XR ASSOCIATION

THE INTEGRATED TECHNOLOGY LANDSCAPE OF THE FUTURE AND THE SYNERGISTIC EFFECT OF IMMERSIVE TECHNOLOGIES

SUMMARY

The Endless Frontier Act (EFA) is a visionary bill that seeks to increase investment in the discovery, creation, and commercialization of the most important emerging technologies in order to preserve America's global leadership well into the 21st century. The bill rightly identifies as priorities key technology focus areas like artificial intelligence, robotics, and advanced communications, among others. But these technologies must not be thought of as separate and independent. The technologies of the Fourth Industrial Revolution[1] are interconnected—and the U.S. approach to research and development should reflect and foster that symbiosis.

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Immersive technologies (virtual reality [VR]; augmented reality [AR]; and mixed reality [MR] – collectively known as "XR") blend the physical environment with virtual content across a spectrum, from fully virtual (occluded) to augmented (overlaid). Immersives are a key part of the future technology ecosystem, and closely tied to the development of many of the technology focus areas highlighted in the EFA. What's more, U.S. rivals like China are investing heavily in XR as the next major computing platform, and they have already developed national strategies to support its growth and adoption.

Immersive technologies will play a preeminent role in achieving our national goals related to economic competitiveness, domestic manufacturing, national security, healthcare, education, and workforce development—and will serve as a catalyst for advanced development in other critical technology fields as well. **As a natural member of the cohort of technologies highlighted in the EFA, immersive technologies should be included in the bill.**

I. THE INTEGRATED TECHNOLOGY LANDSCAPE OF THE FUTURE

While the U.S. must support the growth of individual critical technologies of the future, we must also keep in mind the bigger picture of the technology ecosystem. As the World Economic Forum acknowledged in its Future of Jobs report, we are entering a Fourth Industrial Revolution. 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 management to climate change.[2] 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 an integrated outcome.

1 Professor Klaus Schwab, Founder and Executive Chairman of the World Economic Forum, first introduced the phrase "Fourth Industrial Revolution" to a wider audience in a 2015 article published by Foreign Affairs, and "Mastering the Fourth Industrial Revolution" was the 2016 theme of the World Economic Forum Annual Meeting, in Davos-Klosters, Switzerland. Previous industrial revolutions liberated humankind from animal power, made mass production possible and brought digital capabilities to billions of people. This Fourth Industrial Revolution is, however, fundamentally different. It is characterized by a range of new technologies that are fusing the physical, digital and biological worlds, impacting all disciplines, economies and industries, and even challenging ideas about what it means to be human. (see https://www.weforum.org/pages/the-fourth-industrial-revolution-by-klaus-schwab).

2 "The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution," World Economic Forum, 2016. Available at http://www3.weforum.org/docs/WEF_FOJ_Executive_Summary_Jobs.pdf

II. THE SYNERGISTIC EFFECT OF IMMERSIVE TECHNOLOGIES

Immersive technologies are transformative in their own right. **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),[3] tech luminaries have built aggressive strategies around the development and adoption of XR. Mark Zuckerberg has set VR as one of the three major technology development directions for Facebook in the next decade and has said Facebook will invest more than $3 billion in its development,[4] and Apple has built the largest AR development platform in the world.[5]

Immersive technologies will be a critical catalyst in shaping the economies and communities of the future. According to Goldman Sachs, the AR/VR industry will reach $80 billion by 2025.

