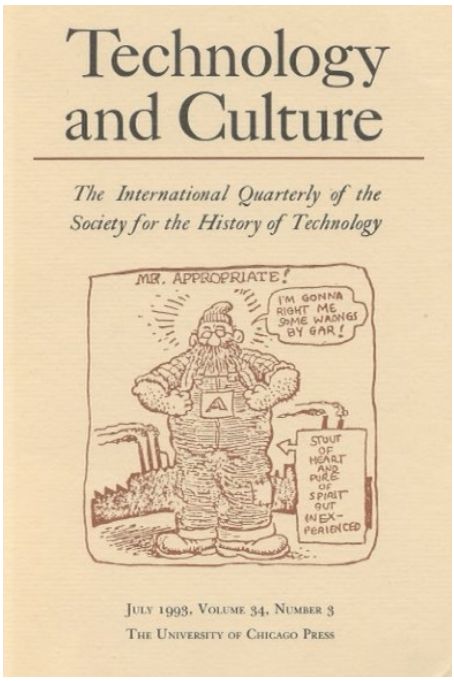

Symposium on the History of Technology: Past, Present, and Future
Massachusetts Institute of Technology
Program in Science, Technology, and Society (STS)
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Imagined Spaces, Virtual Workplaces: Film Production Hits the Wall

Rebecca Perry

Let me begin with a 1993 cover from "Technology and Culture," drawn by one of my favorite cartoonists, R. Crumb. I just love this cover because it demonstrates "T&C's" appreciation of visual representation early on. This drawing of Mr. Appropriate has him saying, "I'm going to right me some wrongs, by gar," which is a good goal for any historian.

I was trained as a fine artist and later worked as a visual journalist and with computers before coming to study with Roe. I believe that when I joined HASTS in 2006, I became one of the last graduate students studying under Roe, if not the last. I was interested in film production and particularly the work of Visual Effects (VFX) and wanted to understand how a community of highly educated, highly mobile tech workers, film and television visual effects artists practiced their craft around the world. I became interested in the work of visual representation in film, in the tools that these highly skilled people were using and how they learned or how their tools and thinking co-evolved. Now I head a training program helping such technologists to learn, and my studies under Roe prepared me for that.

The title of this talk is "Imagined Spaces, Virtual Workplaces: Film Production Hits the Wall." By the wall, I am referring to the new technology of the LED wall that's evolving as a filmmaking tool. And after listening to the excellent talks yesterday, I added a subtitle to highlight my premise – that evolving or what I call "edge technologies" challenge historians to reconsider their traditional research methods.

Figure 1 Cover art by R. Crumb, *Technology and Culture,* July 1993, Vol. 34. No. 3.

I'm speaking here of technologies that have a lot of components that are hard to document, that are ephemeral or that leave a fleeting residue of their passage, and how those can be studied effectively. Regarding "edge technologies," I have more questions than answers, but I'll start by referencing a well-known phrase from Kranzberg's laws. He writes that "Technology is neither good nor bad, nor is it neutral," and that "...technology's interaction with the social ecology is such that technical developments frequently have environmental, social, and human consequences that go far beyond the immediate purposes of the technical devices."[1] This opens onto a fascinating realm to explore.

We can pair Kranzberg with a quote from James Monaco, who writes about film technology, and notes that "Every art is shaped not only by political, philosophical, and economic factors but also by its technology." So the relationship between art and technology is really my subject, and Monaco is saying sometimes technological development leads to a change in the aesthetic of the art, and sometimes an evolving aesthetic calls forth the need for a new technology.

An edge technology is hard to study—an emerging technology, evolving rapidly on the ragged boundaries of culture and invention. And it's difficult to categorize, difficult to isolate and analyze; it is characterized by the intersections of a wide variety of activities and participants. These technologies sort of push at the edges where culture is shifting, and as mentioned, they often leave sparse or fleeting documentary traces.

