Immersive Technologies in Manufacturing

CATAPULT
High Value Manufacturing

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A report by the High Value Manufacturing Catapult Visualisation and VR Forum. With contributions from The IET.

Contents

Foreword

Immersive technologies are predicted to become a $160 billion market within the next three years.

While much of this demand is consumer-led, recent trends indicate the deployment of immersive technology in the workplace is fast becoming the dominant driver for future growth around the globe. It is vital that UK manufacturers ride the crest of this wave and become early adopters, or risk losing competitive advantage and market share: BMW, for instance, has already incorporated virtual reality into its automobile design process.

The UK is well-placed to make the most of this technology. Innovate UK's recent report *The immersive economy in the UK* found more than 1,000 specialist immersive companies are operating in the creative and digital markets. More importantly, it also found that two-thirds of these firms are keen to exploit other markets, ranging from education and training through to advanced manufacturing and energy.

Identifying and removing the barriers to the adoption of these technologies by the UK's manufacturing sector is a key goal of the Government's *Industrial Strategy* and *Made Smarter Review*. Our report, *Immersive Technologies in Manufacturing*, supports that ambition. It provides a forensic examination of where and how industry is already making use of immersive; and where and how this use can be both expanded and deepened.

From sectors as diverse as aerospace and construction, immersive technologies have the power to unlock gains in design and prototyping; reduce costs and environmentally damaging waste; provide more effective education and training; facilitate remote maintenance and repair; and to make manufacturing processes more efficient.

Our report brings back data from the frontline of industry to better inform policy makers, guide funders and investors, and inspire industry to make the most of a group of technologies with the power to transform UK manufacturing at very little cost.

Dr Sam Turner,
CTO High Value
Manufacturing Catapult.

Executive summary

This report explores how immersive technologies are being used across many different industrial sectors ranging from aerospace to oil and gas to construction and at all stages through the lifecycle.

A key finding is that there has been a major uptake of these technologies in the last 3-5 years, coinciding with the increase in availability of low cost head mounted displays (HMDs) and mobile devices (tablets and mobile phones).

The report shows that content development is often done in-house, but as the size of an organisation increases, there is a growing likelihood that this development will be outsourced. The main drivers behind immersive adoption are identified as increased business perception, risk reduction, productivity improvements, higher quality and money saving.

The barriers to adoption were discussed in workshop sessions. These included culture and leadership; skills; security; safety; time constraints; and lack of knowledge of the most appropriate device. However, the biggest barrier was the justification of investment in the first place.

The skills challenge for both the engineers of the future and those requiring reskilling were debated with the conclusion that these skills should be a core part of the curriculum. Huge opportunities for the use of the technology in upskilling the existing workforce, were also identified.

Content generation and the challenges around veracity of data after translation, the potential impact of errors and the barriers to data sharing were discussed. The broad conclusion about the use of common data formats was identified as one of the ways of overcoming these.

In-depth interviews were also conducted with experienced users of immersive technologies from diverse sectors. These interviews covered a wide range of topics including the opportunities for immersive technologies, the solutions which have been deployed in industry and the barriers which had to be overcome to achieve this. The business benefits were then discussed and a view to the future was presented from many different perspectives. The concensus was that, in the future, immersive will no longer be a niche activity but be part of 'business as usual'.

Introduction and background

This report is intended to provide an overview of how immersive technologies are currently being utilised in manufacturing.

This is to show not only how technologies are currently being used, but how they might be used in the future, as well as the barriers to adoption and the opportunities that these technologies present. This report is one component of a larger project entitled Business Engagement in Immersive (BEiI) carried out by the Immerse UK, Digital Catapult and the High Value Manufacturing Catapult (HVM Catapult), with funding from Innovate UK. The high-level ambition of this project is to help to advance the UK in the development and commercial use of immersive technologies and content.

The report draws on three separate sources of data collected and analysed in the first quarter of 2018. The first is from an online survey which asked high-level questions regarding the use of immersive technologies within the respondent's businesses. The second source was a roundtable workshop discussion at the HVM Catapult/IET Applied Visualisation Forum event, and the third involved a number of one-to-one interviews with industrial users of immersive technologies which focused on applications and barriers to adoption within the interviewee's industry sector.

The results of these are presented on the following pages, with relationships/links between the different datasets identified towards the end of the report.

The final aim of the report is to address six key questions;

1. Are manufacturers using immersive technologies?

2. In what parts of the business are immersive technologies being used?

3. Are those businesses using immersive technology creating solutions in-house or externally?

4. What are the barriers to adopting immersive technologies?

5. What added value do immersive solutions provide?

6. What further opportunities are there for immersive technologies in manufacturing?

Data Collection

A survey was used to collect high-level data regarding immersive technologies across a variety of manufacturing sectors.

Questions were chosen to get a baseline understanding of the adoption path of immersive technologies and how these technologies are being used in the manufacturing industry today. A variety of areas of interest were considered, including which industry sectors are using immersive technologies, as well as more specifically how they use them. Questions were included to look at which departments and roles the technologies are used within, and for what purpose.

In January 2018, at the time the questionnaire was being conducted, the HVM Catapult/IET Applied Visualisation Forum event was held at the British Motor Museum. The event itself brought together engineers, practitioners, researchers and technology providers from across various industry sectors to share expertise and best practice, as well as their knowledge and understanding of hardware and software advances and how applying virtual reality (VR), augmented reality (AR), data capture and analytics can be beneficial for businesses. The event enabled the collection of qualitative data, as a significant portion of

the afternoon was dedicated to a series of roundtable workshop discussions where a facilitator led the conversations on specific subject areas.

In addition to the questionnaire and roundtable workshop discussions, a series of interviews were also carried out, which enabled us to further explore some of the themes that became apparent from the first two sets of data. These interviews were carried out by members of the HVM Catapult Visualisation and VR Forum, with known industrial users of immersive technologies, who consented to being interviewed.