Jensen Huang, CEO of America's most valuable semiconductor company, NVIDIA, recently discussed his company's intense focus on the forthcoming "metaverse." In a nutshell, the metaverse is a collective virtual shared space, created by the convergence of virtually enhanced physical reality and physically persistent virtual space, including the sum of all virtual worlds, augmented reality, and the Internet. As Huang describes it, "We'll go into the virtual world using virtual reality, and the objects in the virtual world, in the digital world, will come into the physical world, using augmented reality. So what's going to happen is pieces of the digital world will be temporarily, or even semipermanently, augmenting our physical world. It's ultimately about the fusion of the virtual world and the physical world." **The metaverse, says Huang, "is where we will create the future" and transform how the world's biggest industries operate.**[6] Indeed, experts in fields across the board—from technology to industry, and from academia to economics—believe immersive technologies will be a critical catalyst in shaping the economies and communities of the future. According to Goldman Sachs, the VR/AR industry will reach USD $80 billion by 2025.[7]

A. The Interdependency of Immersive Technology and Artificial Intelligence

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, some scientists assert that VR may in fact trigger an *evolutionary leap* in AI.[8]

3 "Accelerating the Next Computing Platform," Medium.com, January 28, 2020. Available at https://michaeltefula.medium.com/accelerating-the-next-computing-platform-fb3ed88d01e1

4 Facebook CEO Mark Zuckerberg to Spend Billions More on Virtual Reality, Jonathan Vania, Fortune, 2017. Available at https://fortune.com/2017/01/18/facebook-mark-zuckerberg-virtual-reality-billions/

5 Apple Unveils "Largest AR Platform in the World," Alana Foster, IBC 365, 2017. Available at https://www.ibc.org/apple-unveils-largest-ar-platform-in-the-world/1988.article

6 "The Metaverse Is Coming. Nvidia CEO Jensen Huang on the Fusion of Virtual and Physical Worlds," Eben Shapiro, Time Magazine, April 18, 2021. Available at https://time.com/5955412/artificial-intelligence-nvidia-jensen-huang/

7 Available at https://www.goldmansachs.com/insights/pages/virtual-and-augmented-reality.html

8 "Artificial Intelligence and Virtual Worlds – Toward Human-Level AI Agents," Vladimir M. Petrović, Institute of Electrical and Electronics Engineers (IEEE), 2018. Available at https://www.goldmansachs.com/insights/pages/virtual-and-augmented-reality.html

Scientists assert that VR may in fact trigger an evolutionary leap in artificial intelligence.

Human-level intelligence has long been the elusive goal of AI. Over the years, researchers have come to believe that the classical AI approach (the manipulation of a system of symbols) cannot achieve this ambitious outcome. Looking to the evolution of human cognition, researchers posit 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. Why? Because intelligence cannot merely exist in the form of an abstract algorithm; rather, it requires a physical instantiation—a body. This is the hypothesis of embodiment.[9]

As Andy Clark, Professor of Cognitive Philosophy at the University of Sussex explains, the "biological mind is, first and foremost, an organ for controlling the biological body."[10] Intelligence is determined by the dynamics of interaction with the world.[11] Applying this understanding to machine learning, **adaptability to a changing environment, an attribute so keenly characteristic of humans, is necessary for the highest evolution of artificial intelligence** as well. To that end, **interactive virtual worlds represent a powerful testbed for pursuing human-level AI**. Immersive environments are becoming more and more complex and dynamic, with real-time decision-making and other human characteristics increasingly required. Furthermore, computer characters in these worlds are exposed to numerous interactions with human users, between themselves, and with their surroundings. Immersive virtual environments help scientists equip AI with some of the essential mechanisms and interaction patterns characteristic of living beings. **Many scientists now consider "embodiment" to be a necessary condition for developing of any sort of true intelligent behavior.**[12]

B. The Interdependency of Immersive Technologies and Next-Generation Communications

Immersive technology's synergistic effect is not limited to its relationship with AI. **XR is a key part of the new-generation information and communications technologies ecosystem and will play an important role in driving the transformation** and upgrade of core components, extensive smart devices, network transmission devices, cloud computing devices, telecommunications services, and software. What's more, the development of XR itself is inextricably bound to near-eye display, rendering processing, spatial computing, perception and interaction, and network transmission.