So, for historians of technology, the blurred boundaries and ephemeral artifacts that characterize edge technologies present observational and analytical challenges. Other thorny examples include cryptocurrencies and generative AI technologies. An edge technology currently unfolding in film production is known by practitioners as an LED wall or an LED volume. LED volumes are a complex set of systems centered around large surfaces that form walls made of LEDs (light emitting diodes). LED volumes are spaces for imagined, editable worlds against which live actors perform. These structures became key tools for filmmakers during the pandemic, with a new virtual workspace taking shape around them. LED workers form a diverse community which includes electrical engineers, signal engineers, display technologists, color scientists, lighting and camera specialists, motion capture experts, programmers, and 3D computer graphics practitioners. Many of them are contract workers. They are often

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[1] Kranzberg, M. (1986). Technology and History: "Kranzberg's Laws." *Technology and Culture*, *27*(3), 544–560.

geographically dispersed but still form a global community, meeting in their shared virtual workspaces.

As mentioned, an LED volume is essentially a complex set of systems centered around linked panels of LEDs. It is termed the volume, because it encloses and describes a three-dimensional computational space, wherein every element is quantified and its position and movements are tracked. The use of tracking within this 3D space was initially developed for motion capture; displaying environments on LED panels came later. Volumes are highly engineered spaces for displaying computer-generated editable works against which live actors perform.

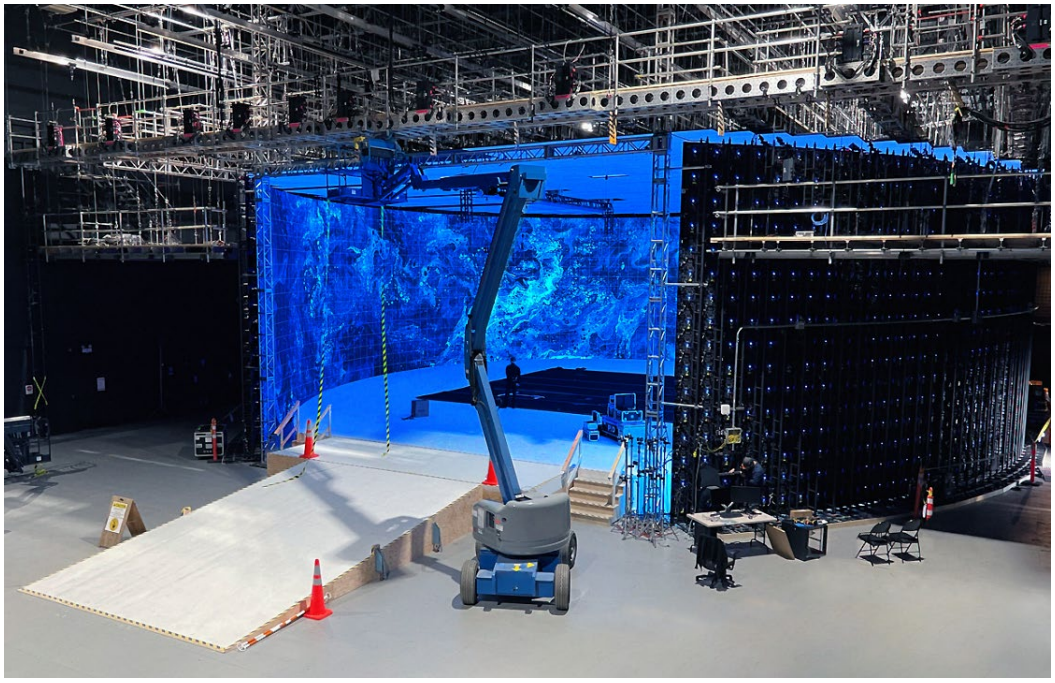

Figure 2. Pixomondo's LED volume in Vancouver, Canada. Photo by PIXOMONDO, in *B&H Explora*, https://www.bhphotovideo.com/explora/sites/default/files/0-ROE-Visual-LED-Panels-in-the-Vancouver-PXO-%26-WFW-Stage.jpg

Introducing the volume as a production tool has blurred boundaries between film disciplines. Film production workers such as camera operators, lighting technicians, and set designers, whose roles were traditionally fenced and reinforced by union rules or other film labor practices, found that their professional identities have become entangled with computation and data management–domains that had resisted unionization.

How can we understand this complex artifact or collection of linked technologies? How can we decode the shared professional knowledge of this loosely defined community of volume workers, and identify the edges of their practice? Some familiar work/culture questions can help us structure our inquiry. We can ask what changes when a new technology is introduced, who benefits and who loses as the technology unfolds? Who profits? How do practitioners and managers describe themselves and their work?

