

# xR Network+

## Innovation in Future Convergent Media and Virtual Production Technologies

Reporting from XR Network+ Workshops 2023/4

White Paper

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Reporting from XR Network+ Workshops **2023/4**

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## xR NetwOrk+



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Engineering and  
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## Executive Summary

This white paper, emerging from XR Network+ workshops conducted across the UK in 2023/24, begins to establish a comprehensive research agenda within the field of Extended Reality (XR) technologies, with a specific focus on Virtual Production (VP). Led by the University of York and supported by the UK's Engineering and Physical Sciences Research Council (EPSRC), XR Network+ brings together academic and industry insights from UK innovation communities in order to support R&D for new XR products, services, technologies, and processes. The national XR Network+ workshops, held at several partner UK universities including the University of Edinburgh, the University of the Arts London, Cardiff University, and Ulster University, gathered data and insights regarding how innovation in XR and VP can be best supported, including current opportunities and barriers.

Key areas explored include:

- **Innovations in XR Technologies:** Discussion on how XR innovations are creating new services and products, enhancing efficiencies, and changing traditional processes by integrating the latest technological advancements.
- **Current Challenges:** Identification of the barriers to adoption and implementation of XR technologies such as cost, lack of skills and skills pipeline, and resistance to technological change, coupled with exploration of the broad utility and various applications of Virtual Production.
- **Opportunities:** Potential identified through the use of Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) suggests substantial improvements in efficiency and effectiveness across industries. However, this is a rapidly changing space and requires support to reach its potential.

The findings indicate a significant gap between technological capabilities and actual implementation, primarily due to cultural and operational constraints within the creative industries. However, the opportunity for significant economic impact and quality of life improvements is apparent, provided there is substantive investment in collaborative research, infrastructure and skills development. Our recommendations for supporting

Virtual Production include strategic advice targeting researchers, industries, and funding bodies to foster an environment conducive to innovation within the XR domain, focusing on training, financial support, policy-making, and collaborative efforts. It is clear that there is a need for impact-driven, applied research which quickly shares outcomes and findings. In addition, discussions on VP's potential to support environmental efficiencies, and equality, diversity, and inclusion, need robust investigation and evidencing.

We emphasise that XR and VP technologies stand at a pivotal point nationally and internationally, at a time when the UK is leading in this field with significant R&D and commercial investment in facilities, with a high level of industry interest, and engagement. If effectively nurtured through strategic collaboration, funding, and policy support, these technologies can lead to revolutionary changes in how industries operate, significantly boosting both economic growth and enhancing quality of life. The paper serves as a strategic blueprint for stakeholders across various creative and technological sectors to leverage the potential of XR technologies, driving research, development, policy, and practical applications toward a technologically integrated creative future. It also serves as an initial evidence-based statement of intent for XR Network+ that the team will revisit at various points as the project develops.

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## 1. Introduction

XR, or Extended Reality, is a term that encompasses all real-and-virtual combined environments and human-machine interactions generated by computer technology and wearables. Extended Reality (XR) technologies, encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), represent a frontier in immersive experiences that have transformative implications across a wide array of sectors. In education and training, XR facilitates the simulation of complex, hazardous, or costly scenarios, providing invaluable hands-on experience without the associated risks. In the entertainment industry, XR enables deeper engagement through interactive gaming, wide ranging virtual performances, and immersive cinematic experiences. Industries such as design and manufacturing utilise XR to interact with and visualise 3D models, significantly enhancing the understanding of product designs before physical prototypes are created. In retail contexts, XR technologies are changing the customer experience by enabling virtual try-ons and in-situ visualisation of products, and creating other types of novel consumer experience. Additionally, the healthcare sector employs XR for advanced training in surgical procedures and enhances real-time patient care by integrating vital data overlays during surgeries.

This continuous innovation in XR not only pushes experiential boundaries but also proposes substantial economic opportunities and improvements in quality of life, making it an essential area for continued research and development, in a rapidly changing innovation space. In particular, recent advances in Virtual Production (a new way of making film and television that harnesses the power of virtualising technologies to create digital environments, which can be visualised and controlled in real time; see Willment & Swords, 2023) have demonstrated significant economic and social potential, for example in supporting remote collaboration and supporting diversity, whilst also reducing the costs and environmental impact associated with traditional filming processes (Keeney, 2023).

XR Network+ Virtual Production in the Digital Economy<sup>1</sup> is a project led by the University of York and funded by The UK's Engineering and Physical Sciences Research Council<sup>2</sup> (EPSRC) to understand innovation in this evolving space. XR Network+ builds a bridge between five UK Arts and Humanities Research Council (AHRC)<sup>3</sup> Creative Industries Cluster Projects<sup>4</sup> and the significant interest that has emerged in supporting R&D in XR technologies

as they converge with Virtual Production (VP) (XR Network+, 2023). Together with The University of York, XR Network+ is conducted in collaboration with the University of Edinburgh<sup>5</sup>, University of the Arts London<sup>6</sup>, Cardiff University<sup>7</sup>, and Ulster University<sup>8</sup>.

This white paper analyses and combines reflections from four XR Network+ workshop events held 2023-4, at the university partner locations in Ulster, London, Edinburgh, and Cardiff, and an innovation showcase at the University of Portsmouth<sup>9</sup>. It draws on notes gathered and collated from across these five events by representatives of the XR Network+ team. These notes were then analysed using a mix of inductive and deductive coding, with relevant themes drawn out to form three main sections, covering important themes emerging from Virtual Production, current challenges, and how the future development of the Virtual Production industry can be supported.

While XR utilises LED screens and extends them with real-time game engine technology, VP tends to describe more specific use cases for creating TV, film and video products where “[i]n broad terms, Virtual Production is a way of making film and television which harnesses computer generated content that allows real-time visualisation and control of the digital environment in which you are shooting” (Swords & Willment, 2024). Combining physical elements (actors, props, partial sets) with digital elements (rendered on LED screens called a volume), VP goes beyond familiar green (or blue) screen technology to merge physical and digital elements in camera. This report engaged various industry experts and researchers to focus on the potential for using VP as one emerging aspect of XR that has recently gained much traction.