Interviewees were selected to represent a range of different industry sectors and it was across these sectors that comparison and analysis of the collected data was performed. These were semi-structured interviews, with questions regarding specific case studies and use cases when immersive technologies were used as part of the solution.
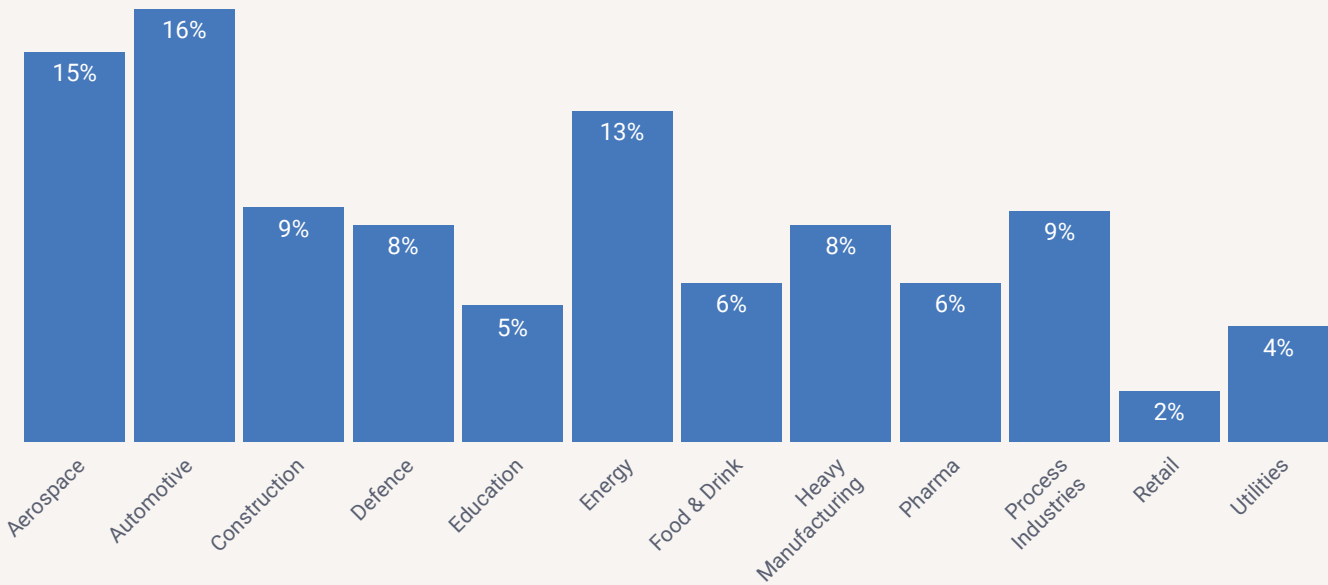
January 2018: HVM Catapult/IET/Immerse UK-hosted Applied Visualisation Forum, held at the British Motor Museum.

Findings:
Survey Results

A questionnaire was developed by the HVM Catapult and distributed online. The survey was anonymous and the target demographic for the questionnaire was a variety of people working in the manufacturing industry across various sectors.

Industry Sector.

Sector	Percentage
Aerospace	15%
Automotive	16%
Construction	9%
Defence	8%
Education	5%
Energy	13%
Food & Drink	6%
Heavy Manufacturing	8%
Pharma	6%
Process Industries	9%
Retail	2%
Utilities	4%

Where in the Product Life Cycle do you use immersive technologies?

Stakeholder Engagement	Design	Assembly	Manufacture	Training	MRO	Disassembly
19%	23%	13%	13%	19%	7%	6%
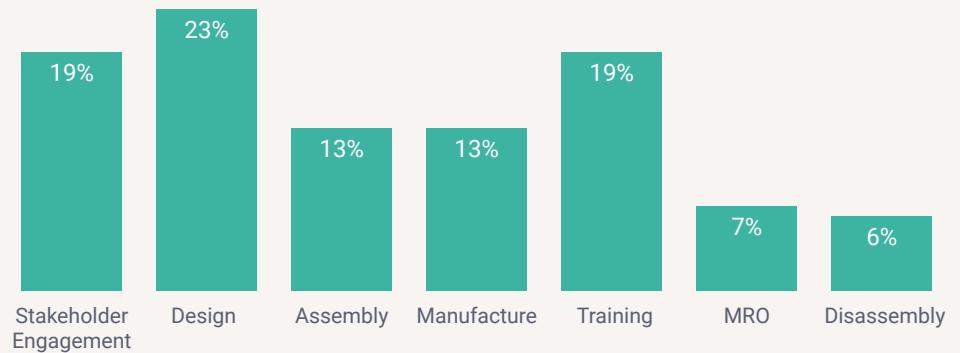
How long have you been using immersive technologies in your organisation?

