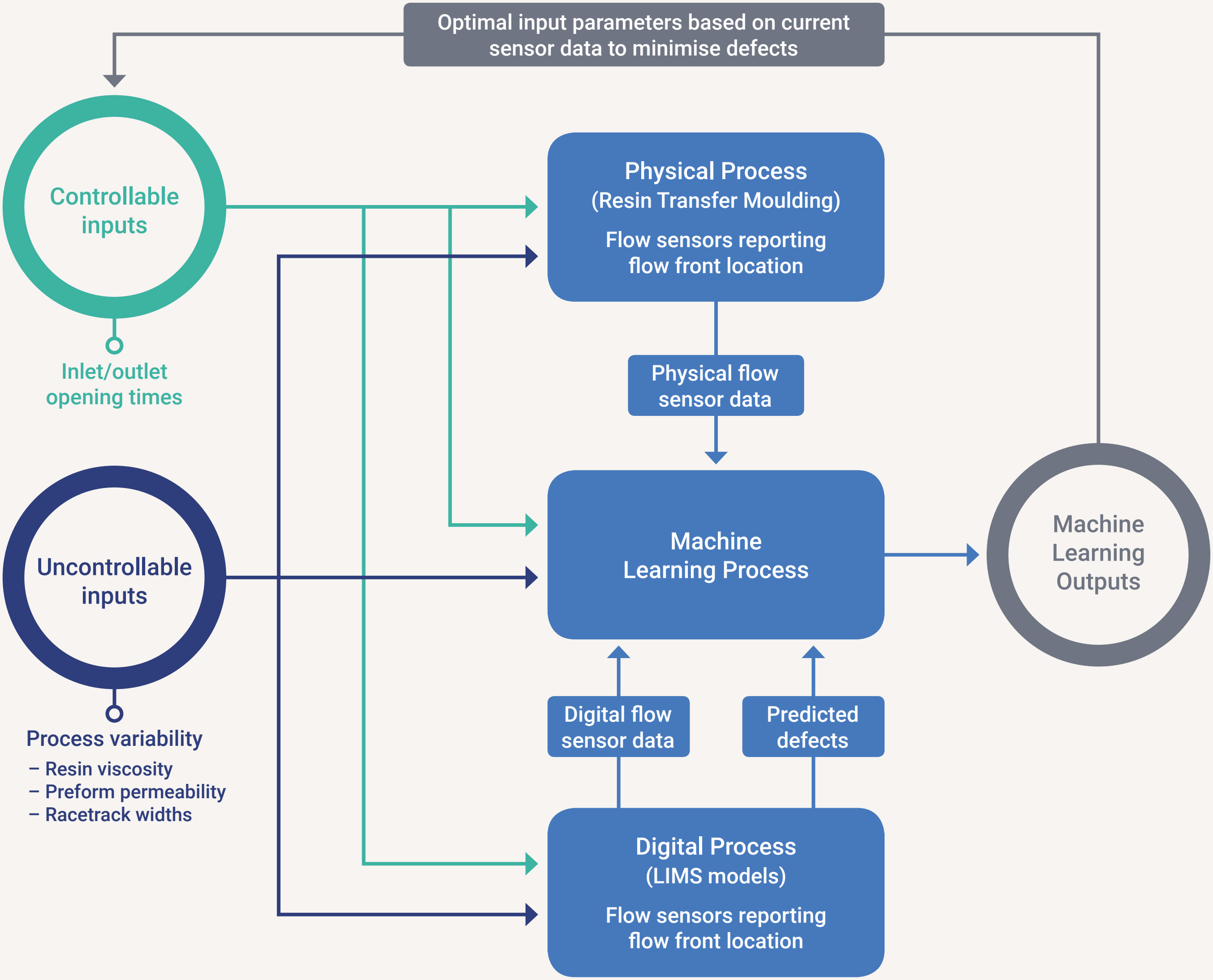
Architecture

Defining an architecture for a digital twin is difficult as there is so much potential variety depending on the use case. Members of the High Value Manufacturing Catapult centres were tasked with producing a generalised architecture of a digital twin and shown across the following pages.

