

February 15, 2022

National Institute of Standards and Technology  
U.S. Department of Commerce  
100 Bureau Drive, Stop 2000  
Gaithersburg, MD 20899

RE: Document #2021-25428/Docket #211116-0234; Study to Advance a More Productive Tech Economy 86 FR 66287

Dear National Institute of Standards and Technology:

The XR Association is pleased to submit comments in response to the National Institute of Standards and Technology's Request for Information regarding its Study to Advance a More Productive Tech Economy.

The XR Association (XRA) represents the broad ecosystem of the XR industry including headset manufacturers, technology platforms, component and peripheral companies, internet infrastructure companies, enterprise solution providers, and corporate end-users. The founders of XRA are Google, HTC Vive, Microsoft, Meta Platforms, Inc. (formerly Oculus by Facebook), and Sony Interactive Entertainment. XRA is leading the way for the responsible development and adoption of virtual reality (VR), augmented reality (AR), and mixed reality (MR) - collectively "XR" technology - by convening stakeholders, developing research and best practices, and advocating on behalf of our members and the broader XR industry. Our mission is to champion the thoughtful advancement of XR solutions that foster positive societal outcomes.

When considering the future investment needs of emerging technology areas, NIST would be remiss if it did not include XR in its study. While immersive experiences have in the past typically been associated with entertainment and gaming, XR technology has undergone dramatic development over the past several years and is now widely considered to be the next major computing platform.<sup>1</sup> Indeed, XR technology is rapidly being adopted across industries as an enterprise solution, particularly in the manufacturing and health care sectors, as companies look to technology to help them weather and recover from the COVID-19 pandemic.<sup>2</sup>

What's more, XR technologies overlap significantly with the emerging technologies identified by NIST for this study and play an important role in the broad technology ecosystem. Developments in previously disjointed fields such as artificial intelligence (AI) and machine learning, robotics, and advanced communications are all building on and amplifying one another. Smart systems—homes, factories, farms, grids and entire cities—will help tackle problems ranging from supply chain

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<sup>1</sup> "Accelerating the Next Computing Platform," Medium.com, Jan. 28, 2020. <https://michaeltefula.medium.com/accelerating-the-next-computing-platform-fb3ed88d01e1>

<sup>2</sup> "XR-Based Workforce Training Identified As Key Tool In Addressing America's Employment Crisis," XRA Association Survey, Nov. 4, 2021. <https://xra.org/xr-workforce-training-addressing-americas-employment-crisis/>

management to climate change.<sup>3</sup> In other words, the future technology landscape is an integrated one. Thus, in order for the United States to position itself as the architect of that landscape, we must implement a technology research and development plan that promotes synthesis.

For the purposes of this RFI, we will focus specifically on the synergies between XR and the internet of things (IoT), particularly in the manufacturing industry, as well as the interdependency of XR and AI. We will also explain why it is imperative for the U.S. to maintain its competitive edge in XR if we are to remain the world's technology leader.

## **The Symbiosis between XR and IoT**

U.S. companies have quickly become reliant on XR technology to help them improve workplace safety, increase productivity, and train and upskill employees. With XR applications, inexperienced personnel can be trained in low-risk environments without the need for expensive additional resources. What's more, by digitally simulating production processes, dangerous maneuvers in manufacturing settings can be identified in advance, protecting even the most experienced individuals. XR allows professionals to practice infinite "what-if" scenarios in a virtual space — ultimately, enhancing safety, delivering cost savings, and improving speed and accuracy.<sup>4</sup> And with respect to product design, VR improves manufacturers' approach to predictive analytics, helping find design flaws in a matter of minutes rather than months.<sup>5</sup>

The fusion of XR with IoT has the power to be transformative in manufacturing. Linking sensors on complex machines to XR technologies gives machinists and technicians a holistic view of the operation of a factory. For example, they can diagnose dangerous temperature fluctuations in a factory or identify where crucial maintenance or repairs are needed. Indeed, XR and IoT can work in tandem to deliver real-time data and intelligence to users. As a pair of Canadian researchers noted in a 2021 paper for the Institute of Electrical and Electronics Engineers (IEEE), "These domains are converging simultaneously, leading to XR systems with IoT embedded capabilities in smart environments, and IoT systems with more immersive, engaging and adaptive interfaces and use cases."<sup>6</sup> These hybrid XR and IoT systems have been dubbed "XRI" to distinguish their unique interoperability:

*The interconnectedness of smart environments through IoT and the potential for more engaging, information-rich, and interactive interfaces through XR proves to be a promising exploration by incorporating audio, visual, and tangible interaction to further integrate the human in the loop. In particular, XRI focuses on virtual, ambient, collaborative, and informational perspectives of information processing.<sup>7</sup>*