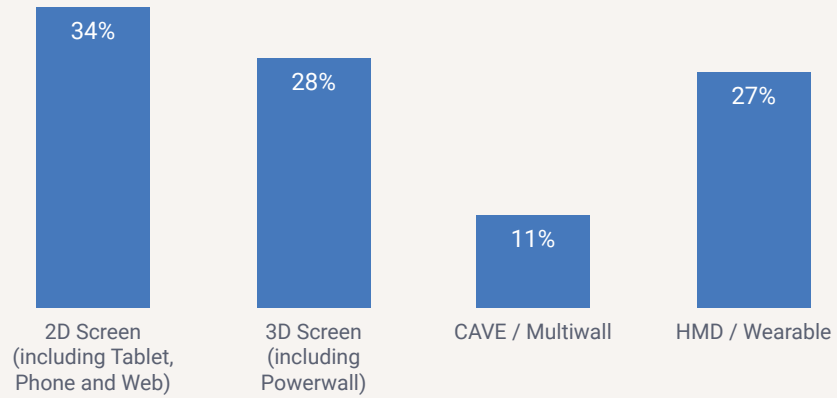| > 1 Year	1 - 3 Years	3 - 5 Years	5 - 10 Years	10+ Years
31%	53%	9%	2%	5%
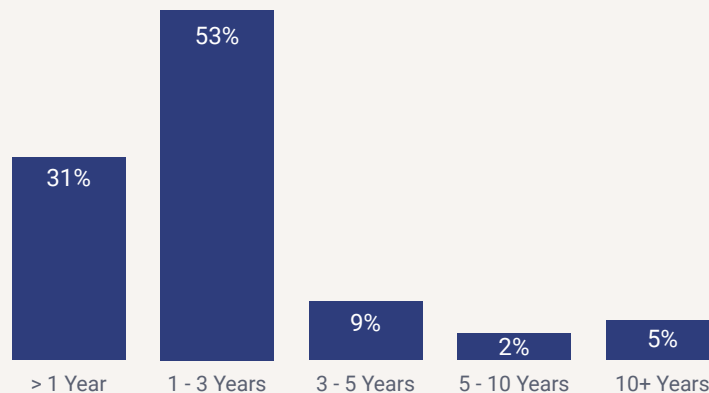
An important interpretation of the above data is that for those who do use immersive technologies as part of their role, the vast majority have been using them for three years or less, with very few individuals having used them for longer than five years. This is probably due to the fact that many of the lower 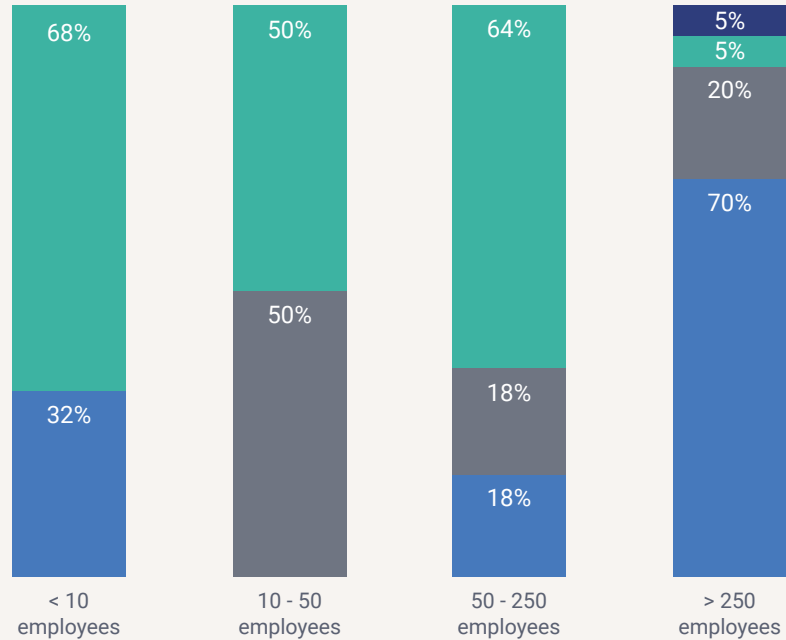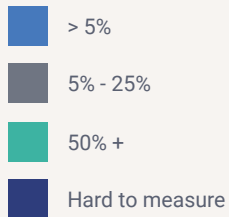cost immersive form factors have only progressed to being enterprise capable within the last three years. Common headsets currently used for virtual reality, such as the Oculus Rift and the HTC Vive, were only released commercially in 2016, with mixed reality headsets such as the Microsoft HoloLens not commercially available until 2017.

How have you deployed the immersive content?

2D Screen (including Tablet, Phone and Web)	3D Screen (including Powerwall)	CAVE / Multiwall	HMD / Wearable
34%	28%	11%	27%

What percentage of your organisation has used the immersive solution? By organisation size.

- > 5%
- 5% - 25%
- 50% +
- Hard to measure

	< 10 employees	10 - 50 employees	50 - 250 employees	> 250 employees
50% +	68%	50%	64%	5%
5% - 25%			18%	20%
Hard to measure				5%
5% - 25%		50%	18%	
> 5%	32%		18%	70%

How different sized organisations develop their immersive technologies.

1 - 10 employees
- 100% Internal - 1st Party (in team)

10 - 50 employees
- 50% Internal - 1st Party (in team)
- 50% Internal - 2nd Party (in organisation)

50 - 250 employees
- 73% Internal - 1st Party (in team)
- 18% Internal - 2nd Party (in organisation)
- 9% External - 3rd Party (outsourced)

> 250 employees
- 55% Internal - 1st Party (in team)
- 20% Internal - 2nd Party (in organisation)
- 15% External - 3rd Party (outsourced)
- 10% All of the above

Legend:
- Internal - 1st Party (in team)
- Internal - 2nd Party (in organisation)
- External - 3rd Party (outsourced)
- All of the above

This data shows a trend that smaller organisations appear to be less likely to use immersive technologies. This may be due to the skill requirements, or costs involved, as to create these technologies in-house requires employees to have particular sets of skills. Alternatively, outsourcing this creation requires an added cost that has to be justified.

How do you measure success and value?

Category	Value
Business perception	20%
Risk reduction	18%
Increased productivity	17%
Improved quality	17%
Money saved	16%
Orders generated	10%
Other	2%
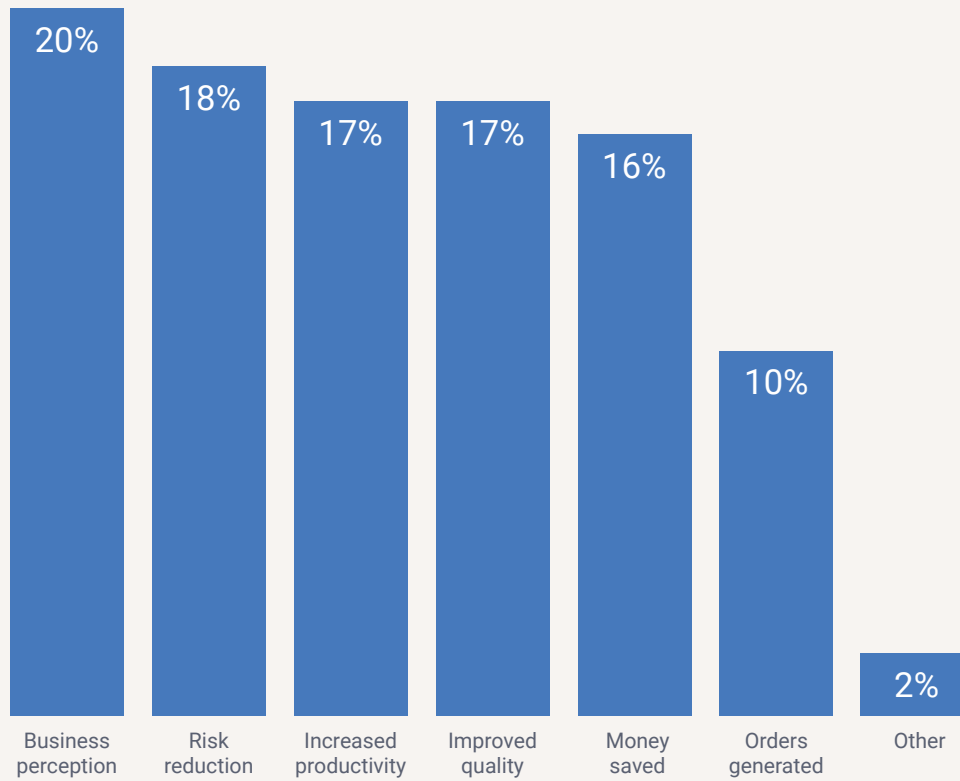
Findings:
Workshop Output

The series of roundtable workshops held at the Applied Visualisation Forum had facilitators lead discussions on specific subject areas which are detailed below.