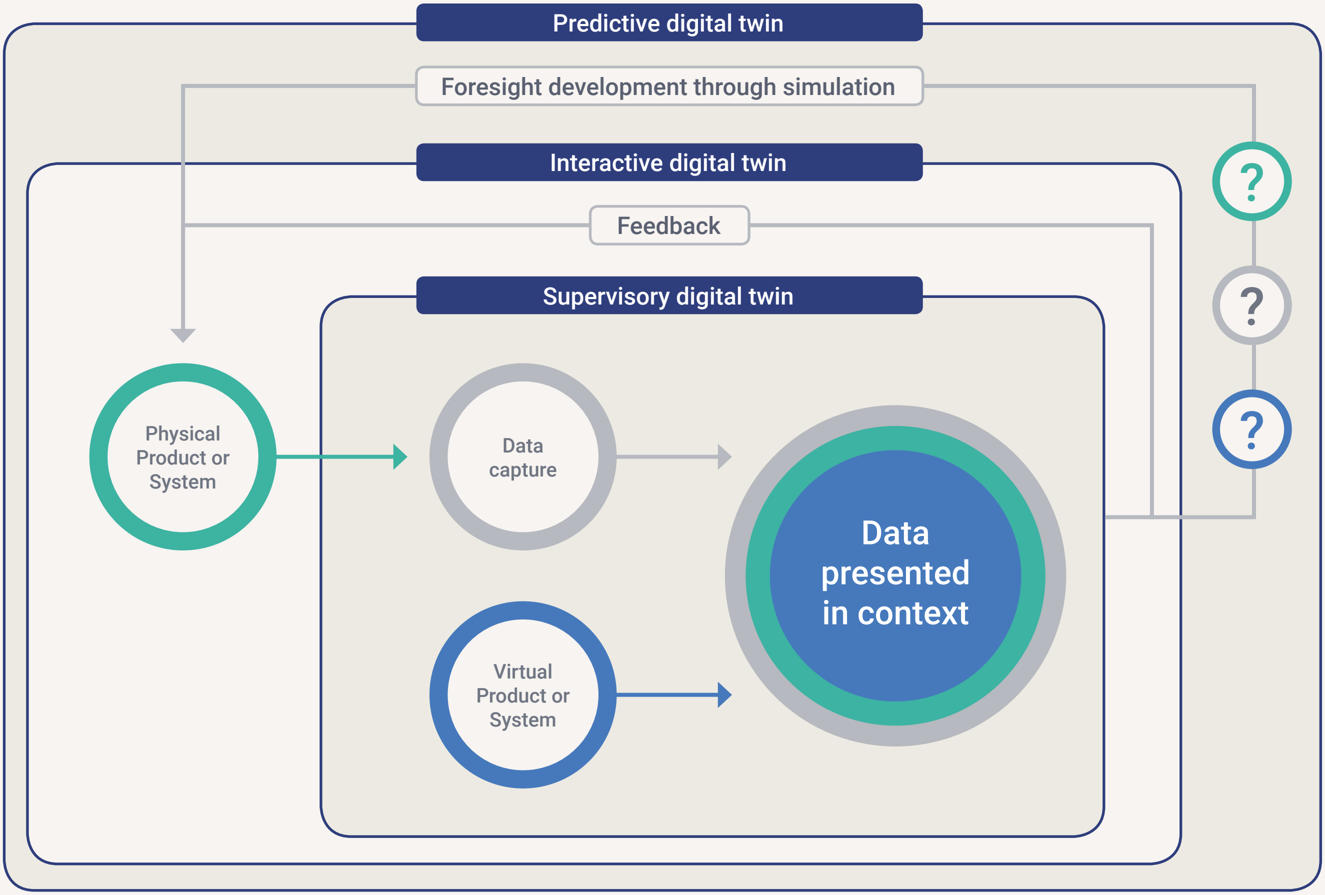





Digital twin Concept
Enterprise Layer
Intelligent Layer
Modelling Layer
Build Layer
Data Layer
Sensing Layer
Reality Layer
Decision making
Service Enablement
Event & Rule Handling
Business Models
Simulation
Optimisation Modelling
Machine Learning
Knowledge Management
Predictive Maintenance
Data Insights
Asset Intelligence
Smart Schedulling
Designed Asset
Designed Structure
Designed Behaviour
To-Be-Built Asset
To-Be-Built Structure
To-Be-Built Process
As-Built Asset
As-Built Structure
As-Built Behaviour
As-Designed Data (EBOM)
To-Be-Built Data (MBOM, BOP)
As-Built Data
As-Operated Data
As-Maintained Data
As-Sensed Asset
As-Sensed Structure
As-Sensed Behaviour
As-Operated Asset
As-Operated Structure
As-Operated Behaviour
As-Maintained Asset
As-Maintained Structure
As-Maintained Behaviour
Application
Data
Digital Asset / Structure / Behaviour
Real Asset / Structure / Behaviour


Optimal input parameters based on current sensor data to minimise defects
Controllable inputs
Inlet/outlet opening times
Physical Process
(Resin Transfer Moulding)
Flow sensors reporting flow front location
Physical flow sensor data
Uncontrollable inputs
Process variability
– Resin viscosity
– Preform permeability
– Racetrack widths
Machine Learning Process
Machine Learning Outputs
Digital flow sensor data
Predicted defects
Digital Process
(LIMS models)
Flow sensors reporting flow front location

The architecture below is perhaps the most powerful because it provides a hierarchal representation which can be used to encompass multiple definitions of a digital twin, by introducing a three-tiered system. Each higher tier is dependent on the behaviour of the lower tiers.