Monaco has called the recording arts (including film, sound, and photography), "the great single artistic contribution of the industrial age."[2] These key recording technologies have been powerful shapers of our cultural landscape ever since the late 19th century development of cinema. They have also been powerful economic contributors. According to the American Motion Picture Association, as of 2023 the U.S. film and television industry is a $134 billion dollar industry, comprising 2.74 million jobs, $242 billion in total wages, and more than 122,000 businesses.[3] However industry profit statements don't necessarily shed light on the benefits of a particular technology, and the figures don't describe painful outsourcing, working conditions or worker displacements linked to advances in film technologies. The story needs context.

In 2018 a small, well-funded group of filmmakers from Industrial Light and Magic and Disney had begun experimenting with new recording techniques they believed could save time and money on post-production, which traditionally consumes a significant slice of film budgets. By 2019 these techniques had developed enough to facilitate remote collaboration and allow filmmakers greater control over visual effects and post-production work. They began calling their working methods, centered on an LED stage, virtual production (VP).

Around 2020, as the pandemic was restricting film crews and actors from gathering on set or traveling to shoot on location, most film and television production ground to a halt. VP techniques presented a promising workaround. Within the new workspace taking shape around the volume, filmmakers in distant locations were able to virtually collaborate. They could also look through their lenses to see visual effects which had previously taken months of post-production work displayed nearly instantly on LED walls behind the performers, ready to be captured by the camera.

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[2] Monaco, James. *How to Read a Film: The Art, Technology, Language, History, and Theory of Film and Media*, New York, Oxford University Press, 1981.

[3] American Motion Picture Association, "The American Motion Picture and Television Industry: Creating Jobs, Trading Around the World," Motion Picture Association [March 6, 2024]. https://www.motionpictures.org/what-%20we-do/driving-economic-growth/ [accessed 6.1.2024].

Centered on the LED volume, VP takes off from traditional film production practices and incorporates reconfigured workflows, plus hardware and software that enables a virtual camera recording a computer-generated 3D world to be paired with a physical camera pointed at a physical stage and actors. The setup lets filmmakers capture computer-generated images and live performers simultaneously in the camera. This collection of rapidly-evolving techniques has disrupted traditional film workflows and the professional identities of film production workers, who have been recast as data workers. In talks and industry presentations, prominent producers and directors joined the ILM and Disney developers in promoting the new techniques as a "democratizing technology," claiming that these opened the door to broader participation by smaller players in the tech-heavy, resource-intensive film industry. But many VFX and other film workers rejected this claim, posting on social media descriptions of their stressful working conditions, struggles to learn new techniques and fears that their skills were being devalued or replaced by developing VP technologies.

At its essence, the LED volume at the center of the process uses contiguous surfaces of video displays, networked together to form one large seamless display surface. The displays are paired with tracking cameras, sensors and software that link a physical camera aimed at the screen with a virtual camera positioned inside a three-dimensional computer-generated scene (created in software such as Epic Games' *Unreal Engine*). As the physical camera moves, the virtual camera follows, streaming computer-generated content to the LED wall. Virtual scenes can be filmed as if they were physical locations, preserving the parallax effects and realistic perspectives a physical camera could capture on a physical film location. Each part of the process generates and consumes data, and managing these data streams becomes a primary task of film workers. Traditional job descriptions are being rewritten. Camera operators and lighting designers have become computer operators, and background painters have become digital environment artists, all operating in a liminal space that is a mix of physical and virtual spaces and tools.