Use of Immersive Technology in Manufacturing

How are you seeing the value of applied visualisation in your organisation?

There were a number of ways in which companies considered immersive technologies to be valuable. These included time-saving benefits, reduction of travel required, reduction in costs of physical tools. Other potential benefits which cannot necessarily be assigned a monetary value included learning benefits, data visualisation, and user engagement. Generally, companies started with a small use case applying immersive technologies to demonstrate the benefit of the adoption of the technology to justify further investment. However, others found it difficult to demonstrate value to gain this initial investment.

Business Barriers

Looking at the ways that data is shared across the supply chain, how do we account for the effects of cyber security, trust in data and intellectual property?

Current barriers to adoption include concerns about accessibility and applicability of the technology, with people noting that some may not feel confident using immersive technologies. Content creation was also a concern, not only how the content would be created, and how reliable and accurate it would be. Issues with standards, security, and IPR ownership were also identified. However, for many the biggest barrier was justifying costs for immersive technologies, as it is difficult to predict the financial benefit of using them.

Skills

What skills will future engineers need and how can we ensure these skills are developed? What skill sets are you missing now and which are vital for the future?

It is generally considered that the skills required for immersive technologies should be taught from an early age. This is partially due to younger children being more enthusiastic and receptive to learning these skills, but also due to the need to introduce a range of skills before individuals specialise. However, many believe it is possible to reskill the current workforce, teaching engineers the software or programming skills needed to utilise immersive technologies. Alternatively, a way needs to be found to entice skilled individuals into manufacturing.

Content Generation

What are the biggest issues around interoperability, data classification and trust in data? How do we ensure data stays accurate or deal with version management?

Just as in the business barriers sessions, people were concerned about content creation, in particular around the data translation process, and the potential fallout of using non-native geometry. A significant area of concern was around accessing resources for immersive technologies. It was generally agreed that a collaborative approach would be best, with companies and businesses sharing information such as models and programs. However, people were aware that this is easier said than done in industry, where such information may be required to be kept private within a company. Also, a topic of discussion was how to integrate immersive content, suggesting that the best way would be to integrate it with already widely used formats and programs.
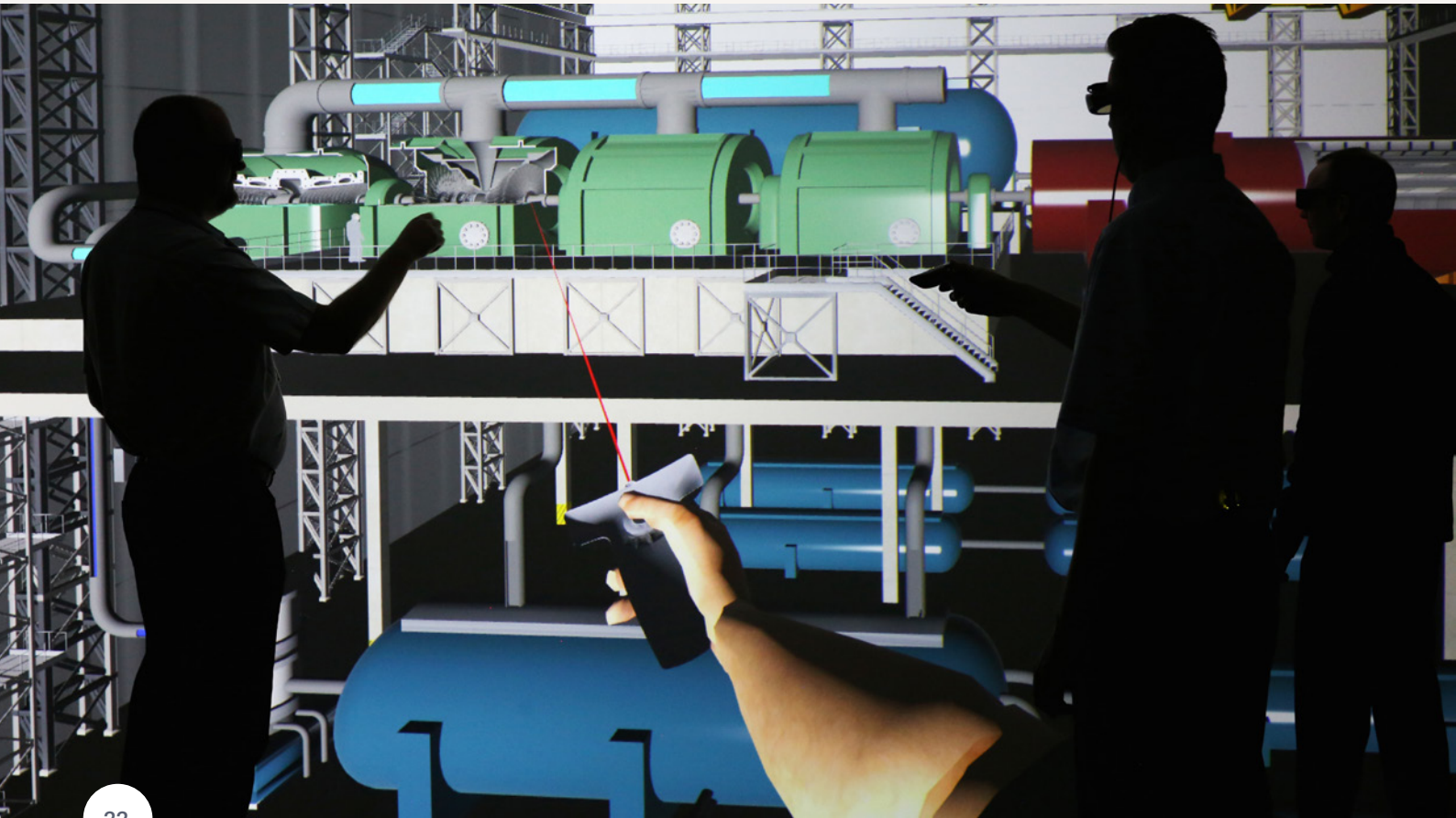
In-depth Interviews

In-depth interviews were conducted with experienced industrial users of immersive technologies. Participants from the following sectors were interviewed; aerospace & defence, automotive, large scale infrastructure, architecture & construction, utilities and oil & gas.