Types of digital twin

Type 1
Supervisory (or observational) digital twin:

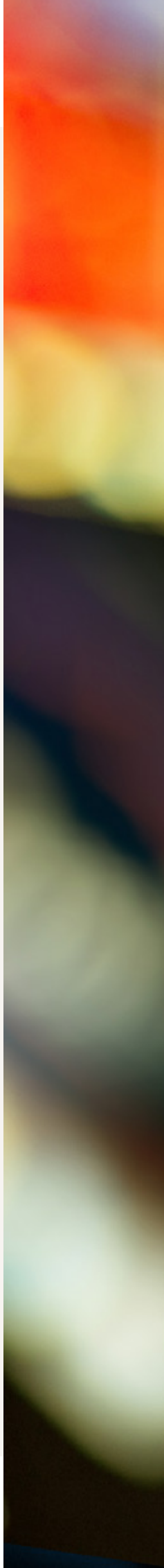
In its purest form, this is strictly a passive monitoring model that receives data streams from the objects that are used to monitor the state of an object or feed into the subsequent development of the digital twin's thresholds. Digital twins must fulfil this role that allows other augmentations and other types of digital twins to be built upon this. Once sufficient data is collected, it can be analysed to identify key thresholds and to issue either alerts or specific orchestrations of workflows in the case of deviations. This analysis is just one of the possible augmentations available to provide extra information to a supervisory digital twin.

Type 2
Interactive digital twin:

This model presumes some degree of control (partial or full) of the physical object (for example, lamps or valves can be fitted with remote control capabilities). In this case, the objective is to set parameters for the object. This could include temperature for a room or a scan of the environment.

Type 3
Predictive digital twin:

Some enterprises will construct a simulation model using a variety of building block techniques, such as finite element analysis, CAD and functional parameters, to establish the key critical parameters for the object's digital-twin model or class. The model, along with the data collected from the object, and the contextual data can then drive simulations to optimise predictions of the object's performance by providing modifications to adjust actions in the system. For example, it may increase the output of a wind farm by optimizing the pitch of the blades.