How best can researchers respond to this digital turn in the production of immersive experiences, including XR and Virtual Production? What are the emergent issues and current challenges being faced by both researchers and industry? How can further innovation within the Virtual Production industry best be supported, particularly in environments that support traditional university-based research, as well as industry research and development, and all related interactions between these different actors? This white paper aims to capture the input of industry and XR Network+ collaborators across the five partner universities and their associated geographies, and propose a research agenda to support innovation in XR technologies in the UK.



## 2. Innovation in XR Technologies

At “the highest level, innovation can be defined as making something new that creates value” (Ottinger, 2021). The Oslo Manual (the international reference guide for collecting and using data on innovation, providing the basis for the Organisation for Economic Co-operation and Development<sup>10</sup> and others to collect and publish statistics on business innovation) chooses to define innovation as:

*a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process).* (OECD & Eurostat, 2018, p. 20)

Innovation in XR has the potential for both the production of new products and services (which can potentially be monetised), and also to change existing processes and procedures in the creative industries, introducing efficiencies, creative opportunities, and potentially environmental benefits. XR, including Virtual Production “can provide huge opportunities for extending a company's core business offering” (Willment et al., 2023, p. 17). Changes in the market, many of which resulted from the sudden pivot to digital during the Covid-19 pandemic,

“offered companies opportunities to undertake R&D, becoming ‘first movers’ to take advantage of the Virtual Production market” while “[c]ompanies who were slower to react have sought to catch-up by acquiring or partnering with organisations who have the required resources, knowledge and services to help them compete” (Willment et al., 2023, p. 19). As a result, “the potential of XR to reshape industries and create new business opportunities has captured the attention of entrepreneurs and investors alike, leading to the emergence of numerous early-stage businesses venturing into this exciting field” although “the XR industry remains in a dynamic and evolving state” (Johannesson & Karlsson, 2023, p. 2). The current innovation ecology surrounding XR is therefore vibrant, and worth understanding to establish trends, to identify ways in which policy and funding can support this activity, and to help companies and academic researchers to target their R&D activities as they seek to develop timely new technologies and processes that result in novel goods and services.

<sup>1</sup> <https://xrnetworkplus.xrstories.co.uk>

<sup>2</sup> <https://www.ukri.org/councils/epsrc/>

<sup>3</sup> <https://www.ukri.org/councils/ahrc/>

<sup>4</sup> <https://creativeindustriesclusters.com>

<sup>5</sup> <https://www.ed.ac.uk>

<sup>6</sup> <https://www.arts.ac.uk>

<sup>7</sup> <https://www.cardiff.ac.uk>

<sup>8</sup> <https://www.ulster.ac.uk>

<sup>9</sup> <https://www.port.ac.uk>

<sup>10</sup> <https://www.oecd.org/en.html>

### 3. Methodology

Five openly-advertised events were held across the UK in 2023/24, attended by a mix of industry representatives and academic researchers. The four events held at partner institutions followed the same format, with talks, open discussion, then break-out groups responding to a set of prompts to elicit discussion. The roadshow event at the University of Portsmouth had a technology demonstration, followed by a roundtable discussion and an online questionnaire asking for feedback.

Venue	Date	Number of attendees	% of attendees from academic community
School of Communication and Media, <b>Ulster University</b>	8th May, 2023	51	4%
Fashion, Textiles and Technology Institute, <b>University of the Arts London</b>	15th May, 2023	50	64%
Design Informatics, <b>University of Edinburgh</b>	24th May, 2023	75	44%
School of Journalism, Media and Culture, <b>Cardiff University</b>	15th November, 2023	52	37%
Centre for Creative and Immersive Extended Reality (CCIXR), <b>University of Portsmouth</b>	5th June, 2024	35	49%
<b>Total</b>		<b>263</b>	<b>39%</b>

**Table 1:** attendees at XR Network+ events. The % of attendees from the academic community indicates the relative proportions of industry and research colleagues attending, with a predominance of industry partners at most events except London.

The same five questions were asked at all four partner events:

- 1. What does Virtual Production mean to you?**
- 2. What are the main areas of research in Virtual Production that you are interested in?**
- 3. What are the challenges in engaging in Virtual Production research?**
- 4. How can we support engagement between researchers and industry in Virtual Production?**
- 5. How can XRN+ best support research in Virtual Production?**

Extensive notes were taken both by project members and attendees, to track discussions. These were later transcribed by project members and combined with the online feedback comments from the Portsmouth showcase. A reflexive thematic analysis (Braun & Clarke, 2021) was undertaken to elicit the main themes, concerns, and opportunities discussed. Quotes given below corresponding to the themes are taken from these event notes (occasionally lightly edited for readability while retaining sense and most wording). The comments are anonymous: no identifying characteristics were gathered at any of the events. Ethical approval for this activity was granted by the School of Physics, Engineering and Technology, University of York, as the project host institution, and Edinburgh College of Art, University of Edinburgh, as project partner.



## 4. Industry, Creative and Academic Perceptions of Virtual Production

### a. Virtual Production is rapidly evolving and has cross-disciplinary appeal

The technologies involved in Virtual Production (such as real-time game engines, motion and volumetric capture, LED wall and visual presentation technologies) are not new. However, the convergence and application of these technologies within film, TV and other media is generating new approaches to production. This new convergence of these different technologies means VP remains in its infancy. Those working in the VP industry are therefore in a phase of creativity and discovery, working and learning with this evolving technology. As such, there is still a lot of discussion about how we define VP, and the fact that different individuals and sectors understand VP in different ways. There continues to be a lack of knowledge around what Virtual Production is and how it can be used.

Although understandings of technologies and approaches may remain in flux, the opportunities that Virtual Production provides means there is interest in VP from across many different cross-disciplinary arenas. Across the workshops, many different areas of research interest therefore emerged, including the use of VP for training applications, within the fashion industry or to expand 'live' performances, (digital) theatre, and cultural heritage. There was also interest in the implications for screenwriting and script development, including the modelling of virtual environments for concept generation and testing – known in other contexts as 'digital twinning'. Across each of these areas of interest, a common theme was how VP influenced audiences and their relationships and interactions with content. This included reflections on the potentials for new opportunities for interactivity and choice, and therefore the potential to create more immersive audience experiences and multi-modal engagements and perceptions.

“Virtual Production seems like an unmissable but difficult train to catch”

“Change is inevitable in this sector – we need to upskill people for change itself”

“We need deep dive workshops, to articulate what VP is! ”

“Virtual Production is too broad!!! We need more specific language!”