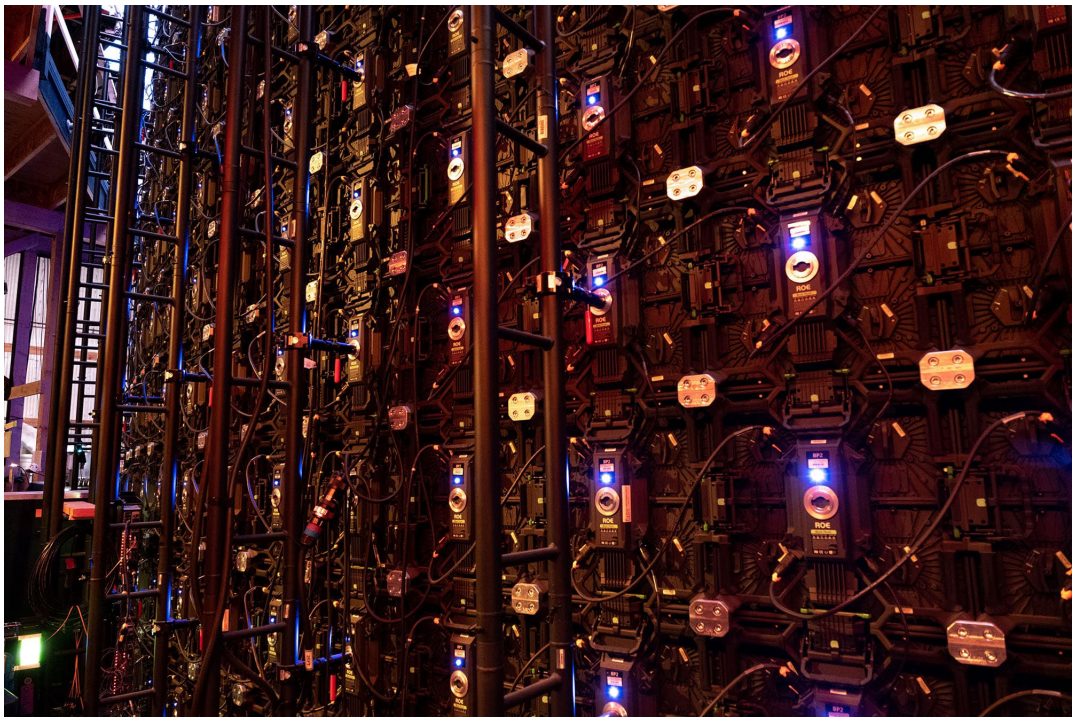

Figure 3. Back of LED wall, showing connected panels. Mike Seymour, *Art of (LED Wall) Virtual Production Sets, Part Two: 'How you make one', VFX Guide*, March 9, 2020. https://www.fxguide.com/fxfeatured/art-of-led-wall-virtual-production-sets-part-two-how-you-make-one/, accessed 6.4.2024.

Filmmakers have been using digital cameras and computer-generated visual effects for some time -- is any of this really new? Some parts are. The focus on managing data flows and data manipulation as primary filmmaking skills is new. The individual technologies that make up a volume were developed decades ago. Visible-spectrum LEDs were demonstrated at General Electric in 1962, and later mass produced by Monsanto and Hewlett Packard, used in small displays such as calculators. In the late 1990s, as digital cinematography evolved and digital cameras were adopted by filmmakers, they found that LED lighting meshed better with digital recording technologies than incandescent lighting. Director John Favereau, Grieg Fraser of Industrial Light and Magic (a Disney subsidiary) and Kim Libreri of Epic Games pushed the development of linked LED displays as a filmmaking tool, and pioneered the techniques for filming Walt Disney Studios' *Rogue One: A Star Wars Story* in 2016 and the television series *The Mandalorian*, which aired in 2019 on Disney+. It was during production of *The Mandelorian* that they began calling their virtual workspace "the volume."

Figure 4. Inside the volume, filming *The Mandelorian,* with inset image of the camera's view. Mike Seymour, *Art of LED Wall Virtual Production, Part One: 'Lessons from the Mandalorian', https://www.fxguide.com/fxfeatured/art-of-led-wall-virtual-production-part-one-lessons-from-the-mandalorian/, accessed 6.1.2024.*

The Mandelorian was filmed in a volume located in El Segundo California, which featured a curved wall, 20'-high-by-180' in circumference. The wall was constructed of 1,326 individual LED screens linked to create a 270-degree semicircular surface and included a hanging ceiling of LED panels.[4] The reported $100 million budget included this as well as seven powerful networked computers to process and deliver images to the wall. It also included miles of fiber optic and other types of cabling, switches, routers, time code generators and different types of computers for processing, synchronizing and displaying images on the wall.

For the series' cinematographers, the volume was a tool to freeze time, and create endless hours of the perfect sunset or repeating cloud patterns, as well as a tool for controlling lighting and reflections on shiny surfaces, such as the body armor of "Mando," the main character. Numerous virtual locations were created for the series, and when a specific location was needed for a scene, the production dispatched teams to Iceland and Utah to digitally capture physical

[4] Jay Holben, "The Mandelorian: This is the Way, "American Cinematographer, February 6, 2020. https://theasc.com/articles/the-mandalorian [accessed 6.3.24]. The LED panels in the Mandelorian had a pitch of 2.84 mm, which is the distance between each pixel on the screen.

landscapes using photogrammetry. The detailed 3D information was transported back for display on the wall and edited into new merged realities behind the actors.