> A digital twin is a connected representation of a physical asset, that could be a product, could be the factory, but the important thing is that it is connected and streaming information about what is taking place.
>
> A digital twin is not just a piece of CAD software with a model in it representing what is going on; an electronic representation is not a digital twin. – **Paul Haimes, PTC**

Use cases for a digital twin

An important point at this level is that the amount of data presented, the fidelity and detail of the model should be what is appropriate for the use case.

What physical object or system?

The range of physical objects and systems that digital twin methodologies can be applied to are broad. They can range from the people, part, process and place orientated to more complex systems, such as supply chains or wider enterprise eco-systems.

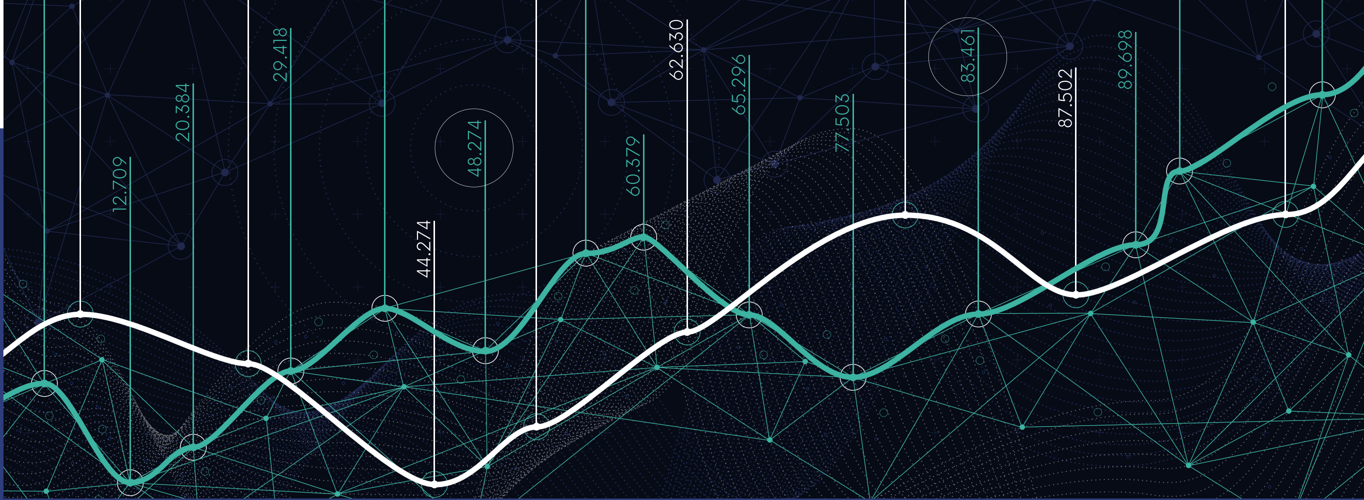
Part: Twins of objects and assets, spanning the simple to very complex, are increasingly being built to meet enterprise or consumer objectives. For example, digital twins of locomotives are built and used to improve yield and reliability. Digital twins of smart consumer appliances do the same and also improve the user experience.

Process: Some processes focus on physical objects such as factory layouts or logistics optimisation. Such digital twins may be assembled from more granular digital twins, whereby all the digital twins for individual manufacturing line equipment can be rolled into one composite digital twin, thus representing the entire manufacturing process.

Person: Increasingly organisations are building models of their customers, employees or citizens, based on the transactions or other interactions that they have engaged with them. A core focus of these models is to understand the state and behavior of the person, as well as to help craft inputs to modify their behavior to improve healthcare, enhance safety or meet a range of other objectives. This form of digital twin can be used to model and predict the development of higher levels of customer intimacy.

Place: Models of dynamic places will increasingly be critical for mobile objects in a broad range of enterprise and consumer use cases, such as parking spots, bridges and train depots. In the manufacturing context, this is looking at the digital twin of the logistics supply chain and the monitoring of dynamic environments such as construction sites.

