FATE AMENABLE TO CHANGE: A TECHNICAL AND SOCIAL HISTORY OF VIRTUAL REALITY IN THE UNITED STATES OF AMERICA, FROM 1965 TO 2005.

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ABSTRACT

For Fate Amenable To Change: A Technical And Social History Of Virtual Reality In The United States Of America, From 1965 To 2005. Tobias Bowman. Green Templeton College.

Virtual Reality (VR) technology lacks a clear definition, unique application, or history, leading to difficulties in identifying primary source materials. This thesis establishes a workable definition of VR, incorporating it into cross-disciplinary methodologies to reveal and arrange newly-uncovered sources into a narrative, spanning 1965-2005. This narrative will hopefully encourage crystallisation around the proposed definition, providing value to developers and historians of technology.

Combining online database sampling, stacked surveys of diverse materials, and interviews, the author situates VR within a broader context of 20th and 21st century American social history. By integrating methodologies from Contemporary History, Economics, and Sociology, the newly-established definition is tested via the narrative, which is itself supported by new-found primary materials. That historical narrative assesses the impact of missing social and technical ‘standards’ in VR’s tumultuous past, with implications for both historians and designers of VR, as well as other modern technologies. The results suggest that, since the mid-1980s, exaggerated capabilities and science fiction applications, extolled by both developers and media writers, far outstripped technical reality (unbeknownst to consumers), forming reverse salients on the research and innovation crucial to any modern technological system’s viability. The period spanning the mid-1960s to mid-1980s witnessed much more limited research, centred around identifying valuable applications concurrently with system development, and long before the release of products. This earlier, more cautious period was demonstrably more successful because its VR applications, such as medical training and virtual design, persisted through the ‘VR Winter’ of the late 1990s when later ‘VRs’ did not. Thus, the definition provided is useful for reliably identifying new source materials through the database sampling and analytics methodology, developed therein, which is valuable to historians of VR.

EXTENDED ABSTRACT

For Fate Amenable To Change: A Technical And Social History Of Virtual Reality In The United States Of America, From 1965 To 2005. Tobias Bowman. Green Templeton College.

The digital computer has shown itself, through the work of numerous historians, to be a highly disruptive and influential technology on the social, economic, and technological systems of the 20th and 21st centuries. Virtual Reality (VR) occupies a unique niche within the broader spectrum of computer technologies, providing not only a new means of interacting with and using computers, but new ways of thinking about creativity, the amplification of human faculties, and concepts of reality. Despite its half-century of development and innovation, VR remains a little-studied technology, however, from historical, physiological, computer-scientific, or socio-cultural perspectives, something explicitly addressed in the thesis. This is despite the technology's prominence both in the 1990s and in 2018. Also addressed is the lack of historical depth attached to current VR narratives by combining existing discussions of VR's past with a wide range of primary materials and oral histories new to the discipline.

Furthermore, an interrogation of the cultural and technical issues plaguing VR which allowed it to avoid the attention of historians so successfully is made. Firstly, problems of definition and vocabulary have hindered the disambiguation of VR. Its examination from any kind of historical systemic perspective (in the manner of Thomas Hughes) is rooted in the technology's translation from state-institutional to private-capital based development, where its definitions became clouded.[1] The earlier systems developed for Intelligence Amplification (IA), at universities and state-funded institutions like NASA Ames (National Aeronautical and Space Administration), integrated a Head-Mounted Display (HMD), motion tracking, and haptic feedback but lacked a name or vocabulary, and have been given those in a unique narrative provided in the thesis under the moniker of 'proto-VR'. Intelligence Amplification technologies were relatively new at the time,

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[1] Thomas Parke Hughes, 'The Evolution of Large Technological Systems', in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, ed. by Wiebe E. Bijker, Thomas Parke Hughes, and Trevor J. Pinch, First Paperback (1989), 51–80.

having been expounded by Douglas Engelbart and Fred Brooks, among others, in the 1960s. Rooted in early cybernetics research, IA research sought to develop means to enhance human faculties through the use of computer technologies, and was widely used in Computer Science and Artificial Intelligence circles in the United States, both at state institutions like DARPA, Universities such as the University of North Carolina at Chapel Hill (UNC) and private companies like Xerox.[2] IA research projects often took the form of Proto-VR technologies at these institutions, and the resulting history of institutional development lent the technology, credibility which was then used to support far more outlandish notions surrounding its capacity for entertainment. Rebranded as VR and borne aloft by the cyberpunk counterculture of a wealthy, expanding Silicon Valley, it nonetheless lacked valuable applications, markets, or even technical feasibility. Without these, VR relied on marketing hype and futurology to sustain interest and investment (as state-sponsored projects fell away) which in turn hyperinflated expectations on the part of the public and created an environment in which VR's nature was fluid, independent of technical possibility or any clear paradigm. The applications and definitions of proto-VR, revolving around IA and determined by institutional and government funding allocations to developers such as Ivan Sutherland and Thomas Furness III, gave way to marketing punditry and (as Steve Woolgar would call it) 'cyberbole' under the banner of VR.[3] This, in turn, meant that the technologies broadly labelled VR comprised far more than the hardware of proto-VR. Simultaneously, many of the systems which retained technical continuity with proto-VR were not called VR but were instead deliberately given different names, such as Virtual Environments (VE), to discretise them from VRs populist, hollow promises.

With such confused definitions, it has proved difficult for historians to separate VR from the broader corpus of computer graphics and displays, leading to the dominance of popular histories which duplicate errors, a challenge which has been addressed in the thesis. The manner of this is via the development of an explicit definition for VR, which is then used to filter primary and secondary materials, as well as material culture, and personal recollections from contributors. Many definitions already exist for VR (Jaron Lanier provides more than fifty[4]) and others are also valid, usefully those surrounding its earliest versions frequently held common denominators. These have been unified into a single definition and tested in the thesis to determine whether it can identify technologies broadly agreed to be VR from any point in the last fifty years. The findings indicate that a valid definition for Virtual Reality is:

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[2] Howard Rheingold, *Virtual Reality: The Revolutionary Technology of Computer-Generated Artificial Worlds-And How It Promises to Transform Society*, 1st edn (New York, N.Y., 1991), 36-8.

[3] Steve Woolgar, *Virtual Society?: Technology, Cyberbole, Reality* (2002), vi; Steve Woolgar, 'Five Rules of Virtuality', in Steve Woolgar (ed.), *Virtual Society?: Technology, Cyberbole, Reality* (2002), 22.

A technology which uses a Head-Mounted Display (HMD) and motion tracking to provide a point of immersive interface between a person and a digital computer-generated graphical environment, in order to create a sense of presence in that environment.

Immersion, is taken mean a technological means of creating the sense of being surrounded by the environment within VR, to the point at which the display (the screen) becomes invisible, in the manner of Steve Bryson and John Walker.[5] Presence here is the sensation of being able to interact with the environment as though it were reality; objects within the environment seemed to be distinct from both the user *and* the display, and rather than interfacing with objects on the screen, the user feels that they themselves are inside the virtual environment.

This definition is advantageous to historians as it replicates the core technical and experiential elements of the technology as it was understood by the people who developed and propagated the terminology. Also, it separates VR from large volume displays, immersive projections, 3D graphics, video games, and virtual spaces such as the Internet. In doing so, VR can be examined both separately from, and in the context of, those technologies. This definition is used in the thesis to separate out VR and proto-VR from other computer technologies, even when there is no clear dividing line by language alone, and with this achieved, a narrative surrounding it is built.

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[4] Jaron Lanier, *Dawn of the New Everything: A Journey Through Virtual Reality* (2017).

[5] John Walker, *Through the Looking Glass: Beyond User Interfaces* (1 September 1988) <https://www.fourmilab.ch/autofile/e5/chapter2_69.html> [accessed 24 April 2017] 'Through the screen to Cyberspace'; Steve Bryson, 'Virtual Reality: A Definition History - A Personal Essay', *ArXiv:1312.4322 [Cs]*, 2013 <http://arxiv.org/abs/1312.4322> [accessed 23 April 2017], 4.

Coupling the definition with a strict United States (US) focus provides as clear a view as possible into the technology's development in one of its most historically important contexts. Such a focus is approached via interdisciplinary methodologies. An historical sampling process, based on the work of corpus linguists, uses the definition of VR to filter a set of online databases for primary and secondary material and then stratifies them for each year studied. The advantage of this method is that it allows for a close reading of hundreds of sources pertaining to VR and proto-VR regardless of whether they name the technology explicitly, and thus many of these are new to history. Furthermore, an oral-historical approach, borrowed from histories of AI by authors such as Pamela McCorduck, provides vital depth and personal experiences as a counterbalance to the primary materials uncovered.[6]

The narrative is thus based on as close an understanding of the contemporary discourse surrounding VR technologies as possible. Throughout this narrative, tensions are visible in the creative intent behind the development of VR, as well as the social structures that formed the contexts for its use and realisation. VR's history is most often told through popular hyperbole and heroic, present-centred, depictions of visionary foresight on the part of both proto-VR and VR developers. For years, VR was depicted as having the potential to revolutionise society, and its histories are often equally divorced from reality. A concerted effort has therefore been made to provide a more balanced and, where possible, wider-ranging study of the governmental, military, academic and entirely personal forces which interacted in the development of both the technologies of VR, and the different ways in which it was defined, applied, and consumed during the forty-year period studied.

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[6] Pamela McCorduck, *Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence*, 2 edition (Natick, Mass, 2004).

By pursuing a chronological structure, the vastly diverse strands of information needed to construct an entirely new historical resource are conveniently compartmentalised. Starting with Ivan Sutherland's description of a system adhering to VR's definition in 1965, an examination of the technical and popular literature surrounding the technologies of VR is made.[7] The thesis includes a history of the earliest days of VR, demonstrating the effects that a wealthy US government, Cold War tensions, military interest in computers, and a fondness for technical blueprints had on the funding and development of an incredibly expensive experimental computer technology. Limited archival resources explicitly linked to VR developers within and without the private sector have hampered previous research into the earliest years of VR, but multiple resources are brought together for the first time here and combined into a multi-faceted, high-resolution study of the history of VR and proto-VR in academic, military, and private-capitalist contexts in the US.

Following the formation of the proto-VR, IA typologies which served as foundations for the invention of VR, an analysis of the highly complex institutional and systemic translation undergone by VR between the end of the 1970s and the 1980s is carried out. This transitional period saw perceived applications of VR become both less martial and more ludic as private developers used the legitimacy granted by proto-VR's use in successful research projects to popularise (and market) commercial versions of the technology. These new versions had, as inspiration, science fiction and internet-based cybercultures, and as such acquired a very different set of expectations and cultural contexts, none of which begat consensus on a paradigm or definition for the technology. Older notions of using proto-VR for IA were still pursued, behind the dark curtain of governmental confidentiality.

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[7] Ivan E. Sutherland, 'The Ultimate Display', in *Proceedings of the International Federation of Information Processing Congress*, 1965.

The popularisation of such exaggerated notions of VR via the media formed a hyperbolic vocabulary which was not tied to specific product standards or technical feats, and this is shown to have had a disruptive effect on the ideological cohesion of the technology. This lack of unified aspiration and approach led to frustrations with the pace of VR research, and the reduction of interest in proven applications of proto-VR technologies both within and without the technical community. Hopes for fantastic capabilities in a few short years, fuelled by popular science fiction, overzealous marketing, and the Internet, were unfounded and previously steady development became rushed, directionless experimentation, as many sought to make VR perform the features that were now expected of it by the public and investors alike. This new VR was separate from that which preceded it and came to dominate popular and institutional notions of what VR should be expected to do.

The period of public-facing VR's explosive cultural boom and bust is covered by two chapters, the first spanning the VR bubble between 1990-1997 and the second, the VR depression from 1998-2005. Disproportionate, unrealistic representations of proto-VR technologies, and the inevitably chaotic development from private companies seeking to realise them led to a host of expensive nigh-unusable products all bearing the VR moniker. This led to a rapid diaspora of rhetoric surrounding VR technologies and applications, rendering the technical and social histories of VR difficult to parse, but these are intertwined in the four historical chapters that make up the main body of the thesis.

Therein, primary technical and popular materials are combined with interviews from experts, and consumers from the time, to cast the technical nature and cultural perception of VR into sharp relief, despite the abundant definitions and vapourware products of the period. In this way, changes in the way VR was defined and developed in the US are described against a dark background of broader social, economic, and technological change. Those shifts are also used to suggest changing discourse patterns in the US among businesses and research institutions, as real applications of VR competed for funding and appreciation against the cyberpunk hyperbole of VR's popular brand. Fallout from VR's over-use is made clear: as disappointment grew, portrayals changed, and companies ceased trading. Eventually, for casual readers of the time, VR became near-impossible to disaggregate from other computer technologies, a difficulty shared by popular historians, sociologists, and journalists alike, both then and now.

Including a focus on the sorely understudied 'winter' period of VR, after the collapse of the 1990s bubble, analysis of both print and internet discourse highlights fascinating technological and semantic shifts pertaining to VR at that time. Advertising and press campaigns deliberately altered the language used to articulate VR, its applications, and its technical foundations, from those of its proto-VR past (a technically defined tool for project-led applications) to a far more vague, hardware-agnostic, ludic and creative fantasy. The suspension of disbelief employed by films depicting VR's power, such as *The Lawnmower Man*, was similarly required for definitions of VR during the 1990s and used to great effect when the appeal of VR's original typologies faded.[8] Projectors, 3D monitors, video games, and websites all became means of experiencing 'VR'. The colossal technical obstacles faced by existing HMD-based VR had proved too difficult for many, and interest shifted to other, more readily available, and successful systems such as the World Wide Web, drawing the technically-untethered VR language with it. Without a clear definition to anchor it to technological capability, the term 'VR' is then shown to have been absorbed by larger successful systems like video games, computer graphics, and personal computing. The conclusion drawn is that, without a technical backing, the concept of VR was not viable, and only returned when HMD-based systems became popular again in the 2010s. VR hardware was, by 2005, invisible on the American high-street, and largely removed from popular culture, save for the occasional sinister reminder of the dangers of computerised illusion in fiction.

By drawing together the strands of private, academic, scientific, and military research, in the contexts of both real-world applications in industry and medicine, and science fiction-derived aspirations, a conclusion to the narrative is formed. This allows the changing technical expressions, and their relation to understandings of VR and proto-VR's purpose, value, nature, and success during the first forty years of its history to be discussed and evaluated. The analysis shows that VR's connotation with fantastical ideals, as a replacement for the more mundane project-led goals of IA, coupled with its uniquely social nature, doomed its initial launches and hype cycles to failure. The dangers of hyperbole as a substitute for demonstrated potential, Venture-Capital based innovation, and a largely homogeneous user base are explained. The key research questions of how Virtual Reality is to be defined, historicised, and used to inform debates about the value of paradigms to technological 'success', are fully addressed. VR was unable to succeed in its earlier iterations precisely because it lacked this shared language, through which the impossibility of goals informed by the language of futurology and science fiction, may have become apparent. Furthermore, that lack of a paradigm ensured that, as the technology of HMD-based VR lost currency with the American public, the vague notions of its *concept* were forcibly applied to other, more popular information technologies, chiefly the World Wide Web. Implications of this research for the more recent history of Virtual Reality, between 2005 and the present day are also considered. Now, as then, VR has no clear definition, and the history and materials collected in the thesis provide one, in the hope of crystallising notions of VRs nature going forward into the 2020s and beyond.

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[8] Brett Leonard, *The Lawnmower Man*, 1992.

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LIST OF ABBREVIATIONS

- 2D: Two-Dimensional
- 3D: Three-Dimensional
- AI: Artificial Intelligence
- AR: Augmented Reality
- ARPA: Advanced Research Projects Agency
- CAD: Computer Aided Design
- CAVE: Cave Automatic Virtual Environment
- CEO: Chief Executive Officer
- CGI: Computer Generated Imagery
- CIA: Central Intelligence Agency
- CRT: Cathode Ray Tube
- DARPA: Defense Advanced Research Projects Agency
- DoD: Department of Defense
- FBI: Federal Bureau of Investigation
- FoV: Field of View
- HITLab: Human Interface Technology Laboratory
- HMD: Head Mounted Display
- IA: Intelligence Amplification
- ICT: Information and Communications Technology
- LBE: Location Based Entertainment
- LEEP: Large Expanse Extra Perspective
- LVD: Large Volume Display
- MIT: Massachusetts Institute of Technology
- n.d.: No Date
- NASA: National Aeronautics and Space Administration
- NSA: National Security Agency
- PC: Personal Computer
- Pers. Comm.: Personal communication
- R&D: Research and Development
- RAVE: Reconfigurable Virtual Environment
- RB2: Reality Built for Two
- SGI: Silicon Graphics International
- UNC: The University of North Carolina at Chapel Hill
- US: United States
- USAF: United States Air Force
- VE: Virtual Environment
- VIEW: Virtual Environment Workstation
- VIVED: Virtual Environment Display
- VR: Virtual Reality

CHAPTER 1: AGAINST A DARK BACKGROUND: INTRODUCING VIRTUAL REALITY, AND ITS HISTORY

‘VR is shared and objectively present like the physical world, composable like a work of art, and as unlimited and harmless as a dream. When VR becomes widely available, around the turn of the century, it will not be seen as a medium used within physical reality, but rather as an additional reality.’

- Jaron Lanier, *VPL Research Inc. at Texpo ’89*.

‘Generally speaking, virtual reality currently has an extremely high ‘talk-to-work’ or ‘excitement-to-accomplishment’ ratio. Between 1992 to 1994, roughly 12 new books have been published, 4 new journals or magazines have been started, and 200 new articles have been published on the topic of virtual reality.’

- Nathaniel Durlach and Anne Mavor (eds.), *Virtual Reality: Scientific and Technological Challenges* 1995, 14.

‘Virtual Reality (VR), sometimes called Virtual Environments (VE) has drawn much attention in the last few years. Extensive media coverage causes this interest to grow rapidly. Very few people, however, really know what VR is, what its basic principles and its open problems are.’

- Thomas Mazuryk and Michael Gervautz, *Virtual Reality – History, Applications, Technology and Future,* 1996, 1.

FRAMING THE VIRTUAL WINDOW: DEFINING VIRTUAL REALITY FOR HISTORIANS OF TECHNOLOGY

The term ‘Virtual Reality’ has been in use since at least 1986 and is, in the 2010s, enjoying a global resurgence. Despite having inspired video games, television shows, books, and films, its history remains sorely underdeveloped, with a dearth of scholarly work, even within the history of technology. As a result, narratives about its creation, usage, and development remain scant. Being a technology enabled and influenced by the successes of the 1980s personal computer revolution, the history of Virtual Reality is also a history of American public opinion, computing, consumerism, and popular culture. Furthermore, Virtual Reality’s history is one of technological concepts, governed by ideas from science fiction, conflicting with the technological limitations of computers.

The past of Virtual Reality, from the 1960s to the 2010s, incorporates elements of these histories in a unique way.

Many technologies are described as being socially constructed. Institutions and individuals help shape the development and use of technologies, and their social structures have formed crucial aspects of the historical identity of Virtual Reality. As a technology, Virtual Reality, and user reactions to it have been as much a product of developments in hardware and software as it has been the result of various social factors. Like hypnosis, but unlike almost any consumer technology, Virtual Reality's successful deployment is reliant upon the willingness and capacity of users to suspend their disbelief, allowing themselves to *feel* present in an entirely virtual environment (though a 'perfect' Virtual Reality system would not need this). For some, achieving these states is easy, for others, it requires considerable effort, even to the point of causing physical discomfort. For others still, it is impossible. Entirely separate from the technical and scientific difficulties associated with creating economical, user-friendly, comfortable Virtual Reality systems, social, cognitive, and physiological barriers to the acceptance of Virtual Reality equipment have also posed major problems.

In this thesis, it is argued that a history of both the technological and social aspects of Virtual Reality can only be achieved by giving a broader account of the relationship between Americans and computers, and a properly contextualised history of that relationship is needed. Diverse levels of familiarity and affinity with computers helped shape the varying levels of acceptance that Virtual Reality received, and the movement of Virtual Reality from state-funded and university-based projects was facilitated by those familiar with and intimately connected to computers and their usage. Moreover, the desire of many of those 'digiterati' to move Virtual Reality into the public sphere, and make it into a consumable product, was rooted in science fiction and a groupthink optimism, rather than its proven technical capabilities.[1] Based on social and cultural expectations more than a semblance of technologically achievable goals, the failure of Virtual Reality was the product of a pervasive understanding on the part of manufacturers, innovators, journalists, and consumers, that Virtual Reality was already something which it was, in fact, yet to become.

Throughout this thesis, the sudden move into public life and private development in 1989 and 1990 is shown to have been driven by the twin cultural pressures exerted by science fiction and computer hacker culture, rather than by technological breakthroughs or economic pressures. Moreover, it was amplified through the unique cultural, financial, and technological lens of 1980s Silicon Valley. Rich with wealth, expertise, drugs, and a popular counter-culture, the area provided a fertile spawning pool for computer technologies to gain a cultural significance that extended far beyond their on-the-ground reality. The early commercial development of Virtual Reality arose from an assumption that the computer interface technologies of NASA Ames' VIVED (Virtual Environment Display) and VIEW (Virtual Environment Workstation) would provide a uniquely immersive and interactive medium for entertainment, in which the user could feel present within the content. In Silicon Valley at the end of the 1980s, that functionality seemed inevitable. Outside of the wealthy, aspirational braggadocio of Silicon Valley, however, those experiences were beyond not only the technological possibility for the period but cognitive acceptability. The portrayal of similar concepts in science fiction rendered the notion of such a technology plausible, and rendered the experience jarringly dissimilar to expectation. The degree to which users could engage with uncomfortable and visually challenging experiences endemic to Virtual Reality systems depended on their familiarity with computers, and their willingness to suspend disbelief when confronted with the earliest rudimentary virtual worlds. As a result, in the late 1980s and early 1990s, different people could experience the same system as either transcendental, meaningless, or somewhere in-between, depending on their personal disposition.

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[1] Stephen Ellis, *Pers. Comm.*, 19th July 2017.

The history of the development of Virtual Reality technology demonstrates the perils inherent in technological development led by a science fiction idealism over clear technical goals: failure, disillusionment, and/or physiologically or psychologically harmful products. It also shows the power of American expectations, popular culture, and the need for technologies to be comprehensible, definable, and literally acceptable. Expectations for the experience of Virtual Reality to match its fantastical portrayal in media as an affordable, evolving, diverse, and revolutionary technology drove product design and project goals. Unsurprisingly, this led to the formation of a technological business with slim technical foundations. A technology 'industry' shaped almost entirely by hope for what the technology *could* be, not what it was ever capable of, is extremely uncommon in the history of technology, if not unique. While many technologies rode waves of hyperbole to bubble-like success, Virtual Reality's high ratio of firms to products, content, or indeed sales at *any* stage of its history separates it from them. Its meteoric growth in awareness and investment were based on ideas and images rather than products or consumers, and even the biggest flops usually have the former. Of the hundreds of US-based Virtual Reality companies in the mid-1990s, only around 10% (at most) were actually manufacturers, and none sold more than 200 units a year globally. Despite this, Virtual Reality movies, TV shows, books, and games were ubiquitous in popular culture, and technology giants like Intel, Nintendo, and IBM all pursued different avenues of Virtual Reality research and product manufacture in the first half of the 1990s.

In a period where featurism (the progressive addition of features for the sake of novelty rather than demand for those particular functionalities) and technological exceptionalism were core aspects of American technological-identity and consumerism, Virtual Reality was advertised and marketed in ways that could not be matched by the technology. Virtual Reality systems lacked growth in capabilities from its state-funded 1980s format, lacked any clear applications or purpose, and cost more than the annual income of most families. At the same time, state funding moved on to Internet research (the so-called Information Superhighway) and subsequently made possible an online network of virtual realities which would come to render contemporary Virtual Reality technology near-obsolete before there was a chance for its supposed value to be demonstrated. Parallel to this is the inherently intimate, personal nature of the experience of Virtual Reality, which made individual impressions vital to acceptance and fed a confirmation bias already rife in Silicon Valley. With access highly limited until the first mass-market release in 1995, users of Virtual Reality in the first half of the 1990s were predominantly those seeking it out, increasing both the baseline acceptability and (perhaps) expectations attached to it. The exposure of a far wider base to 'Virtual Reality' with 1995's Nintendo Virtual Boy dispelled this bias and contributed to the subsequent drought of both excitement and funding in the following years. With graphics that were considered poor for the time (one contemporary account described the fidelity of one 1992 Virtual Reality system as being akin to legal blindness), 1990s Virtual Reality failed to approach the empowering, transformative imagery used to sell the technology in print and film. This was exacerbated by endemic problems with nausea, so common that it was named Cybersickness, and a severe lack of content. In short; the Virtual Reality systems accessible to American consumers in the 1980s and 1990s were expensive, difficult to use, incapable of providing the capabilities expected of them, and for many, entirely unconvincing.

LANGUAGE BARRIER: THE LINGUISTICS OF VIRTUAL REALITY AND VR

Despite the current prominence of Virtual Reality, its definition is a major obstacle to its study. Social and technical changes during the short-lived Virtual Reality boom of the early 1990s led to many technologies being branded 'Virtual Reality' (including the Virtual Boy), and there was no set of standards around which a clear description could be formed. This prevented public expectations from being based in technological reality, further hampering the growth of a tolerant user community. Defining Virtual Reality remains a challenge well into the second decade of the third millennium, a fact that has made it extremely difficult to situate the development of Virtual Reality in its technical and social contexts.

To construct a reliable, accurate narrative of Virtual Reality's past developments, iterations, and contexts, a singular definition is therefore required. There are difficulties and assumptions associated with imposing any conceptual boundaries to the term, since any definition narrow enough to be useful to historical research will exclude some relevant technological and social developments. Because of this, it seemed prudent to find a definition which fulfilled two principal criteria: (i) applicability throughout the four decades of the history of Virtual Reality covered in this thesis, and (ii) common ground with a majority of existing definitions in both popular and technical primary material. As for (i), some of the broadest definitions of Virtual Reality extend back to the 5th Century BCE, with Pliny the Elder's parable of Zeuxis's hyper-realistic paintings, or to Pompeii's illusionary walls.[2] An extremely precise definition, on the other hand, cuts the range too far, limiting Virtual Reality to, as an example, between 1986 and 1997, (supposing that Virtual Reality systems must use DataGlove interfaces). As such, a middle ground is needed, with a definition that provides a clear time-frame for the technology's development and use, without being so large that resolution is lost, or so small that perspective is impossible.

The second problem, that of identifying common denominators in existing sources, relies on the assumption that the sources preserved broadly reflect the range of definitions of Virtual Reality used by contemporary experts and laypeople alike. Among the thousands of sources available to historians of Virtual Reality, this seems a daunting task, but many 1980s and 1990s writers deliberately explained what they meant by the term. While there are several workable definitions in the literature, the one used here is one reached by these methods. As well as being instrumental in making this thesis possible, it will hopefully allow future historians of technology to easily shape and elucidate narrative threads pertaining to Virtual Reality running through the broader history of technology.

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[2] Frank Biocca and Mark R. Levy, *Communication in the Age of Virtual Reality* (1995), 7-8; Oliver Grau, *Virtual Art: From Illusion to Immersion*, New edition (Cambridge, Mass., 2004), 365; Stephen R. Ellis, 'What Are Virtual Environments?', *Computer Graphics and Applications, IEEE*, 14/1 (1994), 17–22.

Throughout the thesis, Virtual Reality shall, therefore, be taken to mean

> A technology which uses a Head-Mounted Display (HMD) and motion tracking to provide a point of immersive interface between a person and a digital computer-generated graphical environment, in order to create a sense of presence in that environment.

To break down each part of this definition; Virtual Reality is a technology, that is: a collection of knowledge and techniques encoded within a physical object of material culture, it is not a concept or philosophy (though many have considered it as such). It incorporates an HMD, which constitutes a pair of screens worn directly before the eyes. Motion tracking is a technology wherein, in this case, the movement of part or all of a VR user is processed as computer input. Immersion, here, is a function of technology, a sense of being surrounded by the environment within VR, to the point at which the display (the screen) becomes invisible, in the manner of Steve Bryson and John Walker.[3] A graphical environment in this case means one in which the virtual world is presented to the user visually, other senses may or may not be involved. Finally, presence here is less a function of technology and more one of content, presence here is the sensation of being able to interact with the environment as though it were reality; objects within the environment seemed to be distinct from both the user *and* the display, and rather than interfacing with objects on the screen, the user feels that they themselves are inside the virtual environment. This borrows elements from the definition of presence given in Steve Bryson's history of VR, while expanding to also require content specifically designed to make the user feel that they are a part of the environment they are seeing (viewing 2D content through an HMD would thus not evoke presence).[4]

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[3] Walker, John, *Through the Looking Glass: Beyond User Interfaces* (1 September 1988) <https://www.fourmilab.ch/autofile/e5/chapter2_69.html> [accessed 24 April 2017] 'Through the screen to Cyberspace'; Bryson, Steve, 'Virtual Reality: A Definition History - A Personal Essay', *ArXiv:1312.4322 [Cs]*, 2013 <http://arxiv.org/abs/1312.4322> [accessed 23 April 2017], 4.

While there are numerous other definitions possible, this one meets the criteria above; it matches the nature of the first American computer-driven Virtual Reality system, and the applications of HMDs and motion tracking throughout dozens of projects and publications from the 1960s through to the 2000s.

Even with a clear definition, however, presenting a history of Virtual Reality poses many problems. While many 20th century technologies emerged as an amalgam of other technologies and then became a 'self-propelling' system (according to the account offered by Thomas Hughes[5]), Virtual Reality never really achieved this degree of momentum throughout the period studied. The HMD screens were taken from miniature televisions and camcorders, the graphics software was taken from video games and Computer Aided Design, the graphics hardware was taken from industrial imaging applications, and the motion tracking was taken from the military (specifically Thomas Furness's Visionics research in the 1960s, and NASA's telerobotics research in the 1980s).[6] The core components of Virtual Reality each have their own concurrent histories, quite separate from Virtual Reality, and most Virtual Reality systems from the 1960s all the way through to 2005 were 'cannibalised' by hand from other technological systems, with little or no internal development or manufacture. Virtual Reality's failure to self-propel from this amalgamation was principally a product of the extremely high costs of the component parts, the technical obstacles to providing experiences of the expected quality, and a lack of both consumers and content. The consequence is that historians of Virtual Reality need to be able to assess where a product or source is discussing Virtual Reality, or just an HMD, a virtual environment, or even the Internet.

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[4] Ibid.

[5] Thomas Parke Hughes, 'The Evolution of Large Technological Systems', in Wiebe E. Bijker, Thomas Parke Hughes, and Trevor J. Pinch *(eds.), The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, First Paperback (1989), 51–80.

[6] Stephen Ellis, Interview, 13 Mar 2018.

Even once a definition for Virtual Reality has been found, use of the term remains problematic. It is accompanied by Augmented Reality technology (AR), which employs the same principles to superimpose 3D images on the real world, and which is sometimes used interchangeably with Virtual Reality in both contemporary and current literature. Virtual Reality as a term was only coined in 1986 and fluctuated wildly in connotations and meaning in the years that followed, having been preceded by terms like Virtual Environments (VE) and Artificial Reality. Furthermore, many Virtual Reality researchers in the 1980s and 1990s deliberately avoided the use of the term, as it was too closely tied to the specific work of one company (VPL). Instead, VE was often used to broadly describe the same technology.[7] 'VE' could be used to differentiate between the Virtual Reality technology in popular culture and the systems developed by researchers, but in doing so would introduce problems with definition for VE as well as Virtual Reality, further clouding the definition and scope of the technology for the purposes of historical research. As such, throughout the thesis, when referring to the technologies of Virtual Reality, the term will only be used to refer to iterations dating from after its naming, to avoid anachronism, and in its truncated format, VR. Examples of similar technologies developed prior to the coining of VR that lacked a name, such as NASA's VIVED, Thomas Furness's VCASS, and Sutherland's 'Ultimate Display' will be referred to as proto-VR.

THE PLACE YOU GO WHEN YOU'RE ON THE PHONE: A BRIEF CHRONOLOGY OF VR

Given the above definition, VR's history began in 1965, with Ivan Sutherland's written proposal for 'The Ultimate Display'. This device would provide a window into a computer-generated virtual space, and could be used to train soldiers, enhance the ability to do work, or provide access to 'the Wonderland into which Alice walked'.[8] Sutherland's real interest, however, stemmed from a desire to examine technical blueprints more easily stored in a computer. In 1962 he had created Sketchpad, an early example of interactive graphics software, while a doctoral student at MIT, and he continued his graphics research in the mid-1960s at Harvard. Following a brief stint at the US Department of Defense's (DoD) Advanced Research Projects Agency (ARPA), he joined the Engineering department at Harvard University in 1965 and led a team that used an HMD manufactured by PerkinElmer to build a prototype immersive display in 1968. It worked by showing two slightly different images to each eye to create the illusion of a three-dimensional image. The image appeared to 'float' in the room beyond, and would respond to user movements, forming the first examples of both VR and AR systems. Sutherland moved the hardware, and some of his students, to the University of Utah the same year. Drawing funding from a range of sources, including ARPA and the American security services, they used expensive computers to generate graphical 3D simulations of virtual space which fostered a sense of presence. Despite the rapid and unprecedented success of his team, Sutherland wasn't committed to the project, or indeed to computer graphics more broadly, and he moved away from proto-VR and graphics work in the early 1970s.[9] Several of the students on his team would pursue their own research into the use of this proto-VR at Utah and elsewhere throughout the decade, but without the financial support and military connections Sutherland had possessed, they were unable to secure the funding needed to develop any wide-scale testbeds for the technology.

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[7] Stephen Ellis, 'Nature and Origins of Virtual Environments: A Bibliographical Essay', *Computing Systems in Engineering*, 2/4 (1991), 321–47; Ellis, 'What Are Virtual Environments?'.

The one organisation with access to necessary levels of funding to further develop VR was the military. In the late 1960s, Thomas Furness III worked with a team for the US Air Force (USAF) on the development of an entirely virtual cockpit for fighter pilots, using the same technologies, optimised by the use of custom-made parts.[10] A patient, 'long-view' approach taken by the USAF toward the VCASS (Visually Coupled Airborne Systems Simulator) system reduced the need for rapid progress or profitability. Furness's work, then known as Visionics, would constitute the main source of military VR research throughout the 1970-80s.

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[8] Ivan E. Sutherland, 'The Ultimate Display', in *Proceedings of the IFIP Congress*, 1965, 508.

[9] Ivan Sutherland, Interview, 25 January 2017.

With a range of academic research throughout the 1970s demonstrating the applicability of HMDs and computer graphics to education and Intelligence Amplification (IA), employees at the Human Factors Laboratory of NASA Ames in California began creating a system for visualising flight telemetry (data about velocity, altitude, air temperature and so on, transmitted to a remote point), to help both astronauts and the commercial aviation industry in the early 1980s.[11] Through the use of store-bought and second-hand parts, Mike McGreevy and Amy Wu assembled a proto-VR system which allowed for the exploration of virtual spaces, such as telemetry from space probes and landers, as well as the processing of visual data for air-traffic controllers and pilots. At around the same time, research with force-feedback and haptic immersion at the University of North Carolina at Chapel Hill (UNC) began to include HMDs, rather than rear-projected 3D or 2D screens, to explore the use of proto-VR for architectural design and biomolecular research.[12] This work demonstrated that the immersion offered by proto-VR could be a valuable tool in augmenting the skills of users in a range of scientific and industrial applications beyond that demonstrated at Ames.

The 1980s also saw the combination of proto-VR technology with entertainment applications, at least partially inspired by connections with science fiction made by both the popular press and innovators such as Furness, John Walker, and Brenda Laurel.[13] A team of researchers for the games company Atari included at least one person who had worked with HMDs in the late 1970s and early 1980s, and they sought to use HMDs as the vehicle for immersion in fantasy worlds. In the early 1980s, several people in the company argued that the technologies of proto-VR could be used to offer users the capacity to feel present in a world of their own making, or in a fantasy of someone else's, thus offering the ultimate form of entertainment. By 1995, one of those on the Atari team, Scott Fisher, had found his way to NASA Ames and brought with him several colleagues from Atari and his Alma Mater, MIT. The influx of people with ludic, artistic expectations for proto-VR led to a shifting of Ames' objectives toward providing a general-purpose testbed for a wide range of applications, and several of Fisher's erstwhile colleagues saw the NASA project as a way to realise the technical feasibility of their own aspirations. From the mid-1980s onward, perceptions of proto-VR as a marketable entertainment tool propagated quickly. The acronym 'VR' was coined in 1986, and Fisher, former Atari colleague Jaron Lanier, and a host of others from the techno-social echo chamber that was Silicon Valley began to envisage a VR which was more capable and powerful than the seemingly mundane, project-oriented capabilities of proto-VR.[14] Its naming heralded a shift from experimental development to private manufacture and accompanied a dispersal of VR concepts from universities, NASA, and the military into private-capitalist business. For them, the future was not in improving fighter pilots, perceptual studies, or the study of architecture, but in creating an entirely new computer-generated universe which had recently been dubbed 'Cyberspace'.

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[10] Thomas Rid, *Rise of the Machines: A Cybernetic History* (New York, 2016) 200.

[11] Stephen Ellis, Interview, 11 July 2017.

[12] James C. Chung and others, *Exploring Virtual Worlds with Head-Mounted Displays* (February 1989) <http://www.dtic.mil/docs/citations/ADA208088> [accessed 18 April 2017].

[13] Rid, 203; Walker, *Through the Looking Glass*; Jas Morgan, 'Brenda Laurel: Lizard Queen', *Mondo 2000*, 7, Fall 1992, 82–92; Brenda Laurel, *Atari Research Memos on the Subject of Interactive Fantasy and Related Topics* (Atari Sunnyvale Research Laboratory, March 1982), 28 <http://www.atarimuseum.com/ARCHIVES/pdf/misc/blaurel_IF1.pdf> [accessed 14 March 2017].

The excitement Cyberspace engendered in the social and political climate of the time served as an accelerant to the spark of VR's largely imaginary ludic capabilities. The combination of Silicon Valley's venture capital culture, the appeal of Cyberpunk science fiction, the growing use of the Internet, popular representations in Star Wars, Star Trek, and other content, as well as the demonstrated technical feasibility of an entirely immersive computer display, allowed some to convince themselves that VR was the future of media, communication, and thought. Gradually, media interest grew from articles in computer and science magazines into the mainstream broadcast and print news services by the early 1990s. There was an excitement and anticipation on the part of interested members of the public for this gateway to infinite, creative virtual worlds. The handful of private VR companies which had taken proto-VR out of the hands of state-funded organisations and turned it to the seemingly inevitable profit of the entertainment industry multiplied rapidly. By 1994-5 there were hundreds of VR firms trading and operating in the United States (US) alone, all of whom sought to be the first to meet the public's demands for VR.[15] The obstacle, at the time, was determining what those demands were. Public excitement for VR revolved around the marketing hype and extravagant prophecies created by the VR firms, celebrities, and the press to generate yet more interest. While some of the first private VR firms were realising, by the mid-1990s, that generating investment through over-promising was ultimately damaging, many did not seem to care. That abundant hype took on a wide range of forms, discussing possibilities as diverse as working from home (telecommuting) and virtual sex, what Ted Nelson called *teledildonics*. VR video games formed the single most visible component of VR applications in the early 1990s, with John Waldern's Virtuality systems peppering games arcades across the US. For most interested Americans, these games were the only way to experience the VR technology which was being so widely discussed.

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[14] Bryson, 'Virtual Reality: A Definition History'.

VR systems required not just one, but several high technologies to function: fast computers, powerful graphics engines, advanced programming languages, miniaturised LCD screens, and magnetic motion trackers (and many systems included peripheral systems of similar complexity, such as fibre-optic glove inputs). This limited the rate of development in the private sector, as most companies lacked internal revenue sources, relying instead on investment, which was itself dependent on sales (projected or actual). Without the funds to develop these diverse technologies into a more cohesive, goal-oriented VR system, development of hardware and software tended to be more lateral than vertical. Companies sought to differentiate their products from each other, rather than advancing on any commercial realisation of the VR concept. With systems often costing in excess of $100,000 in the mid-1990s, companies struggled to build a customer base, despite the apparent widespread appeal of a tool and medium for communications, content creation, and entertainment. Numerous industrial firms trialled expensive VR projects in the design and manufacture of seaports, kitchens, automobiles, and more during the late 1980s and 1990s. While these systems often had promise, their prohibitive costs, training requirements, and complexity slowed workflows, rather than sped them up. Furthermore, the high-speed internet connections that many VR workplace projects relied on failed to materialise, and in fact, are only becoming a technical reality in the second half of the 2010s.

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[15] Sandra Helsel, and Jeffrey Jacobson, eds., *Virtual Reality World's Virtual Reality Market Place 1994* (Westport, Conn, 1994); Sandra Helsel, and Walter Chavez, eds., *VR World's Virtual Reality Market Place 1995*, Virtual Reality Market Place, 1st edn (Westport, Conn, 1995).

While VR was floundering, however, the World Wide Web was making headway through the American media landscape, and without the financial and technological barriers to access which VR had, grew and developed content more quickly. Companies, individuals, and governments flocked to the Web, as far more people had access to a personal computer and a modem than the numerous discrete, expensive, and highly complex technologies of VR. The VR bandwagon moved toward a wider range of computer technologies by 1995 and brought the term with it, confusing definitions further as VR came to encompass video games, the Internet, and the Web, away from the hardware of VR. At the same time, efforts by Nintendo, Atari, and Sega to create VR games systems for the home backfired, with health scares and cheap, low-quality products highlighting to many just how unready and unusable HMD-based VR was. The VR developers who had sought to move VR from state-funded IA to privately-funded entertainment had found that their market, and their vague definitions of VR, had been swallowed by the Web, leaving VR developers a stark choice between falling back on VR's partially-proven scientific roots or moving to Web-based services and games. As a result, connotations for VR split in the late 1990s between HMD-based niche applications, such as mental health therapy, and computer-enabled experiences like games and the internet, without specialised VR hardware.[16]

What followed became a rapid downturn in the fate of numerous VR companies as investors became increasingly worried. Sensing blood in the water, venture capitalists recalled investments and funding, which most VR firms were entirely incapable of returning due to the lack of customers. Of the more-than 400 VR firms active in 1995, almost all of them had either shut down or entirely changed their focus by 1997. Most of the larger, more successful, VR firms survived 1995's 'VR Winter' (to borrow a term from the history of AI), by changing their products and marketing rhetoric to offer a VR that was disconnected from the material culture and display technologies of its past. For much of the American public and the press, VR was an abstract concept, a name representing all of the artificial, computer-generated spaces of the internet, video games, computer software, and even telephones. Rather than Cyberspace becoming VR, VR became Cyberspace.

This did not require a Herculean leap of logic on the parts of the public, or the media, however. The confused, loose definition of VR, combined with the lack of a standardised vocabulary or central paradigm meant that there had never been consensus over the meaning of the word, the nature of the technology, or its functions. As such, the connection between the hardware of VR and the concept and provisions of the digital computer required little effort. The widespread success of the microcomputer and personal computer in the 1980s, accompanied by the laptop in the 1990s, drastically improved the average level of knowledge about the nature and applications of computers. While most applications, particularly in the 1980s, were work oriented, the American computer price war of the late 1980s saw an increasingly diverse group of people using computers. The creation of video games, art programmes, and text-to-speech software helped inform the visual and cognitive languages with which VR was to be articulated in the 1990s.

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[16] Michael Zyda, 'From Visual Simulation to Virtual Reality to Games', *Computer*, 38/9 (2005), 25–32; John Briggs C., 'Virtual Reality Is Getting Real: Prepare to Meet Your Clone', *The Futurist; Washington*, 36/3 (2002), 34; Andrew Freiburghouse, 'Virtual Reality Check', *Forbes; New York*, 2 April 2001, 20; Barbara Rothbaum, Larry Hodges, Renato Alarcon, David Ready, Fran Shahar, Ken Graap, and others, 'Virtual Reality Exposure Therapy for PTSD Vietnam Veterans: A Case Study', *Journal of Traumatic Stress*, 12/2 (1999), 263–271.

The prevalence of PC and laptop devices in the 1990s, brought about by falling costs, technological improvements in both computer science and electrical engineering, and a thriving ecosystem of users and innovators, informed the expectations toward VR.[17] VR was a new way to engage with and use computers, for games as well as the work-oriented applications increasingly common in American workplaces such as spreadsheets, word processing, and mathematical calculation. In both cases, however, VR did not lend itself to those applications as easily as conventional screen-based systems, requiring cumbersome and expensive hardware, as well as advanced computer literacy and a highly limited gamut of applications. The popularity of computers failed to enable a solution in the form of an ecosystem for VR development though, as they lacked the high processing power and graphical capabilities required to run VR systems. For the moment, they provided a more affordable, comfortable (and even portable) alternative to VR's version of the digital frontier. VR's nature as a computer interface ensured that computerisation was the core component of what made VR, VR. Its 1980s and 1990s common denominator was thus comparable to that of any computer system, regardless of its immersion, the user's sense of presence, or its interactivity. As a result, computerisation, rather than immersion or HMDs came to represent the core of what VR was, to many, in the 1990s.

With the expansion of Web-based services in the dot-com bubble of the late 1990s, VR development and research fell back on proto-VR applications, namely scientific research and IA. The military interest failed to return in significant ways, limiting investment to a handful of private concerns, universities, and semi-autonomous state organisations such as DARPA. While public interest in the dedicated hardware of VR waned considerably in the new millennium, academic research demonstrated its value to therapists, students of human perception, and a range of architectural, training, and design applications.[18] Businesses which had been sold expensive VR programmes increasingly moved to other means of 3D provision, namely CAVE (Cave Automatic Virtual Environment) and wall-type systems where multiple people could use the same display to save money. These new displays were considered VR by many but fundamentally differed from most 1980s and 1990s definitions, formed when the business was at its most homogeneous. The immersive, private, and incredibly intimate VR of HMDs was rarer and continued to fade from public discussion and awareness into the new millennium. Online message boards and chatrooms sometimes asked where their promised VR helmets had gone, but for most, the question was a non-sequitur.[19] VR, for many, was real and staring right at them on the World Wide Web.

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[17] US Department of Labor, *Computer Ownership Up Sharply in the 1990s*, Issues in Labor Statistics (Washington, D.C., United States, 4 March 1999) <https://www.bls.gov/opub/btn/archive/computer-ownership-up-sharply-in-the-1990s.pdf> [accessed 20 December 2017].

By around 2005, as computer usage and literacy increased, the generic term 'VR' gave way to terminologies associated with more specific technologies such as teleconferencing, email, social networking, multiplayer online games, video games, websites, and online shopping. The need for a convenient catch-all term to summarise digital media was increasingly irrelevant as people knew more about what computers could be used for, and how the Internet worked. 'VR' therefore faded into obscurity both socially and technologically, without the considerable internal and external forces of marketing hype, press, and public demand. When the smartphone and gaming industries led to drastically reduced costs and challenges in implementing VR during its 2010s rebirth, this re-alignment between VR's social connotations and technical potential became clear. In 2018, VR is again seated squarely within the field-of-view of HMDs, due to technical advances and, most crucially, time enough to forget earlier attempts. It seems that one of the principal confounding factors for the success of many modern technologies is the length of time between its latest iteration and the last failure. By 2018, many consumers, journalists, and investors seem to have either forgotten the failures of the 1990s effort to commercialise VR, or rooted their understanding of those failures in technology, rather than people, hoping that with more advanced hardware and software, the latest attempt will succeed. This recurrent amnesia, coupled with assumptions that more advanced technologies mean that this time will be better, is crucial to VR's re-emergence as a more intimate, immersive way to use computers and smartphones that can create a sense of presence. The apparent stability of this emergence's definition may be a product of VR's shift from being the once-future of media, to an alternative to mainstream two-dimensional (2D) screens, adding a layer of privacy and intimacy to digital media consumption.

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[18] Rothbaum *et. al.* 'Virtual Reality Exposure…'; DavidOrenstein, 'Virtual Reality Saves on Training', *Computerworld; Framingham*, 33/10 (1999), 44; Barbara Schmitz, 'Tools of Innovation', *Industry Week; Cleveland*, 249/10 (2000), 57–66 for examples.

[19] Ayende Rahien, 'Virtual Reality, and Why It's Better to Be Avoided. - Google Groups', 2000 https://groups.google.com/d/msg/rec.arts.sf.composition/kmo6Pr75v5A/b44hqYPcGpoJ [accessed 11 August 2017]; Very3, 'Where Is My Virtual Reality?!!!!!! - Google Groups', 2000 https://groups.google.com/d/msg/comp.sys.ibm.pc.games.action/h0gciw-I48c/p8qO2Y46YzAJ [accessed 11 August 2017].

In this thesis, it is argued that the development, commercialisation, and cycle of failure and rediscovery for VR was the product of a mixture of technical shortcomings (in terms of possibility and skill), a lack of consensus about what VR was, and the inevitable inability of the technology to match public expectations which had been whetted by deliberate hyperbole and allusions to science fiction. The root cause of all of this is a lack of broad consensus about VR's purpose or meaning. Since the mid-1980s there was disagreement over its purpose and place in society, as well as discrepancies between promised capabilities and technical and creative feasibility. This lack of clear definition has been reflected on by historians, amateurs, journalists, and technical experts, during and after VR's first public lifecycle between 1989 and 1997, and in a range of literature both in print and online. Work by historians of technology, particularly within a systems approach (including Thomas Hughes, Peter Swann, Tim Watts, and David Noble) has emphasised the importance of shared definitions, and realistic expectations as keys to successful technologies.[20] Situating Virtual Reality within the historiography of systems, and of social technologies, helps to frame the works dedicated and peripheral to VR.

FIELD OF VIEW: A REVIEW OF THE HISTORICAL LITERATURE PERTAINING TO VR

BOOKS

While multiple definitions have hampered historical investigation of VR, efforts have been made to chronicle the technological, social, cultural, or artistic histories of VR. One of the most widely referenced sources is Howard Rheingold's 1991 *Virtual Reality*.[21] While journalistic and selectively detailed, it provides a unique source of information on the early history of VR and proto-VR, thanks to Rheingold's numerous interviews with staff at NASA Ames, VPL Research, and others, many of whom were personal friends. Rheingold uses, as the underpinning of all technological change, notions of enabling technology and technological convergence. Enabling technology, for Rheingold, is a technology which, once invented, allows development of another technology (for instance, development of the miniature cathode ray tube (CRT) being required for the production of HMDs). The notion that past technologies inform later ones is, in essence, the same idea as technological path dependency articulated by David Mowery and Nathan Rosenberg, among others.[22] Rheingold's second key notion, technological convergence, describes the accidental development of new technologies from existing ones, leveraged by the coincidence of multiple experts from different fields in the same intellectual or physical space. This idea is not too far removed from Campbell-Kelly and Garcia-Schwarz's notion of indirect network effects, i.e. the claim that combining technology with diverse users and sets of knowledge can produce new technologies, and develop existing ones, faster.[23]

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[20] Hughes, 'The evolution of large technological systems', 51-80; Peter Swann and Tim Watts, 'Visualization Needs Vision: The Pre-Paradigmatic Character of Virtual Reality', in Steve Woolgar (ed.) *Virtual Society?: Technology, Cyberbole, Reality*, (2002), 41–60; David Noble, *Forces of Production: A Social History of Industrial Automation*, 1st edition (New Brunswick, N.J, 2011).

[21] Howard Rheingold, *Virtual Reality: The Revolutionary Technology of Computer-Generated Artificial Worlds-And How It Promises to Transform Society*, First (New York, N.Y., 1991).

[22] David Mowery and Nathan Rosenberg, *Paths of Innovation: Technological Change in 20th-Century America*, New edition (Cambridge, 2010); Swann & Watts, 'Visualization Needs Vision', 42-3.

Other works have sought to chronicle VR's history through direct, contemporary engagement with the hardware and innovators, including Ralph Schroeder's *Possible Worlds* and Michael Gigante's chapter in *Virtual Reality Systems.*[24] Gigante's 1993 chapter sought to create a definition of VR that separated it from telepresence and broader notions of 'cyberspace'. Gigante tried to use his definition as a filter, selecting technologies and sources which matched it, and ignoring those which did not. The definition he provided is like that found in the work of Svante Lovén, Jonathan Steuer, and Thomasz Mazuryk and Michael Gervautz. Schroeder, on the other hand, avoided using strict definitions to inform his narrative, and instead focused on the hardware and experiences of contemporary 'Virtual Reality' systems.[25] Written as the VR boom was already starting to attenuate, and with the 'VR winter' on the horizon, his work nevertheless retained Rheingold's optimism. Providing a unique source of first-hand (now impossible) experience with a wide range of VR systems, Schroeder's own definition of VR required a data glove computer input, as a key component. He used this to place VR within a larger network of computers and computer interfaces which formed a prominent element of mid-1990s 'cyberculture'.

More modern accounts of the history of VR are scarce, although Lovén' s *Also Make the Heavens: Virtual Realities in science fiction* and Thomas Rid's *Rise of the Machines* provide some of the most salient examples in book form. Lovén's book examines the cultural history of VR via a bespoke definition to assemble an historical narrative of VR.[26] Focusing more on the cultural, Cyberpunk contexts of modern VR, it lacks the technical detail which makes Thomas Rid's work so valuable.

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[23] Martin Campbell-Kelly, and Daniel Garcia-Swartz, *From Mainframes to Smartphones: A History of the International Computer Industry* (Cambridge, Massachusetts, 2015).

[24] Michael Gigante, 'Virtual Reality: Definitions, History and Applications', in R.A. Earnshaw, M.A. Gigante, and H Jones (eds.), *Virtual Reality Systems*, 1993, 3–14.

[25] Ralph Schroeder, *Possible Worlds : The Social Dynamic of Virtual Reality Technology* (Boulder, Colo, 1996).

[26] Svante Lovén, *Also Make the Heavens: Virtual Realities in science fiction*, Skrifter / Avdelningen För Litteratursociologi Vid Litteraturvetenskapliga Institutionen I Uppsala, 60 (Uppsala, 2010).

Rid’s *Rise of the Machines* (2015) synoptically combines narratives from a range of technologies, and he integrates both technical and popular sources with interviews and oral histories to provide a narrative of VR’s development from military and private perspectives between the 1970s and early 1990s, with a focus on the impact of imagery from science fiction on shaping the hype which private VR firms relied on in the late 1980s and 1990s.[27] An excellent starting point for historians of VR, the book is a well-researched and detailed resource. In addition to these, Jaron Lanier’s book, *Dawn of the New Everything: A Journey Through Virtual Reality,* published in late 2017 is a chiefly autobiographical resource which is nonetheless valuable, on account of Lanier’s unique insight into the history of his own VR company, VPL, and his central position within the story of ‘VR’ specifically.[28]

Textbooks from the period can both comprise historically interesting sources, as well as secondary historical source elements. Ken Pimentel and Kevin Teixeira’s 1993 textbook, *VR: Through The New Looking Glass* included, as a subsection, an historical survey of the technology, which is largely schematic, and descriptive.[29] Seating VR firmly as the latest (but perhaps not final) expression of Cyberspace, the authors cited the allure of the virtual as the driving force behind monolithic progress in VR research. Grigoire Burdea and Philippe Coiffet’s textbook *Virtual Reality*, first published in 1994, and heavily revised in 2003, takes a similar approach.[30] The textbook included an historical subsection, though it’s somewhat teleological and lacks historical thinking or significant research. Jason Jerald’s *The VR Book: Human-Centred Design for VR*, steps away from the highly technical, single-sided histories of VR in textbooks, providing an interesting counterpoint to Burdea and Coiffet, as well as Pimentel and Teixeira, while employing a top-down view on the technology itself from a relatively modern perspective (2015).[31] Integrating interviews, oral histories, and a wide range of primary sources, Jerald’s history of VR revolves around the idea of technologically-achieved mental deception. At times over-reliant on Pimentel and Teixeira's work, Jerald’s schematic, descriptive approach lacks nuance in places, and the diversity of sources, while a clear improvement, doesn’t compensate for the lack of an historical framework. Here, as in almost every other historical resource, the history of VR is merely a subsection, a chapter, or a visible afterthought to accounts of what was, for most, a current technology with little or no history to speak of.[32] Children’s textbooks such as Holly Cefrey’s *Virtual Reality*, and Elaine Pascoe’s *VR: Beyond The Looking Glass* both contain brief, factually inaccurate histories, notable only for their existence amidst the larger body of computer science and Virtual Reality textbooks.[33]

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[27] Rid, *Rise of the Machines.*

[28] Jaron Lanier, *Dawn of the New Everything: A Journey Through Virtual Reality* (2017).

[29] Ken Pimentel and Kevin Teixeira, *Virtual Reality: Through the New Looking Glass* (1993).

[30] Grigoire Burdea and Philippe Coiffet, *Virtual Reality Technology* (2003).

[31] Jason Jerald, *The VR Book: Human-Centered Design for Virtual Reality* (2015).

Documentarist collections relating to the evolution of VR also exist, providing primary material from VR's early history, though without any meaningful historical commentary. The two largest contributors in this sector are John Walker’s *The Autodesk File: Bits of History, Words of Experience,* from 1994, and Ben Delaney’s *Sex, Drugs, and Tessellation* from 2014.[34] Walker’s compendium provides historical content for the tech company Autodesk (which was influential in the early years of VR’s private sector development) in the form of memoranda, company documentation, and memoirs. Walker provides occasional historical framing and context for Autodesk’s work, which is particularly useful in the case of the company’s ‘Cyberspace Initiative’. Delaney’s *Sex, Drugs, and Tessellation*, however, provides source material in a vacuum, and the text consists of articles about VR from the Cyberpunk magazine CyberEdge.[35] Readers are left to themselves far more than in Walker’s book, though in both cases the intention seems to have been to allow readers to form their own opinions from primary material.

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[32] Ellis, *Pers. Comm.*, 7th July 2015.

[33] Holly Cefrey, *Virtual Reality* (2002); Elaine Pascoe, *Virtual Reality: Beyond the Looking Glass* (1998).

[34] John Walker, (ed.), *The Autodesk File: Bits of History, Words of Experience*, Fourth (Thousand Oaks, Calif, 1994) https://www.fourmilab.ch/autofile/.

[35] Ben Delaney, *Sex, Drugs and Tessellation: The Truth about Virtual Reality, as Revealed in the Pages of CyberEdge Journal* (2014).

Sharing Rid's multi-thematic approach is Steve Woolgar's *Virtual Society?*, which dealt with the social dynamics of virtual technologies (mainly the Internet) with one chapter concerning VR, arguing that the failure of the VR business was caused by a lack of shared concepts or paradigms.[36] Peter Swann and Tim Watts's *Visualization Needs Vision: The Pre-Paradigmatic Character of Virtual Reality* analyses the decline of the VR business from an historical and sociological perspective. They attempt to socially contextualize a culturally current technology (writing, as they are, in 2002, when the Internet was a hot topic). Their argument that a lack of paradigms, technical standards, or shared language prevented VR's self-propulsion is an interesting view generated through a deeper attention to social and economic factors, rather than purely those of hardware.

As in every instance here (except for Rid), the histories written as complete books or as book sections are authored by people who are journalists or insiders rather than academic historians. As such, there is little or no attempt by the authors to either: place their narratives in the contexts of existing historical work (such as there is), or to relate them to the broader histories of computing and the US. This trend persists in the journal articles, theses, and monographs that touch on the history of VR. As suggested above, the very nebulosity of the category makes it hard to provide a history of its emergence and growth. When it was mentioned to Steve Ellis at NASA Ames back in 2015 that this research sought to create a history of VR, Ellis' response was to the effect that 'most here would not even have considered that VR *has* a history',[37] its poor definition and persistence in the modern world make it, for many, ahistorical. This perspective appears to have been prevalent among the scientists and developers who produced the technical literature of VR over the years, and even among those who, for various reasons, have attempted to compose chapters or other works on its history. This thesis, by forming a historical narrative around which a research can coalesce, shall hopefully form a genuine contribution to the history of technology by creating a history of VR.

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[36] Woolgar, Steve, *Virtual Society?: Technology, Cyberbole, Reality* (2002); Swann & Watts, 'Virtualization Needs Vision'.

[37] Ellis, *Pers. Comm.*, NASA Ames Human Systems Integration Division, 7th July 2015.

ARTICLES, MONOGRAPHS, AND ONLINE SOURCES

Distinct from the publication and accessibility requirements of books, many articles in print and online have mentioned, in passing, aspects of the history of VR, overwhelmingly from technical contexts, particularly computer science. Works by historians of technology, science, art, or the 20th century do also exist, albeit rarely, and often focus on the use of VR itself for teaching history, rather than VR's history. The bulk of actual histories serve to introduce articles discussing VR in therapy, business, or VR science. Where histories do exist, the problems of definition outlined above produce an effect whereby historical research on VR examines only a component part, such as Robert Stone's 2001 article on the history of haptic feedback, or Daniel Wagner and Dieter Schmalstieg's history of motion tracking. Both texts are explicitly tied to VR, but neither of them focusses on it, in part because there was no consensus on what VR meant.[38]

At the same time, the largest type of secondary source for VR historians are those on the Internet, with an extensive host of online content which claims to portray or explain the history of the technology. Throughout pertinent online and print articles, certain trends appear. Firstly, and overwhelmingly, the sources borrow from each other. Timelines, data, images, and even entire sentences can be shared between articles, in part due to the decreased editorial oversight, running costs, and scrutiny which online media receives in comparison to print (if challenged, online articles can be easily edited, replaced, or removed). This willingness to borrow (or outright copy) the work of other articles online creates the second problem however, which is a feedback loop where the source of a particular strand of the narrative extends back in time from one secondary to another secondary source, ensuring not only that errors in a narrative duplicate, but allowing for new errors to be created with each copy, assumption, and degree of separation from the original source material. Biographies are frequently copied directly from their subject's websites. These errors are further compounded by the source material used, which can almost invariably be traced back to Rheingold's *Virtual Reality.* While a valuable popular history, its single-sided perspective and familiarity with certain players in VR's history is inevitably at the expense of those with whom Rheingold was less well acquainted (such as Furness). A shortage of authoritative, accurate archival sources, coupled with the need to produce articles quickly encouraged highly limited research in the writing of these articles, which proves a formidable obstacle to easy formulation of a reliable historical narrative for VR.[39]

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[38] Robert Stone, 'Haptic Feedback: A Brief History from Telepresence to Virtual Reality', in *Haptic Human-Computer Interaction*, Lecture Notes in Computer Science (2001), 1–16 <https://link.springer.com/chapter/10.1007/3-540-44589-7_1> [accessed 1 November 2017]; Daniel Wagner, and D. Schmalstieg, 'History and Future of Tracking for Mobile Phone AR', in *2009 International Symposium on Ubiquitous Virtual Reality*, 2009, 7–10.

Beyond those overarching problems are more specific historical trends. Some writers rely entirely on a single source for information, in the cases of both oral histories and web articles drawing from Rheingold. Another recurring theme among both articles and books is that of using a bespoke definition of VR to cherry-pick sources and build a narrative from scratch. By defining VR, authors can then maintain far greater control over the range of systems surveyed, which in turn mitigates the highly confusing range of products and technologies named VR since the 1980s produced by the lack of inter-institutional consensus over such a definition. These definition histories themselves split into those using technological definitions, experiential definitions, and hybrids between the two. The third main thematic group among historical sources in print and online are those which (presumably) maintain an internal definition of VR which is not explicitly used in shaping the narrative, relying instead on the broader application of the term in contemporary technology to form notions of a present state of VR, and then building histories back from there (an approach which can invite Whiggish tendencies).

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[39] Ian Evenden, 'The History of Virtual Reality', *Science Focus*, 2016 <http://www.sciencefocus.com/article/history-of-virtual-reality> [accessed 2 May 2017]; Matthew Schnipper, 'The Rise and Fall and Rise of Virtual Reality', *The Verge* <http://www.theverge.com/a/virtual-reality> [accessed 5 February 2018]; Brian Crecente, 'VR's Long, Weird History', *Polygon*, 2016 <https://www.polygon.com/2016/10/26/13401128/25-vr-greatest-innovators> [accessed 5 February 2018].

Several articles from both the 1990s and 2000s sought to use the model shared by Gigante and others to create a custom definition of VR with which sources and technology could be circumscribed. Steuer's 1992 article, *Defining VR: Dimensions Determining Telepresence* sought to redefine VR based on experiential, rather than technical, criteria.[40] The core experience of VR, for Steuer, was presence, an idea shared by Tomasz Mazuryk and Michael Gervautz, Samuel Ebersole, and Steve Bryson, among others. Mazuryk and Gervauz's 1996 monograph sought to go further than simply providing a definition, and instead provided linguistic and reasoning tools to allow historians to develop their own definitions for the purposes of researching the history of the technology, and forming their own by combining the definitions from other writers (including Gigante).[41] Using this, they break VR's history into several strands and organise their narrative by hardware, rather than a strict chronological progression. Different sorts of VR are separated by the different levels of immersion, ranging from desktop PC-based experiences (on a conventional screen), head-tracking desktop experiences, and fully immersive VR systems with stereoscopic displays, motion tracking, and potentially haptic and aural interfaces. Ebersole's *A Brief History of VR and its Social Applications* (1997), shares the assumption held by many other writers at the time that defining VR was crucial to creating its history.[42] Using distinct definitions of 'virtual', Ebersole sought to respond to Steuer's broad definition of VR as the experience of telepresence, but failed to produce an alternative version, and as a result his narrative was so broad in scope that its resolution was limited, though he maintained that science fiction was the driver of the 'need' for VR. Bryson also sought to formulate a definition of VR for the purposes of shaping a new narrative in an article written in 1998, but only published in 2013. A veteran of VPL and the NASA VIEW project, Bryson used the changing definitions of VR to chart its history, allowing the contradictions between his definition of VR and those used in primary material to highlight the changing ways in which the nature of VR was understood in the 1990s.[43] For Bryson, as above, it was the experiences of VR - the 'sense of spatial presence' - that formed his definition.[44]

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[40] Jonathan Steuer, 'Defining Virtual Reality: Dimensions Determining Telepresence', *Journal of Communication*, 42/4 (1992), 73–93.

[41] Tomasz Mazuryk and Michael Gervautz, 'Virtual Reality-History, Applications, Technology and Future', 1996 <http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.42.7849> [accessed 26 May 2017].

[42] Samuel Ebersole, 'A Brief History of Virtual Reality and Its Social Applications', *Retrieved March*, 1997, 35.

Schroeder, in an article for *Futures* in 1993, sought to create a contemporary history based on the VR systems available at the time, examining developments in the technology from an experiential and social standpoint, but without further historical context.[45] This approach simultaneously allowed Schroeder to more accurately identify contemporary systems which were, to him, obviously VR, and also created a more contradictory narrative. Having acknowledged Myron Krueger's work to not be VR, later in the article Schroeder cited that work as a crucial example of early VR research. Only then, after combining all the different strands of contemporary VR into a single, flat image, does Schroeder separate them again, this time by application. This content makes for a disorganised narrative, but a valuable source of information on the actual experiences VR systems of the early 1990s offered, much of which was duplicated in his later book. Oliver Grau, similarly, stayed away from any definition history (the practice of forming a history of a concept or object around a particular definition for that subject), and instead examined VR, not through its material culture, but through its artistic potential, as an expression of illusion.[46] Based in art history rather than technological history, Grau includes frescoes, paintings, and gardens in his history of the virtual, with VR existing for him only as computer graphics, with no mention of VR hardware itself. This is indicative of the fact that, at the time of writing in 1999, VR hardware was extremely rare. Ian Evenden's online article, *The history of VR*, published on the website of the BBC Focus

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[43] Bryson, 'Virtual Reality'.

[44] ibid, 4.

[45] Ralph Schroeder, 'Virtual Reality in the Real World: History, Applications and Projections', *Futures*, 25/9 (1993), 963–73.

[46] Grau, *Into the Belly of the Image*, 365.

Magazine, also falls into this category, avoiding any explicit definition history of VR, and instead choosing sources and areas to cover by some unknown methodology, rife with incorrect names, dates, and spellings.[47] Relying heavily on input from Scott Fisher, the narrative is rather one-sided at the best of times and leans toward a highly present-centred attitude to 20th century VR history, which becomes even more problematic when considering that the article was published in 2016, and remains one of the most read on the web.

Principally available as online resources, oral histories, such as William Aspray's interview with Ivan Sutherland and Kent Bye's interview with Tom Furness are valuable.[48] While Bye's focuses more closely on Virtual Reality than Aspray's does, they both share a participant-led, unstructured approach. However, attempting to get people to recall facts from fifty years past is seldom a successful interview technique (as found in an interview conducted by the author with Sutherland).[49]

The unique nature of the Internet means that online sources, unlike print ones, can include a far greater range of material, presented in more accessible ways. The searchable online timeline of VR hardware compiled by Jenny Carden, for example, seeks to avoid the definition issue by including as wide a range of different VR and proto-VR systems as possible. Valuable to those seeking to gain a greater understanding of the development of VR hardware, the timeline makes a valuable companion to printed histories as well as Christopher Brungert's *HMD/VR-Helmet comparison*

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[47] Evenden, 'The history of Virtual Reality'.

[48] William Aspray, 'Oral History Interview with Ivan Sutherland', 1989 <http://conservancy.umn.edu/handle/11299/107642> [accessed 23 September 2016]; Kent Bye, *50 Years of VR with Tom Furness: The Super Cockpit, Virtual Retinal Display, HIT Lab, & Virtual World Society.*, Voices of VR <http://voicesofvr.com/245-50-years-of-vr-with-tom-furness-the-super-cockpit-virtual-retinal-display-hit-lab-virtual-world-society/> [accessed 6 August 2016].

[49] Sutherland, Interview, 25 Jan 2017.

chart.[50] In a similar vein is Tony Asch's *V-Rtifacts*.[51] The website is a repository of articles, scanned brochures, digitised demonstration videos, and ephemera from a former CEO of a 1990s VR firm. Despite a degree of historical writing, Asch's commentary avoids any historical argument or theme, providing instead first-hand accounts of VR systems, culture, and development in the 1990s.

As these works are, almost uniformly, not written by historians, there are no real attempts by the authors to situate their writing within a broader historiography. While this is unsurprising, it is of worth to do so, as VR undeniably sits within such a context.

SITUATING VR WITHIN WIDER HISTORIOGRAPHY

While a great deal of the history of computing can be gleaned from the work of Rid, Rheingold, and Schroeder, among others, there are further contexts to VR's history which are vital. Post-War American economic and cultural histories, the history of computers, and the social history of the US are crucial parts for VR's technological and social history. There are numerous valuable secondary texts which can help historians of VR understand and contextualise VR's American history.

Martin Campbell-Kelly and Daniel Garcia-Swartz's *From Mainframes to Smartphones: A History of the International Computer Industry*, published in 2015, is an excellent first port-of-call.[52] A predominantly technical history, it introduces some valuable concepts which more finely articulate the assertions made by Rheingold in the broader history of technology. Their description of direct and indirect network effects, referring to the effect which the breadth and diversity of a technology's users has on the kinds of development and change it undergoes, is a valuable concept for historians of VR to understand.

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[50] Jenny Carden, 'VR and AR Goggles', *Tiki-Toki*, 2015 <http://www.tiki-toki.com/timeline/entry/440580/VR-and-AR-Goggles/> [accessed 2 November 2017]; Cristoph Bungert, 'HMDs/VR-Helmets Market Overview', *Stereo3d* <http://www.stereo3d.com/hmd.htm> [accessed 2 November 2017].

[51] Tony Asch, 'V-Rtifacts - When Virtual Reality Was Always Virtual', *V-Rtifacts* <https://vrtifacts.com/> [accessed 6 November 2017].

[52] Campbell-Kelly & Garcia-Swartz, *From Mainframes to Smartphones*.

More social histories of computing include Campbell-Kelley and William Aspray's *Computer: A History of the Information Machine* and Nathan Ensmenger's *The Computer Boys Take Over: Experience, Programmers, and the Politics of Expertise*.[53] Campbell-Kelley and Aspray focused on the formation of a computer industry, particularly in America, through a case-study modality, cherry-picking particularly important developments from the vast American computer business in the 1960s to highlight, among other things, changes in the way computers were perceived, as a valuable source of information for the history of computers themselves. The work by Ensmenger is notable as an attempt to create a more social, institutional, and personal history of the American computer revolution than the widely technical, internalist computer histories which abound. It serves as a useful supplement to the technologically driven work of other historians of computing, and the broader American history of technology (such as Carroll Pursell's *Machine in America*). While a good source of context for students of the early VR and proto-VR pioneers, the work does at times lack resolution, and a more confident use of case studies and oral histories might have lent those 'computer boys' (who were often, in fact, girls) more agency, which is often lacking. Agency aside, understanding that VR's history is a part of a larger history of computing is far from sufficient to be able to situate it cognitively, historically, or phenomenologically, and a broader history of the American Cold War, in terms of both politics and the military-industrial complex which it created, is necessary.

There is considerable literature on a wide range of aspects of America's post-war history, and the detailed research, and broad narrative of William Chafe's *Unfinished Journey* (now in its eighth edition) provides an understanding of the broader political and economic history of 20th century America.[54] Viewing the narrative through the lenses of class, race, and gender, Chafe presents a detailed and convincing history of the growth of American exceptionalism, economic success, and self-identity in the presence of an 'other': the spectre of Communism, war, and death. To integrate Chafe's narrative with a closer attention to technology and material culture, Pursell's *Machine in America* makes a valuable supplement.[55] For Pursell, American society was uniquely linked to and fed by technological progress, and the history of one cannot be told without the history of the other. While at times struggling with artefactual internalism (implying that machines are developed and used because they exist, rather than interrogating who makes them and why), Pursell makes a clear effort to separate the machines from people, but like Ensmenger runs into problems of attaching agency to those who used and developed new machines in the post-war US. While he, like Ensmenger, sought to situate computers within the institutions, social values, and cultural conflicts which caused them, the apparent inevitability of using machines and of technological progress is hard to overlook. In relation specifically to VR, there are further points of contention, as VR's lack of clear technological paradigms, applications, or proven technology at the point of its socialisation and commercialisation suggests that there are instances where social expectations and pressures, such as science fiction and media hyperbole can drive technological development, material culture, and applications. Pursell's insistence that American technology has shaped American society, rather than the converse does not have an immediate counter to this, as VR's social context was informed by science fiction, rather than prevalent technological systems.

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[53] Campbell-Kelly & Aspray, *Computer: A History of the Information Machine*, 2004; Nathan Ensmenger, *The Computer Boys Take over: Computers, Programmers, and the Politics of Technical Expertise*, History of Computing (Cambridge, Mass. ; London, 2010).

Pursell's focus on the techno-cultural history of the US can be augmented by closer analysis of the connection between American consumerism and exceptionalism, which served as motives for the commercial development and manufacture of VR. James Patterson's *Grand Expectations: The*

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[54] William Chafe, *The Unfinished Journey: America Since World War II*, 7th edition (New York, 2011).

[55] Carroll Pursell, *The Machine in America: A Social History of Technology* (Baltimore, 1995).

United States 1945-1974 is an excellent place to start.[56] Confidently approaching a broad modern history of the US with the resolution of a local one, Patterson focuses on personal, individual perspectives to build an idea of the social and cultural pressures of America, periodising them to form a history of expectations. This is a valuable approach to writing histories of technologies with poor material preservation and highly fluctuating primary source types, such as VR. The marshalling of the American public by journalists, seeking to boost readers; pundits, seeking to appear prophetic; and entrepreneurs, seeking to get rich, was a key component of the hyperbole which marked VR's history. A work which further explores the connection between American expectations and the American brand of consumerism (perhaps vital to understanding VR's 1980s and 1990s history) is Colin Campbell's *The Romantic Ethic and the Spirit of Modern Consumerism*.[57] Here, Campbell examines the cultural and social push for novelty and improvement through financial abundance, featurism, and public expectations for technological growth. Disillusionment with American values (particularly in the 1980s and early 1990s) led to romanticisation of consumerism, Campbell argues. Integrating sociological sources, economic theory, and social-historical writing, Campbell deftly and forgivingly explains and contextualises the concept, and demonstrates the value of combining historical and sociological methodologies in the histories of ideas and technologies.

For coverage of Artificial Intelligence (AI), a valuable point of comparison on account of excessive hype and repeated 'failures' is Nils Nilsson's *The Quest for Artificial Intelligence: A History of Ideas*, and Pamela McCorduck's *Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence.*[58] Nilsson's work, published in 2009, provides a tremendously broad, well-researched chronological survey of the development of AI, and is an excellent archival source for students of the technology's history. With the technology as his guiding force, Nilsson's work uses a great deal of technical detail and technological-systemic analysis to guide his narrative in a predominantly intellectual history. Nilsson places the technology, and science driving it, at the front-and-centre of his narrative with the social and institutional forces constructing them far less visible. In contrast, McCorduck's history, first published in 1979, and heavily revised in 2004 is composed almost entirely of oral histories. McCorduck provided little historical commentary or supporting analysis, but the combination of the personal, experiential accounts with the technology-driven study of Nilsson produces a more comprehensive and well-rounded picture, which has proved useful for this thesis.

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[56] James Patterson, *Grand Expectations: The United States, 1945-1974*, Revised edition (New York, 1997).
[57] Colin Campbell, *The Romantic Ethic and the Spirit of Modern Consumerism,* 3rd Ed. (York, 2005).
[58] Nils Nilsson, *The Quest for Artificial Intelligence*, 1st edition (Cambridge ; New York, 2009); Pamela McCorduck, *Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence*, 2nd edition (Natick, Mass, 2004).