“We need to be realistic versus vision, and provide clarity around possibilities / expectations / capabilities of tech”

## b. Virtual Production requires new production processes and pipelines

Pre-visualisation (or 'pre-vis') is a stage of pre-production (prior to on-set or on-location filming in traditional film/TV production contexts), which provides space for creative questions or changes by the cast and crew before official shooting begins. Within pre-visualisation, VR enables filmmakers to be able to 'scout' a virtual environment. This may be a digital version/twin of a real place, or it may be the construction of a virtual location. Recent conversations have also revealed the use of game engine technology to help design and block stages for theatrical performances, and there is much potential for using pre-vis in live performance (as well as the cultural exhibition and immersive experience sector).

Using VR in 'pre-vis' also allows for real-time collaboration, with production crew able to make modifications to virtual environments in real-time. However, this also means that most changes or issues should be fixed during the pre-visualisation stage of VP. This differs from traditional film or set-making, where any changes are predominantly made in post-production (post on-set or on-location filming). One benefit of fixing issues during pre-visualisation is that most shots can then be captured in final image quality live, in-camera, without the need for additional major visual effects work or amending in post-production (ShowrunnerTech, 2024), which should reduce the amount of costly post-production work, such as the removal of 'spill' from greenscreens (Willment & Swords, 2023).

As Virtual Production shifts focus, finance and resourcing from pre-production into the actual production stage, directors and producers may feel that it is more financially risky than traditional approaches, with limited room for mistakes in the overall production schedule. This risk is compounded by the infancy of VP workflows and the potential for technical breakdowns during VP shoots. Resistance to VP may also come from other creatives who believe the technology puts their values, skills and jobs in traditional production at risk.

“There are high expectations with the possibility for mixed results in a conservative industry”

“There is resistance to change/new tech by people who have traditional values and skills”

“Can we identify areas that are mutually beneficial and meet the KPIs of SMEs without taxing resources?”

“What are the limitations of screenwriting virtual locations and what does this mean industrially, economically and environmentally?”

“How do you transfer all these stated benefits into small companies who can't take the risk?”

“There is a fear that VP will lead to loss of jobs and traditional spaces (e.g. loss of cinema)”

“Using new tech in traditional set ups can cause challenges in terms of culture change, therefore best practice is in engaging groups. It is a matter of language or management of current crews – upskilling and knowledge exchange”

## c. Virtual Production has the potential to support EDI and sustainability

Climate change is a pressing threat to all industries, and the creative industries are not excluded (Graves & Morris, 2023). There are potential sustainability gains from using VP rather than traditional production methods that can involve transporting hundreds of crew members and temporary sets to remote locations. Virtual Production offers the opportunity for film/TV production to be undertaken remotely, with some members of the crew not needing to be located in the same physical space (see for example the work of Richard England and Reflex Arc in the creation of film, TV, and accessible interactive experiences (England, 2023). Through VR-based 'pre-visualisation', members of the crew can be situated around the world but come together to 'scout' virtual environments. This remote collaboration may offer new environmental opportunities, given the reduced need to fly all cast and crew to physical locations (Willment & Swords, 2023).

The potential for remote working within Virtual Production could also help to increase accessibility, enabling marginalised groups who have previously been excluded from centres of film and TV production to have their skills in VP recognised (Willment & Swords, 2023). GlassShot and Turbulence's initial report on Virtual Production and its Role in Accessibility (Miles Thomas & Burke, 2023) revealed that rather than 'solving disability access problems' their research made a fundamental switch to: "increasing accessibility for all, thereby creating greater access opportunities for everyone" (p. 20).

The move towards remote working may also provide opportunities for collaboration with smaller studios located outside of traditional geographic or economic centres of film and TV production. Such collaborations could lead to opportunities for the development of collaborative IP around virtual environments and assets.

“How can VP engage with research that is human rights related?”

“I want to know the whole process of VP and its environmental impact”

“What is the environmental impact of green screen production?”

“How can we improve accessibility for grassroots creatives, e.g. small theatres?”

“Challenges = you say UK but is this the Highland and Islands too?”



## 5. What are the current challenges for Virtual Production?

### a. Limited understanding of Virtual Production, and its opportunities

Many gatekeepers within the screen industries (such as long-established broadcasters, distributors and financiers) have a limited understanding of the challenges and potentials of Virtual Production, and how it could be used across different content genres. The media and screen profession in general would benefit from education in VP, and the broader opportunities and challenges of the technology, so that productions using VP have adequate access to finance and distribution channels. One successful example of this type of education is how the XR Stories project has worked with ITV Studios, to explore how digital storytelling (including associated Virtual Production techniques and technologies) can be used to extend the established universe of the longstanding TV drama Emmerdale. XR Stories and ITV Studios collaborated to explore how to use VP assets to create new interactive audience experiences, bringing current and future fans closer to the Emmerdale story world (XR Stories, n.d.).

Given the pace of development in VP technology globally, undertaking work to help different sectors understand the potential of VP is of paramount importance. Other types of industry include the wider apparel sectors spanning fashion, sports, to live entertainment and how they could harness Virtual Production to change the way products (clothing and costume of all types) are showcased, create new types of monetizable content, and provide experiences in wide ranging cultural contexts from heritage to performance sectors. Familiarising various actors in the XR ecosystem with this technology should encourage acceptance and uptake.

“What are the costs versus benefits?”

“What are the opportunities for creative vision?”

“It’s difficult. There is an illusion that it is all LED screens”

“How can we speak to an audience about this, and understand how that audience experiences it?”

“VP expands audience engagement – but where will young audiences be in 5 years?”

“There are easy pickings such as car chases. To do better, runners and writers need to understand how to write for VP so it’s not just car chases”



### b. Perceived challenges to realising ED&I and sustainability opportunities

At present much of the discussion around the environmental and Equality, Diversity, and Inclusion (ED&I) potentials of VP remain aspirational, untested and requiring further detail. Research on VP and sustainability suggests “it can reduce carbon emissions by 20% to 50% compared to traditional film production methods” (Keeney, 2023). The BFI-funded Screen New Deal: Transformation Plan for Wales highlights the case study by consulting company ICF, commissioned by Sony Pictures, which identified that greenhouse gas emissions associated with Virtual Production were found to be 80% lower than the emissions associated with shooting on location (British Film Institute, 2023, p. 53). Further knowledge and detail regarding the impact of the total compute, manufacturing and life cycle assessment of VP equipment is required, in order to advance development of future related technology. Suggestions for longevity of VP practices include embedding circular economy thinking and practices into all stages of the film and TV supply chain (Willment et al., 2024b) as well as efforts to advance creative industry stakeholders’ understanding of, and engagement with, sustainability and climate change research (Dales et al., 2023). Investment, as well as attention and evidencing, is needed in these areas.