Complex or conceptual objects: Digital twin models of complex entities, such as supply chains, enterprises and countries, will emerge to meet specific financial or other economic driven decision-making processes.



Applications

Process monitoring (Type 1): Through the development of digital twin systems, processes can be monitored remotely. This remoteness could be 'shop floor to top floor', or it could be within the supply and value chain. This purely observational instance will allow decisions to be made by the observer without the need to be located with the data source.

Process controls (Type 2): The enablement of control capability from within the digital twin system for remote viewers (with or without the benefit of AI or AuI). Further enhanced through virtual decision making based on both the live and historical data feed. Thus transforming a digital twin into a digital master, and subsequently implementing automatic change based on that data.

Predictive maintenance (Type 3): Through the aggregation of historical data, combined with the real time data feed, it is possible to simulate the future states of equipment, thus enabling the development of predictive maintenance models. This enables a great productivity saving through the ability to respond to demand signals rather than either waiting for failure-triggered signals or being driven by scheduled maintenance. This methodology also allows the derivation of next generation design of systems or products more rapidly than previously.

Rapid new product introduction (Type 4): Through increased customer intimacy (ref value disciplines) greater insight into product or process performance can be developed. This can then be used to influence the next generation developments in physical products or processes. These developments can be through version upgrades (v1 v2 etc) or through stage upgrades (v1.1, 1.2 etc). They may also be developed through digital upgrades (software).

Immersive digital twins

Is an immersive digital twin useful?

Generally, immersion has a primary value in two situations; where depth perspective is required, and where there is a need to understand scale in relation to the observer. However, despite it being rare that these requirements occur in a digital twin, the results discussed indicated that 80% of people in the questionnaire believed immersion would be a valuable delivery mechanism.

The workshops indicated the following areas where participants felt the visual intuitiveness of immersion had a substantial role to play:

- When dealing with complex datasets that have an inter-dependence
- Where context is crucial to the data navigation and decision-making
- When engaging with mixed stakeholder audiences and clear, coherent, simplified dissemination is critical to the message delivery
- A method to improve customer engagement for product iteration through design specification and version control
- Where working at a 1:1 scale benefits both decision-making and navigation
- Where multiple software packages are being used concurrently to iterate designs, immersive environments provide the ability to concatenate the data and accelerate decision-making
- Where the environment and or area of interest is either hazardous or inaccessible
- When access to live scenarios is required by experts who are situated remotely.

In-depth interview

In a wide ranging discussion, Paul Haimes – PTC's vice-president of technical sales in Europe – talks to AMRC Digital Twin Technical Lead, Jonathan Eyre, about digital twins, immersive technologies and the massive disruptive change that is coming to the workplace of the future.


Paul Haimes

JE: So what is a digital twin?

PH: A digital twin is a connected representation of a physical asset, that could be a product, could be the factory, but the important thing is that it is connected and streaming information about what is taking place. A digital twin is not just a piece of CAD software with a model in it representing what is going on; an electronic representation is not a digital twin.

JE: Within your description, you mentioned the connection is critical; what does this mean in terms of how quick a feed needs to be to be real-time and up-to-date?

PH: The important point here on connectivity is the device, the asset, has the ability to capture its own performance with whatever functions it is doing. Then it needs to have the ability to record and persist that information somewhere. Now that could be in the form of an edge device, or some edge compute layer, is then managing that information and discarding what is unnecessary, but then filtering and working and distributing only what is important. The data from the connected asset is being persisted somewhere. It could be historian, it could be a spreadsheet, could be a device cloud, could be a SQL database, but the important thing is it's going somewhere and the data being stored is being turned into information at some point in its life. This could be real time or something done as part of a batch process.

JE: So stored information about something that physically exists, and then re-run that to form a visual about what it was doing previously, would you define that as a digital twin?