Finally, understanding a history of electronic entertainment, particularly games and gaming, relies on a far thinner spread of dedicated historical work, although Maaike Lauwaert's *The Place of Play: Toys and Digital Cultures* is valuable. Via online forum and chatlog records from the recent past, Lauwaert builds an historical survey of the changing role of technology in play, framing it within larger histories of commodification, consumption, and urbanisation in the West.[59] Tristan Donovan's *Replay: The History of Video Games* provides a more schematic, popular history of the medium, and any historiographic links are resultingly lost beyond that.[60] Technology-driven, like Nilsson's work, Donovan's approach concentrates on what was manufactured and sold, rather than the memories of people who were there.

FIVE-YEAR MISSION: THE PRIMARY RESEARCH OBJECTIVES OF THE THESIS

In order to successfully add to these existing narratives and works, this thesis will address the nature of VR in the wider history of technology. The first priority: contributing a viable, unique, and useful historical narrative of VR, rests with its definition. Based on the wide range of definitions provided by historians, technicians, users, and journalists, a prospective definition has already been given. One of the core research aims of this thesis is thus to determine the degree to which that definition allows for the construction of a comprehensible, usable narrative. The validity and viability of this definition will be tested through its use in shaping and guiding the collection of components into this narrative and through the resulting provision of a unique perspective on the evolution of this technology.

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[59] Maaike Lauwaert, *The Place of Play : Toys and Digital Cultures* (2010) <http://www.oapen.org/search?identifier=341443> [accessed 11 November 2017].

[60] Tristan Donovan, *Replay: The History of Video Games* (2010).

The narrative itself forms the core of the second goal. VR is sorely understudied historically, due to problems of definition and a scarcity of sources. Using historical information from an extremely wide range of new material to create a single piece of dedicated historical study is crucial. With the resulting provision of a singular narrative with new sources for future historians of VR, American consumerism, computing, and 20th century technology, the thesis will constitute a significant resource for future historians. Furthermore, such a history allows a far deeper understanding of the nature of VR and its past to form than would otherwise be possible in 2018. Developers and consumers of VR can use the narrative to explore the causes of VR's previous failures and missteps. This history is also used to contextualise VR's problems, definitions, and surprising successes within the broader history of technology, and provides a valuable case-study for pre-paradigmatic and over-advertised technologies.

The third goal is to assess, through the study of VR's history in the US, the importance of established technological and social paradigms, or standards, for the acceptance (success) of any computer technology. The technical development of VR was hindered by a lack of consensus over what it should do, or how it should work. Its social acceptance was hindered by a lack of consensus over what it was for and what its value was. These failures of definition, language, and in private business, technical expertise, prevented the technological reality of VR products from meeting the expectations placed upon it by the American public. Thus, the scale of the resulting disillusionment when VR *was* experienced was influenced by those failures, which therefore contributed towards a rejection of the technology for use by adults. Such failures also hampered industrial and academic developments in VR, as well as those for entertainment. As a result, the final key goal of this research was to identify and describe the apparent necessity for technical and social standards in a technology's success in American contexts, and to highlight the distinctive history and fate of VR in the context of its failure to provide these standards, borrowing from the methodologies of Swann and Watts, Campbell-Kelley and Garcia-Swartz, and Pursell.

METHODOLOGY

A technology such as VR, with assorted nebulous definitions, changing language, and a minimal (nigh-non-existent) history, requires a novel methodological approach, in order to address the shortages of material, secondary literature, or consensus on the nature of the subject matter. Marrying the technical focus of Nilsson with the personal, social, and cultural studies of McCorduck allows a combination of personal and technological narratives. However, this combination can be imbalanced. Nilsson's approach depends on abundant secondary literature and a well-preserved range of primary sources, while McCorduck's approach relies on the central topic being widely understood in unambiguous ways. VR, by virtue of its protean nature, and the consequent shortage of secondary literature, requires further levels of source acquisition and narrative construction in order to create viable historical work. This is alleviated by borrowing heavily from the methodology of corpus linguists such as Anke Ludeling, Stefan Evert, and Marco Baroni, as well as Sebastian Hoffman and integrates word-usage metrics used by historians of technology such as Benoît Godin, and Gratien and Pontillo.[61] Godin's work, which uses Google N-grams to track the changing uses of the term 'Innovation' and ties it in to a history of technology, served as an inspiration to some of the techniques involved in the thesis, though here more redundancies were involved to reduce bias. The intellectual framework provided by corpus linguistics, when coupled with its application to focused historical research, provides a new way of identifying sources and tracking changes in the discussion surrounding VR which is detached from individual accounts and technical reports. This entirely new methodology, combining these approaches, is necessary to chart the history of VR, with its flexible definitions, non-existent hardware standards, and near-total schism between textual and material realities.

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[61] Anke Ludeling, Stefan Evert, and Marco Baroni, 'Using Web Data for Linguistic Purposes', in Marianne Hundt, Nadja Nesselhauf, and Carolin Biewer (eds.), *Corpus Linguistics and the Web*, (2007), 7–24; Sebastian Hoffmann, 'Processing Internet-Derived Text—Creating a Corpus of Usenet Messages', *Literary and Linguistic Computing*, 22/2 (2007), 151–65; Benoît Godin, 'Technological Innovation: On the Origins and Development of an Inclusive Concept', *Technology and Culture*, 57/3 (2016), 527–56; Chris Gratien, and Daniel Pontillo, 'Google Ngram: An Intro for Historians', *HAZINE*, 2014 <http://hazine.info/google-ngram-for-historians/> [accessed 10 November 2017].

The corpora used in this thesis comprise newspapers, magazine articles, books, and conference papers. Each individual corpus is literally the 'body' of texts published. Most corpora, for the purposes of corpus linguistics, cover decades or even centuries and are limited by language rather than country. For linguists, identifying the authors of anonymous content and the origins of terms and linguistic customs are crucial aspects of internet-based corpus linguistics, which has become a tool of some contention in the recent history of the discipline. The Internet serves as the single largest source of accessible corpora, though the collation of these sources by search algorithms, and the inherent preservation bias in digitisation, have proved problematic for many linguists who consider internet corpora to be 'opportunistic' or 'unprincipled'.

For historians, however, their value can be considerable. Online corpora are larger than any library or collection of libraries in the world and can be filtered and searched using complex terms to produce metrics on the changing popularity of terms, by country, year, author, city, language, subject, and countless other features. Databases such as ProQuest, EBSCO, and Google Scholar contain millions of sources which can be honed and refined in this way. In doing so, they can not only produce surface detail on the popularity and connotations of words or phrases (especially in academia) but can provide an invaluable source of primary and secondary materials. Newspaper and magazine corpora can yield, through stratified samples and surface reading, a very fast review of the range of portrayals and discussions surrounding political events, individuals, or technologies.

Several historians have, in the past few years, begun to make use of these online corpora to identify new sources, as well as lean more heavily on the work of corpus linguists to identify the changing uses of words pertaining to, for example, particular technologies or technological processes. The integration of that methodology here has allowed for the technical and social narratives to be tempered by a consistent grounding in previously unused primary material. The technicalities of this system are fully discussed in Appendix 1.

THE OUTLINE OF THE THESIS

In order to best combine the diverse strands of material, narratives, and natures of VR into a coherent text, a chronological structure forms the foundation of the thesis. Chapters two through five break the history of VR into four distinct blocks. Chapter two covers 1965-1980, three 1980-1990, four 1990-1997, and five 1997-2005. While the chapters are sequenced chronologically, within each the content is divided thematically, to maximise detail, allowing close focus on individual developments throughout the period in question.

Chapter two's focus (p.57) is on university and military-based research on the displays, graphics, computers, and tracking technologies which were combined to form proto-VR, up to 1980. As the term 'VR' had not yet been coined, a wide range of technical and popular sources are incorporated to chart the development of projects that integrated what would later be its common components, to narrate proto-VR's development during its earliest period.

In chapter three (p.112) the martial and academic narratives are carried into a new era of development and change, with the growth of the American video games market, and the emergence of new ways in which computers, displays, and their applications were understood and imagined. Spanning a single decade, it covers the crucial period of technological transfer, where private companies started to develop VR technology for the open market, based on innovation carried out in state-funded and university-run environments. The resulting shift in expected applications, functionality, and development styles was accompanied by the establishment of the 'VR' moniker during this time. In the chapter, the technical and interpersonal developments of staff at NASA Ames, the most important source of technological innovation and applications for proto-VR and VR at this time, are charted. In addition, military and academic threads of research and policy are increasingly combined with private company efforts to develop VR. Technical developments at the time are coupled with the cultural changes brought about by the rise of Cyberpunk culture, an economic downturn, and a newfound spirit of consumerism and computerisation. The chapter ends with a small number of private companies generating disproportionate amounts of interest from the press and online groups, and the conscious shift by several such companies toward providing VR technology for ludic uses, setting the scene for the ensuing VR boom.

Chapter four (p.156), while spanning the shortest length of time, is the densest in terms of material and the breadth of content covered. Highlighting the changing levels of state and institutional intervention in the development of VR, the impact that the rapid expansion of VR firms and optimistic hyperbole had on both its social contexts and technological developments is demonstrated. The closing of the chapter portrays a VR in flux, as the development of VR hardware by private companies slowed or stopped altogether, due to a shift in interest and investment toward non-immersive computer-based experiences.

Chapter 5 (p.215) is the final narrative chapter of the thesis and describes the cultural and semantic changes which VR underwent after the collapse of the bubble and start of the VR winter. Here, the combination of technical, popular, and oral histories is essential in forming an entirely new narrative of transformation and abandonment. A period often skipped by narratives on account of the relative invisibility of VR hardware, the study of contemporary material reveals instead considerable discourse surrounding VR and its nature.

Chapter 6 (p.270) forms the conclusion to the thesis, incorporating the different strands to provide a summary of the changing relationship between the imagined and real technologies of VR. It examines the cultural, intellectual, and institutional structures that helped shape VR's unique history, as well as the impacts of its transformation going into the third millennium. The importance of shared language and paradigms for the successful development and cultural acceptance of uniquely experiential technologies like VR is highlighted and contrasted with similar growth patterns in technologies like Artificial Intelligence, Stem-Cell research, and Nuclear Fusion. Detail and Evaluations of the research methodology, a discussion of sources of error, and a testing of the success of the hypothetical definition of VR postulated in chapter 1 are discussed in the subsequent appendices.

CHAPTER 2: IN SILICO

'There is no reason why the objects displayed by a computer have to follow the ordinary rules of physical reality with which we are familiar.'

- Ivan Sutherland, 'The Ultimate Display', in *Proceedings of the International Federation of Information Processing Congress*, 1965, 508.

'As anyone can see who reads the daily press, many people are torn between hopes and fears aroused by digital computers, which they find mostly incomprehensible and whose import therefore they cannot judge.'

- Hubert Dreyfus, *What Computers Can't Do*, xi.

FEAR AND LOATHING IN SILICON VALLEY: AN OVERVIEW OF COMPUTERS, GRAPHICS, DISPLAYS, AND THE BIRTH OF VR, 1965-1979

With the definition from chapter 1 (p.24), the VR narrative begins in 1965, when Ivan Sutherland proposed 'The Ultimate Display'; a theoretical device which culminated, two years later, in the Head-Mounted Three-Dimensional Display (henceforth 3D HMD) which formed the first instance of proto-VR technology.[1] During these early years there was no 'VR' and it would be wrong to imply that the proto-VR developers of the era saw their systems as being part of a singular typology. However, using the aforementioned definition, entirely different instances of university-based and military research have been drawn together by their shared approach to Intelligence Amplification goals via similar hardware which was enabled by the new graphical capabilities of computers. Both academic and military examples are considered separately below, but each was within shared contexts of American Cold War history, considerable government spending on research into computer technologies, graphics, IA, and public opinion towards computerisation.

These early years often lack historical resolution, and it is not fair to suggest that Sutherland's work, by virtue of its primigenial nature, defined and limited all future proto-VR and VR developments.

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[1] Ivan Sutherland, 'The Ultimate Display', in *Proceedings of the International Federation of Information Processing Congress*, 1965.

Instead, it was the first in a subset of computer display technologies discretised by the author in this chapter in order to analyse the ways in which these formed technical pathways which would prove central to VR in later decades.[2] The lack of archival evidence, poor historical preservation, and distortion, have robbed VR's origins of nuance, and notions of the technology prior to the establishment of the VR name vary wildly. While Sutherland is cited as being the 'father' of VR, as well as that of Computer Graphics, this occludes a great deal of the contemporary reality.[3] Here, this narrative and the sources provided shape a new understanding of the discrete technologies which came to comprise VR, before it was 'VR', and pushes back against the heroic, two-dimensional historicisations so often applied to the technology.

Sutherland's proposal and construction of an 'Ultimate Display' was not, as Rheingold puts it, a stand-alone 'technological convergence,' but sits within a far larger field of digital computer and display innovations. It was driven by project goals focused on improving the accessibility of computer information, and the interactivity of graphics for the purposes of enhancing human faculties. These projects were funded by wealthy universities and the US government, during a time where spending on experimental research without demonstrable applications was not only common but encouraged. From this arose new consumer goods, and technological innovation and integration were rapid in a range of areas, including computing. With the economic and human expansion of businesses and organisations, the need for more advanced administrative systems fuelled a booming computer industry. State-funded research into microprocessors and integrated circuits for the Space Race and the Cold War had accelerated computer technology. As a result, both users and expertise diversified, forming the innovative ecosystem required for a proto-VR concept such as Sutherland's to crystallise as it did in 1965.

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[2] Howard Rheingold, *Virtual Reality: The Revolutionary Technology of Computer-Generated Artificial Worlds-And How It Promises to Transform Society*, Reprinted ed. (New York, N.Y., 1992).

[3] 'Ivan Edward Sutherland: American Electrical Engineer and Computer Scientist | Britannica.com' <https://www.britannica.com/biography/Ivan-Edward-Sutherland> [accessed 31 August 2016]; Mario Gutierrez, Frédéric Vexo, and Daniel Thalmann, *Stepping into Virtual Reality* (2008), p.5.

The focus of most recent history of the 20th century US focuses on the Cold War, leaving the influence of computers on history understudied (Thomas Rid's *Rise of the Machines* is a welcome exception).[4] The computer was, at the time, a culturally, economically, militarily, and socially competitive growth technology, in the systems theory of Thomas Hughes, and notions of using computers outside of the office or laboratory were still new in 1965.[5] All proto-VR technologies from this period, by virtue of their computerised nature, require situation in a wider context of public attitudes towards computer technologies. Contemporary literature has highlighted a public mixture of fear, resentment, and anticipation towards computers. For example, David Bergamini's article in *The Reporter* points to an exposé by *The Washington Star* which proclaimed that '… the business of Government is increasingly the business of computers,' Computers were apparently conducting a 'coup' upon the American citizen, thus as David Bergamini put it in 1961,

> By consulting the data-processing machines of the various state and Federal agencies, it has become theoretically possible to assemble an amazingly quick and complete file on any citizen, including, for instance, his age, birthplace, Social Security number, employer, dependents, investments, dividends, liabilities, insurance coverage, license number, veteran's status, security clearance rating—even such intimate items as hobbies, organizational affiliations, physical blemishes, medical history, or ability to speak French.[6]
>
> - David Bergamini, 'Government by Computers?'

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[4] Thomas Rid, *Rise of the Machines: A Cybernetic History* (New York, 2016); Walter LaFeber, Richard Polenberg, and Nancy Woloch, *The American Century: A History of the United States Since the 1890s*, 7th ed. (Armonk, New York, 2013), 259-360; Carol Berkin, Christopher Miller, Robert Cherny, and James Gormly, *Making America: A History of the United States*, 7th ed. (Boston, 2015) 716-795; Lawrence Samuel, *The American Middle Class: A Cultural History*, 1st ed. (New York, 2013).

[5] Thomas Parke Hughes, 'The Evolution of Large Technological Systems', in Wiebe E. Bijker, Thomas Parke Hughes, and Trevor J. Pinch (eds.), *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, First Paperback (1989), 71-6.

[6] David Bergamini, 'Government by Computers?', The Reporter, Thursday, August 17th, 1961', *UNZ.org* <http://www.unz.org/Pub/Reporter-1961aug17-00021> [accessed 2 September 2016], 21.

Moral panics abounded at this time but, in the 1960s and 1970s, technophobia was particularly rife with the computer often portrayed as a sentient, malevolent gestalt of rapid technological change. The pervasive fear of computers specifically implies that discourse was expanding in a vacuum of practical experience. In contemporary television and film (for example *Star Trek, 2001: A Space Odyssey* or *Fiend Without A Face*[7]*),* the inimitable threat posed by computerisation, or 'electronicisation' was a popular theme. Many technological histories of computers seem to miss their diverse social contexts.[8] Nathan Ensmenger does interact closely with this fear but focuses on the equally indicative suspicion and loathing surrounding computer engineers and programmers themselves in the 1950s, 1960s, and beyond.[9] The sudden expansion of computers into business and government brought anxiety to many, and excitement to some, and public expectations, of course, impacted the kinds of products which could be sold, and thus the technologies that could be developed by companies. Miniaturisation of computer components was pursued in earnest only after the notion of computers for the home became prominent in the US, for example.

Computers were developed for administrative and mathematical use, making them less visible publicly. Minicomputers such as the Librascope LGP-30 were seldom sold domestically in the mid-1960s, as they required considerable expertise to program and operate.[10] As such, consumer perceptions of computers formed independently of them, but speculation abounded in print, much of which complements the representation of computers in science fiction TV and film. Computers were powerful and transformative, representing both opportunity and peril.[11]

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[7] Gene Roddenberry, *Star Trek*, 1966; Stanley Kubrick, *2001: A Space Odyssey*, 1968; Arthur Crabtree, *Fiend Without a Face*, 1958.

[8] Martin Campbell-Kelly, William Aspray, *Computer: A History of the Information Machine*, c2004; Georges Ifrah, *The Universal History of Numbers: Computer and the Information Revolution Pt. 3* (New Delhi, 2005); Christian Wurster, *Computers: An Illustrated History* (Köln, 2002).

[9] Nathan Ensmenger, *The Computer Boys Take over: Computers, Programmers, and the Politics of Technical Expertise*, History of Computing (Cambridge, Mass. ; London, 2010).

[10] Bill Bryner, Personal Note, 'LGP-30', 2007. <http://ed-thelen.org/comp-hist/lgp-30.html> [accessed 30 August 2016].

Away from the eyes of the public, however, governmental and military attitudes were, by and large, more ambitious.[12] The 1960s saw the height of the Cold War, the Cuban Missile Crisis, and the Space Race. These, and the Soviet launch of Sputnik, motivated considerable science funding by the government through the foundation of ARPA, alongside new funding for existing state organisations. In 1965 NASA and the USAF were focused on the Apollo Programme, and a key component of the space craft was lighter, more reliable, and faster computers. Contracts with General Electric, IBM, Texas Instruments, and others accelerated the development of computers to suit the growing administrative needs of a global superpower, and to improve the combat simulations which had helped define military strategy since WW2.[13]

The prospect of sudden global nuclear conflict inspired many military planners of the time to explore notions of computer-driven simulation and training. This hunger for innovation, and the expectations placed upon computers, and their potential to transform American institutions inspired individuals across the country to experiment, both materially and intellectually, with computer applications. The development of computer programs for entertainment was also beginning to bud, with one of the first video games *Spacewar!* in use by 1962.[14] Sutherland's investigation of immersive 3D computer displays was not rooted in this ludic offshoot however

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[11] 'Let the Computers Beware!', *Harper's Bazaar; New York*, 98/3047, October 1965, 204–5; Gordon Best, 'Computers and the Changing World (Book Review)', *New Society; London*, 10, 6 July 1967, 268–269; Lucy Eisenberg, 'What Computers Can't Do', *Harper's Magazine; New York, N.Y.*, 231/1383, 1 August 1965, 96–99; Basil Hargreaves, *Computers and the ChaOnging World: A Theme for the Automation Age* (1967); N. Sutherland, 'Revolution by Computer', *Harper's Bazaar; New York*, 100/3071, October 1967, 122, 124, 126, 132; Ian Sclanders, 'The Thinking Machines', *Maclean's; Toronto, Canada*, 75/5, 10 March 1962, 20–24.

[12] Ralph Schroeder, *Possible Worlds : The Social Dynamic of Virtual Reality Technology* (Boulder, Colo, 1996) 54-55; Col. Jack Thorpe, Interview, 10th October 2016.

[13] Andrew May, 'The Rand Corporation and the Dynamics of American Strategic Thought, 1946-1962' (unpublished Ph. D., Emory University, 1998), 33-4.

[14] J. M Graetz, 'The Origin of Spacewar', *Creative Computing*, 6/8, August 1981, 56–57., IV.

(despite VR’s later intimacy with gaming) and was one of many published concepts and projects exploring computer graphics and computerised environments (if you will, virtual realities) in the mid-1960s. Moreover, the notion of an immersive three-dimensional display had been explored previously, in both HMDs for helicopter pilots, developed by Bell Helicopter in the early 1960s, and in an experimental film viewer called the *Sensorama* developed by Morton Heilig in 1962, based on a paper that he wrote in 1955.[15] Using an immersive stereoscopic display with stereo sound, motion, and even smells, *Sensorama* displayed pre-recorded film in stereo. The *Sensorama* was a technical and commercial failure, but notions of sensory immersion driven by technology were known by Sutherland at the time, and may well have contributed toward his work, as discussed in an interview with the author.[16]

ULTIMATE DISPLAY: PROTO-VR RESEARCH AT HARVARD AND UTAH

While Sutherland synthesised HMDs, computers, and interactive computer graphics for the first time into what here has been designated proto-VR, the display technologies were pre-existing. The screens and tracking gear he used when he finally came to build a prototype came from an HMD developed by PerkinElmer for nose-mounted infra-red cameras on attack helicopters. Such displays had been in use for around a decade previously and their use in military applications might have been what brought them to Sutherland’s attention in the first place, during his time both at ARPA and potentially in the Signal Corps after completing his PhD in 1963 (though he would not be drawn on his inspiration at interview).[17] He recounted, in a 1989 interview with William Aspray, becoming familiar with infrared technologies during his time working on Project Michigan, a US Army research project focussed on improving combat telemetry and reconnaissance technologies.[18]

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[15] Morton Heilig, ‘El Cine Del Futuro: The Cinema of the Future’, *Presence: Teleoper. Virtual Environ.*, 1/3 (1992), 279–94.

[16] Ivan Sutherland, Interview, 25 January 2017.

[17] William Aspray, ‘Oral History Interview with Ivan Sutherland’, 1989 <http://conservancy.umn.edu/handle/11299/107642> [accessed 23 September 2016]; Robert Sproull, Interview, 9th September 2016.

The nature of an HMD, such as the one Sutherland was developing, required the screens of the HMD to be close to the eyes, in order to work stereoscopically. Without the miniature CRTs from PerkinElmer displays, the stereoscopic effect would not have been possible. Sutherland's students also did some work with the PerkinElmer displays in the lab at Harvard, and further at Utah. As the PerkinElmer display was originally designed to allow pilots to see the display and the world around them, the images were translucent. This was not changed by Sutherland's team and thus constituted AR, as much as proto-VR.[19]

Sutherland's key contribution was the coupling of a motion-tracking HMD with a new form of interactive computer graphics, a technology he had worked on as part of his PhD research, which had culminated in the software Sketchpad in 1963. However, the notion of being able to immerse oneself in as rich an environment as the computer could generate was, to him and his colleagues, incidental. The key breakthroughs were in generating interactive (movable) 3D images on a computer in real-time and allowing the user to change their perspective of stored data. His personal drive was to find a better way to examine digitised technical blueprints. The funding which allowed this, however, was largely a product of Harvard's expansion of computer graphics research, and of military funding sources keen on Sutherland's explicit intent of providing a system by which personnel can be trained for any situation risk-free. The use of an HMD, which would later define VR for many, was not the core of Sutherland's research, dispelling popular narratives which depict Sutherland as anticipating a host of VR products, or designing an entertainment technology; he did not seek to be a visionary futurologist.

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[18] Aspray, 'Oral History Interview', 5-6.
[19] Sproull, Interview, 9 September 2016.

Improvements in computer graphics, power, and miniature CRT displays needed in Sutherland's project were not the sole technological strands, however. There was also the challenge of getting a computer to constantly track the user's motion and adjust the display to suit. Motion tracking had been a developing technology in the US for some time, though it was still very much in its infancy. Sutherland's team originally used a physical connection between the display and the ceiling to calculate the movement of the user from a base point, but later developed an ultrasound sensor to estimate movement remotely. Tracking systems were new, driven principally by teleoperations research, and without the large market enjoyed by computers, or military investment enjoyed by displays, were incrementally developed by organisations over the late 1960s and 1970s, including NASA Ames.[20] As increasing applications for tracking were found, the hardware and theory diversified and advanced, to the high-resolution optical motion tracking and motion capture technologies used in 1990s and early 2000s VR systems.[21]

The physical tracking system used in Sutherland's system was suspended from the ceiling and attached to the helmet. Nicknamed the Sword of Damocles by Sutherland's colleagues, it, too, was borrowed from PerkinElmer. The ultrasound version, however, was developed for the 'Ultimate Display' by Sutherland and his colleagues, including Bob Sproull, Ted Lee, and Dan Cohen. It worked by scanning the space the user was standing in using a continuous ultrasound wave, and computer-processing the feedback into a rough position.[22] This approach appears to have been completely novel at the time.

The Harvard combination of interactive 3D graphics, stereo HMDs, and motion tracking for creating a sense of presence, discretises VR as separate from computer games or simulators. Though its purpose was experimental, rather than for specific applications, the technology's potential was not lost on Sutherland at the time, and his government funding applications alluded to realistic computer graphics for military training.

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[20] Stephen Ellis, Interview, 13 Mar 2018.
[21] Ivan Sutherland, 'A Head-Mounted Three Dimensional Display', in *Proceedings of the December 9-11, 1968, Fall Joint Computer Conference, Part I*, AFIPS '68 (Fall, Part I) (New York, NY, USA, 1968), 760–1; Grigoire Burdea and Philippe Coiffet, *Virtual Reality Technolology,* 20-4, 35-8.
[22] Ivan Sutherland, 'A Head-Mounted Three Dimensional Display'.

Moving away from existing narratives painting Sutherland as 'the father of computer graphics', and 'the father of VR' (something Sutherland himself has little taste for), attention should also be paid to his students, particularly Bob Sproull. Sproull worked with Sutherland when he was an Associate Professor of Electrical Engineering at Harvard, following his resignation as director of ARPA in 1965.[23] Bob's kind and generous assistance in this project has shed considerable light on the work dynamic and culture of the time. While Sutherland did not credit Sproull directly for his work on HMDs, Sproull, along with several other students, contributed significantly to the hardware and software innovations revolving around what he only refers to as 'the sword.'[24]

When Sutherland started at Harvard, he taught a seminar course on Computer Graphics, and Sproull was one of a handful of students admitted. At the time computer graphics were not what they are commonly understood as today. Computers largely did not use or need graphics but were primarily for data storage and retrieval. Some computers were used to store and display simple images, drawn line by line on an oscilloscope or similar CRT screen, such as blueprints. These images were static, and could not be manipulated or edited on screen, but were simply viewed. Sutherland's Sketchpad was one of the very first attempts to provide interactive computer graphics, where images could be rotated, cropped, and even edited by a computer user on a screen before them.[25]

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[23] Sutherland, Britannica.com; Gutierrez, Vexo, and Thalmann, *Stepping into Virtual Reality,* 5.

[24] Robert Sproull, and Ivan Sutherland, 'A Clipping Divider', in *Proceedings of the December 9-11, 1968, Fall Joint Computer Conference, Part I*, AFIPS '68 (Fall, Part I) (New York, NY, USA, 1968), 765–75 <http://doi.acm.org/10.1145/1476589.1476687> [accessed 31 August 2016]; Sproull, Interview, 9th September 2016.

[25] Ibid.

At the same time, Sutherland was collaborating on several computer research projects, and with students. Among these was Dan Cohen, who was working on simulation. He worked with Sutherland on mathematical obstacles to real-time generation of interactive vector graphics. This led to the development of new algorithms for Cohen's own research, as well as the Sutherland-Cohen clipping algorithm, which would not only become a crucial component of the 3D HMD, but also an industry standard for almost a decade.[26] The algorithm served to improve the speed with which three-dimensional 'wireframe' shapes could be generated by the computers of the time (fig.1), and was crucial to generating more complex virtual images in real-time.[27]

The hardware which Sutherland and his colleagues were using in the development of the trackers, displays, and graphics generators of this proto-VR was exceptionally expensive, and the high cost is part of the reason that Sutherland's team were the first to combine them in the US. A key question is how Sutherland gained access to the funding needed to pursue basic research on a novel computer interface. Sproull believed that the funding was primarily provided by the CIA, while Sutherland himself suggested in an interview at the end of the 1980s that he had considerable ties to the NSA at the time of his research, which he was not able to disclose to his colleagues at the time.[28] In an interview with the author, Sutherland refused to disclose in any detail where the funding had come from, mentioning that much of it, at both Harvard and Utah, was from ARPA (the agency he had run only a year earlier). He denied CIA involvement and side-tracked questions about the NSA.

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[26] William Newman, and Robert Sproull, eds., *Principles of Interactive Computer Graphics (2nd Ed.)* (1979), 65-7, 69, 134, 419.

[27] R. Watson, T. Myer, Ivan Sutherland, and M. Vosbury, 'A Display Processor Design', in *Proceedings of the November 18-20, 1969, Fall Joint Computer Conference*, AFIPS '69 (Fall) (New York, NY, USA, 1969), 209–17 <http://doi.acm.org/10.1145/1478559.1478584> [accessed 31 August 2016].

[28] Aspray, 'Oral History Interview',6.

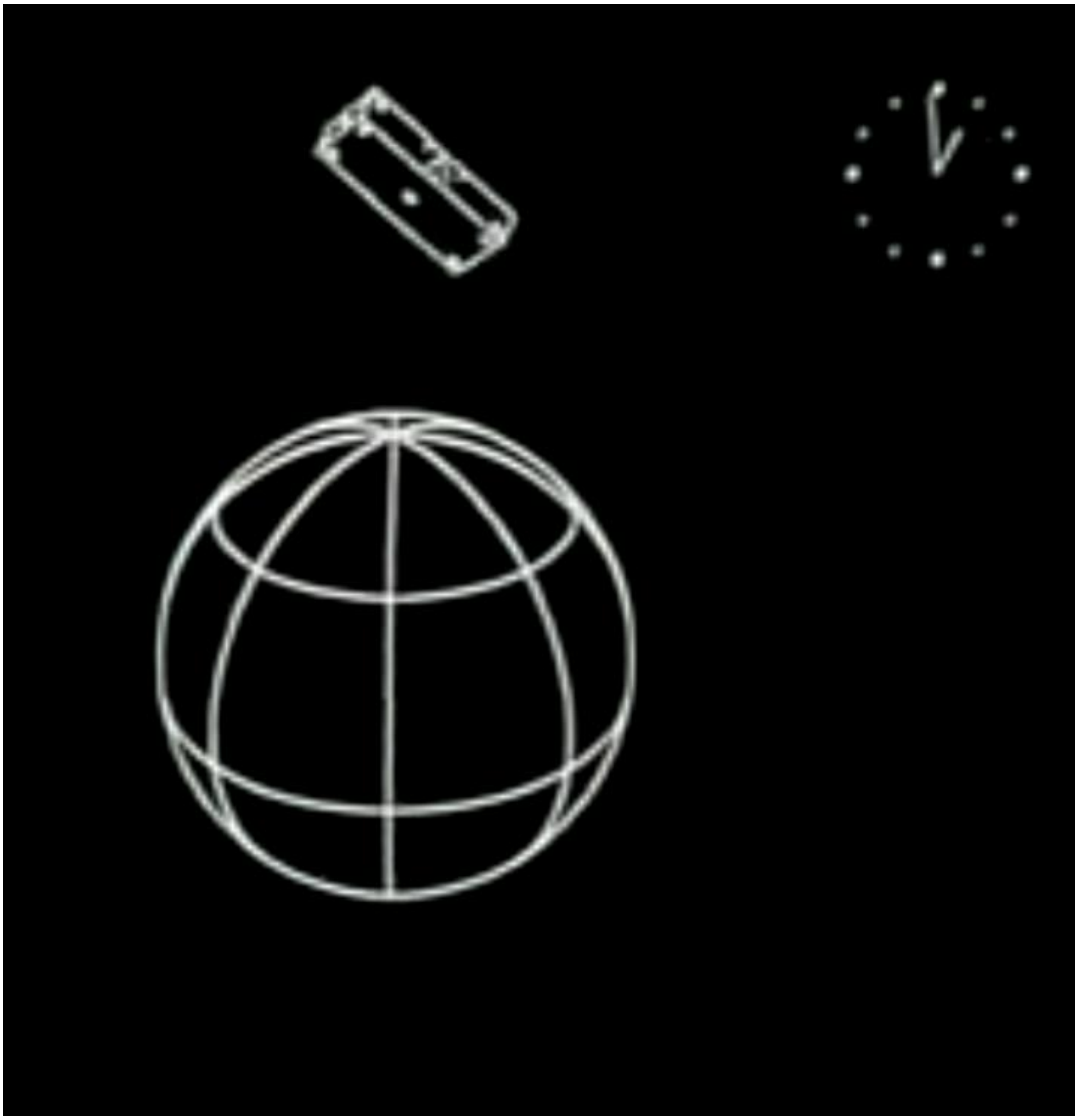

FIG. 1 A still from Edward Zajac's technical demonstration 'simulation of a two-giro gravity attitude control system' one of the first three-dimensional renderings on digital computers, using wire-frame models, in 1963 at Bell laboratories, using an IBM 7090 mainframe computer first sold in 1959.[29]

Discerning the funding objectives or research projects of those agencies during the 1960s is extremely difficult, and other authors have devoted far more time and effort to such questions with limited success.[30] Unlike Rheingold and Schroeder however, who both (not unreasonably) inferred a military connection to Sutherland's work at Harvard, speaking directly with people who worked in the labs at the time suggests a more nuanced, clandestine funding situation. Sutherland's story has changed over the past thirty years, and Sproull's completely contradicts it. Sproull suggested that Sutherland was unable to accept any funding from ARPA precisely because he had worked there so soon before his research position at Harvard, and at Utah.[31]

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[29] Orange Animation, *Simulation of a Two-Giro Gravity Attitude Control System - Edward Zajac* <https://www.youtube.com/watch?v=m8Rbl7JG4Ng> [accessed 12 July 2016]; 'IBM Archives: 7090 Data Processing System', 2003 <http://www-03.ibm.com/ibm/history/exhibits/mainframe/mainframe_PP7090.html> [accessed 12 July 2016]; Ohio State University, 'Bell Labs' <https://design.osu.edu/carlson/history/tree/bell.html> [accessed 12 July 2016].

It appears highly probable however that Sutherland's research into interactive computing and immersion drew a lot of interest from multiple sources within different branches of the US government. The motives for funding the project are unclear, and when asked why his project was funded, he laughed and claimed not to know. Sutherland's original proposal, 1965's *The Ultimate Display,* mentions the use of such technology for training soldiers, and it may have caught the interest of a variety of organisations. With the widespread adoption and military adoration of computerised training systems like SIMNET in the 1980s, and the cockpit simulators of Thomas Furness in the 1970s, a motive perhaps becomes clear. While Sutherland's contributions to the development of VR were considerable, the multiple networks of knowledge, funding, and technical expertise which contributed to its earliest iterations are far wider ranging.

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[30] Christopher Andrew, *For the President's Eyes Only: Secret Intelligence and the American Presidency from Washington to Bush*, (New York, 1996), 216-7; Digital National Security Archive, 'Chronology: The History of the National Security Agency: 1945 to the Present.' <http://search.proquest.com/docview/1679050249/citation/49C936DAE5C4453PQ/1> [accessed 23 September 2016], especially from 1962 onwards, and the directorship of Lt. General Gordon A. Blake; 'Lieutenant General Gordon Aylesworth Blake > USAF > Biography Display' <http://www.af.mil/AboutUs/Biographies/Display/tabid/225/Article/107665/lieutenant-general-gordon-aylesworth-blake.aspx> [accessed 23 September 2016].

[31] Sproull, Interview, 9 September 2016.

STAR WARS: MILITARY RESEARCH INTO PROTO-VR

Similarly inspired by the potential of the *Sensorama*, and potential for IA provided by immersive computing, was Thomas Furness III, an electrical engineer and inventor, who was tasked with developing new instrumentation and cockpit layouts by the USAF. Rid has done some excellent work on Furness, addressing shortcomings in existing histories, and his wider contribution to computing and air-combat is explored in *Rise of the Machines*.[32] From the late 1960s, Furness's team at the Wright Patterson USAF base in Ohio worked on technical advances in the manufacture of displays, computer integration, graphics, motion tracking, and user feedback, in a field Furness called Visionics. Furness helped publicise and popularise the notion of HMDs and computers in the military, capitalising on the success of 1977's *Star Wars,*[33] and referring to his VCASS (Visually Coupled Airborne Systems Simulator) system as a 'Darth Vader Helmet.'[34] His use of science fiction to drive interest in proto-VR would become a recurring theme in the history of the technology, especially once it was informally homogenised under the VR name. Much of his work with proto-VR for the military would not be emulated in the public sector for many decades however due to cost limitations and remained fairly insulated from research by other organisations. Nonetheless, his systems did establish markets for motion trackers, and helped accelerate graphics hardware development into business and science applications. It is also clear that Furness was aware of Sutherland's work when he was working on the VCASS project in 1976.[35]

Like Sutherland, Furness started working with HMDs in 1966, and it seems likely that they both used the same PerkinElmer hardware, though Furness may have also used some displays provided by Bell Helicopter Labs.[36] Their intentions for the technology, while differing at a glance, were also oddly similar. The HMD for both was a means to an end, allowing instinctive user input to improve the understanding and human processing of data, but Furness's military goal, and funding, allowed for a more comprehensive approach to development. For Sutherland, the key development was the graphics hardware: the clipping divider, matrix multiplier, and so on. Development of entirely new displays, for instance, was out of the question due to cost pressures and was unnecessary for the experimental applications being developed. Furness's focus was more on the complete system, devising comfortable and usable helmets, trackers, graphics, and input devices. High levels of funding (some $40m by 1977), and a mandate to create a fully embedded flight control system for military aircraft meant that Furness's team could work on a wider number of technological hurdles and problems. Furness developed his own HMDs, CRT, then LCD screens, ultrasonic trackers, graphics generators, input devices, and more.[37] The reluctance of many of the 1980s and 1990s VR pioneers to work with the military (due to a mixture of ethical concerns, and the military turn away from basic science research following the 1969 Mansfield Amendment[38]) perhaps contributed to the difficulty of transferring technology from Furness's system to VR more broadly, as well as to the high cost, but it remains true that throughout the 1970s and 1980s, military VR and civilian VR were largely separate. Despite that separation, Furness considered them to be closely related. Speaking in 2015, Furness made it clear that he considered the 1960s work of Sutherland, Heilig, and himself to all be kinds of VR, and in no way discrete from the mass-marketed (and explicitly named) VR of the mid-1980s.[39] The degree to which he appreciated that in the mid-to-late 1970s is unclear, though he had encountered Sutherland's display being demonstrated at a conference in the early 1970s.[40]

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[32] Rid, *Rise of the Machines*, 198-206; Rheingold, V*irtual Reality*, 193-196; Schroeder, *Possible Worlds*, 46-7.
[33] George Lucas, *Star Wars*, 1978.
[34] Rid, *Rise of the Machines*, 203-4.
[35] Kent Bye, *50 Years of VR with Tom Furness: The Super Cockpit, Virtual Retinal Display, HIT Lab, & Virtual World Society.*, Voices of VR <http://voicesofvr.com/245-50-years-of-vr-with-tom-furness-the-super-cockpit-virtual-retinal-display-hit-lab-virtual-world-society/> [accessed 6 August 2016].

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[36] Dora Strother, and Hubert Upton, 'HMD/Control System Inv/Stol Operations.' Washington, D.C., United States: American Helicopter Society, 1971. http://archives.rotor.com/documents/publications/doc102209-033.pdf.

[37] Rid, *Rise of the Machines*, 200.

[38] Rheingold, *Virtual Reality*, 211; Herbert Laitinen, 'Editorials. Reverberations from the Mansfield Amendment - Analytical Chemistry (ACS Publications)' <https://pubs.acs.org/doi/abs/10.1021/ac60289a600> [accessed 7 February 2018]; 'The Mansfield Amendment', *The National Science Board: A History in Highlights 1950-2000* <https://www.nsf.gov/nsb/documents/2000/nsb00215/nsb50/1970/mansfield.html> [accessed 7 February 2018].

[39] Bye, 'Voices of VR' 2015.

At the time, Furness's application focus was on efficiency and effectiveness of fighter pilots, he sought to immerse them in a virtual 'super cockpit', to improve telemetry, lethality, and response times. As such, the ergonomic and human factors elements of the system were of considerable importance, and this necessitated smooth computer animation with a high update rate, as well as comfortable, usable displays. His team made considerable progress developing new, custom-made, high resolution HMDs, and fast graphics processors, to reduce eye-strain, headaches, and improve readability through the late 1970s. By the end of the decade, his team had also developed voice recognition, 3D sound, tactile feedback (using air cushions inside gloves), gaze and hand tracking.[41] Experimental test pilots using the system reported being utterly absorbed by the virtual realities of simulated combat, causing sweating and accelerated heart-rate.[42] The notion of presence in virtual space would be expanded and studied further by Furness for the US military in the 1980s. These innovations all became components in some of the most expensive VR systems available during the mid-1990s, and the developments at Wright-Patterson in the 1970s helped set precedents, and establish concepts for, more public iterations of what would eventually come to be known as VR. Of specific interest was Furness's use of Star Wars's science fiction depictions of HMDs to rally public support for his research, and the resulting connections drawn by media and members of the public between HMD-based computer systems and science fiction-inspired capabilities.

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[40] Ibid.

[41] Albert Gore, Fred Brooks, Charles Brownstein, Thomas A. III Furness, Lee B. Holcomb, and Jaron Lanier, *New Developments in Computer Technology: Virtual Reality : Hearing before the Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science, and Transportation, United States Senate, One Hundred Second Congress, First Session, May 8, 1991.* (Washington, 1991) http://hdl.handle.net/2027/pst.000019820071 25.

[42] Ibid., 26.

To directly compare the system to Sutherland's 1968 prototype assumes a false equivalence not uncommon in popular histories of VR, while both proto-VR systems, they were not considered as such at the time, though Furness equates them in modern accounts.[43] With different design goals and implementations, the colossal budget of the USAF team allowed for multiple, powerful computers, bespoke hardware and software, and a rigorous testing environment, which the Harvard and Utah teams had lacked. Furness's team demonstrated to the military, and through press-releases, to the public, that the use of virtual spaces for learning, fighting, and working was not only possible, but extremely useful, and that the science fiction depictions of computerised combat in films like *Star Wars* were closer to realisation than people thought. While both Furness's and Sutherland's projects would establish technological and intellectual precedents for developing VR, it seems likely that Furness was at least partially inspired to develop the VCASS system after encountering Sutherland's coupling of a HMD (which Furness was already working with) with a computer's interactive graphical interface (which Sutherland had devised).[44]

Alongside this, it is not impossible that Sutherland became aware of the military interest in building upon the Navy's Whirlwind tactical simulation research during his time at ARPA, and had used that knowledge to construct his white paper and research proposals around military applications.[45] The military funding for the technologies involved in proto-VR allowed the development of several concepts which would come to prove crucial to establishing developmental pathways for proto-VR. Military funding and ambition for computerised wargames and telemetry fuelled Furness's and Sutherland's research (though the USAF and ARPA, respectively[46]). A direct link between USAF or

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[43] Samsung, 'The History of VR | Samsung Developers', *Mobile Tech Insights* <http://developer.samsung.com/techinsights/gear-vr/the-history-of-vr> [accessed 7 February 2018]; Bye, 'Voices of VR' 2015, 1:20.

[44] Ibid, 1:10.

[45] Kent Redmond, and Thomas Smith, *Project Whirlwind: The History of a Pioneer Computer* (1980); 'Guide to the Project Whirlwind Collection MC.0665' <https://libraries.mit.edu/archives/research/collections/collections-mc/mc665.html> [accessed 1 September 2016].

[46] Sutherland, Interview, 25 Jan 2017.

Naval research into virtual space in the 1960s, or Sutherland's work is unlikely, however. Not only was Sutherland no longer a part of ARPA when he began his work on the 'Ultimate Display' in the late 1960s, but ARPA was a part of the DoD, and separate from the USAF which, with the other parts of the military, treated ARPA with at least suspicion or even disdain.[47] The coupling of HMDs with interactive computer graphics seems to have been an entirely original idea for Sutherland, and Furness's statement under oath before a Senate hearing that he had the same idea, at the same time, suggests that during that period the nature and uses of the computer began to be understood in ways which would encourage and allow experimentation and growth.[48] Both projects helped to suggest a new paradigm for using computers, where computer-generated graphical environments could be of considerable use to the pursuits of design, science, and even war.

PUSHING THE ENVELOPE: USAF RESEARCH IN THE 1970S

Tracing the exact path of the distinct technological and conceptual developments which collectively constitute proto-VR (HMDs, computers, interactive computer graphics, and motion tracking), and the agents and forces responsible, is confounded by the loss of military records. The narrative is further clouded by a dearth of historic documentation from the Harvard School of Engineering and Applied Sciences, and the University of Utah's department of Computer Science. Interviews with Sutherland and Sproull have helped to counter this, regarding the university-based research, but Furness's military work is harder to trace, relying on third-party accounts and conflicting oral histories from Furness himself.

As part of American military research and development at the height of the Cold War, however, it would seem logical that Furness's work on flight simulators and cockpit design fits within a broader historical record of military-industrial research in 20th century America. At the time, military spending was colossal, totalling fully 10% of GDP throughout the 1960s, and increasing in real terms through the 1970s.[49] The growth of organisations like the RAND Corporation, alongside ARPA, pushed considerable funding into military research, revolving around air power and nuclear warfare.[50] It was the pursuit of more advanced, complex fighter aircraft which led to Furness's research into improving cockpit displays which produced the VCASS system in the mid-1970s.

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[47] Thorpe, Interview, 21 October 2016.
[48] Gore, et. al., *New Developments in Computer Technology*, 23-4.

Broader US military historiography remains predominantly fixated on periodised conflict, however, and attention on military research and spending on the home front during the Cold War is an underexplored topic. Black has noted that a lack of attention to the forces and politics of war persists into modern historiography.[51] As such, despite the considerable historical framework that Furness's military work sits within, it is more visible in popular technological and sociological histories than within the colossal corpus of US military history (the aforementioned coverage by Rid remains the best piece of historical work on Furness by some margin). There is considerable scope for historical research into the role of the US military in driving scientific and technological projects during the Cold War. At present, research is scant, and broader understandings of the administrative and philosophical frameworks governing Furness's research, among the countless other projects funded by the military at the time, are limited. Visibility into this research is further confounded by the fate of primary sources: extensive military reports, surveys, and contract filings involved in the development of his VR research, referenced in surviving materials, have been systematically destroyed by the USAF, seemingly without any consideration as to their importance to history.[52] The best way to study Furness's research, then, is through Furness himself. While his oral histories may be unreliable in places, his publications help provide a more concrete source.

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[49] '20th Century Defense Spending United States 1900-2020 - Federal State Local Data' <http://www.usgovernmentspending.com/spending_chart_1900_2020USp_XXs2li111mcn_30f_20th_Century_Defense_Spending> [accessed 1 September 2016]

[50] May, 'The Rand Corporation'.

[51] Jeremy Black, *The Cold War: A Military History* , (2015), preface.

[52] Marcie Green, USAF Historical Research Agency, Pers. Comm.

In the period from 1965 to 1980, when Furness was working almost exclusively for the military, he published very little. The amount of work that was visible expanded considerably when VCASS went public in 1981. He is however listed as the author or co-author on several archival military research reports from the early 1970s, though as mentioned above, the reports themselves appear to have been destroyed. His work appears to have been primarily involved with the development of improved display optics for aircraft pilots in flight and combat, and his recent oral histories support this, though go further to emphasise the common ground between his project and Sutherland's. His PhD thesis, on the effect of vibration on the legibility of HMDs, was not published until 1981.[53]

In contrast to the apparent dearth of publications coming from that research, there is record of several presentations at internal and limited-access conferences and symposia. Throughout the late 1960s and 1970s, Furness participated in a number of conferences at Wright-Patterson, and at a symposium at Fort Belvoir, Virginia. The titles of his talks have survived, but the text appears to have been lost. However, with titles such as 'Helmet-Mounted Displays and Their Aerospace Applications' in 1969 and 'Current Status and Performance of Helmet-Mounted Displays' in 1974, among others, go some way to hinting at what Furness was working on. Indeed, all his visible work from the late-1960s-late-1970s revolved around immersive computer displays, and what he considers to be VR. Furness himself saw that his work on virtual fighter cockpits had led to something different, saying that 'In the process [of my original remit], invented this whole family of helmet-mounted sights, tracking systems, and displays'[54]

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[53] Thomas Furness III, 'The Effects of Whole-Body Vibration on the Perception of the Helmet-Mounted Display 2 Vols' (unpublished PhD, University of Southampton 1981) <http://eprints.soton.ac.uk/52343/> [accessed 7 September 2016] (undertaken as a civilian consultant for the USAF at a site of British human factors research in the 1980s).

[54] Bye, 'Voices of VR', 1:35-1:55; Thomas Furness III, 'Super Cockpit Program Wright Patterson AFB 1986-1989', *Human Interface Technology Laboratory - Supercockpit Home Page* <http://www.hitl.washington.edu/people/tfurness/supercockpit.html> [accessed 7 September 2016]

Through his writing in the 1960s and 1970s, as well as through several oral history projects he has participated in in recent years (including an interview with Thomas Rid), it is possible to derive a limited understanding of his research affiliations and interests.[55] A close study of interviews and contemporary technical literature suggests that, while his work contributed to the development of interactive graphics, virtual presence, and human/computer interaction, they were more incidental components of his military project, which was to drastically improve cockpit design, pilot training, and lethality. Furthermore, his innovations, by virtue of their secrecy, had a minor impact on research in other areas of American society. VR was, for Furness, a product of pursuing a largely unrelated goal, with the common thread being innovative uses of computer generated imagery.

Compounding the lack of a clear 'typology' for proto-VR systems in technical literature, echoing Furness's work or otherwise, there appears to be a considerable discrepancy between perceptions of interactive computing (the core of what proto-VR was about) in the popular media, and its reality 'on the ground' in engineering. As was seen in the earlier discussion of American attitudes to computers, this discrepancy is most visible through the high levels of public anxiety over the role of computers in research and decision making, especially when compared to the reality of the fact. Even at this stage, before most had the chance to use computers, understandings of their role in life was inflated beyond the reality, and this distortion makes historical access to the laboratory life of Furness and Sutherland's teams more problematic.

Furness's development of HMDs, optics, and miniaturised CRTs joined a larger body of technological developments in HMDs at PerkinElmer, Bell Helicopter Company, and other state-funded research firms which were contributing toward the design of more advanced HMDs and trackers used in VR technologies in the late 1980s and early 1990s. Military interest was, of course, focused more on the ends rather than the means, but state funding, particularly from the USAF and ARPA, had a significant impact on the course and speed of research into the various technological systems which formed components of VR in the 1980s.

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[55] Bye, 'Voices of VR'; Thomas Furness III, *The Application of Helmet-Mounted Displays to Airborne Reconnaissance and Weapon Delivery* (Wright-Patterson USAF Base, Ohio., 1970).

The drive for better, faster computers was also mandated by the state during this period. The need for more detailed simulations, and better operation of space vehicles, for example, generated a demand for better computers. Military research on computing, away from the other components of VR, is not surveyed here, but funding for the purchase and development of computers must presumably have been just as abundant as that for Furness's VCASS programme, if not considerably more. A significant proportion of USAF reports from the 1960s remain classified, while ones from the 1950s and 1970s are not. This clouds the view of 1960s military attitudes to digital computers, though by the 1970s computer research was visibly a topic of numerous funding grants and projects. With the invaluable contributions of military contractors and personnel to this thesis, an image of the attitudes of military policy-makers in the 1970s towards technological research begins to form. The prevailing attitude within the USAF towards Furness's research seems to have been highly sceptical at first, based on Furness's own recollections in interviews,[56] as well as in an interview between the author and a former USAF contractor Tony Asch, who recalls that:

> Projects, especially those at a smaller scale (vs. moon landing, aircraft, etc…) have a high tolerance for risk and are often interested in the research results rather than solutions to be widely deployed. The attitude towards VR was that it was a technology to be explored, to encourage a few visionary developers with small contracts, and to evaluate both the VR technology and a number of human factors through the use of VR.[57]

The popular excitement surrounding VCASS brought about by journalists' comparisons between VCASS and *Star Wars* seemingly softened the military mood. The considerable cost of the project was accepted throughout the 1960s and 1970s on the promise of IA and training for soldiers in the far future, rather than short-term goals, a notion quite alien to American business.

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[56] Rid, *Rise of the Machines*, 199; Gore et. al., *New Developments in Computer Technology,* 26.

[57] Tony Asch, Interview, 27 June 2016.

It seems likely therefore that the benefits and potential of proto-VR and interactive graphics for enhancing human faculties and rapid training was understood by the American military, the government, and a growing number of academics and innovators in the 1970s. The colossal financial foundation these offered significantly contributed to funding for computer research. Some material from the late 1950s suggested that fidelity is not the most important aspect of the simulation to be developed (something which the US military widely accepts now) but the flexibility and capability of the system to simulate all the aspects of, for instance, flying a bomber, was far more significant.[58] Military comprehension of human factors research at this time is important, as it contributed toward continued funding for Furness's research, and provided a body of literature for organisations like NASA and UNC to use in their earliest explorations of proto-VR in the early 1980s.

Computers in the 1960s and 1970s were rapidly growing in power and speed but lacked versatility. The narrow research objectives of American state organisations, along with the highly limited pool of computer users, contributed to this. In order to generate interactive 3D graphics, special hardware and software was required. The immersive, realistic virtual worlds which Sutherland had proposed for training soldiers back in 1965 remained far off, and much of the developments both from Furness's and Sutherland's teams in the late 1960s and early 1970s appear to have been as much proof-of-concept projects as attempts to produce tangible results. Once Sutherland's project demonstrated that concept, he abandoned it, and it failed to spawn any direct continuation. Furness however, with clearer goals, and a wider approach, secured funding for a great deal longer, and as such was able to produce more concrete technological innovations, albeit separate from 'civilian' proto-VR research which would only become plausible as computer prices fell in the 1980s. For both, funding was a key component in their ability to innovate, and while their funding came overwhelmingly from the American state, computers and computer graphics more broadly were being increasingly funded, and thus guided, by private capital.

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[58] Tom Sito, *Moving Innovation: A History of Computer Animation* (2013), 63; National Aeronautics and Space Administration, 'Some Considerations in the Design and Use of Dynamic Flight Simulators', 1957, National Archives at Fort Worth.

UNCANNY VALLEY: THE ECONOMIC FORCES PULLING VR RESEARCH FORWARDS

The development of computers powerful enough to generate interactive graphics was driven by economic change and growth in America and enabled by increased, though hesitant and wary, social acceptance. Computers in the 1960s were beasts of mathematical burden, often shared within an organisation by administrative, research, and clerical staff where applicable.[59] Multiple devices were rare, on account of their great cost. In the 1960s the falling cost of components, such as transistors, boosted sales, and thus increased accessibility into the earliest years of the period studied, increasing the number of people using and becoming familiar with the devices. However, costs were still prohibitively high in the 1960s and 1970s, and the lack of any kind of graphical user interface or operating system meant that using computers was a highly complex task, which took time and effort to learn. In 1960, the estimated national expenditure by businesses, universities, and organisations in the US on computer hardware and services was around $590m, by 1965 it had risen to $1.8bn, and by 1970 to $3.6bn.[60] The estimated number of mainframe computers in service in 1960 was around 1,800, and by the end of the decade, it was almost 6,000.[61] The causes for this growth are disputed. Some historians, like Williams and Pursell, suggest it was due to technological breakthroughs in computing (Pursell argues that it was due to the development of semiconductor transistors using silicon and germanium in the late 1950s and early 1960s.) Others like Campbell-Kelly and Aspray believe it was principally due to changes in the economic landscape, and at first glance, this appears to be closer to the truth.[62]

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[59] Campbell-Kelly & Aspray, *Computer,* 2004, 69-116; Nils Nilsson, *The Quest for Artificial Intelligence*. 1st ed., 2009, pp 117-8; Daniel Crevier, *AI: The Tumultuous History of the Search for Artificial Intelligence*. 1993 8-12.

[60] Marcus Einstein, and James Franklin, 'Computer Manufacturing Enters a New Era of Growth', *Monthly Lab. Rev.*, 109 (1986), 10.

[61] Ibid. 9.

While the technologies used in building computers became more efficient, smaller, and more powerful, there was no sudden change or technological singularity that can explain the rapid growth of the computer market in the 1960s and 1970s. The use of transistors in electronics dated to the 1920s and the miniaturisation and development of semiconductor transistors for use in digital computers only came about when it became clear that there was a considerable market for such computers in the US,[63] long after semiconductor transistors were first developed for use in electronics in 1947.[64] It seems likely then that it was the sustained growth of American business that helped to generate a computer market, this in turn made possible the use of computers in Sutherland's research, by making them more affordable and desirable by university departments. The PDP-1 Sutherland used was a minicomputer, a new form factor which was a direct product of computer manufacturers trying to make computers more practical for business users. The increased need of post-war America to manage large amounts of information, be it governmental, scientific, or financial, fuelled demand for computers, which had a knock-on effect on the rate of growth in the computer market. Silicon semiconductor research was most concentrated in Palo Alto, California, (with at least 50 private semiconductor companies operating by 1960), giving it the colloquial name Silicon Valley (or Silicon Gulch),[65] and its considerable growth followed, rather than preceded the expansion of the minicomputer industry, and was thus a product of the rapidly growing American economy, and a necessity for more efficient means of tracking people, materials, and money.

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[62] Michael Williams, *A History of Computing Technology* (1985); Carroll Pursell, *The Machine in America: A Social History of Technology* (Baltimore, 1995), 319-55; Campbell-Kelly & Aspray, *Computer*, 2004.

[63] Julius Lillenfield, 'Method and Apparatus for Controlling Electric Currents', 1930 <http://www.google.com/patents/US1745175> [accessed 26 September 2016].

[64] William Shockley, 'The Path to the Conception of the Junction Transistor', *IEEE Transactions on Electron Devices*, 31/11 (1984), 1523–46.

[65] Pursell, *The Machine in America* ,322-4; David Loehwing, 'From 'Silicon Gulch': Come Dazzling New Applications for Integrated Circuits', *Barron's National Business and Financial Weekly; Boston, Mass.* (17 September 1973), 5.

A survey of popular newspapers and magazines published in California in the 1960s reinforces this view. Notions of the technological marvels (and dangers) which computers could bring were often framed by their cost and the savings they could bring about.[66] While the economic boom that computers heralded was a source of optimism, the technological development of the devices themselves was often portrayed as a threat to jobs. It was rare to see discussion of computers in the 1960s or early 1970s separated from their economic context, with their extortionate cost justifiable or unacceptable, depending on the purpose of the computers in question. Government spending on computers in schools was understood to be worthwhile, whereas spending on computers in non-white schools was not, for example.[67] An organisation's inability to pay for computers was often taken to indicate a lack of success, implying that, for many, ownership of a computer was an integral component of successful business and future growth. Indeed, for Sutherland, Furness, and others working with proto-VR, the considerable funds available to them were a core component of their ability to develop such technologies. Simultaneously, the prohibitive cost of computers limited numbers and encouraged computer users to collaborate and share devices, which facilitated the formation of social and epistemic networks surrounding computer usage. The economics of computers then not only limited computer use to contexts where financial capital was abundant (through funding or earnings) but also incidentally facilitated the exchange of knowledge between peers.

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[66] William Smith, 'Maxi Computers Face Mini Conflict: Mini Trend Reaching Computers', *New York Times* (5 April 1970), 125; Julius Duscha, 'Computers to Aid Teaching: Computers Backed As a Teaching Aid', *The Washington Post* (16 March 1967), section F1,F3.

[67] Duscha, 'Computers to Aid Teaching'; Marian Fay, 'Computer Training for Ghetto Redisents', *Sun Reporter* (7 December 1968), 9.

The backdrop to such extensive spending on computers by schools, businesses, and universities in the 1960s was a period of prolonged economic prosperity. As the average American's quality of life improved, the American government's tax revenues jumped.[68] The economic boom was fuelled by falling manufacturing costs, the receipt of over $180 bn. of war bond maturations, improved post-war education, high consumer optimism, and sustained global economic growth, which created a fertile bed for innovative computer start-ups, as private and state investment in computer science and technology grew.[69] Some of these start-ups pursued research into computer graphics. The economic and social climate fostered growth, optimism, and romanticised consumerism, which seem to have been major factors in the rapid development of new computer technologies throughout the 1960s. It was also the climate within which government funding was afforded to security service research for the purposes of advancing and maintaining American interests, in the projects of Sutherland and Furness, among others.

This economic prosperity fed into the rapidly growing digital electronics industry in the US, just as it did in Japan and West Germany, and the production of some of the crucial components of new computers became considerably more affordable throughout the 1960s by virtue, principally, of the economies of scale. The US was home to several market-leading computer firms, like DEC, IBM, and Intel, and they helped establish technical standards which would allow the gradual diversification of computer developers and technologies. Competition resulted in lower prices that increased accessibility to businesses and universities across the US. While Sutherland's funding was considerable, he did not have to buy the computer used in the Ultimate Display project, as he took it from ARPA when he left (according to Sproull), freeing up funds which were spent instead on the

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[68] Patterson, *Grand Expectations*, 1997.

[69] Alexander Field, *A Great Leap Forward: 1930s Depression and US Economic Growth*, Yale Series in Economic and Financial History (New Haven ; London, 2011), 106-15; Duke University Libraries, 'Brief History of World War Two Advertising Campaigns, War Loans, and Bonds.', *Duke University Libraries Digital Collections* <https://library.duke.edu/digitalcollections/adaccess/guide/wwii/bonds-loans/> [accessed 12 March 2018].

PerkinElmer display.[70] By the 1970s, computers powerful enough to generate and display interactive computer graphics were more common, and interactive graphics was a subject of focus for the R&D divisions of computer companies like Xerox, DEC, and Three Rivers, all of which were seeing unprecedented revenue growth.[71] The research by such companies into graphics broadened the gamut of their applications, and would prove crucial to the privately-developed graphics processors used in 1980s proto-VR and VR systems, as well as the social positioning of computers away from purely administrative machines.

As mentioned above, the US government benefitted financially from the 1960s financial boom and was in a period of heightened tensions with the Soviet Union. As a result, the DoD, intelligence agencies, and military all received a considerable share of US tax revenues. Military and DoD research goals were influential in supporting early VR research, and the shrinking economic burden computers posed led inevitably to the establishment of bigger labs, faster development, and to the widening acceptance that computers and computer-generated experiences, including proto-VR, would have a place in American warfare, science, and perhaps beyond.

The early history of VR, therefore, is arguably defined by state-funded and managed research into applying computer graphics to a range of goals, connected to American military and scientific global dominance. Private computer companies were not combining graphics with tracked HMDs at this time. Iterations of proto-VR outside of a state-funded testing facility were non-existent between 1965-1980. There was, equally, no public demand for such a technology, indeed it seems likely to have alarmed people far more than excited them. The expense of such projects was allowed on account of economic and political changes in the US. Driven by the threat of the Soviet Union, a renewed American Exceptionalism, and the spectre of mutually assured destruction, a core component of the government's agenda was to find opportunities to outsmart opposing forces and maintain technological superiority. Resultingly, the CIA, FBI, NSA, DoD, and ARPA received considerable funding boosts, with very little oversight. It was these funding boosts which allowed and encouraged (particularly in ARPA's case) the pursuit of research into unexplored topics, interactive computer graphics was one of them, and proto-VR technology during this period was almost exclusively produced by the pecuniary abundance wrought by the American state's need to maintain a cutting edge in the technologies of warfare and computer science, and thus the material wealth of the country in the post-war era.

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[70] Sproull, Interview, 9th September 2016

[71] Ibid.

THE SWORD OF DAMOCLES: SUTHERLAND'S CIRCLE INTO THE 1970S

There is more to the story than purely economic forces, however, and the educational and institutional backgrounds of Sutherland and his students demonstrably influenced the shape of proto-VR technologies developed at Harvard, Utah, and even beyond. In 1965 Sutherland had just left ARPA, which had taken him in after the completion of his PhD. Sketchpad, his doctoral project, was designed to function as an intuitive interface between people and computers through the medium of graphics and may have been partially funded by the USAF.[72] Away from proto-VR, Sutherland's thesis was influential on the development of computer graphics, operating systems, and the way in which human-computer interaction was visualised.[73] Sketchpad worked by allowing people to use a light pen, a kind of hand-held computer input, to manipulate computerised images displayed on a screen, changing their perspective or editing them before the user's eyes. Sutherland's Ultimate Display was, in some ways, an expansion of the same idea, making computer-stored images easier to edit, explore and understand by using 3D, and adjustable perspective. The ability to explore a computerised image, a virtual space, in a way which appeared tangible to the user, formed the core concept of the Ultimate Display, and eventually VR.

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[72] Ivan Sutherland, 'SketchPad, a Man-Machine Graphical Communication System' (Massachussetts Institute of Technology, 1963) https://web.archive.org/web/20130408133119/http://stinet.dtic.mil/cgi-in/GetTRDoc?AD=AD404549&Location=U2&doc=GetTRDoc.pdf; Brad Myers, 'A Brief History of Human Computer Interaction', *Technology, ACM Interactions*, 1998, 48.

[73] Alan Blackwell, and Kerry Rodden, *Preface*, Sutherland, *Sketchpad: A Man-Machine Graphical Communication System*, 2003, 3–5 http://weblibrary.apeiron-uni.eu:8080/WebDokumenti/11348-uvod.pdf [accessed 27 September 2017].

Sutherland needed hardware and software which would store, retrieve, generate, and display these moving images, and process the user's movements into a shifting of perspective for those images. As well as the head-mount and motion tracker, which were taken from PerkinElmer, other key pieces of hardware were developed by Sutherland and his students for this earliest proto-VR system, including the Clipping Divider and the Matrix Multiplier.

The Matrix Multiplier was originally designed to work with the machine Sketchpad had been written on, the MIT Lincoln Labs TX-2 (this would be soon replaced by a PDP-1), a custom-made machine funded by the University directly at great expense, with the intention of fostering computer research there.[74] Its function was to calculate the differential between the raw data of images stored in the computer, and what would eventually be shown to the user inside the virtual environment, accessed via the HMD. That way, the main computer only had to access pre-determined data for the virtual environment loaded into it, and the Matrix Multiplier would take that data and process it again. As a result, the generated image could be redrawn as the HMD moved, far more quickly than would have been possible using just the original machine. This created an illusion of a 3D space within the computer that users could 'move' through. Computers at the time, particularly the PDP-1 microcomputer Sutherland used, were not powerful enough to draw-and re-draw graphics every time the user's head moved to keep up. In order to update the graphics display at 30 frames per second, several discrete processing units were daisy-chained together.[75] The Matrix Multiplier which Sutherland's team built could carry out around 3,000,000 multiplications per second, converting the basic environmental layout stored in the computer to a three-dimensional image from a constantly changing perspective. By keeping it and the Clipping Divider as separate units, they could operate at the same time, altering the data being generated by the computer step-by-step as it reaches the display. The layout of Sutherland's setup is demonstrated in fig 2.[76]

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[74] Ivan Sutherland, 'Looking Back: The TX-2 Computer and Sketchpad', *Lincoln Laboratory Journal*, 19/1 (2012), 82–84.

[75] Sutherland, 'A Head-Mounted Three Dimensional Display', 757–64.

The Clipping Divider was driven by software largely created by Bob Sproull and served to create 'windows' (not the Microsoft Operating System) into the graphical world, only generating the parts of an image which the user wanted to see, depending on zoom or rotation, for example. The Clipping Divider was essential to Sutherland's display, as it limited the displayed images to the calculated perspective of the user.[77] This technique would be used in many subsequent interactive graphics systems, and William Newman and Sproull's textbook, *Principles of Interactive Computer Graphics*, would be a key text for computer graphics students between 1979 and 1990.[78]

While often described as a prototype for VR and cyberspace, the 3D HMD was, as mentioned, a technical demonstration. The use of an HMD was rooted in the lack of standardised inputs for graphical interfaces, the desire to track user movement (the head seeming more natural than the hand), and Sutherland's objective of designing a more intuitive way to examine technical blueprints.[79] For Sutherland and his students, the graphics technology, not the HMD, was the breakthrough.[80] In later interviews and oral histories, Sutherland referred to the time spent at Harvard as graphics research, implying that the display itself was largely incidental to him.[81] The combination of graphics and HMD had, it seems, little effect on the formation of later VR technologies in the late 1980s.

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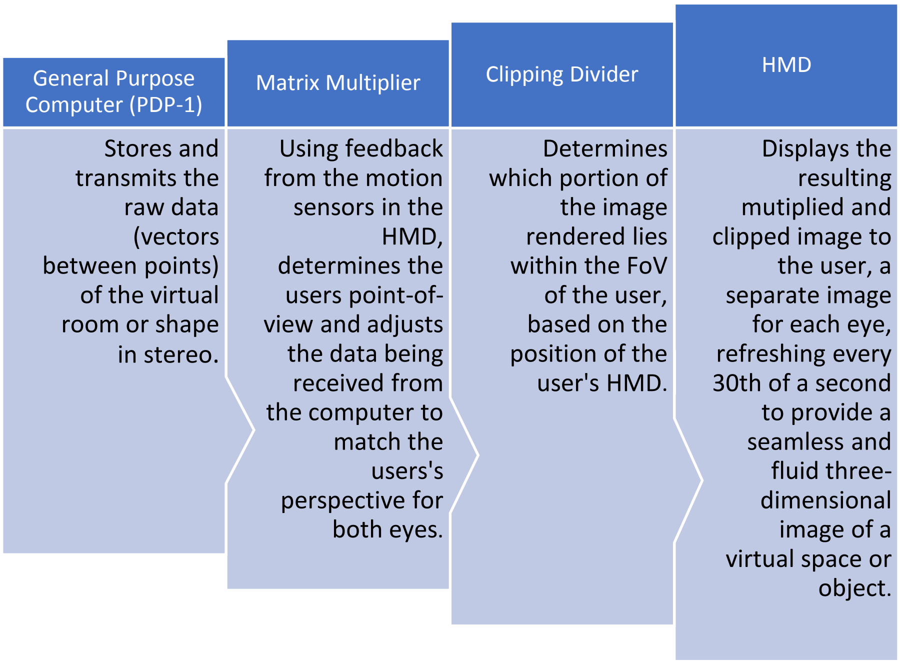
[76] Ibid, 759-9.
[77] Sproull & Sutherland, 'A clipping divider', 765-766.
[78] Newman & Sproull, *Principles....*
[79] Sutherland, Interview. Jan 25th, 2017.
[80] Sproull, Interview, 19th September 2017
[81] Aspray, 'Oral History Interview', 37.



General Purpose Computer (PDP-1)	Matrix Multiplier	Clipping Divider	HMD
Stores and transmits the raw data (vectors between points) of the virtual room or shape in stereo.	Using feedback from the motion sensors in the HMD, determines the users point-of-view and adjusts the data being received from the computer to match the users's perspective for both eyes.	Determines which portion of the image rendered lies within the FoV of the user, based on the position of the user's HMD.	Displays the resulting mutiplied and clipped image to the user, a separate image for each eye, refreshing every 30th of a second to provide a seamless and fluid three-dimensional image of a virtual space or object.

FIG. 2 This chart briefly outlines the key components of the peripheral devices developed by Sutherland, Sproull, and the other students to generate the 3D images quickly enough for the user to not notice any stuttering or delay of image when they moved.

However, a detailed analysis of dispersal of expertise from Sutherland's lab paints a slightly different picture. After the Ultimate Display project ended, which Sutherland himself described as pioneering, much of the team disbanded.[82] Sutherland was recruited by Dave Evans, another computer graphics expert, at the University of Utah. The display, with the Clipping Divider and Matrix Multiplier, were stripped out of the Harvard lab and followed him, where it was rebuilt and demonstrated at computer graphics conferences into the early 1970s.[83] Most of his students didn't follow, including the most prominent student contributors, Cohen and Sproull (though Sproull was invited, and presumably so was Cohen).[84] Sproull felt that the 'Sword' had run its course technologically, and the future of computer graphics lay in other directions (a view, it would transpire, that Sutherland would quickly come to share.[85]) Sutherland himself took a far smaller role in teaching and research at Utah in the early 1970s, in order to run his new company, Evans and Sutherland, and left Utah altogether in 1974. His work then revolved around selling graphics processors, though his own research interests had moved on to integrated circuits, and his interest in computer graphics never returned.[86] By that point, the system he built was not being used for research, and students of his who had demonstrated it at conferences in the first half of the 1970s apparently stopped doing so at around the same time.

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[82] Ibid. 25.

[83] Sutherland, Interview, 25th Jan 2017

[84] Sproull, Interview, 19th Jan 2016.

[85] Ibid.

Sproull went to Xerox, where he worked on increasing the graphical fidelity of computers and minicomputers, especially the digital reproduction of text for screens. He joined a large and well-funded group of researchers examining 2D graphics, and industry-applicable 3D seemed to many a long way off, despite the Harvard breakthroughs. Sproull's move away from 3D interactive graphics and HMDs towards improving the fidelity of 2D displays appears to serve as a microcosmic reflection of broader attitudes to computer graphics and virtual space in the US at the time (Furness's highly confidential Visionics research for the USAF was the understandable exception). The rapid expansion and diversification of interest into graphics research is reflected in the technical literature of the time, and, to a certain extent, in popular literature as well. The people who had experimented with and been exposed to Sutherland's 3D HMD were among (but not the extent of) those who began to conduct their own research in the 1970s, which would inform its later development

MIGRATION: THE DIVERSIFICATION OF LITERATURE AND EXPERTISE IN THE 1970S

By 1970 the number of annual publications in technical and academic journals in the US concerning computer graphics reached around 1,500, indicating a drastic increase in projects and funding from the 150 or so in 1965. Analysis of a sample of those articles shows that they were mainly split between the use of computer graphics as a novel tool for solving mathematical problems, and the development and implementation of improved graphics fidelity. Both 2D screens and 3D stereoscopy were used, though the latter was in the minority of publications. There is also a smattering of articles published during the 1970s researching the social or psychological issues surrounding the use of computer graphics, suggesting that, as usage of graphics increased, so too did concern surrounding the risks to public health such a technology posed (i.e. technophobia), a recurrent theme in the broader history of technology.[87]

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[86] Sutherland, Interview, 25th Jan 2017.

The focus at this point then can be seen to cluster around the concepts first developed for Sutherland's Sketchpad programme in the early 1960s: the production of images on a screen which can be manipulated for improved understanding, and thus amplifying human intelligence. Both VR and interactive computer graphics have connections with the field of IA, and these would become more explicit in the 1980s. Research into IA via graphics, and that which integrated HMDs, often had similar objectives but the latter was far less common and is also the only subset which can be considered proto-VR. Similarly, the main point of contrast between technical publications in 1970 and the mid-to-late 1960s is principally that of volume, with the broad topics and aspirations of works pertaining to interactive graphics remaining much the same. In other words, Sutherland's, Sproull's, and Cohen's work did not cause rapid shifts in the dialogue surrounding graphics but rather encouraged the continuation of existing work. In the case of Sproull's 1979 textbook, they shaped a great deal of teaching for computer science in the 1980s. Regardless, the development of the 3D HMD at Harvard and Sutherland's graphics work at Utah did not bring about any rapid, visible advancement in the use of computers for proto-VR.

More detailed metrics are depicted in figures 3 & 4, although there are so few relevant articles surviving and accessible from 1965-1969 that they have been grouped into a single dataset.

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[87] Mark Brosnan, *Technophobia: The Psychological Impact of Information Technology* (New York, 1998).