9 Id.

10 "Being There: Putting Brain Body and World Together Again," Andy Clark, Cambridge, MA, USA: MIT Press, 1996.

11 In terms of human cognitive development, bipedalism is recognized as a pivotal factor. Upright walking quite literally changed the human perspective of the environment and changed the way humans interact with it, thereby shaping of our intelligence. For example, free forelimbs enabled many useful activities like manufacturing and using tools, and manipulating the environment in general. Indeed, human intelligence is inseparable from the human body, and vice versa. Discussed in "Artificial Intelligence and Virtual Worlds—Toward Human-Level AI Agents," Vladimir M. Petrović, Institute of Electrical and Electronics Engineers (IEEE), 2018.

12 Unlike the traditional paradigm where AI is based on a "system of symbols" and its manipulation, the hypothesis of embodiment is based on the premise that an intelligent system must be deeply grounded in its physical surroundings. Research and development in robotics further supports this notion. In his seminal work in the field, Rodney Brooks, Professor of Robotics at the Massachusetts Institute of Technology and former director of the MIT Computer Science and Artificial Intelligence Laboratory, showed that physically-grounded mobile robots were superior to symbol system-based robots because of their enhanced ability to adapt to the changing environment—an attribute central to human behavior. Similarly, researchers posit 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 necessary ingredient of their further development. What's more, various challenging scenarios can be designed and tested in these virtual worlds, requiring an agent to activate appropriate reasoning about its environment and its role in it, learn and intelligently interact with the dynamic environment including a successfully coping with uncertainties, and predict the events and behavior of other dynamic entities in a dynamic environment. Discussed in "Artificial Intelligence and Virtual Worlds – Toward Human-Level AI Agents," Vladimir M. Petrović, Institute of Electrical and Electronics Engineers (IEEE), 2018. Available at https://www.goldmansachs.com/insights/pages/virtual-and-augmented-reality.html

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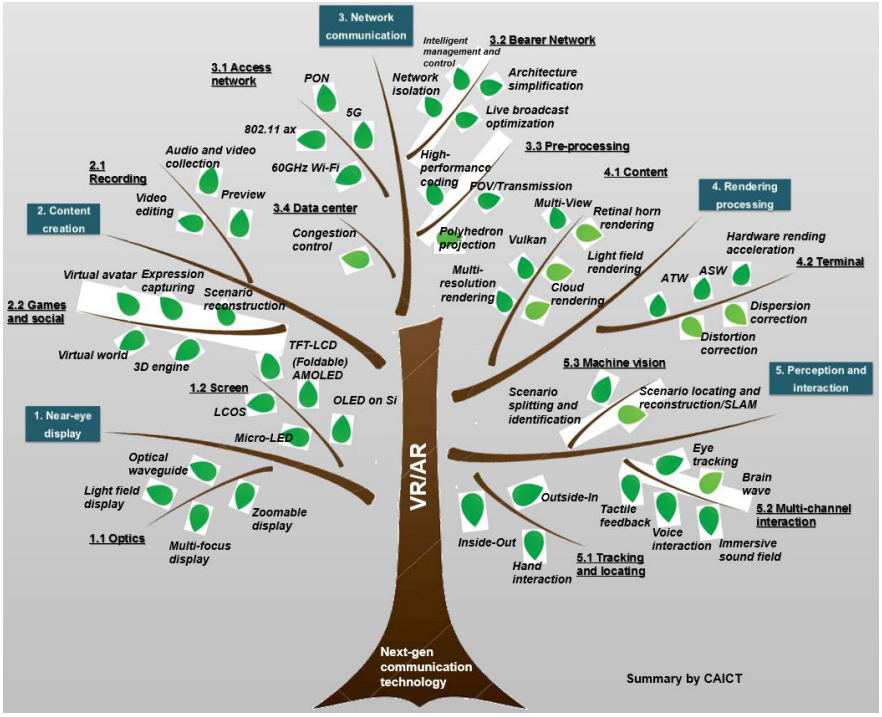
The immersive experience involves all of these various technologies and systems, and XR can only evolve as they evolve. Likewise, the development of these technologies and systems will track advances in XR. They are interdependent – part of a unified ecosystem. Developments in one of these fields prompt and enable developments in the others. Even 5G will be impacted. The ultra-high bandwidth, ultra-low latency, and ultra-high mobility of 5G enable the advanced immersive experience. Indeed, a reliable 5G network will help VR and AR applications evolve to the next level. As VR becomes a key field of early 5G commercial use, 5G technology will improve to meet its requirements.