PH: How far the digital twin term extends is an interesting point. For me it's the way you act on information. If you take for example an analytics model, a predictive maintenance perhaps, that digital twin information if it is being monitored and assessed against a predictive model then for me that is forming part of a digital twin: data coming in is being acted upon in real-time against a known behaviour that leads to a particular outcome. Digital twin has to extend simply beyond just gathering data, ones and zeros; it is about what you do with it. If you are just gathering data, you might think you have a digital twin, but you could have just spent a great deal of money that is probably not going to deliver a great deal of value back into the company.

JE: So here you mentioned value; what do you deem to be the best value? Do you see it being more in design, simulation around real-time or maintenance and repair?

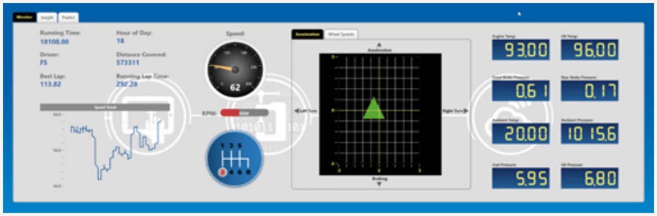
PH: That is the million-dollar question and it's always going to be different depending on the company you are talking to. When it comes to digital twin, the most common reference is maintenance and keeping assets running. For example, we are just doing some work with a forging company that has connected one of its forging lines that historically failed every three to four months. In that instance, through connecting the line and not having any machine learning ability here, the operators learned to understand the signals and the feeds coming off the line to the point where they were then able to spot where problems were developing with the clutch. They were then able to proactively fix the issue before a failure happened just in time rather than after the case. That is now saving them around $200,000 a year because that line has now been running for nine months without any failure.

JE: The first example with the forging company, from what you have described, is a monitoring application with data connected to a visualisation of that information. Do you describe this as a digital twin?

PH: I do, I think it's the value of the digital twin. If we go back to the real-time understanding of how the product is being used you're feeding that information, you are then feeding this into the engineering environment so if the engineers have access to the dashboards that allow them to see what is going on with the products they are designing, they might have a requirements list that they are working on, but the insight that the digital twin provides allows them to validate redundant parts to reduce the number of requirements or constraints of a system. When thinking about the app generation of today where we want them focused on purely what we want them to do is now filtering down into the way we interact with things such as mobility, vehicles, household appliances, anything we make and touch. Consumers want the simplistic approach to the way in which they interact with products. Steve Jobs said 'simplicity is the ultimate complexity' and what he meant was making something the easiest to use is actually quite complex and difficult, but certainly we see a shift in the way people are interacting with devices.

JE: If you think back to the SCADA systems with HMIs showing cells running at a factory level with real-time connectivity, would you classify that as a digital twin system?

PH: I would, seeing the data and seeing what is going on is useful but most importantly it is how you act on it that makes the difference. They have been around a long time and have been used to good effect to be able to react to issues on the line perhaps more quickly, but what we are talking about with Industry 4.0 is the ability to predict



rather than react. It is that vision of machine learning around the spotting of patterns goes way beyond what a human could possibly do to understand the intricacies of what is happening on the line. Then of course on top of this you have the connected worker with augmented reality to then maintain it and that in theory offers benefits in reduced time to solve particular issues on the line form an integral part of digital twins.

JE: With all what we have discussed in mind, how do immersive technologies fit into this picture?

PH: That's a good question. I'm going to give you a high-level answer to this question because of the number of connected devices on this planet is going to explode and the sheer amount of data that then needs to be processed, turned into something valuable, but then delivered back to the user. This all stems to why we bought Vuforia, why we continue to aggressively develop AR capability: it is the value that is derived from all this data that still needs to be delivered back to the human and the fastest, most digestible way to consume this digital information I believe will be through an augmented experience. Our ability to have information streamed to us about things we need to know, I think we are on the verge of some hugely disruptive phase, where at some point, somebody is going to come out with something useful in terms of eyewear that is un-intrusive, cool from a consumer point of view, safe to use in an industrial context and all of that together with things like GPS locations and GEO-fencing. I see it as something that will explode in the next five years or as soon as a device comes around that is capable of delivering that. The data will be streamed us based on our location, based on our role within the business, based on consumer buying habits from our general lives and so forth. All of that will explode in terms of the way we consume information. .