**“The creative industries don’t feel sustainable as they are project driven. How do we change that to make things sustainable and therefore attract the right people and make them stay?”**

**“There’s talk of equality and inclusion but let’s see how that plays out”**

There are presently known issues of inequality and mistreatment in the TV and film industries (Bull, 2023; Ozimek, 2020) and care needs to be taken not to exacerbate them when introducing VP working practices (Swords et al., 2022). A report by Swords et al. (2022) describes the culture of overwork in the UK television industry and cautions that operating under such pressure – such as, for example, introducing unfamiliar VP technologies and workflows – can work against ED&I goals by putting pressure on training, progression, and recruitment processes. There is evidence that positive interventions can be made in these areas (Ozimek & Rueda, 2022; Raising Films, 2021; Thomas & Einarsdottir, 2023).

Ultimately, and unsurprisingly given this emerging area, more research needs to be commissioned into the environmental and ED&I potentials (and challenges) of Virtual Production, to ensure that any positive opportunities are realised.

### c. Communication challenges across disciplines and industries

Crew and the related workforce in general from across other industries bring with them their own backgrounds, ways of working, languages and terminology to the Virtual Production set. These different experiences, industry backgrounds and languages can create communication challenges, particularly with common terms and vocabulary. This can be as simple as different crew members having alternative names for different pieces of equipment. Each VP company has their own unique workflows and production standards, meaning there is little continuity across different teams and productions. Crews from different industries also bring with them different work cultures, which may pose a challenge in terms of ways of working. One example of this is professionals from the gaming industry who bring extensive experience of working with real-time game engines but may have limited experience of the high-pressure culture of on-set working (Willment & Swords, 2023).

**“Don’t be shy to share knowledge”**

**“We have to learn to work in different sectors”**

**“There are different languages across creative practices”**

**“There is a friction between industry expectations and academic teaching, learning and research contexts”**

**“Which VP? It means different things to different folks”**

**“We need a translator between technical staff, creatives, and producers”**



### d. Unrealistic expectations of Virtual Production technology

Game engine technology provides the mechanism through which to drive the vision of the creatives on the team. However, creatives who have not had experience with VP technologies may not understand its technical limitations, such as the game engine software at the centre of any VP stage. Creatives therefore may expect more from VP technicians and this relatively new production pipeline than is feasible, and so education around current limitations is needed to manage expectations of what is possible with the technology, as well as timelines and budgets. This education for creatives may also help writers and storytellers to better understand how to write for VP. Virtual Production has been heavily utilised in particular genres, such as science-fiction, or for particular shot sequences, such as car chases. A better understanding of VP, integrating it into all aspects of the creative and technical production processes, could lead to enhanced creative output.

“This is all experimental but there is no latitude for mistakes in production schedules”

“We need to reduce cognitive load for creatives, and the barriers to use”

“There’s a real tension between what the industry expects and what we can actually deliver from our research. And then you’ve got all these complications, like who owns the intellectual property”

“As a producer it’s a time expensive activity – we need to drill down how to earn £ from it as well as choose exciting developments and ideas”

“Can we magically create a way to align the different timescales businesses and researchers work to?”



### e. Prohibitive cost and access to infrastructure and equipment

Cost remains a fundamental barrier to widespread adoption of VP. The costs of creating (or renting) an LED-wall based VP studio are very high (with rentals often costing thousands per day). These costs can be particularly high when compared to traditional shooting methods such as filming on location or with a green screen. These high costs mean that indie studios and lower budget productions are often priced out of being able to adopt LED wall-based VP – potentially limiting ambition or new creative contexts. Hardware and software costs also remain a large barrier for individuals and SMEs wanting to make the move to working in VP, with the high costs of accessing the technology meaning that many companies struggle to be able to play, learn and prototype in VP. Much VP training also continues to focus on high-budget LED wall exemplars, with limited reference on how to adopt VP within lower budget productions or other places within creative workflows. There are however examples of lower budget success, particularly if large LED walls are not used. Views of Small and Clever Productions’ ‘How We Made a Comedy Series for the BBC Using Virtual Production’ (Moss, 2022) have now exceeded 185,000 on YouTube (Small and Clever Productions, 2022). They did not use LED screens but followed the process and pipelines of VP using green screen and have shared their learnings for all.

There is also limited discussion on distribution channels, and how to ensure that companies can earn money from producing VP content. Currently, the majority of LED volumes and LED-based VP studios are built and owned by large corporations (Willment & Swords, 2023). Many of these larger studios continue to privilege commercial opportunities, rather than providing access for local grassroots creatives and SMEs to use their LED volumes to test and develop concepts and work at an affordable level.

Recently the UK has had significant investment in VP facilities, which have yet to be fully deployed. These include a number across the UK, with UKRI investment initiatives such as the Creative Industries Clusters Programme<sup>11</sup>, CoSTAR<sup>12</sup>, and XRNetwork+, in addition to key investments from major entertainment companies such as Netflix, Disney etc.

<sup>11</sup> <https://creativeindustriescusters.com>

<sup>12</sup> <https://www.ukri.org/councils/ahrc/remit-programmes-and-priorities/convergent-screen-technologies-and-performance-in-realtime-costar/>

“Having access to equipment that will be there for the future”

“There is a limitation on access to equipment and funding”

“A kit directory please”

“Costs are a barrier – including to iterate ideas in a hugely technical field”

“We need an entryway into the VFX world especially for indie studios”

“Can we create affordable and accessible spaces and facilities where researchers and industry can co-exist / collaborate?”