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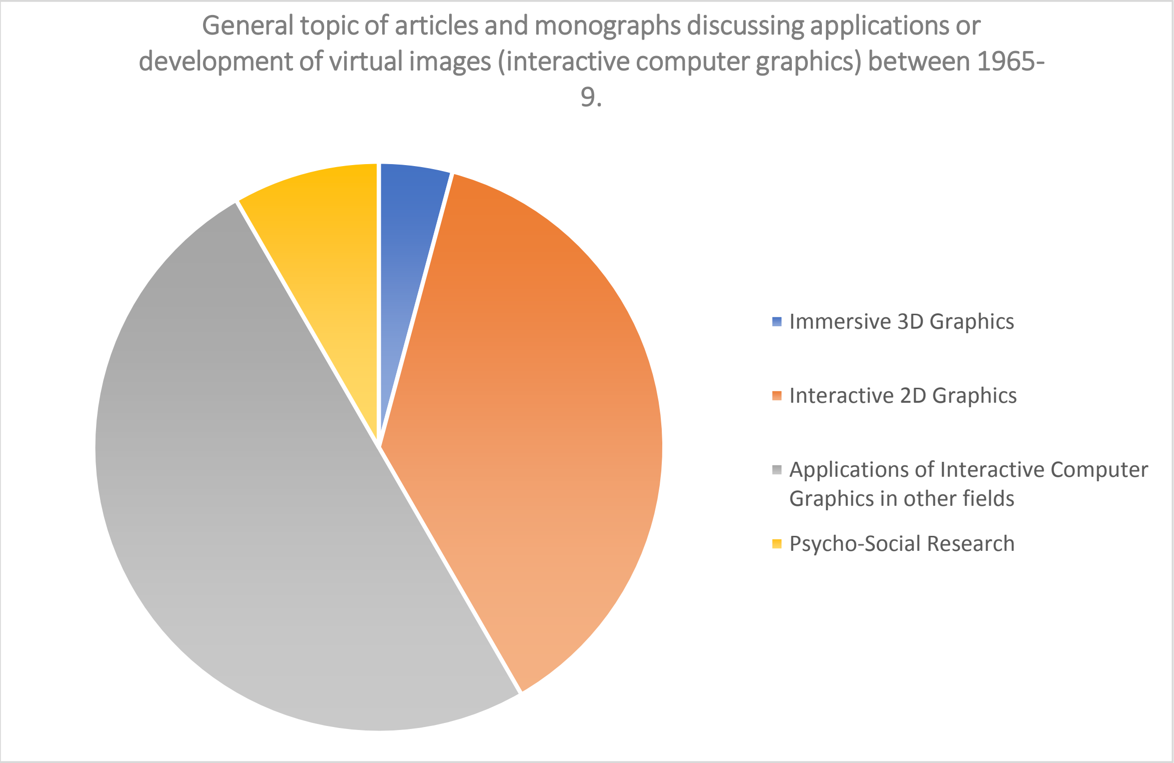

FIG. 3 This chart lays out the average distribution of technical literature which directly refers to applications of or developments in interactive computer graphics by subject over four years from between 1965-1969.

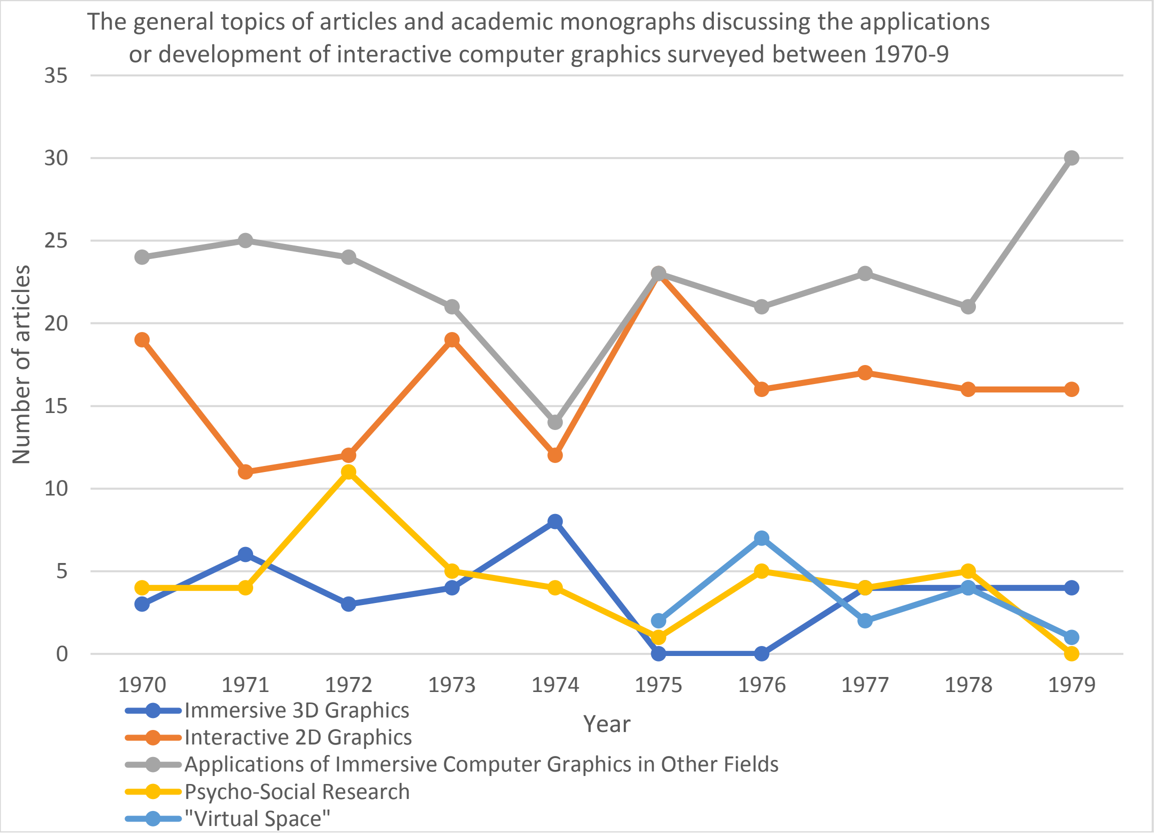

FIG. 4 This chart lays out the rough distribution of technical literature which directly refers to applications of or developments in interactive computer graphics, the core component of proto-VR, in their abstracts and conclusions, from 1970-9.

These figures are non-interactive 2D graphical representations of data, which highlight the limited range of fields in which computer graphics research was being funded and developed (based on the assumption that funded research is far more likely to produce publications than after-hours work.)

At this time, articles in newspapers and magazines were largely enthusiastic about discussing the actual and potential uses of computers, though awareness of computers as interactive visual tools, as opposed to simply calculators, was slow to catch on. Only a handful of newspaper and magazine articles surviving from 1970 mention computer graphics, but advertisements running in the *New York Times* for computer graphics salesmen start appearing at the same time, where it was briefly explained (early in the decade) and repeatedly described as a rapidly growing market.[88] Several of these adverts crop up in the early 1970s, and they go some way to show that computer graphics R&D gradually moved from state-funded research to private capitalism as it became less costly and more feasible to implement, on account of improving understandings, mathematics, and hardware (i.e. faster computers, larger storage capacity).

Very little attention was paid to the potential impact of computer graphics (discretely from computers) on the US consumer during the 1970s. While the psycho-social research papers described in figures 3&4 suggest that there was a budding concern about their possible psychological or physiological effects on people, the implications of interactive computer graphics do not appear to have been seen to be particularly newsworthy.

The academic and technical publication metrics for the 1970s visible in fig. 4 provide a broad overview of the distribution of graphics research by subject ('virtual space' refers to research into presence in computer generated environments.) The considerable scientific research into computer graphics at the turn of the 1970s, visible through oral histories, and through technical writing, does not appear to have been noticed at all by the contemporary popular media, and it would, in fact, take almost a decade to do so.

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[88] 'Classified Ad: Technicians Computer Maintenance', *The Philadelphia Enquirer* (24 September 1970), 38; 'Display Ad 518 - No Title', *New York Times* (17 Jan 1974), Sports, 275; 'Classified Ad 51 -- No Title', *The Washington Post; Washington, D.C.* (17 June 1979), Business Finance, G17.

Through the early 1970s, the technical and popular literature examining virtual space (i.e. computer graphics) shows a considerable increase in volume (and thus, by extension, funding), as well as a gradual diversification of research interests, and public perceptions. This appears to be driven by the development of a business market for microcomputers with graphics capabilities, and graphics consoles for mainframe computers (separate computers which could tie-in to a mainframe computer, and display data stored on the mainframe graphically).

The rapid expansion of the computer and graphics industries in the 1970s created a great deal of research diversity when compared to the 1960s, and its fair share of disarray. As Joseph Licklider pointed out in 1969, ‘four generations of graphical systems are in operation at once. “Computer Graphics” means different things to different people.’[89] If this confusion was abundant in 1969, when computer graphics and digital computers were still in their infancy, the wide range of approaches, attempted standards, and conceptualisations of how users could interact with computers, and how virtual space should be explored, seems almost inevitable. Of the wide range of technologies and ideas which are visible through the publications and accounts of the time, the immersive stereoscopy of devices like Sutherland’s and Furness’s are almost invisible, but not quite.

Many developments involving the creation of virtual environments, primarily driven by reduced costs and larger markets (as opposed to the fixed pathways of most state-driven innovation, and the desire for modern computing evoked by some popular histories of VR), moved toward improved computer consoles and terminals, placing screens in offices and schools across the country, on desks, rather than on heads. The cause for this appears to mainly be one of cost: an immersive HMD would have cost hundreds of thousands of dollars to develop, and would have provided an experience which was, in many ways, worse than that of a single 2D screen: graphical fidelity was certainly no better, and the three-dimensional image could be choppy or lag behind the user's movements.[90] A CRT screen mounted inside a console or in a monitor on top of a desk was far more affordable and easy to use and was thus considerably easier to market. Commercial considerations and technical obstacles (particularly regarding lag and resolution), rather than ideological or social concerns, dictated that research pursue 2D graphics over 3D.

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[89] Licklider, J. CR, 'A Picture Is Worth a Thousand Words: And It Costs...', in *Proceedings of the May 14-16, 1969, Spring Joint Computer Conference* (1969), p. 617 <http://dl.acm.org/citation.cfm?id=1476898> [accessed 24 October 2016].

It is important, however, to point out that despite reductions in cost, the price of computers and graphics hardware was extremely high. A low-budget graphics processor, without a display, or software, could be expected to cost in the region of $18,000 in 1970, and by the end of the decade, the price of a system capable of providing interactive two-dimensional computer graphics, like the Apple II, was around $2000 (adjusted for inflation, these systems would cost $112,000 and $12,000 respectively in 2015).[91]

Arguably then, throughout the 1970s, the hardware, technical innovation, and cultural place of interactive graphics in the US moved away from Sutherland's Ultimate Display, and from proto-VR, rather than toward them. The focus on 2D displays and the miniaturisation of computers for home and office use dwarfed research into immersive stereoscopy. Sutherland himself had all but abandoned that work by 1974. Evans and Sutherland did supply equipment for another 3D HMD research project in 1979, but aside from that Sutherland's engagement with the technology appears to have tailed off. Research into 3D displays was carried on however by his colleagues and students, as well as Furness.

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[90] Sproull, Interview, 9th September 2016.

[91] Murray Rubin, 'Low Cost Graphics', *Computers And Automation*, 17/11 (1968), 18–19.

Much of the money Sutherland made from Evans and Sutherland was from selling graphics hardware for use in combat and flight simulators to the US government and contractors.[92] These were not using 3D displays, but whole-vehicle simulators (i.e. the user sat in a facsimile cockpit). The use of HMDs to create a sense of presence in virtual space, later called VR, was for Sutherland a non-sequitur. When asked if he considered 1980s and 1990s VR a continuation of his work, he said he had never given it any thought.[93] Shortages of funding and considerable technical hurdles rendered the continued pursuit of what was, for Sutherland, a finished technical exercise pointless. However, other sources of research into immersive graphics were appearing and increasingly diversifying out of state-funded research projects into a broader gamut of academic and private-capitalised projects across the US and abroad.

Linear timelines of technological and social development pervade the historiography of computing, and certainly the history of VR. It seems likely that direct systemic links between Sutherland's work in the late 1960s, and commercial VR from VPL, Pop Optix, and others in the late 1980s do not exist, or are extremely tenuous. Instead, the Sutherland and Furness projects form parts of a larger narrative of increasing computer capabilities, and of the development of novel ways of thinking about computer applications, interaction, and user agency. Sutherland was not attempting to establish a standard, and innovators like Eric Howlett and Mike McGreevy were not trying to echo Sutherland's work in 1987-88. Between the present-framed proto-VR of the 1960s and the VR buzzword of the 1980s and 1990s, there were technological, temporal, social, and intellectual divides. The understanding of, and intentions for VR in the 1980s were far more ludic and artistically driven than the utilitarian, objective based aspirations of Sutherland's and Furness's work on virtual space and immersion in the 1960s and 1970s. The conceptualisation of computers as being tools for entertainment, recreation, and creativity was not something generated by either of those research projects and yet forms one of the most visible intellectual components of VR research and products in the 1980s and 1990s.[94]

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[92] Sutherland, Interview, 25th Jan 2017.

[93] Ibid.

The source for this paradigm shift in the conceptualisation of computers, particularly when integrating HMDs, stems both from the development of the video game market in the US, and the work of another academic group active during the 1970s: Nicholas Negroponte's MIT-based Advanced Visual Studies lab, and the Architecture Machine Group. Negroponte and Kristina Hooper's work on the Aspen Movie Map project (funded in part by DARPA), and that of his student Scott Fisher, helped prove that entertaining and artistic computer applications were possible and that HMDs could facilitate computer-based entertainment.[95] Fisher and Hooper would go on to work together in the 1980s in one of a number of groups developing the hardware, software, and ideas behind what would come to be known as VR.[96]

The late 1970s were a period of considerable investment in the computer graphics industry, and expertise became increasingly diverse within the US. Many of the team who worked with Sutherland at Harvard, or at Utah, moved into a mixture of private firms (such as Xerox and Bell Laboratories), other universities, and state agencies (such as NASA.) This diversity broadened the spectrum of funding opportunities, research goals, and objectives in interactive graphics research throughout the late 1970s, encouraging alternative perspectives and applications for the technologies which had been trialled in Sutherland's project, and which were being worked on, for instance, by Negroponte and colleagues at MIT.

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[94] Kevin Kelly, and Barbara Stacks, 'An Interview with Jaron Lanier', *Whole Earth Review*, Fall, 1989, 108–19.

[95] Scott Fisher, 'Viewpoint Dependent Imaging: An Interactive Stereoscopic Display', in James Pearson (ed.), *Processing and Display of Three-Dimensional Data*, Proceedings of SPIE, 1982, 0367, 41–45 <http://dx.doi.org/10.1117/12.934299> [accessed 1 November 2016]; Aubrey Anable, 'The Architecture Machine Group's Aspen Movie Map: Mediating the Urban Crisis in the 1970s', *Television & New Media*, 13/6 (2012), 498–519.

[96] Christopher Watkins, and Stephen Marenka, *Virtual Reality Excursions with Programs in C* (2014), 69.

This diversity and the growing differentiation of perceived applications for computers and displays led to the continued pursuit of HMD-based proto-VR research in the 1980s. Conceptions of the possibilities inherent within virtual spaces discussed in the 1960s and early 1970s were increasingly diluted by ludic, explorative, and creative applications such as games, product prototyping, and digital art. The artistic potential of graphics, particularly when coupled with the sense of immersion and presence conveyed by a 3D HMD was explored in the late 1970s at the MIT Architecture Machine Group, research that was only made possible by the expansion of expertise and interest in novel uses of computers, itself brought about by the increasing competition and decreasing costs of the American computer industry.

THE CHANGING PORTRAYAL OF COMPUTERS AND VIRTUAL SPACE IN MEDIA DURING THE 1970S

This diversification of research and move away from the strictly utilitarian understandings of computer graphics and virtualisation is also reflected in popular literature. The fear of computers and those who used them, rife in the 1960s, matured in the following decade into a combination of grudging acceptance, ignorance, and considerable optimism. The range of attitudes towards computer interaction became diverse in terms of moral alignment, while simultaneously being highly limited in terms of spectrum, as public understandings of what computers could do crystallised at the same time that the technical capabilities and possible applications were expanding.[97] Changing understandings of computers, of course, had knock-on effects on notions of becoming present within one via proto-VR. There were only a handful of newspaper and magazine articles which discussed computer graphics directly, even fewer which addressed the interactive graphics technologies of the time (even though by this stage many of these were created by private businesses and thus, advertised publicly for sale). Indeed, the largest body of references to such technologies, or the computerised realities they create, was by far advertisements for positions and products provided by private companies developing computer graphics hardware and software.

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[97] Hubert Dreyfus, *What Computers Can't Do: A Critique of Artificial Reason* (New York ; London, 1972), xix-xx, xxvii-xxxii.

Explicit mention of computer displays in a social, cultural, or technological context was only intermittently visible in popular media throughout the 1970s. While most then were only mentioned in passing, as a component of many new computer systems, reactions to the display itself were highly limited. Of the few that did, many fixated on the computer display as a tool of dehumanisation, a technological means to the end of reducing people to figures on a screen, of reducing agency, or even replacing (or surpassing) people altogether. The computer was, seemingly, often distanced from the real lives of most people, a distant or even fictional threat.[98]

'Hypothetical environments',[99] were discussed in a variety of ways throughout the 1970s, but the considerable costs and limited functionality of contemporary computers served as limiting factors in the expansion and diversification of computer users, thus limiting the number of sources of innovation and development. Put simply, there were not enough people using computers outside of highly specialised research environments to have a visible impact on the public understanding of what computers could do. The relegation of computers (which increasingly had some form of graphical display by the mid-1970s) to the office and the laboratory kept them largely out of public sight, though not public mind.

This limited exposure to actual machines allowed for widespread hyperbole on the part of pundits, and attitudes towards computers in publications diversified considerably. Many Americans wanted to know what computers did, and why they did it, and popular sources were happy to provide answers, often divorced from the technical truth, and affiliated far more closely with the realm of science fiction. Little of the public discourse surrounding computers seemed to focus on immersion or virtual space (that would only come in the 1980s, explored in chapter 3, p.112). The scarcity of information and understanding prevalent in depictions of the technology most visible to the public led to a spectrum of tones regarding the place of computers in American society, ranging from optimistic exclamations of the 'enormous potential for people determined to find solutions to mankind's most pressing problems', to purely technical, aloof advertisements for jobs constructing 'virtual environment(s)', and even to the claim that human interaction with computers was not only dangerous but risked creating an 'unGodly Idol.'[100] It is possible that there was a re-emergence of fear and suspicion surrounding the human-computer interface in the US towards the end of the 1970s, but with so few relevant sources available, that this is almost impossible to verify statistically, and there is considerable scope for further research in this area.

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[98] Ibid, Gary Arnold, "'Damnation': Watch for the Killer Roaches: Film 'Damnation Alley"', *The Washington Post* (22 October 1977), 31; John Canaday, 'Art: Less Art, More Computer, Please', *New York Times* (30 August 1970), Arts & Leisure, 87; Alexis Greene, 'The Coming Impact of Technology on the Arts', *New York Times* (26 February 1978), Arts & Leisure, D1.

[99] Carter Horsley, 'Architects Find Computer a Friend', *New York Times* (29 August 1971), real estate, R1.

A further problem, which is indicative of the nature of public perceptions of computerisation and computer-generated experiences at the time, is the considerable diversity of expressions used throughout the 1970s to refer to such technologies and possibilities. Virtual environments, 3D computer graphics, interactive computers, visible interfaces, 3D computers, and many more terms come up in a wide range of articles, though they appear to be discussing roughly the same thing, i.e. the computer-generated spaces where information can be accessed, displayed, and shared.

This lack of a shared language, or paradigms, for human-computer interaction is unsurprising, given the highly limited opportunities for first-hand experience with such a device in the 1970s. However, given the recourse of many journalists at the time to 'computer experts' and computer scientists (Rheingold's 'High Priest'), it is surprising to note the scale of the gulf between many portrayals of computer capabilities in opinion pieces and applications in popular and technical literature. Alexis Greene's 1978 depiction of computers which can 'imitate the sounds of an entire symphony orchestra' and as 'tools for composers, painters, and choreographers... that no human performer could possibly match' were based on interviews with computer scientists from Stanford University and Bell Laboratories.[101] John Porter wrote in 1970 that the problems of 'an exploding world population, hunger, disease, urban misery, crime, environmental pollution, natural disasters, inflationary economies' could all be solved by computers within the next decade, again citing the research of Bell Laboratories.[102]

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[100] John Porter, 'Computers Take Step to Maturity', *New York Times* (11 January 1970), 473; 'Classified Ad 212 -- No Title', *New York Times* (13 June 1976), Help Wanted, 163; P.H, 'Synagogue Size: The Dangers of Computerization', *The New York Jewish Week (1973-1985), Manhattan Edition* (2 October 1977), 18.

As equally as computers were portrayed as future providers of solutions to global issues, and transformers of art and music, they were sources of considerable apprehension. David Kozinski wrote in 1972 that the computer threatened to 'de-humanize one of man's dearest utterances music.'[103] In 1979 Mary Elson and Len Ackland broke a story in the Chicago Tribune explaining that 'the United States' defence system is "operationally vulnerable" because of computer problems', blaming 'Unchecked use of computers in society' for 'billions of wasted tax dollars' and compromising American national security. As part of a larger series of exposés in the latter part of the decade on the growing 'backlash' against computer usage, the Tribune questioned 'unbridled growth' of computers, which apparently '[touched] every facet of our lives.' In 1979 this remained far from the truth, objectively, and yet the fear and anger directed toward computers and their irresponsible use by politicians, scientists, or the American military was clear.[104]

While many journalists saw computers as threatening or promising, some did try to maintain a voice of reason, with Steve Ditlea responding to anti-computer rhetoric in 1979 by arguing that

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[101] Greene, 'The Coming Impact of Technology on the Arts'.
[102] Porter, 'Computers take step...'.
[103] David Kozinski, 'Consort Fights Computer's Threat', *The News Journal* (12 July 1972), 52.
[104] Mary Elson, and Len Ackland, 'Computer Problems Make US 'Vulnerable"', *Chicago Tribune* (30 July 1979), 1, 8.

'Without computers, the US as we know it would simply not exist.'[105] Ditlea points out that 'for many people, computers are synonymous with "Big Brother" government... blamed for today's deadly weapons, the depersonalization of society, and for a variety of contemporary problems ranging from unemployment to white collar crime.' The controversial argument in his column, however, is that 'computers are neither intrinsically bad *nor* good,' while inanimate machines, the level of explanation Ditlea needs to support his statement suggest that a great deal of animus was in fact attached to computers by the end of the decade. 'If a computer is fed instructions which are properly composed,' he explains, 'it will follow them to the letter, mistakes and all, without any consideration of their consequences. It has no regard for motive or intent good or evil.' Balanced and representative opinion pieces relating to computers seem to have been the exception, however, and drastic exaggerations of their potential value or the damage they could cause to American society were far more common in such journalism. Ditlea is not immune from this, suggesting that computers can 'in the long run... be adapted to accomplish an infinite number of different tasks.'

The mid-to-late 1970s saw an explosion of technical publications in the form of books, monographs, articles, and working papers, dealing with interactive graphics. There were also papers exploring what such technologies might be used for in the future, with several applications taken up by VR, such as medical training and high-school education being actively discussed as possibilities.[106] The late 1970s also saw a growing body of research on the psychological and sociological ramifications of using computers. Herbert Simon argued that computers allow for people to 'other' themselves from the minds of computers, helping people learn that 'mind, too, is a phenomenon of nature, explainable in terms of simple mechanisms... the computer aids him to obey, for the first time, the ancient injunction, 'know thyself"'.[107] Joseph Weizenbaum in his influential *Computer Power and Human Reason* decried that very mechanisation of man visible in Simon's article as damaging and unrealistic and warned that overreliance on machines would damage society, cognition, and human individuality.[108]

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[105] Steve Ditlea, 'Without Computers, We'd All Erase.', *Chicago Tribune* (12 May 1979), section 1, 10.

[106] A Kirsch, and others. 'A Medical Training Game Using a Computer as a Teaching Aid.' *Methods Inf Med* 2, no. 4 (1963): 138–43; Gerard Deignan, and Robert Duncan. 'CAI in Three Medical Training Courses: It Was Effective!' *Behavior Research Methods & Instrumentation* 10, no. 2 (n.d.): 228–30 (1978) doi:10.3758/BF03205129.

Indeed, there were, by the author's estimation, some one thousand regularly published individuals in the computer research field who wrote about proto-VR technologies (discretely or systemically) in the 1970s. Beyond those, there may have been as many as four thousand writers, who published infrequently but could still be considered experts in the field. That represents a growth of some five hundred percent over visible researchers in the American graphics field at the end of the 1960s. With such a rapid and considerable increase in the research and development sector, and accompanying expansion of investment from historically large companies like IBM, Intel, and Xerox, it seems surprising that public engagement was so limited, and that the promise of computers and virtual space in media could have been, for the most part, so divorced from technical realities.[109] Pervasive exaggeration of promise and peril seems to have shifted public attitudes toward an over-expectant position. A survey by David Ahl of readers of *Creative Computing* magazine found that, in 1975, 'most people are remarkably optimistic about the benefits the computer can bring to society in a number of areas' while also finding that 'people feel they are unable to escape the influence of the computer and that it has some undesirable affects [on society].'[110] The gulf between technical reality and expectation would not only be mirrored in later VR technology, but goes some way toward demonstrating the shortage of computers outside of business and academic contexts, as well as the limited set of contexts for developing new applications which might make the most of the interactive graphics technologies and HMDs of the period.

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[107] Herbert Simon, 'What Computers Mean for Man and Society', *Science*, 195/4283 (1977), 1186–91.

[108] Joseph Weizenbaum, *Computer Power and Human Reason: From Judgement to Calculation*, New edition (San Francisco, 1976), 8-9.

[109] John Mentzer, 'Save Time & Money on Marketing Research with Computer Simulation.' *Marketing News* 13, no. 10 (November 16, 1979): 1; 'Computer Games People Play.' *Infosystems* 20, no. 10 (OCT 73): 26.

[110] David Ahl, 'Survey of Public Attitudes Toward Computers in Society', in *Proceedings of the June 7-10, 1976, National Computer Conference and Exposition*, AFIPS '76 (New York, NY, USA, 1976), 227–230 <http://doi.acm.org/10.1145/1499799.1499835> [accessed 12 March 2018].

Of the broader range of companies, laboratories, and organisations working with and on computers in the late 1970s, only a small number were working with HMDs, stereoscopy, or indeed any notions of creating user immersion. Furness was still working with the USAF by the end of the 1970s, developing displays, graphics, and input-output devices for immersive human-machine interaction. His research was largely unreported throughout the 1970s. The other primary source of proto-VR research at the time was at the Computer Science department at the University of Utah, where many students of Ivan Sutherland and Dave Evans, having experienced the unique possibilities and immersive environments of Sutherland's 3D HMD, had pursued their own research in similar veins. Donald Vickers published an article and appeared in several conference publications as a researcher into the applications of HMDs in immersion in virtual space throughout the 1970s, in addition to his doctoral thesis on the same topic (a thesis approved in 1972 by a supervisory committee chaired by Ivan Sutherland).[111] By this time Sutherland himself, however, had become increasingly detached from the work in the department, as his consulting firm Evans and Sutherland had become successful, selling graphics hardware that could cost in excess of $1m.[112]

Another student of Sutherland's at Utah, James Clark, also published on the express topic of using HMDs for human-computer interaction and presence in virtual space (i.e. the same concept as

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[111] Donald Vickers, 'Sorcerer's Apprentice - HMD and Wand (Sorcerer Apprentice HMD with Wand for Interaction with Computer Generated Synthetic Objects, Describing Creation of Illusory Three Dimensional Environment)', in *Remotely Manned Systems: Exploration and Operation in Space; Proceedings of the First National Conference, Pasadena, Calif.; United States; 13-15 Sept. 1972* (1973), 293–304 <http://search.proquest.com/docview/22035998/1D10D4B3E51B4E0APQ/1> [accessed 31 October 2016]; Donald Vickers, 'Sorcerer's Apprentice: HMD and Wand' (unpublished Ph.D., The University of Utah, 1972) <http://search.proquest.com/docview/302743281/citation/1D10D4B3E51B4E0APQ/2> [accessed 31 October 2016].

[112] Thorpe, Interview, 21 October 2016.

VR).[113] Other students at Utah also published throughout the 1970s, but there are signs toward the end of the decade that this highly specialist knowledge was beginning to diffuse into other areas of academia, with research (some of which remained unpublished) exploring the possibilities of combining interactive computer graphics with a stereo HMD at Syracuse University, in New York, in 1973; and UNC in 1979, as well as work by Tom DeFanti at Ohio State University in 1973.[114] DeFanti is particularly notable as he went on to help develop the CAVE system. Ohio was one of the key sites for further research into HMDs after Utah, not only at Ohio State but also at Wright-Patterson and Drayton USAF bases, which produced several proto-VR papers on account of the USAF research into using HMDs for aircraft telemetry and flight training throughout the 1980s.

THE ONCOMING STORM: TOWARD THE 1980S

At MIT, architect and computer scientist Nicholas Negroponte had established research labs examining human-computer interaction and IA in the late 1960s, but it was only in the late 1970s that stereoscopic computer graphics and immersion appear to have been combined with those goals there. The intended uses, in line with Negroponte's architectural background, were more social and artistic than many of the contemporary scientific and technological researchers in the field, and Fisher's telepresence research led to a pursuit of proto-VR technologies quite separate from the highly utilitarian developments of both Furness and Sutherland, but in full knowledge of both Sutherland’s research and Heilig’s *Sensorama*.[115]

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[113] James Clark, 'Three-Dimensional Man-Machine Interaction', in *International Conference on Computer Graphics and Interactive Techniques: Proceedings of the 3rd Annual Conference on Computer Graphics and Interactive Techniques : Philadelphia, Pennsylvania; 14-16 July 1976* (1976), 287–287 <http://search.proquest.com/docview/31632419/1D10D4B3E51B4E0APQ/3> [accessed 31 October 2016]; James Clark, *A 3-D Design of Free-Form B-Spline Surfaces*, 1974, 83P <http://search.proquest.com/docview/22084802/1D10D4B3E51B4E0APQ/7> [accessed 31 October 2016]; James Clark, 'Designing Surfaces in 3-D', *Communications of the ACM*, 19/8 (1976), 454–60.

[114] James Lipscomb, 'Review of Three-Dimensional Display Techniques in Molecular Computer Graphics for Crystallography.' (unpublished M.S., UNC, 1979); Richard Riesenfeld, 'Applications of B-Spline Approximation to Geometric Problems of Computer-Aided Design.' (unpublished Ph.D., Syracuse University, 1973); Tom De Fanti, 'The Graphics Symbiosis System--an Interactive Mini-Computer Animation Graphics Language Designed for Habitability and Extensibility' (unpublished Ph.D., The Ohio State University, 1973).

1990s narratives for VR portrayed Fisher’s research as pursuing the same goals as Sutherland’s, but while Fisher was demonstrably aware of Sutherland’s 3D HMD, and the technology that drove it, his intention for it was not industrial or scientific, but artistic. These projects were not understood to be based on the same technology but have been shown to be in this narrative. For Fisher, proto-VR was a means of emulating reality for the purposes of art and entertainment.[116] His research was therefore not some conscious pursuit of Sutherland’s Ultimate Display, but a product of changing understandings of the power of computers, enabled by increased numbers of units, users, and ideas. Fisher’s work at MIT was partially sponsored by ARPA, which Sutherland had acted as director of a decade previously, and which (most likely) funded Sutherland’s work on the 3D HMD at Utah.

Unlike the graduates of the computer science departments of Harvard and Utah, the MIT group’s student activities are harder to trace, producing fewer publications in the 1970s, and currently without oral histories. The bulk of Fisher’s writing, including the work acknowledging ARPA’s involvement, was not published until after 1980 but pertains to work started in around 1978, when Fisher moved to the Architecture Machine Group.[117] Some details are extractable from Fisher’s own writing, though there does not have appear to have been much collaboration within his department, while interviews with people who later worked with Fisher at NASA suggest that a reluctance to share research may have been a particular character flaw.[118]

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[115] Hugh Aldersey-Williams, 'A Bauhaus for the Media Age', *New Scientist*, 1655, 11 March 1989, 54–60; Scott Fisher, 'Viewpoint Dependent Imaging : An Interactive Stereoscopic Display' (unpublished Thesis, Massachusetts Institute of Technology, 1981) <http://dspace.mit.edu/handle/1721.1/42959> [accessed 12 March 2018], 6-7, 30-1.

[116] Ibid, 4-11.

[117] Ibid, 41–45.

[118] Ellis, Interview, 1 Jul 2017.

As a student, not a professor, it is also true that Fisher lacked the ‘reach’ which Sutherland and Furness exerted on colleagues, students, and others. His interest in virtual space for art was not well propagated at the time and seems to have been largely anomalous (though Mike McGreevy would come to graphics research at NASA from an arts background),[119] but broadly fell under the umbrella of IA. The HMDs and computers he was able to use were far removed from the cumbersome repurposed-hardware machines of Sutherland’s group or the burgeoning, bespoke hardware of Furness’s. Fisher’s displays looked more like heavy-rimmed glasses, and the computers had (comparatively) fast data storage and access technology, allowing more detailed virtual environments to be created and displayed than were possible in Sutherland’s display. Their source was the Matsushita Company of Kadoma, Japan, a private technology company which at the time occasionally traded under, and would latterly adopt fully, the name Panasonic.[120] Matsushita also provided experimental optical discs (apparently precursors to the VCD format, also created by Matsushita, in 1993) to Fisher’s project, which allowed for faster data retrieval and considerable data storage, neither of which had been available at the end of the 1960s. Fisher’s research therefore not only showed a considerable move away from the utilitarian aspirations of Sutherland’s students and Furness’s team, but it was also distanced from the US military-industrial complex. The gulf between the projects highlighted the speed with which the technical capabilities of computers were improving and the direct impact that had on the range of applications to which computers could be turned.

The only remaining link to the military came in the motion tracking needed for translating the user’s movement in the real world to the movement of their projection into the virtual one. The magnetic tracker was manufactured by Polhemus Navigational Sciences, Inc., a firm that crops up several times in the history of VR and who had manufactured the motion tracking hardware for Furness's work on immersive flight simulation and cockpit design in the 1960s all the way through to the 1980s.[121]

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[119] Ellis, Interview, 13 Mar 2018.

[120] 'Corporate History - History - About Us - Panasonic Global’ <http://www.panasonic.com/global/corporate/history/chronicle.html> [accessed 1 November 2016].

Fisher would keep working with proto-VR and nominal VR into the 1980s, and so would Furness, at the end of the 1970s, who had working prototypes of a 3D HMD for exploring virtual space. His considerable budget allowed the incorporation of input and output technologies augmenting stereo vision, which neither Sutherland in the 1960s nor Fisher contemporaneously could match, but Furness's work remained classified. While Sutherland and many of his students had moved on to different areas of graphics research and the creation of virtual worlds, Furness kept working on improving displays, motion tracking, and haptic (tactile) feedback. While his work in the 1960s had revolved around real-time displays in real aircraft, a lot of his research would come to be used in computer-aided training and flight simulation.[122] This culminated in the Super Cockpit programme in the 1980s, but Furness developed a proof of concept demo of this technology in the late 1970s, developing high resolution HMDs, motion tracking, graphics, and feedback gloves and suits. It is in the form of this feedback gear that Furness's contributions to broader VR are most clear, as the creation of devices like a feedback glove (or even a full body suit) had not been explored by Sutherland or indeed Fisher at that time but would become among the most visible material-cultural components of late 1980s VR. For Sutherland, his students, and for Fisher, computers were interacted visually, rather than in a tactile or auditory manner. Furness's research helped establish technological pathways for processing and generating these kinds of input and output, which ranged from artificial g-forces, to voice commands, to pushing a virtual button and feeling real pressure.[123]

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[121] Bye, *Voices of VR*; 'Polhemus History - Over 40 Years of Experience' <http://polhemus.com/company/history/> [accessed 1 November 2016]

[122] Bye, *Voices of VR*.

The late 1970s also saw research into proto-VR coming from a wider range of disciplines. Computer scientist James England was developing immersive stereoscopic displays of his own at North Carolina State University in 1978.[124] England referenced Sutherland's early 1970s research on tablet interfaces in his conference paper on the project, but not Sutherland's earlier work on an extremely similar display technology.[125] Whether this was an oversight, ignorance, or deliberate concealment remains to be seen. Publishing research on stereoscopic displays for pilots was Donald Erwin, at the US Army Research Institute for the Behavioural and Social Sciences in Alexandria, Virginia, also in 1978.[126] There does not appear to be any link between Erwin's and Furness's military work, though they both worked in similar areas, with Erwin developing immersive 3D graphics for flight simulators. Furness worked with fighter jets, and Erwin with helicopters. Unlike Furness however, Erwin did not publish widely afterward, nor does he appear to have moved into the private sector as Furness did in the 1990s.

In 1979, computer scientists John Roese and Lawrence McCleary of the Naval Ocean Systems Center in California published research on a stereoscopic CRT display for use with 3D computer graphics.[127] This system does not appear to have contained the motion tracking element crucial to Sutherland and Furness's work, as well as subsequent VR projects, but was very closely related.

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[123] Ibid.

[124] James England, 'A System for Interactive Modeling of Physical Curved Surface Objects', in *Proceedings of the 5th Annual Conference on Computer Graphics and Interactive Techniques*, SIGGRAPH '78 (New York, NY, USA, 1978), 336–340 <http://doi.acm.org/10.1145/800248.807412> [accessed 14 November 2016].

[125] Ibid. p. 339.

[126] Donald Erwin, 'The Importance of Providing Stereoscopic Vision in Training for Nap-of-the-Earth (NOE) Flight', *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 22/1 (1978), 81–86.

[127] John Roese, and Lawrence McCleary, 'Stereoscopic Computer Graphics for Simulation and Modeling', in *Proceedings of the 6th Annual Conference on Computer Graphics and Interactive Techniques*, SIGGRAPH '79 (New York, NY, USA, 1979), 41–47 <http://doi.acm.org/10.1145/800249.807423> [accessed 14 November 2016].

There is no reference in their work to Sutherland or Furness, so there is again no visible link between either of them and earlier instances of the same technological experiments, with the military connection being the only one between Furness and this project. Their work pertained to modelling molecules in 3D virtual space, something pursued further by Fred Brooks at UNC shortly after. In the same year, there was also work by medical doctor Russell Brown, at the Radiology Department of the University of Utah. He described a means of immersive viewing of CT scan data using a stereoscopic display helmet, employing three-dimensional computer graphics.[128] The link between this and Sutherland's work is through their shared institution. While Sutherland had left Utah by the time Brown conducted this research, there is an acknowledgment of support by the Evans and Sutherland Computer Corporation of Salt Lake City, Utah, where in 1979 Sutherland was working full time as a developer and consultant.[129] As Bob Sproull has mentioned in interviews with the author, during this time Sutherland was the one going from client to client setting up their equipment, so it seems highly likely that Brown and Sutherland actively worked together on the project, something only reflected in this single publication.[130] There are also signs of very similar research being carried out independently in Canada.[131]

Furness considers his 1970s work to be VR, and similar to Sutherland's, while Sutherland does not consider his work to be even remotely connected to VR. The matter of definitions is, of course, a complex one which many VR and proto-VR pioneers struggled with, an excellent example being the more-than-50 definitions provided by Jaron Lanier in *Dawn of the New Everything.*[132] While Sutherland's Display does not fully meet the definition provided by the author, it demonstrably allowed for the pursuit of proto-VR research by Sutherland's students in the late 1970s and thus should be considered relevant. Fisher's student work at MIT, by virtue of its immersion, computer generation, and provision of a 3D virtual space, also meets the criteria for inclusion outlined in chapter 1 (p.18). Colleagues of Sutherland, and several students of the MIT Architecture Machine Group, as well as Fisher also went on to research and publish in the areas of proto-VR in the 1970s and beyond, as did numerous other researchers in private and governmental fields, often with seemingly little or no intellectual, typological, or philosophical connections between them.

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[128] Russell Brown, 'A Computerized Tomography-Computer Graphics Approach to Stereotaxic Localization', *Journal of Neurosurgery*, 50/6 (1979), 715–20.

[129] Ibid. p. 720.

[130] Sproull, Interview, 9th September 2016.

[131] Sunil Chawla, 'An Interactive Computer Graphics System for 3-D Stereoscopic Reconstruction from Serial Sections an Application in the Study of Pulmonary Metastic Growth' (unpublished M.Eng., McGill University (Canada), 1979) <http://search.proquest.com/docview/302992115/citation/3279C833E35E4C3FPQ/18> [accessed 14 November 2016].

[132] Jaron Lanier, *Dawn of the New Everything: A Journey Through Virtual Reality* (2017).

With this in mind, does the notion that development of 1960s and 1970s proto-VR was nucleic, or isolated appear sustainable? It does not seem reasonable to try and argue that the development of proto-VR was tied to specific institutions, or geographic locations, or individual innovators as both Rheingold and Schroeder have contended.[133] Interviews between the author and those involved in proto-VR projects have suggested an alternate narrative. Sutherland's work, while a starting point of many histories, was never intended to form anything beyond a means to examine computerised blueprints. Furness's work was top secret, and technically distinct from other proto-VR technology at the time or otherwise. Fisher's work was funded and produced by Japanese concerns and based in an entirely different conceptual framework. The disparate VR research of other students, scientists, and innovators throughout the 1970s; England, Erwin, Roese, McCleary, Brown, and others, highlights the fact that the pursuit of proto-VR research extended far beyond what is described in the standard narratives. Research into proto-VR was not by any means a large area, but it was more diverse has been appreciated.

The reasons for the distorted view of the development of VR in available histories seem to predominantly be rooted in preservation bias; more material is available from the projects of Sutherland and Furness than the others, which invariably only produced a single thesis or paper.

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[133] Schroeder, *Possible Worlds*, 18-23, 45; Rheingold, V*irtual Reality* 1992, 60-2, 137-8.

More to the point, Sutherland’s work with the 3D HMD produced some highly influential graphics technologies, discrete from what others would come to consider VR. Furness went on in the 1980s and beyond to talk widely about his connections to VR, and the sheer number of his publications, while not all surviving, ensures his work a more prominent place in existing historical narratives. His role was undoubtedly significant, but others made crucial contributions, which have been only partially recognised or entirely neglected. These works play a prominent role in this thesis, and further research on their contributions to the technologies which made up VR will be necessary in future. It is impossible to portray the development of VR in linear, progressive ways, with each project pointing towards a singular ‘VR’. There was a broad canvas of concerns both in and outside of educational and state-funded institutions, developing technologies that would form the basis of more fully evolved VR.

Research into immersive virtual environments, into what would come to be known as VR, developed across the US at roughly the same time, as a natural component of the broader development of computer graphics and high-speed computing. There was a critical mass of people working on VR-related projects in the late 1970s, and VR was a developing technology with a variety of supporting philosophies and ambitions, not driven by any single individual, institution, or technological development. Instead, the root causes for the development of VR can be comfortably attributed to the rapidly expanding computer market, changes in the way computers, displays, and virtual space were thought about, and research into graphics and displays. Scott Fisher, for example, would not have been able to pursue his master’s thesis project (in proto-VR research) had Matsushita not already been developing the technology needed in building miniaturised screens, or high capacity/speed optical disks. Sutherland’s research hinged on the microcomputer boom of the 1960s, which allowed devices like the PDP-1 to develop, at a price which made computers more easily attainable for research.

The rapid growth of the global computer industry, and the unrivalled expansion of the computer market in the US led to incremental technological developments which allowed different notions of immersion in virtual space to propagate among a limited but growing range of disciplines. This, in turn, helped to develop a fertile bed of technologies and projects throughout the US from which a fledgling VR industry could spring in the mid-to-late 1980s. The existing 'official' history of VR is missing a great deal of detail in some areas, and is rife with misconstructions in others. Research on these early decades of VR is bedevilled by shortages of and bias in archival evidence. Indeed, the majority of historical attention, which has been paid to a small subset of VR research projects, has missed the potentially equally significant, but far less well-preserved work of numerous other individuals at the time, who were able to secure funding and hardware for research into proto-VR technologies deemed relevant, and imbued with promise.

CHAPTER 3: CONSENSUAL HALLUCINATION

'When the past is always with you, it may as well be present; and if it is present, it will be future as well.'

- William Gibson, *Neuromancer,* 1984.

'Physical reality is tragic, in that it's mandatory.'

- Jaron Lanier, in an interview with Kevin Kelly and Barbara Stacks, 1989.

THE PRICE OF NOTHING, AND THE VALUE OF EVERYTHING: THE IMPACT OF TECHNOLOGICAL AND INTELLECTUAL DIVERSITY ON VR DEVELOPMENT - 1980-1990

The early 1980s witnessed a marked diversification and diffusion of proto-VR projects. By the end of the decade, there would be a wide range of firms carrying out research and development into the hardware, software, and psychology of virtual world use and generation. At the start, however, research remained confined to a handful of academic and institutional programmes, most prominently perhaps NASA Ames, The MIT Architecture Machine Group (and later Media Lab), and the University of North Carolina at Chapel Hill, as well as Thomas Furness's work for the USAF. However, while Furness's work used prohibitively expensive custom-made components, and Sutherland's 3D HMD had needed at least three discrete computers to function adequately, 1980s VR developers had a wider range of ways in which proto-VR systems could be implemented. A nationwide shift to cheaper, more powerful computers is described below, along with its collateral effect on the proliferation and development of VR technologies throughout the decade and beyond.

The 1980s witnessed drastic foreign policy changes under Ronald Reagan's administration, which contributed to a renewed American supremacy in the Cold War. While history stubbornly refused to end,[1] the decade was one of the first in which technologies wrought by the semi-conductor and integrated circuit found prominence in the lives of many people through ownership, media, and work. Seeking to emulate Franklin Roosevelt, Reagan wanted to re-ignite American pride and exceptionalism, with technological featurism becoming a defining component of American consumer culture. While the excesses of the 1980s would go on to cause widespread decline in the 1990s, the conversion of proto-VR in academic and military contexts to VR in private businesses was enabled by this renewed American consumer confidence, and financial expansion, particularly the venture-capitalist environment of Silicon Valley. This was accompanied by, and furthered, the ever-growing use of computers in the private and professional lives of Americans, leading to the rise of Cyberpunk subcultures, hackers, and the hyper-accelerated growth of Silicon Valley.

At the forefront of this wave of abundance, expectation, and computerisation was the emergence of so-called microcomputers (not to be confused with the minicomputers of the 1960s and 1970s). Devices including the Commodore 64, Apple II, and later, IBM PC were computers designed using miniaturised components. The development of microprocessors, modular computer design, and ever smaller integrated circuits allowed computers to shrink. Contemporaneously, computer hardware was increasingly being sold separately from software, and manufacturers were often sourcing components from multiple providers. IBM set the standard with the IBM PC, which dominated the domestic and international PC market from its launch in 1981 to its discontinuation in 1987, defining PC typologies well into the 21st century.[2] The separation of hardware and software, and the breakdown of hardware into separate components lowered costs. 1980s consumers saw computers become widely available in stores across the country.[3] Monolithic mainframe-and-mini-computers of the 1960s and 1970s, cornerstones of proto-VR provision, were increasingly supplemented by smaller, cheaper, personal computers which could be bought and run by individuals and small businesses, which drastically diversified the spectrum of computer users during the decade.

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[1] Francis Fukuyama, 'The End of History?', *The National Interest*, 16, 1989, 3–18.

[2] Martin Campbell-Kelly, and Daniel Garcia-Swartz, *From Mainframes to Smartphones: A History of the International Computer Industry* (Cambridge, Massachusetts, 2015).

[3] James Van Dusen, Interview, 8th May 2017.

Previously, those exposed to the concept of a 3D HMD for immersion, at conferences or university departments, would not have been able to do much with that knowledge, lacking a computer powerful enough to support it. By the 1980s more people than ever had access to a computer, and to computer science, as the computer became a part of American consumer culture and identity. For example, Furness was unusual in his ability to combine both the technical knowledge and necessary facilities to integrate the ideas he encountered in Sutherland's 3D HMD when he saw it in the early 1970s.[4] The USAF funded this research, which required not only considerable amounts of money but highly specialised knowledge.[5] Similarly, Fred Brooks, a Utah student in the early 1970s, used his knowledge and applied it in the computer science lab at UNC, relying on the rare funding and research infrastructures it provided, and developed a wide range of VR technologies in the 1980s and 1990s.[6] Researchers at the University of Utah also developed hardware and software based on the Sword in the early 1970s.[7] Specialist knowledge and high funding were essential for 1970s proto-VR research (and arguably, beyond) and it was only possible at confluences of the military-industrial complex, abundant funding, and ideologically driven technological exceptionalism. Those high costs also served as a natural barrier to private development, with investors finding that proto-VR had an unhealthy risk : reward ratio.[8]

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[4] Howard Rheingold, *Virtual Reality: The Revolutionary Technology of Computer-Generated Artificial Worlds-And How It Promises to Transform Society*, Reprinted edition (New York, N.Y., 1992), 21-2; Ivan Sutherland, Interview, Jan 25th 2017.

[5] Kent Bye, *50 Years of VR with Tom Furness: The Super Cockpit, Virtual Retinal Display, HIT Lab, & Virtual World Society.*, Voices of VR <http://voicesofvr.com/245-50-years-of-vr-with-tom-furness-the-super-cockpit-virtual-retinal-display-hit-lab-virtual-world-society/> [accessed 6 August 2016]; Thomas Rid, *Rise of the Machines: A Cybernetic History* (New York, 2016), 198.

[6] Rheingold, *Virtual Reality* 34.

[7] Ibid, 112.

[8] Howard Rheingold, Interview , 11 April 2017.

In the 1980s however, with the advent of micro and personal computers, prices fell, and knowledge diversified. A private individual could expect to have to pay around $5,800.00 (adjusted for inflation) for a personal computer in 1978 (in this example, an Apple II), sold without a display. By 1982 however, a more powerful computer, such as a Commodore 64, cost $1000 (adjusted for inflation), often bundled with a CRT monitor for a little more. The price and availability of microcomputers continued to fall through the mid-1980s as a rebounding US economy encouraged a price war for computer technologies at stores like Sears and Toys 'R' Us.[9]

The proliferation of computers in turn encouraged the development of proto-VR, as the range of applications and developers diversified. This development was reflected in an expanding body of technical literature surrounding immersion, graphics, and virtual spaces, and in the proliferation of VR concepts in popular media by the end of the decade. 'Cyberpunk' works such as *Neuromancer* (1984) dramatically affected popular perceptions of such immersive computer displays, rendering them more subversive, addictive, and alluring, though without any real technical developments to support this image.[10] It was instead the increased visibility of computers in American society during the 1980s which catalysed fiction and anticipations of 'entering' computerised environments. Private investment in VR technologies accelerated as costs fell, and while the technological 'reality' of VR became less implausible, its ease of access and development increased.

The combination of falling prices, economic solvency, and a global Manifest Destiny built on computers allowed for a far more heterogeneous group of computer users to form across the country during the 1980s, and this growing diversity became a core component of the contemporary proto-VR and VR narrative. Martin Campbell-Kelly and Daniel Garcia-Swartz have called this process *indirect network effects*. Originally applied to software technologies, the concept can be expanded to encompass hardware and technological systems, including VR. Briefly, most technologies can benefit from innovation and development in one of two ways. Some technologies are developed for a specific user base, such as the 1950s mainframe computer, developed (as Rheingold puts it) for 'High Priests' of electrical engineering. Such technologies are used almost exclusively by those it was designed for, limited by government control, financial cost, and specialist language and knowledge.[11] Development and innovation for these technologies is predominantly by and for the designers themselves. These are examples of *direct network effects*. Technologies exposed largely to direct network effects may develop in a more linear fashion, as the user base all shares a higher range of common denominators than average.

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[9] Kathleen Burton, 'Backlog-Driven Micro Price Slashing Predicted', *Computerworld*, 19/30, 19 July 1985, 71; David Nocera, 'Death of a Computer', *Texas Monthly*, April 1984, 134–45, 216–31.

[10] William Gibson, *Neuromancer* (1984).

Indirect network effects exhibit the opposite. Some technologies, regardless of original intent or environment, are adopted by a range of user bases, with skills and expertise broader, not necessarily deeper, than those used in its construction. To take personal computers as an example; the personal computer was developed for office use by firms such as IBM and Xerox, but found users among mathematicians, artists, game makers, writers, and hobbyists among countless others who could 'exchange information, swap ideas, talk shop … whatever.'[12] Thus, entirely new applications for the PC arose which were not obvious to its developers.[13] The technological transfer (in the manner of Hughes) of hardware and software for the PC by tinkerers, hackers, and hobbyists, as well as larger organisations, is a prime example of indirect network effects in action, and drastically altered the perception and development of proto-VR and VR in the 1980s.

Proto-VR experienced largely direct network effects in the 1960s and 1970s, Sutherland and his students had to be well versed in computer science and had to be working at Sutherland's lab to access proto-VR hardware. The same went for Furness and his team at Wright-Patterson. These intellectual and institutional boundaries went further, however. The 3D HMD was presented at graphics conferences, and to groups of electrical engineers and students, as people exposed to the idea at Utah or elsewhere dispersed, conceptual echoes of the technology could only be seen in similar contexts: well-funded research institutions with large electrical engineering or (new) computer science departments. Specialist knowledge, equipment, and perceptual framing were common denominators of early proto-VR development. Proto-VR in Furness's lab developed in much the same way as Sutherland's, albeit discretely: military applications dominated, and systems used high-power, high-cost computers. Development was focused on utility and determining value. Despite being in different institutions, run by different people, the goals, approaches, and systems of Sutherland's and Furness's projects had similar computers, displays, trackers, and applications. This phenomenon was due to the dominance of direct network effects in contemporary computer technologies. VR projects in the late 1980s, however, demonstrated a far wider range of intent, typology, and approaches.

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[11] Rheingold, *Virtual Reality*, 78.

[12] Gotanero, *Invitation Sent to Steve Dompier by Fred Moore on February 17, 1975 Inviting Steve to Attend the First Meeting of the Homebrew Computer Club on March 5, 1975 at the Home of Gordon French.*, 12 November 2013, <https://commons.wikimedia.org/wiki/File:Invitation_to_First_Homebrew_Computer_Club_meeting.jpg#/media/File:Invitation_to_First_Homebrew_Computer_Club_meeting.jpg> [accessed 5 March 2017].

[13] Campbell-Kelly & Garcia-Swartz, *From Mainframes to Smartphones*, 4, 174.

The 1980s wave of new computer owners and users, often described as 'hackers,' helped bring about a change in understanding and expectation for VR, in both development and public perception.[14] Mid-1980s American proto-VR projects (such as at NASA, UNC, or Atari) had distinct objectives, applications, funding, oversight, and facilities. VR development by later private firms often did not.

This change was the product of indirect network effects. Developers with experience beyond electrical engineering, in a nationally diverse Latourian laboratory tribe; scientists, engineers, artists, programmers, doctors, hackers and entrepreneurs engaged with the technology across a range of institutional and organisational contexts.[15] Thus, when people were exposed to the concept of 3D immersive computer graphics, there was a greater chance than ever that that person would be able to in some way apply that concept, and this was due almost entirely to the microcomputer and personal computer throughout the 1980s. The diversification of developers, and broadening of the system provided a source of indirect network effects, which over the 1980s allowed VR to be modified, improved, cheapened, and streamlined. It also allowed for new ideas of the kinds of media VR could display, marking a shift from solely utilitarian training and IA applications to ludic and artistic ones.

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[14] Laura A. Kiernan, 'Hackers, Dispatchers Battle: Hackers, Dispatchers Battle at Airport', *The Washington Post ; Washington, D.C.* (4 March 1974), Local News; Christopher Lehmann-Haupt, 'Hackers as heroes: Hackers: Heroes of the Computer Revolution. By Steven Levy.' [book review], *New York Times* (10th Dec 1984), 14; John Markoff, 'Cyberpunks Seek Thrills In Computerized Mischief', *New York Times* (26 Nov 1988), 1. For examples of the way the word 'hackers' completely changed in connotation over 15 years.

Moving from MIT to the Atari Sunnyvale Research Laboratory, then to NASA Ames during the 1980s, Scott Fisher's career provides an example of VR's growing exposure to indirect network effects. At MIT, Fisher worked alongside electrical engineers and computer scientists but was himself an artist. His knowledge base and aspiration for 3D HMDs was different from Sutherland's or Furness's as a result. His lightweight proto-VR device was developed with considerable help from colleagues in the department, not least his supervisor, the computer interaction pioneer Nicholas Negroponte. The system Fisher developed used faster computers, larger programs, and more detailed displays than Sutherland's (or those of many of Sutherland's students) sourced from both US and Japanese manufacturers. His research was partially sponsored by Matsushita of Japan, and Japanese influence on US VR projects would become a concern of public and government alike later in the decade.[16]

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[15] Bruno Latour and Steve Woolgar, Jonas Salk (ed.), *Laboratory Life: The Construction of Scientific Facts*, 2nd edition (Princeton, N.J, 1986).

[16] Albert Gore, Fred Brooks, Charles Brownstein, Thomas A. III Furness, Lee B. Holcomb, and Jaron Lanier, *New Developments in Computer Technology: Virtual Reality: Hearing before the Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science, and Transportation, United States Senate, One Hundred Second Congress, First Session, May 8, 1991.* (Washington, 1991) http://hdl.handle.net/2027/pst.000019820071, 39.

Fisher went on to further explore notions of computer-driven immersion for entertainment at the Atari video game company, and then at NASA, where he was joined by other hybrid artist-engineers like Mike McGreevy, and it was the changing innovative environment which computers enjoyed that allowed his freedom of movement. This is perhaps best highlighted by his departure from research institutions altogether in 1990, to start his own VR R&D firm, a practical impossibility only a decade earlier given the lack of capital, skilled employees, and adequate technology.

VR's ludic potential was rendered clearer to people at MIT, at Atari, at NASA, and the surrounding Silicon Valley over the course of the decade through the work of Fisher, Brenda Laurel, Jaron Lanier, and others. As the understanding of VR's potential exponentially grew, the gamut of expectations placed upon its future technological iterations similarly expanded. Fisher's personal impact should not be overstated, but his artistic background and relative success in the VR business (it could not, in fairness, be called an industry) exemplifies the changing networks surrounding 1980s VR research.[17] Jaron Lanier was exposed to Fisher's HMD-based entertainment concept at Atari, and he was able to develop his own iterations, thanks to the availability of cheap, user-friendly microcomputers, and the falling cost of optics and portable televisions. New vectors of development and ideas formed as a result of the diversification of developers brought about by the widening access to the computer, and computer knowledge. The casting of proto-VR in a non-military light, through a prismatic Silicon-Valley start-up culture of homebrew innovators and tinkerers, diversified into a spectrum of applications separate from the 1970s pragmatism necessitated by the scarcity of computers.

The rise of private-capitalist concerns in VR research was brought about by, and accelerated this diversification. ARPA, the USAF, and US security services had, throughout the 1970s, provided the bulk of proto-VR funding, and were thus instrumental in the direction of VR development. This changed in the 1980s. A key factor was accessibility. In the 1980s, private individuals could buy computer hardware and develop independently or in small organisations, and through their own innovations and purchasing power create an industry. The video-game and consumer electronics industries were expanding very quickly, and proto-VR research was possible at private firms like Atari and Autodesk, as never before. Consumer economics were now a considerable driving force in the computer industry, and thus in proto-VR. A reliable bellwether for the shift from state-management to private capital is legislation; increasing US government intervention, through a series of antitrust suits, to curb the growth of American computer firms like IBM, is an indicator that the consumer computer industry had 'flown the nest' of government stewardship.[18]

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[17] Rheingold, *Virtual Reality*; Ian Evenden, 'The History of Virtual Reality', *Science Focus*, 2016 <http://www.sciencefocus.com/article/history-of-virtual-reality> [accessed 2 April 2017]; Michael Heim, *The Metaphysics of Virtual Reality*, 1st edition (New York, 1994) 112; Ken Pimentel and Kevin Teixeira, *Virtual Reality: Through the New Looking Glass* (1993), 31-51; Mario Gutierrez, Frédéric Vexo, and Daniel Thalmann, *Stepping into Virtual Reality* (2008) 5-6.

This is not to suggest that involvement by the US government disappeared, merely that it was joined by other private sources of money and research, and that the projection of 'soft power' through research contracts and reports was reduced. Quantifying this reduction is challenging, as government R&D policy on a micro-level is highly opaque. However, visible US DoD contracts from the period do not mention new VR projects, beyond an interest in flight simulation and virtual communications through ARPANET.[19] The most obvious continuation of Government funding was in Furness's VCASS, and then Super Cockpit (from 1986) programmes during the 1980s, the second of which built on the developments of VCASS in the 1970s.[20] There were also some DoD funded research projects at universities, particularly at UNC.[21]

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[18] Campbell-Kelly & Garcia-Swartz, *From Mainframes to Smartphones,* 5; Emerson Pugh, *Building IBM: Shaping an Industry and Its Technology* (1995), 253-4.

[19] Ruth Buescher, *AFHRL (USAF Human Resources Laboratory) FY 86 Annual Report.* (January 1986) <http://www.dtic.mil/docs/citations/ADA181732> [accessed 28 April 2017]; Herbert Bell and Elizabeth Casey, *Directory of AFRL/HEA Technical Publications Submitted to DTIC from 1969 to 2007* (September 2007) <http://www.dtic.mil/docs/citations/ADA480314> [accessed 28 April 2017]; Hossein Bidgoli, *The Internet Encyclopedia, Volume 2 (G - O)* (2004), 114-23.

State-funded research on HMDs, graphics, motion tracking or haptics are invisible from the early 1980s, though whether this is a product of changing administrative objectives or preservation bias is unclear. This period was almost bookended by the Reagan administration, and Reagan's 'Peace through Strength' policy diverted considerable government funding to defence between 1981 and 1984 and might have had an impact on funding devoted to proto-VR related research.[22]

Later in the 1980s, the Army also became involved in computer graphics and virtual space research in Colonel Jack Thorpe's SIMNET program.[23] He highlighted military (and thus government) willingness to fund research on virtual space for military applications in an interview. Recalling:

> The program [SIMNET] was approved in April of 1983, a year later we had done a soft prototype of what a simulator might be like, and took that to a show in Washington DC, that the Army hosted every year, called A.U.S.A., the Association of the United States Army… It was extraordinary, there was not a single detractor, people kept coming in. This was a time where things would cost tons and tons of money for no good reason. And so, to have somebody, especially a DoD team, especially a DARPA team say 'hey, you know, we think we can build something like this, and we can do it for one one-hundredth of what we currently pay for it.' And one of the guys who came down to see this was a four-star named Max Thurman, and he was the vice chief of staff of the Army, the number two guy, and he walked in and it took him about a nanosecond to get it… and he turned to his executive… this is a full colonel… and he says 'we want this, figure out how to fund it. Go to DARPA and figure out how to fund it.' And at that point, the Army took over funding and eventually… we spent over a seven/eight-year period it was like about $275m, and most of that was Army money.[24]

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[20] Thomas Furness III 'The Super Cockpit and Its Human Factors Challenges', *Proceedings of the Human Factors Society Annual Meeting*, 30/1 (1986), 48–52.

[21] Robert Filer, *A 3-D Virtual Environment Display System* (December 1989) <http://www.dtic.mil/docs/citations/ADA216279> [accessed 18 April 2017]; James Chung, Mark Harris, Fred Brooks, Henry Fuchs, Michael Kelley, John Hughes, and others, *Exploring Virtual Worlds with HMDs* (February 1989) <http://www.dtic.mil/docs/citations/ADA208088> [accessed 18 April 2017].

[22] 'Milestones: 1981–1988 - Office of the Historian' <https://history.state.gov/milestones/1981-1988/foreword> [accessed 18 April 2017]

[23] Col. Jack Thorpe (USA, Retired), Interview, 10 October 2016.

[24] Ibid.

The rapid decision to embark on the financial undertaking, some half-billion US dollars in 2015, helps show the willingness on the part of the US military to explore technologies like VR. Moreover, the SIMNET project was cheap compared to Furness's simulator programmes: single station (non-networked) tank simulators of the 1970s ran costs in the billions. Undeniably situated in the newfound push for American Cold War Supremacy during the rapid growth spasms of the early Reagan years, this kind of spending by the US military was obviously not made lightly. State investment clearly persisted in the 1980s, with private capital expanding into the shared spaces of computer and graphics research, which seems to have allowed the mechanisms of the American State to withdraw naturally.

As the role of private capital in the development of computer technologies grew, so too did the diversity of funding sources, including from abroad. The late 1980s and early 1990s saw considerable anxiety over the impact of Japanese investment and research into VR on perceived US exceptionalism. The Advanced Telecommunication's Research Institute in Kansai, Japan, was established in 1986 to investigate basic research hurdles to the implementation of VR, much as NASA and VPL did, and was funded predominantly by Nippon Telephone and Telegraph, a major Japanese telecoms company at the time. The employment (poaching) of American VR researchers by Japanese companies deepened existing anti-Japanese anxiety in both the US government and media.[25]

As funding diversified, so did understanding. With every million spent by Furness's team on their own VR, the gap between it and the VRs created by private investment and innovation (as well as at NASA) widened. Military applications and hardware, by virtue of their secrecy, were subject to direct network effects and were thus increasingly removed from the new technical iterations and uses of VR being explored in the US at the time.

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[25] Rheingold, *Virtual Reality*, 219-39; Hobart Rowen 'Is Japan's Investment Really A Threat?', *The Washington Post; Washington, D.C.* (4 February 1988), A23; 'Chip Wars: The Japanese Threat', *Business Week, Industrial/Management Ed.; New York*, 23 May 1983, 80; Andrew Pollack, 'Japanese Portables Threaten American Lead in Computers', *New York Times* (24 Nov 1990), 1.

Furness and his team understood immersion, HMDs, and virtual space in a very different way to people outside the USAF, a fact that was highlighted by the collision of Furness's and NASA's visions of VR in 1984. Fisher was invited to deliver a paper at NASA Ames, while he worked at Atari, on virtual environments and human interfaces. Furness was also in attendance. During the Q&A session, NASA's McGreevy (another artist-engineer) purportedly asked Furness how much he thought it would cost to implement the kind of virtual environment workstation described in Fisher's talk, and which McGreevy was already developing at Ames in the VIVED (Virtual Environment Display).[26] Furness replied that a suitable display couldn't be built for less than $1m. McGreevy suggested that he could make it for a hundredth of that with off-the-shelf components, and promptly did so using shop-bought computers, trackers, and Citizen Pocket TV's for screens.[27] Its 100x100 pixel resolution was a tenth of Furness's displays, and in monochrome, but the core technology was the same, and the gulf in costs more than made up for the technical differences. That price difference demonstrates the effect that a closed (direct), as opposed to an open (indirect) developmental process can create over several years.[28] Indeed when Citizen learned that Ames was using its TVs in HMDs, they begun sending prototype screens to Ames for McGreevy's team to try out gratis, further reinforcing the benefits of an open, public system.[29] Jack Thorpe's work on simulator fidelity for SIMNET had already suggested that visual fidelity was not as important as sound, or comfort, for creating a reliable sense of presence in a virtual space, but Furness's pursuit of visuals as a primary means of immersion led to hyperinflated costs, with limited returns compared to far cheaper systems.[30] The development of the VIVED system from commercially available parts for a fraction of the price of contemporary military offerings and earlier proto-VR shows how far the civilian and military research had split.[31]

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[26] Stephen Ellis, Interview, 13 March 2018.
[27] Scott Fisher interviewed in Jason Jerald, *The VR Book: Human-Centered Design for Virtual Reality* (2015).
[28] Rheingold, *Virtual Reality*, 140-1.
[29] Ellis, Interview, 13 March 2018.

While NASA Ames was state-funded (albeit poorly),[32] much of that funding was lobbied by the commercial airline industry for flight simulator, human factors, air craft design, and air traffic control research.[33] As such, Ames was more open to different approaches to technological problems, and to partnership (formal or otherwise) with private companies. When Fisher came to NASA in 1985, he brought a free-thinking attitude which had been fostered at Atari, which encouraged the exploration of potential technological 'dead-ends'. While such a philosophy would not have found much traction at military-funded labs, the culture of innovation and venture capital in the surrounding Silicon Valley had helped foster an experimental approach to development at NASA in the 1980s. Private companies, when faced with the validation provided by a VR project taking shape at NASA, were increasingly motivated to pursue their own VR projects later in the decade.

As VR became more widely known in the late 1980s (whilst remaining a 'fringe' technology[34]), and development drifted toward entertainment applications, government involvement appears to have attenuated. The adolescence of Silicon Valley start-up culture also had a part to play in this commercialisation. The meteoric rise of Venture-Capital firms in the area, as well as countless manufacturing and development laboratories which had capitalised on the plentiful and cheap industrial space throughout the 1970s, led to a fertile environment for new ideas to be paired with funding. The initial public offering of Apple Computer in 1980 for $1.3bn ($3.7bn in 2015) shows the substantial sums of money moving through the private computer industry of Silicon Valley at the time. Willingness to take financial risks allowed VR to develop in ways that would not have been mandated in government or university spending grants and allowed for more diverse technical and intellectual innovations in VR to develop from the mid-1980s onwards. The fostering of, and enthusiasm for, VR in firms ranging from start-up Autodesk to the venerable, fiscally conservative Pacific Bell pushed VR development more quickly toward a usable, marketable version of VR. Pacific Bell is an interesting example: one of the largest telephone companies in America at the time, it had powerful connections to research labs around the country. Founded in 1906, its fortune arose from gradual acquisition of other telephone companies, rival services, and technologies. Reluctant to adopt automatic exchanges due to the perceived risks until the 1960s, the company was demonstrably cautious in its decision making.[35] To devote large sums of money to an untested VR telecommunications project concordantly suggests a degree of faith in the final success of VR.

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[30] Thorpe, Interview, 21 October 2016.
[31] Rheingold, *Virtual Reality*, 140-1
[32] Ibid, 144.
[33] Stephen Ellis, Interview 11 July 2017.
[34] Ibid, 196.

As Sutherland's work at Utah led to students pursuing related research elsewhere, VR research at Ames inspired several private VR projects, the difference being that NASA's work took place in an environment of far wider possibilities for engagement, and funding without oversight (comparatively, at least), while retaining a considerable body of expertise. This allowed for fast diffusion and a wide range of approaches to developing VR. As a result, several different organisations created VR equipment, which in some instances resulted in retail products (at unaffordable prices.) As the 1980s had begun with a marked shift in the range of expectations and usability of VR, so did it end, with the development of mass-media hype, Usenet discussion and a period of speculation and marketing which might be described as a VR boom.

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[35] Roger Conklin, 'Why the Bell System Opposed the Automatic Dial Telephone', *Singing Wires: The Monthly Journal of Telephone Collectors International*, October 2008 <http://www.telephonecollectors.org/resources/dial1.htm> [accessed 2 May 2017].

THE NEW DAWN: THE MOVE TO NASA AND OTHER INSTITUTIONS IN THE EARLY 1980S

Work on VR at NASA Ames began long before Fisher's talk in 1984, however, and in the early 1980s it served as a point of exposure of VR technology to hackers and private interests. Since the late 1970s, Ames had carried out research into gaze tracking, instrument display, and perceptual studies as part of a collaboration with the University of California, Berkeley. In return for support from the Civil Aviation lobby, Ames had also been working on improving aircraft and air control displays for some years. The complexity of contemporary civilian aircraft cockpits was nearing that of fighter aircraft in the 1960s, which had driven Furness's research into data visualisation and Visionics (fig. 5). Stephen Ellis and one of his students, Michael McGreevy, joined Ames as part of the Berkeley contingent, and they became full time position holders by the turn of the 1980s. Ellis's Berkeley work on human factors and eye movement was quickly replaced with a new mandate to study displays. Display research played to Ellis's expertise however and was later integrated with his perceptual studies work as 'one of the best ways to track people's eye movements was to use an HMD.'[36]

At the same time McGreevy's work focused on computer-generated imaging for flight simulation, and David Nagel, the division head, was interested in the use of stereoscopic displays. McGreevy drew inspiration for HMD-based computer graphics from science fiction, and specifically from a futurology piece in the July 1, 1966 issue of *Life* magazine.[37] Part of his work centred on projecting graphical representations of flight data into the pilot's field-of-view (FoV). This required powerful computers but, due to the limited funding Ames received, McGreevy and his colleagues had to use decade-old machines. Thus, the virtual environments were not much different than Sutherland's, but between 1980 and 1984 the quality increased drastically, and those environments were paired with a stereo, tracking HMD to form the VIVED system in 1984. VIVED, a fully realised immersive proto-VR system was developed to support research into teleoperations (networked collaboration and work in virtual space), a concept described by Myron Kreuger at the University of Wisconsin-Madison, and Nicholas Negroponte at MIT in the late 1970s.[38]

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[36] Ellis, Interview, 11 July 2017.

[37] 'From the Surveyor: The Stark and Airless Beauty of the Moon.', *Life*, 1 July 1966, 62–67.

FIG. 5 A photograph of the cockpit of a Boeing 747 as it would have looked in 1980. Picture courtesy Shahram Sharifi. https://upload.wikimedia.org/wikipedia/commons/2/2d/Iran_Air_Boeing_747-200_cockpit_Sharifi.jpg [Accessed 26th Feb 2019].

Thus, VIVED encapsulated the same applications and technology (interactive, visual, networked) of later 1980s VR, in a far cheaper way than previous iterations. Initially suffering from high latency and low-resolution displays, it was far from ideal but demonstrated that it was possible. Unclassified, VIVED was exposed to visitors to Ames,[39] and this served as a vital point of knowledge communication and exchange, influencing both NASA and private VR projects.

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[38] Rheingold, *Virtual Reality*, 151-2; Shirley Biagi, *Media/Impact: An Introduction to Mass Media* (2014); Hugh Dubberly, 'Extending Negroponte's Model of Convergence', *Interactions*, 18/5 (2011), 74–79.

[39] Ellis, Interview, 11 July 2017

In a period where the workings of the US government were opaque, Ames was relatively amenable to outside access. Visitors to Ames were required to pass a security check, be assigned a NASA identification document, and an internal employee to vouch for them (Fisher did this for many former colleagues and friends when he joined in 1985), but access was possible.[40]

As a result numerous people outside of NASA, including many working in universities, got to experience the concept and hardware of virtual presence, many for the first time, and on a financially and materially duplicable level, at a time when more had experience using computers than ever before.[41] The culture and surrounding environment at Ames thus encouraged new links between the government-funded VR programme and the public. The development of high-end PC graphics hardware suggested to some that, if NASA could do it, they could too, and - free from institutional shackles – turn the technology into a world-changing entertainment platform, in accordance with the prophecies of science fiction writers like Vernor Vigne and William Gibson.

While the Ames research demonstrably spurred the establishment of some of the earliest VR firms, Ames' motivations require further investigation. Aside from the aviation lobby, Ames' VR research was a drop within an ocean of federal funding for the space administration at the time. Ames was producing knowledge and technologies around a wider remit of aircraft design and human factors, and this was attributable not only to technical need but to political ambition. By 1980 the space race had been paused for five years. The 1975 Apollo-Soyuz mission was the last time NASA had sent astronauts into space, and since then their funding and remit had been largely unchanged. While funding between 1975 and 1980 decreased as a proportion of the national budget, the sum increased, allowing NASA to diversify R&D from the extravagant space program. Ames received relatively little of this, $1.713bn out of around $23.47bn in 1980 (7.3%), and $2.159bn of $22.316bn in 1985 (9.6%). The apportionment to individual departments was not publicly recorded. There is mention of funding for ‘Human Factors’ in the 1970s accounts totalling $151.3m in 1979, but nothing visible thereafter.[42] The Human Factors division (where McGreevy and Ellis were based) had the aviation lobby supporting it, and was working with powerful computers on display, training, and flight control research.[43] However, McGreevy, Wu, and Ellis’s work on proto-VR would not have been a main project at Ames, which still had to fulfil NASA’s remit; expanding and maintaining American superiority in space.

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[40] Ibid; Rheingold, Interview.

[41] Rheingold, *Virtual Reality*, 140-8; Lois Rosson, 'The Virtual Interface Environment Workstation (VIEW), 1990', *NASA*, 2014 <http://www.nasa.gov/ames/spinoff/new_continent_of_ideas> [accessed 9 March 2017].

To guarantee future funding, Ames needed to stay relevant, and a key part of that was supporting space stations, particularly after the highly publicised fall to Earth of NASA’s Skylab in 1979. Work in space was coupled with displays and human factors in telepresence. By allowing the remote control of orbital hardware in real time, space stations could be built and maintained without the enormous cost of human crews, and it allowed astronauts and technicians on the ground to collaborate more closely. NASA’s telepresence technology shared common elements with proto-VR; including immersive displays, haptic (force) feedback, motion tracking, and artificial presence (through stereoscopy). Early telepresence used video feeds, but McGreevy worked with perceptual psychologist Elizabeth Wenzel to digitally reconstruct real places and immerse users in them as a more data-rich, versatile instance of the real-space in which they worked. Digital reconstructions of real places went on to be a core aspect of many commercial VR products.

This formed part of wider Intelligence Amplification research. IA became, in the late 1980s, one of the main ‘apps’ of VR, and had its roots in computer-aided design and Sutherland’s proto-VR system. While enhancing human faculties was a core component to most technology, 1980s and 1990s VR often had more profound claims, described by technology journalists and pioneers as changing the nature of human consciousness, and even humanity itself.[44] Some exposed to the experimental technology at Ames clearly thought that with further development, the technology could gain the power Rheingold had ascribed to it. By the 1990s, this had captured media attention and was rapidly whipped into a cyberbolic frenzy which helped fuel the VR boom.

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[42] *NASA Pocket Statistics* (Washington, D.C., United States,), 1991, C-17 <https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19910073587.pdf > [accessed 7 March 2017].

[43] *NASA Pocket Statistics*, 1991, C-14-15.