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<sup>3</sup> "The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution," World Economic Forum, 2016. [https://www3.weforum.org/docs/WEF\\_FOJ\\_Executive\\_Summary\\_Jobs.pdf](https://www3.weforum.org/docs/WEF_FOJ_Executive_Summary_Jobs.pdf)

<sup>4</sup> "3 Reasons You Should Invest in Virtual Reality Learning and Development," McKenzie Cassidy, *HR Exchange*, Oct. 19, 2021. <https://www.hrexchangenet.com/learning/articles/3-reasons-to-consider-vr-employee-training>

<sup>5</sup> "Virtual and Augmented Reality in Manufacturing," Jonathan Wilkins, *Manufacturing Business Technology*, Jun. 14, 2019. <https://www.mbtmag.com/home/blog/13252033/virtual-and-augmented-reality-in-manufacturing>

<sup>6</sup> "A Hybrid Quality-of-Experience Taxonomy for Mixed Reality IoT (XRI) Systems," Tara Tsang and Alexis Morris, 2021 IEEE International Conference on Systems, Man and Cybernetics, Oct. 17-20, 2021. <https://ieeexplore.ieee.org/document/9658887>

<sup>7</sup> Ibid.

While the blending of XR and IoT technologies into XRI is still emerging, some companies have already begun to use XRI. For example, as the lead contractor for NASA’s Orion spacecraft, Lockheed Martin, is using AR to increase production efficiency and quality.<sup>8</sup> In a December 2021 speech at the Augmented World Expo, ClickBond President and CEO Karl Hutter, whose Nevada-based company makes fasteners used on the Orion spacecraft, talked about how his company and Lockheed are blending AR and IoT to improve accuracy and efficiency in the complicated construction of Orion. Hutter explained how AR digital twin overlays are used with IoT grip gauges and other sensors to help workers determine both where to place the fasteners and whether the fasteners have been appropriately secured. He noted that the use of AR systems has helped Lockheed achieve a 91 percent reduction in touch labor, an 85 percent reduction in training time, and zero errors across hundreds of activities.<sup>9</sup> Separately, in January 2022, a Lockheed factory in Pennsylvania announced it had become a “Smart Factory” after implementing an Industrial Internet of Things (IIoT) regime that blends IoT, AR, and other technologies onto a single platform.<sup>10</sup>

German elevator manufacturer, thyssenkrupp, has been using Microsoft’s mixed reality glasses and predictive maintenance IoT suite to help technicians identify mechanical failures and access remote support to fix such problems. This system has been used at One World Trade Center in New York City, for example.<sup>11</sup> British researchers investigating the synergies between XR and IoT noted how the thyssenkrupp system integrates various features of both technologies:

*First, the elevator company connected the [IoT] sensors and systems in its elevators to the cloud. The cloud service captures and stores data coming from the elevators, such as motor temperature, shaft alignment, cab speed and door functioning. Access to real-time data visualization in the cloud allows quick detection of failures and identification of the faulty components. In the showcase video we can see the technician looking at a 3D model of the elevator in AR mode where the details about the faulty components are highlighted.<sup>12</sup>*

Other industries are embracing XRI as well. In 2021, Kaleida Health embarked upon an ambitious data and technology modernization project that seeks to leverage a variety of emerging technologies — including IoT, AI, VR, and wearables — to help the largest healthcare provider in Western New York not only simplify its health records, but also to track inventory of medical equipment and support optimal health care outcomes for patients.<sup>13</sup> Researchers have also looked at ways wearables could be combined with VR to help provide personalized exercises for stroke victims undergoing physical

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<sup>8</sup> Lockheed Martin Embraces AR on the Factory Floor, *Assembly* magazine, Aug. 27, 2019.

<https://www.assemblymag.com/articles/95163-lockheed-martin-embraces-ar-on-the-factory-floor>

<sup>9</sup> “Enabling Aerospace Manufacturing Talent with XR and IoT Tools,” speech by ClickBond President and CEO Karl Hutter at the Augmented World Expo, Dec. 2021. <https://www.youtube.com/watch?v=gwqq-8p9fl>

<sup>10</sup> “Lockheed Martin Achieves IIoT Smart Factory,” Aegis Software, SME, Jan. 11, 2022.

<sup>11</sup> “How Microsoft HoloLens will aid thyssenkrupp elevator engineers,” Tom Wadlow, *Technology Magazine*, May 17, 2020.