“There can be an element of gatekeeping in the audience spaces that specific broadcasters like to work in”

“We need to manage risk differently to standard production. Cost of that mitigation can be high, if screens don’t work for example”

### f. Skills shortages

As identified in a recent StoryFutures (2022) report, demand for workers with VP skills and knowledge is far outstripping supply. There are talent shortages across all aspects of Virtual Production (Eaton, 2024), from technical and real-time game engine skills, to skills in financing and business planning, as well as new professional and technical skills (Willment et al., 2024a). Hence there needs to be investment in training the next generation of Virtual Production workers. However, there also needs to be investment in upskilling those already working in film and TV production at all career levels to work with VP, and for game developers, used to working within game-engine environments, to redeploy their skills in other creative contexts. Many smaller companies lack the time and financial capacity to be able to train or upskill staff to work in VP (Jones et al., 2022). For those who have the technical skills relevant to VP, the film and TV industry may represent a less desirable career option as film and TV work is often project driven, providing limited job security when compared to the full-time employment potentially available in other sectors, such as gaming. Such in-built precarity discourages those with the relevant skills joining the VP industry. It is also a challenge to train individuals to be resilient and adaptable when the VP industry (and technology) is currently defined by rapid evolution and change.

“Reskilling those working in traditional physical production so we keep advantage of their skills”

“Getting early career Unreal Engine and other tech staff to want to do XR / VP and not just games”

“It is difficult to train people in being resilient/ adaptable to change”

“Student engagement – we have to take time to teach the tech. How do they learn? How is it relevant? How do we best engage them, and what do we deliver?”

“There is a creative barrier to entry due to lack of knowledge and skills. We should focus on principles not platforms?”

“Directors used to traditional methods may need a change in mindset to best utilise VP. There needs to be training and a change in understanding about the tech”

### g. Finding appropriate collaborators for projects

Across the XR Network+ workshops, companies highlighted the challenges of finding appropriate collaborators and researchers to work with on Virtual Production projects. Universities offer a significant resource, and can also be a locus of legal advice and innovation support, including using non-standard interventions, as the Creative Industries Clusters Programme (UKRI, 2018-2024) evidences. However, one of the challenges for researchers (in a higher education rather than industry R&D context) in particular is their existing workload. If daily work is focused predominantly on delivering teaching, for example, there is little time available to invest into developing industry collaborations or exploring new opportunities for exploiting the potential of this technology. There were also questions and concerns around IP and copyright within industry and academic collaborations. Beyond this, there was also an admission that industry and academic timescales were often very different, and therefore hard to balance within collaborations, especially those focused on short-term deliverables.

“How do you persuade people to engage?”

“Getting the right introductions and companies willing to collaborate”

“Partnerships opportunities for SMEs to know who and what and when so it can be planned and resourced”

“How do you manage expectations: what’s the output?”

“We need to understand the capabilities of the university and expert academics. Look for good fit to work area (KTPs)”

“Don’t trick companies into doing projects that are purely for a university’s benefit”

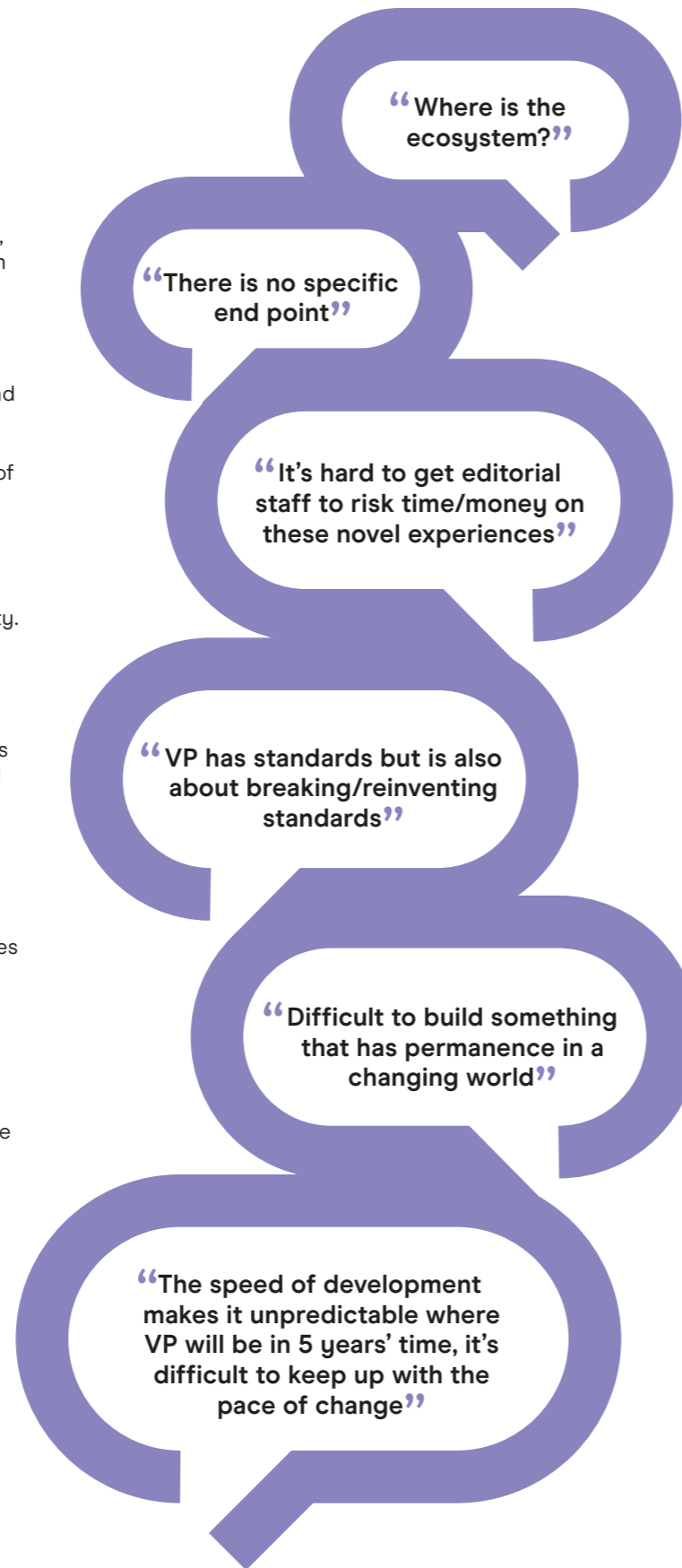
“We need a partner in the space as well as kit – people with reference points, contacts, understanding of risk”

## h. Uncertainty over the future of the technological and creative industries

The speed of change of technologies related to XR (Ball, 2022; Henry & Shannon, 2023), and especially AI (Graylin et al., 2024; Hackl & Cronin, 2024; Suleyman & Bhaskar, 2023), as well as the positive and negative claims made about the potential of such changes (Narula, 2022) make it difficult to predict how the use of XR across the creative industries will evolve over the short, medium and long terms. The experience of the Covid-19 pandemic introduced another element of uncertainty in long-term planning (Swords, 2020), with all industries more aware of the contingencies that need to be considered.