The reaction of those beyond Ames aside, the systems NASA was involved were not the product of a unified research team, nor were they an example of technological determinism.[45] The VIVED system was one among dozens of research projects, run by small group of researchers within Ames, and thus the network effects were predominantly direct.[46] Adopting the technology for entertainment seems to have been far from the minds of McGreevy and colleagues when VIVED was announced publicly in 1984, but as interest in their system grew, broader perspectives on the possible applications of such a powerful immersive tool became more apparent. This resulted in the redevelopment of VIVED into a multifunctional VR test-bed and shifted the perceived purpose of VR to a broader spectrum of possible applications.[47]

The VIVED system (which cost $2000 without the 1970s computer) was technically more advanced than Sutherland's display, tracking, and graphics hardware, and was considerably cheaper and lighter than Furness's.[48] Motion tracking was achieved by a Polhemus ultrasound tracker, as

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[44] Rid,*Rise of the Machines*, 220-4, 33-6; Rheingold, *Virtual Reality*, 185, 378-391; Brenda Laurel, 'Interface as Mimesis', in Donald Norman and Stephen Draper (ed.), *User Centered System Design: New Perspectives on Human-Computer Interaction*, (1986); David Sheff, 'The Virtual Realities of Timothy Leary', *Upside*, April, April 1990, 70; Jean Baudrillard, *Simulations* (1983); Douglas Trumbull, *Brainstorm*, 1983.

[45] NASA Ames Research Center, 'Guide to the Human Systems Integration Division Virtual Environment Documentation and Equipment, 198601993.' (2010) <https://history.arc.nasa.gov/hist_pdfs/guides/afs8078_virtualenviron.pdf> [accessed 9 March 2017]; Stephen Ellis, Pers. Comm, NASA Ames Human Systems Integration Division, 7th July 2015.

[46] Ellis, Interview, 11 July 2017.

[47] Rheingold, *Virtual Reality* 139; 'NASA's Virtual Workstation: Using Computers To Alter Reality', *NASA TechBriefs*, 12/7, August 1988, 20–22; Jo Ann Oravec, *Virtual Individuals, Virtual Groups: Human Dimensions of Groupware and Computer Networking* (1996).

[48] Ivan Sutherland, 'A Head-Mounted Three Dimensional Display', in *Proceedings of the December 9-11, 1968, Fall Joint Computer Conference, Part I*, AFIPS '68 (Fall, Part I) (New York, NY, USA, 1968), 757–764 <http://doi.acm.org/10.1145/1476589.1476686> [accessed 1 June 201; Kent Bye, *50 Years of VR with Tom Furness: The Super Cockpit, Virtual Retinal Display, HIT Lab, & Virtual World Society.*, Voices of VR <http://voicesofvr.com/245-50-years-of-vr-with-tom-furness-the-super-cockpit-virtual-retinal-display-hit-lab-virtual-world-society/> [accessed 6 August 2016]; Tom Furness III, and Dean Kocian, 'Putting Humans

Furness had done, avoiding Sutherland's Sword.[49] VIVED used a DEC PDP-11 computer, with a separate graphics processor that was designed by Evans and Sutherland. Unlike the primogenial PDP-1 that Sutherland and Sproull used, the PDP-11 was smaller and cheaper. It had more than fourteen times the available memory and ran a little over five times as fast as Sutherland's PDP-1. The PDP-11/40 used to run VIVED was first released in 1972, so was over a decade old when used at Ames, a fact that corroborates the claims of underfunding reported in interviews and narratives.[50] The VIVED headset integrated '3D' audio, simulating directional sound, and a voice-recognition system. Once Fisher joined the project, a motion tracking glove input was added, allowing for virtual hands. These additions made the virtual spaces of the VIVED far more interactive than Sutherland's 'window' into virtual space. This interactivity allowed users to experience a far deeper sense of presence (as defined in chapter 1, p.18) in the virtual environments generated by the device.

NASA's VIVED represented a shift for non-military proto-VR systems both technically and conceptually. The changing understandings and expectations of proto-VR's capabilities had a role in shaping its technical development beyond NASA, but even there within a highly structured research administration, the perceived role of proto-VR in the 'modern' world changed considerably over the course of a few short years. As the people, the money, and the place of computers in American society all shifted, so too did the perceived benefits of immersion in virtual space. The aim Sutherland and contemporaries had put forward for VR was more utilitarian, as

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into Virtual Space (with Visually Coupled Cockpit simulator)', in *Aerospace Simulation II; Proceedings of the Second Conference, San Diego, CA; US; 23-25 Jan. 1986*, 214–30 <http://search.proquest.com/docview/24218420/10839237EA194DC0PQ/35> [accessed 17 November 2016]; Scott Fisher, 'Viewpoint Dependent Imaging: An Interactive Stereoscopic Display', in J. Pearson (ed.), *Processing and Display of Three-Dimensional Data*, Proceedings of SPIE, 1982, CCCLXVII, 41–45 <http://dx.doi.org/10.1117/12.934299> [accessed 1 November 2016].

[49] 'Time Machines: NASA Goes Virtual at CES', (2013) *Engadget* <https://www.engadget.com/2013/12/15/time-machines/> [accessed 19 April 2017].

[50] Digital Equipment Corporation, 'PDP-11/40 Processor Handbook' (1972) <https://pdos.csail.mit.edu/6.828/2005/readings/pdp11-40.pdf> [accessed 9 March 2017]; NASA techBrief August 1988, 12-7.

were computer applications more broadly. Technically, glove inputs, interactive virtual objects, or 3D audio could have been developed in the 1960s, but their development hinged on a new understanding that computers could be for more than data storage, computation, and retrieval. The notion of *entering* a computerised space became visible in some science fiction and discussions of virtual space in the 1980s, as the work of Furness and Dean Kocian at Ohio and McGreevy and Fisher at NASA showed.[51] The notion of doing work entirely on (or within) computers, was far from prominent. The move toward using computers to augment human faculties, visible at NASA Ames, Xerox, MIT and elsewhere in the early 1980s, carried alongside it the dispersal of proto-VR technologies into the realms of private business, further diversifying the technological, material-cultural, and systemic positioning of the VR concept. NASA's desire to create an infinitely dynamic simulator, and for interaction with machines both on Earth and in space was closer than ever as technical obstacles were addressed and understood, and this drew with it the potential for the same technologies to be turned to other purposes, by other agents.

OTHER WORLDS: THE ENTRANCE OF PRIVATE ORGANISATIONS INTO VR RESEARCH, AND BEYOND

Fisher, like many others, had been headhunted for Atari Sunnyvale by Alan Kay, who had led the development team for the Xerox Alto, arguably the first PC, at Xerox PARC in the 1970s, and who had worked with Sutherland in the late 1960s and early 1970s at Utah.[52] Kay was brought on by Atari with the promise of administrative autonomy, and was given remit to assemble 'the best minds in the industry… to explore the possibilities of video gaming, computing, and human interaction.'[53] Kay had already tried to recruit the MIT Architecture Machine group wholesale but resorted to hiring its members one by one.[54] Kay's subsequent focus on virtual space and immersion, and hiring of HMD researcher Fisher suggest that Kay had brought, from his time at Utah with Sutherland, a desire to further develop the technologies of proto-VR he had encountered there.[55]

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[51] Ibid, 12-7; Furness & Kocian, ' Putting Humans into Virtual Space'.

[52] Alan Kay, *FLEX: A Flexible Extendable Language* (1968).

[53] Kurt Vendel, 'The Atari LA Lab' <http://www.atarimuseum.com/otherprojects/lalab.html> [accessed 19 April 2017]; Rheingold, *Virtual Reality*, 94-6.

Kay did not hire many Utah graduates though, focusing instead on Arch Mac students who had been exposed to Negroponte's ideas of virtual communication, virtual environments, and IA. Among them were Brenda Laurel and her husband Eric Hulteen, researchers in immersive gaming. Hulteen also worked on voice input for computers at MIT, something Kay found of interest.[56] The research at Atari was diverse, exploring networking, interactive virtual spaces, simulations, and helmetless virtual worlds. The eponymous ALAN-K project was designed as a high-speed alternative to IBM's Ethernet, allowing computers and people to communicate more types of digital information. Information like that which was involved in Laurel's 'Interactive Fantasy' project, creating computer-generated, interactive, dynamic virtual environments, using both HMD and projected CAVE display typologies.[57]

Fisher was keen on the 'gloves-and-goggles' approach to immersion in virtual space, but at Atari devoted most actual work to the Media Room, which used projectors to convert a room into a virtual space. While less isolating, more grounded, and thus arguably less immersive than HMD-based proto-VR, the Media Room and other CAVE type systems were often considered just as valid a means of immersion.[58]

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[54] Brian Crecente, 'VR's Quintessential Innovators', *Polygon*, 2016 <https://www.polygon.com/features/2016/10/26/13411364/heilig-fisher-marks-de-la-pena-laurel-vr-bio> [accessed 2 April 2017].

[55] Fisher, 'Viewpoint Dependent Imaging', 1982.

[56] Rheingold, *Virtual Reality*, 135-6.

[57] Brenda Laurel, *Atari Research Memos on the Subject of Interactive Fantasy and Related Topics* (Atari Sunnyvale Research Laboratory, March 1982), 28 <http://www.atarimuseum.com/ARCHIVES/pdf/misc/blaurel_IF1.pdf> [accessed 14 March 2017].

[58] Brenda Laurel, and Eric Hulteen, *Media Room Event: Revised Proposal* (Atari Sunnyvale Research Laboratory, 17 August 1983), 1–7 http://www.atarimuseum.com/archives/pdf/misc/mediaroom.pdf. [Accessed 6th April 2016].

The team was in a constant state of flux, but through the early 1980s they helped push the boundaries of computerised entertainment and transformed conceptions of what computers were for. Atari was a video game company, giving the computing work and theory carried out at Sunnyvale a necessary ludic element. At Ames, projects were tightly managed, with deadlines and clear objectives, and little room for creative experimentation or fun. At Sunnyvale, avant-garde innovation was actively encouraged. Kay's team was trying to invent new forms of play, and when Fisher brought Sunnyvale colleagues to Ames, he also reinforced those notions there.

Jaron Lanier was also at Sunnyvale from 1983-4.[59] Partially self-educated, Lanier hailed from a different background to most at Sunnyvale, his appointment no doubt encouraged by Kay's desire for a diverse set of ideas. Lanier's own interests were in programming languages, and he had written a successful video game for Atari in 1983.[60] While at Sunnyvale, he worked on Laurel's Interactive Fantasy project, and a new computer language (though this may have been on his own time.) There is little documentary evidence of Lanier's own projects at Atari though, perhaps due to the short span of time he worked there. However, while there, he met a colleague, Thomas Zimmerman, who had developed a computer interface glove at Atari. He wanted to use the glove for altering musical tones generated by a computer, and he developed a means of measuring the curvature of a fibre-optic cable by marking it with tiny indentations, increasing its effective refractive index when it became curved, and using a light sensor to calculate the severity of said curve.[61] Zimmerman had studied Humanities and Engineering joint honours at MIT prior to his work at Atari and was hired by Lanier when the lab shut down in 1984. He would go on to study again at MIT, developing technologies used in late 1990s and 2000s iterations of VR. They first met at an Atari working group exploring computerised music, which Lanier's game, *Moondust*, had made extensive use of.[62] The shut-down of the Atari lab was brought about by the collapse of the video game market, largely caused by excessive hype paired with cut costs and poor-quality games (the 'Atari Shock').[63]

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[59] 'Jaron Lanier's Bio' <http://www.jaronlanier.com/general.html> [accessed 20 April 2017].

[60] Jaron Lanier, *Moondust* (1983).

[61] Thomas Zimmerman, 'Optical Flex Sensor', 1990 <http://www.google.co.uk/patents/US4937444> [accessed 20 April 2017].

Atari was then bought out by Warner and split in 1984. The Sunnyvale lab was apparently closed at that time. Lanier had made enough from *Moondust* to work independently on his own interactive fantasies, virtual worlds, and programming languages on a Commodore 64 in his Palo Alto bungalow. He brought on Zimmerman to work with him and paired a DataGlove with his personal computer. This was, in 1984, only possible due to the rapid cost reductions and capability enhancements the US computer industry enjoyed at the time, all of which provided a vital context for proto-VR and computer development. The glove would go on to be a core component of Lanier's VR products, as well as those of several other companies. The extent of its usefulness is unclear, but contemporary accounts suggest that the glove was used by Lanier in his research on visual and gesture-based programming languages.[64]

While short-lived, Atari's Sunnyvale lab produced several ideas and technologies which would be further developed by independent actors, private companies, and state-funded organisations. Voice control, room-projection, and new ideas of human-computer interaction all advanced. The hunger for innovation and experimental research, which Kay had brought from Xerox and fostered at Atari, might have contributed to the diaspora of former employees from NASA after Fisher had employed them there, as the attitude to funding, experimentation, and personal projects was (and remains) very different between public and private organisations, and demonstrably frustrated some, including Fisher.

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[62] Rheingold, 160-2.

[63] 'David Crane (Atari) - Interview', *Arcade Attack*, 2016 <http://www.arcadeattack.co.uk/david-crane/> [accessed 22 April 2017]; Jonathan Takiff, 'Video Games Gain in Japan, Are Due for Assault on US', *The Vindicator*, 20 June 1986, 3; Peter Bernstein, 'Atari and the Video-Game Explosion', *Fortune; New York*, 104/2, 27 July 1981, 40; Aljean Harmetz, 'Sigh of Relief on Video Games', *New York Times* (10th Jan 1984), Business Day, D1.

[64] Kevin Kelly and Barbara Stacks, 'An Interview with Jaron Lanier', *Whole Earth Review*, Fall, 1989, 108–19 http://www.jaronlanier.com/jaron%20whole%20earth%20review.pdf [Accessed 16th April 2017].

Warren Robinett also moved between Atari and NASA (though not from Sunnyvale). He worked briefly on McGreevy's VIVED system before joining Fred Brooks's team at UNC's Department of Computer Science, where he continued to work on some of the proto-VR technologies he had seen at NASA. Work on the peripheries of VR at UNC, namely human factors and 3D displays, had persisted since the early 1970s. When Robinett and others arrived in the mid-to-late 1980s, headsets, gloves, and virtual spaces were more commonplace there. Many of the research objectives at the department centred on improvements to medical and architectural computer imaging, which were among the first applications of VR.[65] Sutherland's students and colleagues had carried out medical visualisation research using HMDs at Utah, and UNC's work appeared to be at least indirectly related. Brooks, chair of the department, was apparently aware of the collaboration Sutherland's team had participated in with medics, and enlisted help of members of UNC's medical faculty. The culmination of this was the establishment of a clear set of medical and architectural applications for proto-VR (and later VR), and the creation of its own VR hardware. The work at UNC sought to convert theory generated at Utah and NASA to industrial applications and was successful in doing so by the early 1990s. Unlike Robinett and Fisher, many Atari alumni went not into education, but their own businesses, demonstrating both falling costs of implementation, and the widening cultural currency of computers in the 1980s.

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[65] Nicholas Negroponte, *The Architecture Machine* (1970); James Chung, Mark Harris, Fred Brooks, Henry Fuchs, Michael T. Kelley, John Hughes, and others, *Exploring Virtual Worlds with HMDs* (February 1989) <http://www.dtic.mil/docs/citations/ADA208088> [accessed 18 April 2017]; Hiromasa Nakatani, Shinichi Tamura, Kokichi Tanaka, and Michitoshi Inoue, 'A Binocular Stereoscopic Display System for Echocardiography', *IEEE Transactions on Biomedical Engineering*, 2/BME-26 (1979), 65–68; Kokichi Tanaka, and Shinichi Tamura, 'A Parallel Processing System for the Three-Dimensional Display of Serial Tomograms', in *Real-Time Medical Image Processing* (1980), 61–76 <http://link.springer.com/chapter/10.1007/978-1-4757-0121-0_6> [accessed 15 November 2016].

In the 1970s, the break-up of a lab would have led to a diaspora of expertise to a limited pool of existing organisations with the wealth and will to allow research in similar avenues (like the Xerox PARC exodus in the late 1970s). This kept the network effects largely direct, and the bandwidth for innovation limited. The 1980s, however, saw a change toward broader usage of computers. Low-cost devices helped many conduct private research and business involving computer science as never before. Lanier's computer at the time, a Commodore 64, was stocked in popular American retailers such as Toys 'R' Us and Sears for around $150 (some $330 in 2015), and only needed a compatible TV or monitor to use.[66] Despite the low price, it was patently powerful enough to write programming languages and software to support Zimmerman's glove. The drastically improved accessibility of computers in the 1980s completely changed the landscape of computer hardware and software R&D. Individuals working at universities like MIT, and UNC, and at research institutions like NASA, were able to start their own computer, game, or VR firms. This diffusion of expertise also caused a dilution though, and many of the problems encountered with poorly optimised or incompatible VR systems may have been caused by the shortage of expertise brought about by this increased diversity of backgrounds.[67] That diversity encouraged the formation of a diverse, dynamic ecosystem for new products and ideas for the computer, a small subset of which focused on the immersive, illusory powers of interactive graphics and HMDs, a combination which would soon come to be known as VR, and this can only be partially reflected in literature.

Surviving publications most often came from university labs or well-funded institutions with a wide reach. Research at short-lived companies run from Palo-Alto basements less so. The partisan competition of business limited documentation further. In the mid-1980s, Jaron Lanier's VPL was the most visible in print and had made the cover of *Scientific American,* but at the time had no VR products.[68] The visibility of such companies was low, and their products were poorly engineered or prototypical, and the core of the VR concept thus came not from those firms, but from NASA.

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[66] W*ish Book '85*, 1985, p.598 <http://www.wishbookweb.com/FB/1985_Sears_Wishbook/#602> [accessed 21 April 2017]; Ian Matthews, 'Commodore 64 - The Best Selling Computer In History', *Commodore Computers,* 2007 <http://www.commodore.ca/commodore-products/commodore-64-the-best-selling-computer-in-history/> [accessed 21 April 2017].

[67] Steve Ellis, Interview, 12 Apr 2018.

TRUST, BUT VERIFY: MEDIA ATTENTION AND VALIDATION OF THE VR CONCEPT AT NASA

Fisher joined NASA in 1985 and transformed VIVED into what was termed a full Virtual Environment Workstation (VIEW). Zimmerman's glove, presumably encountered at Atari, was added to the VIEW, connecting NASA to Zimmerman and to Lanier's private company, VPL.[69] The idea of combining hand inputs and immersive displays may have been inspired by UNC's ARM (Argonne Remote Manipulator).[70] The glove allowed VIEW to be used in a wider range of applications and research projects than VIVED had, including telerobotics and training simulations. As Zimmerman's glove was unique in the US at the time (Pacific Bell had a switch-based glove developed in 1981 by Gary Grimes, but it was not digital[71]), Fisher had to contract VPL to produce the DataGloves for Ames. A not-insignificant part of Ames' budget was devoted to research contracts and scholarships, so this was not atypical. In 1985, the Ames research centre apportioned $187.7m from its total budget of around $2.16bn to research contracts, which was around three quarters of its total spend on research and development for the same year.[72]

The Ames-VPL contract served as both a major source of income for VPL and a ringing endorsement for the firm, which until then had only one customer, the parallel-computing-research firm Thinking Machines.[73] This drew the attention of larger technology firms like Thompson Avionics, Abrams-Gentile Entertainment (who licensed the DataGlove to Mattel) and Pacific Bell, among others.

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[68] Lawrence Tesler, 'Programming Languages', *Scientific American*, 251/3 (1984), 70–78.

[69] Rheingold, *Virtual Reality*, 151.

[70] Ibid, 14-5; *NASA Pocket Statistics.* C15-27.

[71] Gary Grimes, 'Digital Data Entry Glove Interface Device', 1983 <http://www.google.co.uk/patents/US4414537> [accessed 23 April 2017].

[72] Ellis, Interview; *NASA Pocket Statistics.* C15-27.

[73] Jaron Lanier, interviewed in Rheingold, V*irtual Reality*, 163.

Lanier himself was VPL's public face and generated interest. The DataGlove sold in the late 1980s for $8800, much of which was for the complex manufacturing process necessitated by the notched fibre-optic cables that allowed the DataGlove's precision. Ames purchased several in 1985 and they were delivered in the following year. The high cost of the VPL contract stands out, as Ames' computers (PDP-11A's until 1988, then HP 9000s) could not interface with the gloves. The gloves were therefore unusable on delivery, and it took over a year to make them functional, something achieved by Robinett. It was also in 1986 that Lanier supposedly gave VR its name while talking with Fisher about a name for the technology that VIEW represented.[74]

By the mid to late 1980s, the Human Factors division at Ames contained a contingent of staff who had extensive experience of working together, who had diverse approaches to knowledge creation, and who had all worked with computer-based immersion. Rheingold suggested that the development of VR at NASA was the product of 'technological convergence', a chance collision between people of different expertise that produced indirect network effects. This is not entirely unreasonable, but the establishment of those network affects appears to have been more the product of the deliberate curation of a diverse team with different experiences of computers. The management of this team by Nagel and Fisher seems to have been, at least partially, an attempt to 'supercharge' Ames' research portfolio and to broaden the scope for innovation throughout the end of the 1980s, a period in which American technological exceptionalism was briefly threatened by the Soviet Union and democratic rivals in Europe and Japan. The temporary détente in the space race may well have led some at NASA to diversify their interests (or their portfolio) beyond spacefaring vehicles and computer consoles.

While Fisher's reunification of former colleagues brought the advantages of experience with similar technologies and work ethics it also allowed much of that work to persist in a perceptual echo chamber. Indeed, many on the VIEW team believed they were at the technological forefront of human interaction, media consumption, and thought itself, and there was a lack of external perspectives.[75] This is evidenced by the behaviour of both Lanier and Fisher at the end of the 1980s. While Lanier did not work *at* Ames, he worked for it, and spent some time there working directly with Fisher and his team.[76] In 1988, Lanier recalled an incident where he had been offered a research lab by the Stanford Research Institute (later SRI International). While SRI estimated that a workable VR system would not be ready for public sale before 2010, Lanier believed so strongly that it would be ready by 1990 that he turned down SRI's offer, apparently saying VPL could do it faster on their own. Instead, VPL had filed for bankruptcy by 1990.

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[74] Steve Bryson, 'Virtual Reality: A Definition History - A Personal Essay', *arXiv:1312.4322 [Cs]*, 2013 <http://arxiv.org/abs/1312.4322> [accessed 23 April 2017].

Lanier's faith that VR was imminent was not unique, and many at Ames shared that optimism.[77] Ellis and Rheingold described the mood at the time in Ames and Silicon Valley more broadly toward VR (and more generally) as very optimistic. The considerable funding and diverse research efforts that went into VR in the late 1980s serve as testament to that, and there was a strong sense that a working, marketable VR system, enabling the prophesied social upheaval, was only years away. As the years passed, and VR remained out of reach, the mood shifted slightly. For Rheingold, many working in VR became bored with it as the much-heralded VR revolution (and profits) failed to materialise. Among the venture-capitalists of Silicon Valley, this led to a substantial degree of disillusionment, a feeling that was amplified in the institutions where a prominent proportion of the staff were researching VR.

A swift churn in personnel followed as despair grew. Warren Robinett left Ames in 1988, but Steven Bryson, one of VPL's programmers, and a key part of the NASA/VPL contract joined Ames at the same time. However, he promptly left to go to the contractor Sterling.[78] Douglas Kerr, Robinett's replacement, left in 1989. When McGreevy returned from training in Washington in 1987, he and Fisher had very different notions of how the VIEW project should be executed, which culminated in, effectively, two separate VR teams pursuing the same goals in different ways, perhaps because VR, like other fringe technologies, tended to draw 'strong characters'.[79] Fisher left Ames completely in 1990, and the development of VIEW came to a halt then. Dave Nagel also left in 1990. Hence, there were numerous upheavals at both Ames and VPL by 1990, and while there is clearly no singular cause, frustration with the process of VR research at their respective organisations seems to have been commonplace. Many left Ames to continue VR work in the private or education sectors. Robinett and Kerr left to pursue VR research at UNC and the Human Interface Technology Laboratory (HITLab) at the University of Washington respectively. Fisher left to establish his own firm, Telepresence Media (co-founded with Brenda Laurel from the Sunnyvale days). This diffusion and resulting expansion of talent from a handful of Californian organisations to a broader national network of universities and companies was a product of the falling costs of computing and fostered indirect network effects. Not everyone stayed working on VR: Nagel left Ames for Apple, which never developed VR products (though it would later muddy vocabulary with its largely unrelated Virtual Reality Modelling Language).

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[75] Ellis, Interview 11 July 2017; Rheingold, *Virtual Reality*, 185.
[76] Bryson, 'Virtual Reality'.
[77] Ellis, Interview 11 July 2017; Rheingold, Interview; Rheingold, *Virtual Reality*, 34.
[78] Bryson, 'Virtual Reality'.

As these changes took place, VR received more press attention. VR research at NASA lent it legitimacy, and the media coverage amplified this by reaching out to innovators, consumers, and investors. Buoyed by investor optimism and media coverage, VPL launched expensive VR products in the late 1980s. The EyePhone, VPL's own HMD with motion tracking and (optional) 3-D sound, cost around $9,400. VPL could also provide two Silicon Graphics 'Reality Engine' computers to generate the virtual realities, one for each eye, costing from $75,000 to $250,000 each, depending on the level of graphics processing power sought. The motion tracker was $2500. VPL's flagship VR complete system, Reality Built for Two (RB2), allowed two users to interact in a shared virtual space

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[79] Ellis, Interview 11 July 2017; Rheingold, *Virtual Reality*, 142-5.

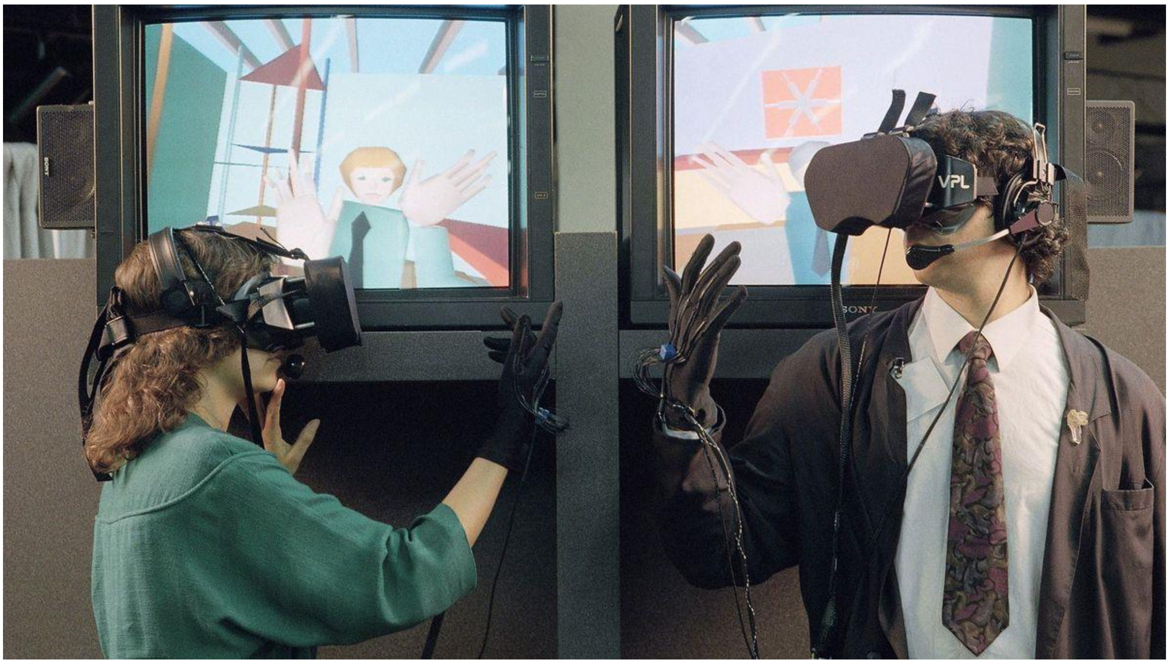

FIG. 6 A photograph of two people demonstrating VPL's Reality Built For Two hardware and Swivel software at the Texpo Telecommunications Show in San Francisco, California, June 7th 1989, wearing VPL EyePhones and DataGloves. The screens behind them show their individual perspectives, and highlight the graphical capabilities of RB2. Originally from a VPL press pack, this digital copy is available courtesy of Jeff Reinking/Associated Press, retrieved from http://mashable.com/2014/04/20/virtual-reality-predictions/#dz3tc3rtgqc [Accessed 14th May 2016].

over a hardwired computer network (fig. 6). It used four high-power Silicon Graphics workstations, and cost a little under $500,000.[80] It is unclear whether RB2 was ever sold, and VPL quickly declared bankruptcy after its unveiling at the San Francisco Civic Auditorium on the 7th and 8th of June 1989.[81] The DataGlove, VPL's first commercial product, appears to have been the most successful in terms of sales, no doubt because of the patent for the fibre-optic movement sensors in the glove's spine that Zimmerman had signed over to them. Developing HMDs was, as McGreevy had shown in 1984, not impossible for a determined team with cash, but the glove was bespoke and had to be sourced from VPL for a high-end version, or from Mattel in the form of a Nintendo Power Glove, for a considerably poorer specification. The high prices of VR products in the late 1980s (not just VPL's) highlighted the degree of confidence in VR's appeal. The VPL demo at the San Francisco Civic Auditorium was well attended, and received coverage in InfoWorld, New Scientist, Popular

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[80] Stuart Johnston, 'The Expensive World of 'Virtual Reality': Not Just Another Pretty Space.', *InfoWorld*, 12/8, 19 February 1990, 50.Rheingold, *Virtual Reality*, 166.
[81] Ibid.

Mechanics, and others. Pacific Bell funded the event, directly committing them to VR's future success.

The end of the 1980s witnessed a smattering of private firms working on VR tech, which expanded to include gloves as the DataGlove grew in popularity. James Kramer developed a data glove which used strain gauges, but was heavily sued by VPL in 1989 for violating a confidentiality agreement and infringing proprietary technology, something Kramer staunchly denied, but as a student with limited financial means was forced to stop.[82] Elizabeth Marcus also developed a data glove using Hall-Effect sensors (but not whole VR systems) and sold them from her Palo Alto based Exos., Inc., While it appears that Exos was running by 1989, it was largely invisible before 1991, perhaps due to VPL's intervening bankruptcy. Eric Howlett's firm Pop Optix began producing full VR systems in 1989. Howlett was contracted by NASA Ames to produce lenses for the VIEW display by McGreevy in 1985. The resulting 'LEEP' (Large Expanse Extra Perspective) lenses provided a wider, more immersive FoV, and (while expensive) became a key part of the VR HMD ecosystem. McGreevy apparently encouraged VPL to use Howlett's lenses in their EyePhones, which were first released shortly after Pop Optix's own HMD, the Cyberface.[83] The original Cyberface used the same monochrome LCD screens as the VIEW and EyePhone systems. These were taken from Sony portable televisions, with a 320x240 pixel resolution that gave a blurry image. Cyberface did not sell well, and updated versions in the 1990s, the Cyberface 2, 3, and 4, did little better, despite resolution upgrades to 720x240 in the 1994 Cyberface 3. These were unable to match displays from competitors like Polhemus's 1280x1024 pixel Looking Glass.[84] The Cyberface is notable as (seemingly) the first VR headset on sale in 1989, though VPL's were far more broadly adopted, and expensive. Pop Optix also offered a complete VR system, computer, trackers, and software, in the 1990s, but buyers of the 1989 HMD needed their own computer and software to run it.

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[82] John Wagner, 'Area Firm Sues Student Developer of 'Talking Glove"', *The Stanford Daily*, 195/11, 15 February 1989, 1.
[83] Eric Howlett, 'Leep VR: A History of LEEP', 2006 <http://www.leepvr.com/history.php> [accessed 26 April 2017].
[84] Simson Garfinkel, 'Look Ma! No Gloves!', *WIRED*, 1/2, 3 January 1994.

The optimism was not universal, however. Alongside the Cassandran prophecy of SRI (both correct and ignored) was the view of the influential engineer Henry Fuchs. Fuchs, a graduate of the University of Utah in 1975, has been the Frederico Gil Distinguished Professor of Computer Science at UNC since 1978. He cautioned Rheingold in the 1980s about VR research, warning against the blinding optimism in VR, the reluctance of VR innovators to leave their echo chambers, and the dangers posed by the growing expectations in the face of slow progress: 'The lag problem, for example comes across in popular articles as an artefact of today's systems that will probably be solved by some chip one day soon. It isn't that easy.'[85] Fuchs suggestion that useful, wearable VR might not be realised until 2035-40, was far more downbeat than the claims made by many of his contemporaries. Pessimism (or indeed realism) concerning VR's future appears to have been drowned out in popular and technical literature published at the time, which saw articles discussing VR multiply far beyond published VR research at institutions in the US at the end of the decade. The optimism, hunger, and hyperbole surrounding VR visible in media and business at the time shows the enormous extent to which laypeople and experts alike could fall under the sway of supposition, hope, and science fiction. The massive influence placed on expectations for VR by science fiction is exemplified in one of the earliest major tech firms to work on VR.

LIKE CITY LIGHTS, RECEDING: ENTERING CYBERSPACE AT AUTODESK

Autodesk was founded in 1982 by John Walker, who co-developed its first product: a programme called AutoCAD. CAD stood for Computer Aided Design, which has become crucial to product design and engineering globally in the 21st century. As computers with interactive graphics became more widely available in the 1980s, computer aided design became more popular. It allowed rapid manipulation and editing of designs without reprographics work, which cost more money and time. Sales of AutoCAD were strong throughout the 1980s, and by 1986, Autodesk had grown from 13 employees to 255, with annual profits of $40m.[86] Autodesk's roots in computerised architectural design could arguably be taken as extensions of Brooks' and Engelbart's IA theories of the 1970s, and Autodesk started working on 3D displays for design in 1988. Walker outlined his aspiration for such an immersive, interactive design model in a 1988 internal memo, in which he discussed NASA's VIEW, and VPL's DataGlove.[87] He also discussed the influence of science fiction, a feature that he emphasised more clearly in interviews with Rheingold. Walker was a fan of Gibson's 1984 novel *Neuromancer*, which popularised notions of a proto-VR network called Cyberspace. Walker may have met Gibson through their mutual friend, the LSD-and-media theorist Timothy Leary, and he mentioned his passion for aspects of Gibson's visions of the future in his memos.[88] Walker named Autodesk's flagship VR project *Cyberspace*, and its labs were called *Cyberia*. He mandated an 'Autodesk Cyberpunk Initiative' to develop new VR and networking technologies, and used Cyberspace to refer to the network of computer networks increasingly named the 'Internet'.[89] He also singled out as a major influence, Frederick Pohl's Heechee novels (particularly 1980's *Beyond the Blue Event Horizon*) in the creation of Autodesk itself, and particularly its flagship software AutoCAD.[90] Fiction was clearly a major influence on Walker's motivations for running the company, and this seems to have filtered more broadly into VR developers and aspirants at the time.

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[85] Henry Fuchs interviewed in Howard Rheingold, *Virtual Reality*, 34.

Considering the aparadigmatic nature of VR, it could be suggested that 'Neuromancer' provided conceptual and linguistic common ground around which diverse, dispersed VR developers could rally, as the term Cyberspace is prevalent in much of 1980s and early 1990s VR discourse.[91] However, fictional technology was never going to be a firm foundation for a real-world technological paradigm.[92] Conversations between the author and Ellis, and Rheingold suggest that while science fiction may have influenced many, such notions of shared virtual space leveraged by technology predate 1984. Gibson's writing, while demonstrably influential, was at most an accelerant, but fiction more broadly was clearly a driving force. The fact that earlier stories like Ray Bradbury's *The Veldt*, and *The Happiness Machine,* alongside Pohl's *Beyond the Blue Event Horizon*, and Vernor Vigne's *True Names*, were also cited as inspiration for 1980s VR systems by Walker, Bryson, McGreevy, Lanier, and others is a phenomenon worthy of further study. *Neuromancer's* effect is explicitly applicable to Autodesk's Cyberspace team and McGreevy at Ames.[93]

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[86] John McCarty, 'Micro-Miracle: Autodesk Has 'Image' of Success.' *The Pittsburgh Press*, 30 May 1986, B-6, B-8; John Walker, ed., *The Autodesk File: Bits of History, Words of Experience*, 3rd ed. (1989), 106-71.

[87] John Walker, *Through the Looking Glass: Beyond User Interfaces* (1 September 1988) <https://www.fourmilab.ch/autofile/e5/chapter2_69.html> [accessed 24 April 2017].

[88] Rheingold, *Virtual Reality*, 183-4; Walker, *Through the Looking Glass.*

[89] Walker, *The Autodesk File,* 476.

[90] Frederik Pohl, *Beyond the Blue Event Horizon* (2000).

Away from the innovators, the notion that reality might be mimicking, or outpacing science fiction was a pull for journalists. Famously, HMDs in Star Wars had injected vital interest into Furness's work.[94] Cyberpunk culture inspired Walker, and his appeal for links between the two drew investment. Research has recently highlighted the massive influence exercised by science fiction on technologies with long, undefined development cycles like nanotechnology and Artificial Intelligence.[95] VR, it seems, joins this group. As science fiction authors turned toward human-computer interaction, computer engineers felt a growing pressure to do so.

In addition to VR, Autodesk ran research projects on data storage, communication, hypertexts, and displays. While most projects were target-led, Cyberia's mandate was to 'replace contemporary user interfaces with something very different', and such an open-ended goal allowed for more experimental research in the Atari Sunnyvale vein.[96] For Walker, VR was the evolution of computer interfaces, from manually switching diodes, through punch cards, direct programming, operating systems with a keyboard, mouse, and screen, and finally VR, where the user was present within the computer's virtual space. In the Cyberpunk Initiative he mobilised Autodesk to produce a usable, cost effective (c. $15,000) VR product within a year.

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[91] David Bell and Barbara Kennedy, *The Cybercultures Reader* (2000), p.515.
[92] Peter Swann and Tim Watts, 'Visualization Needs Vision: The Pre-Paradigmatic Character of Virtual Reality', in S. Woolgar (ed.), *Virtual Society?: Technology, Cyberbole, Reality*, (2002), 51-8.
[93] Rheingold, *Virtual Reality*, 140.
[94] Rid, *Rise of the Machines*, 204.
[95] Milburn, Colin, 'Nanotechnology in the Age of Posthuman Engineering: science fiction as Science', *Configurations*, 10/2 (2003), 261–95; D. Lorenčík, D., M. Tarhaničová, and P. Sinčák, 'Influence of Sci-Fi Films on Artificial Intelligence and Vice-Versa', in *2013 IEEE 11th International Symposium on Applied Machine Intelligence and Informatics (SAMI)*, 2013, 27–31.

A demonstration version of Cyberspace was created just months after Walker's first memo, and Autodesk showcased it on June 7th, 1989, the same day VPL demonstrated RB2, albeit at different venues. VPL and Autodesk had vastly different approaches to their products, however. VPL was building no-expense-spared bespoke hardware, but Autodesk's was more utilitarian. The Autodesk unit used less powerful computers and was designed with ease-of-use in mind, as it was intended as a product for architects and designers, not computer engineers.[97] In the summer of 1989, Lanier noted 'Autodesk is creating a Volkswagen VR; we're doing a Rolls Royce, both are important.'[98] The significant pricing gulf was visible in a more tangible, higher-resolution world in RB2 than in Cyberspace, but they appear to have both used the same basic display hardware, with the VPL system generating more detailed graphics.[99] Lanier did not seem to see VPL and Autodesk in direct competition, but while VPL's product was demonstrated in 1989 and apparently ready for the market, Autodesk would continue developing Cyberspace for several years after that reveal, only to falter years later. While the prototype was developed quickly, Autodesk would never sell a single VR product.

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[96] Walker, *Through the Looking Glass*, 1.
[97] Ibid
[98] Rob Ponting, '3-D Displays', *InfoWorld*, 11/30, 24 July 1989, 22.
[99] Rheingold, *Virtual Reality*, 166-7.

After Walker's clarion call for action and the speed with which the prototype was created, the reasons for the failure of the Cyberspace project are hard to discern in the historical record. Walker did not preserve any internal documentation between 1992-3, and Autodesk was drastically restructured in the early 1990s. By 1991, the lack of usable VR products led to cutbacks at Cyberia, though it was not shut down.[100] Autodesk was publicly optimistic, but by around 1993 the hardware side of the project was struggling. A developer kit (for people wanting to make applications for it, rather than for clients) came out in 1993, with the software garnering far more attention than the hardware (which was perhaps unsurprising considering Autodesk's software expertise).[101] In the fourth edition of his 1989 book *The Autodesk File* (1994), Walker commented that releasing so late had lost Autodesk the chance to 'own the market', hinting at the rapidly growing and diverse range of private VR firms at the time.[102] In 1991 the company announced a restructure to focus on AutoCAD, an event that took place the following year. Because of this, Cyberspace never passed the development stage, presumably having been quietly shelved at some point during those three years, with the kit released as a loss mitigation.[103]

Autodesk continued to develop a raft of non-VR products, tying its income to non-Gibsonian aspirations, but it also adapted AutoCAD to support 3D displays in addition to conventional 2D. Walker, more comfortable as programmer than as director, wrote of his dismay that the environment of experimentation for experimentation's sake within US technology research had diminished by the end of the 1980s.[104] While the truths of VR development were clear to VPL, NASA, and Autodesk, all of which had stopped developing their own VR hardware by 1991 (though Ames continued to research VR using hardware provided by Virtual Research and Kaiser), the popular media were behind the curve.[105] Excitement for a Cyberspace future, a *Neuromancer*-esque VR experience, suffused magazines and television well into the 1990s and helped pull the second wave of VR businesses into the VR bubble.

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[100] Rheingold, *Virtual Reality*, 184-5; Bell & Kennedy, *The Cybercultures Reader,* p.515.

[101] IGI Consulting, *Emerging Markets for Virtual Reality* (1992); Autodesk, Inc, *Cyberspace Developer Kit.* (Sausalito, CA, 1993); John Walker, *Preface*, in J. Walker (Ed.) *The Autodesk File,* (1989) https://www.fourmilab.ch/autofile/ Through the Looking Glass.

[102] John Walker, *Preface*, Through the Looking Glass.

[103] Mark Stephens, 'Autodesk Reorganizes, Forms Five Business Units', *InfoWorld*, 13/27, 8 July 1991, 104.

[104] John Walker, 'The Risks of Caution' in Walker, John, (ed.), *The Autodesk File,* (1989) https://www.fourmilab.ch/autofile/ 622-3.

LINES OF FORCE: THE CHANGING ‘ABOUTNESS’ OF VR TOWARD THE END OF THE 1980S

For much of VR’s history until the late 1980s, there was no discrete name for the technological cluster which comprised VR. Without a name, it lacked a language, a standard, or a paradigm. It was not an easily defined thing. To borrow a term from Library and Information Science, it’s ‘aboutness’ was in flux.[106] Experimental computer displays developed for entertainment and IA applications would be described as ‘VR’ towards the end of the decade, but this coalescence required a name to rally behind, and before Lanier’s ‘VR’, it received little interest in the media, which was more focused on a moral panic surrounding video games at the time.[107]

However, with the establishment of the name, Rheingold and other journalists caught wind of a technology that, supposedly, was going to change the nature of humanity.[108] Media interest grew exponentially, but definitions varied wildly, and it failed to generate widespread interest until it was named ‘Virtual Reality’. One of the few early articles that avoided such confusion was in

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[105] Ellis, Interview, 13 March 2018.

[106] Birger Hjørland, ‘Towards a Theory of Aboutness, Subject, Topicality, Theme, Domain, Field, Content . . . and Relevance’, *Journal of the American Society for Information Science and Technology*, 52/9 (2001), 774–78.

[107] Glenn Collins, ‘Video Games: A Diversion Or a Danger?’, *New York Times* (17 February 1983), Home, C1; Jonathan Greenberg, ‘Japanese Invaders’, *Forbes*, 127/8, (13 April 1981), 98; Peter Kerr, ‘Should Video Games Be Restricted by Law?’, *New York Times* (3 June 1982), Home, C1; Kofi Owusu, ‘The People’s Viewpoint’, *Washington Informer*, 19/42 (10th August 1983), 15.

[108] Rheingold, *Virtual Reality*, 185.

October 1987's *Scientific American* (which had also covered Lanier's VPL in 1984) on new computer interfaces, including VIEW and Zimmerman's glove.[109]

In retrospect, much of the early VR coverage was optimistic to the point of delusional fantasy, science fiction made real. The development of the Cyberpunk subculture, popular in the San Francisco Bay area, could have been a factor in this. Gibson's *Neuromancer* and *Mona Lisa Overdrive*, *Software* by Rudy Rucker, and movies like *Tron* by Steven Lisberger and *Videodrome* by David Cronenberg established cybernetics, computers, and transhumanism as vehicles of social and human change.[110] Aside from the impact of this on developers, popular writers appeared galvanised by it and catered to public fascination with Cyberpunk ideas. The release of the Mattel PowerGlove for Nintendo, licensed from VPL's DataGlove patents, amplified this fascination, though lack of content and ergonomic problems dampened its long-term appeal, factors that would come to beset VR development.[111] Bradbury's *The Veldt* and *The Happiness Machine* aside, VR's components predated this subculture, but that fact was understandably lost.[112]

Media depictions of VR increasingly took on their own mythos in the late 1980s, influenced by reader expectation, science fiction, and the marketing hyperbole of VR companies. As firms were increasingly dependent on private capital, attracting investment was key, and technology-driven hyperbole was the tool of choice. A major problem with promoting VR to investors was its name.

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[109] Frank Vizard, 'Tricked-Out Videogames', *Popular Mechanics*, October 1989, 106; Hugh Aldersey-Williams, 'A Bauhaus for the Media Age', *New Scientist*, 11 March 1989, 54–60; Rob Ponting, 'Virtual Reality System Readied', *InfoWorld*, 11/30, 24 July 1989, 17, 22; James Foley, 'Interfaces for Advanced Computing', *Scientific American*, 257/4, October 1987, 126–35.

[110] Gibson, *Neuromancer*; William Gibson, *Mona Lisa Overdrive* (1988); Rudolf Rucker, *Software*, (1994); Steven Lisberger, *TRON*, 1982; David Cronenberg, *Videodrome*, 1983; Thomas Richaud, 'science fiction and Politics: Cyberpunk science fiction as Political Philosophy', in Donald Hassler and Clyde Wilcox (eds.) *New Boundaries in Political science fiction*, (2008), 65–77.

[111] Vizard, 'Tricked-Out Videogames' 1989, 106; Ted Trautman, 'The Trouble With Toys', *The New Yorker*, 11 February 2014 <http://www.newyorker.com/business/currency/the-trouble-with-toys> [accessed 28 April 2017]; Steve Jacoby, 'Survivors of the Toy Wars', *Cincinatti Magazine*, December 2000, 64–71; 'Mattel: Back to Barbie Dolls After Getting Zapped in Electronics', *Business Week, Industrial/Management Edition, New York*, 20 February 1984, 84 A.

[112] Ray Bradbury, 'The Veldt', in *The Illustrated Man*, Reprint edition (2012), 9–27; Rheingold, *Virtual Reality,* 140.

VR, Virtual Environments, Virtual Memory, and Virtual Space were all in increasing use.[113] VR remained firmly in quotation marks until the end of the decade, but the technological, on-the-ground reality of VR already differed significantly from popular descriptions, some of which, such as Jones's below, bring attention to the seemingly impossible capabilities of VR as described in American media.

> Eyes bugging out of my head, I have been reading an account of the progress of work on 'Virtual Reality' in the US. It borders on the incredible. It is possible to build your own world via a computer, and then enter and explore it, and you can do this with a companion or companions… The potential that this work opens up is almost impossible to appreciate and certainly impossible to survey

- David Jones, writing under his pseudonym Ariadne.[114]

The 'account' in question was an interview with Lanier in the privately-published underground magazine *Whole Earth Review* (WER) in 1989.[115] That interview formed, for many, a cornerstone of VR's vocabulary and paradigm. VR was described there as an immersive computer interface using a glove, a headset, and a computer (or several). Remarkable claims about VR's power were thinly veiled as suppositions and predictions, as in the following quotation. That interview displays Lanier's aspirations and drive for a specific image of VR, and some of the earliest interactions between journalists and the VR 'mythos' (considered such due to the lack of visible separation between technical possibility and future potential).

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[113] Tobias Bowman, 'Against a Dark Background: Changing Trends in the Perception and Understanding of Virtual Spaces in the United States of America, 1966-2014.' (University of Oxford, 2014) <https://www.academia.edu/9538775/Against_a_Dark_Background_Changing_trends_in_the_perception_and_understanding_of_Virtual_Spaces_in_the_United_States_of_America_1966-2014> [accessed 29 September 2015].

[114] David Jones, 'Ariadne', *New Scientist*, 1691, 18 November 1989, 104; Michael Crichton, 'Spaceport America', *Popular Mechanics*, May 1989, 33–8; Aldersey-Williams, 'A Bauhaus for the media age', 54–60.

[115] Kelly & Stacks, 'An Interview with Jaron Lanier', *Whole Earth Review*, Fall, 1989, 108–19; Henrik Bennetsen, *From Counter-culture to Cyberculture: The Legacy of the Whole Earth Catalog* https://www.youtube.com/watch?v=B5kQYWLtW3Y [accessed 26 April 2017].

> The virtual worlds VPL has created are in full Technicolor with shaded, contoured surfaces! They are far from photographic quality, yet there is a sense of completeness… When I first arrived at 8:30 in the evening, Jaron said he wanted to make up a world for me – a crazy, imaginative world… He immediately sat down at his Mac and began creating it.

- Kevin Kelly, in the preface to 'An Interview with Jaron Lanier'.[116]

At the end of the 1980s though, the 'Technicolor' environments described did not exist, headsets were monochrome and lacked third-party content (EyePhones would get colour screens in 1990).[117] Lanier's demonstrations used expensive Silicon Graphics workstations, out of reach of almost all private customers. Lanier's excitement about using virtual avatars ('I've considered being a piano') ignored the fact that, even in his own system, such functionality was more limited than the experiences he described.[118] This was largely a product of the difficulties VPL (and other companies of the time) faced with optimising the advanced technologies they were using, often without the expertise which had been required (and abundant) at proto-VR research institutions.[119] Lanier provides conflicting dates for that interview, either 1986 or 1989, the latter seems far more likely, as the RB2 project is only visible in around 1988, though as the SGI IRIS workstations used were available from 1985, a date of 1986 is not impossible.[120] Timing aside, the interview's publication in 1989 marked shifting public expectations concerning VR's imminent performance. Before that year, the lack of tangible applications or products led to confused journalism and diverse expectations, but Lanier was a charismatic salesman, and the securing of Pacific Bell and their backers Thomson Avionics polarised and aligned notions of VR behind his passionate, optimistic, broad-brush vision of a VR revolution. Whether his passion was a product of sentiment or marketing shrewdness is difficult to assess.

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[116] Kelly & Stacks, 'An Interview with Jaron Lanier', *Whole Earth Review*, Fall, 1989, 108.

[117] Michael Teitel, 'The Eyephone: A Head-Mounted Stereo Display', in *SC-DL Tentative* (1990), 168–171 <http://proceedings.spiedigitallibrary.org/proceeding.aspx?articleid=940098> [accessed 24 May 2017].

[118] Kevin and Stacks, 'An Interview with Jaron Lanier', p.108.

[119] Stephen Ellis, Interview, 12 Apr 2018.

[120] Jaron Lanier, 'VPL Software Lives! VPL Software Lives' <http://www.jaronlanier.com/vpl.html> [accessed 26 April 2017]; Jaron Lanier, *Dawn of the New Everything: A Journey Through Virtual Reality* (2017), 4.

Autodesk benefitted from the same optimism. The black-and-white, laggy, low-resolution Cyberspace device was described in 1989 thus: 'A shaded 3-D colour model surrounds you, and as you move about, turn, and tilt your head, the system displays in real time the scene from each new point of view.'[121] The discrepancy between the technological achievability of systems in the late 1980s, and the capabilities which were ascribed to them, grew drastically at the end of the decade. In addition to a fast computer and an HMD, VR needed specialist software to run. Young Harvill had arguably come closest with *Swivel 3-D*, but it was bundled with VPL hardware and was only made available on its own after superior alternatives had hit the market.[122] The near impossibility of buying and running a complete VR system in 1989 did not stop writers from embellishing what they had seen or been told as a come-on for readers. [123] What began in the late 1980s would grow into an explosion of hype and excitement, with growing shock and disbelief, as well as optimism, that VR could be the Next Big Thing.

THIS IS NOT AN EXIT: THE END OF THE 1980S

The 1980s saw proto-VR become VR, and technical development and discourse move toward the entertainment industry, and away from state-institutional concerns. Technical developments in other fields, conceptual changes, and representations of VR in literature, TV, and film, all heightened expectations for VR. The booming personal computer industry increased the literacy, cultural awareness, and solvency of VR in society. Reported and charted by computer science literature, technology magazines, science fiction, and Cyberpunk culture the pursuit of VR research by private companies arose quickly, rapidly changing the technical, developmental, and social landscape. This shift pushed VR technologies into a wider range of contexts, deepening confusion as to its purpose and technological foundations, and hindering development as many private VR companies lacked employees with the technical skills to make their products work, on account of highly specialised graphics and signal-processing technologies of VR systems.

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[121] Ponting, '3-D Displays', 22.
[122] Lanier 'VPL Software Lives!'.
[123] Rheingold, *Virtual Reality*, 178-9.

The dark futurologies portrayed in 1980s science fiction aligned public support, business models, and project plans along particular lines of force, which emanated from the two poles of institutional legitimacy and fantastical hope. Many of the earliest firms were buoyed directly by this hope, or by the visible excitement in print media agitated by that same fictional image of VR. While these firms failed to generate successful products, they sowed seeds for future companies. Fake Space, Polhemus, RPI, Enter, Division, Simm-Graphics, Telepresence Research and Sense8 joined VPL, Pop Optix, and Autodesk in the VR business by 1990.[124] While most VR companies had no actual products to sell, the widespread expectation and perceived potential of VR caused a great deal of frustration for innovators. A diffusion of talent prevented a shared concept or paradigm for VR from forming in the late 1980s, which proved damaging to the technical and social promotion of the technology. Even Furness, in his well-funded USAF lab, became frustrated with VR's slow development, and with the use of his technology by 'steely-eyed killers', and quit.[125] At his new venture, the HITLab, he sought to chart the shape of American virtuality through a database of virtual worlds, perhaps in an attempt to marshal the tremendous creative forces of the private VR industry at the time (which were spread thin across as wide a range of approaches as there were companies), into technical standards, paradigms, or goals. The complete lack of these, along with Furness's failure to manufacture them, had an impact on the directionless, hollow nature of VR's public offerings in subsequent decades.[126]

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[124] Ibid, 154.

[125] Ellis, Interview, 13 March 2018.

[126] Campbell-Kelly & Aspray, *From Mainframes to Smartphones*, 203-8; Swann & Watts, *Visualization Needs Vision* 41-60.

Attracted to sensationalism far more than put off by the dearth of technological achievement in producing actual VR systems, the media and many of VR's proponents remained incredibly optimistic. The struggles faced by VR companies were rarely depicted as the product of technological failures, but managerial incompetence, when in fact it was a mixture of the two. The tremendous challenge posed by making a computer interface tool 'the future of media', coupled with this sensationalism, fed a gulf between experiential, material reality and VR hyperbole. The collapse of 1980s VR projects in 1990 appears to have been unthinkable to the Silicon Valley pundits of 1989 who lived in an America increasingly energised by a vision of post-war, big-science, globalised Manifest Destiny for which the guiding light was not God, but the microprocessor.

The rise of Cyberpunk culture was a key element in VR's expansion in late 1980s California. A growing disillusionment with Cold-War-era American technological exceptionalism, and concern about the government's role (or lack of one) in the lives of individuals made technologically-derived fantasy and escapism popular. The 1990s witnessed a glut of small VR firms forming amidst a major economic downturn, government concerns over the threat posed by Japanese VR research on a quintessentially 'American technology', and considerable shifts in the way that VR was portrayed and understood with the development of computer policy and the infamous 'Information Superhighway'. By the end of the 1980s, the VR business, like the economy, was already stalling, with international competition and intranational dissonance confounding progress. Reluctance to confront the chasm between technological possibility and rhetoric was, perhaps, a product of the twin desires of making science fiction real in 1980s America, and for the rudimentary sensory titillation of the personal computer to be elevated to something far more immediate, immersive, and visceral through the medium of Virtual Reality.

CHAPTER 4: EXCESSION

'We must declare our virtual selves immune to your sovereignty, even as we continue to consent to your rule over our bodies. We will spread ourselves across the Planet so that no one can arrest our thoughts.

We will create a civilization of the Mind in Cyberspace. May it be more humane and fair than the world your governments have made before.'

- John Perry Barlow, 'A Cyberspace Independence Declaration', 1996.

'Ah, but a man's reach should exceed his grasp, or what's a heaven for?'

- Robert Browning, 'Andrea del Sarto', *Men and Women*, (1855), line 98.

VR TROOPERS: THE FORMATION, EXPANSION, AND COLLAPSE OF THE VR BUBBLE BETWEEN 1990 AND 1997

VR's development and public awareness developed amidst a maelstrom of social and technological change in 1990s America. Perestroika had brought with it an exopolitical and exocultural vacuum, as the US's main competitor collapsed. Self-reflection on American cultural identity ensued, and the strained recession of the Bush era was followed by a period of introspection and recovery during the Clinton administration. At the time, political support for an 'Information Superhighway' demystified much of cyberspace's frontier mythos, and a more conformist public normalised less-extreme components of the anti-governmental, counter-cultural protest movements of punks and Cyberpunks, and shed the rest. The rapid social progress and economic change of the 1960s, 1970s, and 1980s had been, for Chafe, traumatic and trying on the American public (though which public is a matter for debate, for conservative middle America had seldom also been Cyberpunk counter-culturalists or hippies).[1] The 1990s became a period of increased social and cultural homogeneity, with American culture fundamentally altered by the colossal technological changes which helped define the preceding tumultuous decades. As a result, the digital frontiers of Cyberpunk and hacker culture began to move into the businesses and living-rooms of middle America. Newfound economies of scale for microprocessors and integrated circuits encouraged the diversification of entertainment, work, and research applications for computers. The network effects of such a diverse userbase allowed computer science and technology to advance in a range of ways, as gaming and administrative applications required higher storage capacities, faster processors, and better computer graphics.

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[1] William H. Chafe, *The Unfinished Journey: America Since World War II*, 7th edn (New York, 2011), 481-4.

The wide acceptance of computers across a range of contexts helped dispel fears surrounding computer hardware and moved them to computer software, or applications. Games and the Internet became increasingly popular plot points in television and print media, making the intimate immersion of VR as titillating as it was threatening.[2] VR's once-central role in Cyberspace receded, becoming instead a niche medium for PC based iterations of cyberspace like the Internet. As the appeal of counter-culture waned, so, too, did the popular portrayal of VR and Cyberspace as tools of rebellion. The expansion of the American computer market carried on its currents different technical iterations and concepts for VR, with private approaches to the technology diffusing out from the late 1980s 'big bang'.

The period 1990-5 saw budgets, scope, and expectations for VR projects inflate. The meaning of the term broadened as the VR 'brand' grew in technical feasibility and public acceptance. The move into private companies from state-funded institutions and universities, coupled with the techno-social change of the 1990s, drastically altered VR's technical and social pathways. Moving further from the nucleus of proven proto-VR systems like NASA's VIEW, companies sought profit through cost-cutting and new applications, chiefly in entertainment. With private business came marketing hype, which accelerated the division between technological possibility and expectation, even among those using the technology itself. Inflated hopes allowed grievous shortcomings in latency, graphical fidelity, user comfort, and content to be overlooked in the name of VR's potential futures. Such shortcomings remained throughout the 1990s however, and businesses failed as consumers and investors lost patience, rapidly eroding VR's material footprint in the US.[3]

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[2] Steven Posey, 'I, Robot... You, Jane.' *Buffy the Vampire Slayer*, April 28, 1997; Saban Entertainment, *V.R. Troopers*, Syndication, 1994; Nutter, David. '2Shy.' *The X Files*, November 3, 1995; Lee Smith, 'A Virtual Murder.' *Murder, She Wrote,* 31 October 1993.

At the start of the decade, private VR firms were spread thin. Existing companies like Autodesk took on VR projects, lending it private-capitalist legitimacy. NASA and the USAF had ceased VR hardware development, but optimism among Silicon Valley 'digiterati' allowed private enterprise to fill in.[4] Academic contexts also broadened; the Universities of Washington and North Carolina ran VR projects in 1990, advancing basic research on VR's implementation.[5] VR research in Japan and Western Europe also took off, occasionally collaborating with American projects, and exchanging staff. More American universities began VR projects during the early 1990s, like MIT and Stanford, and the universities of Oregon, Houston: Clear Lake, Wayne State, South Florida, Texas, Colorado, Minnesota, Arizona, and others between 1991 and 1995.

Academic research and business were joined by popular writing, which drew even more from science fiction and marketing than the others. Magazines like *Whole Earth Review*, *Mondo 2000*, and *Omni* ran frequent articles on VR and served as mouthpieces for many of its private proponents. Rheingold's seminal popular-history *Virtual Reality: The Revolutionary Technology of Computer-Generated Artificial Worlds-And How It Promises to Transform Society* was published in 1991, contributing to heightened expectations and helping to popularise the 'Virtual Reality' brand, particularly as the shortened expression 'VR'. Between 1990 and 1995, VR became more public, more expected, and more distorted from its technical capabilities, it was thought to already be something which it could never have been.

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[3] Tony Asch, Interview, 14 May 2017; Simon Julier, *Pers. Comm.* 29th November 2017.

[4] Ken Pimentel and Kevin Teixeira, *Virtual Reality: Through the New Looking Glass*, (1993), 52-62; Ralph Schroeder, *Possible Worlds : The Social Dynamic of Virtual Reality Technology* (Boulder, Colo, 1996), 1-25.

[5] Howard Rheingold, *Virtual Reality: The Revolutionary Technology of Computer-Generated Artificial Worlds-And How It Promises to Transform Society*, First (1991), 110, Pimentel & Teixeira, *Through the New Looking Glass,* 203; Jih-Fang Wang, 'A Real-Time Optical 6D Tracker for Head-Mounted Display Systems' (unpublished Ph.D., UNC, 1990) <https://search.proquest.com/docview/303911686/abstract/10A8F603516A4A70PQ/3> [accessed 24 May 2017].

By 1992, this distortion was visible in primary material. VR developers and the American government both warned that excessive hyperbole was damaging VR's future.[6] It fell largely on the deaf ears of writers and pundits who appreciated VR's power as an audience hook and established an echo chamber where exaggerations of capabilities and applications were themselves built on hype, for short term gain, sometimes in the knowledge that it could cause long term damage to their own interests.

The privatisation of VR was accompanied by a need for profit and products, disincentivising basic VR research. This only exacerbated the hype problem, as technical reality was increasingly left behind in movies like *The Lawnmower Man*, and review pieces in *Mondo 2000*, the *New York Times*, and *Popular Science*.[7] Promotional materials for VR hardware like VPL's Reality Built For Two described how 'multiple participants, wearing an Eyephone and DataGlove experience themselves as being in the same environment together ... across a continent' and how users could 'create and perform in their own productions.'[8] While neither of these capabilities were actually possible in any VR system in 1990, explicit allusions in company materials to higher resolution EyePhones with more complex computer graphics also failed to materialise.[9] As a result, VR discourse was progressively dominated by discussion of fantastical and ludic applications, leaving utilitarian, technically grounded ones nigh-unmentioned. 1990s VR's was increasingly oriented toward the video game industry in the first half of the decade. Location-based entertainment (LBE), such as game arcades, were popular and W-Industries (later Virtuality) was the most successful company, offering a range of VR games at venues across the country by 1991.

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[6] Schroeder, *Possible Worlds*, 124-5; Benjamin Woolley, *Virtual Worlds: A Journey in Hype and Hyperreality*, New edition (London, 1993), p.20; Jas Morgan, 'Brenda Laurel: Lizard Queen', *Mondo 2000*, 7, Fall 1992, 82–92; 'Virtual Reality', *Cryptologic Quarterly*, 12/3–4 (1993), 21–50.

[7] Brett Leonard, *The Lawnmower Man*, 1992; John Perry Barlow, 'Being in Nothingness', *Mondo 2000*, 2, 1990 <https://w2.eff.org/Misc/Publications/John_Perry_Barlow/HTML/being_in_nothingness.html> [accessed 3 March 2017]; L. Shannon, 'Peripherals; Putting Yourself in the Picture', *The New York Times*, 7 July 1992 <http://www.nytimes.com/1992/07/07/science/peripherals-putting-yourself-in-the-picture.html> [accessed 7 June 2017]; Michael Antonoff, 'Living in a Virtual World', *Popular Science*, June 1993, 83–86, 124–25.

[8] Chuck Blanchard, 'What's new in Reality Built For Two' (at Ars Electronica 1990: Digital Dreams - Virtual Worlds, Linz, 1990) <http://90.146.8.18/en/archiv_files/19902/E1990b_189.pdf>, 2-3.

[9] Ibid, 5.

One of the few areas of persistent private development was in cost reduction, as almost none of the 1990s VR firms ever made a profit. A key vector for these reductions came from the video game and PC industries, broadening the range of indirect network effects. Increasing dependence on the entertainment industries for technology and funding reduced the visible range of applications, however, and further distorted public perceptions of VR's uses. Cost reduction was particularly important considering the shift in customer base. VPL's RB2 system cost nearly $500,000 in 1991, and selling VR systems to civilian consumers necessitated far lower costs than the public and military sectors had, and it is unclear whether VPL ever sold an RB2 system at full price.[10] While prices did fall, the arcades were the only point of access for most people, colouring VR's presentation and perception away from its IA roots. The ability of arcades to swallow the high cost of LBE VR systems and sell access to those systems to refund their investment relied on technical shortcuts, which led to reduced quality of graphics, motion tracking, and latency, ensuring VR's most public face was a far cry from its technical best, and even further from media depictions.[11] The clear schism between on-the-ground reality and popular dogma visibly contributed to frustration and disillusionment with the technology, and entertainment applications would fade in the second half of the decade.

Fluctuations in consumer appetite and investment cannot be lain entirely within the context of the video game industry, or the broader entertainment market. Deliberate attempts by the CEO-Idealogues of late-1980s and early-1990s VR companies to ferment consumer demand led to exaggerations of VR's ability to provide compelling experiences or enhance productive capabilities, and drew focus away from the general research which could have made it so. VPL's aforementioned exaggeration of RB2's power was joined by claims from John Walker at Autodesk that a portable VR computer system with a range of rich, vibrant virtual worlds would be available by the end of 1992, and that content had been ready since 1991.[12] Similarly, Tom Coull at Sense8 claimed that entire worlds 'that previously took weeks to build that are now created in a single day' in their 1995 *WorldUp* system, and that their VR systems could create 'fine art'.[13]

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[10] Asch, Interview, 14 May 2017.

[11] Ibid.; Stephen Ellis, Interview, 13 Mar 2018; Schroeder *Possible Worlds*, 99-123; Pimentel & Teixeira, *Through the New Looking Glass*, 52-79.

The public desire for new electronic media stirred up by VR companies soon found a receptacle in an unexpected, if accessible format, however. 1994's World Wide Web caused Internet adoption to skyrocket, and the 1997-2000 dot-com bubble propelled users toward PC and Internet-based experiences. The virtual frontier, some decade old, became far more open. The VR 'digiterati' had been right about the oncoming change in the way people interacted with computers, yet the change was not brought about by VR, but by the Internet. To stay relevant, the VR brand had to shift.

Increasingly, 'VR' was applied to anything computer-related, and even e-mail was repeatedly described as VR in magazines, newspapers, and television, to the vexation of many VR innovators.[14] The confused discourse surrounding VR's nature, created by the competition between private VR firms in the early 1990s, allowed the term to be easily co-opted for the internet age. Rather than cyberspace arriving via VR, VR arrived via cyberspace, which could be accessed with a computer and a modem, with no helmets or gloves. The hardware of VR, its material culture, became an irrelevant, embarrassing vestige, companies like Virtual Research decried their former product mainstay, HMDs, as 'difficult to put on, prone to breakage,' and unhygienic, and the mainstream press panned the Nintendo Virtual Boy 'VR' system.[15]

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[12] John Walker, *The Dark Night of the Soul: Remarks for the Tenth Anniversary Meeting* (1 February 1992) <https://www.fourmilab.ch/autofile/e5/chapter2_69.html> [accessed 24 April 2017]; John Walker, *Information Letter #14* (1 April 1991) <https://www.fourmilab.ch/autofile/e5/chapter2_69.html> [accessed 24 April 2017].

[13] 'Home Page', *Sense8 Corporation*, 1996 <https://web.archive.org/web/19961114203113/http://www.sense8.com:80/> [accessed 14 March 2018]; Debbie Nelson, 'Sense8 Takes Virtual Reality Mainstream With Breakthrough Development Tool', *SENSE8 Corporation - Press Releases*, 1995 <https://web.archive.org/web/19961114204524/http://www.sense8.com:80/wup_pr.html> [accessed 14 March 2018]; 'Applications of Sense8 Products', *SENSE8 Corporation*, 1996 <https://web.archive.org/web/19961114203123/http://www.sense8.com:80/ahtml> [accessed 14 March 2018].

[14] Willem Homan, 'Virtual Reality: Real Promises and False Expectations.', *Educational Media International*, 31/4 (1994), 224–27.

That Nintendo system exacerbated the move of VR's meaning towards web-based applications. Built down to a low price and lacking content or unique applications, it was 'nothing like the mega-hyped, virtually unbelievable sunglasses that were first modelled for consumers.'[16] As such, it was very different from the prophecies of Lanier, Laurel, John Perry Barlow, Timothy Leary, and others. The assumption that HMD-based VR would be more enthralling than the VR of the internet was crushed by poor displays, limited features, and a content drought.[17] That notion of accessing computers with a helmet, gloves, or body suits seemed pointless in the face of the meteoric internet scene. The diverse, vibrant, seedy, virtual world of the Web seemed far closer to Cyberspace than anything done in VR at the time. While the hardware flopped, the term remained chronically over-used in media, and firms developing VR abandoned existing hardware pathways or died out.

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[15] 'Virtual Research Systems: Window VR', *Virtual Research Systems* <http://www.virtualresearch.com/products/win_vr.html> [accessed 7 August 2017]; Charles Passy, 'Face Reality: Vitual Boy Is $180 Flop', *The Palm Beach Post*, 132; Curtiss, Aaron, 'New Nintendo 64 Is a Technical Wonder', *The Los Angeles Times*, 29 September 1996 <http://www.newspapers.com/image/160128801/?terms=%22virtual%2Bboy%22> [accessed 14 March 2018]; Edward Rothstein, 'Mario's Back', *The Springfield News-Leader*, 2 December 1996 <http://www.newspapers.com/image/207774344/?terms=%22virtual%2Bboy%22> [accessed 14 March 2018].

[16] Bob Tourtollotte, 'When Reality Proves to Be a Virtual Damp Squib', *The Times of India* (6 September 1995), section Business Times, 19.

[17] Charles Passy, 'Face Reality: Vitual Boy Is $180 Flop', *The Palm Beach Post*, 132; Curtiss, Aaron, 'New Nintendo 64 Is a Technical Wonder', *The Los Angeles Times*, 29 September 1996 <http://www.newspapers.com/image/160128801/?terms=%22virtual%2Bboy%22> [accessed 14 March 2018]; Edward Rothstein, 'Mario's Back', *The Springfield News-Leader*, 2 December 1996 <http://www.newspapers.com/image/207774344/?terms=%22virtual%2Bboy%22> [accessed 14 March 2018].

It appeared that VR developers had misunderstood the target of public excitement for cyberspace. Such intense interest was not for developers' products but promises of a new information medium. While VR developers felt consumers had become bored waiting for VR technology to catch up to the hype espoused by Rheingold's book and others, there may have never been much appetite for it. VR was not, as many in the business hoped, the future of media, and this only became clear in the second half of the decade. By 1996 *Whole Earth Review*, *Mondo 2000*, and *Omni* had collapsed, Cyberpunk was out of fashion, and the *aesthetic* lure of Gibsonian cyberspace was fading.[18] The Internet was the new Cyberspace, and it was cheaper, more comfortable, and more social than VR had even promised to be.

Without science fiction applications, VR research fell back on its core uses; data management, simulations, and training. 'VR' and 'Virtual Reality' remained in widespread use, divorced from their material roots, and applied to communications, work, and play through other non-VR systems. In this chapter, the drastic change from hailed zeitgeist to appropriation and misattribution is explored through the convulsions in media, public opinion, and technological change that defined the period.

LOST IN TRANSLATION: THE MOVE FROM STATE-INSTITUTIONS TO PRIVATE-CAPITAL

Returning to the early 1990s, several private companies were working under the moniker of VR. Telepresence Research had developed from the ashes of NASA's VIEW project, which was riddled with personality clashes as much as technical hurdles, Scott Fisher felt his own company could develop VR faster, much like Lanier with SRI in the 1980s.[19] With VPL's bankruptcy, US VR development moved away from its earlier developers entirely. VPL continued working for several years afterward but shifted toward more 'affordable' products. The numerous firms joining it each pursued their own strands of VR R&D, depending on their strategy and staff.

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[18] Arturo Escobar, David Hess, Isabel Licha, Will Sibley, Marilyn Strathern, and Judith Sutz. 'Welcome to Cyberia: Notes on the Anthropology of Cyberculture [and Comments and Reply].' *Current Anthropology* 35, no. 3 (June 1, 1994): 211–31. doi:10.1086/204266.

[19] Stephen Ellis, Interview, 11 July 2017.

Computer technology firms, in general, were highly insular at this time, with a rapidly expanding computer market driving struggles for industrial pre-eminence, leading standards, and bleeding edge products.[20] Competition hampered sharing of research and the establishment of standards, and this was particularly prominent among VR firms. A lack of shared purpose was clearly visible. John Perry Barlow, an activist and lyricist, evangelised VPL's cyber-anarchic and free-thought VR applications in a call to digital action which resounded with many.[21] Autodesk's research, on the other hand, was more utilitarian, and cost oriented. Other VR firms lacked the capital to make themselves known at the time, and their desire to hide their research from competitors furthered the independence and lack of clear public message on what VR was.

VPL's iteration of VR became one of the most public facing, with Barlow's Electronic Frontier Foundation highlighting VPL's hardware at Cyberthon in 1990. A mixture of Cyberpunk counter-cultural pressure and Silicon Valley money drew interest from a diverse group, from hackers to journalists, Wall Street investors, and celebrities, who had a chance to try commercial VR systems of the time.[22] 1990s was still early days, however, and only three VR firms attended: VPL, Autodesk, and Sense8. The shortage of usable units meant that access to VR at Cyberthon was via raffle, hampering exposure but furthering mystique.[23]

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[20] James Van Dusen, Interview, 8 May 2017; Asch, Interview, 14 May 2017.

[21] Thomas Rid, *Rise of the Machines: A Cybernetic History* (2016), 225-6; Chris Chesher, *Colonizing Virtual Reality: Construction of the Discourse of Virtual Reality, 1984-1992*, 1 (1994), 1 <http://cultronix.eserver.org/chesher/?utm_source=friendfeedlikes&utm_medium=twitter> [accessed 5 June 2017]; John Perry Barlow, 'Being in Nothingness', *Mondo 2000*, 2, 1990, 37-44; and also Barlow, John P., 'A Cyberspace Independence Declaration', 9 February 1996 <https://w2.eff.org/Censorship/Internet_censorship_bills/barlow_0296.declaration> [accessed 5 June 2017].

[22] Escobar, *et. al.* 'Welcome to Cyberia', *211.*

[23] Rid, *Rise of the Machines*, 23-43.

Despite limited availability and poor-quality hardware, Cyberthon was, for many, a demonstration that VR was *possible*, away from the occluded wonder of military and NASA research. Frontier rhetoric was a strong part of early VR journalism and evangelism, framing the visible chasm between portrayal and technological reality.[24] Cyberthon didn't run as planned in following years, perhaps down to a lack of funding (although the EFF persists into the 21st century). Subsequent years would have offered more firms to Cyberthon however, as the 1990 crèche of private firms spawned many more companies working on discrete virtual realities.[25] None of them were willing to co-operate technically. Pop Optix, one of the first VR firms to come out of the late 1980s, focused mainly on displays and optics, and did not offer total VR systems (i.e. including a computer and software). The headsets, as with all VR products, were costly, being $8000 for 1993's Cyberface 2, and $10,000 for 1994's Cyberface 3. In addition, of course, a powerful computer and specialist software would be needed. While free software was available, its basis in the LISP programming language limited adoption, due to its predominantly academic application base.

Division, Sense8 Corp, W Industries, and VPL Research did provide total VR systems. Most of which sourced components from third party vendors, although W Industries made the *Virtuality* system in-house. Regardless of source, total systems were costly, with VPL's *RB2 Professional* costing between $65,000 and $430,000, Division's *PROvision* between $50,000 and $200,000, and W Industries *Virtuality* $60,000. These systems were sold primarily to universities and other VR firms, with some large businesses purchasing individual systems for pilot programmes (the auto industry, in particular, would go on to adopt VR for car design).[26] Most of the applications at the time were in simulation and design, and thus primarily IA.

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[24] Chesher, *Colonizing Virtual Reality*, 1994; Rheingold, *Virtual Reality*, 154, Barlow, 'Being in Nothingness'.
[25] Asch, Interview 14 May 2018.
[26] Grigore Burdea and Philippe Coiffet, *Virtual Reality Technology (2003),* 355-6; 'Computers Mold Motion into Virtual Reality', *The Pantagraph* (6 April 1992), 23.