<https://technologymagazine.com/ai/how-microsoft-hololens-will-aid-thyssenkrupp-elevator-engineers>

<sup>12</sup> “Extended Reality in IoT scenarios: Concepts, Applications and Future Trends,” Tiago Andrade and Daniel Bastos, 2019 IEEE 5<sup>th</sup> Experiment International Conference, June 12-14, 2019. <https://ieeexplore.ieee.org/document/8876559>

<sup>13</sup> “Kaleida Health is Advancing Healthcare Innovation and Saving Millions,” Cisco, Aug. 19, 2021.

<https://www.cisco.com/c/en/us/solutions/collateral/data-center/kaleida-health-case-study.html>

rehabilitation, while also providing healthcare workers a more efficient way to monitor those patients.<sup>14</sup>

The British research team noted that XRI presents a unique solution for businesses because it solves the technological challenges of combining real-time visualization, interaction with large volumes of data, and collaboration and information sharing. “XR is removing the hurdle of distance while IoT is increasing access to information and new experiences. Together they allow data rich complex scenarios to be transformed into accessible applications that blend real and virtual worlds, in order to offer enhanced and more natural interactions between humans and data,” the researchers concluded.<sup>15</sup>

## **Interdependency of XR and AI**

The relationship between immersive technologies and AI provides a powerful example of technological symbiosis. Recently, major advances have been made to bring VR and AI together to create a single form of technology that offers seemingly endless possibilities. Machine learning is essential to the development of XR and the creation of the immersive experience. Through AI, researchers improve simulations by endowing artificial agents with simple and complex rules that emulate human behavior. But, this is not a one-way relationship. Immersive technologies are helping to advance AI as well.

Indeed, researchers have posited that immersion of advanced AI agents in virtual worlds — exposing them to essential, real-world conditions and large numbers of human users with whom they must interact — is the special ingredient needed to bring AI to the next level. Adaptability to a changing environment is necessary for the highest evolution of artificial intelligence, and interactive virtual worlds represent a powerful testbed for pursuing human-level AI.<sup>16</sup>

Recent research indicates that current AI-XR applications are showing promise in programs designed for medical training, autonomous cars and robotics, entertainment/gaming, military training, and advanced visualization.<sup>17</sup> For medical training, researchers noted that “combining AI and XR provides an opportunity to better interpret XR dynamics by developing an objective approach for assessing user skill and performance. Through this method, data can be generated from either the XR tool or XR user, after extraction and selection of features from data, and then fed into AI to determine the most relevant skill assessment features.”<sup>18</sup> Similarly, as a training tool for the U.S. armed forces, AI determines the human participant’s skill level in order to adapt itself to serve as a realistic enemy fighter.<sup>19</sup>

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<sup>14</sup> “Remote Monitoring of Physical Rehabilitation of Stroke Patients Using IoT and Virtual Reality,” Octavian Postolache, D. Jude Hemanth, Ricardo Alexandre, Deepak Gupta, Oana Geman, and Ashish Khanna, *IEEE Journal on Selected Areas in Communications*, Feb. 2021. <https://ieeexplore.ieee.org/document/9183980/authors#authors>

<sup>15</sup> Andrade and Bastos.

<sup>16</sup> Ibid.

<sup>17</sup> “The Combination of Artificial Intelligence and Extended Reality: A Systematic Review,” Dirk Reiners, Mohammad Reza Davahli, Waldemar Karwowski, Carolina Cruz-Neira, *Frontiers in Virtual Reality*, Sept. 7, 2021. <https://www.frontiersin.org/articles/10.3389/frvir.2021.721933/full>

<sup>18</sup> Ibid.

<sup>19</sup> Ibid.

## The Importance of U.S. Competitiveness in XR

As noted, XR is widely considered to be the next major computing platform (predecessors being the personal computer in 1984; the World Wide Web in 1993; and the smart phone in 2007), and the U.S. must be at the forefront of designing and creating it.

U.S. tech luminaries have built ambitious strategies around the development and adoption of XR. Mark Zuckerberg announced his newly renamed company, Meta Platforms, Inc., invested \$10 billion in AR, VR, and related hardware in 2021 alone, saying during the company's 2021 3<sup>rd</sup> quarter earnings call that "the metaverse will be a successor to the mobile internet. ... It will unlock a massively larger creative economy [...] than what exists today."<sup>20</sup> XR will be the portal into the metaverse. Microsoft, through its HoloLens hardware and its cross-platform development tools (Azure, Mesh, etc.), has been aggressive in the enterprise space<sup>21</sup>. HTC, Sony, Valve and others are also continuing to make significant advancements in both hardware and software.<sup>22</sup> And Apple, Google, and Unity have each built substantial AR development platforms in pursuit of democratizing consumer access to AR technologies.