JE: My last point is, are digital twins going to be universal for everyone or do they have to be highly configurable viewports for users?

PH: I think it has to be role based, it's part of the value of the digital twin is that you are gathering vast amounts of information about your connected assets and that information is valuable to different people in different ways. If we talk about the connected factory, for instance the forging company we mentioned earlier, we have the CEO and directors that have their dashboard view of what is happening on their shop floor lines. They want to be able to see all the relevant information at a high level, such as the overall equipment effectiveness (OEE) of the assets, But they don't need to see the temperatures of the furnaces, they just care about what is making them money on the shop floor. This goes all the way down to the engineers on the shop floor who need the information relevant to them in the area they are working, which can't be the one size fits all for these two examples. The value in which we are talking about is the way in which we condition data so it becomes valuable for the user. It comes back to Steve Jobs with 'simplicity is the ultimate complexity', the way in which we are able to condition data to deliver what is necessary is one of the key points of the Fourth Industrial Revolution that we are rattling towards now is about providing just that.

Summary

At the start of this activity the primary question was whether or not added value was obtained by creating a digital twin within an immersive environment. After reviewing the results of the surveys, and after considering the transcripts of the in-depth interviews, a number of conclusions can be drawn.

1 The provision of a 3d model is not a requirement for the creation of a digital twin. In some cases it can add some value, but this value is derived from the capability to derive a greater understanding of the contextualisation of the data presented. However, this is not always the case, and in some cases, a 3d model will be excessive to requirements.

2 The occasions in which a digital twin will benefit from being deployed in an immersive environment are those in which spatial awareness is beneficial. For example, in cases wherein design iterations are being developed based on real-time data which is contextualised to the human-in-the-loop.

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- Growing your VR/AR business in the UK: A business and legal handbook (Digital Catapult & PwC)
- Immersive content formats for future audiences (Digital Catapult & Limina Immersive)
- Evaluating immersive user experience and audience impact (Digital Catapult & Nesta, with i2 Media Research)
- Creative tools and workflows for immersive content creation (Digital Catapult & Opposable Group, with TechSpark)
- The immersive economy in the UK - The growth of virtual, augmented and mixed reality technologies (Innovate UK)
- Immersive Technologies in Manufacturing (High Value Manufacturing Catapult)

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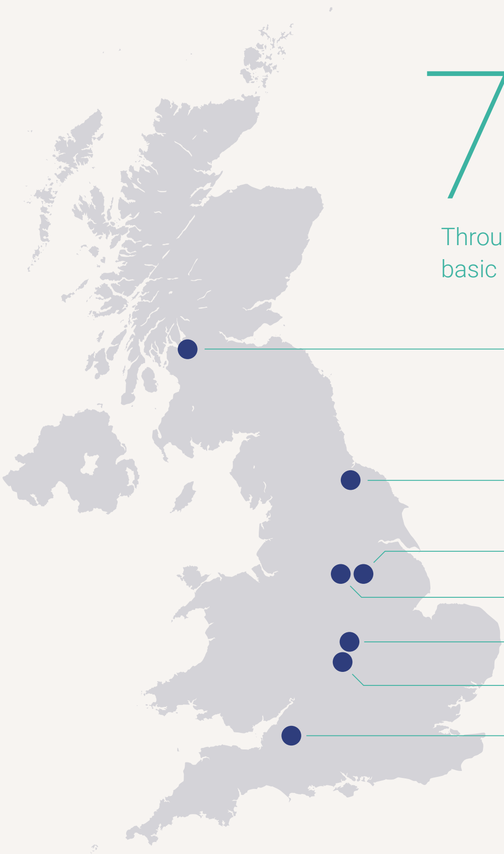

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