By 1992-3 lower-cost systems began to emerge in competition. Sense8's *WorldToolKit* VR system cost between $3,500 and $12,500 depending on hardware and VPL began offering a 'budget' VR system called *Microcosm* for around $75,000, presumably in an attempt to return to financial solvency.[27] The extreme costs of the systems were caused by the small production runs and high-technology involved, but this was compounded by companies like VPL seeking to provide a 'Rolls-Royce' experience in contrast to the cheaper conventional PC-based systems.[28]

Between these systems, however, there was considerable variation, due to insular corporate policy and a wide range of approaches to realising the hyperinflated expectations placed upon VR in the early 1990s. Division offered bespoke VR creation software (a C Library), but a VPL DataGlove was mandatory. Sense8 Corp also sold a C Library which used different virtual models and was compatible with a wide range of computers (PC, Sun, Silicon Graphics (SGI)) and input devices, from Logitech mice to DataGloves. The flexibility of Sense8's system brought it closer than any other to forming a technical standard, but lacked a stable ecosystem to grow within. Regardless, NASA Ames used the software in the early 1990s and drove their VR research systems through to 2018.[29] The W Industries Virtuality lacked a C Library but included software to build an entire world from the code up, though it could only run on Amiga computers. Similarly, VPL's total systems lacked most of the software needed to integrate it with computer systems, except for their landmark modelling suite *Swivel 3D*, as well as having limited compatibility, *RB2* for SGI workstations, and *Microcosm* for Macintosh.[30]

Total systems aside, HMDs were made and sold by at least a dozen companies by 1992-3. HMDs split into two rough technical archetypes; high-resolution monochrome Cathode Ray Tube (CRT), and low-resolution colour Liquid Crystal Display (LCD). The convincing virtual worlds in *The Lawnmower Man* were simply impossible but were nonetheless expected by consumers and investors, and colour displays were integrated by most VR firms in an attempt to approximate the vibrant, colourful worlds of VR mock-ups in advertising materials while lacking the technology to do so.[31] Advanced Technology Systems (a.k.a V.R.G), Kaiser Aerospace, and Pop Optix (trading as LEEP Systems Inc. in the very early 1990s) all offered monochrome HMDs in high resolution (1280x1024 pixel). The representations of Virtual Environments in marketing materials were almost never generated through an HMD, but companies had to try and duplicate the hype they created, resulting in products too expensive for consumers to buy, and which lacked even an approximation of the capabilities the interested public had come to expect.[32] CRT-based HMDs could achieve far higher quality in colour, but were heavy and fragile, mandating the use of new LCDs. No VR company was wealthy enough to make its own LCD panels, so they were taken from other, more successful, technological systems. At first, this meant portable televisions, the screens of which found their way into LEEP, VPL, Virtual Research, and Virtuality HMDs. Polhemus and VRontier Worlds colour HMDs, released in 1992, used screens from camcorder viewfinders with a colour resolution between 360x240 and 442x238 pixels. LCD HMDs of the time offered about a tenth of the resolution of CRT-based HMDs, in exchange for colour images and lightness, which implies that companies thought consumers would be willing to take a considerable reduction in visual acuity in exchange for those features. The highest resolution colour display for sale at regular consumer prices (around $10,000) was Liquid Image Corporation's Mirage HMD, which offered a 720x240 pixel widescreen colour display for $9,500.[33]

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[27] Pimentel & Teixeira, *Through the New Looking Glass*, 254-278.

[28] Rob Ponting, '3-D Displays', *InfoWorld*, 11/30, 24 July 1989, 22.

[29] Ellis, Interview, 13 March 2018.

[30] Jaron Lanier, 'VPL Software Lives! VPL Software Lives' <http://www.jaronlanier.com/vpl.html> [accessed 26 April 2017]; Pimentel & Teixeira, *Through the New Looking Glass*, 78.

The novelty of LCD displays was the prime limiting factor on resolution of miniaturised versions. As the screens source for HMDs shrunk, coming from portable TVs, then viewfinders, so too did the

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[31] Ellis, Interview, 11 July 2017.
[32] Ibid, Tony Asch, *Review Notes*.
[33] Richard Holloway and Anselmo Lastra, 'Virtual Environments: A Survey of the Technology', 1993, 14.

FoV of the HMD, which hampered immersion and the poor optics increased eye strain. Reliance on other industries forced VR companies down non-optimised technical pathways, creating endemic display quality problems in the VR business. Repurposing HMD based VR for entertainment, which was very different from its data-visualisation roots, required advances in displays which were not possible for such a small 'industry' to achieve. Tom Furness's Super Cockpit seems to have been the only VR system with high-resolution colour displays, principally because it relied on considerable Air-Force funding to make bespoke LCDs. While the Super Cockpit LCDs could not be purchased, Canadian military contractor CAE, simulation experts who had built systems for, among other things, the VR attractions at Disney World in Florida, offered a 1000x1000 line resolution full-colour CRT HMD, with integrated motion tracking and fibre-optic inputs, costing $1,000,000 in 1992.[34]

Boom-type displays like the Fake Space BOOM (fig. 7), formed the main alternative to HMDs. Fake Space Labs and LEEP systems both offered Boom displays, which suspended the display on a mechanical arm, allowing for heavier, higher-resolution displays and more accurate absolute position tracking via use of rotary encoders built into the arm. The Fake Space BOOM cost around $74,000 and the LEEP Freedom Boom around $10,000 (though as monoscopic, it does not constitute a VR display). Reflection Technology made a monocular HMD, *Private Eye,* marketed as VR, and costing just $500, and they planned but never completed a monochrome CRT stereo display for 1993.[35]

Other companies made a range of devices beyond displays or total systems, such as 3D mice, gloves, body suits, and haptic feedback devices, including Airmuscle, Xtensory, CM Research, EXOS, Mattel, Virtex, VPL, Polhemus, CiS, Spaceball, Ascension Technology, Gyration, Logitech,

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[34] Pimentel & Teixeira, *Through the New Looking Glass*, 256-7.

[35] Ibid, 261; Sandra Helsel and Jeffrey Jacobson (eds.), V*R World's Virtual Reality Market Place 1994* (1994), p. 37.

MULTIPOINT, SimGraphics, Shooting Star, GEC Ferranti, and Spatial Positioning systems. VR input devices were more varied than displays, numerous gloves made by Airmuscle, VPL, Virtual Technologies, Exos, and Mattel, differed in precision and build. Some, like the Airmuscle Teletact, used inflatable air pockets and a compressor to exert pressure on the hand, allowing users to 'touch' virtual objects. The gloves all cost between $4,000 and $15,000.

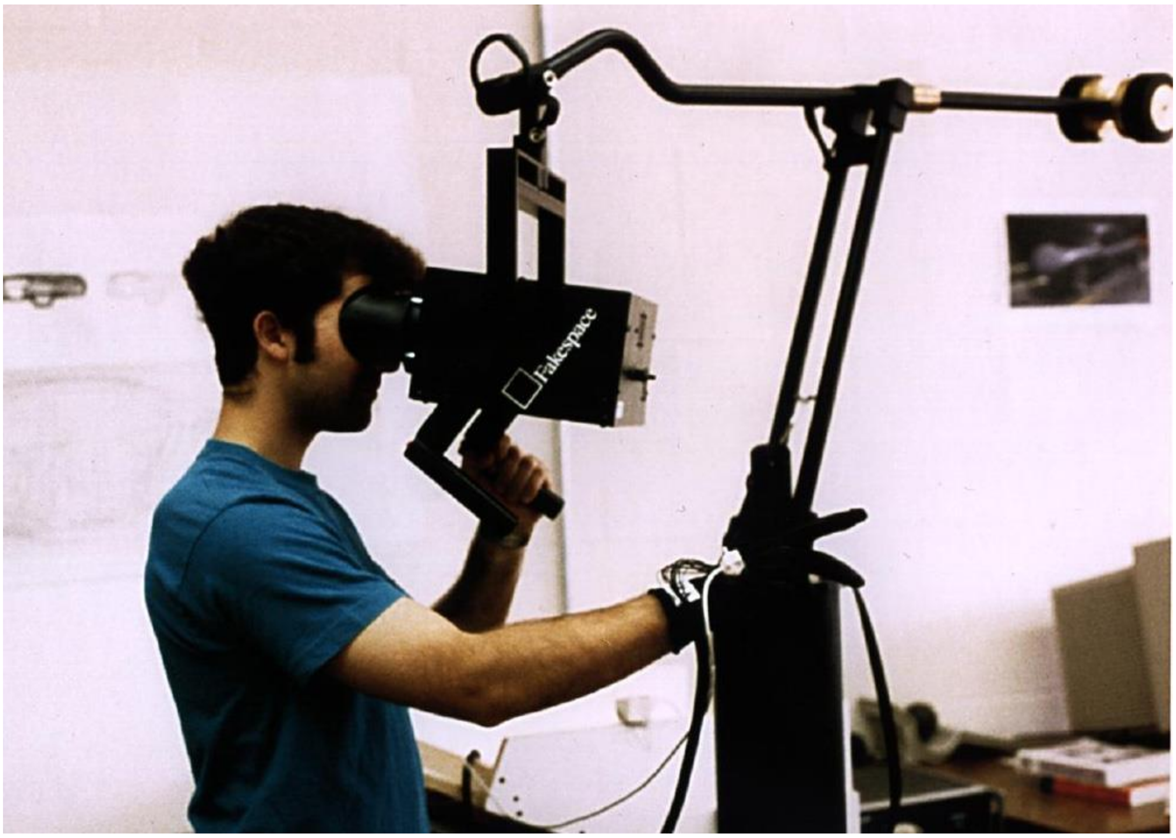

FIG. 7 A Fakespace BOOM VR display. The more accurate display and tracking afforded by the boom was offset by requiring a hand on it at all times. Image credit K.P Beier, University of Michigan.[36]

Space balls were another form of computer input seen in some VR systems of the time, comprising a sphere mounted to a surface which could track the forced applied to it, CiS' Geometry ball and the Spaceball 2003 were prominent examples. The most ubiquitous input devices, however, were 3D mice, which could be lifted from the desk and used in mid-air, with varying levels of accuracy and freedom. The Ascension Bird and Spacepad, Gyration GyroPoint, Logitech 3-D Mouse,

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[36] Klaus-Peter Beier, 'UM-VRL: Virtual Reality: A Short Introduction' <http://www.umich.edu/~vrl/intro/> [accessed 7 June 2017].

Multipoint Z Mouse, Polhemus IsoTrak, FasTrack, and InsideTRrak, and SimGraphics Flying Mouse all worked in roughly the same way but had widely ranging costs, between $250 (Z Mouse) and $4,000 (Flying Mouse). The most popular appears to have been the Logitech 3-D Mouse, which used ultrasonic motion tracking and cost $1,000 in 1993.[37]

By 1993-4, VR businesses had multiplied, and VR trade shows were large enough to draw sizeable crowds. Alan Meckler's Mecklermedia had run such shows from 1990, but the 1994 VR Expo was on a larger scale.[38] The company also published *Virtual Reality World*, a bimonthly magazine which ran from spring 1993 through to December 1994, and a handful of journals and books discussing VR, principally *Virtual Reality Market Place, VR Report,* and *VR: An International Directory of Research Projects* in 1994. The first Meckler VR Expo ran in California in May 1994, and then New York in December, and they turned out to be the last of their kind. While present at the brand-new Electronics Entertainment Expo (E3) 1995, VR was but a part of a larger tech convention ecosystem.[39]

Between Cyberthon and 1994 expo, SIGGRAPH and other computer conferences and trade shows saw VR companies attend, particularly as promotional tools in engineering and pharmaceutical shows, where VR technology showcased a firm's cutting-edge credentials.[40] These shows were often the only chance for people to see and interact with high-end VR gear and can provide insight into the anticipation, and misapprehension, surrounding VR at the time. For instance, at the Education Foundation of the Data Processing Management Association Conference on Virtual

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[37] Pimentel & Teixeira, *Through the New Looking Glass*, 269; 'Ascension Technology Corp » Product History' <https://www.ascension-tech.com/products/product-history/> [accessed 10 July 2017].

[38] William Safire, 'On Language; Virtual Reality', *The New York Times*, 13 September 1992 <http://www.nytimes.com/1992/09/13/magazine/on-language-virtual-reality.html> [accessed 14 May 2016].

[39] Atari Explorer Online, *AEO at E3 1995* (1995) https://www.youtube.com/watch?v=fC9ZJWHFjhc [Accessed 28 March 2018].

[40] Asch, Interview, 14 May 2017.

Reality in Washington, DC on the 1st of June 1992, Steve Ellis recalled in an interview with the author that:

> I gave a kinda introductory speech with my virtual environments, virtual image, virtual space thing... and afterwards they had some demos, and they had some of the latest VPL stuff, and I was waiting in a line, and there was a woman behind me who, earlier in the meeting, had gotten up on the podium, and given a talk about a users' group that she was running about VR, and she was all enthusiastic and wanted people to come, this was a Usenet group, and had all sorts of ideas about how to advance the technology, and then in the line, she happened to be behind me, she confided in me that she had never actually used one of these systems, but she was already out there organising for it, and then I realised this thing had really hit a nerve.[41]

At the same time, marketing hype was approaching a crescendo. Movies, TV shows, and toys all had VR connections (such as in Fig. 8), and hundreds of American companies were working on various aspects of the VR brand. 'VR' was often applied to products regardless of their connection to VR itself. The excitement encouraged the formation of a dedicated, large-scale trade show like the 1994 expo, which usefully provided a companion publication charting 134 active companies in 1993, and 209 in 1994. Considering that by 1994, over 25 of 1993's VR firms had shut down, in the space of a year, more than 100 new VR firms attended the expo.[42]

This boom was partially hollow, however. Many of those 'VR' firms called themselves such but provided consulting or peripheral technology for VR applications from other companies. Many firms in attendance did not use 'VR' in mission statements, suggesting many may have been at the expo to be seen, rather than because they contributed to the technological system. Only the firms in Table 1 used 'VR' or 'Virtual Reality' explicitly, which paints a picture of the mid-1990s VR technology scene.

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[41] Ellis, Interview, 13 March 2018.

[42] Helsel & Jacobson, *Virtual Reality Market Place*, 1994.

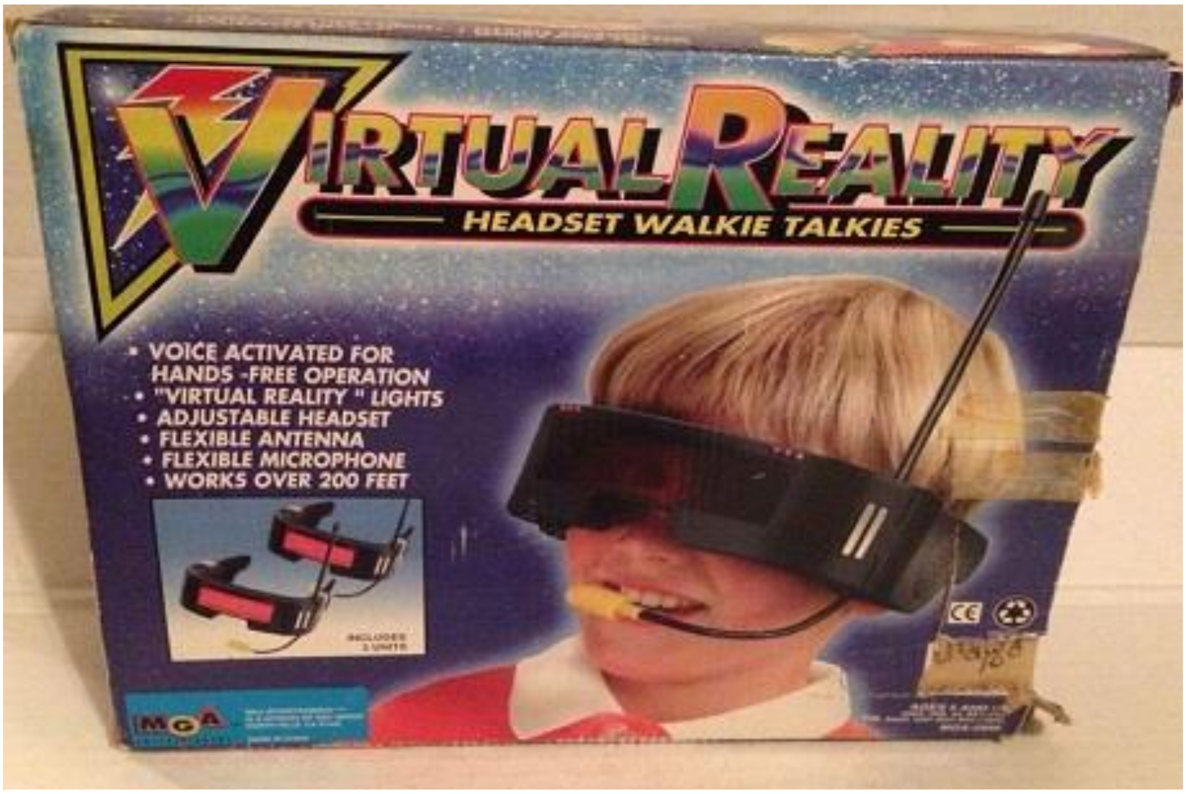
VIRTUAL REALITY
HEADSET WALKIE TALKIES
• VOICE ACTIVATED FOR HANDS -FREE OPERATION
• "VIRTUAL REALITY " LIGHTS
• ADJUSTABLE HEADSET
• FLEXIBLE ANTENNA
• FLEXIBLE MICROPHONE
• WORKS OVER 200 FEET
INCLUDES 2 UNITS
MGA
CE

FIG. 8 Released in 1995, this Micro-Games America toy used a mock visor and ‘Virtual Reality lights’ to emulate VR, despite being unrelated. Credit: the VR shop, 2016 <https://www.virtual-reality-shop.co.uk/virtual-reality-headset-walkie-talkies/> [accessed 7 June 2017].

That these total only around a third of the firms in attendance suggests that the ‘VR’ term was considered either inapplicable or undesirable by VR firms in 1994. The use of ‘Virtual Environment’, ‘Artificial Reality’, and other terms highlights the lack of common language for the technology, which prevented consensus on project goals, and kept VR company products separate from stable technical foundations and expertise. Many of these VR firms may not have produced *any* products.[43] Apart from Virtuality, LEEP Inc, Division and StrayLight Corp., the main VR firms did not use ‘VR’ as the term was so connected to hype, instead emphasising their reliability of service, further suggesting problems with VR systems’ performance.[44] This change in connotation, wrought by excessive hype for the VR ‘brand’, was discussed in the NSA’s *Cryptologic Quarterly* in 1993.[45]

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[43] Asch, Interview, 14 May 2017.

[44] Tony Asch, ‘How to Make VR ‘Real”’, *Virtual Reality Report*, 1/6 (1991), 3–4.

[45] *Cryptologic Quarterly*, 21–50.

A-G	I-T	T-X
Adams Consulting Group	Interactive Associates	Transformation Software Ltd.
Audio Cybernetics	InterActive Simulation Inc.	The University of North Carolina Center for Research in Journalism and Mass Communication
Atlantis Cyberspace	InVideo Systems, Inc.	VictorMaxx Technologies
Avatar Partners	ISCAN	Viewpoint Datalabs
Bristlecone Corporation	LEEP Systems Inc. (AKA Pop Optix)	VIRTOOLS
Ciné-Med	Lepton Graphics Systems	Virtual Images Inc.
Computer Graphics	Mak Technologies	Virtual Reality Group
Systems Development Corporation	Mecklermedia Corporation	Virtual Research
The Columbia University Computer Science Department	Media Magic	Virtual Reality Inc.
Cutting Edge Computer Consulting	Newtech Video and Computer	Virtual 'S' Ltd.
Cyber Reality Systems	PCVR Magazine, Reactor Inc.	Virtuality (UK-based, but dominated US LBE VR systems)
CyberCube Corp.	RPI Advanced Technology Group	Virtus Corporation
CyberEvent Group	Shooting Star Technology	Visions of Reality Corporation
Cybereye Limited	SimGraphics Engineering Corp.	VR News
Cybermind Corporation	Simsalabim Systems Inc.	VREAM Inc.
The David Sarnoff Research Center	SophisTech Research	VRASP
DEC	SRI International	Waite Group Press
Division Inc. (UK based but with a larger presence in the US than in its home country)	StereoCAD Inc.	Wordswork
Forte Technologies Inc.	Stereographics Corporation	Worldwide Target Demographic Television
General Reality	StrayLight Corp.	WorldsBest
Go Virtual	Stratos Product Development Group	Xtensory Inc.
Glass Mountain Optics	Technalysis	

Table 1: List of Companies using 'Virtual Reality' or 'VR' in their marketing materials in 1995

Their concern echoed sentiments from Laurel, Lanier, and others: the overuse of 'VR' damaged its future. Painting VR's potential with a broad brush by businesses and media alike had warped public expectations far beyond technical possibility.[46] The *Quarterly's* observation that 'despite all the media attention and hype, VR development is still in its early stages. Major hardware deficiencies exist…' would likely have resonated with few, and shocked many for whom VR was the imminent future of content.[47] Concern about this risk led the VR magazine *CyberEdge* to produce and sell pin badges condemning hype, often worn by the very VR advertisers, journalists, and businesspeople responsible.[48] The popularity of these badges at the time demonstrates not only that people were becoming aware of the hype, but that it was not entirely regarded as a good thing. Without hype though, investment in the fantastical promises from VR companies would have dried up, and so the fervour continued, perpetuating media excitement in entertainment, as well as journalism. Shows like *V.R. Troopers* (1995), movies like *The Lawnmower Man* (1992), novels like *Disclosure* (1994), and video games like *Dactyl Nightmare, Legend Quest,* and *Lawnmower Man* cemented an exaggerated vision of VR's power in the context of numerous books and articles extolling the technology's power, potential, and virtues.[49]

The excitement and interest seemingly generated by VR reverberated in a journalistic echo chamber and peaked in 1994. Countless articles erroneously portrayed the technology's potential and boundless future.[50] A key reason for the disconnect between public optimism and technical reality seems to be Western media's hunger for attention. 1990s tabloid journalism exhibited itself as printing articles with attention-grabbing content, regardless of its journalistic integrity, and VR was at the forefront. Contrary to suggestions by Lanier, Rheingold, and others that it was the journalists alone who created the VR hype, VR companies were providing the fuel. The former CEO of VR developer StrayLight, Tony Asch, recalled in an interview that:

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[46] Ibid, 47

[47] Ibid, 22; Roy Kalawsky, *The Science of Virtual Reality and Virtual Environments: A Technical, Scientific and Engineering Reference on Virtual Environments*, (1993), 251-3.

[48] Ben Delaney, *Sex, Drugs and Tessellation: The Truth about Virtual Reality, as Revealed in the Pages of CyberEdge Journal* (2014), 1; and also Steve Ellis, Interview, 12th Apr 2018.

[49] *V.R. Troopers* (1994); *The Lawnmower Man*, 1992; Michael Crichton, *Disclosure*, New Ed (1994); W Industries, *Dactyl Nightmare* (1991); W Industries, *Legend Quest* (1991); Simon Pick, *The Lawnmower Man* (1993).

[50] Louis Brill, 'Your Home Is Your Virtual Reality Castle', *CD - ROM World; Westport*, 9/7 (1994), 12; Glenn Cartwright, 'Virtual or Real? The Mind in Cyberspace', *The Futurist; Washington*, 28/2 (1994), 22; Homan, 'Real Promises…', 1994; Barbara Schmitz, 'Separating Myth from Reality', C*omputer - Aided Engineering: CAE; Cleveland*, 13/10 (1994), 58; 'Japan: Tokyo: Nintendo Introduce New 3-D Virtual Reality system' (1994), Associated Press Video Collection; 'USA Army Uses Virtual Reality technology to train troops' (1994), from Associated Press Video Collection, streaming video <http://ebscovideos.ebscohost.com/v/102209212/usa-army-uses-virtual-reality-technology-to-train-troops.htm> [accessed 22 May 2017].

> Editors, you know, everything from technical magazines to… broad-based regular media and we got about a fifty percent hit-rate [on their mailed press releases]… and I always laugh because they would reprint our press releases including the typographical errors… this is not bragging, because I think all of the people in VR kind of had the same experiences, it was just like 'wow yeah we could, you know, there's a really cool photo we can put on the front or the lede of our magazine' and you could tie it into anything, you could send it to a magazine for weavers, and somehow you could work in weaving into the first couple of sentences of the article, and you'd know that they'd publish it, even though it had absolutely nothing to do with what their industry was about. It was a great come-on for their readers.[51]

Both Asch and Rheingold mentioned this phenomenon, where marketing hype was printed as fact, due as much to lax editorial standards as to avarice. Such careless faith extended all the way back to the business itself, hence the host of companies at VR trade shows not selling VR. Companies like Minus Habens Records, Ixion, and RPI Advanced Technology Group, which claimed to offer VR sound, software, and hardware options respectively, but appear not to have sold actual VR products.[52] Ixion, a consulting firm, claimed to have around 20 employees and started trading in 1993, Minus Habens was older, but its sole 'VR' was a magazine and pamphlet discussing the future of VR, and a CD of electronic music. Despite this, both of these firms sold themselves as VR providers, as it gained more interest or attention.

RPI Advanced Technology's 1994 mission statement self-referred to 'America's oldest operating VR and Multimedia firm' with a founding date of 1969. However, besides registering a couple of patents for a 'VR Chair' in 1999, it doesn't appear to have sold a single VR product, despite offering HMDs, motion trackers, and 'semi-immersion full-D chairs'.[53] Plausibly the early-to-mid-1990s VR market was awash with companies marketing non-existent VR products and selling non-VR products as VR, further confusing and weakening the term itself.[54]

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[51] Asch, Interview, 14 May 2017.

[52] Helsel & Jacobson, *Virtual Reality Market Place*, 1994, 28, 33, 38.

The disparate range of VR companies and language was further hindered by, and indeed highlights, the lack of any market leader to establish standards or common platforms in an artificially flooded market. The handful of consumers that actually bought VR hardware in 1993-4 were private and state-funded institutions, as wealthy individuals apparently often felt of VR 'that's promising, but promising isn't something I'm going to spend my money on.'[55] A lack of standards led to a glut of hardware options, but limited applications, and wealthier organisations had to choose the makeup of their VR system from a vast range of options, leading to confusion highlighted in the NSA's *Cryptologic Quarterly* in 1993:

> Vendors offer a vast array of display devices, interaction devices, computational environments, and even application development software for VR systems. Choosing among all the different devices can be a time-consuming process; integrating all the components is even more difficult.[56]

- 'Virtual Reality', *Cryptologic Quarterly*

This disarray was confounded by the existence of companies like RPI which distributed marketing material for VR hardware which did not actually exist (i.e. vapourware). RPI claimed in contemporary private business correspondence that hardware would be provided 'upon receipt of our next round of funding, or a 50,000+ unit distribution program, whichever comes first' implying a lack of clear funding provision or distribution.[57] RPI also claimed to lack standard products or product sheets, suggesting their products were still in the prototype stage.

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[53] Ibid, 38; Asch, Interview, 14 May 2017; Frans de la Haye, 'Chair Assembly, in Particular a Chair Assembly for Use in Virtual Reality Devices', 1999 http://www.google.com/patents/US6056362.

[54] Raymond Williams, *Keywords: A Vocabulary of Culture and Society*, Expanded ed. (1983).

[55] Howard Rheingold, Interview, 11 April 2017.

[56] 'Virtual Reality', *Cryptologic Quarterly*, 12/3–4 (1993), 45.

RPI was not alone in this. Of the 44 companies in 1994 which claimed to sell VR hardware, only 10 visibly did so. The most successful of which was Bruce Bassett's Virtual Research, based on sales figures provided by Mr Bassett, showing sales of HMDs grow from 11 in 1991 to 107 in 1995. These would have been a mixture of Flight Helmets, EyeGen, and VR4 HMDs, and far outsold the products of any other VR manufacturer of the era.[58] Virtual Research's customer base was made up of universities, private organisations, and rivals including Division, Fakespace, General Reality, Cybercube, and Argus VR. High manufacturing costs kept profits low, but Virtual Research still dominated the market unchallenged until the 1996 VR crash, at which point it was planning to enter the LBE VR market (but did not then do so).

Aside from the lack of challengers, Virtual Research's success seems rooted in the comfort and ease of use offered by its flagship HMD, the Flight Helmet, which could be worn with eyeglasses.[59] It was also mentioned in around 80 academic publications between 1990-5, more than any other HMD. NASA Ames made use of the Flight Helmet and subsequent V4, V6, and V8 HMDs from Virtual Research well into the 1990s.[60] Even so, the Flight Helmet was dependent on Sony portable TVs for the LCD screens, and when those TVs were discontinued, the Virtual Research was forced to cease production of the Flight Helmet. VPL's research presence overall is greater, due to the age and pre-eminence of the DataGlove, not for displays. The 'success' of 100+ total annual company sales illustrates the size of the VR market at the height of the craze, reinforcing the impracticality of so many competing firms. The significant oversaturation did not deter many from trying to become the leader of an incredibly small but culturally popular market, resulting in the heightened visibility of over-hyped, poor-quality VR gear in the US at the time.

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[57] Anthony Ryder, Business correspondence, 'RE: Your FAX of 3/3/93', 3 March 1993, RPI, StrayLight Private Archive.

[58] Bruce Bassett, 'Scannable Document on Jun 26, 2017, 9_58_26 AM,' n.d. Personal archive of Bruce Bassett.

[59] Asch, Interview, 14 May 2017; Nadia Magnenat-Thalmann, and Daniel Thalmann, *Artificial Life and Virtual Reality* (1994), 129-30; Pimentel and Teixeira, *Through the New Looking Glass*, 258.

[60] Ellis, Interview, 13 Mar 2018.

EXPANSION AND FAME: THE VR BOOM OF THE MID-1990S

The term 'VR' was applied more broadly into the mid-1990s while use in Woolley's *Virtual Worlds* and numerous articles in the *Washington Post*, *New York Times*, *Scientific American*, *TIME Magazine* and others maintained its credibility.[61] Awareness and discussion were often at some remove from actual experiences with VR, with access restricted by prohibitive costs and limited production.

Access then, for many, was possible only in the arcade. W Industries (trading in the US under the name Virtuality) dominated this market, with several static VR systems for gaming arcades from the early 1990s. These devices were important, as they were the point of exposure for most people to actual VR technology. The technical quality and content was well surveyed in Schroeder's *Possible Worlds*, but merits revisiting to place those VR games in the broader entertainment industry and allow comparison with expectations and non-arcade VR products.

At the time, the video game industry was enjoying considerable growth in the US. It had expanded from arcade-based services to in-home ones in the early 1990s with games consoles like the Super Nintendo, Atari Jaguar, and Sega Genesis. The successful in-home market fuelled innovation in gaming software and peripheral design (such as light-guns and controllers). The limited range of games and high endemic costs of the arcade scene, coupled with the partial collapse of the US gaming industry in the 1980s, had pushed Japanese games consoles for the home to the forefront of the market. Thus, owning a console and games privately became a more prevalent model for gaming in the 1990s US. Between 1987 and 1993 the value of the in-home video game market went from $750m to around $6.5bn (the equivalent of $1.5bn to $10.6bn in 2015).[62]

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[61] Mark Potts "'Virtual Reality"', *The Washington Post* , 1992 http://search.proquest.com/docview/140552270/abstract/embedded/EGPA1XVE7LNCWGWY?source=fedsrch ; Larry Hedrick, 'Reality Check - Virtual, of Course.', *Nation*, 269/7 (19990906), 25–28; Gary Chapman, 'Barbed Wired', *New Republic*, 212/2/3 (1995), 95–21; Safire, 'On Language', 1992; L. Shannon, 'Peripherals'; Lance Morrow, 'Living in Virtual Reality', *Time* May 16 1994, <http://content.time.com/time/magazine/article/0,9171,980734,00.html?iid=sr-link2> [accessed 7 June 2017].

Arcades were far more dependent on cash income, and thus liable to rapid changes in the market, and saw revenues in the US fall from $11.5bn in 1982 to $2bn by 1991 (or $28bn to $3.4bn in 2015). Seeking to reverse arcade fortunes, developers sought a novelty which console games could not reproduce at home, and this manifested as VR, among other things. Games consoles lacked the power to support such a technology in the early 1990s, nor did most computers, so VR was, for arcades, desirable, implementable, and unique. Virtuality machines, developed by Briton Jonathan Waldern's W Industries (established 1985), were distributed in the US by Horizon entertainment in October 1991.[63] Powered by Amiga 3000 computers, Virtuality arcade machines ran a small number of games, and numbered in the 200s nationwide (though this is an estimate), and were the largest single source of VR content to the American people.[64] Other sources existed in the form of the short-lived VR8 from 1993, though it only sold a few units.[65] StrayLight sold around 30 LBE VR systems in the early 1990s, but Virtuality dominated the arcade market up to 1995, at which point Nintendo and Atari both tried to adapt VR for the in-home console market.

Whether Virtuality games constituted VR, however, is questionable; the principle confounding factors of this are the freedom of movement afforded by the experience, the limitations of the virtual environment, and the visual acuity of the displays. Limited range of movement caused by having to stand or sit in a confined space while playing, hampered mobility and thus presence (fig.

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[62] 'Nintendo Revives Video Games', *The Press-Courier*, 30 July 1989, 20; Patricia McKanic, 'Video Values', *Lakeland Ledger (NYT Regional)*, 24 March 1994, 1E.

[63] Gareth Knight, '1000CS', *Amiga History Guide* <http://www.amigahistory.plus.com/virtuality.html> [accessed 8 June 2017].

[64] International Association of Amusement Parks and Attractions, *Funworld 10* (1994), p. 100.

[65] Andrew Williams, *History of Digital Games: Developments in Art, Design and Interaction* (2017); 174-5.

9). The games offered on the standing player 1000CS unit: Dactyl Nightmare, Grid Busters, Hero, and Legend Quest encouraged movement and exploration, but a highly limited range of player movement clashed with this. The problem expressed itself differently in the 1000SD Virtuality units, in which players had to sit in a close-hugging seat, with the helmet suspended from an arm behind it. Presence was hampered by the constant reminder that they were sitting, and stationary while being placed in a moving virtual environment. Virtuality tried to counter this by changing content for the 1000SD unit. Games like Battlesphere, Exorex, Total Destruction, VTOL, and Flying Aces were set inside vehicles, reducing the sensory conflict caused by sitting still, but the high costs of such static experiences disincentivised repeat users.

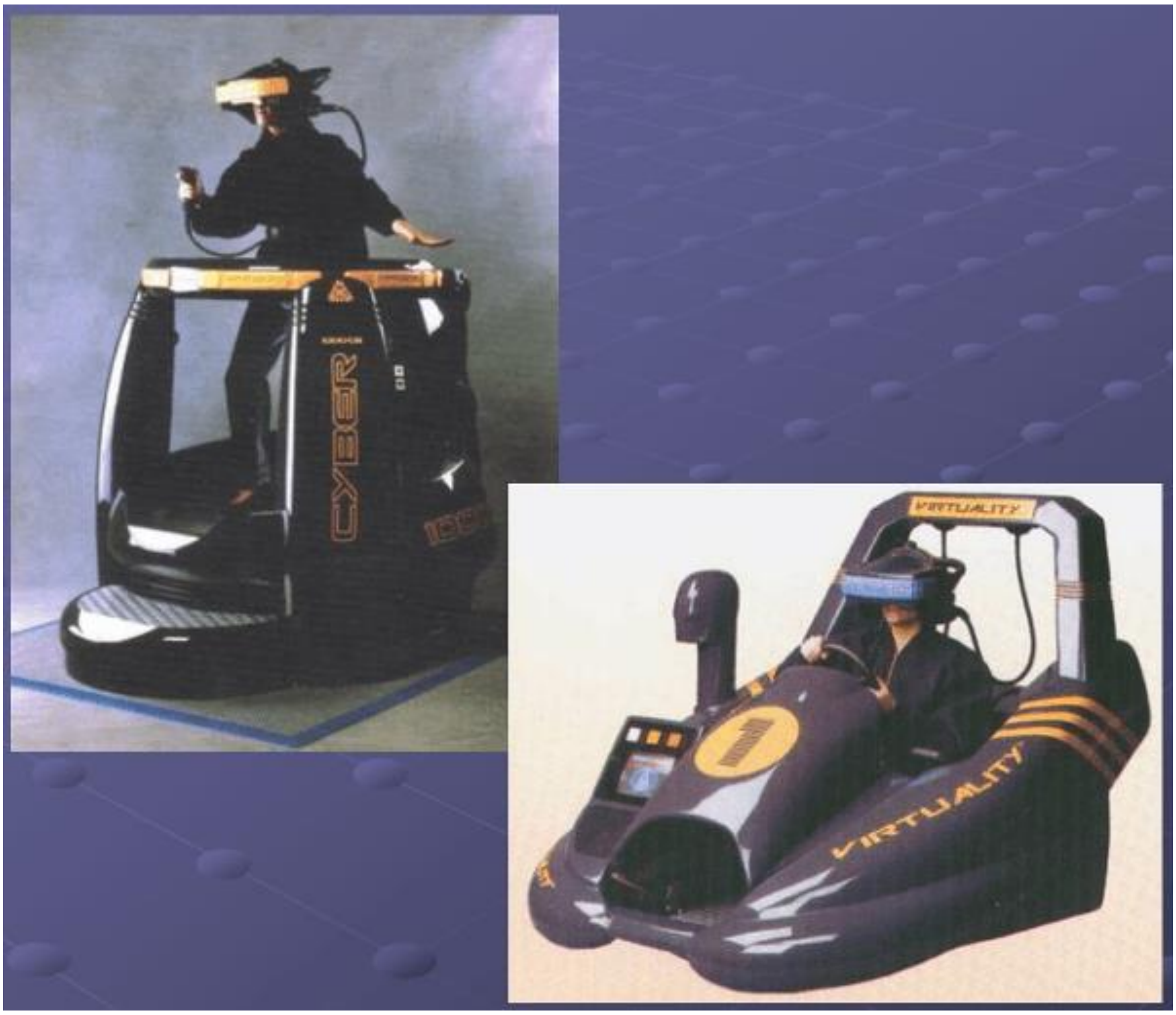

FIG. 9 1994/5 Models of the sitting and standing Virtuality arcade machines. Image courtesy Adam Pratt, 'Article: Looking At VR From A New Perspective', *Arcade Heroes*, 2014 <http://arcadeheroes.com/2014/03/11/article-looking-VR-new-perspective/> [accessed 8 June 2017].

The virtual environments in Virtuality games also, in some areas, fell short of what many understandings of VR seemed to hold true. Such environments are always limited by the power of the host computer but in the case of video games, also by the narrative. Games always have a story, and the inclusion of that in VR meant that the player pay attention to specific sounds and images, forcing the player at times down linear paths or forcing their gaze, limiting the degree of presence felt. Furthermore, the digital player avatar was often limited to a pair of hands or a disembodied weapon, presenting this in first-person 3D, and limiting the places that players could go, were considerable limiting factors to the sense of presence which is, for many, a common denominator of VR definitions.[66]

The primary limiting factor is the visual acuity of HMDs; their resolution, refresh rate, and latency. Cannibalising display technologies from other industries produced HMDs largely unsuited to the detailed, vibrant, responsive, large FoV requirements of VR. Producing larger, static VR units for arcades allowed for more computing power, but the displays themselves were low resolution. The fast motion tracking (and thus low latency) of Virtuality machines (using a Polhemus FasTrack) was noted by former Ames programmer Warren Robinett in 1991, though they were apparently poorly configured by inexperienced Virtuality engineers.[67] While responsive, users felt that the quality of the computer graphics, particularly the frame rate, was poor, and the cost of over a dollar per minute kept experiences short, disorienting, and unrewarding.[68] The poor displays were often orders of magnitude worse in resolution, contrast level, and vibrancy than those used in the Virtuality promotional materials (and in VR of the time generally), contributing to the disparity between expectations and real-world experiences of VR.[69] Paying for a VR game, and expecting to be transported to another world, only to find an experience, in the words of Myron Krueger, akin to being 'legally blind' was a jarring, incoherent shock.[70] A Virtuality machine installed at the Berkeley Student Union drew round-the-block crowds when it was first installed, but after a couple of weeks the machine was barely used, on account of the disappointing experiences and high cost to play.[71] The cost was reflective not only of the complexity of the machines to manufacture, but also their obligatory attendant, required by W Industries' legal department, due to concerns about the un-studied physiological and psychological ramifications of VR use. Virtuality's later collapse was arguably rooted in these higher costs, health scares, and the jarring shock between expectation and experience which severely curtailed return customers.[72]

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[66] Schroeder, *Possible Worlds*, 83-98.

[67] Asch, Review Comments; Schroeder, *Possible Worlds*, 85; Steve Ellis, Interview, 12 Apr 2018.

[68] Ibid., 86; Kyle Fowle, 'A Look Back at the Doomed Virtual Reality Boom of the 1990s', *Kill Screen*, 2015 <https://killscreen.com/articles/failure-launch/> [accessed 8 June 2017]; Eric Strand, *GIS World* (1993), VI, P.30.

[69] Alice LaPlante, 'Virtual Capitalists', *CIO; Framingham*, 5/14 (1992), 97.

While Virtuality machines were the most visible point of access to VR for most people in the 1990s then, they were not representative of the technological ideals or even potential of other forms of virtual environments. A unique aspect of some Virtuality games, which was hard to find outside of the arcade, however, was shared experiences. Time inside an HMD is profoundly isolating and intimate, and Lanier, Fisher, Laurel, and others hoped to counter this by allowing real people to interact in those virtual spaces. Achieving this over distance was extremely difficult in the 1990s, due to internet bandwidth restrictions. VPL's RB2 has this capability, which was used to justify its near-half-million-dollar price tag. Virtuality's systems achieved the same thing at a fraction of the cost by networking four Amiga 3000 computers, for shared play with up to four players. While this was a potent demonstrator of VR's potential, poor implementation meant players got in each other's way more than helped, and this was a cause of frustration for some.[73]

While clearly the most successful, and most publicised, the physical presence of Virtuality machines across the US was limited. Companies dominant within the in-home gaming market sought to capitalise on the hype while delivering a more profitable, player-friendly product. The Atari Jaguar VR and Nintendo Virtual Boy were both planned for release in 1995. Many VR companies, keen to monetise the excitement about their technology, saw the video game industry as a crucial vector for VR.

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[70] Pimentel and Teixeira, *Through the New Looking Glass*, 48.
[71] Ellis, Interview, 13 Mar 2018.
[72] Asch, Interview, 14 May 2017.
[73] Schroeder, *Possible Worlds,* 102-3.

The private VR business had failed to generate profit for much of the 1990s and thus been funded by the speculations of investors, as a result, many businesses saw the video game industry as a key source of revenue if that investor good will dried up.[74] While industrial and academic niches were pursued by a range of firms, the public interest of substantial video game companies in the mid-1990s was, for many firms, a sign of things to come. Nintendo's VR system had been in development with help from Reflection Technology since 1991 and produced prototypes by 1994, and the retail model a year later was demonstrated at E3 and the Consumer Electronics Show 1995. Atari's VR system developed from a partnership with Virtuality in 1994, supposedly in response to Nintendo's own project, and produced a working prototype at E3 in 1995. While Atari's Jaguar console was already on sale, the 'VR' peripheral never was, as Atari cancelled the project in 1995, perhaps because of the Virtual Boy's reception.[75]

Launched in the US on the 16th of August 1995, with a sizeable advertising campaign and press coverage, the Nintendo Virtual Boy promised an immersive VR gaming experience.[76] While sales estimates for 1995 exceeded 1.5m, actual sales totalled fully 350,000 units. The final game for the Virtual Boy was released in March 1996, and the console was discontinued in the US at that time, having been already pulled from shelves in Japan the previous year.

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[74] Ibid., 58-60; Rheingold, *Virtual Reality,* 371-2; Asch, Interview, 14 May 2017.

[75] Anon, 'Atari Drops Jaguar?', *Next Generation*, 2/13, January 1996, 21.

[76] Nintendo America, *Nintendo Introduces Video Game Players To Three-Dimensional Worlds With New Vr System*, 19, November 1994 <http://www.planetvb.com/modules/advertising/?r17> [accessed 9 June 2017].

A lack of content, technical shortcomings and misleading marketing were undoubtedly factors, but there was a broader systemic cause to the widely unexpected flop, expressed in Nintendo's attempt to anticipate and meet public need. More than the gap between promise and delivery, Nintendo clearly believed that the American public wanted a VR system, because the notion was popular in media, though this may have been misconstrued. Seemingly, the visible brouhaha surrounding VR throughout the early 1990s was not rooted in a desire for immersive gaming or computing, but for new ways to communicate and share human experiences, a core aspect of VR descriptions harking from Gibsonian cyberspace. A closed game system, regardless of capability, failed to meet this need, and the Virtual Boy thus offered VR, but the wrong parts of it. The experiences the Virtual Boy *could* provide were already accessible in other technologies at the time, in a slew of 3D video games for computers such as Doom, Duke Nukem 3D, and Myst, and the ones it *could not,* communication and shared media, were available on the new, meteoric World Wide Web.

American computer users had had varying degrees of internet access since the early 1980s, using a modem, a suitable phone line, and technical knowledge. The World Wide Web removed the technical aspect through use of a single address and protocol platform. As ease-of-access grew, so did users and content development. By 1995, a wide range of web pages existed, and the US telephone network was upgrading constantly to enable better communication among the network of computer networks comprising the internet.

Online communities, such as the Whole Earth Review's WELL, and LucasArt's Habitat, demonstrated that such social networks were possible and enjoyable over the internet, and the excitement for VR was amplified in those online communities which had formed a core component of the 1980s vision for VR espoused by Rheingold and Lanier.[77] VR's earliest private-sector iterations included mandates for this networked functionality, but implementing that deeper interaction between people, computers, and each-other was technically challenging. The varying approaches to providing this social networking highlighted the lack of consensus which plagued 1990s VR development, exacerbated by the proliferation of small, competing firms in the early-to-mid decade.[78] A clear desire for such computerised social networks among the most computer literate demographics, (mainly highly-educated, young to middle-aged people[79]), coupled with the need to make a profit, encouraged rushed development of advanced features without the infrastructure (broadband internet) or basic research to support them. The Web did not require broadband, nor the complex protocols needed to coordinate and share a virtual space in real time and satiated that public hunger long before VR could have been ready, regardless of individual company's efforts (as broadband took another decade to reach widespread distribution).[80]

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[77] Randy Farmer and Chip Morningstar, *Habitat* (1986).

Dial-up internet could not support networked VR at a distance, and the slow rollout of broadband drove many VR developers to turn their attention away from social networking and toward other VR applications, such as games or industrial work, undermining one of their main sources of interest and excitement. The interconnected cyberspace that people were excited by could not be provided by VR but could be accessed through their home computer without the cost, discomfort, or wait. The Web pulled the rug out from beneath VR in late 1994 and 1995, and in VR's case, the rug in question was a flying carpet.

When the cyberspace which had been promised by VR was revealed as expensive arcade games and technically dire, isolating home-consoles, it seemed to many that VR could not provide what the Web did. Rheingold described it as getting bored and Asch as there being blood in the water. The VR façade crumbled, revealing an unflattering technological truth demonstrated to millions through purchases, reviews, and personal networks, and the divide between expectation and reality repeatedly cited as a cause for concern, was starkly revealed. Money flowing through US VR businesses shrunk rapidly from around 1996, and most of 1995's 400 VR companies were closed, rebranded, or had changed pathways by 1997. The discontinuation of the Virtual Boy in 1996, and the closure of Virtuality around 1997 erased HMD-based VR systems from a wide swathe of public view while the Web increasingly provided the services VR could not, and for many, they became the same.

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[78] Sandra Helsel, and Walter Chavez,(eds.), *VR World's Virtual Reality Market Place 1995*, (1995).

[79] Thomas Rubey, 'Profile of Computer Owners in the 1990s', *Monthly Labor Review*, 122 (1999), 41–42.

[80] Kevin Kelly and Barbara Stacks, 'An Interview with Jaron Lanier', *Whole Earth Review*, Fall, 1989, 108–19; Charles Ferguson, 'The US Broadband Problem | Brookings Institution', *Brookings*, 2001 <https://www.brookings.edu/research/the-u-s-broadband-problem/> [accessed 12 June 2017].

Some VR firms persisted, Fakespace and LEEP Optics sold HMDs into the 2000s but Autodesk, VPL, and others left the market or shut down entirely. Most of the surviving firms shifted to high-cost bespoke machines for specialist applications, such as medical simulation and therapy. The VR systems of 1996/7 then were not mass-market entertainment devices, but academic and industrial tools, relying on VR's original applications of IA and data management.

INDUSTRIAL VR: APPLICATIONS AND ACADEMIC DEVELOPMENT BEYOND THE CONSUMER MARKET

Academic VR research followed more application-based paths, with attention to basic research; the establishment of technological foundations for further advancement. Mandated by funding grants, academic VR development usually had clearly defined goals, which were often shared with developments in VR for industry. Large firms seeking to leverage VR to improve workflow sought the advice and expertise of university-based VR researchers, such as those at the University of Washington's HITLab, and the University of North Carolina at Chapel Hill (UNC), to develop hardware and software for VR which could then be used in pilot programmes, to assess any potential value VR had to industry. While a major source of investment in VR businesses, it remained unclear by 1997 whether industrial applications of VR were useful, or desirable.[81]

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[81] Schroeder, *Possible Worlds*, 46.

Boeing established an all-electronic training centre for pilots of the new 777 in 1994, the first aircraft designed entirely on computers. It seems that VR systems were implemented for maintenance training as well as simulation in a dedicated facility costing over $100m (circa $170m in 2015).[82] The source of VR expertise for the facility was from the HITLab, which designed a VR system allowing virtual models of the 777 to be explored and tested by multiple networked users, this concept of using VR to explore a shared virtual space for the purposes of working collaboration was also being explored at UNC.

UNC had developed a system using HMDs to ‘walk’ through architectural blueprints in 3D using a treadmill by the early 1990s, based on 1980s research exploring the schematics for UNC’s new computer science department building, Sitterson Hall.[83] This process brought to light issues with the design which were then changed, indicating the potential benefits of an immersive VR system for product and architectural design. The key challenge in translating this to widely usable industrial applications was the technical limitations of the ‘Reality Engines’ driving the system, since rendering images in stereo, and with the higher framerates necessitated by VR systems, reduced the available polygons of a mock-up building by an order of magnitude, leaving VR models with between 500-1000 polygons while AutoCAD and 3D Studio regularly used between 5000-10,000.[84] While VR had clear potential, therefore, it was also demonstrably unsuitable to replace or augment existing computer-based design tools. The Japanese firm Matsushita worked with VPL to develop an architectural walkthrough-system for kitchen showrooms, which generated a degree of attention, but it yielded a highly limited, cumbersome experience, and was not widely adopted.[85]

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[82] Ibid, 49; Paul Proctor, ‘New Boeing Training Center To Meet 777 Crew Demand’, *Aviation Week & Space Technology*, 11 July 1994, 36; LaPlante,’Virtual Capitalists’, 94-5; David Mizell, ‘Virtual Reality and AR in Aircraft Design and Manufacturing’, in *The 1994 Wescon Conference; Anaheim, CA; USA; 27-29 Sept. 1994* (1994), 91 <https://search.proquest.com/docview/27299638/F1E8A7788E414418PQ/14> [accessed 26 May 2017]; Chris Esposito, *Virtual Reality Research at Boeing.* (1992), XXXVI <https://search.proquest.com/docview/16574780/13BD149A12E64350PQ/39> [accessed 25 May 2017]; Pr Newswire, ‘New Boeing Training Center Supports Service-Ready 777’, 1994 https://global.factiva.com/redir/default.aspx?p=sa&ep=ODE&an=prn0000020011030dq6r00y1h&aid=9SAI000300&ns=18&OD=&cat=a. [accessed 12 June 2017].

[83] Pimentel and Teixeira, *Through the Virtual Window,* 42-5.

[84] Ibid., 90.

UNC also collaborated in 1991 with VPL, the HITLab and MIT's Media Lab to trial the 'Reality Net', a high-speed long-distance computer network (in practice akin to broadband) that would allow social networking and collaboration in VR. Sharing virtual spaces was a recurrent theme of early VR evangelism, and, as can be seen, it was the lack of such capability that damaged the Virtual Boy four years later. VPL's collaboration with universities in an attempt to bring such a virtual social space to fruition in 1991 shows how important it was thought to be, while the exclusion of other companies speaks to the insular, clandestine nature of private VR research at the time. The Reality Net's design borrowed the Army's SIMNET Dead Reckoning system, where the only information transmitted was changing movement and actions by each user.[86] Their hope was to 'change the nature of reality as we know it', but the technical obstacles were too great, and the project was dropped before it could be tested.[87]

Several non-VR firms watched VR's development, with varying degrees of separation, via the HITLab's Virtual Worlds Consortium, members of whom had privileged access to HITLab research and personnel under Tom Furness. Furness had left the military, with many others, at the end of the Cold War. Disillusioned by the use of his research for war, Furness established the consortium to help turn his expertise to civilian ends, 'beating his swords to plowshares.'[88] By 1992 this consortium had twelve members comprising a mixture of private firms, universities, and governmental bodies. For a $50,000 fee, signatories could collaborate with the lab, and guide its objectives. Alongside the membership fees, the lab was funded by the University of Washington and government grants.[89] By 1995 the membership had grown to twenty-seven, and it served as a hub for commercial and industrial interest in VR, providing it with considerable influence in the adoption of experimental VR projects by some of those companies in the 1990s.[90] In 2018, the consortium had 48 members and shared research on VR among other human-interface technologies.[91]

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[85] 'Today's Japan - Tuesday October 2nd', *Today's Japan* (Tokyo, Japan, 1990); LaPlante, 'Virtual Capitalists' 96; Schroeder, *Possible Worlds*, 47; Ellis, Interview, 13 Mar 2018.

[86] Col. Jack Thorpe, Interview, 10 October 2016; Rheingold *Virtual Reality*, 173.

[87] Ibid, 174.

[88] Ibid, 211.

The technology giant IBM did not join the consortium but sought to develop its own VR technologies independently (presumably for the preservation of sole rights), having been blindsided by the runaway success of copies of its own product, the PC.[92] IBM felt VR could form the next generation of computer interfaces, and sought to establish hardware standards for the technology in advance of this, using existing PC architecture, as well as hardware for telepresence. The IBM telepresence system used an HMD and glove to display telemetry from a scanning electron microscope, allowing users to feel present in thesub-molecular world and 'feel' the shape of individual atoms.[93] While not VR, many technological components were the same, and it thus lent itself to IBM's research in VR.

Simultaneously, Intel decided to pursue VR research, and sought to accelerate VR's arrival by creating its own VR hardware and software by collaborating with Sense8. Eric Gullichsen and Pat Gelband, formerly of Autodesk's Cyberspace, had founded Sense8 in February 1990, and quickly had a working demonstration model, it was their speed of development which brought them to Intel's attention, as the tech giant hoped to launch its own VR product before IBM or any of its other rivals could.[94]

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[89] Schroeder, *Possible Worlds*, 52-3.
[90] Ibid.
[91] 'HIT Lab Accomplishments' <http://www.hitl.washington.edu/home/accomp.php> [accessed 4 Apr 2018].
[92] LaPlante, 'Virtual Capitalists', 94.
[93] Rheingold, *Virtual Reality,* 362.
[94] Pimentel and Teixeira, *Through the New Looking Glass*, 58-61

The reason Intel wanted to bring their system to market so quickly was to capitalise on a proprietary computer graphics technology they had recently purchased from General Electric called DVI (Digital Video Interactive). DVI allowed for digital images to be wrapped around virtual objects, giving the appearance of being far more detailed than the number of polygons would allow. Intel was not focused on hardware (though Intel's ActionMedia PC video card had DVI built in in 1990[95]) as much as software. Intel and Sense8's WorldToolKit software, incorporating DVI support, was released in 1991 and came closer than any other to becoming the standard, but it was hampered by excessive competition and a small customer base.[96] Limited users meant limited network effects, and WorldToolKit failed to develop beyond its initial offering.[97]

The Virtual Worlds consortium mitigated this problem by sharing research among all the member organisations, broadening the diversity of usage and expertise needed for effective technological development. Very few of the companies ran their own VR research, however. Microsoft's membership might have been down to the association between their Windows Operating System and PCs, as well as their sharing a home city in Seattle.

In addition to Boeing and VPL, The Port of Seattle organisation was a member of the consortium and pursued VR research in the early 1990s. The Port wanted to assess the viability of using VR to plan upgrades to the rapidly growing seaport more quickly, and cheaply, than conventional methods. Fred Brooks at UNC and Walker at Autodesk had cemented this idea of VR in architecture, but the draw for the Port organisation was its networking capabilities.[98]

Collaborating and editing blueprints in real time from across the world drastically improved workflow in an industry where experts had to be flown in at great financial and temporal expense.

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[95] Asch, Interview, 7 July 2017.

[96] Ellis, Interview, 13 Mar 2018.

[97] Pimentel and Teixeira; *Through the New Looking Glass*, 62.

[98] Rheingold, *Virtual Reality*, 211-3.

The fact that the project was pursued without the broadband Internet needed to make it work suggests that the scale of the undertaking, and potential of the technology, were under-and-overstated respectively. Shell was similarly interested in using VR for interactive communications in oil rig design and prospecting, though it does not appear to have had a place in the consortium, reiterating the importance of instantaneous computerised communications to VR's appeal, hence the later collapse of that appeal when the Web made internet access easy.[99]

Other companies like US WEST Communications, Franz Inc., Alias Research, Digital, and John Fluke Manufacturing were also members of the consortium, though the reason for their interest in VR is largely unclear. Fujitsu, another member, had a large, well-funded VR research programme based in Japan.[100] As the rights holders to 1980s internet video game *Habitat,* Fujitsu had access to an online community from which understandings of VR's appeal as a social tool had crystallised. While not American, membership of the consortium and ownership of Habitat lent it a degree of influence within and beyond the HITLab.

The Ford Motor company was also a member and, like Matsushita with virtual kitchens, sought to create VR showrooms for their cars, allowing customers to tailor them to their needs and see the desired car and pricing options before ordering it, and 2D versions of the software were released for PC as *Ford Simulator* throughout the mid-1990s.[101] This level of functionality is commonplace today, but the VR showroom has been replaced by the convenient familiarity of the website. Insight, Inc. established itself as the provider of VR technology for many of the VR projects undertaken by industry, potentially including Ford's, though the Ford project did not make it into actual showrooms. As member of the consortium, Insight had a portion of the fee waived in exchange for lending its staff to the HITLab. The HITLab's reach was not limited to the consortium, however, and from 1991 organised symposia on VR, which cast a wider net over American business (fig.10).

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[99] Ibid, 212-3; Elwood Nestvold and P. Nelson, 'Explorers Still Hope to Improve on 3-D Seismic's Wealth of D', *Oil & Gas Journal; Tulsa*, 90/11, 16 March 1992, 55-7.
[100] Rheingold, *Virtual Reality*, 285-87.
[101] Ibid, 171; The SoftAd Group Inc, *Ford Simulator 7 CD-ROM (1996)*, 1996.

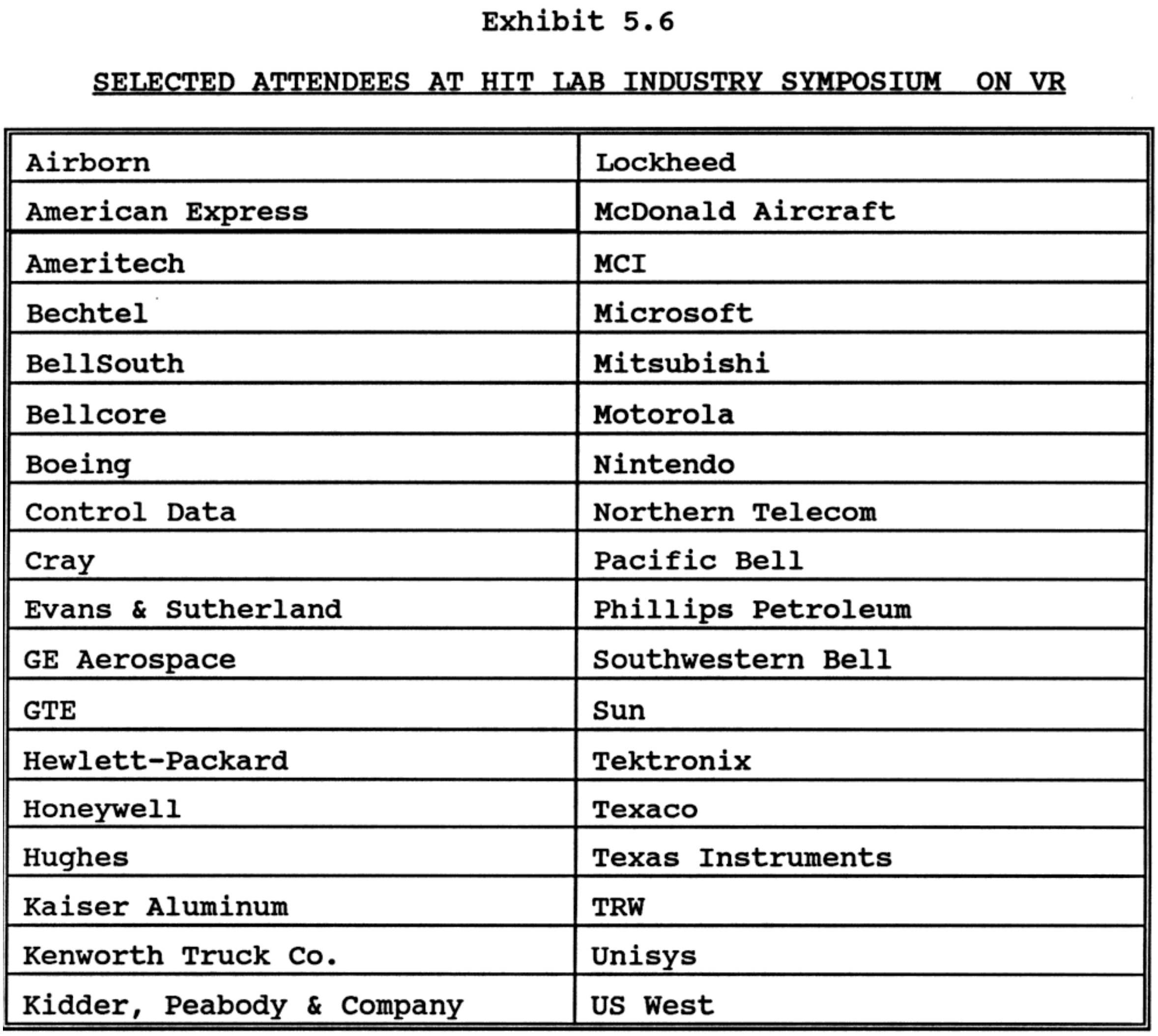

Exhibit 5.6

SELECTED ATTENDEES AT HIT LAB INDUSTRY SYMPOSIUM ON VR

Airborn	Lockheed
American Express	McDonald Aircraft
Ameritech	MCI
Bechtel	Microsoft
BellSouth	Mitsubishi
Bellcore	Motorola
Boeing	Nintendo
Control Data	Northern Telecom
Cray	Pacific Bell
Evans & Sutherland	Phillips Petroleum
GE Aerospace	Southwestern Bell
GTE	Sun
Hewlett-Packard	Tektronix
Honeywell	Texaco
Hughes	Texas Instruments
Kaiser Aluminum	TRW
Kenworth Truck Co.	Unisys
Kidder, Peabody & Company	US West

FIG. 10 A partial list of attendees at the HIT Lab symposium in 1991, taken from IGI Consulting's *Emerging markets for VR* (1992), page 169.

Evans & Sutherland and Cray had both manufactured computers for private and public VR programmes in the past and their interest in VR seems understandable. Numerous aircraft companies attending perhaps hoped to emulate Boeing's work with VR training, and Nintendo's presence provides one of the first visible points of exposure of the games giant to VR technology, which culminated in 1995's Virtual Boy. The fact that telecommunications firms attended was no doubt due to the positioning of VR as the ultimate communications tool, since Pacific Bell funded

VPL's early research for that very reason, and Nippon Telephone and Telegraph sponsored the Advanced Telecommunications Research Institute in Japan. The largest phone company in the US at the time, AT&T, did not attend, despite overtures from the HIT Lab, perhaps because the developmental nature of VR suggested that new telecoms technologies were not needed at that early stage.

Diverse consortium members aside, the HITLab also pursued its own independent research, with a long-term goal of rendering VR broadly usable. While working more broadly on Human Interfaces, the focus during the early 1990s was on VR. For Furness, a key project was the establishment of a free VR database.[102] Due to the range of competing firms, there was a bewildering range of software and hardware options for potential VR consumers, and Furness hoped to help people make sense of the VR marketplace as it was at the start of the decade. The model for Furness's database was the Usenet system popular in the early days of the internet. The project never reached fruition, and it seems that the reason was primarily the significant complexity of cataloguing all the VR software being created as it was developed. As time has passed, this has only become more difficult, and as a result, the preservation rate for software is poor due to low distribution and highly fragile storage media.

Separately, Furness and Rheingold set up an online Usenet together, Sci.virtual.worlds, providing a virtual space for people to share VR news and discuss the technology, and maintaining an electronic mailing list. It had a Frequently Asked Questions page, and links to other useful sites, expanding to include websites, in addition to books, magazines, journals, newsgroups, mailing lists, and more.[103]

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[102] IGI Consulting, *Emerging Markets for Virtual Reality* (1992), p. 169; Rheingold, *Virtual Reality*, 210-1.

[103] 'Sci.virtual-Worlds Reference Frequently Asked Questions (FAQ)' <http://www.hitl.washington.edu/projects/knowledge_base/virtual-worlds/reference-faq.html#7> [accessed 14 June 2017].

Using the Usenet and catalogue to try and ease access to VR was not enough for Furness, who tasked the HITLab with making its own VR software, with the hope of establishing concrete technical standards, and a de-facto platform for developers to work with, alleviating the dearth of content. Thus, VEOS (Virtual Environment Operating System) was designed for ease of use, and was available for free, on account of its patronage by the University of Washington. The University of Alberta, in Canada, also released free VR software at the time called Minimal Reality, but VEOS's connection to the HITLab and its consortium gained it greater attention. The key principle of VEOS was that it could turn high-end PCs into 'Reality Engines' with access to a standardised C Library. Surprisingly, despite its institutional pedigree and non-existent price, it failed to establish popularity or become an arbiter of technical standards. There were technical and social problems which caused this, and the competitive and partisan nature of the technology industry disincentivised cooperation or shared platforms. With no standard VR programming language, VEOS's lead developer William Bricken chose the LISP programming language, feeling it would become prominent in the US computer ecosystem. While LISP was a powerful language for research software, the PC industry favoured smaller, more easily compressed languages like Microsoft's BASIC, and the pre-eminence of DOS and Windows drove LISP into obscurity.[104]

Using LISP hindered VEOS's compatibility, as well as access, due to the rare specialised knowledge needed to work with it. Furthermore, the small pool of VR systems being run nationally, hindering any momentum it might have gained. The failure of free VR software to succeed hints at larger structural barriers to the wider use of VR at the time. One of those was ergonomics. Bulky, uncomfortable displays with slow motion tracking were bottlenecked by computer power and the screen weight-to-resolution ratio. Many HMD manufacturers, such as General Reality, offered smaller, low-resolution displays precisely because they were lighter, and thus more comfortable (fig. 11).

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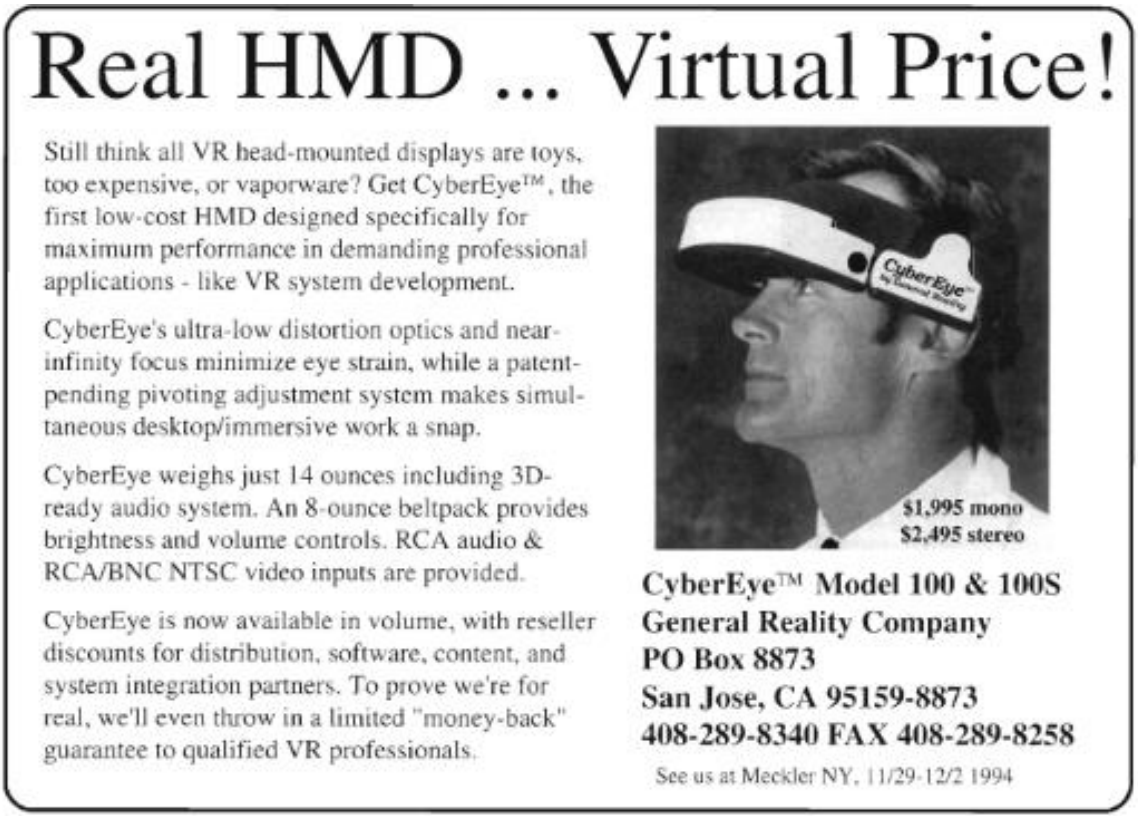
[104] Schroeder, *Possible Worlds*, 44-5; Van Dusen, Interview, 8 May 2017.



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See us at Meckler NY, 11/29-12/2 1994

FIG. 11 An advertisement for a General Reality Cybereye from 1994, taken from a tech magazine, note that in addition to the focus on light weight and comfort, the ad mentions that General Reality would have a presence at one of the Mecklermedia VR trade shows that same year. General Reality Company, 'Real HMD... Virtual Price!', *Pix-Elation*, 10, 1994, 7.

The low resolution equated to lower prices, making these displays among the easiest to buy in the 1990s (costing $2-3,000, rather than $10,000+). Physically smaller screens had a limited FoV, creating the sensation of seeing the virtual world through a blurred window from inside a very dark room.[105] The General Reality Cyber Eye had a resolution of 250x250 pixels in 1994, and was updated to 450x450 in 1997, neither of which were considered adequate (high end displays by 1997 could be in excess of 1000x1000).[106] Low-cost headsets from Division, Optics 1, VFX, and others suffused the market with headsets people were more likely to buy (on account of cost), but they were of a far lower quality than what was technically possible, further damaging VR's image. Furness sought to resolve the quality/weight trade-off through an entirely new type of display, by projecting virtual images directly onto the retina of the eye via a laser.[107]

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[105] Tony Asch, 'Narrow Field of View Is Good… - CyberEye 100', *V-Rtifacts*, 2009 <http://VirtualRealitytifacts.com/narrow-field-of-view-is-good-cybereye-100/> [accessed 15 June 2017]; Asch, Interview, 14 May 2017.

[106] 'General Reality Company Ships New CyberEye(TM) HMDs' (1997) <https://www.thefreelibrary.com/General+Reality+Company+Ships+New+CyberEye(TM)+Head-Mounted+Displays-a019021191> [accessed 15 June 2017].

The HITLab developed a prototype monochrome retinal scanner in 1991, while Japan's Nippon Telephone and Telegraph had had one working five years earlier. Nippon's connection to the Japanese Advanced Telecommunications Research group, which itself worked with the HITLab, is likely to have been the source of the HITLab's retinal scanner expertise. Technical issues with the refresh rate and generating colour were not surmounted, nor was the thorny issue of convincing people to shine a laser into their eyes.[108]

As well as the Virtual Worlds database, VEOS, consortium research, and the Retinal Microscanner, the HITLab developed VR medical training, gaze tracking, and 3-D audio systems. Of equal interest was the HITLab summer school.[109] The 1991 summer school seems to have been one of the first examples of VR being used as part of an academic curriculum in the US. Over a week, children would build their own virtual worlds, and test them on the final day. Despite developing VEOS, the HITLab used VPL's *Swivel 3D* for the summer school (perhaps due to its relative ease of use). Teaching computer graphics, using VR software and virtual worlds, served to test the value of VR to schools in the US, and to serve as outreach for the University of Washington.[110] Continuing for several years, other VR school programs sprung up around the world, but high costs kept VR out of schools except in funded experiments.

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[107] Douglas Holmgren and Warren Robinett, 'Scanned Laser Displays for Virtual Reality: A Feasibility Study', *Presence: Teleoperators and Virtual Environments*, 2/3 (1993), 171–84; Rheingold, *Virtual Reality*, 194-8.

[108] Ibid.

[93] Schroeder, *Possible Worlds* , 69-71.

[110] Ibid, 70.

The HITLab was far from the sole source of academic research into VR at the time. While NASA had halted development of the VIEW system in 1990, Steve Ellis was pursuing studies in human eye movement and gaze tracking through the early 1990s. Ames was also using VR to carry out immersive examinations of telemetry from the Martian Viking lander.[111] The use of VR to interact with data in new ways, carried out at NASA, was also prominent in other IA work at UNC, with molecular chemistry, as well as at Boeing, the Port of Seattle, and others. Ellis's use of the VIEW hardware for telepresence research may also hint at NASA's changing understanding of the value VR posed to their work, toward a system more grounded in reality, and AR than the intimate illusions of VR, perhaps due to Fisher's departure from Ames in 1990. Equally, it is important to stress that Ellis and colleagues were working on software and applications using third-party hardware from Virtual Research and Kaiser, not their own, in the 1990s.[112]

Evidence of this shift is corroborated by Ellis, who mentioned in a personal communication with the author that VR's problem was not hardware, nor had it been for some time. The main problem was instead in the lack of software and applications which could justify the use of the technology.[113] This was caused by the same limited distribution and small range of platforms available which had hindered the take up of VEOS. VR applications for Boeing, the Port of Seattle, and others were custom made, while video games for VR were poor adaptations of successful titles, cheaply made, or poorly suited to HMDs, leading to jarring animations or disconcerting visual effects. There were only a handful of games made explicitly for VR, and these were made for a limited pool of systems. Existing games adapted for VR, such as StrayLight's versions of Descent and Duke Nukem 3D, had to be heavily modified.[114] Creating VR content was expensive in time and money, attenuating opportunity for indirect network effects in a vicious cycle of limited expertise, markets, and content.

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[111] Ellis, Interview, 11 July 2017; Pimentel & Teixeira, *Through the New Looking Glass*, 3-4.
[112] Ellis, interview, 13 Mar 2018.
[113] Ellis, pers. comm., NASA Ames Human Systems Integration Division, 7th July 2015
[114] Asch, review comments, 7 Jul 2017.

Like Ames, Autodesk also shifted focus from hardware to software. Shutting down 'Cyberspace in a briefcase' and developing existing software for use in building virtual worlds instead. The resulting Cyberspace Development Toolkit was first rumoured in around 1991, and announced in 1992 with a same-year release promised, though this never took place. Autodesk instead continued developing apps for desktop PCs and Macs.[115] While numerous (often smaller) private companies did continue to develop VR hardware and software, a significant source of basic research into VR and its applications came not from the private sector by the mid-1990s, but from academia.

UNIVERSITY RESEARCH: EDUCATION AND DEVELOPMENT

Charting academic VR research illustrates a more diverse set of applications and perceived uses than the market-driven entertainment contexts of the popular media. Mark Merickel's 1991 thesis from Oregon State University's department of education examined the importance of graphical fidelity to problem-solving in children and used, among other things, an Autodesk Cyberspace prototype, making it one of the rare examples of the Cyberspace system being used outside of Autodesk.[116] Finding that the Cyberspace hardware could be useful for teaching and perceptual studies, the research was supported by the Autodesk Cyberspace team, clearly still operating in 1991. Merickel's work formed part of a growing body of academic research into human development using VR, with Dorothy Strickland carrying out similar work at UNC in 1995, this time developing VR systems to study autism in children.[117] The VR hardware, displays, gloves, and trackers were apparently supplied by UNC's computer science department under Fred Brooks, and Strickland's research suggested modifications to trackers to improve their utility in the developmental studies used in her research. Some of the software was taken from Matsushita's virtual kitchen. Strickland's work suggests that other departments in UNC were paying attention to Brooks's work with VR at Sitterson Hall and were seeking to explore it themselves.

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[115] Pimentel and Teixeira, *Through the New Looking Glass*, 58.

[116] Mark Merickel, 'A Study of the Relationship between Perceived Realism and the Ability of Children to Create, Manipulate and Utilize Mental Images in Solving Problems' (unpublished PhD, Oregon State University, 1991) <https://search.proquest.com/docview/303950254/abstract/39A70FB3D19D474FPQ/23> [accessed 25 May 2017], p.viii, 53.