As with *The Mandelorian* volumes can save the expense of transporting cast, crew and gear to physical locations and instead bring locations to the wall. But building a large-scale volume can cost millions, and even renting a volume can cost tens of thousands of dollars per day.[5] Despite the costs, the technology has been embraced by filmmakers -- one industry site noted that by 2021 there were over 120 large LED volume studios globally, with many more in the planning stages.[6] Smaller walls are proliferating for diverse uses including smaller-budget entertainment productions, advertising and education. Volumes themselves have become entertainment venues, as with *The Sphere*, a nearly 2,000-seat LED immersive display space that surrounds viewers, which opened in 2023 in Las Vegas.

As a technological object, the LED volume is neither good, nor bad and is certainly not neutral. It is an information/disinformation machine, a hired canvas, a sophisticated tool for persuasion, and it is a space ripe for AI-powered manipulations. The volume is a contradictory artifact—both highly engineered and entangled with very human creative activities. It is a cultural marker for changing work practices and professional identities in the entertainment industry's global community of migratory tech workers, and a factor in contentious labor disputes. The art and business of crafting imaginary worlds involves using ever more complex tools, and many workers fear the industry emphasis is shifting from valuing craft expertise to introducing significant automation and AI-assisted techniques. This is a familiar story in the history of technology.

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[5] Form Studios, https://www.formstudios.com/virtual-production-rental/ [accessed 6.1.24]
[6] Holben, Jay, "The Mandalorian: This Is the Way," *American Cinematographer,* February 06, 2020, *https://ascmag.com/articles/the-mandalorian [accessed 6.1.24]*