Opportunities

What typical problems or use cases do you see as opportunities to apply immersive technologies?

One interviewee identified that they didn't see their use-cases with immersive technologies as "typical", as it depended "on who you speak to within the business", suggesting that often the use-cases were very specific. They discussed that in large infrastructure industries "the main use case we have is probably more training; awareness training to prepare engineers for situations they might come across".

In the construction industry, examples were given that there is a need to "engage with the three-dimensional data" which is an opportunity for immersive technologies to be applied. Also suggested as an opportunity was the ability "to make [processes] more efficient and cost efficient".

Efficiency and cost reduction were also stated as drivers by other interviewees, along with the desire to "continuously improve processes", make for "quicker product industrialisation" or to meet a "new manufacturing requirement".

Even the need to update to meet legislation requirements may be an opportunity to use immersive visualisation: "the legislation has an effect... i.e. some chemicals might be covered under tighter restraints and restrictions that force you to change your procedures".

> Using things like the Oculus Rift and the like, you do spot mistakes on-site far quicker than you would otherwise.

Solutions

What technical solutions have you or your company developed?

An aerospace engineer interviewee discussed their use-case: a proof of concept was developed to demonstrate a hardware and software agnostic augmented reality system. An application was created and deployed to a mixed reality headset which displayed virtual work instructions, CAD overlays and virtual cues to guide a user to assemble a pneumatic circuit. The back-end integration allowed two-way communication to enterprise systems (MES and PLM) eliminating the need re-author content for the augmented experience.

In the construction sector, one interviewee discussed technical solutions for construction builders on-site, stating that "On-site, people have iPads with the model on the iPad all the time". This would be used to resolve issues or concerns "when they hit snags on site they automatically go to the 3D model". They also discussed using immersive solutions to interact with clients, as it would enable better visualisation of the products.

The defence interviewee stated that they use pre-existing software and solutions as there are "perfectly good ones out there on the marketplace to do the sort of work we want to do". They create new or use pre-existing 3D data to create VR scenarios for manufacturing facility planning. Once the base data is there, they add in enhancements

for realism such as textures, lighting and dressing up the space with everyday items – machines, desks, whiteboards and other items in the office spaces. To ensure accuracy they "work with the facilities manager, sub-contractor teams, design teams, architectural firms".

Utilities have used "virtual reality headsets that allow our engineers to bring to life plans for new treatment works and other equipment". They state that this immersive "cutting-edge technology is a viable alternative to traditional CAD visualisation as it allows for powerful interaction with conceptual design models".

> The goal of all this is to build up a really realistic and practical VR scenario.

Barriers

What barriers do you typically face when trying to implement immersive technologies within your business?

One common barrier identified was scepticism of the technology: "We still have the occasional people come in that are sceptical, but after they have tried it, they understand it and say it was beneficial." This can mean that it is hard to engage people with the immersive solutions as "they don't engage with the 3D and don't understand the value that it can bring to them". An automotive interviewee stated that this engagement can be difficult when immersive solutions are "perceived to be an additional task to their day-to-day job".

Another barrier can be the extra time required to create immersive solutions, as they can cause additional workload. In particular, reaching out to the various individuals you wish to consult with, "our biggest barrier is our time to go out and invite people in to engage with all the areas of the business to do the stakeholder management activity". An interviewee from the automotive sector discussed how barriers were "both cultural and technical", including issues with the technology being "too convoluted". Another technological barrier is knowing what to use in which scenario as there are a "range of solutions that are out there covering; different platforms, different hardware, different interactive devices if you like, different screens, different projectors". As discussed by the large infrastructure interviewee, Immersive solutions often tend to be requirement-heavy, whether that is requiring specialised

> There's definitely a competence barrier in terms of the VR and AR systems that are available.

equipment, or simply having large file size; "running large models over the network is a struggle due to bandwidth".

One company was able to avoid the skill barrier imposed by generating immersive experiences by having an individual who was "given the freedom to explore how to use the tool and make it work". An aerospace engineering interviewee discussed how "security is key". They referenced how the system needs to be robust and data needs to be secure and a plan needs to be created on how to manage this. Also discussed were that human factors and safety around the use and deployment of augmented and mixed reality devices, which needs to be identified and measured in industrial use-cases. Usability and ergonomics of both hardware and software requires development and further understanding.

Benefits

What business benefits have you seen from the adoption of immersive technologies and how have you captured and/or quantified these benefits?

One of the most repeated benefits across the interviews was cost reduction. This ranges from a reduction of development costs, to decreased travelling and planning costs. For example, a construction interviewee stated that "The cost of representing an environment to access remotely, can easily total all the travelling saved by not having to travel to go see the site." Also cited were cost benefits such as "Making changes in early stage of the projects is very cheap" compared to "changes when something's under construction which is incredibly costly."

A major infrastructure interviewee stated that "the business benefits are usually quite difficult to quantify" but went on to say that there are benefits from "time reduction" which can lead directly to "project saving". An interviewee from the automotive industry also agreed that "it's very difficult to quantify the benefits" but discussed retrospectively seeing the benefits for the technology for previous problems. The interview from the aerospace sector suggested that a full deployment of their VR and AR solution "could save aerospace manufacturers in order of hundreds of millions a year".

Another benefit is the visualisation communication aspect of immersive solutions. An interviewee from the construction sector stated that when using 3D immersive headsets "clients can engage much more easily with what the proposal is". Additionally, the clients being able to have visual representation of the project allowed them to give "more relevant feedback at early stages, so you can adapt the design to suit them early on".

Immersive visualisation in the construction industry is helping customers get better products

Future

Where do you see immersive technologies developing and being used in your industry sector in the future?