But the U.S. and its allies are not alone in pursuing advances in immersive technology innovation. China recognized the outsized potential of immersive technology years ago and has taken impressive steps towards controlling its future. XR is featured prominently in the CCP's Made in China 2025 strategy, and the Ministry of Industry and Information Technology, the National Development and Reform Commission, the Ministry of Science and Technology, the Ministry of Culture and the Ministry of Commerce have all released detailed strategies concerning XR. In addition, Chinese provincial and municipal local governments are proactively building industrial parks and labs to promote the development of local VR industries.<sup>23</sup>

Harvard University's Belfer Center for Science and International Affairs recently highlighted China as a "full-spectrum peer competitor" to the U.S. in the technology race.<sup>24</sup> And China is not the only nation investing heavily in XR. Countries that had early 5G commercialization strategies, including Japan and South Korea, planned for VR as a key 5G application field. Governments worldwide are generously funding XR research and development, and XR-related inventions are increasing exponentially.<sup>25</sup>

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<sup>20</sup> "Facebook's metaverse spending will top \$10 billion this year," Janko Roettgers, *Protocol*, Oct. 25, 2021. <https://www.protocol.com/bulletins/facebook-metaverse-10-billion-dollars>

<sup>21</sup> "With Apple and other rivals in the wings, mixed reality is Microsoft's race to lose, Daniel Rubino, *Windows Central*, April 2, 2021. <https://www.windowscentral.com/microsofts-bet-hololens-paying>

<sup>22</sup> "The AR, VR future coming in 2022: What we learned from CES" Scott Stein, *CNET*, January 10, 2022 (<https://www.cnet.com/tech/computing/vr-and-ar-looked-to-the-metaverse-at-ces-2022/>)

<sup>23</sup> "Virtual Reality/Augmented Reality White Paper," China Academy of Information and Communications Technology (CAICT), 2017. <https://www-file.huawei.com/-/media/corporate/pdf/ilab/vr-ar-en.pdf>

<sup>24</sup> *The Great Rivalry: China vs. the U.S. in the 21st Century*, Graham Allison, Harvard University Belfer Center for Science and International Affairs, Dec. 7, 2021. <https://www.belfercenter.org/publication/great-rivalry-china-vs-us-21st-century>

<sup>25</sup> Allies like the United Kingdom are taking a strategic approach to XR. The Digital Catapult is the British government innovation agency for the digital and software industry, developed in conjunction with Innovate UK. Digital Catapult explicitly lists immersive technology as one of its three specialty areas for provision of assistance. This focus is accompanied by extensive grants and investments in R&D by the UK government to support the immersive technology sector in the UK. See also <https://www.digicatapult.org.uk/technologies/immersive/virtual-reality>

Still, China remains the United States' chief rival in terms of defining the future of technology. China aims to control the technical and ethical standards for those technologies it believes will be both foundational and ubiquitous in the 21<sup>st</sup> Century,<sup>26</sup> including XR.

In order to ensure that emerging technologies, like XR, IoT, AI and others, are imbued with U.S. cultural values, we must promote their development here in America where regulations are predominantly influenced by U.S. legislation. U.S. leadership in XR development is needed to ensure the technology advances in alignment with cultural values that place a premium on freedom of thought and expression, learning, cooperation, and other standards of an open and flourishing society. Technology reflects the culture and values of the people who create it.<sup>27</sup>

## Conclusion

XR is, and will continue to be, an integral part of a future technology ecosystem that blends AI, IoT, and other vital technologies. Indeed, these technologies must not be thought of as separate and independent. They are interconnected, and the U.S. approach to research and development should reflect and foster that symbiosis. In addition, it is not a question of if, but when, XR technology will become ubiquitous and replace our current modes of computing. Any forward-thinking approach to computing technology innovations - and the resultant economic growth and competitiveness - must include XR.

We hope the information we have provided helps the National Institute of Standards and Technology to better understand the interconnectedness and synergies that are being developed among important emerging technologies, such as XR. We welcome further discussion on this topic and are glad to answer any questions you may have.

Sincerely,



Elizabeth Hyman, CEO

XR Association

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<sup>26</sup> China Task Force Report, Michael T. McCaul, Chairman, U.S. House of Representatives, September 29, 2020.

<sup>27</sup> "China's AI tech leaves aside questions of ethics," Yasu Ota, *Nikkei Asia*, August 23, 2020.

<https://asia.nikkei.com/Spotlight/Comment/China-s-AI-tech-leaves-aside-questions-of-ethics>