The rapid application and development of Virtual Production technology and approaches means there is a high degree of uncertainty about its future trajectory, and this brings both opportunities and areas of instability. We are already beginning to see the next iteration of VP, with 2023 developments including the use of generative AI tools (such as Dall-E or Midjourney) for virtual environment creation (Kadner, 2023), and further tools being developed in this emergent industry, such as Holodeck (Yang et al., 2024), and those being developed by Disguise and Cuebric (Disguise, 2024).

We could see the re-use of VP assets from linear storytelling (such as films) into non-linear storytelling formats, such as immersive VR experiences and games (SAUCE, 2020). There could be opportunities for the exploration of new content forms, which develop features such as cross-modal perception and other new forms of sensory audience engagement (Abdo et al., 2024) with adequate R&D (and associated funding to support this). This evolution in Virtual Production technologies, applications and workflows could revolutionise storytelling. However, the rapid development of and increasing applications for VP also means it is impossible to predict what workflows will look like in five-to-ten years' time. Note also that the XR Network+ project is running over five years and looks to establish a roadmap for 10 years beyond its end date of 2027.



## 6. What support does the UK VP industry need?

### a. Funding opportunities

Funding R&D is crucial for developing products, processes, and skills, and facilitating networking and collaboration within the Virtual Production space. Targeted funding approaches and applications proportionate to the size of funding on offer can reduce friction during the process, as can clearly communicating funding criteria and timelines for decisions to be made. Making clear the expectations around timelines, when different funding calls will open and close, and eligibility criteria, allows researchers and companies to appropriately plan and resource their time. These methods can help with attracting the most relevant candidates and not overburdening applicants.

Funding opportunities would be more valuable if they also extend to administrative and technical support, professional development, industry placements and conference attendance. Additionally helpful are opportunities for companies to showcase their work, and the buy-out of university-based staff time from teaching and/or administrative duties, which would help encourage industry engagement, including skills development, for these researchers at teaching-intensive universities.



### b. Flexible funding deliverables

Innovation in XR and VP R&D would be aided by funders being flexible in their approach to the deliverables provided by companies. If deliverables are not over-determined but led by and designed by industry, this allows space for curiosity, stimulation, and learning from failure. If companies are asked to plan too far in advance in relation to deliverables, this limits opportunities for exploration. There are benefits to both developing new projects or ideas and also supporting the improvement and commercialisation of existing products and / or IP.



### c. Networking and relationship building

There is a need for a body that can act as a ‘front’ door to the Virtual Production community, actively building and facilitating networks. (It is likely that the AHRC-funded CoSTAR Network will provide this, once fully established<sup>13</sup>). Work should be invested into actively creating opportunities for people to meet and learn together, both at a national and international level. These opportunities should take multiple forms, such as specific networking and meet-up events, meetings, panels, conferences, and mentoring opportunities and make a conscious and concerted effort to bring together academic researchers, industry professionals, freelancers, SMEs and larger firms. Opportunities for showcasing new and ongoing work, through the creation of regular showcase events, would also be beneficial, as would the development of a ‘bank’ of interested industry partners and academics (which includes their areas of interest/expertise). This ‘bank’ could be made available to the XR Network+ community to facilitate collaboration, although there are challenges here in terms of managing and sharing data across a wider network, and defining who is within or outside of this community and therefore able to access this information. The development of these networks is important for learning about the current needs of the industry, which could help to tailor subsequent funding calls or in-kind support. For example, XR Network+ launched an R&D challenge posed by the Royal Shakespeare Company in June 2024, to explore the creative possibilities of Virtual Production technologies in live theatre performance (XR Network+, 2024). In supporting two project teams, this guided call aims to build skills, produce innovative outputs, but also support the community in conjunction with a leading partner. The creation of these networks and provision of links to established partners is central to ensuring innovation continues, even after any funding has ended.

“A scheme for industry placements for technical knowledge”

“Technicians can be a useful bridge”

“We learn by doing – so we need to incentivise doing”

“Bring together artists and freelancers and researchers, not just bigger firms”

“Demo events (within your facility) and talks from large studios using this tech commercially already, and with pizza!”

“Create opportunities for ‘collisions’ between tech and creatives”

<sup>13</sup> <https://www.ukri.org/councils/ahrc/remit-programmes-and-priorities/convergent-screen-technologies-and-performance-in-realtime-costar/>

### d. Provision of technology and VP space

Those undertaking innovation in Virtual Production require affordable and accessible R&D spaces, where industry and academics are able to come together to play, test, and collaborate on VP projects. Access to collaborative spaces, technologies (and attendant technical support) are necessary to foster learning, exploration and growth. These spaces would ideally also provide in-kind support to help troubleshoot any technical issues that might occur during collaboration. A directory of such facilities, made available online, would make finding and accessing them easier.