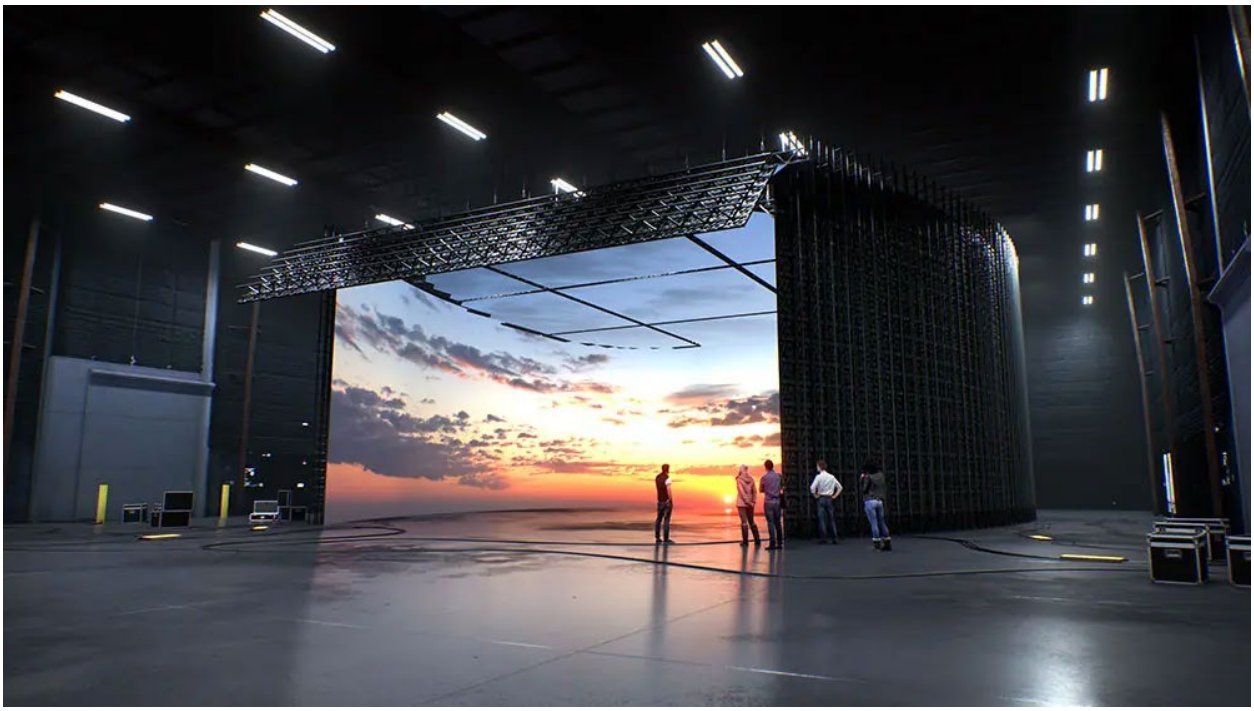

Figure 5. The LED Stage at Trilith, Atlanta, GA, *Atlanta's Trilith Studios to Open 18,000-Square-Foot Virtual Production Facility With NEP,* IMDB. https://www.imdb.com/news/ni63459261/; accessed 6.7.24.

Nearly every aspect of film production is being captured as editable data: cinematography and color science; camera tracking and motion capture; computer-generated environments, facial replacements, and digital doubles, display engineers. Cameras, lenses, and backgrounds have become computational objects existing in a contested zone between two conflicting cultures—a culture of intuitive, creative visualization decisions made by cinematographers, directors, and visual effects specialists; and a culture of technical expertise—digital camera operators, computational color scientists, technical artists, and display engineers making these data-driven decisions. These two cultures coexist with clashes and considerable overlap. Many professional positions sit close to the edges and participate in both (technically oriented visual effects artists are an example). Film industry unions have struggled to maintain the professional boundaries defined in the early years of filmmaking, but this has become more difficult. Last year's extended Hollywood strikes reflect these struggles, and more appear to be on the horizon.

It may be useful to think of the impressive physical spaces created by the walls of a volume as the tip of an iceberg poking above the surface. To analyze these technologies requires

peering below the surface, where the even more impressive virtual spaces of the volume extend outward and include the operators of software and hardware, computer servers that generate and display images on the walls, camera systems that surveille and track the locations of objects and actors within the space, and electrical signal flows connecting overlapping systems together. The precise edges of the iceberg are slippery and hard to grasp, extending to all those who define themselves as volume workers. Computation is a theme tying diverse practitioners to the volume.

Contradictions are part of what signals an edge technology. In this case, they include the push to call the technology democratizing vs clear indications of broad industry consolidation; layoffs vs contract hiring; traditional union job categories vs difficult to categorize types of computer work; the push to use AI to automate, vs the artisans, craftspeople, and creative workers with years of training; film studios chasing financial incentives around the globe vs the decentralization of place as a critical factor in production decisions. Debates around these contradictory influences reveal participants' desires for more well-defined professional identities.

Following the power shifts and listening to what key funders and stakeholders say about themselves in talks and presentations is one way of understanding how power is shifted in the volume workplace. Skilled, resourceful individuals and small studios operating with relatively modest budgets can acquire and work with smaller LED walls and virtual production technologies to produce sophisticated effects. But while film funders claim this as a "democratizing" effect of the technology, these could equally be seen as techniques for wresting more control of production from traditional visual effects companies.

Historians of film technologies face challenges in grappling with the volume's subsurface traces. Though the systems are composed of physical elements like computers, image processors and wiring, film companies generally preserve little written documentation accessible to researchers. Teams engage with one another via verbal utterances, messaging applications such as Slack, email or other ephemeral communications and documents stored in private, temporary online repositories, including Google storage spaces. While some practitioners have traditional film or television production backgrounds, there is no one training path or apprenticeship or course with syllabi to examine. Understanding the volume as a technology requires immersion in these cultures, perhaps aided by ethnographic techniques. How are people communicating, where is the work being performed, what terms do people use to describe themselves and their work? Who are the innovators and which part of the community is generating change? In the

entertainment industry workplace ethnographies can be difficult to arrange, as most film sets are secretive spaces, fenced in and policed by non-disclosure agreements. Fortunately, the proliferation of social media communications, recorded online talks and conference presentations can provide some insights.

Future historians will need to be as agile and innovative as their subjects and consider both observable and less-visible evidence. Being attentive to cultural traces and interactions, no matter how fleeting, is as important as studying texts, physical structures, and systems, to understand what's happening at the edges of these technologies. Though the complex embrace between technology and the cinematic arts presents research challenges, it also offers rich opportunities for the adventurous explorer of these new hybrid domains. As the old curse goes, may you live in interesting times.