Synergies between immersive technologies and next-generation communications technology [13]



III. ENSURING THE UNITED STATES SHAPES THE FUTURE TECHNOLOGY ECOSYSTEM

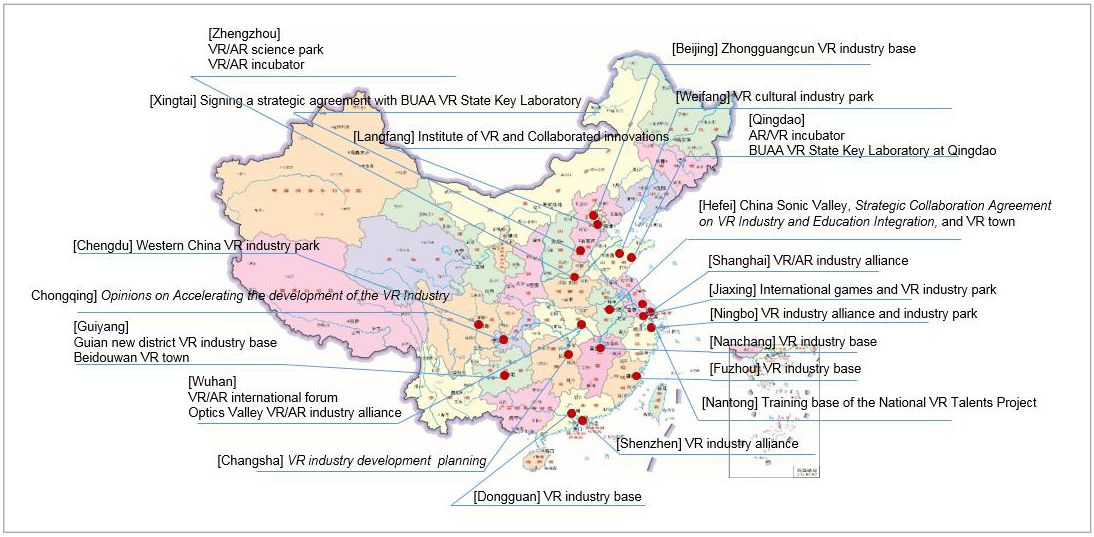
The new industrial revolution is already underway, and immersive technologies are playing a crucial role. In combination with other technologies, as well as on their own, immersive technologies will bring dramatic changes to society and to people's individual lives. Currently, VR applications can be classified as industry applications or public applications. The former includes areas such as manufacturing, medicine, education, military, and e-commerce. The latter includes games, social networking, movies, and live broadcast. As noted above, according to Goldman Sachs, the VR/AR industry will reach USD $80 billion by 2025. The XR era has emerged.

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

XR is featured prominently in the CCP's Made in China 2025 strategy.