One of the suggested applications for immersive technologies across multiple interviewees is to interact remotely with clients. There are current limitations in that these clients often don't have access to the technology themselves, such as virtual reality headsets, though an interviewee stated that it is "becoming more likely people will have them at home", which would enable greater accessibility.

Some individuals interviewed had specific ideas of how they'll focus on immersive technologies in the future, whereas others discussed more generally the possible applications. Examples included "I can see advanced visualisation, whether its projection or immersion, being developed further to the point that all staff are not just aware of the technology, but understand how it adds value to what they're actually doing and how it fits into the bigger picture organisationally". Among the applications suggested by interviewees were "asset management and asset support teams", "learning and development tools", "remote support", "process monitoring and control", and "product based" applications.

Based on the results of their project, the interviewee from the aerospace sector stated that they will absolutely be doing more projects like it in the future. The interviewee

> Those that have used the technology… will want to carry it forward.

from defence discussed that they were excited about "the option of taking VR to the masses". The oil & gas interviewee stated that they are heading towards using immersive technologies to "facilitate globalisation when we have people sitting in different facilities around the world all being able to collaborate on a design in the 'virtual workshop'". All interviewees agreed that they would expect immersive technologies to be developed for their industry sector looking forward.

Summary
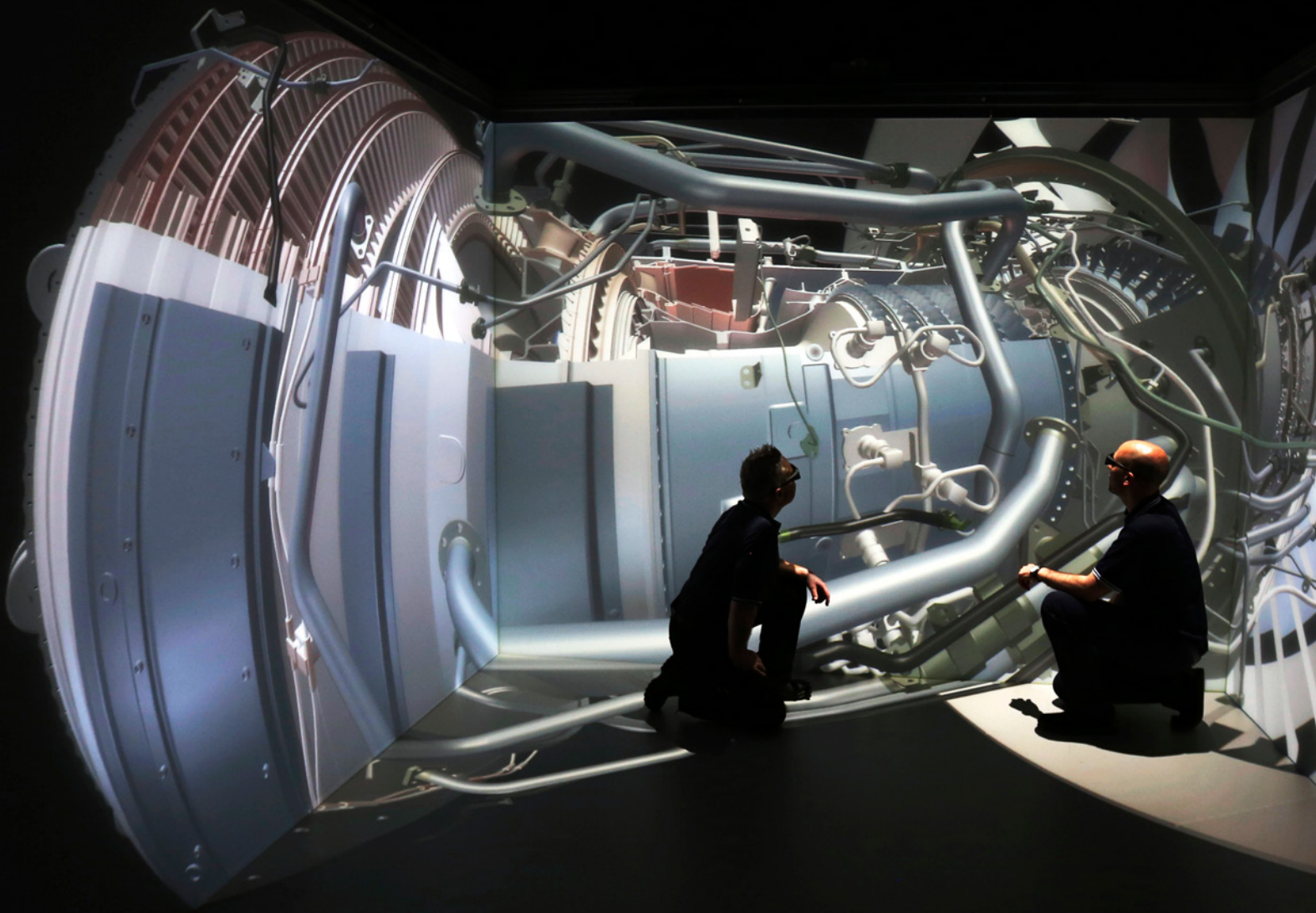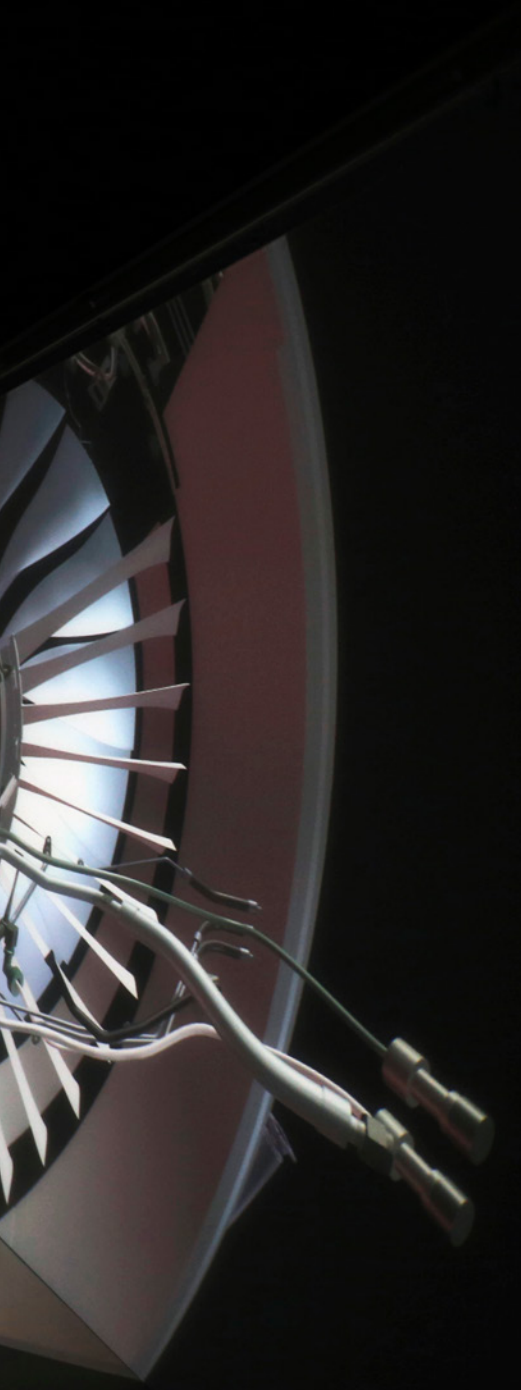
Are manufacturers using immersive technologies?