[117] Dorothy Strickland, 'Issues in Virtual Reality: An Application to Aid Children with Autism; a Portable Head Tracker; and Cortical Brain Activity Measurements in a Virtual World' (unpublished PhD, North Carolina State University, 1995) https://search.proquest.com/docview/304222176/437E9704ACE94315PQ/17.

The growing legitimacy of VR in academic contexts that this work implies is further supported by the growing number of doctoral theses using VR in the early 1990s, from around eighty visible in 1990 to at least 900 by 1995. Research both using and concerning VR was demonstrably gaining momentum in academic fields during this period. Strickland and Merickel's education research was joined by Christine Byrne's at the University of Washington and numerous Canadian projects.[118] 1997 saw several VR education studies at Pennsylvania State University, the University of Florida, and elsewhere.[119] This research continued beyond the collapse of the VR entertainment market, as human perceptual and developmental studies remained an application where, echoing Ellis's sentiment, the use of VR hardware made sense, and more importantly, where the colossal buying power of American schools could be leveraged.[120] The desire of several VR manufactures to 'break into' the education sector was echoed in media reports, and the evidence suggests that there was at least a degree of understanding that entertainment alone would not sustain VR.[121]

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[118] Christine Byrne, 'Water on Tap: The Use of Virtual Reality as an Educational Tool' (unpublished PhD, University of Washington, 1996) <https://search.proquest.com/docview/304270496/abstract/585FFC1C2A0045D8PQ/7> [accessed 26 May 2017]; Alexander Okapuu-von Veh, 'Sound and Vision: Audiovisual Aspects of a Virtual-Reality Personnel-Training System' (unpublished M.Eng., McGill University (Canada), 1996) <https://search.proquest.com/docview/304334333/abstract/585FFC1C2A0045D8PQ/3> [accessed 26 May 2017].

[119] Pallab Chakraborty, 'A Virtual-Reality-Based Task Training Model for Mine-Equipment Operation' (unpublished PhD, Pennsylvania State University, 1997) <https://search.proquest.com/docview/304388144/abstract/9F861E7D133A4B34PQ/18> [accessed 26 May 2017]; Etienne Garant, 'A Virtual Reality Training System for Substation Operators' (unpublished M.Eng., McGill University (Canada), 1997) <https://search.proquest.com/docview/304404117/abstract/9F861E7D133A4B34PQ/2> [accessed 26 May 2017]; Khalid Naji, 'The Development of a Virtual Environment for Simulating Equipment-Based Construction Operations in Real-Time Object-Oriented Systems' (unpublished PhD, University of Florida, 1997) <https://search.proquest.com/docview/304346482/abstract/9F861E7D133A4B34PQ/10> [accessed 26 May 2017].

[120] Denise Caruso, 'Education Secretary Criticizes Use of Computers in Schools', *InfoWorld*, 6/7, 13 February 1984, 14; Glenn Rifkin and Lewis Perelman, 'Can Technology Effectively Replace Human Teachers?', *ComputerWorld*, 24/41, 8 October 1990, 25; Frank Crawford, 'The Internet - Will Your Kids Know More than You', *AUUGN*, 16/2, April 1995, 11.

UNIVERSITY RESEARCH: HARDWARE AND SOFTWARE

Much of the academic research into VR throughout the 1990s was directed towards new ways of creating, generating, displaying, and using virtual environments. As noted above, the term 'VR' was often avoided by academics due to its lax definition and populist image.[122] Indeed, throughout contemporary academic discourse in published technical articles, scientific journals, and theses, 'VR' was progressively used as a cursory moniker, or excluded entirely, in favour of terms such as Synthetic Reality, Synthetic Environments, Artificial Reality, Artificial Environments, and most commonly, Virtual Environments.[123]

Despite this, many academic theses using VR were directly concerned with basic research into the technology itself. The earliest theses describing scientific and technological developments of VR hardware and software show up in the late 1980s, but become more widespread throughout the 1990s, no doubt due to its growing popularity and commercial availability. Doctoral theses, by necessity, reflect a delay of several years, but title changes could mean that PhDs written in the late 1980s could have changed title to include VR after it became commonplace.

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[121] Megan Santosus, 'Degrees of Change', *CIO*, 15 May 1997, 78–80, 84–86; Laura Rongé, 'VR in the Classroom', *Popular Science*, September 1996, 62.

[122] Asch, 'How to make VR 'Real"', 1991, 3-4; Homan, 'Real Promises and False Expectations', 224-6.

[123] For Synthetic Reality see Stephen Ellis and Arthur Grunwald, 'Head-Mounted Spatial Instruments II: Synthetic Reality or Impossible Dream', in *JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 P 521-532 (SEE N90-29780 24-54); US*, 1989 https://search.proquest.com/docview/25240423/62EB17B6D2754C84PQ/3; Jim Mollenauer, "'Through the Looking Glass' at Megabit Rates', *Telecommunications, Americas Edition; Dedham*, 30/11 (1996), 28 for examples. For Artificial Reality see Myron Krueger, *Artificial Reality* (1983); Glenn Cartwright, 'Virtual or Real? The Mind in Cyberspace', *The Futurist; Washington*, 28/2 (1994), 22. For Virtual Environments see Stephen R. Ellis, 'What Are Virtual Environments?', *Computer Graphics and Applications, IEEE*, 14/1 (1994), 17–22; David Brown, Steven Kerr, and John Wilson, 'Virtual Environments in Special-Needs Education', *Communications of the ACM; New York*, 40/8 (1997), 72–75; Dacid Zeltzer, and Rita Addison, 'Responsive Virtual Environments', *Communications of the ACM; New York*, 40/8 (1997), 61–64; Mark Green and Sean Halliday, 'A Geometric Modeling and Animation System for Virtual Reality', C*ommunications of the ACM; New York*, 39/5 (1996), 46; Guiseppe Mantavani, 'Virtual Reality as a Communication Environment: Consensual Hallucination, Fiction, and Possible Selves', *Human Relations; Thousand Oaks*, 48/6 (1995), 669.

Alfred Tadros at MIT's Department of Mechanical Engineering published a master's thesis in 1990, which explored development of motion tracking, force-feedback inputs, and software changes for smoother interaction with virtual environments, in a similar vein to Fred Brooks's work at UNC on the GROPE project a decade previously.[124] Unaffiliated with the MIT Architecture Machine Group or later Media Lab, Tandros's thesis suggests the VR work there in the late 1980s had diffused into other departments by 1990, and is emblematic of VR's spread from its earliest academic homes to a wider range of universities.

In 1993, Patrick Kenney at the University of Houston at Clear Lake designed a VR environment for space exploration as part of his master's thesis. NASA's Johnson Space Center was based there, and Clear Lake served as the education provider for NASA staff.[125] Kenny may, then, have been exposed to people who knew of the work of Ellis and colleagues at Ames and sought to further the field.

Several academic VR projects were mentioned in publications from 1994. Stand-out examples include Andrew Johnson's SANDBOX project (Scientists Accessing Necessary Data Based On eXperimentation), a PhD at the computer science department of Wayne State University, Michigan. SANDBOX allowed interactive access to networked scientific research databases and the reconstruction of experiments recorded there in VR.[126] SANDBOX was intended to enable research from a wide range of disciplines beyond computer science, using a portion of NASA's FIFE research database as its source. While remaining strictly experimental, SANDBOX used Carolina Cruz-Neira's CAVE system to create an immersive environment using projectors 'in the round.' Without HMDs, CAVEs are not strictly VR by the author's definition, but Johnson felt otherwise, and with understandable reason. It is interesting to note that Yifan Wang at McGill in Canada was working on a similar project for recreating experiments and laboratories virtually at the same time.[127] In1994, the VR 'brand' was nearing peak popularity in the press, but as public expectations grew, the technical challenges posed by VR were not being resolved by such academic research in the few short years between the technology's first visibility across the US's academic network, and the collapse of the VR bubble in 1996-7.

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[124] Pimentel and Teixeira, *Through the New Looking Glass*, 42-3; Alfred Tadros, 'Control System Design for a Three-Degree-of-Freedom Virtual Environment Simulator Using Motor/Brake Pair Actuators' (MIT, 1990) <https://dspace.mit.edu/bitstream/handle/1721.1/13972/23056040-MIT.pdf?sequence=2> [accessed 24 May 2017].

[125] 'JSC History Collection' <https://www.jsc.nasa.gov/history/history_collection/uhcl.htm> [accessed 20 June 2017]; Jennifer Ross-Nazzal, 'The Right Place - Houston Makes History', *Houston History*, 6/1, Fall 2008, 8-9; Shelley Henley Kelley, 'Mutually Beneficial: University of Houston - Clear Lake and NASA Johnson Space Center', *Houston History*, 6/1, Fall 2008, 36-7.

[126] Andrew Johnson, 'SANDBOX: A Virtual Reality Interface to Scientific Databases' (unpublished PhD, Wayne State University, 1994)

By 1995 the number of theses developing VR had grown further. Robert Cross at the University of Indiana's Computer Science department developed a prototype distributed rendering suite for VR.[128] Cross sought to address the computer power shortage which hampered quality in virtual environments by networking multiple computers to share the processing load. This idea had an analogue at UNC at around the same time in the Pixel Planes project, which networked dozens of graphics processors to generate extremely high quality, high resolution, and low latency computer graphics for VR since the beginning of the decade.[129] These networked computer setups (massively parallel computing architectures) were a popular model for supercomputers, and their use for VR seemingly originated at UNC, driven, like Cross, by hunger for better graphics in VR.

<https://search.proquest.com/docview/304173650/abstract/F1E8A7788E414418PQ/12> [accessed 26 May 2017].

[127] Yifan Wang, 'Audio/Video Services for a Virtual Laboratory' (unpublished M.Eng., McGill University (Canada), 1994) <https://search.proquest.com/docview/304175467/abstract/F1E8A7788E414418PQ/37> [accessed 26 May 2017].

[128] Robert Cross, 'Interactive Visual Realism Using Distributed Rendering' (unpublished PhD, Indiana University, 1995) <https://search.proquest.com/docview/304202562/abstract/437E9704ACE94315PQ/5>

[129] Schroeder, *Possible Worlds*, 28; Rheingold, *Virtual Reality*, 35-6.

1995 also saw new academic research into inputs, gloves, and robotic programming using VR, among others. In that year, Carolina Cruz-Neira published her doctoral thesis describing the CAVE, which would in the late 1990s become a prominent c*haîne-opératoire* for accessing VR. Working at the Electrical Engineering and Computer Science department of the University of Illinois at Chicago, Cruz-Neira had clearly shared her work before publishing it (since Johnson used it a year earlier), and CAVE systems were quickly commercialised.[130]

The following year saw VR research continue independent of the commercial downturn. Michael Harreld developed a complete system for modelling blood flow in the brain in VR at the University of California, Los Angeles.[131] By 1997, the collapse of the commercial VR business meant academia was the main source of VR research. Cynthia Calongne at Colorado Technical University designed a software interface specifically designed for VR, supposed to remove distractions and improve ease of access to VR systems for people from a wide range of skillsets.[132] Understanding accessibility as a key failing of VR, Calongne sought to improve VR's chance of success by making it easier to use, though it was seemingly too little, too late, as her work was among the first to focus on the soft power of its openness rather than VR's direct power.

UNIVERSITY RESEARCH: PHILOSOPHY, METAPHYSICS, AND PRESENCE

The third main branch of university-based academic VR research in the 1990s was into its philosophy and metaphysics. Public concerns about the societal and personal effects of VR were reflected in university research into the issue. Much of this research subscribed to a 1980s optimism rather than mid-1990s pessimism, and this lag might help suggest why research continued after public interest in HMD-based VR waned.

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[130] Carolina Cruz-Neira, 'Virtual Reality Based on Multiple Projection Screens: The CAVE and Its Applications to Computational Science and Engineering' (unpublished PhD, University of Illinois at Chicago, 1995) https://search.proquest.com/docview/304289415/abstract/437E9704ACE94315PQ/2.

[131] Michael Harreld, 'Brain Aneurysm Blood Flow: Modeling, Simulation, Virtual Reality Visualization' (unpublished PhD, University of California, Los Angeles, 1996) <https://search.proquest.com/docview/304270991/585FFC1C2A0045D8PQ/60> [accessed 26 May 2017].

[132] Cynthia Calongne, 'A User Interface Paradigm for Virtual Environments' (unpublished D.C.S., Colorado Technical University, 1997) <https://search.proquest.com/docview/304461491/abstract/9F861E7D133A4B34PQ/9> [accessed 26 May 2017].

Judith Kornelsen's 1991 thesis from Simon Fraser University's Department of Communication, Canada, is worth mentioning because it came before visible American examples.[133] Interrogating existing discussions of media and the self, most notably from Marshall McLuhan, Kornelsen explored notions of the body in VR, and how the lack of a 'self' in many VR set ups impacted presence and judgment, with its concomitant impacts on personal projection into virtual spaces. She analysed this in terms of what she called 'self-recreation', a notion echoing Allucquere Rosanne Stone's musings on the potential of VR for new gender expressions and the value of VR in mitigating physical dysphoria for trans people at 1990's 2Cyberconf conference in Austin, Texas.[134]

In subsequent years, growing popular awareness of VR begat increased public concern and drove further research on VR's nature. In 1992 Robert Kelley's PhD thesis at Indiana University mirrored Kornelsen's.[135] Kelley suggested that VR could encourage people to question the reality of reality, based on holistic experiences gained from VR. This kind of Baudrillardian thought process; that creativity is subversive of reality, or that creativity has the *capacity* to blur the boundary between reality and representation had persisted since television, if not before.[136] Whilst VR never saw the same kind of full-blown moral panic that computers, video games, and television had experienced, such discourse concerning video games was occasionally applied to VR, and this trend increased as VR migrated into the entertainment industry.[137] Kelley's assumption that VR will only become more pervasive, and intrinsically subversive of reality, points to the widespread assumption that VR's ascendency was guaranteed, despite its technological impossibility in such a transformative form.[138]

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[133] Jude Kornelsen, 'Virtual Reality?: Marshall McLuhan and a Phenomenological Investigation of the Construction of Virtual Worlds' (Simon Fraser University, 1991) <http://summit.sfu.ca/system/files/iritems1/3572/b14100915.pdf> [accessed 25 May 2017].

[134] Rid, *Rise of the Machines*, 234; Allucquere Rosanne Stone, 'Will the Real Body Please Stand Up?', *Cyberspace: First Steps*, 1991, 81–118.

[135] Robert Kelley, 'Virtual Realism: Virtual Reality, Magical Realism, and Late Twentieth-Century Technologies of Representation' (unpublished PhD, Indiana University, 1992) <https://search.proquest.com/docview/303985173/abstract/13BD149A12E64350PQ/8> [accessed 25 May 2017].

[136] Margaret Shotton, *Computer Addiction: Study of Computer Dependency* (1989); Ellen Wartella and Nancy Jennings, 'Children and Computers: New Technology. Old Concerns', *The Future of Children*, 10/2 (2000), 31–43; Schroeder, *Possible Worlds*, 90-5.

There were also sporadic theses on the philosophy of VR. Carol Gigliotti at Ohio State University wrote about the ethics of boundless creation enabled in VR in 1993, if anything could be represented in virtual space, what should not be?[139] The use of VR in design, military training, games, and schools raised questions for her about whether those realms would interact, and what should be done if they did.

As the technical limitations of 1990s VR became more apparent, however, such concerns over policing its content seem to have diminished. The focus shifted to VR's value as a communications medium, and how new ways of self-expression could change society. Mark Wolf's 1995 doctoral thesis, from the University of Southern California, explored the impact VR might have on future society and culture.[140] Claiming that this change had already begun, separate of VR, Wolf was concerned that communication via machine, such as e-mails, bulletin boards, and chatrooms, would be damaging to social skills and cohesion, particularly as such media became more immersive and capable.[141]

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[137] John Halford, 'Virtual Reality: Creating Your Own Values?' *The Plain Truth*, March 1994.

[138] Kelley, 'Virtual Realism', 92-5.

[139] Carol Gigliotti, 'Aesthetics of a Virtual World: Ethical Issues in Interactive Technological Design' (unpublished PhD, The Ohio State University, 1993) https://search.proquest.com/docview/304062645/abstract/342C9D34C21147A1PQ/4.

[140] Mark Wolf, 'Quantizing Perception: Art, Communication, and Cognition in the Digital Age' (unpublished PhD, University of Southern California, 1995) <https://search.proquest.com/docview/304233116/abstract/342C9D34C21147A1PQ/6>

[141] Chuck Huff, *Social Issues in Computing: Putting Computing in Its Place* (1994); Rory Cellan-Jones, 'We Don't Talk Any More - Is Technology Harming Communication?', *BBC News*, 29 December 2011, section Technology <http://www.bbc.co.uk/news/technology-16313832> [accessed 22 June 2017].

At the same time, Catherine Morris explored similar themes in her master's at the University of Houston.[142] Morris examined the impact of VR and the Internet (which were largely lumped together) on humour and language. Her epistemological combination of the Web and VR reinforces the idea that contemporary understandings of the two were often confused, but her study focused on the expression of humour online, and how it differed from in-person communications. Morris's assumption that VR would join this ecosystem later was commonplace and may explain later disillusionment and consumer ennui surrounding VR's failure to deliver expectations in the late decade.

In 1996, Kenneth Hillis finished a PhD exploring the use of VR to create an alternate self, a sense of presence in a body that did not resemble one's physical form or life.[143] Hillis, like Kornelsen and Allucquere Rosanne before him, was fascinated by the re-inventive potential provided by HMD-based presence in VR, and the capacity for self-projection in an infinitely controllable, profoundly intimate HMD-based virtual environment.[144] For Hillis, the removal of physical bodies from virtual environments would have removed the human ability to separate right from wrong, while also removing prejudice, discrimination, and subjectivity. Interestingly, even in 1996, Hillis assigned power and roles to VR it did not, and could not, have, furthering the notion that academic research into VR lagged a little behind public mood.

Michael Snow at the Virginia Polytechnic Institute wrote, also in 1996, about the impact of 'presence' in VR on task performance.[145] Snow found that the degree of presence felt could be altered by hardware and software changes, with a narrow FoV, poor audio content, or inaccurate motion tracking as the principle confounders. Countering Hillis, Snow demonstrated that the impact of presence on judgment was minor, though generally beneficial.

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[142] Catherine Morris, 'Technohumor: The Construction of Humor through Electronic Communication' (unpublished M.A., University of Houston, 1995) https://search.proquest.com/docview/304192715/342C9D34C21147A1PQ/8.

[143] Kenneth Hillis, 'Geography, Identity, and Embodiment in Virtual Reality' (unpublished PhD, The University of Wisconsin - Madison, 1996).

[144] Ibid. *Abstract*.

[145] Michael Snow, 'Charting Presence in Virtual Environments and Its Effects on Performance' (unpublished PhD, Virginia Polytechnic Institute and State University, 1996).

Research into VR's potential role in society carried into 1997, despite its public recession. Kimberley Osberg's doctoral thesis from the University of Washington bore now familiar themes. Like Hillis, she was concerned with the dangers VR could pose to rationalism and value judgments.[146] Osberg tested this via a teaching trial, using a mixture of VR and textbook-based methods for adolescents, and sought to determine the implications of successful teaching via VR upon people's ability to attach relative significance to actions, objects, and people. She found that students attached equal, if not greater, meaning to facts and objects introduced to them in VR, compared to traditional classroom methods.

As definitions of VR became increasingly blurred throughout the decade, this was reflected in the degree to which VR and other ICTs were linguistically or intellectually combined in academic research. Eric Tinianow's doctoral thesis from Syracuse University in New York, submitted in 1997, demonstrates this amply. Considering VR as an extension of the Web, and video games, Tinianow studied changes in discourse surrounding VR on Furness and Rheingold's sci-virtual-worlds Usenet.[147] His conclusion was that VR was a new form of mass medium, as it had the power to bring about new social, psychological, and physiological norms. For Tinianow, this change would be negative, based on feedback from surveys of Usenet users. He also argued that VR could change the way users perceived themselves, others, and the world around them. Tinianow's assessment of the transformative, dynamic nature of Internet culture was eerily accurate, though his attachment of VR to that *zeitgeist* was an overreach.[148]

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[146] Kimberley Osberg, 'Constructivism in Practice: The Case for Meaning-Making in the Virtual World' (unpublished PhD, University of Washington, 1997).

[147] Eric Tinianow, 'Virtual Reality as a Mass or Massive Medium' (unpublished PhD, Syracuse University, 1997) <https://search.proquest.com/docview/304388258/abstract/989BC64E5D7340EDPQ/7>

[148] Andrew Smith, *Totally Wired: On the Trail of the Great Dot-com Swindle* (2012), 1-7, 200-1.

Associations between VR and computer use had been present throughout the 1990s and by the end of the decade were becoming commonplace, as poor definitions for VR and the increased use of computers in American society meant that, for many, VR and computer usage (particularly web usage) were understood to be synonymous. Tinianow's inability to separate the technological reality of VR from the marketing hype reproduced verbatim in newspapers and journals contributed to his acceptance of the Internet, computer games, and VR as expressions of the same core system, and microcosmically demonstrates why the Web supplanted VR. In believing one could meet friends and strangers in VR, that the Internet facilitated VR, and that VR and the Web were vitally connected, Tinianow had demonstrably blended technological realities with marketing punditry and failed to grasp the scale of the divide between VR's technical potential and public rhetoric.[149] Much like the majority of interested American consumers, truth and fiction had combined in his mind to form an unattainable ideal, destined for technological failure.

Throughout the 1990s, research into the effects of VR usage on the human body were alarmingly under-studied. Colloquially, understandings that VR often caused eyestrain abounded in popular writing, and by the mid-1990s, anecdotal evidence suggested that prolonged VR use impaired judgment and spatial perception for a time after use.[150] Limited inroads were made into physiological VR research, visible in theses and technical publications, in 1996-7, and the reason for the lack of research may have been the absence of VR from American homes, thus reducing cultural pressure to address public health concerns.

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[149] Tinianow, 'VR as a Mass or Massive Medium' 10-11, 13-4.

[150] Neil Gross, 'Seasick in Cyberspace: No One Is Sure What Causes Virtual Reality's Side Effects, but the Threat of Litigation Makes Them Serious', *Business Week*, July 10 1995, 110; Jon Van, 'Virtual Reality Side Effect: Cybersickness: Disorientation Is One Of Technology's Bugs.' *The Washington Post,* September 25, 1995, WashTech; Schroeder, *Possible Worlds*, 93-5.

Much of the visible research came from NASA which had been carrying out research into Simulator Sickness as a precursor to VR's physiological impacts in the preceding decades.[151] Beyond governmental walls, however, there was little. Tinianow made brief reference to eye strain and RSI in his thesis, referencing an article in *USA Weekend*, the now-defunct magazine companion to popular American newspaper USA Today.[152] The widespread popular reports, set against the lack of scientific study, could be explained by widespread low-level physiological and psychological symptoms during and after VR use, which were among a sufficiently small part of the population to avoid expedient efforts to understand the causes of said symptoms.

Neill Gross, in the trade journal *Business Week,* tried to explore this in greater detail by contacting VR manufacturers for their own explanations and responses to the problems caused by VR use in 1995, which, in his writing, enumerated 'eye strain, nausea, and flashbacks' a term he called 'cybersickness'.[153] The word cybersickness appears to have first appeared around 1992, in a discussion by Michael McCauley and Thomas Sharkey of the impact of perceived motion in virtual environments. They described cybersickness as a suite of symptoms which behaved like an advanced version of motion sickness, with the only solution they could suggest being highly managed exposure to VR technology, and better equipment design.[154]

Kay Stanney and Robert Kennedy, both NASA researchers, studied aspects of cybersickness in 1997 and found that VR exposure could cause considerable disorientation, nausea, and eyestrain.[155] They developed a questionnaire to evaluate sensations of sickness and used it to compare different VR devices, and their methodology would find wider use in the 21st century, with contemporary American researchers seemingly neglecting the opportunity it offered for establishing a standard index of cybersickness levels. In the same year, they presented a paper at IEEE 1997, demonstrating an experimental measure of disorientation and adaptation to immersion in virtual environments. They found that, even after brief periods of use, VR users' spatial perception was impaired for some time, leaving many VR users physiologically maladapted to the real world. Despite calling for further research, there seems to have been little reaction to the release of their findings, perhaps as by that point, HMD-based VR was far from common.

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[151] Robert Kennedy and Kay Stanney, 'Postural Instability Induced by Virtual Reality Exposure: Development of a Certification Protocol.' *International Journal of Human-Computer Interaction* 8, no. 1 (March 1996), 25–47; Donald Parker and Deborah Harm, 'Mental Rotation - A Key to Mitigation of Motion Sickness in the Virtual Environments?' *Presence: Teleoperators and Virtual Environments* 1, no. 3 (1992): 329–33; Robert Kennedy, Marshall Jones, Michael Lilienthal, and Deborah Harm, 'Profile Analysis of after-Effects Experienced during Exposure to Several Virtual Reality Environments.' In *AGARD, Virtual Interfaces: Research and Applications 9 P (SEE N94-37261 12-53);* US, 1994. https://search.proquest.com/docview/26553317/72EA940A122C4E6BPQ/4 [Accessed 25 May 2017]

[152] Tinianow, 'VR as a Mass or Massive Medium' 189.

[153] Gross, 'Seasick in Cyberspace', Para. 2, 4-5.

[154] Michael McCauley and Thomas Sharkey, 'Cybersickness - Perception of Self-Motion in Virtual Environments', *Presence: Teleoperators and Virtual Environments*, 1/3 (1992), 311–18.

[155] Kay Stanney and Robert S. Kennedy, 'The Psychometrics of Cybersickness', *Communications of the ACM; New York*, 40/8 (1997), 66–68.

Stanney and Kennedy's writing, like Tinianow's, lagged behind the shift in public interest away from HMD-based VR. This delay, visible throughout American academia into the late 1990s and beyond was partially due to the inevitable delays caused by peer review and funding applications, as well as by the continued pursuit of HMD-based VR technologies for human factors research after the ascendency of the Web had dismantled VR's promise for the entertainment industry.[156] An example of this persistent connection between VR and academia (or perhaps, science) is StrayLight's provision of VR hardware for company shows and demonstrations, particularly within the pharmaceutical industry, well into the 2000s.[157] As can be seen, academic VR research was seemingly gaining acceptance and traction around 1997, when public appeal was already diminishing.

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[156] Steve Woolgar, 'Five Rules of Virtuality', in *Virtual Society?: Technology, Cyberbole, Reality* (2002), 13; Paul Sanberg, Morteza Gharib, Patrick Harker, Eric Kaler, Richard Marchase, Timothy Sands, and others, 'Changing the Academic Culture: Valuing Patents and Commercialization toward Tenure and Career Advancement', *Proceedings of the National Academy of Sciences*, 111/18 (2014), 6542–47; Kristal Zook, 'Academics: Leave Your Ivory Towers and Pitch Your Work to the Media', *The Guardian*, 23 September 2015, Higher Education Network section https://www.theguardian.com/higher-education-network/2015/sep/23/academics-leave-your-ivory-towers-and-pitch-your-work-to-the-media.

[157] Asch, interview, 14 May 2017.

EXCEEDING ONES GRASP: THE COLLAPSE OF THE VR BUSINESS AND THE ASCENDENCY OF VIRTUAL SPACE IN 1997

By the end of 1997, the American public could not buy HMD-based VR. Expensive bespoke hardware and software joined older systems no longer supported by their manufacturers, in a niche market with users in the dozens.[158] Available systems ran on professional systems unavailable through mainstream retailers, such as Sun's *Swivel* (formerly VPL's) and Brown University's *Sketch* on SGI Desktop PCs.[159] Popular VR systems like the Virtual Boy had been discontinued by 1997, and VR kits for home computers, like the Forte VFX1, suffered from the same obstacles and higher prices.[160] No longer visible in arcades or TV, the material culture of HMD-based VR shrank to the academic and industrial contexts where it was demonstrably valuable. The (by now) persistent attribution of the term to computers, games, and the internet perpetuated a larger social presence devoid of technological foundation.

The causes of this decline from a position of such popularity are diverse. Since being pulled from the institutional cradles of NASA and UNC, VR had increasingly been defined, exaggerated, and sold as a far more powerful iteration of the technology than was actually possible. Enthusiasm and hyperbole fed each other, reducing the possibility of the technology ever meeting expectations. Companies seeking to succeed avoided collaboration, leading to multiple parallel developments in line with the science fiction aspirations of their founders rather than viable goal-oriented project management. VR, at its very inception, was an idea without execution, unachievable in the time allowed (measured in years, not decades). The basic research of military and university projects, fundamental to any technology, gave way to the chaos of private capital.[161] 1990s VR was, as a result; expensive, uncomfortable, nauseating, dangerous, visually unappealing, incompatible, and nigh-unusable. It was the hope for what VR may become, rather than what it was, which drove development, investment, and public attitudes. That hunger for a product which did not, and could not, exist was a key cause of VR's fall from grace. In a period of economic boom and technological success, the World Wide Web had delivered a thriving creative and financial ecosystem in which VR's promises were made more real than ever.[162]

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[158] Lanier, 'VPL Software Lives!'
[159] Ibid, para 7.
[160] Sarah Dobbs, 'What's A Wearable?' *Micro Mart; London*, February 20, 2014; Nathan Cochrane, 'VFX-1 Virtual Reality Helmet by Forte' *Game Bytes*, 1994; Brook Talley, 'VFX-1' *InfoWorld; San Mateo* 18, no. 48 (November 25, 1996): 80.
[161] Thorpe, Interview, 21 October 2016.

The success of the Web could be attributed to its usability, accessibility, and the cultural and social hunger for computer-aided connectivity, computer-driven cultural change, and easily accessible information. That same hunger had been thought, by many, to only be satiable through VR. The Web, therefore, deflated VR's bubble rapidly, as Cyberpunk culture turned into a more mainstream computer-using demographic online. Popular fiction by William Gibson, Vernor Vinge, Bruce Sterling, and Neal Stephenson, had cemented ideas of a fresh digital world in the minds of many, and in the 1980s this had combined with the counter-cultural liberalism of the San Francisco Bay area to create an incubator for VR, outside of which the concept faltered. The 1990s return to social conservatism (or the progressive acceptance of the counter-culture of the previous decades into mainstream culture), shifted discourse away from a subversive Cyberspace, from fringe technologies, and towards the online (once-frontier) communities like the WELL which had shaped much of VR's early language and concepts.

By the time VR companies had sprung up, however, the changing technological environment and discrete approaches led to slow progress, meaning that the quality of VR technology displayed at 1990s events such as Cyberthon, Cyberconf, and the Mecklermedia trade shows was universally poor as it was rushed, hampered by limited capital, and poorly-optimised. Despite this, media outlets continued to extoll VR's virtues. The notion of a technology which allowed people to do anything, be anyone, and express oneself in new ways interested many for whom life away from their computer was less fulfilling, less reflective of their true selves, and even real. Many computer users, more broadly, were excited by the prospect of being able to talk, work, play, and even have sex from the profoundly intimate comfort of an HMD connected to their home computer.

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[162] Colin Campbell, *The Romantic Ethic and the Spirit of Modern Consumerism*. (1987), 77-95.

VR's core appeal thus grew from its position as a unique gateway to a futuristic computer and Internet culture, and in late 1994 access to that culture, that cyberspace, became far easier through the World Wide Web. Very quickly governments, companies, and private citizens were creating and sharing content. The online world became richer, more diverse, more engaging, and dystopian as it approached the transformative, sublimatory experience of fictional Cyberspace in 1996 and 1997. At almost the same time VR, the hyped, vaunted foundation of this new cyberspace-based future arrived on the shelves of Toys 'R' Us, and demonstrated in an irrevocable, physical way, that VR was nothing like what had been promised, it could not, and would not, deliver the intimate transportation to an infinite nexus of human creation described in newspapers, novels, magazines, and advertisements. If the uncomfortable linearity of the Virtual Boy was VR, what then was the web? For the popular media and much of the public, the Web, and the connectivity it gave people to individuals and services became VR. The meaning and usage of the term shifted, expanded, and gradually began to fade while the material culture of data gloves and HMDs rapidly vanished into obsolescence and obscurity. From 1987 to 1997, VR had passed from state stewardship to private firms, which generated colossal public interest and a smattering of products before promptly vanishing. Only the name persisted in the public eye, separated from its hardware, and rooted solely in the virtual itself.

There was no single event or technological failure which led to the collapse of public interest and investment in VR companies in the late 1990s. Instead, it seems that that desperation for profit, rapidly changing consumerism, extreme technical hurdles, cultural misunderstandings, and over-use of the VR moniker fuelled a discrepancy between public expectations for VR, the capabilities of VR products, and their technical foundations. This had, at its core, the efforts of private companies to adapt VR for use as an immersive entertainment medium, when its proven uses lay in the work of Sutherland, Furness, Negroponte, Kreuger, and others; in IA. As time passed, it became increasingly clear that VR was not suited to providing the experiences which had been expected, nor was it technically capable of doing so. It also became clear that the Web more closely met and even exceeded these desires, in a manner less physically uncomfortable, complicated, or expensive than VR. As Internet infrastructure and connectivity developed, and download and upload speeds improved, the Web increasingly surpassed even science fiction fantasies of electronic communication and cyberspace from only a few years earlier. With VR development falling back to its demonstrably valuable uses in IA, the culture and language of VR was subsumed by the Web among the turmoil of the dot-com bubble, and the growing place computers had in the lives of everyday Americans. To turn VR from a thinking tool into an object of entertainment, creation, and communication may have been possible if a shared language, approach, and paradigm had been adopted and championed by a single successful firm, around which others could have gathered, and concerted efforts to combat VR’s technical and scientific obstacles could have been made. However, the insular nature of American technology companies, and the lack of shared industrial standards rendered such a monumental task impossible in the time-frame allotted, which demanded products in years rather than, as Henry Fuchs suggested, half a century.

The fate of VR after this shift is fascinating, as the technology underwent dramatic changes in society and culture, and the fundamental expressions of its nature and purpose were repositioned by VR companies, as much as by the press. In the early 1990s, concerns had been raised by VR’s advocates that the proliferation and dilution of ‘VR’ could damage it, and by the end of the 20th century this seems to have become true. Increasingly derided as vapourware, an announced but non-existent technology, VR’s roots appeared overcomplicated and broadly valueless. This shift in understanding persisted into the 21st century and fundamentally altered the ways in which VR was perceived and conceptualised up to the 2010s and beyond.

CHAPTER 5: VR IS DEAD. LONG LIVE VR – 1998-2005

`'> what is taking so long for them to design and market a 3d helmet and walking pad thingy so I can actually walk into a new world and look around 360 degrees?`
`> I mean I have heard and seen pictures of the 3d helmet but serously dont you think they should be getting close to perfecting it?`
`> I only mention this because I had a dream last night where I bought one, went into a game where it plopped me into a huge city with cars and poeple walking around, and I had to hide in this huge detailed city as police were driving around looking for me and the object of the game was not to get caught.`
`> I just hope it was a dream.`
`> anyways I am gettiong tired of the monitor in the dark room thing.`
`>'`

- Very3@aol.com, 'where is my virtual reality?!!!!!!', in the comp.sys.ibm.pc.games.action Usenet, 2000.

`'Is the idea of VR a failure? We think not, but the field does face difficult research problems involving many disciplines. Thus, it should have been expected that major progress would require decades rather than months. This holds especially true in the area of systems, which require synthesizing numerous advances.'`

- Burdea et. al. 'VR Reborn', 1998

THE PRICE OF FAILURE: AN OVERVIEW OF THE 1990S WINTER AND SUBSEQUENT TRANSFORMATION OF VR

The period immediately following the bursting of the VR bubble and the establishment of the dot-com bubble in 1997, was a complex time for VR technologically, socially, and semantically. The considerable over-inflation of the early to mid-1990s VR technology scene had drastically warped consumer expectations, failed to even approach them, and frustrated investors. VR had been framed by marketing, false promises, and hype (or to borrow a term from Steve Woolgar, Cyberbole) as its source of direction and funding, and was inherently unsustainable.[1] The outlandish promises of the early 1990s had driven popular notions of VR into a narrow set of paths which the hardware was unsuited to, and adaptation of existing typologies seemed not only extremely complex but perhaps impossible. As a result, in the period of 1998-2005, the marketed and perceived functions and technology of VR underwent radical transformations as developers, pundits, and salespeople all tried to salvage a former American hot topic. From a material-cultural and purely technological standpoint it can appear that, during this time, VR technology itself took a nosedive in visibility, perceived viability, and development. Innovation slowed to a crawl, and the VR business as it was in the early 1990s ceased to grow, and almost ceased to be. However, in this chapter, it shall become clear that this was not entirely the case, and this recession marked only a chrysalid stage for VR development and led to an entirely different social and technological paradigm for VR going into the new millennium, and up to the present day.

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[1] Thomas Hughes, 'The Evolution of Large Technological Systems', in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, Wiebe Bijker, Thomas Hughes, and Trevor Pinch (eds.), First Paperback (1989), 51–80; Steve Woolgar, 'Five Rules of Virtuality', in Steve Woolgar (ed.), *Virtual Society?: Technology, Cyberbole, Reality,* (2002), 9.

1998-9 saw the number of advertisements for full HMD-based VR systems collapse in the US, as key Cyberpunk print publications like *Mondo 2000*, *Omni*, and the *Whole Earth Review*, bastions of VR evangelism, ceased publication. VR in television and film moved increasingly away from the sanitised, over-ambitious interpretation of real-world technology seen in films like 1996's *Strange Days*, 1994's *Disclosure*, and 1992's *The Lawnmower Man*, and toward a more insidious, deceptive, and sinister chill of non-consensual sensory immersion in 1999 films like *The Matrix*, *The Thirteenth Floor*, and *eXistenZ*.[2] The shift in popular culture: from VR being a tool enhancing intellectual, physical, and sexual power, to becoming a means of deception, debilitation, and violation, suggests a paradigm shift in the way that immersive VR was perceived and understood. The VR in those later, darker films, was not HMD-based, brightly coloured, and adorned with the plastic and chrome of 1990s material culture, but was more closely connected to the dystopian imagery of cyberspace.

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[2] Kathryn Bigelow, *Strange Days*, 1996; Barry Levinson, *Disclosure*, 1995; Brett Leonard, *The Lawnmower Man*, 1992; Lana Wachowski and Lilly Wachowski, *The Matrix*, 1999; Josef Rusnak *The Thirteenth Floor*, 1999; David Cronenberg, *eXistenZ*, 1999; Svante Lovén, *Also Make the Heavens: Virtual Realities in science fiction,* (2010), 17.

By the late 1980s and early 1990s, assumptions by inventors, investors, journalists and even politicians (such as Al Gore) held that VR, using gloves and goggles, would provide the means to access an immersive, empowering information superhighway where people could talk, work, and consume through a computer-mediated landscape.[3] Connecting the highly technically complex and varied proprietary VR systems of the time to the slow, telephone-based infrastructure of the Internet could not provide these experiences, and technological realities approaching popular notions of cyberspace were only achieved in highly controlled and expensive laboratory conditions. Having committed considerable funds to, and shaped the public imagination in favour of, this particular vision VR developers and marketers alike were left in a quandary by the widespread rejection of the immersive VR message, and the collapse of the VR business. The notion of path dependency, borrowed from economic history, is a useful tool here, describing the increased difficulty of changing a course of events the longer things continue along a particular 'path' or, in other words, the importance of history to present and future events.[4] While it is contended here that technical and social paths develop separately of each other (or at least at different speeds), the early claims made about VR created clear cultural and social pathways that would prove difficult to alter as disaffection with VR deepened. Having set off down a path riddled with technological hurdles and even impossibilities, in the name of marketable science fiction connotations, VR found itself between the rock of history and the hard place of consumer fatigue. From 1998 onward, there was a visible shift in the way that expectations for and expressions of VR were made: VR ceased to be the means by which Cyberspace was accessed, and the culture, infrastructure, and technology of the Internet and the World Wide Web became a gateway to an ever-expanding, collaborative VR, encouraging shifts in material culture and the career paths of dozens of people tied to the VR business. The end of the 20th century, and indeed the early 21st, witnessed VR as a concept repositioned from being a tool of interface and communication to being a *metaphysical* notion of shared virtual space and community. This idea was enabled and hosted by the Internet.

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[3] Ralph Schroeder, *Possible Worlds: The Social Dynamic of Virtual Reality Technology* (1996), 150; Howard Rheingold, *Virtual Reality: The Revolutionary Technology of Computer-Generated Artificial Worlds-And How It Promises to Transform Society*, 1st edition (1992), 221.

[4] Stan Leibowitz and Stephen Margolis, '770 Path Dependence', *Encyclopedia of Law and Economics*, 2000, 981 <http://reference.findlaw.com/lawandeconomics/0770-path-dependence.pdf> [accessed 31 August 2017].

The period saw uses of full 'traditional' VR using an HMD, motion tracking, and haptic feedback retreat to university applications, for research in medicine and human factors, and promotional materials for major industrial trade-shows in the US. Many of the VR schemes run by American business in the early 1990s changed paths entirely and were either migrated to 2D desktop systems or shifted away from the immersive helmet paradigm toward the more intuitive, comfortable, and (perhaps most importantly) sharable VR technology of Large Volume Displays (LVDs). LVDs, such as CAVE VR systems, allowed multiple concurrent users of a single stereoscopic 3D display, making them more cost effective and better suited to the collaborative environments of development teams.[5]

As the use of traditional VR waned so too did development as companies manufacturing and selling HMDs began to fail. Those that survived did so by branching out into other product areas or by redefining their range of products, and the nature of VR, in order to survive.[6] A schism took place within HMD typology when high-end, motion tracked HMDs fell by the wayside, and cheap, light, overwhelmingly monoscopic, non-motion tracking face mounted displays (FMDs) reached the mass market. Coming almost exclusively from Japan, FMDs were understood as VR by many, and they were discussed in terms of being a part of the VR material-cultural landscape. However, their almost completely different ranges of functionality, price, and application highlighted just how little consensus there was over the definition and nature of VR itself. The expensive tracking stereo headsets, crucial to the-once vaunted cornerstones of VR: immersion and presence, were passed up in favour of far cheaper, mass-produced displays which offered little more than the illusion of watching a large television. At the time, widescreen and high-definition digital televisions were just beginning to enter the American market, at high prices nonetheless dwarfed by the cost of VR systems in the early 1990s.[7]

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[5] Grigoire Burdea and Philippe Coiffet, *Virtual Reality Technology* (2003), I , 60-83, 349-61.

[6] Robert Lindstrom, 'Meet Your Future: 13 Ways Presenting Will Change', *Presentations; Minneapolis*, 12/4 (1998), 64–73; 'Virtual Research Systems: Window VR' 1999, <http://www.virtualresearch.com/products/win_vr.html> [accessed 17 July 2017]; Fred Hapgood, 'Virtual Reality Gets Physical', *CIO; Framingham*, 14/3 (2000), 242–44.

By the late 1990s, there was a general assumption in print media that HMD-based VR was a foolish, expensive fad, suited to games and not much else. The widespread and considerable investment in hosts of HMD-based VR solutions had been misplaced. Technological advances had been too slow, too far between, and not unified behind any constructive vision. The threat (and pull) of VR-enabled cybersex, which was never really a technical possibility (but of course a media sensation), failed to materialise along with all the other promises which were made in the early 1990s. This was explicitly understood and realised by innovators, journalists, and members of the public interested in VR.

Through the early 2000s then, VR can be seen in two ways. From an objective, technical standpoint, VR was a failed technology: it had almost no market penetration, there was no technological transfer, and no innovation. In short, it had failed to become a technological *system*. From the perspective of those engaged with computers and VR discussion though, it was very much alive. Yet how could there continue to be considerable discourse in the US about VR when the helmets, gloves, and feedback devices crucial to its past iterations were all but invisible in the public eye? The solution, and VR's lifeline lay perversely in the diversity of opinion on just what constituted VR, and the lack of standards and pathways endemic to the technology throughout its history. By 1999 it was clear from the popular literature that for many, including the crucial business market, that helmet-based VR's moment had passed. Going into 2000 and 2001, there were major shifts in the word usage and linguistics surrounding VR technology.[8] Moving away from connotations of immersion, technological complexity, or the revolutionary frontier rhetoric of the 1990s, 2000s VR was couched in increasingly pragmatic and reductionist terms. The lack of understanding or vision surrounding VR is visible via contemporary literature in repeated, wildly varying definitions, and a seeming assumption that what could never be done was already possible.[9]

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[7] Joel Brinkley, 'HDTV: High Definition, High in Price', *The New York Times*, 20 August 1998, section Technology <https://www.nytimes.com/1998/08/20/technology/hdtv-high-definition-high-in-price.html> [accessed 21 March 2018].

Throughout the late 1990s, and up to the end of the Clinton presidency, the development of Internet infrastructure had been a part of government policy. While the Bush administration did not formulate a conclusive policy for further implementation of broadband until 2005, Internet use throughout the early 2000s expanded rapidly. The proliferation of websites and Internet services (like Amazon, founded in 1994, eBay in 1995, Myspace and Second Life in 2003, Facebook in 2004 and YouTube in 2005) provided access to a networked, interactive, and computer-enabled working, social, and sexual life. In other words (as discussed in the previous chapter, p.156) the Internet in the 2000s came to viscerally embody the sensations and potential that much of VR's hype had described. The intellectual, social, and epistemic path-dependency which VR suffered was adopted, supported, and amplified in the Internet, while the jumbled and mismatched hardware of VR continued to change and grow without clear direction or momentum. The desire of individuals and businesses alike to use the Internet and the World Wide Web grew with bandwidth, access, and hardware, with cheaper computers and specialist hardware like Web-PCs flooding the market.

It was around the year 2000 onwards that a key shift in the perception of VR became visible, as VR firms, journalists, and innovators alike began to use the term VR to describe online experiences (among countless other things) which were not strictly VR. The sense of presence and immersion was still implied, but it was now gained from the engaging, rich content provided by interactive, collaborative online services in an increasingly contributive Web (what was hoped to be DiNucci's Web 2.0.)[10] Not only were the headsets and gloves of 1990s VR gone, they had been deliberately cast aside. Numerous articles and statements from journalists, pundits, and even VR companies which manufactured HMDs (most notably Virtual Research in the below quotation from 1999, which had been the leading manufacturer of HMDs in the mid-1990s), placed the blame for VR's 1990's failure on HMDs, not on the notion of VR itself.[11] The fact that the old iteration of VR had promised much and delivered nothing as a result of major stumbling blocks to innovation and development caused by advanced technologies and a shortage of suitable expertise, encouraged a shift towards a version of VR which required a more easily-learned set of skills, and less rarefied tools and systems. VR systems of the early 1990s had been publicised and funded almost entirely by media deception and wishful hyperbole, and the consequences of this were seemingly ignored by many of the developers and pundits who had witnessed the aftermath first-hand. VR's future lay away from HMDs as an umbrella term for a number of the more socially contentious uses of the Internet: online shopping, chatrooms, gaming, and cybersex.[12]

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[8] Sarah Fister, 'Tech Trends', *Training; Minneapolis*, 36/8 (1999), 24–26; Barbara Rothbaum and Larry Hodges, 'The Use of Virtual Reality Exposure in the Treatment of Anxiety Disorders', *Behavior Modification*, 23/4 (1999), 507–525; John Mayer, 'It's All in Your Head', *GCN*, 20 June 2000.

[9] Burdea & Coiffet, *Virtual Reality Technology*, 277; 'Automakers Spend Big on New Computer Design Tools', *Ward's Auto World; Detroit*, 35/2 (1999), 32;Christopher Ryan 'Virtual Reality in Marketing', *Direct Marketing; Garden City*, 63/12 (2001), 57–62.

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[10] Darcy DiNucci, 'Fragmented Future', *Print Magazine*, 4, April 1999, 32, 221–22; Nate Anderson, 'Tim Berners-Lee on Web 2.0: 'nobody even knows what it means'", *Ars Technica*, 2006 <https://arstechnica.com/information-technology/2006/09/7650/> [accessed 7 August 2017].

[11] Virtual Research Systems: Window VR.

[12] Junko Yoshida, 'Virtual Reality All Shook up', *Electronic Engineering Times; Manhasset*, 1157, 2001, 1,176; Thomas Naylor, 'Trading Our Souls for Virtual Reality', *Across the Board; New York*, 38/4 (2001), 19; William Halal, 'TeleLiving: When Virtual Meets Reality', *The Futurist; Washington*, 37/2 (2003), 44–46; Emily Keshner, 'Virtual Reality and Physical Rehabilitation: A New Toy or a New Research and Rehabilitation Tool?', *Journal of NeuroEngineering and Rehabilitation*, 1/1 (2004), 8; David Kushner, 'My Avatar, My Self', *Technology Review; Cambridge*, 107/3, April 2004, 50–55; Anne Sachs, 'Virtual Reality: In What May Be the Next 'It' Sponsorship, Leading Athletic Companies Are Discovering Big Business Not in Real-Life Athletes, but in Virtual Ones.', *Footwear News : FN; Los Angeles*, 61/5 (2005), 142; Nicole Constable, *Romance on a Global Stage: Pen Pals, Virtual Ethnography, And 'mail-order' Marriages* (2003); John Briggs, 'Virtual Reality Is Getting Real: Prepare to Meet Your Clone', *The Futurist; Washington*, 36/3 (2002), 34; Stella Koh, 'The Real in the Virtual - Speech, Self and Sex in the Realm of Pure Text', *Asian Journal of Social Science*, 30/2 (2002), 221–38.

> Perhaps the biggest problem has been the head mount display (HMD). These displays were difficult to put on, prone to breakage, and created hygiene risks within heavy use environments. In addition, the equipment precluded any group interaction because it was immersive… Historically, many believe the 'real' VR applications must include an HMD. WindowVR dispels this common misconception delivering a fully integrated VR solution complete with display, position tracking, and built-in navigation controls.
>
> - *'Your Window to the Virtual World!'* Virtual Research Systems.[13]

The diversification of VR's use as a term in the mid-2000s only contributed to the confusion surrounding what it meant, as the line between VR and the Internet or video games increasingly muddied, direct applications of the term (i.e. referring to the discrete technologies of VR) began to fall out of use. By 2005 usage had fallen by around 80% from 1990 levels in newspapers and magazines (based on survey figures from EBSCO and ProQuest). The rapid changes in definition which people had attached to VR had been essential to its survival of the demise of HMDs, glove interfaces, and haptics in the 1990s, but without those, there was limited technical or material-cultural uniqueness left to separate the systems of VR, video games, and the Internet. Using VR to describe websites and games fell out of common occurrence in the 2000s (fig. 12), and similarly the technology would be considered a fad, confined to memory, until drastic changes in other technologies, such as smartphones, computer graphics, and online content creation, sparked a revival of traditional VR hardware, along with a newfound appreciation for 'retro' technologies in around 2012.

Re-aligned almost exclusively with the video game and pornographic industries, VR was reinvented yet again for the current decade, but that was only made possible by the cognitive dissipation and technological failure of the previous generation of VR which has been so poorly examined or understood. Interestingly, by the VR revival in the 2010s, the 'new' definitions established in the early 2000s had been lost. By that point, VR hardware had returned to its mid-1990s roots, which suggests that ignoring the path dependency of hardware eventually leads to its abandoned technical traits being eventually 'rediscovered' and embraced.[14] The fluid, dispersed hopes, dreams, and definitions attached to VR in the early 2000s were key to calming the disillusionment and anger of investors and VR's core demographics respectively, following the mass disappointment and abandonment of the VR hardware of the mid-1990s, and allowed the VR revival visible in the 2010s and, perhaps, beyond.

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[13] Virtual Research Systems: Window VR.

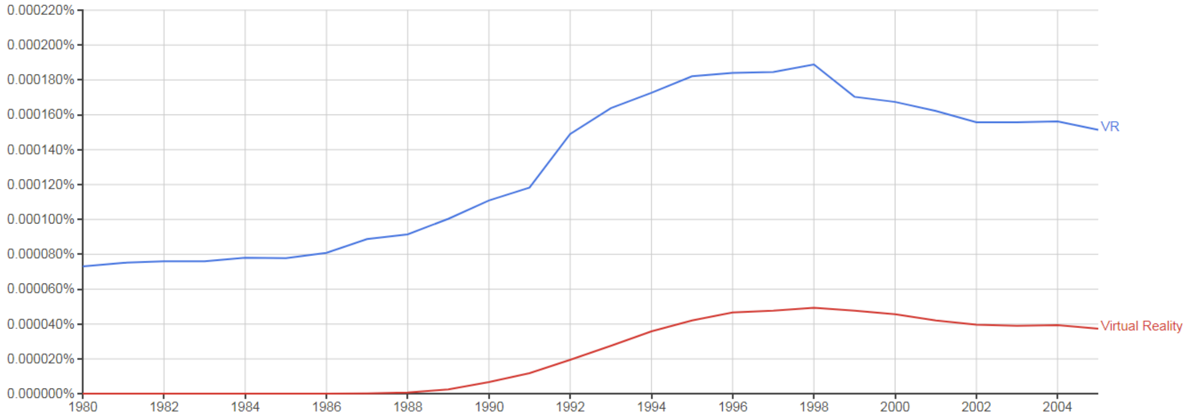

FIG. 12 A Google Ngrams Graph, charting the popularity of the terms VR and Virtual Reality in books. Usage peaks in 1998 for both before trailing off, with VR consistently remaining the more popular term, in line with its looser definition and broader application beyond the HMD based high technology. In 1998 0.00018% of the entire Google-archived US literary corpus contained 'VR' and 0.000049% contained Virtual Reality, falling to 0.00015% and 0.00039% respectively by 2005. The presence of positive results prior to VR's naming in 1986 seem to be caused by the way in which Google's text-scanning software combines characters, an error that becomes invisible in search results once the term comes into usage.

DARKNESS AND DOUBT: THE SHIFT FROM POPULAR HOPE TO DISAPPOINTMENT AND PRAGMATISM, AND THE SUPREMACY OF THE INTERNET - 1998-2000

DISAPPOINTMENT AND PRAGMATISM

By the turn of 1998, the optimism, hype, and excitement about VR which had flowed through the American tech industry and interested laypeople was long gone, and the excessive promises and diverse, grandiose visions shown to investors and large organisations had come back to haunt many of the existing VR firms producing software and hardware. Investor caution, and a desire to cut losses led to attempts to claw back invested funds, and VR firms, which had numbered over 500 in its 1995 peak, fell drastically.[15] Exact numbers are hard to determine, precisely because the collapse of the business was so quick that trade shows, academic compendia and magazines all fell away from VR so quickly. VPL was long gone, with bankruptcy turning to complete shutdown in 1993. Sense8, once considered a leading provider of VR systems, had also shut down by 1998 (though its systems would continue being used by NASA Ames into 2018). Virtuality, the largest single manufacturer and designer of in-house VR for location-based entertainment, had tried to branch out in 1996 with Atari's Jaguar and overstretched at the same moment as investor good-will dried up. The machines and licensing were sold off in 1997 to CyberMind UK and, by 1998, were all but invisible in US arcades. The company's founder, Jonathan Waldern, turned his attention to Japan, instead of the West, and VR arcades dwindled rapidly by 1998. By the year 2000, they were almost non-existent in the arcade scene. This is in part due to the collapse of the arcade industry in the US at this time (which shrank to a new low market size of $1.33bn in 1999), but also because the machines (expensive in material, maintenance, and staff) had been recalled when the arcades were unable to buy them outright.[16] VR was understood by journalists, scientists, innovators, and the public, to have failed.[17]

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[14] Joël Bellaïche, 'On the Path-Dependence of Economic Growth', *Journal of Mathematical Economics*, 46/2 (2010), 176-7.

In a range of technical and popular media at the time, however, mentions of VR continued to be prolific, even though one could not buy a VR system as an American consumer, nor could one play VR games in arcades. There were three main reasons for this. First, during the late 1990s VR remained fresh in the minds of a sizable portion of the US public and, more importantly, in the minds of writers and journalists for whose publications, a few short years earlier, VR had been a phenomenal draw for readers and customers. Many publications from the late 1990s continued to talk about VR as if it was an imminent technological reality.[18] Articles talking about video games, online shopping, virtual networks, real estate, and others all used the word VR, or the term Virtual Reality, without there being a single mention of specific technology itself in the body of their writing. To many journalists and some academics, VR was a powerful, controversial buzzword. Even after investor and consumer desire had dried up, it continued to be used, contributing further to the second main factor in the persistence of VR rhetoric after its technological withdrawal.

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[15] Lawrence Rosenblum, Grigoire Burdea, and Susumu Tachi, 'VR Reborn', *IEEE Computer Graphics and Applications*, 18/6 (1998), 21–23

[16] Tony Asch, Interview, 14 May 2017; Robert Johnson, 'Arcade Fans Discover New Use for Skee-Ball: Fighting Video Fatigue - To Many, 92-Year-Old Game Has a Virtue Virtual Reality Can't Match', *Wall Street Journal* (22 February 2001), section A, 1.

[17] Drew Winter, 'Ditching Virtual Reality', *Ward's Auto World; Detroit*, 34/1 (1998), 64; Rosenblum et. al. 'VR Reborn'; Hirokazu Kato and Mark Billinghurst, 'Marker Tracking and HMD Calibration for a Video-Based AR Conferencing System', in *AR, 1999.Proceedings 2nd IEEE and ACM International Workshop on Augmented Reality* (1999), 85–94 http://ieeexplore.ieee.org/abstract/document/803809/; Frederick Brooks, 'What's Real about Virtual Reality?', *IEEE Computer Graphics and Applications*, 19/6 (1999), 16–27; Fister, 'Tech trends'.

The second reason is that there was considerable confusion concerning the meaning of VR and Virtual Reality in the late 1990s and early 2000s. Prolific over-use of the term by journalists, politicians, television shows and movies had clouded meaning. There was no shared definition or language for VR, a problem from the inception of the term in the late 1980s. However, by the end of the 1990s this ambiguity, coupled with the proliferation of a whole raft of different images and attempts at the same basic technological system, meant that there was no clear understanding of what VR meant. This is perhaps made most clear by the observation that, in the late 1990s and beyond, a large proportion of articles in magazines, newspapers, and technical journals discussing VR made the explicit point of defining the technology for the purposes of their writing.[19] If, when writing an article about a much-discussed, culturally present technology, one needed to open by defining it, discord seems implicit. After all, most articles in the 1970s about television did not begin with a definition of television. This is made clear by the diversity of definitions visible in that writing. For some, VR had presence and immersion as its core tenets, and the ability to place yourself within the environment and interact with it was key. For others, it was the use of 3D computer graphics, for others still it was 3D displays, and for some, it was simply by virtue of being on a computer, or accessible on the Internet, which made VR, VR.[20]

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[18] Bill Laberis, 'Virtual Reality', *ENT: Enterprise Solutions for Managers of Windows NT; Fort Washington*, 4/9 (1999), 62; Lindstrom' Meet your future'; Dan Lonkevich, 'American Re-Uses Virtual Reality to Fight Arson', *National Underwriter, Property & Casualty/Risk & Benefits Management Ed.*, 103/28 (1999), S23; Denise Pappalardo, 'Virtual Reality', *Network World; Southborough*, 15/39 (1998), 54–58; Michael McCarthy, 'Virtual Reality', *Adweek, Eastern Edition*, 40/24 (1999), 30–36; David Stamps, 'On the Road to Virtual Reality', *Training; Minneapolis*, 35/9 (1998), 86–88.

[19] Winter 'Ditching Virtual Reality'; Guiseppe Riva, Brenda Wiederhold, and Enrico Molinari, *Virtual Environments in Clinical Psychology and Neuroscience: Methods and Techniques in Advanced Patient-Therapist Interaction* (1998), 1; Christina Botella, Rosa Baños, Conxa Perpiñá, Helena Villa, Mu Alcaniz, and A. Rey, 'Virtual Reality Treatment of Claustrophobia: A Case Report', *Behaviour Research and Therapy*, 36/2 (1998), 239-40; Barbara Rothbaum, Larry Hodges, Renato Alarcon, David Ready, Fran Shahar, Ken Graap, and others, 'Virtual Reality Exposure Therapy for PTSD Vietnam Veterans: A Case Study', *Journal of Traumatic Stress*, 12/2 (1999), 263-4.

The commercialisation and over-use of the terminology and imagery of VR, coupled with poor understandings of just what the term meant, compounded and exacerbated frustration, disappointment, and even anger surrounding VR's absence at the end of the 1990s. Investors, businesspeople, and consumers had been surrounded and bombarded by imagery telling them that VR was the next big thing. In some cases, millions of dollars had been spent on projects that did not leave the prototype phase, failing to establish standards or viable pathways to technological innovation and style. The term 'vapourware', used to mean a technology that was announced or promised but never materialised (or was fraudulent), surged in usage at this time, with peak usage (across a sample of publications from 1965-2008) coming in 1998 and 1999 (see fig. 13).[21] VR could easily be used as the poster-child for vapourware. A widely discussed and marketed technology, sold with outlandish promises, which failed to manifest as anything even approaching the expectations of the time. Products like the Virtual Boy, Virtuality, and Jaguar VR had promised much and delivered little.

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[20] McCarthy 'Virtual Reality', 1999; Jaikumar Vijayan, 'Virtual Reality Trading Floor Adds New Dimension', *Computerworld; Framingham*, 33/13 (1999), 67; Rosenblum et. al. 'VR Reborn'.

[21] 'Google Ngram Viewer - Vaporware', 2017; Roger van Bakel, 'Getting Real: VR Grows Up', *WIRED*, 3/8, 1 August 1995 <https://www.wired.com/1995/08/getting-real-vr-grows-up/> [accessed 11 August 2017].

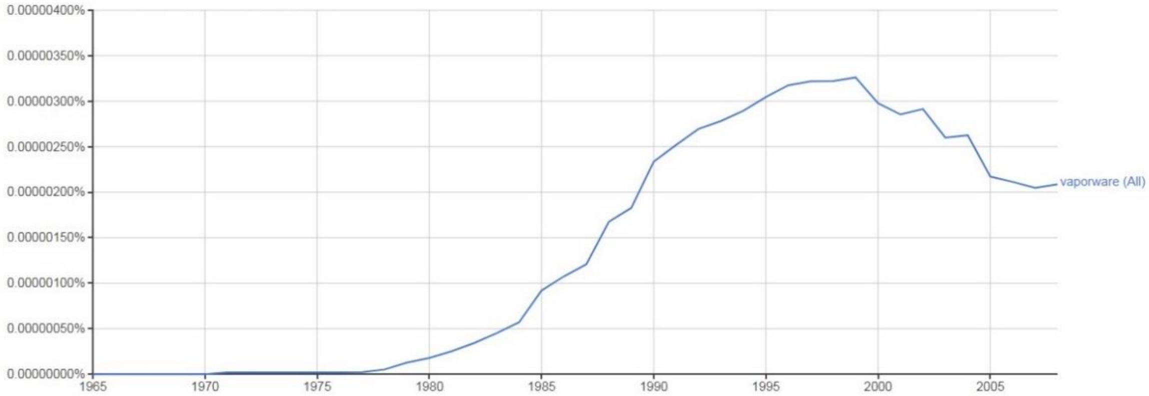

Fig. 13 A Google Ngrams Graph, charting the popularity of the term ‘Vaporware’. Usage peaks in 1998 and 1999, with 0.0000032% of the entire Google-archived US literary corpus being made up of that term.

Late 1990s products such as the Sony Glasstron and Olympus Eye-Trek FMDs were positioned as updated visions with none of the digital frontier spirit, immersion, or creative ambition of earlier VR. The differences in experience, however, demonstrated the scale of the technical hurdles facing true VR. The period, therefore, saw considerable discussion of the technology from a point of confusion, and reflection in print, escalating to anger online. Articles in print with titles like ‘Ditching VR’, ‘We’re Virtually There’, ‘A New Reality’, ‘What’s Real about VR’ captured that mood,[22] and discussions ranged far further online, with hosts of Web-pages in the late 1990s hosted by the now defunct Netscape, along with Bulletin Board Sites (BBS) such as ZeroNet and Fidonet, discussing the future of VR at a time where it seemed that it was little more than a set of empty promises. A range of discussions in the ‘comp’ Usenets such as comp.robotics.misc, comp.sys.ibm.pc.games.action, and a range of other late 1990s pages and forum posts expressed anger and frustration with the apparent disappearance of VR from the technological horizon.[23] This anger seems to have stemmed from the failure of immersive, science fiction cyberspace to materialise at what must have seemed like the promised hour to thousands of excited VR hopefuls in 1997 and 1998.

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[22] Winter ‘Ditching Virtual Reality’; Mark Gibbs, ‘We’re Virtually There’, *Network World; Southborough*, 15/30 (1998), 113; Bob Brewin, ‘A New Reality’, *Federal Computer Week; Falls Church*, 13/35 (1999), 1,41; Brooks, ‘What’s real about virtual reality?’.

[23] Very3, ‘Where Is My Virtual Reality?!!!!!! - Google Groups’ (3rd March 2000) https://groups.google.com/d/msg/comp.sys.ibm.pc.games.action/h0gciw-I48c/p8qO2Y46YzAJ [accessed 11 August 2017]; Danny Shin, ‘Does Anyone Know Where I Can Pick up Those Virtual Reality Glasses?? - Google Groups’ (15th December 1999) https://groups.google.com/d/msg/comp.robotics.misc/9k8r0HHIYNo/zpKDX7PWEioJ [accessed 11 August 2017]; Ayende Rahien ‘Virtual Reality, and Why It’s Better to Be Avoided. - Google Groups’ (21st June 2000) < https://groups.google.com/d/msg/rec.arts.sf.composition/kmo6Pr75v5A/b44hqYPcGpoJ> [accessed 11 August 2017].

The considerable disconnect between technical reality, popular understanding, and marketing hype which had caused this anger was also what caused the usage of the term VR, and its visibility in popular media, to persist after the technology itself had retreated from the shore of market retail. People were still talking about VR because VR represented a raft of different things (such as the Internet, or video games), or because they were sharing their shock and disbelief that such a widely publicised (supposedly revolutionary) technology, with TV shows, movies, games, and countless articles attributed to its power, could turn out to be little more than vapourware. It was however maintained in the fields of human factors research, training and education, combat simulation, and product design in 1998 and 1999, thus preserving a thread of research and development continuity.

While attempts to make and sell VR for gaming, entertainment, and even sex had failed to develop into successful technological systems, the late 1990s saw a more pragmatic approach to adopting VR technology in scientific and business applications. The early 1990s had been a period where a wide range of companies, universities, and large research laboratories had used VR because it was trendy, rather than essential or even useful. The popularity and considerable hope surrounding VR in the 1980s had led to the understanding for many organisations that it would be best to position themselves for the upcoming VR revolution ahead of time. By aligning themselves with the technical VR pathways which were beginning to form, they artificially reinforced unsuitable, unsustainable pathways governed by science fiction, rather than technical standards. Firms like Ford, Boeing, the Port of Seattle company, Matsushita, and others ran pilot VR projects. Similarly, universities across the US and beyond developed VR labs or individual test-beds in engineering and computer science departments. As Juan Barcelo *et. al.* pointed out in 2000, 'VR is such a *hot* concept that many people tend to use it even when its use is logically inappropriate.'[24] As the prohibitive costs, low quality, and complex machinery of VR showed it to be an inconvenient tool for the vast majority of business and scientific work it was initially extolled for, more businesses and research institutions fell back from using fully immersive, HMD-based VR. The use of helmets and gloves slowed down work, not only because there were no technical standards, making integration with existing systems difficult, but because more experienced employees were unwilling to take VR-based training and work seriously.[25] VR ended up being a money pit, not a source of income. This is reflected in contemporary material repeatedly describing the move away from helmets, the failure of VR, and the passing of its moment.[26] Instead, a more catholic approach to computer integration in research, development, and the office was pursued by American firms in the late 1990s, with the adoption of Internet based workflows, CAVE systems, LVDs (such as the Fakespace Immersive WorkRoom and Panoram PanoWall), tele-commuting, tele-presence, and a host of other features that Steve Woolgar has termed 'epithetized phenomena'.[27]

There was a visible move toward a more pragmatic approach on the part of those US organisations with the funds to invest in VR trials. A wider range of interface systems to boost productivity using computers, rather than simply VR, was in play here. This was not only because traditional VR had shown itself to be prohibitively expensive, hard to integrate, and slow, but because the range of functions which computers could perform were expanding rapidly. In the early 1990s, VR had represented the forefront of computer technology: interactive 3D graphics, and new kinds of inputs, like touch and voice. Personal computers seldom had the power to support the 3D graphics generated by 'Reality Engines' at the time, as well as the unusual input devices, which often worked with Unix based operating systems, such as Silicon Graphics's IRIX OS. By the late 1990s however, PCs dominated the computer market, and could be fitted with graphics cards such as the 3dfx Voodoo 2, ATI Fire GL2, or the NVidia Elsa Gloria III, which were capable of generating the interactive, richly textured 3D environments that had once been a unique selling point of VR systems.[28] They could also connect to the Internet using modems, support multiple kinds of displays, including stereoscopic 3D, and the majority of input devices in the late 1990s could be easily installed into Windows systems. In short, desktop computers could, for a comparatively small outlay, do everything VR in the early 1990s *promised* but had failed to deliver.

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[24] Juan Barceló Maurizio Forte, and Donald Sanders, 'The Diversity of Archaeological Virtual Worlds', in *Virtual Reality in Archaeology*, British Archaeological Reports, 843 (2000), 3.

[25] Robert Hays, Dennis Vincenzi, Alton Seamon, and Scott Bradley, *Training Effectiveness Evaluation of the VESUB Technology Demonstration System* (1998) <http://www.dtic.mil/docs/citations/ADA349219> [accessed 11 August 2017], 58; Burdea & Coiffet, 'Virtual Reality Technology', 338.

[26] Winter, 'Ditching virtual reality'; Fister 'Tech trends'; 'Virtual Research Systems: Window VR',

[27] Steve Woolgar, 'Five Rules of Virtuality', 3.

As large organisations moved towards adopting systems like LVDs and Internet-enabled collaboration, over VR, the range of products offered by the surviving VR companies changed. Fakespace, a producer of the well-known BOOM series of VR displays, developed several non-head-mounted display systems as part of their late 1990s and 2000s product line-up, including the Immersive Workroom. The Immersive Workroom was a modular variant of Carolina Cruz-Neira's CAVE system, developed in 1992. By projecting images onto the floor, ceiling, and surrounding walls (typically using rear projection onto a small enclosure), people standing within the CAVE would be able to get a sensation of existing within an immersive, interactive environment (see fig. 14). These set-ups could support stereoscopic graphics using shuttered glasses, and projectors which showed two slightly different images in alternating sequence, with the shuttered glasses alternating between transparent and opaque at an identical frequency (in the case of active glasses) to facilitate depth perception.

While not HMD-based, and thus (this thesis argues) not VR, CAVE systems were widely considered to be a variant of VR technology, and they gained considerable ground over HMD-based VR set-ups in the late 1990s and early 2000s to the point of eclipsing them in terms of capability, visibility, and market penetration. Despite costs of up to $500,000 in around 1998, the fact that a dozen or more people could use the same CAVE at the same time made it a cost-saving technology, and the price of third-party CAVE-esque systems fell drastically by around 2001, to approximately $100,000.[29]

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[28] Burdea & Coiffet, 'Virtual Reality Technology', 139-40.

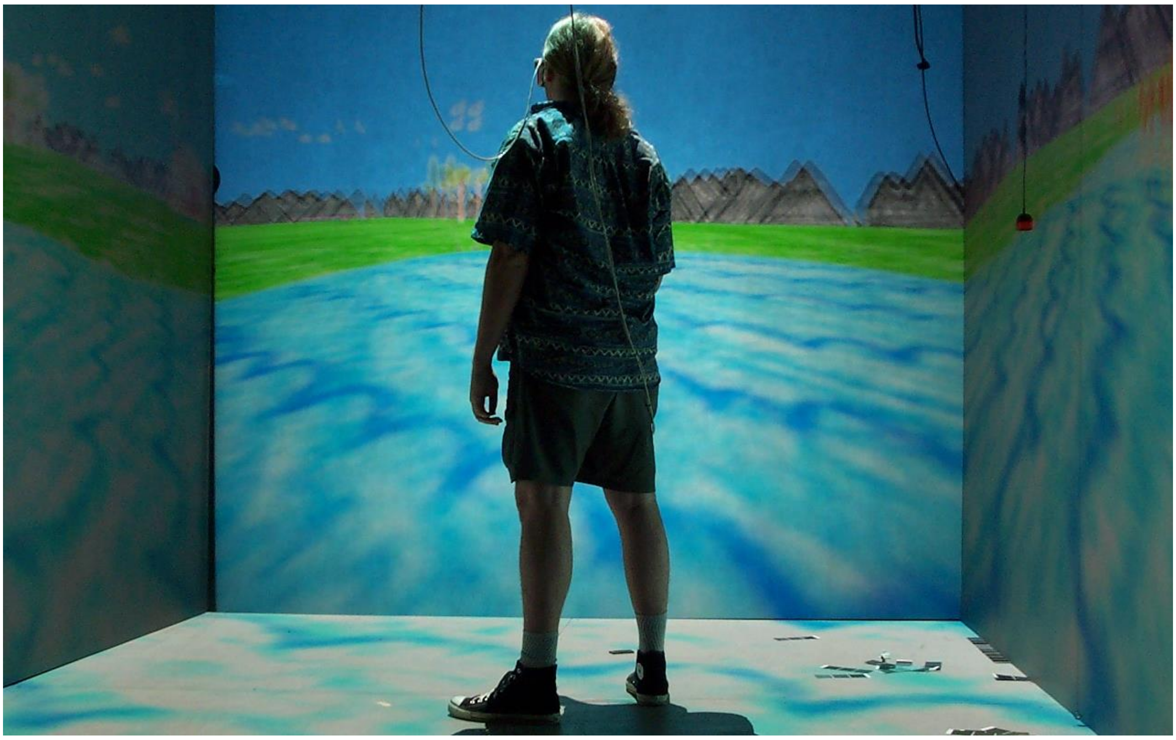

FIG. 14 A photograph of a person using a CAVE system, standing in roughly the centre of the room. Image credit: Dave Pape, Associate Professor in the Department of Media Study at the University of Buffalo. https://upload.wikimedia.org/wikipedia/commons/thumb/6/6d/CAVE_Crayoland.jpg/1024px-CAVE_Crayoland.jpg

The Fakespace Immersive Workroom was one among a handful of commercial CAVE systems available in the late 1990s, as well as the modular Fakespace RAVE (Reconfigurable Virtual Environment), and the Trimension Systems ReActor. Fakespace marketed the Immersive Workroom as a VR product, as well as their non-3D Immersive WorkWall, a 24ft flat screen display.[30] Fakespace, well-known among VR manufacturers, sold the Workroom alongside its traditional BOOM displays, and table-mounted PUSH displays, all for interactive display of VR environments. The WorkRoom was a static CAVE configuration, 3x3x4 metres in size, and supporting up to 12 simultaneous users, with a resolution of 100,000 pixels, or around 8 dots per inch (DPI). The system sold, in 2000, for $300,000.[31] The Fakespace RAVE, on sale at the same time, allowed more or fewer panels and projectors to be used, depending on the size of CAVE needed, as different applications demanded. It had a base size of 2.3x2.4x4 metres and a resolution of around 200,000 pixels per m^2 (or around 16 DPI). The higher resolution, and modular nature pushed the cost to $500,000.

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[29] Ibid. 80.

[30] Mechdyne Corporation, 'Press Release - Fakespace Unveils Fully Immersive Display System At Canada's First Virtual Environment Technologies Centre' (1999) <https://www.mechdyne.com/article.aspx?id=66> [accessed 11 August 2017].

The late 1990s saw large volume systems like these increasingly being chosen over individual HMD-based VR systems by the handful of organisations which were experimenting with immersive computing workflows at the time. In doing so, corporate and employee understandings of what VR meant began to change. Rather than being the sole domain of 'gloves and goggles', increasingly in 1998 and 1999, VR just meant 'Immersive' '3D' or even just 'using computers'.[32]

There were however at the time several projects which did still use HMD-based VR, in universities and businesses in the US. One of the areas in which traditional VR was, in fact, gaining traction was in medical training research. Between 1998 and 2005 there were hundreds of articles published exploring the benefits of VR technology for training, practice, and assessment in laparoscopic (keyhole) surgery, hepatic surgery, and a range of other surgical practices which required specialist knowledge and training.[33] Studies conducted in the late 1990s found that, at the trainee and junior doctor level, HMD-based VR training systems could be just as effective as traditional medical teaching methods such as cadaveric dissection.[34] Research carried out at universities in the US and abroad examined the uses of VR in teaching and learning, but also in helping doctors better understand patients' conditions.[35] Trial programmes were run in the late 1990s in Seattle, Los Angeles, New York, and other cities. Patents were also published for purpose-built dedicated VR medical training simulators in 1998, and several VR-based medical training products were put on sale at around the same time, including Sandia National Laboratories' BioSimMER, HT Medical Systems Inc.'s PreOP Bronchoscopy Simulator, Viatronix's Virtual Biopsy, Immersion Medical's CathSim, Boston Dynamics' Anastomosis simulator, Virtual Presence Ltd.'s MIST-VR, and others.[36]

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[31] Burdea & Coiffet, 'Virtual Reality Technology', 83.