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.[14]

VR industry development layout in provinces and cities in China[15]



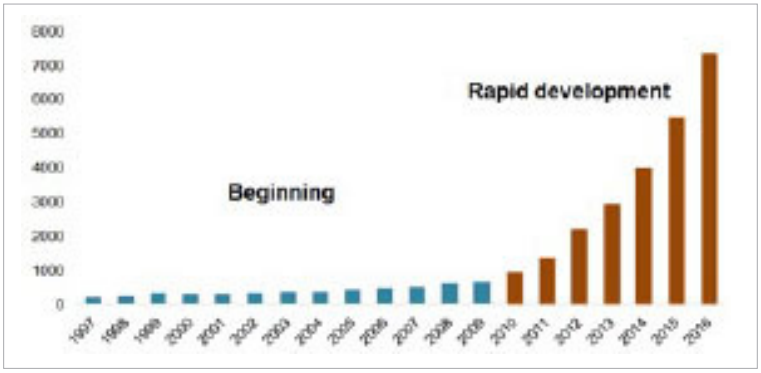
China is not the only nation investing heavily in XR. Countries that had early 5G commercialization plans, including Japan and South Korea, planned for VR as a key 5G application field. Indeed, **governments are generously funding XR research and development, and XR-related inventions are increasing exponentially**.[16] By the end of May 2017, the number of global VR patents had reached 59,000, with about 29,000 patent families. Those numbers have continued to grow. Now is the time for the U.S. to step-up its public investment in immersive technology and to forge mutually-beneficial XR development and production partnerships with U.S. allies like the countries of NATO, Southeast Asia, and India.

14 Id.

15 Id.

16 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

Number of global VR patent applications in each year[17]



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 21st century,[18] including immersive technologies.** If the United States fails to invest in XR research and development, China will soon own the field. What's more, 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.[19]

IV. RECOMMENDED AMENDMENT TO THE ENDLESS FRONTIER ACT

Immersive technologies are a critical and inseverable part of the technology ecosystem of the future. XR will help to advance breakthroughs in advanced manufacturing, advanced communications, spatial computing, and biometrics. As the next major computing platform, immersive technology is also part of a cohort of technologies that includes artificial intelligence and quantum computing – and that triad is expected to dramatically alter the way we learn, collaborate, recreate, manufacture, and provide essential human services. Developments in immersive technology will precipitate new research directions in various scientific fields and vice versa. Innovation is an integrated process.

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Although the EFA requires its list of 10 key technology focus areas to be reviewed and refreshed every three years, the field of immersive technology is already ripe. Both U.S. competitors and allies have prioritized it for heavy investment and their R&D strategies are well underway. Whoever dominates this grand fourth computing platform will enjoy irrefutable technology primacy, just as those who led the rise of the first three platforms do now. **Like its predecessors, this new platform will unleash the prosperity of thousands more companies in its ecosystem, along with countless new ideas that were not possible before its arrival.** Indeed, as the EFA says, "the country that wins the race in key technologies…will be the superpower of the future."

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

18 China Task Force Report, Michael T. McCaul, Chairman, U.S. House of Representatives, September 29, 2020.

19 "China's AI tech leaves aside questions of ethics," Yasu Ota, Nikkei Asia, August 23, 2020. Available at https://asia.nikkei.com/Spotlight/Comment/China-s-AI-tech-leaves-aside-questions-of-ethics.

Because of the magnitude of immersive technology's coming impact, as well as its synergistic effect on the development of the adjacent technologies named in the EFA, we urge Congress to amend the bill as follows:

> "(2) KEY TECHNOLOGY FOCUS AREAS.—
>
> "(A) INITIAL LIST.—The initial key technology focus areas are—
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> "(i) artificial intelligence, machine learning, and other software advances;
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> "(ii) high performance computing, semiconductors, and advanced computer hardware;
>
> "(iii) quantum computing and information systems;
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> "(iv) robotics, automation, and advanced manufacturing;
>
> "(v) natural and anthropogenic dis- aster prevention or mitigation;
>
> "(vi) advanced communications and immersive technologies;
>
> "(vii) biotechnology, medical technology, genomics, and synthetic biology;
>
> "(viii) cybersecurity, data storage, and data management technologies;
>
> "(ix) advanced energy, batteries, and industrial efficiency; and
>
> "(x) advanced materials science, engineering, and exploration relevant to the other key technology focus areas described in this subparagraph."