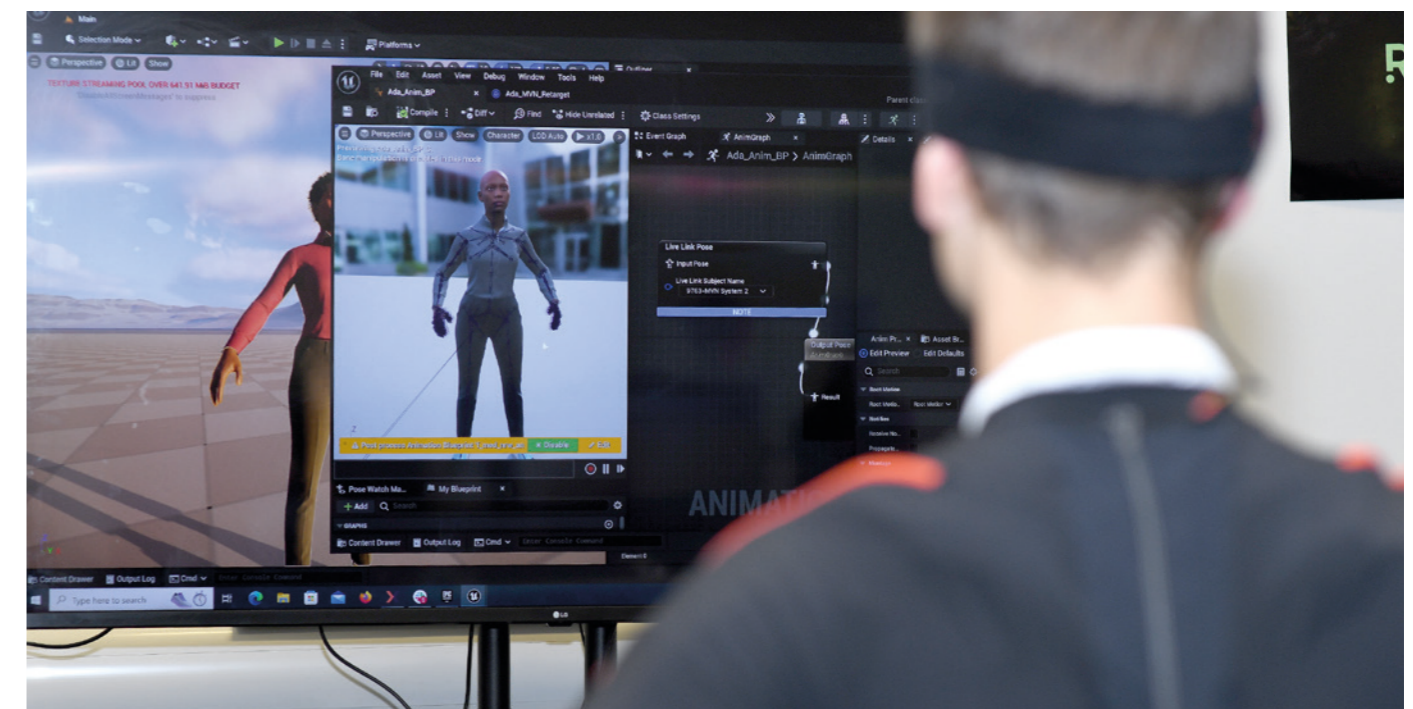
“We really need the right setup – the space, the gear, everything. Without the proper kit, even the best ideas are going to struggle to take off”

“Can we improve access to the infrastructure required?”

“Development of artist facing tools”

“Space to explore and scope an idea before an application”

“We need to play and learn and prototype – at reasonable cost!”



### e. Training Programmes

There is a need for varied training programmes to ensure the development of appropriate knowledge and skills for the successful implementation of VP. This training provision should be varied, addressing all levels and entry points into VP. A comprehensive training pipeline would include introductory sessions to ‘demystify’ VP for creatives, industry representatives, technicians and researchers who are interested in understanding and potentially using these technologies, as well as for gatekeepers and decision-makers such as broadcasters, funders, and policy makers. Training provision may include the development of specific programmes or ‘bootcamps’, focused on digital skills provision (such as training in computer programming and/or the use of game engines) as well as related skills and areas of expertise, such as contracts and intellectual property rights. There is also the potential for developing industry standard training programmes with their own recognised accreditation to ensure engagement and interest. Mentoring is an important tool in the creative industries and programmes to connect established organisations with individuals, SMEs and those looking to upskill could support career or company development.

It is also important to build on examples of successful Virtual Production training initiatives. Examples of success include the ‘VP Futures’ programme<sup>14</sup>, a co-production training and development programme between StoryFutures Academy<sup>15</sup> and Future Screens NI<sup>16</sup>. This partnership was designed to deliver a package of targeted VP training, development, and production support for the UK’s screen industries (StoryFutures, 2022), demonstrating the importance of in-kind support of programme partners, including Industrial Light and Magic<sup>17</sup> and Epic Games<sup>18</sup>, for those enrolled on the course.

“There is a need to balance the costs necessary to develop knowledge, and the skillset applicable to VP, with low funds for training currently available”

“How can we best embed VP education (and ED&I) to roll out as policy and into professional practice”

“Establish industry standard professional training programmes? It might raise both engagement and interest”

“Demystifying the pipeline and processes, and understanding the skills needed to make it work”

<sup>14</sup> <https://www.storyfutures.com/resources/storyfutures-academy-presents-vp-futures-behind-the-scenes-of-a-virtual-production-accelerator-programme;>  
Available at: <https://web.archive.org/web/20221220022947/https://www.storyfutures.com/resources/storyfutures-academy-presents-vp-futures-behind-the-scenes-of-a-virtual-production-accelerator-programme>

<sup>15</sup> <https://legacy.storyfutures.com/about/storyfutures-academy/>

<sup>16</sup> <https://www.futurescreens.org>

<sup>17</sup> <https://www.ilm.com>

<sup>18</sup> <https://www.epicgames.com/site/en-US/home>

## 7. XR Network+’s Future Role

During its funded duration (2022-27<sup>19</sup>), XR Network+ is uniquely positioned to be able to provide companies with access to specialist knowledge and advice through their links to various UK universities, and the small and larger grant funding<sup>20</sup> it is delivering throughout the UK. The network can play a key role in demonstrating to companies the capabilities and ‘fit’ of a university and expert academics, and how a relevant university might best support a company. KTP (Knowledge Transfer Partnerships) or Industry Fellowships could provide support through access to new graduates and academic researchers to build companies’ technical expertise and innovation. XR Network+ is also well placed to become embedded within the broader universities’ student population training provision, providing an opportunity to show how new technologies (such as VP) are influencing industry – in addition to advancing our understanding of new and future technologies, and informing and supporting the development of future technology related research. XR Network+ is also supporting the embedding of outputs from any industry collaborations into teaching resources. This training provision could help to ensure that students remain well equipped for industry careers.

However, it should be noted that the funding for XR Network+ is for a defined period of time and is not a long-term support mechanism for the creative technology industries. Likewise, the AHRC-funded CoSTAR Network, which aims to support a similar domain, covers the period between 2024-2029. Building mechanisms – including an ecosystem – which continue to support innovation in XR beyond the end of these programmes should be a priority for funders as they plan ahead to future rounds of innovation funding.