[32] Lindstrom, 'Meet your future'; Gibbs 'We're Virtually There'; Rosenblum et. al. 'VR Reborn'; Brewin 'A new reality'; Paul Stewart and Pietro Buttolo, 'Putting People Power into Virtual Reality', *Mechanical Engineering; New York*, 1999, 18–22; McCarthy, 'Virtual reality', 1999; Orenstein, 'Virtual Reality Saves…', 44; Blake Evans, 'Get Real', *Builder; Washington*, 2000, 80; Christina Farnsworth and Michael Nicksic, 'Get Real with 3-D', *Builder; Washington*, 23/3 (2000), 171–76; Brian Caulfield, 'Virtual Reality Gets Real', *Internet World; Cleveland*, 6/3 (2000), 36–37.

[33] Jacques Marescaux, Jean-Marie Clément, Vincent Tassetti, Christophe Koehl, Stéphane Cotin, Yves Russier, and others, 'Virtual Reality Applied to Hepatic Surgery Simulation: The next Revolution.', *Annals of Surgery*, 228/5 (1998), 627; Richard Satava and Shaun Jones, 'Current and Future Applications of Virtual Reality for Medicine', *Proceedings of the IEEE*, 86/3 (1998), 484–489; Michael Tuggy, 'Virtual Reality Flexible Sigmoidoscopy Simulator Training: Impact on Resident Performance', *The Journal of the American Board of Family Practice*, 11/6 (1998), 426–433; N. Taffinder, 'Validation of Virtual Reality to Teach and Assess

Away from surgical science, there was a significant body of research literature concerning the use of immersive, closed VR systems for treatment of mental health conditions, and physical and mental rehabilitation. At the same time, a range of pilot programs ran for treatment of phobias, anxiety disorders, ADHD, and neurological conditions such as stroke damage and congenital blindness.[37] Examples include the Rutgers Ankle, a device developed at Rutgers University by

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Psychomotor Skills in Laparoscopic Surgery: Results from Randomised Controlled Studies Using the MIST VR Laparoscopic Simulator', *Medicine Meets Virtual Reality: Art, Science, Technology: Healthcare and Evolution*, 1998, 124; Aafia Chaudhry, Christopher Sutton, Jonathan Wood, Robert Stone, and Rory McCloy, 'Learning Rate for Laparoscopic Surgical Skills on MIST VR, a Virtual Reality Simulator: Quality of Human-Computer Interface.', *Annals of the Royal College of Surgeons of England*, 81/4 (1999), 281; A. Gallagher, N. McClure, J. McGuigan, I. Crothers, and J. Browning, 'Virtual Reality Training in Laparoscopic Surgery: A Preliminary Assessment of Minimally Invasive Surgical Trainer Virtual Reality (MIST VR)', *Endoscopy*, 31/04 (1999), 310–313; Paul Gorman, Andreas Meier, and Thomas Krummel, 'Simulation and Virtual Reality in Surgical Education: Real or Unreal?', *Archives of Surgery*, 134/11 (1999), 1203–1208; Robert O'Toole, Robert Playter, Thomas Krummel, William Blank, Nancy Cornelius, Webb Roberts, and others, 'Measuring and Developing Suturing Technique with a Virtual Reality Surgical Simulator', *Journal of the American College of Surgeons*, 189/1 (1999), 114–127.

[34] Rory McCloy and Robert Stone, 'Science, Medicine, and the Future: Virtual Reality in Surgery', *BMJ: British Medical Journal*, 323/7318 (2001), 912; Burdea & Coiffet, *Virtual Reality Technology*, 293-304.

[35] Leigh Strother-Vien, 'Medical VR Helps Doctors Learn What 'tired' is', *Advanced Imaging; Melville*, 13/7 (1998), 26; Anonymous, 'Doctors May Feel Their Patients' Pain', *The Futurist; Washington*, 33/1 (1999), 13.

[36] Charles Jacobus and Jennifer Lynn Griffin, 'Method and System for Simulating Medical Procedures Including Virtual Reality and Control Method and System for Use Therein', 1998 https://www.google.com/patents/US5769640; Burdea & Coiffet, *Virtual Reality Technology*, 290-302.

[37] Ibid, 305-14; Chetz Colwell, Helen Petrie, Diana Kornbrot, Andrew Hardwick, and Stephen Furner, 'Haptic Virtual Reality for Blind Computer Users', in *Proceedings of the Third International ACM Conference on Assistive Technologies* (1998), 92–99 http://dl.acm.org/citation.cfm?id=274515; Max North, Sarah North, and Joseph Coble, 'Virtual Reality Therapy: An Effective Treatment for Phobias', *Virtual Environments in Clinical Psychology and Neuroscience: Methods and Techniques in Advanced Patient-Therapist Interaction*, 58 (1998),

Michael Girone, Grigoire Burdea, and others. The device was designed for orthopaedic rehabilitation of ankle injuries, although it was understood at the time that it could easily be adapted for other kinds of joint care.[38] The computer interface served to join a robotic platform, bound to a patient's ankle, to a PC running a 3D simulation. The patient then used their foot, and thus their ankle, to control an aircraft in a basic flight simulator game. By increasing the complexity of the tasks in the game, therapists could control the degrees of freedom and work required of patients over the course of the game. This set-up was run entirely on a 2D CRT computer monitor, which lacked stereo, and did not use motion-tracking or an HMD (except tracking the motion of the patient's ankle). It could not, by most modern parameters, be considered VR, but it was openly described as VR therapy by its creators, as well as by other writers.[39] It was clearly possible, at the time, for people to create a non-3D, desktop based computer system and call it VR with sufficient plausibility for that statement to be accepted and duplicated by other medical and technological professionals. From the standpoint of the definition of VR adopted by this thesis however, it was little more than a haptic interface for computer programs (a component of many VR systems, but not constituting that whole alone).

The same team would also go on to develop a range of other rehabilitative tools using computer software, all joined under the VR moniker. Applications included the treatment of wrist and hand injuries, as well as tele-rehabilitation suites, where patient rehabilitation could be conducted at home.[40] Again, this system was considered VR because it was PC-based, used force feedback and

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112–119; Riva et. al., C*linical Psychology…* (1998); Madeline Grealy, David Johnson, and Simon Rushton, 'Improving Cognitive Function after Brain Injury: The Use of Exercise and Virtual Reality', *Archives of Physical Medicine and Rehabilitation*, 80/6 (1999), 661–667; Rothbaum & Hodges, 'Treatment of Anxiety Disorders'; Grigoire Burdea, Viorel Popescu, Vincent Hentz, and Kerri Colbert, 'Virtual Reality-Based Orthopedic Telerehabilitation', *IEEE Transactions on Rehabilitation Engineering*, 8/3 (2000), 430–432.

[38] Michael Girone, Grigoire Burdea, Mourad Bouzit, Viorel Popescu, and Judith Deutsch, 'Orthopedic Rehabilitation Using the 'Rutgers Ankle' interface', *Studies in Health Technology and Informatics*, 70 (2000), 89–95.

[39] Burdea & Coiffet, *Virtual Reality Technology*, 305-6.

[40] Viorel Popescu, Grigoire Burdea, Viorel Popescu, Vincent Hentz, 'A Virtual-Reality-Based Telerehabilitation System with Force Feedback', *IEEE Transactions on Information Technology in Biomedicine*, 4/1 (2000), 45–51.

haptic inputs, and worked over the Internet. While the treatment was shown to be just as effective as *in situ* work with a physiotherapist, none of the system components would have been considered parts of VR in 1990 (except a haptic interface), nor would they in 2018.[41] The late 1990s then was clearly a period in which the definitions and cultural rules surrounding VR were in a state of flux after the collapse of the 1980s VR models, and a paradigm was yet to be found.

Other physiotherapeutic projects developed in the very late 1990s, such as rehabilitation for people who had suffered a stroke, were also considered to be 'VR Therapy' even though they did not use any kind of 3D display and were thus only as immersive as the patient could allow themselves to feel. The potential for computer programs to repeatedly deliver the same therapy appealed to rehabilitation experts.[42] At this time, there was a visible divide within technical discourse surrounding such computer-based therapy, with some calling it VR, and others VE. It may be useful to recall that Virtual Environments was a term favoured by a growing body of researchers into 3D displays and human factors in the late 1980s and early 1990s, in light of the way that 'VR' had been coined by Lanier as a marketing tool, and often referred to vastly exaggerated versions of the technology being developed at places like Ames and UNC. The pro 'VR' digiterati were, incidentally, all out of the American VR scene by the end of the 1990s, Lanier was working on tele-presence apps for Internet2, Laurel was designing video games for girls, and Fisher was in Japan working on AR.

As for mental rehabilitation, the landscape in the late 1990s was somewhat different. 'VR' projects in physiotherapy were developed in a context of VR-based mental health, psychological, and psychiatric research programmes, as well as fully-fledged medical products, which (by the late 1990s) had become well established. This seems to have been driven by the healthcare industry's free-market demands for technical innovation, and by the evidence-based benefits of some VR systems in care and training. While some of these systems called themselves VR when they were in fact just computer-based therapy, others merited the name. In 1998 there were a few pilot schemes involving the use of VR therapy in treating social anxiety, phobias, and claustrophobia, among others. For example the Speech Improvement Co. used full HMDs with a VR modelling language (proprietary, but most likely running on an SGI RealityEngine2 or InfiniteReality system).[43] Developed by Clark Atlanta University's Virtual Technology Laboratory, the system created the illusion of standing on a stage before a packed auditorium, during which the user would have to deliver a short presentation. For those suffering from glossophobia, this was a valuable tool, and the use of stereoscopic HMDs created very real fear-responses in patients, but a in completely controllable environment.[44] The same team developed a wider testbed for phobia exposure therapy in the following year. Under the broad term VR Therapy (VRT), which gained a minor foothold in broader mental health literature in the late 1990s and early 2000s, the technology was understood to be better for patients than 'real' therapy because it was more controllable and patients could more easily remove themselves from the situation (as well as being far cheaper in the long run).[45] The team had been exploring using computers in phobia therapy since 1992, but it was only in 1998/9 that laboratory-based research projects began to be adopted and used in the public sphere (an example being the aforementioned Speech Improvement Co's system.)[46]

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[41] Heidi Sveistrup, Joan McComas, Marianne Thornton, Shawn Marshall, Hillel Finestone, Anna McCormick, and others, 'Experimental Studies of Virtual Reality-Delivered Compared to Conventional Exercise Programs for Rehabilitation', *CyberPsychology & Behavior*, 6/3 (2003), 245–249.

[42] Burdea & Coiffet, *Virtual Reality Technology,* 308.

The late 1990s saw a growing number of articles discussing both the viability and utility of VR-based therapy for mental health conditions, driven by an ever-increasing body of knowledge surrounding VR in therapy, broadening familiarity with computers by both patients and practitioners and the reduction in costs. While good HMDs were still very expensive, 3D graphics and software suites were easier to use than ever before, and the computer hardware needed to generate those virtual environments was becoming more powerful and more accessible with every year. By 1998, widespread adoption of the PC for graphics work (marked, if nothing else, by the decline of the high-end dedicated graphics workstation) meant that it was easier for universities, private businesses, organisations and individuals to build and run VR systems, and display them using a range of different technological approaches, including stereo headsets, shuttered-glass displays, LVDs and more.

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[43] Tad Simons, 'The Virtual Crowd', *Presentations; Minneapolis*, 12/9 (1998), 43

[44] Burdea & Coiffet, *Virtual Reality Technology*, 311; Strickland, Dorothy, Larry Hodges, Max North, and Suzanne Weghorst, 'Overcoming Phobias by Virtual Exposure', *Communications of the ACM*, 40/8 (1997), 34–39.

[45] North et. al. 'Virtual Reality Therapy', 112–119.

[46] Botella et. al., 'Virtual Reality treatment'.

Use of HMD-based VR in cognitive and mental therapy constituted one of the largest sources of traditional VR-based research and development during its post-boom ‘winter’ in the late 1990s, and as such relied on either HMDs manufactured in the mid-1990s, or extremely expensive high-end devices, such as those manufactured by Kaiser Optical or N-Vision. The reason that this research seems to have hit its stride after the more visible, publicised, and well-funded areas of scientific research had moved on to LVDs and Internet-based projects seems largely to be that the cost of VR setups had previously been prohibitive to the large-scale, long term trials needed in mental health care, which has historically never attracted the same kinds of funding as other areas of medicine. As mentioned above, surgical and biochemical VR research was also being pursued at this time, continuing a process started by Fred Brooks at UNC in the 1980s. By the end of the 20th century, the infrastructure driving VR was sufficiently affordable and easy to use for a much broader group of people to develop and experiment with applications for the technology, long after interest in it had moved on.[47] It is also possible that this is a product of saturation bias, where this research seems prominent because it was the largest set of VR projects left. This late-stage expansion echoes the growth of homebrew VR innovation which accompanied the PC revolution of the 1980s.

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[47] Michael Dempsey, 'After the Hype, Real Applications Emerge: Virtual Reality: Five Years Ago, the Desire of VR Enthusiasts to Create the Impression of an Alternative Reality Was Let down by the Cost and Problems of Developing Early Systems', *Financial Times; London (UK) [Surveys Edition]* (1 November 2000) 06; Fister, 'Tech trends'.

VR therapy was, by 1999 and 2000 also being used in the treatment of Post-Traumatic Stress in veterans of the Vietnam war, in a scheme supported by the Army. Run by Barbara Rothbaum and colleagues at Emory University, in Georgia, it used imagery of being in an army helicopter over the Vietnamese jungle, the project saved money and sped up treatment of thousands of people suffering from flashbacks and other mental illnesses after the war. In 2000, Rothbaum, Larry Hodges, Samantha Smith, Jeong Hwan Lee, and Larry Price published further work on therapy for the fear of flying. Further commercialisations of VRT came in 2001, with Virtually Better, a company founded by Rothbaum and Hodges, whose extensive research in the field quickly positioned the company as a leader in VRT provision. Virtually Better marketed VR-based therapy programs for fear of public speaking, which was taken up by a dozen clinics across the US at the time.[48]

The Georgian research powerhouse at Emory, Virtually Better, and Clark Atlanta was by no means the sole source of VRT research at the time. 2002 saw research from Joann Difede and Hunter Hoffman on VRT for survivors of the destruction of the World Trade Center in 2001. As a collaboration between Cornell University in New York, and the HITLab at Washington, the project was little more than a pilot study, but acceptance of VRT as a valid mode of therapy was spreading at the time, as numerous publications sought to validate its value. In 2003, David Walshe *et. al*, an international team from Ireland, Korea, and California, developed a system using driving-based video games *Midtown Madness*, *London Racer*, and *Rally Championship* in a VR environment to treat fear of driving following accidents.[49] In 2004, Sandra Harris *et. al.* at California State university carried out a large test program for glossophobia sufferers from among the student body and was deliberately attributed to the field of 'VRT research' and contributed to a growing understanding of the effectiveness of VR therapy.[50] In the same year, Paul Emmelkamp *et. al* in 2004 at the University of Amsterdam worked on VR treatment for Acrophobia (and first published in CyberPsychology & Behaviour, in the US), as well as a study to determine the effectiveness of VR in therapy statistically. Both CAVE and HMD-based VR systems were found to be just as effective as *in vivo* therapy.[51]

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[48] Matthew Boyle, 'Skill Set: Speech Therapy', *Fortune; New York*, 144/3, 13 August 2001, 188; Virtually Better, 'Company', *Virtually Better, Inc.* <http://www.virtuallybetter.com/company-overview/> [accessed 14 August 2017]; Barbara Rothbaum, Larry Hodges, David Ready, Ken Graap, and Renato Alarcon, 'Virtual Reality Exposure Therapy for Vietnam Veterans with Posttraumatic Stress Disorder.', *The Journal of Clinical Psychiatry*, 2001.

[49] David Walshe, Elizabeth Lewis, Sun Kim, Kathleen O'Sullivan, and Brenda Wiederhold, 'Exploring the Use of Computer Games and Virtual Reality in Exposure Therapy for Fear of Driving Following a Motor Vehicle Accident', *CyberPsychology & Behavior*, 6/3 (2003), 329–334.

This trend in research began in the late 1990s, and by the early 2000s, there was an established scientific community using VR in psychological research, not only in treatment but in the diagnosis of conditions like ADHD.[52] While VR exposure was being used in trials and making its way into clinical practice in the US, there was still little understanding of its benefits or risks.[53] It had been demonstrated by researchers in the US that VRT therapy could help people suffering from mental illness and physical disability, but it was not clear what the risks of such work were. Pilot studies going back to the 1980s had attempted to examine the mental and physiological ramifications of VR use, but there were no statistically significant samples conducted using scientific methodology.[54] This was despite longstanding and considerable colloquial evidence and accounts of VR causing headaches, nausea, eye strain, impaired perception, impaired judgment, vomiting, and rumours about it causing brain cancer; it even had a name, Cybersickness.[55] Furthermore, the infra-red lasers used for gaze tracking were demonstrated to cause cataracts with prolonged use, retinal scanners (which were solely experimental) could cause long-term retinal damage, and low-frequency light pulses in HMDs could cause seizures in otherwise healthy individuals.[56]

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[50] Sandra Harris, Robert Kemmerling, and Max North, 'Brief Virtual Reality Therapy for Public Speaking Anxiety', *Cyberpsychology & Behavior*, 5/6 (2004), 543–550.

[51] Paul Emmelkamp, Mary Bruynzeel, Leonie Drost, and Charles van der Mast, 'Virtual Reality Treatment in Acrophobia: A Comparison with Exposure in Vivo', *CyberPsychology & Behavior*, 4/3 (2004), 335–339; Merel Krijn, Paul Emmelkamp, Roeline Biemond, Claudius de Wilde de Ligny, Martijn Schuemie, and Charles van der Mast, 'Treatment of Acrophobia in Virtual Reality: The Role of Immersion and Presence', *Behaviour Research and Therapy*, 42/2 (2004), 229–239.

[52] Albert Rizzo, Albert Buckwalter, Todd Bowerly, Cheryl van der Zaag, L. Humphrey, Ulrich Neumann, and others, 'The Virtual Classroom: A Virtual Reality Environment for the Assessment and Rehabilitation of Attention Deficits', *CyberPsychology & Behavior*, 3/3 (2000), 483–499.

[53] Martijn Schuemie, Peter van der Straaten, Merel Krijn, and Charles van der Mast, 'Research on Presence in Virtual Reality: A Survey', *CyberPsychology & Behavior*, 4/2 (2004), 183–201; Hari Srinivasan, Chi-Cheng Chu, and Rajit Gadh, 'Virtual Reality for Design and Manufacturing', *Appliance Manufacturer; Troy*, 47/5 (1999), 23–25; Albert Rizzo, Maria Schultheis, Kimberly Kerns, and Catherine Mateer, 'Analysis of Assets for Virtual Reality Applications in Neuropsychology', *Neuropsychological Rehabilitation*, 14/1–2 (2004), 207–239; James Winters, Jill Clelland, Edmund Rumble, and Layla Sandell, 'Construction Practice', *Nuclear Engineering International*, 50/616 (2005), 16–19.

[54] John Merritt, 'Often-Overlooked Advantages of 3-D Displays', in *1988 Los Angeles Symposium–OE/LASE'88* (1988), 46–47 <http://proceedings.spiedigitallibrary.org/proceeding.aspx?articleid=1251453> [accessed 22 May 2017]; Richard Held and Nathaniel Durlach, 'Sensorimotor Adaptation', in *Symposium Proceedings*, 1989, 51 [accessed 23 May 2017]; Stephen Ellis and Arthur Grunwald, 'Head-Mounted Spatial

Despite these disturbing revelations, there was, at the turn of the 21st century, very little concrete understanding of just what effects long-term VR exposure had, or why it caused the problems that it did. To add to the confusion, different people experienced different symptoms, a few would only suffer minor headaches, some would be so nauseated they would vomit, and some would feel fine. It seems that, for many VR researchers in the US, securing funding or ethical permission to examine the physiological and psychological impact of VR exposure was difficult. While there was a widely accepted understanding that experiencing VR for more than half an hour was not good for you, the existing studies lacked enough subjects for statistically significant *p* values.[57] This is perhaps due to the considerable attenuation of consumer interest, which occurred at the same time that VR systems finally became sufficiently affordable to be more widely used in academic studies.[58] They were increasingly being used in specialist applications (rather than as a mythic panacea for cultural

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Instruments II: Synthetic Reality or Impossible Dream', in *JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 P 521-532 (SEE N90-29780 24-54); US*, 1989; Michael McCauley and ThomasJ Sharkey, 'Cybersickness - Perception of Self-Motion in Virtual Environments', *Presence: Teleoperators and Virtual Environments*, 1/3 (1992), 311–18.

[55] Jon Van 'Virtual Reality Side Effect: Cybersickness: Disorientation Is One Of Technology's Bugs', *The Washington Post ; Washington, D.C.* (25 September 1995), 17–18; Kay Stanney and Robert Kennedy, 'The Psychometrics of Cybersickness', *Communications of the ACM; New York*, 40/8 (1997), 66–68; Burdea & Coiffet, *Virtual Reality Technology*, 269-276.

[56] Ibid, 266-8; Erik Viirre, Bj Price, and Bradley Chase, 'Direct Effects of Virtual Environments on Users', in *Handbook of Virtual Environments*, Human Factors and Ergonomics, (2014), 521–29.

[57] See 54 and 56.

[58] Antonin Viau, Anatol Feldman, Bradford McFadyen, and Mindy Levin, 'Reaching in Reality and Virtual Reality: A Comparison of Movement Kinematics in Healthy Subjects and in Adults with Hemiparesis', *Journal of Neuroengineering and Rehabilitation*, 1/1 (2004), 11; 'Increasing Speed Helps Modeling, Virtual Reality', *Civil Engineering; New York*, 68/8 (1998), 28; David Tubbs, 'Virtual Sets: Studios in a Box', *Broadcast Engineering; Overland Park*, 40/12 (1998), 90–92.

woes), including intensive therapy, but without consumer or government pressure to establish standards of safety.

Despite this, it is important to note that during the pragmatic late 1990s, there was a scattering of publications on the subject of VR safety. It was understood that around 78% of all VR users experienced cybersickness and that it was caused by poor refresh rate of displays, simulation latency, and confusion of the sensory channels caused by partial immersion in a VR environment (much like motion sickness).[59] These observations by Burdea and Coiffet, who were seeking to provide a meta-analysis of the existing studies in 2003 (none of which had significant participant numbers) were little more than speculation without multiple large studies to support them. There was certainly nowhere near as much research being published on the physiological and psychological impact of VR exposure as there was on the safety of using computers, mobile phones, cars, or even the Internet.

THE SUPREMACY OF THE INTERNET

This is unsurprising, however, when one considers the colossal expansion and development of Internet and Web-based services into the arts, media, work, communication, and wider society at the time, with the dot-com bubble reaching its crescendo in 1998/9. As highlighted in the last chapter (p.156), the rapid expansion of online infrastructure and services provided for many of the consumer desires which had been anticipated to be delivered by VR in the early 1990s. VR, however, had developed too slowly, and Internet use expanded rapidly through the late 1990s, with 18 million homes paying for Internet access in 1997, and 41.5m in 2000. Those figures did not count institutions, businesses, or government facilities such as libraries, which were (and still are) vital points of access to online and ICT services for millions.[60]

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[59] Burdea & Coiffet, *Virtual Reality Technology*, 269.

[60] Eric Newburger, *Home Computers and Internet Use in the United States, August 2000* (2001) <https://cps.ipums.org/cps/resources/cpr/p23-207.pdf> [accessed 15 August 2017].

As Internet and Web services increasingly dominated computer usage, as well as media, content, and public awareness in the late 1990s, the early 1990s vision of VR seemed increasingly out of place. To many, it was a toy, a fad, which it had lost the moment. In 1998, Drew Winter in *Auto World* proclaimed that 'The much-hyped VR is not working out as expected.'[61] Winter had expected VR to form the backbone of computer interfaces for design and work, and for an immersive virtual space where, for example, cars could be explored by customers and even purchased without needing a real showroom. Discussing the suitability of VR to the automotive design industry, which had taken on various VR workplace pilot programmes in the early 1990s, he continued: 'So-called VR, with its goofy headsets, goggles, and gloves, may be a great toy for computer buffs, but in the work-a-day world of vehicle design it just doesn't fly… especially when the technology makes some viewers nauseous after only a few minutes.' In the same year, Rosenblum *et. al.* pointed out that 'Inevitably, the public (and, worse, research sponsors) developed entirely unrealistic expectations of the possibilities and the time scale for progress [of VR research].'[62]

A year later, Nina Adams, the founder of VR training-oriented Adams Consulting Group, went on record to say that 'Taking eight months to build a VR program is just too long' when she sold off her firm in 1998, and her interviewer, Sarah Fister, went far enough to say that VR's moment had passed, that people were 'a long way from learning via VR, and some of those same experts now think they'll never get there. Is VR too expensive, cumbersome and impractical to take seriously as a mainstream training tool?'[63]

By 2000, there was explicit discussion of VR as the product of a hype bubble which had long since burst, and that VR was being used, developed, and understood in increasingly different ways from its early 1990s vision, toward the online, Internet-enabled services of the late 1990s and early

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[61] Winter, 'Ditching virtual reality', 64.
[62] Rosenblum et. al., 'VR Reborn',21
[63] Fister, 'Tech trends', 24.

2000s. Fred Hapgood, writing in the IT business magazine CIO in the year 2000, commented that 'the problem was with the vision behind VR: the original idea was too sweeping; too ambitious.' Describing the move away from HMDs to LVDs, and desktop PCs, he continued 'both projection-based and augmented VR compromise the technical purity of the original VR concept… but such compromises define the difference between an idea that works in the imagination of forecasters and futurists and one that works on the factory floor.'[64] In other words, VR had not worked because its initial concepts were divorced from capability, and wed to science fiction expectations, resulting in a shift toward a definition which reflected technical plausibility.

The notion that the paradigms of VR were moving away from the original 1980s ones was echoed both explicitly and implicitly in a wide range of literature discussing VR from around the time of the turn of the 21st century. The truth at the time, however, seems to have been that, for those interested in the use of computers, the range of suitable and accessible applications was growing at a remarkable rate during the late 1990s, and the Internet was one of the principal means of distributing computer content. The mass popularity of the CD format, which was at the time replacing 3.5 and 5.25-inch floppy disks as the main means of data storage also contributed to this change. As it was possible to store 600 megabytes of data on a CD, they represented a sea change in the way that computer content was thought about and used. With floppy disks only being able to hold a little over 1 megabyte (and with high capacity iterations such as the Iomega Zip Disk remaining a novelty more than a logical upgrade),[65] the 1990s saw increasing numbers of features in computer programs like games and graphics software.

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[64] Hapgood, 'Virtual Reality gets physical', 242, 244.

[65] Lui Gough, 'Tech Flashback: Iomega ZIP 100 and the Superdisk LS-120', *Gough's Tech Zone*, 2012 <http://goughlui.com/2012/11/02/tech-flashback-iomega-zip-100-and-the-superdisk-ls-120/> [accessed 17 August 2017].

As users came to expect more, software development budgets grew. One and two-person projects became dozens, and even hundreds of people by the end of the 1990s, and this posed a number of challenges for the US (and global) software industry. More employees meant bigger payroll, longer development cycles meant bigger overheads and a need for greater profits.[66] This, in turn, needed to be driven by bigger sales, and the market forces of the American computer hardware and software industry, in flux at this time, turned to the Internet to market and sell their products. As videogame retail profits soared, and developer salaries fell, cultivation of a large, engaged, diverse, and well-informed ecosystem of computer users became increasingly essential to keep the development industry sustainable in the US.[67] Software and hardware developers such as Atari, Microsoft, Apple, and Autodesk all had Websites established between 1994 and 1996, and Internet presences in varying forms before that.[68] The Web allowed for more vibrant and dynamic presentation of information, with hyperlinks, HTML, and software such as Apple's VR Modelling Language (VRML) allowing for easy-to-implement animation on websites, perfect tools for advertising and themed pages.

The aforementioned VRML was one of the leading software packages for creating 3D environments in games, Web pages, and VR programs in the late 1990s. Its name centred around the concept of VR itself, a digital realm created independently of the real world (i.e. VR's social pathways, but not its technical ones), but VRML was used far more for the Web than for VR systems. This was a product of scale if nothing else. The Web had grown from 2,700 pages in 1994, to over 1.1 million in 1997, and over 3.7 million in 1999, with more than 110 million users in the US alone, around a third of the country's population (and that does not account for, as above, people sharing a computer, businesses, or government institutions).[69]

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[66] Frederick Brooks, *The Mythical Man-Month: Essays on Software Engineering*, 2nd edition (1975), 13-26; Bob Crossley, 'Study: Average Dev Costs as High as $28m' <http://www.develop-online.net/news/study-average-dev-costs-as-high-as-28m/0106030> [accessed 17 August 2017]; Jeff Wofford, 'The Rise and Fall of the Lone Game Developer', *This Too Shall Pass*, 2014 <https://www.jeffwofford.com/?p=1579> [accessed 17 August 2017].

[67] Ibid.

[68] Welcome to Microsoft (1994) https://www.microsoft.com/en-us/discover/1994/; Atari Explorer Online, *AEO at E3 1995* (1995); Autodesk – Thank you for visiting! (1996) https://Web.archive.org/Web/19961019051551/http://www.autodesk.com:80/; Welcome to Apple, (1996) https://Web.archive.org/Web/19961219202222/http://www.apple.com:80/.

The growth of the Internet (particularly the Web), and the widespread discussion of VRML in popular and technical press encapsulates a core component of VR's history in the late 1990s.[70] As VR itself became less relevant and the Internet grew in inverse, exponential fashion, understanding of the paradigms of VR began to change to better reflect the realities of computer use, and the software market. VRML is one among thousands of examples of this, where the concept of VR was adjusted, redefined, and recalibrated to better fit in among a host of technological systems dominated by a low-cost, mass usage communications medium. VRML was not written specifically for VR, in fact, it was written for use online, but it was still called a VR language, in part because it was developed in the mid-1990s when traditional VR was very much a hot concept.[71] Additionally, however, it embodied the transition of VR's meaning from goggles, immersion, presence, or creation, to computers, being online, and the artificial. VR was all about cyberspace again. The near total lack of a unifying ideology, vocabulary, paradigm, or system for VR, which had so hindered its growth in the earlier part of the decade, was at this point a crucial component of its survival in the

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[69] Matthew Gray, 'Web Growth Summary', *Internet Statistics*, 1996 <http://www.mit.edu/people/mkgray/net/Web-growth-summary.html> [accessed 17 August 2017]; 'Total Number of Websites - Internet Live Stats' <http://www.Internetlivestats.com/total-number-of-Websites/#trend> [accessed 17 August 2017]; Julia Murphy and Max Rosen, 'Internet', *Our World In Data* <https://ourworldindata.org/Internet/> [accessed 17 August 2017].

[70] Brutzman, Don, 'The Virtual Reality Modeling Language and Java', *Association for Computing Machinery. Communications of the ACM; New York*, 41/6 (1998), 57–64; Messmer, Ellen, 'E-Comm yet to Embrace Virtual Reality', *Network World; Southborough*, 17/19 (2000), 87, 96; Walczak, Krzysztof, and Wojciech Cellary, 'X-VRML for Advanced Virtual Reality Applications', *Computer*, 36/3 (2003), 89–92; Gibbs, 'We're virtually there'; Stamps, 'On the road…'.

[71] Girschweiler, Bruno, 'VRML Virtual Reality Modeling Language', *W3C*, 1995 <https://www.w3.org/MarkUp/VRML/> [accessed 9 April 2018].

Information Age. Its nebulous aboutness could quickly shift to suit the technological and social landscape of late 1990s America. That landscape was dominated by a techno-culture in which the costs of computing were a fact of life, novelty was always good, and consumerism was romanticised, driven by clear policy directives for the establishment of economic and cultural domination through technological change, namely Al Gore's Information Superhighway.[72]

THE CHRYSALID: THE METAMORPHOSIS OF VR'S WORD USAGE IN THE EARLY 2000S, AND THE CHANGING BOUNDARIES OF VIRTUALITY

Between the late 1990s and the mid-2000s, VR as a concept underwent several marked changes. The definition used here for VR, which required both a HMD, motion tracking, and the deliberate fostering of presence, would not have applied to many of the things being called VR during this late period. Technically, however, the core principles of traditional VR remained unchanged. Graphics hardware and software for PCs improved rapidly during this period, allowing for a wider range of systems to be used in creating and rendering virtual environments for VR, but the technology of HMDs, motion tracking, and haptic input/feedback did not develop at anywhere near the same pace as graphics technology, primarily because computer graphics research was driven by the colossal video game industry, which by 2000 totalled around $20bn (which was in fact a small decline from the previous high of $23bn in 1998).[73] While VR was, at that stage, still positioned toward providing medical, training, and simulation technologies more than anything else, other kinds of computer technologies took off on the gaming and Internet tidal wave, and the technological and cultural definitions of VR grew further and further apart during this time.

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[72] Gil Press, 'Al Gore Invents The Internet: This Week In Tech History', *Forbes* <https://www.forbes.com/sites/gilpress/2016/01/11/al-gore-invents-the-Internet-this-week-in-tech-history/> [accessed 17 August 2017]; Colin Campbell, *The Romantic Ethic and the Spirit of Modern Consumerism* (York, 1987), 77-95.

[73] NPD Group, 'Image - US Inflation-Adjusted Revenues.png | Video Game Sales Wiki | FANDOM Powered by Wikia' <http://vgsales.wikia.com/wiki/File:US_Inflation-Adjusted_Revenues.png> [accessed 17 August 2017].

There was broad literature from the end of the 1990s and the beginning of the 21st century talking about VR, but very little of it actually discusses the technology that was developed and then called VR in the late 1980s. A combination of changing attitudes, consumer desires, marketing trends, and deliberate attempts by former VR companies to shift their image and product tooling encouraged a re-couching of VR in terms of collaborative 3-D environments for work and, toward 2005, even video games. The video game industry itself was weary of VR, and memories of the Nintendo Virtual Boy, Jaguar VR, Forte VFX-1, and a host of failed stereo-shuttered glasses sets from the mid-1990s overshadowed attempts to get games running in stereo, on specialist hardware, when they could ship a game with lower technical requirements and be much less likely to draw condemnation, ire, or health-related panics.

Without the financial pull or consumer push to develop better, safer VR hardware, the technology stagnated in the early 2000s. Developing better displays and inputs required complex optics, human factors, and electrical engineering to achieve. Rather than continue investing money into improving VR systems, a process gradually understood to need decades, tech and VR firms like Apple, Virtual Research, and Silicon Graphics, sought to redefine what VR meant, so that working, profitable 'VR' could be marketed, without the colossal investment of money, personnel and time that traditional VR would have required while retaining the perceived popular appeal of the name. In other words, American business sought to shake off VR's technical path dependency by changing its social context. As such, the early 2000s saw the wider development of LVD, stereo-shutter, lenticular, projector, and haptic computer interfaces in the US, with applications ranging from healthcare, like the aforementioned BioSimMER, through to Nazi-exterminating action games like Wolfenstein 3D.[74] For developers, publishers, hardware manufacturers, and consumers the appeal of immersive 3D was best leveraged when it was explicitly separate from the hardware of earlier

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[74] Chinon - *Cyber Shades 3D Glasses + Video Game Bundle Collection* https://www.amazon.com/Glasses-Collection-Wolfenstein-Dwellers-Slingshot-Pc/dp/B005KMPLNY

VR. However, to avoid a whole new range of marketing and product pathways, the VR name was kept (eventually to become '3D') and applied to a wide range of applications and hardware. This led to the assignment of the VR name to a host of separate systems, where stereoscopic screens, 3D graphics, and websites were all considered to be enabling technologies of the new VR liberated from the shackles of poor hardware design, and more powerful than ever, due to a larger community of users and easily marketable products.

Examples of this are visible in the late 1990s and persist into the early 2000s. By 2005, there was a considerable shift in the visible associations attached to VR and Virtual Reality and its still highly limited technical expression in US consumer products. In 1998, a wide range of newspaper reports, technical journals, and magazine articles were still explicitly discussing VR, but separate from its pre-existing technological or typological definition. For Mark Gibbs in *Network World*, online experiences constituted VR, and the act of surfing the Internet, and using the World Wide Web were core components of VR, with the method of rendering or displaying that to users irrelevant. Gibbs made explicit reference to Apple's VRML as a cornerstone of future American society, allowing business meetings and commuting. The 1980s and early 1990s refrain of VR being the ultimate communications and networking tool was repeated here, except that VR was now separated from its once-definitive hardware, and instead was an 'old' term for a new technology, the Web.[75] Similar sentiments were echoed by David Stamps in *Training* in the same year. The notion that VR was synonymous with the Web, the Internet, or more broadly with 'cyberspace' seems to have grown during the late 1990s and 2000s. With further articles in *Adweek*, *Across the Board*, *The McKinsey Quarterly*, *Builder*, *Internet World*, *The Financial Times*, *Control Engineering*, *Bobbin*, and dozens of others all describing the virtues and challenges posed by VR, but with the either explicit or tacit assumption that VR just meant something accessed through a computer, and backed by the Internet.[76] The popularity of VRML appears to have contributed to this, as a widely used and high-impact technology for Web-design, having VR in the name seems to have contributed to the notion that Web pages could host VR. This trend remained into 2005, and continued beyond that to a limited degree, but was one among a range of other definitions and word uses for VR which were visible in popular media at the time.

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[75] Gibbs, 'We're virtually there'; Stamps, 'On the road…'.

THE CHANGING BOUNDARIES OF VIRTUALITY

Between 1998 and 2005, VR was used to describe a wide range of technological systems, as well as discrete technologies. CAD was repeatedly described as a kind of VR during this time, as was CGI for television and film.[77] There were also articles referring to VR as full-bodied simulators (such as for astronauts and aircraft pilots), 3D computer and console-based video games, training programmes using 3D graphics, Virtual Private Networks, or online world Second Life.[78] The presentation of VR in television was noticeably diminished by this time, with shows like *VR.5* and *VR Troopers* long cancelled by the end of the 1990s, and replaced by a plethora of televised explorations of Internet culture, the World Wide Web, and the new nature of cyberspace in shows like *The X-Files*, and *Buffy The Vampire Slayer.*[79] Portrayal of VR in film at this time also underwent a radical change. As mentioned in the top of this chapter, films like *The Lawnmower Man*, and *Disclosure*, which had showcased the (entirely fictional) intellectual, sexual, and social power of VR was replaced by films like *The Matrix* and *eXistenZ*, the former of which formed a nexus for dialogue about computers and VR at this time, and neither of which portrayed the illusory potential of VR in a positive light. In both films, computer technology was used (in both the narrative and through CGI) to fool people into perceiving things which were not real, thus manipulating them for the ends of mysterious others. Not only are themes of enlightenment turned to ones of deception and doubt brought about by VR, but the pervasive male sexual fantasies rampant in popular VR writing shifted to a more overtly violatory, uncomfortable viewing experience.[80] The notion that VR and computers were tools of deception and that experiences in VR should not be trusted, echoed the fears surrounding computerisation which had abounded in the 1960s and 1970s. Once again, this fear and mistrust was visible in contemporary literature, and it seems reasonable to assume that at least part of this was rooted in the serial over-promise and disappointment of VR, as well as in the widespread moral panics about computing and Internet use, and (in the early 2000s) revelations that government might not be a reliable source of information.[81]

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[76] McCarthy, 'Virtual Reality', 1999; Naylor, 'Trading our souls…'; Poonch Baghai and Beth Cobert, 'The Virtual Reality of Mortgages', *The McKinsey Quarterly; New York*, 3, 2000, 60–69; Blake Evans, 'Get Real'; Caulfield, 'Virtual Reality gets real'; Thomas Kim, 'Virtual Reality Revs up on the Internet: As Surfing the Internet Replaces Long-Haul Flights - and Computer Simulation Replaces Clay Models - Product Development Times Have Been Radically Shortened', *Financial Times; London (UK)* (1 November 2000),06; Dave Harrold, 'Virtual Reality Saves Money!', *Control Engineering; Barrington*, 47/11 (2000), 36–43; Jordan Speer, 'CAD: CITDA Symposium, CADExpo Tackle Technology Integration', *Bobbin; Columbia*, 42/2 (2000), 72–81.

[77] 'Increasing speed helps modelling' 1998; Stewart and Buttolo, 'Putting people power into VR'; Orenstein 'Virtual Reality saves on training'; Blake Evans, 'Get real'; Fara Warner, 'Lear Won't Take a Back Seat', *Fast Company; Boston*, 47, June 2001, 178–85; Jenny Summerour, 'Virtual Reality', *Progressive Grocer; Deerfield*, 80/8 (2001), 25–28; Jim Engelhardt, 'The 3D Future Is Now', *Geospatial Solutions; Newton*, 14/10 (2004), 32–36; David Tubbs, 'Virtual Sets: Studios in a Box', *Broadcast Engineering; Overland Park*, 40/12 (1998), 90–92; George Lepouras and Costas Vassilakis, 'Virtual Museums for All: Employing Game Technology for Edutainment', *Virtual Reality*, 8/2 (2004), 96–106; Brad Gilmer, 'Virtual Sets', *Broadcast Engineering; Overland Park*, 42/4 (2000), 58–60; Matt Straeb, 'The Reality of the Virtual Set', *Broadcast Engineering; Overland Park*, 41/9 (1999), 66–71.

[78] Craig Covault, 'Virtual Reality Utilized In Station, Shuttle Ops', *Aviation Week & Space Technology; New York*, 149/13 (1998), 74; Pappalardo, 'Virtual Reality', Sep 1998; DeVeaux, 'Virtual Reality', 2000; Lonkevich 'American re-uses virtual reality to fight arson'; Yoshida 'Virtual reality all shook up'; Amit Garg, Geoffrey Norman, Kevin Eva, Lawrence Spero, and Sumit Sharan, 'Is There Any Real Virtue of Virtual Reality?: The Minor Role of Multiple Orientations in Learning Anatomy from Computers', *Academic Medicine*, 77/10 (2002), S97–S99; Laura Sullivan, 'Virtual Fire', *Risk Management; New York*, 47/1 (2000), 8; Kushner, 'My avatar'; Edward Castronova, 'Real Products in Imaginary Worlds', *Harvard Business Review; Boston*, 83/5, May 2005, 20–22.

As has been discussed, much of VR's linguistic and semantic identity came from its futuristic depictions when the 'brand' was launched in the 1980s.[82] The pervasive, compounding errors of repeated new definitions of VR technology in academic and popular writing alike may have accelerated this.[83] Furthermore, VR's apparent quality of experience as depicted in exaggerated advertisements and popular news sources with credible narratives informed a great deal of the technology's perceived nature. The lack of public consensus on what VR really was, made it very easy for wildly different definitions of VR to be used concurrently and held in the same regard even if they were in conflict.

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[79] Stephen Posey, 'I, Robot… You, Jane', *Buffy the Vampire Slayer*, 1997; Chris Carter, 'First Person Shooter', *The X Files*, 2000.

[80] Jay Bolter, 'Transference and Transparency: Digital Technology and the Remediation of Cinema []', *Intermédialités: Histoire et théorie des arts, des lettres et des techniques*, 2012, 171.

[81] David Miller, 'Caught in the Matrix', *Index on Censorship; Thousand Oaks*, 33/2, April 2004, 112–17; Margo McCall, 'Virtual Tradeshows Persist in Reality', *Tradeshow Week; Los Angeles*, 33/22 (2003), 12.

[82] Warner, 'Lear won't take a back seat'; Burdea & Coiffet, *Virtual Reality Technology*, 277.

VR's technical identity was more grounded in reality, but still underwent a series of transitions during this late 1990s and early 2000s phase. The persistence of VR-themed articles after the public's admonishment and investor revolt surrounding VR years earlier was due in part to a conscious admission of this transformation process, and an assumption that the difficulty in defining VR was because, in the 1990s, the technology of VR had been unable to deliver the capabilities implicit in its linguistic identity.[84] Indeed, several articles made explicit mention of this notion that VR, as it was, had failed and that VR was being reborn in new technological forms, revolving around the Internet, 3D monitors, and LVDs.[85] The collapse of investment in traditional VR had encouraged many firms to drop the term from their materials. A number of technical and trade writers from the 2000s who explicitly discussed the notion that VR firms were changing the way that they defined VR in order to make it easier to use, manufacture, and develop, and establishing a crucial break between the VR of the 1980s and the 21st century.[86] True VR, as defined in the thesis only really existed in medical and training applications, confined to universities and a few private firms. In other words, many organisations and experts sought to shift the trajectory of VR technology, as well as its place in US technoculture.

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[83] Edwin Powell, 'Cyberspeak: Virtually Virtual', *Office Solutions; Mt. Airy*, 17/10 (2000), 11; Hideyuki Tamura, Hiroyuki Yamamoto, and Akihiro Katayama, 'Mixed Reality: Future Dreams Seen at the Border between Real and Virtual Worlds', *IEEE Computer Graphics and Applications*, 21/6 (2001), 64–70; Tim Watts, Peter Swann, and A. Pearson, 'Virtual Reality? When Visualization Needs Vision', in *Proceedings of the 2000 IEEE Engineering Management Society. EMS - 2000 (Cat. No.00CH37139)*, 2000, 426–30.

[84] Len Vermillion, 'Q&A: Displaying New Types of 'Realities''', *Product Design & Development; Highlands Ranch*, 60/9 (2005), 22; Kenneth Bryden and Karen Chess, 'Virtual Engineering Offers Applications', *Power; New York*, 147/2 (2003), 67–72.

[85] Daniel Freeman, Philippa Garety, Paul Bebbington, Mel Slater, Elizabeth Kuipers, David Fowler, and others, 'The Psychology of Persecutory Ideation II: A Virtual Reality Experimental Study', *The Journal of Nervous and Mental Disease*, 193/5 (2005), 309–315; Karen McMahon, 'Virtual Farms', *Farm Industry News; Minneapolis*, 37/11 (2004), 36; o'Corporate Profile: Christie-New Stereoscopic Projector Key to Seismic Visualtzation', *Oil & Gas Investor; Houston*, 2002, 32–33; Don Sherman, 'VR Streamlines Mercedes' Development Process', *Automotive Industries; Radnor*, 181/3 (2001), 10; Rosenblum et. al., 'VR Reborn'; Burdea and Coiffret, *Virtual Reality Technology*, 70-84.

For those convinced, or unaware of the change, VR was thriving, with a growing market and rapidly broadening adoption in businesses and homes alike.[87] The acceptance that VR was a fluid concept, rather than a technological absolute, helped legitimise the rapid changes in VR rhetoric and pathways that it underwent at the time, in keeping with the quickly altering technological landscape of the early 2000s. The new versions of VR were more collaborative, easy to use, learn, and integrate into existing systems. Predominantly screen-based, the new VR relied on 3D computer graphics and more open means of delivering stereoscopic video, using shuttered glasses on large monitors or projector screens, with devices like the Fakespace Work Wall, and Virtual Research Window VR, as well as countless CAVE Systems (and alternative room-based VR systems such as SPIDAR).[88] These systems still provided varying degrees of immersion and presence when motion tracking was integrated (though it wasn't always), and was far more comfortable, as they used glasses rather than a full HMD. The toil of developing motion trackers and haptic inputs for VR in the early 1990s meant that developing software for the new VR at the end of the century was comparatively cheaper and easier. The early 2000s, therefore, saw considerable expansion of 'VR' into businesses and universities across the US (and to a more limited extent, into homes), while the older forms of VR were almost invisible in writing, products, and advertising by 2001. The transformation of VR was widespread, and there seems to have been acceptance that 3D screens and CAVEs were VR, by the early 2000s[89].

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[86] 'Saturn's Next Frontier', *Automotive Industries; Radnor*, 184/12 (2004), 21–23; Hapgood, 'Virtual reality gets physical'; Briggs, 'Virtual reality is getting real'.

[87] Ibid, 36; Yoshida, 'Virtual reality all shook up'; Andrew Freiburghouse, 'Virtual Reality Check', *Forbes; New York*, 2 April 2001, 20.

[88] Robert Stone, 'Haptic Feedback: A Brief History from Telepresence to Virtual Reality', *Haptic Human-Computer Interaction*, 2001, 1–16.

This change in the understanding of how VR could be expressed and accessed was a key contributing factor in the adoption of non-HMD VR by US business in the 21st century, and the systems to which VR aligned itself. As screen-based VR moved toward information science and workplace management in business, HMD-based VR increasingly drew its technologies from and aligned itself with, the video game industry. [90] Several devices in the late 1990s and early 2000s sought to capitalise on the tremendous hope that had been pinned on commercial VR and were designed to avoid the backlash that came from technological disappointment presented by poor displays, laggy motion tracking, and cybersickness. The solution, for several large Japanese and American companies, became known as the Face Mounted Display (FMD). The core principle behind an FMD was that it was sufficiently small and light to be worn like eyeglasses while providing a full colour image in good resolution.

The lightness and form factor were largely achieved by removing the stereoscopic and head-tracking components, crucial to VR HMDs of the past. This meant that users of FMD's did not see the virtual environment move when they moved their physical bodies and that the window into the computer-generated world that they did see did not appear to be 3D, but instead was more akin to sitting very close to a large television.[91] The two most popular devices in this market were the Sony Glasstron and Olympus Eye-Trek FMD series. The Glasstron was first released in 1996 but received a crucial upgrade to SVGA resolution (800x600 pixels) in 1998. The displays capitalised on the collapse of the HMD market, and the perceived desire for immersive displays with high resolution, and none of the discomfort associated with VR's HMDs. The Eye-Trek was released in 1998 and, again, received a number of upgrades between then and 2001. Both systems were marketed with VR overtones (though terminology tended to be limited to phrases like 'virtual experience' in official materials) but lacked the motion tracking and stereo elements largely considered to be staples of VR by those who supported the move of VR from headsets to LVDs.[92]

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[89] Blair Kuhnen, 'Virtual Realty', *Giants; Oak Brook*, 70/4 (2005), 28; Chirs Smyrniotis, 'Computer Modeling Brings Slag Control into the 21st Century', *Power; New York*, 149/8 (2005), 61–62; Rafal Wojciechowski, Krzysztof Walczak, Martin White, and Wojciech Cellary, 'Building Virtual and AR Museum Exhibitions', in *Proceedings of the Ninth International Conference on 3D Web Technology* (2004), 135–144.

[90] Michael Zyda, 'From Visual Simulation to Virtual Reality to Games', *Computer*, 38/9 (2005), 25–32.

[91] Mike Wiley, 'Sony Glasstron PLM-A35 Review', *IGN*, 2001 <http://www.ign.com/articles/2001/10/12/sony-glasstron-plm-a35-review> [accessed 23 August 2017]; 'OLYMPUS | News Release: Eye-Trek FMD-700' <https://www.olympus-global.com/en/news/2000a/nr000524fmd700e.html> [accessed 23 August 2017].

Sony would go on to manufacture a stereo (but non-tracking) Glasstron system for business users only in 1999, costing 600,000 yen ($5000 in 1999, or $7500 in 2018) it was far more expensive than even the high-specification Glasstron units sold to the public. Sony predicted a run of 5000 units worldwide, and it was discontinued thereafter, very few such systems made it into the hands of American consumers, and it was anomalous among FMDs.[93] While neither of them became wildly successful, they both survived on the US market for several years, with Olympus claiming in 2000 that the Eye-Trek had more than 70% of the FMD market share.[94]

A not-insignificant reason for this is the video game industry. The Sony PlayStation 2 console popularised the DVD format in the US in the year 2000, leading to the adoption of high-end home-theatre hardware by American consumers. This created a consumer base for displays which gave the appearance of a 50+ inch television, without the physical space such a large CRT, rear-projection, or Plasma screen would require. Sony, as the manufacturer of the PS2, was centrally invested in the DVD standard, and in promoting display technologies to make their console appear to be innovative. A part of this effort was directed toward capturing the attention of consumers who still wanted game-console-based VR to be realised, and Sony released a head-tracking, stereoscopic headset exclusively for use with the PlayStation 2 in September 2002.[95] The device was released in Japan and sold so poorly than it never spread further. Its failure aside, the fact that Sony was willing to invest the time and resources into designing, testing, and releasing a HMD-based VR system with low latency and heavy, wide FoV optics for the PS2 highlights the idea that HMD-based VR remained a concept which businesses wanted to provide products for, but clearly the economic, technological, and cultural environments were not suitable. For most though, VR at this stage was split between business applications, consumer versions (which were overwhelmingly not true VR) and academic/medical applications (which occasionally were).

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[92] Sony Marketing Co., Ltd., 'Sony Global - Press Release - Sony Announces New Personal LCD Monitor PC Glasstron', 1998 <https://www.sony.net/SonyInfo/News/Press_Archive/199809/98-101/index.html> [accessed 1 September 2017]; Sándor Kopácsi, 'Virtual Reality in Flexible Manufacturing - Main Document', 2001 <http://old.sztaki.hu/~kopacsi/vr/vr_main.htm> [accessed 1 September 2017].

[93] 'Connecting The Personal LCD Display - Sony LDI-D100B Service Manual' <https://www.manualslib.com/manual/1241828/Sony-Ldi-D100b.html?page=12> [accessed 15 November 2018]; 'Sony Japan | Press Releases | Business-Use Head-Mounted Display Capable of Displaying 2-Dimensional Images and 3D Stereoscopic Images Released', 1999 <https://www.sony.co.jp/SonyInfo/News/Press_Archive/199906/99-053/> [accessed 15 November 2018].

[94] Kopácsi, 'Virtual Reality in Flexible Manufacturing'

PACE OF CHANGE: THE IMPLICATIONS OF EVER-SHIFTING DEFINITIONS FOR A HOLISTIC VR

So, what in that case was VR at the turn of the 21st Century? Was it a 1980s pipe dream?[96] The network of networks that made up the Internet? Was it video games? Was it any digital medium consumed through a 3D screen, or FMD? For a few people, existing pathways were unchangeable: it remained a highly complex immersive computing tool for creation, communication, and presence in diverse virtual environments.[97] At universities across the country, academics who had cut their teeth on interactive computer graphics, proto-VR, and VR in the 1980s and early 1990s were still pursuing a range of human factors, psychological, industrial, and computer graphics applications using high-end, expensive HMD-based VR set-ups, often with mid-1990s hardware dating from the boom (VPL DataGloves and Virtual Research Flight Helmets remained in use in a small scattering of VR research projects into the 2000s, including at Ames).[98] That definition was just one among many, however, and during this late period, the number of technical, scientific, and popular articles concerned with that particular VR were far outnumbered by a host of others concerned with an exponentially larger brand of VR. While being a technology which had failed to get off the ground, encumbered as it was by excessive expectation and insufficient drive, the notion of VR persisted. The term, and the concept, did not die with its earlier technological iterations.

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[95] Sony Marketing Co., Ltd., '報道資料 Sony Japan | Press Release | Release of 'HMD' that Allows You to See All Directions of the Virtual Space in the Game ※ 1', *Sony Info*, 2002 <https://www.sony.co.jp/SonyInfo/News/Press_Archive/200209/02-042/> [accessed 23 August 2017].

[96] Charles Seife, 'Gambling With Our Votes?', *Science; Washington*, 306/5697 (2004), 798–99 for an example of how 'Virtual Reality' was being used to mean something that was unlikely in the current circumstances.

[97] Christian Luciano, Pat Banerjee, and Sanjay Mehrotra, '3D Animation of Telecollaborative Anthropomorphic Avatars', *Association for Computing Machinery. Communications of the ACM; New York*, 44/12 (2001), 64–67; Ryan, 'Virtual Reality in Marketing'; Kheir Al-Kodmany, 'Visualization Tools and Methods in Community Planning: From Freehand Sketches to Virtual Reality', *CPL Bibliography*, 17/2 (2002), 189–211.

For the North American layperson, (to disaggregate: the layperson interested in computer technology) VR was less to do with any particular display or input set up, or a virtual environment, and more a loose connotation with computerisation. VR had gone from being a confused term about cyberspace, computers, and virtual presence, to being a profoundly diffuse, anodyne phrase that meant whatever one wanted. Used to refer to the Internet, the Web, games, operating systems, imagination, software, network architecture, computers, and even communication using computer technologies.[99] To summarise: VR was a buzzword, a piece of jargon, a colloquialism with no clearly understood meaning, no shared cultural base, and no widely understood language, increasingly distant from the material, applicable truths of VR.

In consumable media, now including websites as a major component, VR was defined and re-defined to provide writers with an excuse to put the term VR in their title, rather than to establish any kind of semantic clarity over the use of the word. As Raymond Williams pointed out in *Keywords*, the more a word is used, the less potent and useful it becomes, and the less meaning can be attributed to it. The widespread, rapid overuse of VR in the 1990s had inflated its connotations and meanings to the extent that it now realistically meant nothing. There was no way to establish a clear, concise definition through consensus because any such definition would need to refer to technological norms which did not exist, or alternatively to systems and cultural processes which already had established vocabulary and contexts, like the Web, or video games, or tele-conferencing, for example. The ambiguity of the term allowed for VR to refer to a wide swathe of technological systems and practices in the final years of the 20th century, and the first few of the 21st, without meaning any particular one.

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[98] Budera & Coiffret, *Virtual Reality Technology*, 25; Kevin Arthur, 'Effects of Field of View on Performance with Head -Mounted Displays' (unpublished Ph.D., UNC, 2000), 3.

[99] Williams, Raymond, *Keywords : A Vocabulary of Culture and Society*, Flamingo ed., and expanded. (London, 1983) 15-17.

This is perhaps best reflected in the typologies of actual VR products on sale during this period when compared against the considerable body of VR-related literature (including the hordes of articles with VR in the title, and nowhere else).[100] With the FMDs from large manufacturers such as Sony and Olympus drawing custom from many US consumers who wanted the HMD experience in the early 1990s, and the cheaper, easier to manufacture 3D screens and projectors occupying much of industry's VR computerisation projects (which were mainly oriented around improving workflow), there was little room for a VR HMD market. As a result, commercially available HMDs for VR setups were (for the most part) expensive, and manufactured in small quantities by the private sector (including for the military, which had stopped developing its own VR hardware and moved to buying civilian technology for VR training experiments).[101] FMDs made by Fakespace, while providing the stereo imagery crucial to VR, were not technically head-mounted, as devices like the Fakespace BOOM and PUSH units had to be manually held up against the face of the user, severely hampering freedom of movement, immersion, and presence.

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[100] Pappalardo, 'Virtual Reality', Sep 1998; Laberis, 'Virtual Reality', 1999; Baghai and Cobert, 'Virtual Reality of Mortgages'; DeVeaux, 'Virtual Reality', 2001; Richard Tomkins, 'A Baby Boom in Virtual Reality', *Financial Times; London*(17 October 2002), 21; Ron Ruggless, 'No Games: Deal to Take Dave & Buster's Private a Virtual Reality', *Nation's Restaurant News; New York*, 36/23 (2002), 1,97; Jennifer Alvey, 'A 'Virtual' Reality', *Public Utilities Fortnightly; Arlington*, 141/17 (2003), 48–53; Stuart Cohn, 'The Non-Merger Virtual Merger: Is Corporate Law Ready for Virtual Reality?', *Delaware Journal of Corporate Law; Wilmington*, 29/1 (2004), 1–42, none of which concern VR.

[101] Burdea & Coiffret, *Virtual Reality Technology*, 328-42.

The main manufacturers of HMDs at this time appear to have been Kaiser Electro Optics and N-vision, both of whom manufactured a high-end line of HMDs used in a considerable proportion of VR research at universities and businesses in the early 2000s. The Kaiser ProView Series were all on sale between 1998 and 2003, and cost anywhere between $4,995 (or $7,380 in 2015) for a low-resolution colour stereo unit, to $34,995 (now $50,000) for a 1024x786 resolution colour system in the year 2000. N-Vision had two main ranges of VR displays on sale in the early 2000s, the Virtual Binocular, and the DataVisor. The Virtual Binoculars were a 'low cost' VR system, and could be either hand held, desk mounted or strapped to the user's head (making them technically an HMD). With a resolution of 640x480, the display quality was comparable to high end systems in the early 1990s, and they sold for $10,000 (now $14,000). Their DataVisor range of high-resolution systems had been on sale since the mid-1990s and were designed for technical demonstrations and VR-based research. Used by NASA after the decommissioning of the VIVED system, alongside Virtual Research V4, V6 and V8 HMDs, the DataVisors ranged in capabilities but were unanimously expensive, heavy, and cumbersome.[102] The 'cheapest' DataVisor, the Hi-Res, used CRTs and sold for $35,000 in 2000 ($49,000). The LCD version, the DataVisor 80, sold for $90,000 in the same year ($125,000).

The Hi-Res and 80 both had a resolution of 1280x1024, also known as SXGA (Super eXtended Graphics Array). It was the de-facto standard for high-end LCD monitors and some CRT monitors in the early 2000s, which tended to cost around $2,500 in 2000.[103] This meant that HMDs of the early 2000s could provide the same clarity as contemporary monoscopic monitors for at least fourteen times the price. The excessive cost of these displays was further increased by the cost of powerful graphics cards needed to render stereoscopic imagery for 3D, and a sufficiently fast computer system to run them, as well as the knowledge and training required to build and run such environments (as there were only a handful of 3D modelling programmes which supported stereoscopy). When faced with the financial, technical, and ergonomic challenges and disadvantages offered by HMDs, the turn toward projector, screen, and monoscopic ideations of VR by 2000 seems to not just be a dilution and corruption of the VR concept, but a practical and economic necessity. VR was simply too expensive and cumbersome to be adopted, just as it had been five short years earlier when the VR bubble was at the point of bursting.

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[102] Steve Ellis, Interview, 12th Apr 2018.

[103] 'Monitors', *HWM*, 2/5, June 2002, 75–83.

On the ground, therefore, in the realm of practical experience by consumers and users, there was no VR, and there never had been outside of the arcade. VR was a much-touted, publicised, and marketed broken promise. As technology developed, and the techno-and-cyber-culture of the US developed, the 'goalposts' defining VR changed, keeping it constantly on the cusp of being 'here' but never quite arriving. This was an experience shared by Artificial Intelligence technology throughout the 20th and 21st centuries, which went from meaning speech recognition to fully sentient Singularity in half a decade as computer technology caught up with prescribed goals, a phenomenon explored in superb detail by Pamela McCorduck, among others (the parallels between AI's history and that of VR, particularly in regard to the AI Winters, are remarkable, and merit further research).[104]

A lack of consensus over what VR was, or was for, arose from its aparadigmatic nature in the early 1990s and 1980s, and enabled VR as a concept to disperse and adapt to suit the cultural, technological, and economical environment of the time, joining the background radiation of the US computer revolution at the height of the dot-com bubble. That same lack of vision meant however that VR was not held to cultural pathways established by its earliest confused years or the technical roots of proto-VR.

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[104] Pamela McCorduck, *Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence*, 2nd edition (Natick, Mass, 2004), 417-534; Michael Bouso, 'Defining Artificial Intelligence (AI)' <http://www.nextcollision.com/blog/defining-artificial-intelligence-ai> [accessed 24 August 2017].

The explorative and recreational aspects of VR, core to many of its early demonstrations and companies at Cyberthon and beyond were taken up by the burgeoning video game industry, which was now dominating the in-home market as well as arcades. The artistic and creative aspects of VR, a once-crucial component of the VR paradigm talked about by Lanier and many others in the late 1980s and early 1990s as being like 'digital LSD' was absorbed into 3D desktop graphics, with graphics tablets, digital painting, and a host of powerful 3D modelling software suites allowing widespread digital creativity and imaginative freedom on desktop PCs using standard or panoramic 2D (such as the Panoram PV290, fig .15) or 3D displays like the Elsa Ag Ecomo4D, depending on one's budget.[105] The communicative aspect of VR, the notion of shared immersive experience which for many formed the link between VR and Gibsonian cyberspace had never come to fruition due to technical obstacles but was emulated in far more accessible form in the Internet and the World Wide Web. Online games like World of Warcraft and environments such as Second Life combined all these elements together and for many in the early 2000s, the cyberspace of games on their PC, at their desk, and in their home was the closest to true VR that they hoped (and wanted) to get.[106]

There remained, for some, an understanding that 'true', 'pure' VR required a helmet, but there were widespread indications in literature both online and in print that that version of VR was understood to be far more trouble than it was worth practically, economically, ergonomically, and technologically.[107] The university research carried out using HMDs was undeniably VR, but nearly invisible to the average interested American, and kept out of public view by companies working with VR.[108]

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[105] Burdea & Coiffret, *Virtual Reality Technology*, 71, 75.

[106] Castronova, 'Real Products in Imaginary Worlds'; Kushner, 'My Avatar'.

[107] Vermillion, 'Displaying New Types of Realities'; Lepouras and Vassilakis, 'Virtual museums for all'; 'Survey: Virtual Hype, Real Products', *The Economist; London*, 358/8214, 24 March 2001, Insert 14,17; Hapgood, 'Virtual reality gets physical'. Briggs, 'Virtual reality is getting real'

[108] Ibid, 35.

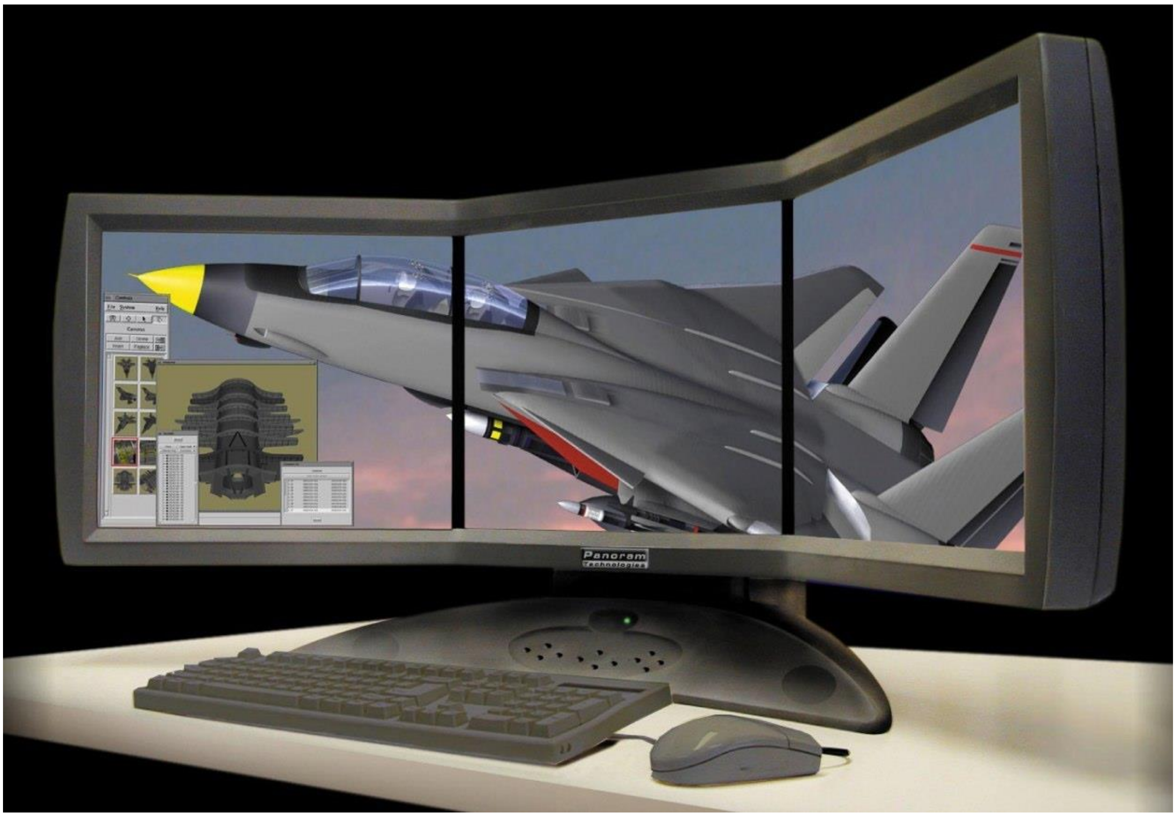

FIG. 15 A promotional photo of the Panoram PV290 triple LCD monitor, priced at almost $10,000, these units sold in small numbers, but their considerable size meant that they were discussed in some contemporary materials as being a form of VR display.[109] image courtesy of Panoram Technologies, Inc. http://www.digitalimage4k.com/panoram-pv290-triple-18-lcd/.

For many in the US at the dawn of the new millennium, it was simply one kind of VR, and it was not the one most people needed. Colossal confusion over what VR actually was meant that its technological failure and the complete and utter lack of a system or pathway was ignored, and the notion of VR was copied onto various other systems where it could be made to fit, while leaving its technical, material-cultural form (HMDs, Gloves, Bodysuits, and Trackers) to fade into obscurity. VR survived the 1990s winter and persisted into the 2000s by dying. Most VR was not VR anymore, and the rapid, near-total change in word-usage surround the term implies that this death and rebirth spanned most US techno-culture at the time.

AFTEREFFECTS: THE AMBIGUATION, ABSORPTION, AND RECESSION OF VR

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[109] Burdea and Coiffret, *Virtual Reality Technology*, 75; 'Panoram PV290 Triple 18" LCD', *Digital Image Associates*, 2014 <http://www.digitalimage4k.com/panoram-pv290-triple-18-lcd/> [accessed 25 August 2017].

If VR in the 2000s could mean almost anything, and therefore had little weight or significance, where does that leave those wanting to study the social and technological history of VR during this period? The 'digiterati' who had expounded and expanded VR's virtues in the late 1980s and early 1990s had fallen silent as the fruit of their labour produced diminishing returns. Rather than becoming an all-encompassing technological and cultural means of interacting with people and computers, VR technology itself shrunk and retreated to the handful of areas in which its unique qualities were obviously useful. The immersion and tremendous sense of presence in virtual environments that the technology created made it useful in studying human thought, training for extreme situations, and helping people recover from psychological damage. The prophesied applications of VR technology in games, office management, face-to-face communication, shopping, and sex never materialised. Attempts to apply VR to these forms of media were met with confusion and reluctance, as developers without standards sought to impose extremely high costs and confused terminology on a group of industries which would not only have had to produce new software to utilise VR's potential, but convince employees, consumers, and investors that strapping on a helmet and gloves before doing anything was a good thing. Instead, more affordable technologies satiated the desire for novelty in the Information age, with Web-conferencing, video-calls, LVDs and 3D Projectors filling the space which VR's promise had staked out. While these alternative solutions differed considerably in price and implementation (being far closer to existing technological systems and thus more acceptable), for the manufacturers, consumers, and salespeople they were still VR. Most in the US at the time would consider the stereo 3D of a shuttered-glass CRT to be just as valid for defining VR, as a headset, a glove, or even a full data suit.

The problem for historians becomes, then, how to periodise the definition of VR, as the perceived nature of the technology changed considerably during this crunch period. Prior to the 21st century, VR had a series of different definitions, being a fully immersive recreational and creative experience, where body and mind are united in a computer in the 1980s. In the early 1990s, a wide range of design and business applications were discussed (though never viably realised), and VR became a way to entirely place oneself in another world, an office, an upcoming building, or a medieval dungeon. The core aspect of those definitions of VR came back repeatedly to the HMD, a device which obscured the real world, and placed you within a new reality. A sense of being there, of presence, and of being a part of a virtual environment was key. By the year 2005, this was not the case. HMD-based VR all but died out, and the use of ‘VR’ to describe 3D displays was itself waning by the end of the period. Where it was used though, it was an abstraction of earlier definitions. CGI, which encouraged the suspension of disbelief, formed the core component of 2000s VR, and older concepts of VR were considered no more valid than any of the new ones: they were even seen as misguided, even naïve. To accurately understand the history of VR, historians must also try and examine critically the diverse range of backgrounds and contexts for VR’s different definitions and ask themselves which particular kind of VR they are examining, and who it was for.

THE ABSORPTION OF VR

Increasingly, the displays and software of VR would morph into 3D in the years after 2005, as VR was absorbed by video games almost completely. The association between VR and HMD-based immersion would only be rekindled with the advent of better, cheaper screens from smartphones in the early 2010s, and the design of lower-cost commercial HMDs like the Oculus Rift and PlayStation VR. 3D monitors and displays similarly never gained widespread appeal in the mid-2000s, and there seem to have never been more than a handful of pilot programmes across the US testing the benefits of 3D over 2D screens, which was by that time the totality of the difference between VR and real life in the Occam’s Razor of the colossal US corpus. The eye-strain, hardware requirements, and higher cost of 3D screens, without worthwhile benefits, led to a reduction in 3D schemes in business. 3D itself would continue in entertainment and gaming environments up to the present, with its definition and associations clearly separate from VR, and devoid of any substantial claims of enhanced productivity or quality of life which had permeated HMD-based VR's 1990s heyday.

The only areas in which VR's potential remained visible during the mid-2000s were in mental health therapy and psychological research. Numerous university research projects in the mid-2000s used VR to examine perceptions of racism, danger, sexism, mental illness, and a wide range of socio-cultural phenomena, as well as helping in the experimental treatment of conditions like post-traumatic stress, anxiety, depression, and xenophobia. There was quality to being able to immerse people's vision and hearing entirely in another world, or in the same world, but another body which was unique at the time. Prohibitive costs and the lack of any standardised system, manufacturing, or consumption paths to drive investment and content, however, meant that applications of VR had to be tailor made for each project, which kept trials small, slow, and tightly budgeted. The term itself remained popular in academic circles, with VR far outstripping Virtual Environment, AR, or cyberspace in academic publications either discussing the technology itself, or its applications (see fig. 16).

When a considerable amount of the dialogue concerning VR ceased to be about VR as it was previously understood, it seems clear that either a marked semantic shift had taken place over the course of a single decade, or that modern assumptions about the historic perception of VR had been incorrect. The truth is perhaps a mixture of the two. It is clear that after the VR bubble burst in around 1996, there was a clear, visible, traceable pressure to redefine VR and move the intellectual property away from the existing paths and material culture which it had accrued until that time (Cyberpunk aesthetics, heavy displays, gloves, and graphics-oriented workstations) toward a more laissez-faire, holistic 'VR'. It also seems likely though that the loud voices of VR pundits in the early 1990s obscure a great deal of the confusion that persisted with 'on the ground' users and would-be consumers of VR over what it means.

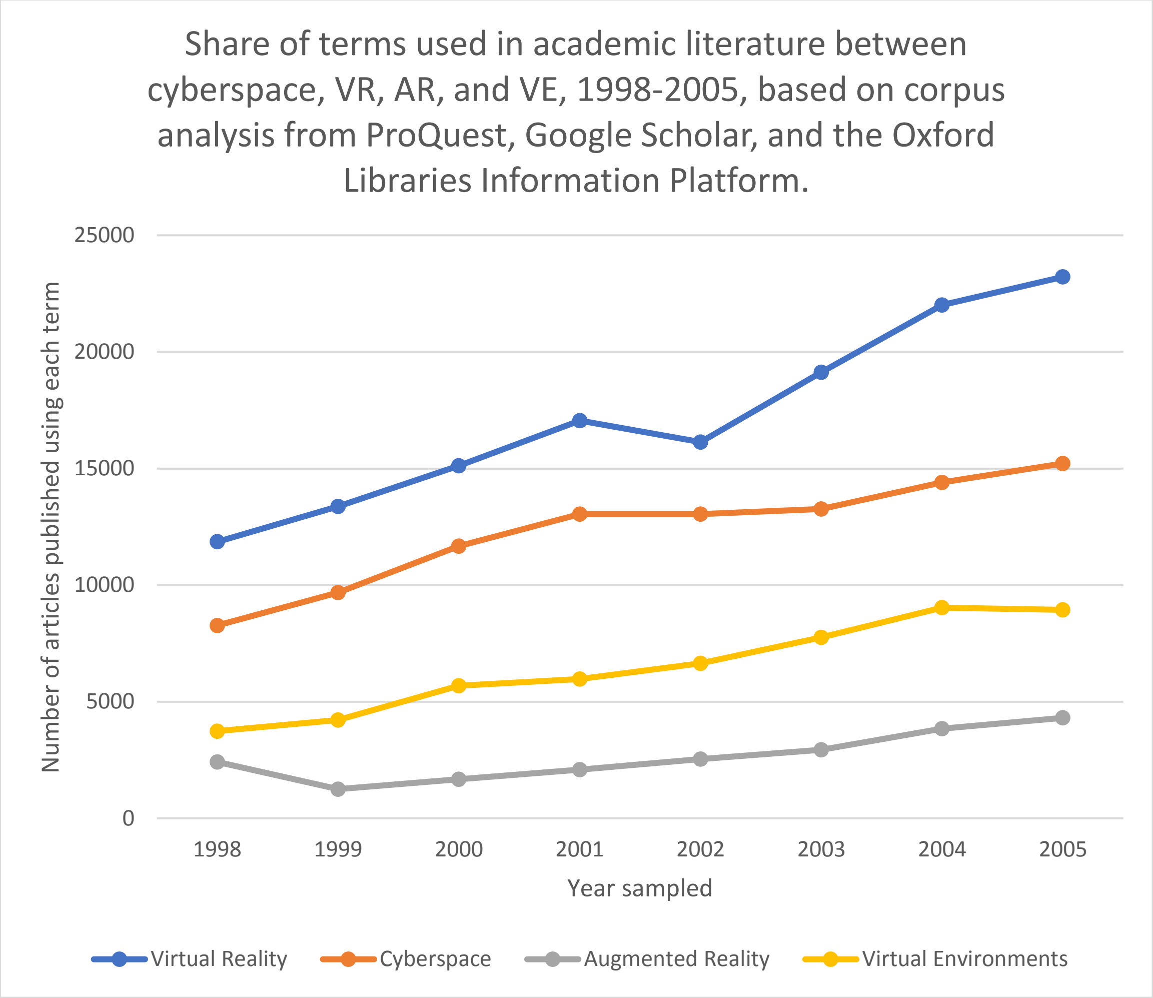

FIG. 16 A chart showing the rough division of articles between four different primary terms, many articles used some or all of these interchangeably, in which case the phrase used in the title was chosen. VR remains the dominant term in US academic publications concerning the technology of computer-driven immersion throughout this period while others make gains.