Just under half of the questionnaire respondents are already using immersive technologies in their industry roles. This suggests that these technologies are already prevalent in the manufacturing industry.

The questionnaire data implies that these technologies are more accessible to larger companies and organisations. However, the data also indicates that even some small organisations are already using these technologies, implying that these technologies can be accessed across organisation sizes. The roundtable workshop discussions included a mix of those already using immersive technologies, and those who wish to. As the technologies become low cost and consumer driven, they will be more accessible, which is likely to increase the uptake of their use.

In what parts of the business are immersive technologies being used?

The data demonstrates that immersive technologies are being used across many industry sectors, from aerospace engineering to construction indicating that immersive technologies are considered relevant to a variety of sectors across manufacturing. The job roles which use immersive technologies within these industries are also varied, including broader roles such as R&D, operations, production, as well as specific high-end roles such as CEOs and Directors, with marketing and communications driven uses.

Immersive technologies are used throughout the product life cycle. The most predominant use of was reported to be in stakeholder engagement, design, and training. Manufacturing, assembly, MRO (Maintenance Repair Overhaul), and disassembly were also reported to be lifecycle stages in which immersive technologies were also used.

Are those businesses using immersive technology creating solutions in-house or externally?

The results suggest that larger businesses (> 250 employees) are more likely to outsource content creation to third parties, with smaller companies generally creating content in-house. In the roundtable workshop discussions, most felt that in general outsourcing was a better option than in-house, although this would mean that the company would have less control and the costs would be higher. However, it was also considered that simpler tasks could potentially be done in house. It was also agreed that using existing solutions would be more reliable and risk-free, and worth the extra expenditure.

This perhaps explains why smaller companies tend to create content in-house, as smaller tasks more

manageable and the costs are lower. Larger companies, on the other hand are more likely to have the finances to have content generated by third parties, and perhaps value the ease and speed of outsourcing more.

> We use off the shelf solutions as we aren't in the business of developing VR systems.

What are the barriers to adopting immersive technologies?

Barriers to adoption were discussed extensively in both the roundtable workshop discussions and the in-depth interviews. There were a variety of possible barriers to adoption of this technology identified including financial, skill-based, cultural and demographic based challenges. Issues also arose over data governance, incorporating both data handling and data validity.

The roundtable discussions brought up concerns with the user acceptance of the technology, and the impact on current business cultures and ways of working, including greater workloads and additional processes. Also identified were potential issues around system and application security, in particular the sharing of data in regards to IP restrictions and the reliability and security of data when shared.

What added value do immersive solutions provide?

Respondents to the questionnaire reported measuring success and value in multiple ways: money saved, increased productivity, improved quality, risk reduction and organisation perception, and to a lesser extent orders generated.

In the roundtable workshop discussions individuals from companies who are already using immersive technologies spoke about how VR has allowed them to save time and money. Examples included collaborative driven VR, reduction in the amount of travelling required, replacement of high-cost physical mock-up tools with immersive virtual environments, and immersive training solutions.

The interviewees stated that there were clearly cost benefits to the technology, with potentially huge savings if properly developed. One use-case scenario was suggested to potentially save the manufacturers "hundreds of millions a year". However when the benefits are less tangible, such as time saving and improved engagement, the interviewees reported it was difficult to put a quantitative value to such scenarios. Often, an accurate financial figure for savings cannot be generated making ROI calculations difficult.

What further opportunities are there for immersive technologies in manufacturing?

Many of those taking part in the roundtable discussions considered VR's best use to be as an education or training tool. Others suggested possible applications such as safety and remote support applications. Recommendations were also put forth to use immersive technologies for data visualisation, specific applications such as mapping a process, or more generally as an engaging method of user interaction.

The interviewees discussed their current use-case scenarios for what their companies are developing using immersive technologies. This ranged from virtual instruction, inspection, and verification in the automotive industry, to engaging with three-dimensional data in construction. As well as their current projects, they discussed potential uses, with opportunities suggested in asset management and digital work instructions for high value, complex assembly tasks.

> It has saved us £180,000 by not having to build real-life prototypes.

Future of Immersive in Manufacturing

Trends suggest that the use of immersive technologies will only increase over the coming years.[1]

Considering the above, relaying the benefits of these technologies to organisations across industry sectors has great value. Further, demonstrating how to implement these technologies successfully, can not only show organisations the art of the possible, but also help organisations with best practice, and provide clarity for those uncertain about how best to invest in immersive technologies.

Further interest lies in understanding the future adoption path of immersive technologies within enterprise level organisations. Understanding how best to overcome the barriers to adoption and why the use of these technologies is often siloed or isolated, is important to being able to encourage more widespread adoption.