Some of the factors here are within the control of XR Network+ (for example, how the funding programmes are organised). However, many are not, due to the time-limited and resource-constrained nature of the funding (which is in common with all UKRI grants).

Further resourcing for the sector is needed. Addressing the issues identified in this white paper requires a concerted effort not only from technical and academic leaders but also from industry stakeholders who must be brought into the conversation early and persuaded to remain engaged. Joint industry and academic approaches to strategic collaboration, targeted funding, and continuous professional development will provide the best ecosystem to support innovation in the XR space. However, this will require adequate and continuous resourcing.

<sup>19</sup> <https://gtr.ukri.org/projects?ref=EP%2FW020602%2F1>

<sup>20</sup> <https://xrnetworkplus.xrstories.co.uk/funding/>

“Where are we going? What will UKRI / UK Government invest in?”

“We need to keep an eye on trends”

“We need investors who understand all of the above”



## 8. Recommendations

Various priorities have emerged from the community engagement at the XR Network+ events, which allow us to formulate recommendations for researchers, universities, SMEs, larger companies, funders, and the whole XR ecosystem.

### For Researchers:

- There is significant opportunity to undertake novel and innovative research in VP with the potential for commercialisation; however this is best done in conjunction with industry partners, and with careful management of this collaborative relationship.
- There is also the need to record evidence of, and predict activity in, the XR and VP space. There is a pressing need to undertake research that evidences many of the assumed advantages of VP, including the oft-suggested environmental benefits and the suggestion that it will support equality, diversity, and inclusion within the creative industries. It is unlikely that industry partners have the capacity to undertake and communicate this type of research.

### For Universities:

- Universities have a timely opportunity to provide the locus for innovation activity in VP, including access to facilities and equipment set up to encourage experimentation, and the provision of training (both to their student body and to local industry). Using estates and facilities in this way provides the opportunity to support the local and national innovation ecosystems in the creative industries at an exciting time for VP development.
- Universities have the opportunity to experiment with different models of intellectual property, and the provision of legal and business support of benefit to the creative economy. This shouldn't be seen as a 'profit-making' exercise alone, but the creation of a tide which floats many boats, as a locus of 'createch' innovation which drives impact.

### For SMEs:

- Engaging in the emerging Virtual Production ecosystem provides many networking benefits, including making contacts, access to training, and being aware of trends.
- Entering into collaborations with researchers, institutions, and other industry partners in the creative economy may provide competitive advantages in the VP space. However, the needs and capacity of small businesses must be carefully balanced with conflicting needs and value systems of other partners, and this should be set out in detail at the outset of partnerships.

### For larger and more established Industry Partners:

- By engaging actively in innovation partnerships, larger and more established technology firms can contribute to a robust ecosystem in Virtual Production, while also reaping their own benefits as the centre of technological advancements, enhancing competitiveness. Activities may include the development of novel technologies and workflows, the establishment of internships and fellowships to encourage knowledge exchange, and providing access to VP tools and spaces (including rental, subsidisation, sponsorship, and training activities). In return, established firms can develop bespoke solutions, engaging in state-of-the-art knowledge.
- Partnering with universities and their related communities will also provide mechanisms for talent recruitment and development, and developing relationships around cutting-edge technologies can provide training tailored for the future industry workforce.

### For Funders:

- A range of large scale and smaller funding is needed to support the variety of projects operating in the XR space. It is important that this is delivered in an agile manner, allowing R&D to happen in both academic institutions and industry as well as in combination. In particular, given that the majority of companies in the creative industries are SMEs, the processes for applying to and awarding funding for innovation in XR must reflect the needs and business practices of these practitioners.
- The XR sector is dependent on a mix of private investors, incubators that support individuals and ecosystems, and innovation funding from governments and centrally-funded research projects. We stress the importance of the support of this ecosystem, and the building of networks across different partners via funded activity.

### For General Ecosystem support:

- Specific industry networks are needed to provide joined-up thinking to access equipment, infrastructure, training, and innovation opportunities in XR and VP. This will benefit all players in the ecosystem to engage with and support these networks, encouraging a plurality of experiences, technical expertise, viewpoints, access to technology, and creative approaches to allow innovation to flourish.





## 9. Conclusion

This white paper, stemming from the collaborative efforts under the XR Network+ initiative, synthesises the broad spectrum of insights and discussions from a series of workshops focused on the advancing field of Virtual Production (VP) and Extended Reality (XR) technologies. Anchored by the innovative collaborations among the University of York, University of Edinburgh, University of the Arts London, Cardiff University, and Ulster University, this report offers a comprehensive outline of the current landscape, challenges, and burgeoning opportunities within VP as observed throughout 2023 and 2024.

This white paper has started to frame a coherent research and development agenda that refines our understanding and application of XR technologies in various sectors, including film, television, healthcare, and the consumer and experience economy, among others. The workshops highlighted the transformative potential of XR to not only streamline production processes but also to democratise content creation by integrating cutting-edge technologies such as real-time game engines, motion capture, and volumetric rendering.

Key findings from the discussions underscore the dynamic nature of VP, characterised by its dual capacity to influence creative possibilities and operational efficiencies across industries. Despite the technological advancements, there remains a prevalent gap in widespread understanding and adoption, attributed to the nascent stage of these convergences in technology. Challenges such as high

costs, resistance to change from established industry professionals, and a shortage of skilled personnel significantly throttle the pace at which these technologies can be integrated into mainstream production cycles.

The recommendations set forth by this report advocate for a multi-pronged approach to nurturing the ecosystem of Virtual Production. Emphasising the need for targeted funding opportunities, flexible deliverables, robust training programmes, and facilitated industry-academia collaboration, the white paper proposes practical steps to enhance the scalability and sustainability of VP ventures. These include the development of industry standards, increased accessibility to VP facilities and equipment, and the cultivation of networks that support ongoing innovation and commercialisation.

In synthesising the discussions and reflections from the XR Network+ workshops, this white paper not only amplifies the essential role of academia and industry partnerships in propelling XR innovation forward but also stresses the importance of strategic investments and policy crafting to sustain momentum in the burgeoning realm of Virtual Production. The collaborative endeavours and the knowledge shared amongst the participating institutions and attendees underscore a collective commitment to advancing a forward-thinking agenda that promises to reshape the landscape of digital media production.



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