> It will be a standard way of working in the future

1. Digi-Capital Augmented/Virtual Reality Report Q1 2018
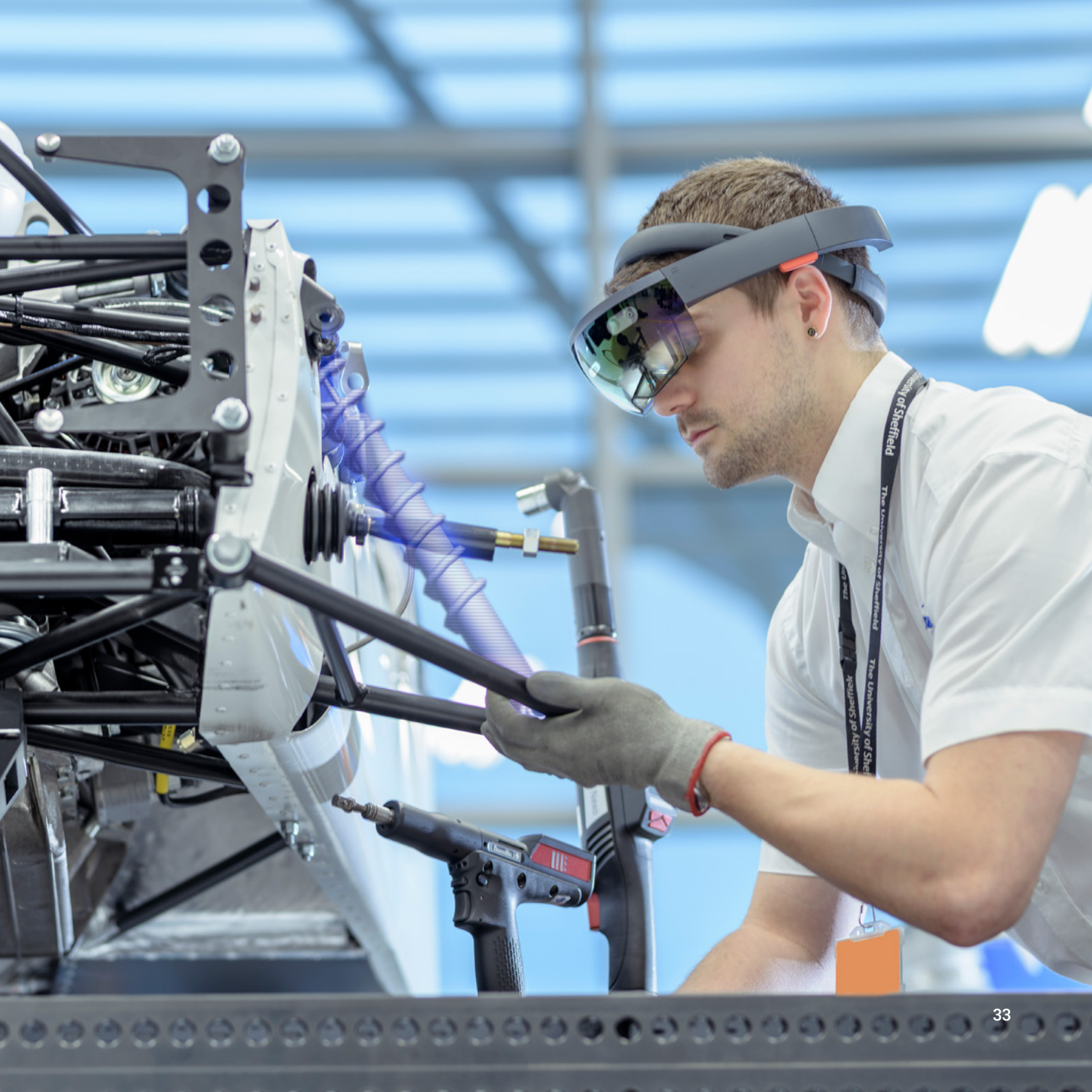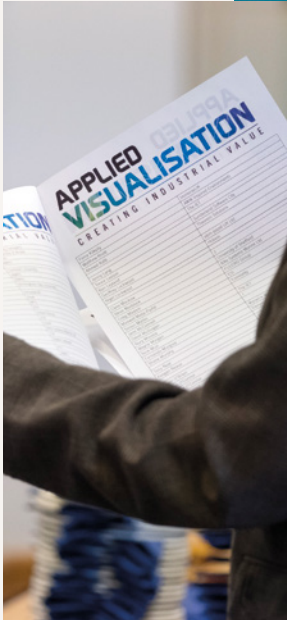
Acknowledgements and background

Immerse UK, Digital Catapult and the High Value Manufacturing Catapult have been working together on a large-scale programme of business support, funded by Innovate UK, for the UK's immersive technology industries since September 2017. This report forms part of that work along with the following complimentary reports, launched in Q2 and Q3 2018:

– Feasibility of an Immersive Digital Twin: The definition of a digital twin and discussions around the benefit of Immersion (High Value Manufacturing Catapult)

– 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).

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caTAPULT
High Value Manufacturing

We work with
Innovate UK

7 centres

Through our 7 centres we have capabilities and competences which span
basic raw materials through to high integrity assembly processes.
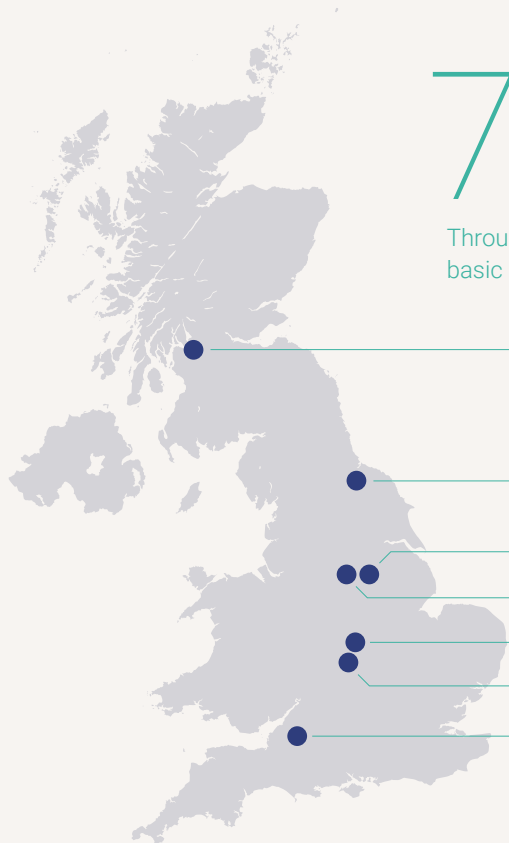
Advanced Forming Research Centre

Centre for Process Innovation

Advanced Manufacturing Research Centre

Nuclear AMRC

Manufacturing Technology Centre

WMG centre HVM Catapult

National Composites Centre

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