Part of this is visible through the tremendous raft of definitions and redefinitions that were in writing, television, and online during the early 1990s, as well as a number of explicit comments by academics and innovators alike that the nature and core principles of VR were becoming lost in the wash of marketing hype which overwhelmed VR in the early 1990s. Lanier and Laurel, both directly invested in stirring up hype in order to generate crucial investment, were also keenly aware that by advertising VR as the future of speech, art, thought, sex, and life itself, it was losing what little chance it had of forming a discrete technological system, or cultural paradigm.[110] By the time the 2000s came around, the public denunciation of HMDs by companies like Virtual Research and Liquid Image, and the VR branding of successful products such as the Sony Glasstron and Apple's VRML provided to the American public, for the first time, an image of what 'VR' had really meant all along, inadvertently creating a language and standards for VR which was not directly about VR at all, but were instead the product of marketing gurus' desires to capture the wide-eyed optimism and fervour which had surrounded early VR in the now-successful Web.

As such, coverage of and public expectations for bodily immersion, visual transportation, and presence in virtual worlds through VR waned, and interest moved towards the systems and technologies which the Glasstron, EyeTrek, and VRML enabled: video games and the Internet. It was these technologies, far more successful and culturally relevant than VR had been independently, which carried and transformed the VR moniker for most people. VR hardware and software itself, such as it was, drew increasingly from the game industries' developments: improved graphics hardware, 3D modelling engines, and later the smartphone industry. VR had never been able to rely on internal innovation to create itself, instead drawing on larger, more successful industries to survive. Portable televisions, camcorders, smartphones, PC graphics cards, video games, and a host of other, commercially successful technologies in the 1980s and 1990s formed the technological and economic pathways upon which VR's development was nearly entirely dependent while its cultural language was articulated through the vocabulary of wishful futurology-as-fact. The near total abandonment of HMDs and haptic interfaces in the mid-2000s represented the absorption of VR's culture and aims into the game and Internet industries, businesses, and systems in the US at the time, only to re-emerge when gaming HMDs hit the market in more recent years, providing a new focal point for discourse.

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[110] Jas Morgan, 'Brenda Laurel: Lizard Queen', *Mondo 2000*, 7, Fall 1992, 82–92; C. Conn and others, 'Virtual Environments and Interactivity: Windows to the Future', in *International Conference on Computer Graphics and Interactive Techniques: ACM SIGGRAPH 89 Panel Proceedings; 31 July-04 Aug. 1989* (1989), 7–18 <https://search.proquest.com/docview/31691690/324BD81D505B4E00PQ/36> [accessed 23 May 2017].

While physical hardware is not essential for the formation of discourse, it was the hardware of VR which made it separate from conventional desktop gaming, office work, design, and Internet access. The transfer of VR rhetoric from HMDs to 3D screens and graphics led to its dissipation when 3D screens were completely outnumbered by 2D screens. With each successive semantic transformation, the line separating VR from other kinds of computer use became increasingly superficial, and it took the re-release of VR's unique hardware, the HMD, for it to re-emerge.

THE VR RECESSION

A factor in the later US history of VR which has been largely ignored is the destruction of the World Trade Center in 2001. Up until around 2001, there were signs that US businesses were increasingly willing to invest considerable sums in piloting 3D design systems, in the hope of finding shorter development times for new products. The widespread consumer and investor caution following the attacks, accompanied by a renewed economic nationalism which saw the 2001 US recession deepen, along with the persistent threat of war, had a considerable impact on business spending. Furthermore, the colossal financial cost of the Afghan war directed money away from business stimulus packages planned for 2003 onward, further dis-incentivising private expense on experimental technologies.[111] This seems to have effectively paused the early 2000 trend towards the 3D graphics workplace, as businesses turned to more reliable, steadily developing ICT products. Hindered further by limited understanding of the health risks, VR's meaning became increasingly nebulous by that time, as well fading from television broadcasts and books (though not online, as the number of Internet sites increased exponentially throughout the 2000s, enabling VR-related sites to grow numerically).

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[111] Kimberley Amadeo, 'How the 9/11 Attacks Still Damage the Economy Today', *The Balance*, 2017 <https://www.thebalance.com/how-the-9-11-attacks-still-affect-the-economy-today-3305536> [accessed 25 August 2017].

VR, as a concept, managed to survive a near-total collapse of its parent businesses, popular culture representations, and consumer marketing via a series of transformations. However, the question of its fate as a technology is distinct from and more complex than, the use of its name. While the technology of VR as it had been developed in the period spanning 1965-2005 had passed through a period of increased visibility and investment and then a period of diminished usage and slowed development, it did not fade away entirely. The core technologies of VR remained in use throughout the 1990s and 2000s. Unlike many technological failures, which stem from a single manufacturer, industrial standard, or price war, VR is unusual in being a technology without those core components. There was no leading manufacturer, defining standards, or direct competitors to fuel a capitalist productivity drive. This meant on the one hand that the technological development was dispersed, slow, and directionless, dependent largely on innovation in other systems (which did have those components), and on the other hand meant that when some of the main sources of income and developmental pressure collapsed, as they did in 1995-6, individuals, small firms, and research organisations continued to use the technology in the highly specialised contexts within which VR was advantageous to use.

VR itself, therefore, did not fail, but only ever had a fairly small area of suitable applications, and viable ecosystems to inhabit in capitalist, consumer-oriented America. The popular notions of VR, however, were hyperinflated, distorted, and transformed by a range of agents: innovators, reporters, scientists, and salespeople in the name of attracting interest and making a profit. Collaterally, this elevated discussion of VR far above the level suiting a technology so young and expensive to develop and make, in terms of the volume and confidence of that discussion. Excessive faith in VR's technological ascendency gave way to caution and anger, much as the US economy experienced in the new millennium. It might be fair therefore to argue that VR's failure was not one of technological performance but of establishing what it *was* good for, or what its purpose was and instead publicly demonstrating what it was *not* good for. Too much was expected and advertised of the technology in the name of attracting investment and over-inflating demand and this, coupled with the optimistic hope of cyberpunk popular culture, led to widespread collapse of interest when the scale of the over-inflation became clear. As a result, usage levels of HMD-based VR fell back to very low levels, only to expand when computer and optics technologies were sufficiently advanced to allow for useful, practicable applications of VR technology outside of specialised academic, medical, and psychological contexts. High fidelity colour displays first began to appear around the year 2005,[112] but their advanced technology kept costs prohibitively high, and it was only with the advent of the smartphone some years later that the cost of HD (and super HD) displays that were small and light enough to fit inside a HMD was sufficiently low to make attempts at selling VR hardware which American businesses might want. The period between 1998 and 2005 was, for VR, a recession, where applications of the technology dwindled to a sustainable number in the face of a broad public rejection of marketing rhetoric, and for which subsequent growth would remain at the behest of far larger and often younger industries. The fantasies and promises of VR were always lurking, however, and the pull of an immersive, intimate, personal window into a computerised world proved impossible to resist for long.

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[112] Vermillion, 'Displaying New Types of Realities', 22.

CHAPTER 6: FALL OUT

`‘I was told you were on an intergalactic cruise, which I can handle, but in your office, which I can’t.’`

- Zaphod Beeblebrox, in *The Hitch Hiker’s Guide to the Galaxy*, (Fit the Twelfth), Douglas Adams, 1980.

`‘VR was once the dream of science fiction. But the internet was also once a dream, and so were computers and smartphones. The future is coming.’`

- Mark Zuckerberg, founder of Facebook, ‘10101319050523971’, *Facebook*, 2014.

`‘Unfortunately, no one can be told what the Matrix is. You have to see it for yourself’`

- Palmer Lucky, founder of Oculus, Twitter post, January 11, 2016.

ALL GOOD THINGS…: REVIEWING THE FINDINGS, METHODOLOGY, AND FUTURE OF VR’S PAST

PANOPTICON: A SUMMARY VIEW

Attempting to summarise the VR story in a single, continuous narrative would invalidate and erase the discrete strands of its history. This is, after all, a tale of (at least) two Virtual Realities, one of which represents a niche Intelligence Amplification technology, developed for the purposes of increasing the human capacity for work and thought by a series of electrical engineers, computer scientists, and military researchers. This VR was first developed in the 1960s and it maintained, with varying levels of visibility, a presence in American universities through to the 21st century. The other VR was quite different, however. Culturally subversive, transhumanist, and transformative, it was rooted not in any extensive technical plausibility by its advocates, developers, and salespeople, but in imagination, aspiration, and fantasy. This second VR was far more visible and tantalising and was kept largely separate from the disparate, underdeveloped, and entirely non-optimised information, display, and graphics technologies which underpinned its grounded (technologically achievable) sibling. This VR only really became known in media around the mid-1980s and was inspired by the

IA technologies of proto-VR, but bound instead to aspiration, rather than achievability. It would metamorphose and migrate throughout the following two decades and beyond.

Without any defining paradigm, unifying language, or shared ambition, beyond the umbrella of IA, proto-VR's discrete existence is partially artificial, and was a product of the lens of shared artefactual and experiential definitions. Innovators at a range of institutions across the US developed the technologies of presence and virtual space for martial, architectural, computer-scientific and product design applications, among others. This period demonstrated that the technology had value, and its accessibility and suitability could have been increased through technical development and research in that manner, with a project-led focus built around IA. The technology was quickly subverted by VR however, how did this happen? The answer lies with one of the core aspects of what makes VR's history so unique.

The progress in VR development made by university, military, and state-institutional personnel was a product of clear research goals and artificially limited scope for application. The securing of funding in such environments demanded a clear demonstration of workable applications and a technological foundation which could be built upon. Even so, development required decades of investment in order to generate technologies approximating the VR produced by private industry in about 2005. The arrival of a new set of roles for the still-nascent technology, in the form of popular VR advocated by Scott Fisher, Jaron Lanier, Brenda Laurel, Howard Rheingold, and countless others worked like a prism, refracting gradual institutional progress into a wide range of public and private contexts. This drew funding from IA-based proto-VR and cast it into a private pseudo-industry that lacked the goals or direction needed to produce viable systems or achieve any realisation of the loosely held image for the new VR, one of unchallenged thought, psychedelia, recreation, and a new digital frontier. The detachment of this imagery from the technology which had defined its material culture hindered discussions of its impossibility, rendering it even more valuable from an external perspective. For engineers and scientists in the field, like Steve Ellis, this new ‘VR’ was a fantasy, Virtual Environments came to be the name of the technically proven tools for research and IA.

Despite having the use of computers as the central theme, VR was born from attaching science fiction tropes and technologies to the idea represented by a real technology (proto-VR), without real understanding or acknowledgement of the difference in achievable applications between them, or the technical hurdles (if not impossibilities) which such transformations required. The technology of proto-VR itself formed only some of the syntax for this new paradigm: informing the computerised nature of its popular aesthetic. The rest was aspirational: rooted in futurology, internet counter-culture, and pure fiction. Attempts to match this fictional image were hampered by limited accessibility, technical expertise, and funding. The systemic cause of these difficulties was the cutting-edge nature of many of the ‘enabling technologies’ VR relied on, all of which had to come from other successful industries (with their own viable development ecosystems) and were thus not optimised for VR. Optimisation in-house would require considerable knowledge of a wide range of state-of-the-art systems which, in most VR businesses, was lacking. Furthermore, the cyberspace frontier imagery attached to VR systems at Cyberthon and elsewhere was technologically impossible at the time, on account of limitations to computer speed, storage, and graphics technology. Manufacturers of VR could not, therefore, for technical reasons, match the expectations of the American public created by popular culture, wishful thinking, and hype.

The arrival of popular images of VR was inherently disruptive to the development of that technology because it attached grand expectations, names, and a vocabulary rooted in Cyberpunk science fiction to a slowly developing but proven Information Technology. These popular images cannot be rightly considered a paradigm, however. There was, at the time, no singular Kuhnian shift in the core concept of the technology, as there *was* no core concept, nor did one arise. ‘VR’ was oxymoronic by name and nature, meaning different things to different people, dividing the academic community, and preventing any specialist language, typology, or central concept to be defined, beyond being a new medium for entertainment by the late 1980s, and an experimental tool for both military and industrial IA in the form of its proto-VR (and VR) applications. There was little consensus on what the defining technological or social components of VR were. VR meant VR. This prevented innovative or cultural pathways for VR from developing: there were no shared ideals of the implementation or standards of VR around which developers could build a product ecosystem, limiting interoperability and accessibility. There was also no consensus of how the technology should work, around which consumers and businesses could foster demand and supply.

This lack of shared language, standards, or indeed paradigms slowed the rate of technological development, due to a dilution of expertise among many different systems. It simultaneously prevented any of those systems from reaching an economic or social currency which would have allowed it to be self-sustaining. VR’s temporary failure in the 1990s was largely a product of this rapid dispersal of effort and talent in the US. The refraction, caused by the popularisation of the VR name and imagery, indirectly contributed to that same imagery’s failure to come into being. With hundreds of companies, universities, and other organisations seeking to develop a successful VR technology, inspired and confused by impossible expectations, a lack of consensus on how to achieve them or even what to achieve meant that development was confused, sporadic, lateral, and slow.

This allowed a hyperinflation of expectations and caused the dereliction of basic research into realistic applications which, in turn, reduced the proportion of VR research from academic and enterprise backgrounds. As state-institutional and academic VR research dispersed to VE and non-HMD-based systems, private investment in companies developing and selling hardware and software for the new VR increased. Buoyed by the optimism of its pioneers, and borne on a larger wave of Internet-based frontier spirit, hundreds of VR companies formed between the establishment of VR in 1986, and 1996. Yet the development of VR technology and applications during that time was slower and less productive of viable systems than the incremental innovations carried out by research institutions both before VR's naming and during its tumultuous second life.

As highlighted in this narrative, as well as in the work of Campbell-Kelley & Garcia-Swartz and Rheingold,[1] a prerequisite for successful development of a technology in a capitalist society is a diverse user base. Proto-VR and its non-ludic descendants had research grants and government funding to support them, attracted by IA and military applications respectively. However, the private businesses developing the new entertainment-oriented VR relied on people adopting and funding VR hardware. The cultural, linguistic, and technical baggage which VR at the time was saddled with, including unrealistic expectations, confused definitions and concepts, and expensive, low-fidelity experiences, prevented VR from gaining such user acceptance. Disconnected from technical reality, the solution to VR's problems was more investment and pricier technology, which without products, necessitated drastic over-selling of VR systems' potential. Thus, fantastical promises about VR's nature shifted American public expectation even further from the technological possibilities. The contrast between the promised lands of VR and the reality of video game arcades and home computers hampered the willingness of users to perceive VR systems' actual capabilities as acceptable. Indeed, there was an increasing disparity between what was actually available in 1990s VR and the contemporary virtual experiences presented in video games and computer-generated imagery, especially in film. The broad range of definitions for VR which suffused late 1980s and early 1990s American popular culture made such acceptance difficult on a wide scale, making VR's failure a product of cultural and social demands outstripping technological potential.

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[1] Martin Campbell-Kelly, and Daniel Garcia-Swartz, *From Mainframes to Smartphones: A History of the International Computer Industry* (2015); Howard Rheingold, *Virtual Reality: The Revolutionary Technology of Computer-Generated Artificial Worlds-And How It Promises to Transform Society*, First (1991).

VR technology was simply not ready when people wanted it to be, a fate which has befallen technologies such as Artificial Intelligence and Nuclear Fusion power, among others. Its failure then was only partial. IA applications stuck more closely to the realities of the technology and continued to be developed, albeit slowly, and retained usefulness. Such specialist applications did not need to meet quite such outlandish expectations, but as VR was based on the same hardware, the technological underpinnings were identical. VR's commercial failure is made most clear by its fate *after* the collapse of the VR bubble and market in 1996-7. As the Web provided many of the applications that VR had promised for around a decade the faith in and popular excitement for the versions of VR which were tied to its distinctive and definitive hardware eroded. Flexible definitions and a lack of standards, coupled with the savvy use of the VR moniker in Web-based technologies, shifted the excitement of VR onto a new platform without the cumbersome and complex technical baggage of generating presence, of weighty, blurry, unflattering HMDs, or of private virtual worlds.

Through the end of the millennium and beyond, VR became increasingly detached from the hardware that had once defined it, even though ties to this technology persisted in niche applications. As such, it was the popular notion of VR that failed. Technological failure, while inherently subjective, can be construed both as a technological failure to generate working products, or the failure to create socially acceptable and desirable ones, i.e. the failure to produce technologies capable of generating capital. In this case, VR was principally a victim of the latter, which in turn contributed to a failure of the former when the criterion for success was based on VR's science fiction imagery. Absorbed by other systems like the Web and Video Games, its usage was transformed, overused, stripped of meaning and eventually abandoned. This was the product, chiefly, of VR's unique history. The limited accessibility of VR technology and the divide between popular-cultural presentation and technological possibility allowed VR companies and manufacturers to attach unrealisable functionalities and purposes to VR, guaranteeing its inability to perform the functions expected of it, constituting an (accidental) artificially-induced technological failure, and as a result its economic one.

VR's history is thus characterised by its technological origins and the difficulties posed by a lack of funding, and high technology, by the perils to sustainable development and social acceptance brought about by hyperbolic marketing, and by the mercenary subduction and transformation of ideas toward profitable ends. While the drive for fame and profit catalysed the dispersal of VR into private companies in the late 1980s and early 1990s, with the popularisation of unrealistic promises, the expectation of profit was based upon a flawed understanding of the ease with which VR's technical hurdles could be overcome, produced by the lack of standards, shared understandings, or technologically-grounded ideas of commercial VR alluded to above. The first is a not uncommon thread in many 20th century computer technologies, the second was amplified to unprecedented levels by the split between Proto-VR and VR, which removed any realistic basis for the hype, and the third was only made possible by the unique separation of public understanding and on-the-ground reality which permeated 1980s and 1990s VR, and in-turn shaped its future for the decades to follow.

THE OLD FUTURE OF MEDIA: VR BEYOND 2005 AND INTO THE THIRD DECADE OF THE 21ST CENTURY

So, how did this shift in understanding away from its unfounded technological roots impact development of VR technologies in the public eye following 2005? In the remainder of the decade, there were in fact (based on the definition used throughout the thesis) no visible iterations or major developments of the technology. Niche VR companies continued to develop VR hardware and software and sold it to other organisations such as teaching hospitals, but never to the public. From a technical standpoint, the immersive imagery of VR's HMDs was continued in the form of FMDs which had suffused the late 1990s and early 2000s market. A poor cousin to HMDs in terms of presence or interactivity but cheaper, the less nauseating FMDs served as the 'face' for VR hardware for much of the 2000s. From a social standpoint, VR had joined a slew of terms like 'dial-up', 'DOS', and 'workstation', in comparative obsolescence. As the American public (for the purposes of disaggregation, the American computer user) became more familiar with computers, the Internet, and their functions, so the vocabulary of such systems could become more precise. In this process, the application of the term 'VR' to technologies like webpages, CD-ROMs, and video games began to fall away without the cultural pressure generated by journalists, writers, pundits, and others seeking interest through a once-controversial term. In the absence of this pressure, VR gravitated toward its technical reality as it had been in the mid-1990s: an expensive, ill-thought-out child's toy. For many in the late 2000s, including some of those who had once sung its praises, VR was now an embarrassing fad, while proto-VR continued running (entirely separately and often called VE) in the background.

It was, however, ironically, the pervasiveness of FMD hardware at the time that allowed the reincarnation of 1980s-esque VR in the 2010s. As the displays became cheaper and more prevalent, accessibility and thus indirect network effects increased. Oculus's integration of motion trackers and improved optics into a second-hand Sony Glasstron FMD created the prototype HMD that would eventually become the Oculus Rift. The Rift, developed by a diverse team[2] was a product of both network effects and the fact that FMDs did not provide the interaction and presence that VR had sought to offer. With the improved displays and graphics hardware of the 2010s, leveraged by the smartphone and video game industries respectively, HMDs promised to be more comfortable and immersive than ever before. The massive investment in the Rift by Facebook in 2014 jump-started a new VR business, again pushing the technology to the forefront of the public view, this time with a new-found ideological and conceptual harmony.[3] The US is still the undeniable leader of the VR market, and it remains the source of hardware innovations that dominate the field.[4]

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[2] The corporate backgrounds of which have been the source of a copyright infringement lawsuit against Oculus which led to a $500m payout by Facebook to the former employer of Oculus employees ZeniMax: Michelle Castillo, 'Facebook to Pay $500 Million in Damages over VR Suit', 2017 <https://www.cnbc.com/2017/02/01/facebook-loses-vr-case.html> [accessed 19 December 2017].

VR's paradigm and social position in the 2010s is defined by a mixture of technical and experiential traits. Oriented principally around gaming, the technology has retained a great deal of the ludic connections that were a core element in its 1990s iterations. From the position of a niche entertainment medium, the use of 2010s VR technologies for industrial, medical, and academic applications are most commonly couched in terms of a toy being adapted for serious work. This tone is reminiscent of articles covering VR's industrial applications in the mid-to-late 1990s, even though industrial applications were developed before ludic ones. Being intimately bound up with gaming is only one half of the social component of the modern definition of VR, the other being its immersive nature. Focus on presence in virtual environments has, in recent years, been supplanted by comparisons with large-screen experiences such as IMAX.

Technologically, the widespread distribution of computer technologies such as personal computers, smartphones, and tablets has generated the common language which VR had previously lacked, allowing a narrower, more technologically accurate definition to form. The VR of the 2010s is closely tied to the HMD and to motion tracking. Confusion between VR and AR is persistently visible in popular media but defining VR as an experience mediated by computers is no longer viable, due to the increased familiarity with and usage of computers in American society. With the personal computer having enjoyed a central place in most American homes for almost A quarter of a century, there is now a sufficiently high average baseline of computer knowledge among young and middle-aged Americans to differentiate VR from other computer technologies. VR is more easily defined, understood, developed, and accepted in the second decade of the 21st century than ever before. The main disadvantage seems to be that, by making clear what VR is, it is also clear that it is not yet able to provide the experiences which many people still want of it. Numerous articles from the 2010s describe VR as still not being ‘ready’.[5] Readiness seems to not refer to the technological necessities of detailed graphics, low latency, and high comfort needed by earlier systems, but instead to VR’s difficulty in adding anything new to digital or real life. In other words, VR is still failing to provide a usable, believable iteration of cyberspace. Many of the technology companies who invested significant funds in VR research in the 21st century, such as Facebook, Sony, Microsoft, and Valve have found that people find VR to not be worth the expense, and concerning for both health reasons and the inability to share experiences via HMDs, and those firms seem unwilling to find ways to address those constraints.[6] If the virtual worlds of games and the internet can now be reached on their phones, tablets, and laptops, what exactly is the need for VR? This is a question which the latest crop of VR companies has yet to answer, but a clear demonstration of what VR can uniquely achieve, and the value of that achievement, would go a long way to realising the dreams and ambitions of Lanier, Rheingold, Timothy Leary, and others.

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[3] 'Update 3-Facebook to Buy Virtual Reality Goggles Maker for $2 Bln', *Reuters*, 26 March 2014 <http://www.reuters.com/article/2014/03/26/facebook-acquisition-idUSL4N0MM4IP20140326> [accessed 1 June 2015]; Mark Zuckerberg, '10101319050523971', *Facebook*, 2014 https://www.facebook.com/zuck/posts/10101319050523971.

[4] Persistence Market Research, 'Global Market Study on Virtual Reality: Sensors to Emerge as the Biggest Component - PMR', *GlobeNewswire News Room*, 2017 http://globenewswire.com/news-release/2017/11/14/1185821/0/en/Global-Market-Study-on-Virtual-Reality-Sensors-to-Emerge-as-the-Biggest-Component-PMR.html [accessed 20 November 2017].

Recent VR system costs have had both economic and social ramifications. VR systems remain extremely expensive, a fact that has paved the way for cheaper smartphone-based systems such as Google Cardboard and Samsung Gear VR to take over much of the American VR market (while global PlayStation VR sales were initially good, they seem to have plateaued, and are nevertheless dwarfed by mobile-VR users).[7] Without the computing power of dedicated VR systems, smartphone-based VR systems are in many ways further from 'real' cyberspace than dedicated VR systems, and the bulk of content (though not the totality) for such systems is limited to simple mobile games and so-called 360° video. The lighter optics, less-accurate tracking, and limited content provided by these mobile systems is fuelling speculation of a content drought and furthering questions about the point of VR in the popular press.[8]

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[5] Shane Atchison, ‘Is Virtual Reality Ready for Hollywood?’, *Recode*, 2016 <https://www.recode.net/2016/9/7/12818100/is-virtual-reality-ready-for-hollywood> [accessed 20 November 2017]; Arthur Levine, ‘Virtual Reality Coasters Aren’t All They’re Kraken-Ed up to Be’, *USA Today* <https://www.usatoday.com/story/travel/experience/america/theme-parks/2017/10/25/virtual-reality-coasters-seaworld-kraken/796478001/> [accessed 20 November 2017]; Neil Mandt, ‘VR Can Be a Mainstream Tech — but It’s Not Ready yet’, *VentureBeat*, 2017 <https://venturebeat.com/2017/08/08/vr-can-be-a-mainstream-tech-but-its-not-ready-yet/> [accessed 20 November 2017]; ‘Maybe We’re Not Ready for Virtual Reality’ <https://www.circa.com/whoa/humor/maybe-were-not-ready-for-virtual-reality> [accessed 20 November 2017]; Selena Larson, ‘’Tis the Season of VR, but It’s Not Quite Ready for the Masses’, *CNNMoney*, 2016 <http://money.cnn.com/2016/10/06/technology/vr-oculus-touch-controllers-daydream/index.html> [accessed 20 November 2017].

[6] Janko Rottgers, ‘Sony Sells 2 Million PlayStation VR Headsets, but Study Shows VR Growth Stalling’, *Variety*, 2017 <http://variety.com/2017/digital/news/sony-2-million-psvr-vr-growth-1202633072/> [accessed 11 April 2018].

The hardware technologies of VR are, however, still largely unaffected in terms of development. This is because, just like in the 1980s and 1990s, VR systems need to borrow hardware from other financially successful and self-maintained systems like smartphones and video games. In the case of smartphone-based VR systems, this is entirely the case. For the high-end headsets like the HTC Vive, PlayStation VR, and Oculus Rift, the displays, trackers, and graphics technology were all originally developed for the phone and gaming industries, rather than starting with new bespoke hardware in-house. The limited user base for high-powered VR systems has furthered the aforementioned lack of content, which blighted VR in the 1990s.

Back in the early 1990s, a vast range of platforms, technical standards, prices, and target audiences created an environment in which consumers lacked the money or knowledge to implement VR as it was offered to them. Many of those with both the relevant skills and adequate funding found that there were very limited combinations of hardware and software that would form a complete, compatible system. As a result, principally because of high prices, adopters were scarce which limited the indirect network effects upon VR applications. Without a large user base, developers were not encouraged to write content for VR and users, hackers, and tinkerers struggled to make their own. The 2010s are witnessing a similar phenomenon, where high technological requirements and prices have both curtailed the number of developers actively pursuing the creation of content for VR and limited the number of people with the means and funds to modify existing content or create VR communities, hampering uptake of the technology required for its maturation. It is far easier for developers to make content for mobile VR, which has a smaller range of platforms and hardware standards and limited technical requirements. The fact that almost anyone with a smartphone can put it in a stereoscopic headset and start using it, creates a potential user base numbering in the billions, and so developers overwhelmingly create VR content for these kinds of systems instead. Here, the limited technical capabilities of smartphones, which are far less powerful than the desktop computers and laptops used to run dedicated, high-end systems, necessitate simpler content experiences, from 2D and 3D video to interactive experiences limited by the memory and processing power of the phone.

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[7] Ibid., para 4.

[8] Joe Durbin, 'VR/AR's Biggest Obstacle: Lack of Content', *VentureBeat*, 2016 <https://venturebeat.com/2016/09/18/vrars-biggest-obstacle-lack-of-content/> [accessed 20 November 2017]; Steve Kovach, 'What Happened to Virtual Reality?', *Business Insider*, 2017 <http://uk.businessinsider.com/what-happened-to-virtual-reality-2017-1> [accessed 20 November 2017]; Michael Schaiman, 'Addressing The Lack Of Communal Experience In Virtual Reality', *Forbes*, 2017 <https://www.forbes.com/sites/forbesagencycouncil/2017/04/26/addressing-the-lack-of-communal-experience-in-virtual-reality/> [accessed 20 November 2017].

The result is that, in the late 2010s, VR as experienced by most people still lacks the means to demonstrate its worth and meet the appearance of demonstrations in the media. Once more there is a possibility of a disconnect between expectation and technical reality, only this time with *lowered* expectations curtailing funding for the ‘real’ VR systems which have yet to reach a large audience. Excessive hyperbole and a lack of clear, universal applications are only part of the problem, with the tale of two VRs now dividing again to include a third alternative. This is made possible only through the portable computing power of the smartphone, its pervasiveness in the US shaping a cost-effective, content rich (comparatively, at least) VR ecosystem which many can try and which most may find disappointing. In 2018, VR is still being compared to science fiction, and the root is once again the discrepancy between technological possibility, on-the-ground experience, and the expectations of the American public. With predictions in late 2017-18 of the market reaching record sizes in the next few years, the optimism and financial excess of the first VR bubble seems oddly small.[9] The considerable potential and optimism surrounding smartphone-based VR and AR systems is at odds with the endemic fears surrounding a content drought, and unsatisfactory experiences in contemporary VR systems. This suggests that again, as in the 1990s, the financial potential of VR seems to be exaggerated when compared to on-the-ground experience and sentiment among many commentators.

YOU *CAN* GET THERE FROM HERE: COMPARISONS WITH THE HISTORIES OF OTHER ‘FAILED’ TECHNOLOGIES

A history of unmatchable expectations, disappointment, and developmental recession is not entirely unique to VR. There have been a handful of other technologies which have been the focus of media campaigns and public excitement, only to fall away. While VR might have been the most popular, relative to its technological footprint (i.e. the number of developers, scale of investment, and iterations of the technology) other technologies have experienced similar fates. What then makes VR so special? So unique? A brief examination of some of these other technologies is hoped to address this.

Artificial Intelligence technology is cursed with a similarly vague definition to VR, produced partially by its name. Artificial intelligences could be represented by automata and constructs, such as 1770’s Turk (which was, of course, a hoax driven by an unseen human hand.)[10] However, to use a definition centred on the digital computer, and the experiential component of devising machines that could pass the famous Turing test brings the timeline forward to the mid-1950s. Government-funded research by the American and British governments sought to create computers that were able to learn and interact with humans on a personal level. A core component of this was speech recognition, and the limitations of computer technology posed more difficult to surmount than imagined, slowing research considerably, leading to widespread governmental and academic disillusionment with the potential of the technology.[11] The resulting budget cuts led to a period known as the AI Winter, where state-funded and academic research all but stalled in the absence of abundant funds. Akin to the dispersal and slowdowns of dedicated proto-VR research in the 1970s and late 1990s, the AI Winter was a product of the social context and institutional structures within which the technology was developed, rather than specific technological challenges or lags. Like VR, AI needed time to realise, far more time than both sets of visionaries seemingly expected.[12]

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[9] Zion Market Research, 'Virtual Reality (VR) Market Size Projected Reach $26.89 Billion by 2022', *GlobeNewswire News Room*, 2017 <http://globenewswire.com/news-release/2017/11/14/1185542/0/en/Virtual-Reality-VR-Market-Size-Projected-Reach-26-89-Billion-by-2022-Zion-Market-Research.html> [accessed 20 November 2017].

[10] Nils Nilsson, *The Quest for Artificial Intelligence*, 1st edition (2009), 13; Schaffer, Simon, 'Enlightened Automata', in *The Sciences in Enlightened Europe*, ed. by William Clark (Chicago, 1999), 127.

The major increase in support for AI research offered by the governments of Japan and Russia in the 1980s spurred the US into a second raft of AI funding. Several speech recognition technologies became available at the time (though were largely unusable to many), such as DragonDictate and X-10 Powerhouse. These provided speech recognition for DOS-based computers, and as one of the core aspects of AI, the use of natural language by computers became more feasible. At the same time, however, the expectations and technical definitions began to shift. As the technology became more successful and better known, expectations from government drove research, but the lack of any particular AI 'product' kept popular depictions of AI in media separate and distinct from actual technology. It remained a science fiction technology, arguably, until the 2010s, at which point companies started to use the term to more broadly refer to the Big Data projects of companies like Google and Facebook. The popular usage of the term is, however, at odds with the technical foundations of modern AI research, which are rooted in producing truly intelligent machines which can learn using neural-networks, and whole-brain simulation. While public perception differs from reality the differences, unlike VR, are caused by the technological limitations of the companies selling it, rather than by what is technically feasible in the short-term. Companies like Google and Facebook use a limited definition of AI because they can only claim to use AI in limited contexts. VR, on the other hand, had (and has) the opposite problem, where a lack of technological capability encouraged firms to exaggerate the capabilities of their technology to attract investment. VR was framed as a transcendental, empowering technology while AI has held a sinister role in much science fiction since the 1950s (if not before), a fact that has played a part in the diverse ways in which American private companies and governments have gone about discussing the impacts of their AI research.[13]

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[11] Ibid, 89-105.

[12] Hubert Dreyfus, *What Computers Can't Do: A Critique of Artificial Reason* (1972); Hubert Dreyfus, *What Computers Still Can't Do: A Critique of Artificial Reason*, Rev Ed (1992).

Like VR, AI was the product of a group of people with similar backgrounds overestimating the facility of realising their technological dreams. Unlike VR however, AI remained in highly limited research and development contexts for many decades and has still not developed any true public face, with virtual assistants like Apple's *Siri* and Amazon's *Alexa* taking up the role, driven by AI technologies, but seemingly partitioned from AI by a more digestible euphemism.[14] Instead, AI is (even in 2017) relegated to an unseen servant behind curtains of data mining and collection by companies gathering information from the billions of users of the world's online services, a ghost in cyberspace. Part of what makes VR's history so unusual is that in the late 2010s it is technologically well-founded, and indeed proven (though short of useful applications), and yet its earliest public outings were in the late 1980s, where 'readiness' was not the question so much as

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[13] Luke Dormehl, *Thinking Machines: The inside Story of Artificial Intelligence and Our Race to Build the Future* (2016), 157-8; Olivia Solon, 'Killer Robots? Musk and Zuckerberg Escalate Row over Dangers of AI', *The Guardian*, 25 July 2017, <http://www.theguardian.com/technology/2017/jul/25/elon-musk-mark-zuckerberg-artificial-intelligence-facebook-tesla> [accessed 19 December 2017]; Matt McFarland, 'Google's Eric Schmidt Downplays Fears over Artificial Intelligence', *Washington Post*, 16 March 2015, <https://www.washingtonpost.com/news/innovations/wp/2015/03/16/googles-eric-schmidt-downplays-fears-over-artificial-intelligence/> [accessed 19 December 2017]; Claire Zillman, 'At Davos, IBM CEO Ginni Rometty Downplays Fears of a Robot Takeover', *Fortune* <http://fortune.com/2017/01/18/ibm-ceo-ginni-rometty-ai-davos/> [accessed 19 December 2017].

[14] Apple, 'Use Siri on Your IPhone, IPad, or IPod Touch', *Apple Support* <https://support.apple.com/en-us/HT204389> [accessed 19 December 2017]; Amazon, 'Amazon Alexa' <https://developer.amazon.com/alexa> [accessed 19 December 2017].

‘existence’. Companies sought to make a viable VR from a host of technologies which were not designed for those purposes, in an attempt to recreate the technologies of science fiction and futurology. A fictitious equivalent might be American firms in the 1970s offering computers for the home which were capable of speech, reasoning, and carrying out basic tasks without programming, because they had seen AI research in labs and wanted it to be a contemporary reality when it was, in fact, decades away.

Other technologies, such as fusion for power generation, Stem Cell research, and robotics, among others, have encountered similar summer and winter cycles, caused by a mixture of changing government, academic, and popular attitudes to the technologies. VR’s near disappearance from the material culture and public eye of the US in the late 1990s was caused by changing public opinion, sudden obsolescence caused by the Web, and the mercurial attitudes of American investors. US agencies did not lose interest in VR as such, but the sudden and unexpected take-off of private funding allowed the state management of the technology to recede by the mid-1990s, when in fact it was not yet ready to grow as a *system* on its own.

With these other cyclical technologies, the extreme technological requirements, specialist knowledge, and security constraints kept them firmly out of any semblance of the American Free Market. Development was, and is, predominantly limited to institutions funded by national or supra-national organisations (such as Euratom), and Universities (which are, in the US, funded by their home state, students, private companies, and sometimes the federal government). VR technology also had extremely high costs (the first VR system sold by VPL cost half a million dollars in 1989), and yet private businesses believed that they could develop and sell versions of the technology as products to millions of people and form a new mass medium. A parallel to this might be the plethora of news articles hailing the advent of domestic robots in the 1980s, which did not materialise, and are now understood to be another thirty years away at the very least.[15]

What is it about VR, then, that was so different from these other technologies? On the one hand, there are technological differences. Stem cell research and fusion power both require extremely complex facilities, robotics requires expensive materials and advanced knowledge of computer science, electronics, and mechanics. In the case of fusion power, abundant space and materials are needed. Some private companies *are* experimenting with fusion power, such as Apollo Fusion, Tokamak Energy, and Lockheed Martin, but while the technology has shown promise, it cannot achieve the sustained energy generation which is required of it. Stem Cell research, similarly, requires expertise and complex machinery, as well as licenses to operate in the US because of lobbying by religious pressure groups. Private firms developing robots often have to fight strong resistance in the US from pressure groups which believe robots will deprive people of their livelihoods. In all of these cases, there are clear limits, either scientific and social, which prevent widespread experimentation and development of these technologies, all of which bear the same hallmarks of repeatedly high expectations in the American press.

VR on the other hand did not require complex facilities to develop, just expensive computers which could be operated anywhere there was power. The manufacturing of VR's assorted hardware did require specialist spaces for computers and screens, but these were produced by larger, successful businesses and 'imported' into VR systems. Furthermore, there are social differences between VR and both principal types of fusion power; cold fusion power's failure to produce reliable results led to damaged academic reputations and a temporary slowdown, but further experimentation and development persisted, as its potential application was easily understood and accepted to be valuable.[16] Magnetic Confinement fusion (so-called 'hot' fusion), on the other hand, has not suffered setbacks due to a lack of viable systems, as it is widely understood to require decades of research before it can be implemented, and if the same logic had been applied to VR, its fate may have been different.[17] As it was, the successful trial applications of the VIVED and VIEW systems at NASA, when published, were seized upon by people unconnected with research, hoping to adapt the technology to match images of PC immersion from science fiction. The academic credentials of proto-VR researchers served as endorsement for people seeking to adapt the technology to entirely new purposes.

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[15] José Antonio Díaz and M. Rosario Hilde Sánchez Morales, 'The Future of Smart Domestic Environments: The Triad of Robotics, Medicine and Biotechnology', in *The Robotics Divide: A New Frontier in the 21st Century?*, ed. by Antonio López Peláez (London, 2014), 117–35 <https://doi.org/10.1007/978-1-4471-5358-0_7> [accessed 13 November 2018]; Steve Furber, 'Realising Turing's Dream', *International Journal of Unconventional Computing*, 13/1 (2017), 195–201; David Needle, 'HERO Walks, Talks, Educates, and Protects.', *InfoWorld*, 27 December 1982, 1; 'Will The Robot Be Father To The Industry?', *Inc Magazine*, 3 January 1983.

Similarly, the development of technologies for the manipulation and transplanting of human stem cells triggered an academic and popular boom for the technology, with numerous academic and popular sources in the early 2000s advocating its potential to cure cancer and replace failing organs. When this failed to occur in an unrealistically short timeframe, research funding for stem cell technology attenuated in the 2010s, and this coupled with a lack of continued public support led to a drastic slowdown in stem cell research for several years.[18] Unlike VR, the clear and proven applications for stem cell research were sufficiently close to its portrayed potential that research soon picked up again, as it was shown to have empirically demonstrated potential, which VR did not in the public eye, it’s proven applications were in fields which had not captured public interest in the 1980s and 1990s. Stem Cell’s development was, similarly, one with a historied past, reaching back to the 1950s, but many in the 2000s understood it to be a novel technology. It’s ahistoricity and unrealistic predictions of imminent power echo VR’s, and suggests that a failure to acknowledge the history of many technologies may cause or be caused by an endemic lack of understanding of the basic principles underlying all technologies, which can in turn separate them from the destabilising effects of media hype. VR, similarly, was a widely used term for a technology which was understood to be brand new, and with its arrival came claims and expectations for technologies which would dismantle national and racial barriers, blur right from wrong, and create an entirely new Baudrillardian map upon which global society could be built. While its technical foundation consisted of decades old graphics, tracking, and computer sciences, designed to improve the faculties of pilots and air-traffic controllers, this past was not widely known and much like in the case of stem cell research, this seems to have encouraged expectations to hyperinflate, with concurrent damage to the basic research in both cases.[19]

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[16] Univerisity of Utah, 'New Energy Times - University of Utah Press Release' <http://newenergytimes.com/v2/reports/UniversityOfUtahPressRelease.shtml> [accessed 24 March 2018]; Denise Cetta, 'Cold Fusion Is Hot Again' <https://www.cbsnews.com/news/cold-fusion-is-hot-again/> [accessed 24 March 2018]; Gary Taubes, *Bad Science: The Short Life and Weird Times of Cold Fusion*, 1st edition (New York, 1993), 242.

[17] Laila A. El-Guebaly, 'Fifty Years of Magnetic Fusion Research (1958–2008): Brief Historical Overview and Discussion of Future Trends', *Energies*, 3/6 (2010), 1079.

[18] Davor Solter, 'From Teratocarcinomas to Embryonic Stem Cells and beyond: A History of Embryonic Stem Cell Research', *Nature Reviews Genetics*, 7 (2006), 319; Ariff Bongso and Mark Richards, 'History and Perspective of Stem Cell Research', *Best Practice & Research Clinical Obstetrics & Gynaecology*, Stem Cells in Obstetrics and Gynaecology, 18/6 (2004), 827–42; Bill Wineke, 'Cash Talks in Stem-Cell Research', *Wisconsin State Journal* (19 July 2006), A1, A4; Bill Redekop and Mia Rabson, '"Scientific Integrity" Restored', *Winnipeg Free Press* (10 March 2009), section Top News, A3.

What separates VR from these other constantly ‘coming’ technologies was rooted in its transfer from innovative, developmental contexts, into private business. The vector of this was the science fiction and Cyberpunk counter culture of the time, coupled with enough technical knowledge to invent systems (but not to optimise them), abundant computer users, willing investors, and excitable journalists in the 1980s Silicon Valley. Robotics, fusion power, and stem cell technology all had clear, widely understood applications and a considerable body of academic research driving their advancement. VR did not have this, and was expected to succeed when it was in its embryonic stages, while the criteria for success were vague notions of transcendental experiences, as opposed to the slightly drier applications of teleoperation and data visualisation. Many technologies took longer to develop than expected, but VR not only took longer to develop, but there was no consensus on what the technology would look like when it was developed, which left research and product development far too open ended for a return to widespread VR research while the hype and disappointment was still visible.

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[19] Jean Baudrillard, *Simulations* (1983).

For all its drawbacks, Rheingold's description of a technological convergence holds a degree of truth. While Rheingold's assertion that the collection of staff at Sunnyvale, Ames, and elsewhere was fortunate happenstance, is demonstrably flawed, his broader notion that VR's appearance was a product of the right time and place coinciding may be valid. It was after all only in the financial-technological crucible of Silicon Valley, coupled with the counter-cultural electronic frontier spirit of the San Francisco Bay area and contemporary tech journalism that proto-VR acquired its glamour as the future of media. The indirect network effects afforded by the simultaneous development of the PC industry remain a vital, intranational component, but on its own does not explain what made VR technology find a private footing when other technologies at similar stages of development did not do so. It seems likely that computer-using, science fiction-loving, hackers of the Bay, as a part of a wider local cyberpunk counterculture, fanned those unrealistic notions of VR's potential into a flame with excessive funding and promises, with little fuel.

FALL OUT: CONCLUSIONS

When the thesis project began, it had three main goals, the first was to assess the viability of the definition of VR as 'a technology which uses a Head-Mounted Display (HMD) and motion tracking to provide a point of immersive interface between a person and a digital computer-generated graphical environment, in order to create a sense of presence in that environment'. The second goal was to establish a technical and social-historical narrative of VR technology, in accordance with that definition. The third goal was to see if the resulting history of VR highlighted the importance of shared language, culture, and paradigms on the success of technologies.

HIGH DEFINITION: TESTING THE FRAMING FOR VR

First, then, the definition. How has it stood up to the test implicit in the construction of a doctoral thesis? The results have been varied and unique. It seems that the definition itself has held true, as it was applicable to a host of technologies named VR, but not to ones which were not. Furthermore, it also brought to light technological and semantic variations in the use of the term, as several elements from traditional narratives, such as Fred Brooks' GROPE system and Myron Kreuger's Artificial Reality were excluded via this definition. The difficulty posed by varying and confused understandings of what VR was, formed of course a key aspect of its history, but even so, the amount of supposedly VR material excluded by this definition raises interesting points. Either the definition is far too narrow, and needs to be broadened to include non-computerised, non-immersive technologies designed to create a sense of presence, or many existing narratives bunched together separate technologies to create a continuous timeline of progress and development which did not, in fact, exist. Defining VR as a *technology which uses a Head-Mounted Display (HMD) and motion tracking to provide a point of immersive interface between a person and a digital computer-generated graphical environment, in order to create a sense of presence in that environment* seems to have been useful. Not only in the cases of proto-VR technologies which most closely mirrored its earliest named iterations, but also in the VR era (particularly during the bubble) where a host of products and technologies called VR suffused the market. This definition allowed these to be cut through to the technology which was experientially and technically the same, despite variations in typology and hardware.

To assess the definition's *viability*, however, requires more than just a determination of whether it produced a usable, valid narrative. It must also be robust across a variety of narrative contexts and relate in some way to contemporary (late 2010s) usage of the term. From the core meaning of viability, the definition must be able to stand on its own, and not need external modifiers, qualifiers, or a particular period in order to work. To what extent, then, is this definition truly viable? To consider its robustness, the interface between proto-VR and VR is an excellent testing ground, as is the later shift from the VR of hardware to the VR of the Web. In both cases, language surrounding the technologies of VR changed drastically, as perceived applications, purpose, and even technical natures changed. In these instances, the definition appears to hold up well. In the first instance, it has provided coverage of VR and proto-VR systems despite substantial shifts in primary, technical, and popular material. For both highly specialised journals and popular magazine articles, this definition identifies discussions about technological instances of VR, and the experiences, thoughts, and events surrounding them. In the second instance, the rapid and expansive move of dialogue and even technical/scientific research away from existing modalities of VR could leave many definitions entirely bereft, or without real-world analogues during the late 1990s. However, while discourse changed during that period, the definition continues to produce results from a range of materials (albeit far smaller), highlighting the persistence of VR technologies from academic and private contexts during the VR winter, despite the diffusion of its name, and understanding, among a very wide range of far more successful technologies.

It can also be related to modern usage of VR. VR systems in the late 2010s have responsiveness and presence as core concepts, and even the smartphone-based versions are using digital computers to generate the graphical environment. Motion tracking, a core component of the definition, is perhaps one of the most identifiable separating factors for modern VR from other kinds of display systems. FMDs (increasingly for AR) still exist and are separated from VR, 3D screens, widescreen projection, and other 'immersive' displays by motion tracking. It was a core component of the new mass-market VR solutions in the 2010s, and the definition appears to apply just as soundly to VR hardware in 2017 as it does to proto-VR hardware from 1967.

ONCE UPON A TIME…: A SOCIAL AND TECHNICAL HISTORY?

As Steve Woolgar pointed out in the opening chapter of his book *Virtual Society?* a question mark in a title can permit friendliness to the cautious academic while maintaining the immediacy and truthfulness of the narrative within.[20] While it is materially obvious that a narrative has been produced here, and that it challenges existing popular and historical narratives of VR technology, caution is still very much required. Obviously, sources of bias remain a concern no matter how much work is done in mitigation. There are undoubtedly (and indeed hopefully) sources to be uncovered and narratives charted which challenge this history and will add to the growing body of research on the technology's past in the future.

This work can be used as a platform for closer research on VR technology's past iterations, in line perhaps with some of the suggestions for future research in Appendix 2. To what extent can this history claim to be both social and technical? Arguably, the combination of technology and its social contexts is more important to VR than to many, as those contexts impacted its development, commercialisation, transformation, abeyance, and multiple rebirths. Moreover, it was the inherently personal motivations of the people driving VR developments in its earliest years which allowed the separate inventions and technologies to be brought together into a new means of immersing people in virtual space. In addition, technological advances and changes are not the sole requirement for VR's functionality (setting aside acceptance and success, which are of course socially dependent). Up to the 2010s, in order to work, users need to be *willing* to accept the virtual worlds provided by VR as authentic in order to feel present, and in order to enjoy the experience regardless of technology level height or engineering. This is contingent entirely upon individual tastes, personal philosophies, and beliefs about technology and the self. The range of such selves change over time as technology develops and can be historicised. If, to take McLuhan at his word, technology is an extension of the self, then the willingness to be fooled by and present within a VR relates to a willingness to favour one's solipsism over the external realities of others.

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[20] Steve Woolgar, *Virtual Society?: Technology, Cyberbole, Reality* (2002), 10-11.

While a matter for philosophers and psychologists, the presence of user willingness as a component of a functioning VR system is not only unique but inherently socialised. As a matter of necessity, therefore, portrayal of how VR was perceived and experienced requires a strong social focus. The documentary basis for this thesis was largely sourced from popular materials like contemporary newspapers and magazine articles, as well as from interviews with a number of people who had had practical experience with a range of the systems in use throughout VR's history. As for the technical history, this drew from a wider gamut of sources, considering the changes in displays and computer power, which both developed considerably over the forty years spanned by this narrative. There is clear headroom here (but insufficient space in a DPhil thesis) for even more technical details, on the architecture of VR software, the technology of motion tracking, and of computer graphics, among other areas. While an attempt to please both technical and historical audiences would have produced a confused picture, paying attention to both VR hardware, and the challenges posed by technological obstacles throughout, helps to ensure that this history retains its technical component. Without it, the social aspect would be untethered, and the nature of the hyperbole, understandings, and expectation placed upon VR would be lost. While the history of VR is very much a history of its shifting contexts, particularly from the mid-1980s onwards, it is also one of combining computers, displays, IA, and video games into technologies for exploring a new, digital frontier.

This narrative social and technical history of VR provides new insight into aspects covered by other histories and brings new factors and sources to historical light. With the use of a viable definition to weave a technical and social history the third research goal, assessing the impact on VR caused by a lack of technological and social paradigms, comes into play. As stated above, VR's acceptance, success, and even functionality were a product of the ways in which people felt about and interacted with the technology. Those feelings, in turn, were shaped by the *image* of VR technology projected through articles, books, film, and marketing in the 1980s and 1990s.

The images of VR that were carried along those vectors are relevant here because they rested on hopes and unreasonable expectations for what the technology could achieve, and how quickly it could be developed. Technical standards are usually established by either the economic or technological dominance of a particular way of manufacturing and leveraging a technology. Typically, this is determined by a mixture of utility, market forces, and artificial influence by regulatory bodies such as governments and associations. The lack of any clear market leader (or market), the inability to demonstrate utility (through the lack of applications), and the absence of regulatory bodies, prohibited the creation of any such standards for VR. As a result, there were no shared understandings of how VR technology should be developed, what it should comprise, how it should be built, or what it should be used for. The most visible effects being widespread lateral innovation by competing firms seeking to develop the technology in similar, but entirely uncoordinated, ways and the disconnection between the technological capabilities of VR and its image. This was partially caused by the absence of technical standards, which also allowed the considerable investment and research, carried out by numerous American VR firms, to produce little by way of tangible improvements to the technology.

The fact that, in the 2010s, many VR systems still rely on outsourced components and cannibalised systems suggests that a lack of clear rules for how VR should work and what it should do has had an impact on the pathways along which it could move. In the proto-VR period, this was even more pronounced, where differing approaches to graphics, displays, programming languages, and software prevented proto-VR systems from being integrated with other technologies and kept research projects largely isolated throughout the 1970s and early 1980s. Concordantly, it seems likely that a lack of technical paradigms (while entirely normal in the early stages of its development) confounded the technology's success as time passed and the *system* moved from the Invention and Development stages (under Hughes' systems theory) to the Innovation, Transfer, and Growth stages.[21]

What then, of social paradigms? Was there a demonstrable lack of a singular core concept, modality, or *chaîne opératoire*, and what impact, if any, did this have? The necessity of establishing a definition for the technology, three decades after it was named, helps suggest an answer. So, too, does the way discourse surrounding VR changed in the post-bubble VR winter of the late 1990s. Definitions and understandings of VR's nature and place in society were demonstrably fluid, tumultuous, and entirely separate from their technological core. When books, paintings, music, or the imagination were called VR, complete detachment from the technology and vision of those who had named it was inevitable. Its earliest, proto-VR iterations existed within a wide range of social contexts, each determined by academic interest, military policy, or (in Sutherland's case) a fondness for technical blueprints.

What then was the impact of this? As well as the changing discourse and set of understandings for VR's place and function, it hindered the establishment of technical paradigms by creating a technological and financial environment in which no one product or project could be favoured, demanded, or meaningfully used. It also hindered social acceptance which intrinsically limited the degree to which people could feel present in virtual environments, and therefore its saleability and usefulness. The VR brand promised to sate consumer appetites for new ways of communicating, creating, and consuming media, which had been caused by the increasing space consumed by the computer in personal and professional lives. It was fundamentally unable to, however, because of the technological limits of VR's technical basis. Excessive hype, designed to increase investment, and without popular products, shifted that appetite for VR-based concepts toward Web-based versions of the same ideas, while the VR name remained on account of its fundamental flaw: it was more a concept than a discrete technology. The technology that VR was based on (proto-VR, VE etc) became so separated from the VR concept by the rhetoric of advertisers and media hysterics that eventually, the link snapped. VR’s material culture was jettisoned, and public wants shifted to the communications and entertainment applications provided by the Web. The things people wanted from VR were *never* provided by VR as defined in the thesis, but by websites and games which were called VR at the time, and in the 2000s the use of the VR name also faded. The lack of a social paradigm was what allowed the networked spaces of the internet, and the intimately personal spaces of VR to appear related when they were in fact vastly different. This confusion between the Web and VR was a clear contributory factor to the collapse of the VR bubble as interest (and VR cyberspace rhetoric) moved onto the Internet and the Web. If there had been a clear, shared, and demonstrable idea for where VR fit in society, why it existed, and what the term meant, the history of the technology may have been vastly different.

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[21] Thomas Hughes, 'The Evolution of Large Technological Systems', in Wiebe E. Bijker, Thomas Parke Hughes, and Trevor J. Pinch (eds.), *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, First Paperback (1989), 51–80.

VR’s acceptance, development, and technical makeup were determined by the scientific, technological, legislative, economic, social, and cultural forces placed upon it. Without technical or social paradigms, those forces were directionless. VR sat within the larger background radiation of American consumerism, featurism, and technological exceptionalism that filled the second half of the 20th century, and it seems clear that the lack of paradigms helped ensure that that did not change. It is impossible to judge what impact a wider paradigm might have had, but without one, the damaging divide between expectation and technological possibility was seemingly inevitable. Discussion and further examination of this impact is only possible through the creation of the social and technical narrative which, in turn, relied on a viable definition. While the research goals have been met, there is, and always shall be, more work to be done.

NO QUARTER: CLOSING WORDS

Building this history has been, at every step, both challenging and deeply rewarding. There is now, hopefully, a new expression of a chronically understudied and underappreciated technology which may be both useful and inspiring to other historians and archaeologists of VR. The technology's fractured presentation in material culture and literature, and unique expression, expansion, and foundations mark it as a unique technology that is worthy of further study. As VR technology seems reluctant to fade away, or even be clearly defined, its fate remains as uncertain and amenable to change as ever. As it again heads toward a possible second bubble, a new age of Cyberspace, its place in the modern world is once more being questioned. Hundreds of VR systems are on sale from the US, China, Japan, and beyond. By integrating PCs or even smartphones rather than dedicated graphics workstations, VR has become more accessible and usable than ever. Where, then, does that leave its history? Beyond the ivory towers of academia, is there a value to this narrative which can be identified and explained?

Unequivocally.

VR developers, by virtue perhaps of its pre-paradigmatic past, need clear understandings of the wants of audiences, the value of content, and the power of good applications for explaining just why people should care about VR, and what it can be used for. The nature of current technological iterations are direct products of the technologies of the past, not just for VR, but for technology in general. The notion that the past matters (beyond the self-aggrandising heroic histories of science) is sorely needed for developers and users of VR alike. Through the use of histories like this one, people can appreciate that current iterations of VR exist in specific ways and that they could do so in others as well. Histories can elucidate the pitfalls and troubles faced by the earlier VR pioneers. It is also perhaps in these histories that an appreciation for VR as a technology rooted in helping people think and work, long before helping them play, might be formed. This is more important than it may seem, as VR may only be able to match its historic promise of transforming society if its applications can extend beyond the living room, the games room, or the bedroom, and into the wider intellectual and scientific spaces of industry, the clinic, knowledge creation and the real world. VR has clear potential to be useful, but it is perhaps away from entertainment that such value will be found to reside. It is in bringing Cyberspace and physical space closer that VR may find its promised land, and it is through its history that such potential might be understood and made real.

APPENDICES

APPENDIX 1: THE IMPLEMENTATION OF DATABASE SEARCHES FOR SOURCE SAMPLING

The purpose of this appendix is to detail the means by which sources were sampled and surveyed in this thesis. The value of this method is that it can bring to light a range of sources relevant to technologies or concepts which are poorly defined or otherwise nebulous.

Building a set of sources pertaining to VR and proto-VR required three core databases as the corpora for the study. While most current historians using online corpora rely on one source (typically Google Scholar), multiple databases are used here to minimise the bias inherent in their distinct algorithms. To minimise source occlusion, multiple searches on multiple databases were combined. The databases used were the ProQuest database platform, Google Scholar, and the Oxford Libraries Information Platform (OxLIP+).

To resolve the growth in number of sources from 1965 to 2005, an inversely proportional sampling size was used. Based on a model proposed by James Cummings, the proportion of articles sampled ranges from 100% of 1965’s corpus to 0.05% of 2005’s, thus accommodating the jump from 50 articles to an estimated 100,000. As a result, the sample of sources surveyed for the later years was proportionately small. Rather than resorting to the random sampling preferred by corpus linguists, a stratified, structured sampling approach was employed, using the frequency of specific terms within sources to determine their sampling selection. In this way, sources statistically likely to pertain to the technology or social contexts of VR and proto-VR were the most likely to be sampled. This minimised the amount of interference, and number of confounders caused by diverse uses of the word ‘virtual’, for instance. For the proto-VR period, the language of Virtual Reality and VR was non-existent, so a range of other terms were used to pick out academic and popular written sources which pertained to those technologies. These terms were: Interactive Computer Graphics, Virtual

Environment, Three-Dimensional Computer Graphics, Simulated Environment, Stereoscopic Computer, Stereoscopic Graphics, and Virtual Reality. Once 'VR' appeared though these terms were refined. From 1988 onwards, the terms Virtual Environment, Virtual Space, Virtual Reality, Stereoscopic Graphics, Stereoscopic Computer, Cyberspace, and VR were used instead. From 1990 the company names VPL, Sense8, and Virtuality were added. Virtual Research, Telepresence, and Autodesk had to be excluded from the search due to issues with disambiguation. By 2000, the use of 'VR' was so widespread that it dominated searches, and only Virtual Reality, VR, and AR were sampled.

This gradual adjustment of search terms in response to the changing relevance of keywords (what might be called *content-aware sampling*) is vital here, as it allowed sources pertinent to VR to be revealed within large corpora. Maintaining a single set of search criteria within individual years is important for controlling samples reliably, but on the larger time scales used in most historical research, terms need to change as language does.

While corpus linguistics relies on statistical tools and programming logic to order and display linguistic trends, historians must be able to examine and study sources 'in person' to be able to discern their meaning and the contribution they make to the narrative and study of the discipline. In this case, fifty discrete sources per year was chosen as a baseline, following feedback from colleagues and supervisors, totalling 2000 written sources.

Sources under 10 pages long received a full reading whenever possible, while those over 10 pages long received a briefer reading, focusing on the introductory and concluding sections. These sampled materials served to supplement other sources, including oral histories, interviews, physical hardware, and selected primary and secondary literature.

The interviews conducted for this thesis were largely unstructured. Initially, the hope had been to use a semi-structured interview model, but this proved unsustainable when considering the extremely diverse range of experiences and backgrounds of the participants. As a result, the decision was made to move to a participant-led interview process which would allow them to contribute what they felt was of the most value. Specific questions were prepared, based on their expertise. As such, a diverse set of personal histories of VR technology and its innovators was assembled and transcribed, adding on-the-ground, contemporary experience of the technologies, institutions, companies, and people involved.

As a result, the narrative provided is more comprehensive, reliable, and reflective of the uniquely social and technical paths of proto-VR and VR between 1965 and 2005 in the United States, and the reasons those boundaries were chosen merits attention.

Studying only the US ensured that sampling only sources in English would still represent the majority of those available. Furthermore, proto-VR formed in the US, and it was in America's Silicon Valley (arguably uniquely there) that the VR concept was able to arise from that. The American VR boom that followed proto-VR development was larger, and more intimately tied to cultural and social structures, than in any other country at the time.

While the start date of 1965 is determined by the publication of Ivan Sutherland's 'The Ultimate Display'[1] the end point must, by definition, be procedurally as well as historically determined. 2005 marks the nadir of the VR winter, where innovation and public visibility were at their lowest point since 1990. The term 'VR' was being subsumed by broader gaming, Internet, and computer cultures, as the first generation of HD-ready games consoles hit the consumer market. There is also an issue posed by the quantity of material available in later years. Between 2010 and 2011, more material was added to the corpus of VR writing than during the years 1965-2005. This much extra material would, in a single narrative, have had a diluting effect, particularly on the resolution of the understudied VR winter period detailed in chapter 5 (p.215). The 2005 cut-off was designed to allow emphasis to be placed on this period of semantic change and technological transfer, without the overshadowing of the more recent VR rebirth.

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[1] Ivan E. Sutherland, 'The Ultimate Display', in *Proceedings of the International Federation of Information Processing Congress*, 1965.

APPENDIX 2: AN EVALUATION OF THE RESEARCH METHODOLOGY AND SUGGESTIONS FOR FUTURE RESEARCH

The purpose of this appendix is to highlight problems with the methodologies outlined in Appendix 1 and discuss ways to mitigate them in future research which uses this method, as well as broader suggestions for work on the history of VR.

In a project of this kind of scale and pioneering nature, the shortage of secondary literature and local historiography necessitates, as explained in the introduction, a combination of existing methodologies and entirely novel ones. The combination of traditional primary archival research with oral histories and Internet database sampling was designed around the necessity for this narrative to form a definition history with both technical and social components. Furthermore, the establishment of a hypothetical, but stable, definition of the technology and the use of that to shape the materials sourced and sampled, has also been tested by the narrative creation process. The gathering and use of material identified by the sampling process has yielded significant results, and in detailing these, it is hoped that other historians of VR will be able to use similar techniques while being better equipped to handle the potential pitfalls of this method in an increasingly connected and digitised academic environment.

STATISTICAL SIGNIFICANCE

One major issue was the changing ratio between time spent researching material from a particular year and the amount of material published, and therefore the statistical significance of the sample. By using the stacked sampling method employed in this research, the same amount of time and effort was invested in understanding sources when it was possible to read a significant proportion of the visible material as otherwise. While visible of course does not in any way equate to ‘all’, in later years such a broad-spectrum approach to research is impossible. Tens, and then hundreds of thousands of sources quickly give way to millions in the new millennium. Time constraints and research pressures meant that, in addition to the existing material, only 50 new sources for each year of the 40-year narrative were studied in detail, with another 200 per year only filtered by title. The result of this was that, in the later years of the narrative, a smaller percentage were read than initially planned, as expectations of hundreds of thousands of sources proved to be significant underestimates, when incorporating all three databases. To enforce a nominal statistical significance would be meaningless here, as the sample size in the final years was, by necessity, around 0.0005% of the total. As the corpus survey is but one of multiple strands of material used in the thesis, the oral histories, secondary sources, and clearly identifiable primary materials (such as published books and theses) serve as controls for the literature identified in this way. Historians seeking to apply rigorous statistical tools and mathematics to discourse, or seeking to lean more heavily on the methodologies of corpus linguistics may want to consider using datasets of larger sample sizes to generate statistically significant findings for the years they study. It is important to remind the reader that, in later years, and assuming a significance of 1.5%, this would demand studying some 1500 sources for 2005 alone. An awareness of the potential for samples to be non-representative was combatted through stacked sampling, which itself caused further issues.

STACKED SAMPLING AND OBSCURED SOURCE PROBLEM

The stacked sampling method used search algorithms to put the results with the most keyword matches first. While this helped to ensure that sources directly related to VR were identified and sampled for each year from an enormous potential pool, it also introduced considerable (and deliberate) bias, as well as an incidental one. Relevant sources using different terms from those searched for, incorrectly indexed, or missed by the search algorithms would have a vastly reduced probability of being sampled. While some sources will always be missed, the stacking process effectively guarantees that this will happen, due to size of the corpus, and limits on study time. There are only limited options for mitigation of this. Increasing the breadth of search terms and the use of searching wildcards (for instance searching for Virtual plus any other word) would disperse material relevant to the research questions. The identification of further specific terms which could be added might help in limited contexts, but as every search term added broadens the size of the sampling pool, and every term removed limits the visibility of relevant material, this is a process of diminishing returns. Terms such as Artificial Reality, for instance, were used in the 1970s and 1980s to describe related interactive graphics work, particularly by Myron Kreuger, and could have been included in the proto-VR algorithms but may have reduced the visibility of more strictly proto-VR projects.

ALGORITHMIC BIAS

When using search algorithms to sample millions of sources, the writing of the algorithm itself becomes an issue. Meaning, simply, a set of rules, the algorithms are devised by the organisations which control the databases. Algorithms are often proprietary, and it is difficult to influence them in any meaningful way. As such, there are biases introduced which are outside of the influence of the historian. The use of multiple databases is an important means of limiting the impact of this, and the inclusion of control terms for database metrics (i.e. choosing a generic term and searching for that, year on year) may serve to highlight algorithmic issues and improve the data’s clarity.

DIGITISATION FILTER

While other historians have begun to use online databases in their research, the problems raised by these over physical archives merit attention. While in a physical archive, research parameters are imposed by space, cataloguing, and time, online archives have different limitations. While an online archive can hold a nigh-unlimited number of sources and is catalogued by machines, these steps require physical materials to be digitised and processed first. This means that digital corpora studied will only contain the subset of materials which have been digitised and uploaded. Of course, every archive can only ever represent a subsection of the surviving material, but with online corpora, it can be, in the case of amalgamated databases like EBSCO and Google Scholar, hard to tell what is included and what is not. This is confounded by the generation of catalogue entries for online databases, which are sometimes automated, and sometimes manual. This can create incorrect entries more of the time, hampering the visibility of relevant sources, and giving others undue prominence. Attaching incorrect dates to entries can be damaging to primary research, especially as errors are duplicated procedurally. During the research, an article with a clearly incorrect date necessitated a cross-reference of nearly 1000 sources, which revealed that nearly forty articles sampled were dated in the wrong decade, or even the wrong century.

As a result, it is important to make clear that there are numerous sources of considerable value to the history of VR which were missed by this sampling method, by virtue of their not being digitised, or referred to in existing texts, or by the numerous interviewees and participants in the project. The degree of bias in this case further varies depending on the database used, with different databases containing different records and documents. This is the main reason multiple databases were used and combined when generating samples to review. While existing methodologies rely on a single online source the combination of the Google Scholar, ProQuest, and OxLIP+ databases helped to reduce the impact of this bias. Sources missing from one archive were less likely to be missing from all three. Doing this also helped to minimise the algorithmic bias.

REMEMBERING

A key source of information for the construction of this thesis has been interviews and conversations with numerous people who worked in different parts of VR’s narrative. Beyond those conducted explicitly for this thesis, oral histories, interviews, television appearances and narrative materials such as book forewords have been valuable sources of personal, direct insight into the cultures and mindsets of VR's users and developers. The nature of the Remembering Problem was only made explicit through conversations with my supervisor, after discussing spoken and written accounts from Tom Furness III. While not interviewed for this thesis, he was interviewed by Thomas Rid for *Rise of the Machines* and by Kent Bye for the *Voices of VR* online podcast in 2015. There were instances in both interviews where Furness appeared to contradict himself, and accounts of his work in Rheingold's *Virtual Reality*.

It is important to remember that, for interviewees and providers of other forms of oral history, the events being discussed may be from a very different time of that person's life. It is easy to only partially remember, change, and forget things, especially when faced with the extra pressure of being asked questions by an historian about their own work, and the work of those around them. Mis-remembering can introduce conflicting information and confuse narratives. Participants are lending their knowledge and attention out of their own good will, and such valuable resources should never be discounted or taken for granted. Instead, in order to mitigate the risks of error posed by misremembering, the Russian proverb of 'trust, but verify' is valuable whenever possible.

In cases where the participant is providing information on matters for which there is no other verifiable source (such as confidential military matters or interpersonal relationships), a common occurrence in this research, then a degree of uncertainty must be accepted. No one has a perfect memory, and accounts of events which have no analogue are extremely valuable precisely for their unique perspective, but the potential for mis-remembering is always there.

RAMIFICATIONS

In addition to the authors own personal biases (which are addressable only as they are identifiable), the largest sources of error in constructing this narrative (and thus testing the definition of VR postulated) come from the colossal number of available sources online and the human nature of many of the key contributors. While attempts were made, within the methodologies employed, to counteract and reduce the impact of individual sources of bias, these can never be completely effective. So, what are the ramifications of these biases? In some cases, these remain Rumsfeldian ‘unknown unknowns’ and cannot be quantified, but in others, some assumptions might be drawn. There will be, as a matter of course, material of relevance which was missed or not studied in the pursuit of the thesis, which may have contradicted other sources or otherwise altered the narrative. It is the hope that in subsequent revisions of this thesis, which the author hopes to publish, some of these will be identified and mitigated.

Furthermore, the individual accounts which lent a great deal of the personal and social perspective so vital to understanding VR’s technological history have the potential to be in error. While each and every participant has demonstrated in equal measure a keen memory and a willingness to admit when their memory fails them, the possibility remains. These personal recollections have informed the colour and shape of the social and cultural contexts which VR exists within. However, in accordance with the original methodology, this has been balanced with the study of the material culture in the form of hardware and software as well as the hundreds of popular and technical articles sampled and studied. These have helped to provide broader context for the topics discussed in interviews and, in turn, have provided foundations for deeper conversations about the ways in which VR was understood, and aspired to, by developers and consumers during its tumultuous history. Interviews with proto-VR pioneers such as Bob Sproull and Ivan Sutherland have shed light on the earliest parts of the narrative, where the hardware and literature is slim, and as a result, their input has served to fill the void left by the poor preservation of confidential materials and physical hardware from the 1960s and early 1970s. Sproull and Sutherland each issued differing accounts of particular elements of this history, and these have been combined with secondary sources and other oral histories to attempt to find a middle ground, though at times the reader must be left to form their own conclusions, as is only right.

Overall, it is hoped that the mitigation of bias from the combination of different kinds of sources (and different kinds of bias) has produced a narrative which is as accurate as it can be though, ideally, future historians of the technology will examine and challenge this narrative, and contribute to a deeper understanding of the uniqueness and complexity of the technology's history.

THE WAY WE LIVE NOW: SUGGESTIONS FOR FUTURE RESEARCH

One of the core aims and aspirations for this thesis was that it would serve as a valuable resource for other people who might seek to understand the history of VR. Historians, technology journalists, VR developers, sociologists and others might, hopefully, be able to find value in this work. Just as this thesis was built on interdisciplinary methodologies, it is hoped that contributions from a range of different disciplines will add to the value of this research.

From an historical perspective, there are a number of ways in which future research could work with, and from, this thesis in order to build a more comprehensive and representative history of the technology. A wider gamut of interviews and oral histories is an excellent place to start. Over the course of the thesis around twenty different people were interviewed in person, by phone, or over email, and there are hundreds more who have valuable contributions to make but could not be contacted. For any future historian, identifying and approaching some of the individuals who worked with VR in the 1980s and 1990s, in particular, would be valuable. Interviews with Jaron Lanier, John Walker, Thomas Furness, or Eric Gullichsen, for instance, may bear fruit, though they have all been interviewed before, and the other sources should be identified first to avoid the frustrating experience of being asked the same thing twice. However, the employees of companies such as Autodesk, VPL, Sense8, or the HITLab are, in many cases, completely ignored (particularly less-senior employees), and they may yield entirely new perspectives which could drastically alter the history of the technology.

Another area in which subsequent research might yield interesting results is from an experiential survey of the material culture of VR. The existence of VR and proto-VR hardware in military, academic, laboratory, business, industrial, entertainment, and domestic contexts has produced an extremely wide range of different hardware typologies and, more importantly, preservation biases. Some kinds of hardware are far easier to find than others. The entertainment VR hardware such as the VFX1, Virtual Boy, and Virtuality Systems still exist, though Virtuality Systems are very hard to find in working order. Military and proto-VR systems, particularly those built for academic research in the 1970s and 1980s, are extremely hard to find, but absence of evidence is not evidence of absence. A survey and examination of VR and proto-VR hardware from a range of different contexts may not only bring to light previously-unknown VR companies and research but help provide vital perspective to accounts of the experiences. Written and oral descriptions of the quality and nature of proto-VR and VR experiences throughout its narrative vary wildly, a product of its socially dependent nature. For some, the desire for it to work was enough for it to do so, for others, the visual quality was so poor it was akin to being blind. While using and interacting with the virtual worlds provided by these systems would require working computers and other hardware, itself a considerable confounder, it could allow the collection of these experiences into a single database. A modern user would be entirely divorced from the perspective of contemporary users of course, but an evaluation of the range of applications available, and their functionality could provide unique insight into the actual experiences which the articles, accounts, and recollections mention.

Another avenue of research might be to broaden or change the parameters of the source sampling used in the thesis, as mentioned above. A shorter period of time (perhaps, as an example, just 1990 to 1996) would allow for a far higher resolution in terms of the number of sources studied from that period and would undoubtedly allow for a much more detailed and accurate narrative. A series of studies spread out over VR’s history would allow for a more comprehensive understanding of its technical, social, and accidental developments and innovations through the proto-VR and VR phases and would undoubtedly provide challenges and updates to this work, which has a fairly broad forty-year span. Furthermore, study and comparison with VR corpora and histories from both the United Kingdom, or Japan, could also allow for different perspectives on both American VR history, and otherwise.

In the early planning phase of the thesis, it was hoped that a methodology of discourse analysis would shape one of two core components to the narrative, the other being a material cultural study of hardware, which has already been mentioned above. In a discourse-analytical project, corpora could be studied using the statistical and analytical tools of corpus linguists to assess the changing usage of key words relating to VR, at the determination of the author or project led. Study of changing word usage in this way would provide a representation of public and academic understandings of VR's place in society and culture which individual accounts or sources could not and, as the author's master's thesis suggested, could in places contradict existing narratives.[2] A detailed discourse-analytical study of VR could add entirely new threads to the technology's history, and that of the systems with which it is connected, chiefly computers. Difficulties particular to VR's history are posed here by the colossal disconnection between technological reality and language, and such a study might, by focusing on this comparison, serve to highlight this difference in new and valuable ways. Theoretical and mathematical toolkits have already been proposed by corpus linguists such as Sebastian Hoffman and Anke Ludeling *et. al.* for use by historians to enable the statistical modelling of language from particular places and times and would be of great value here.[3]

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[2] Tobias Bowman, 'Against a Dark Background: Changing Trends in the Perception and Understanding of Virtual Spaces in the United States of America, 1966-2014.' (University of Oxford, 2014) <https://www.academia.edu/9538775/Against_a_Dark_Background_Changing_trends_in_the_perception_and_understanding_of_Virtual_Spaces_in_the_United_States_of_America_1966-2014> [accessed 29 September 2015].

[3] Anke Ludeling, Stefan Evert, and Marco Baroni, 'Using Web Data for Linguistic Purposes', in Marianne Hundt, Nadja Nesselhauf, and Carolin Biewer (eds.) *Corpus Linguistics and the Web*, (2007), 7–24; Sebastian Hoffmann, 'Processing Internet-Derived Text—Creating a Corpus of Usenet Messages', *Literary and Linguistic Computing*, 22/2 (2007), 151–65.

Further research suggestions include pursuing a thematic, rather than chronological structure, for VR's history in order to allow wider accessibility and to situate developments more firmly in terms of their context, rather than their timelines. Further study by VR engineers, assessing the approaches to technical hurdles taken by developers of past iterations, might also shed a more detailed light upon the context and motivations behind the dispersed and patchy development of VR technology in its early years and serve as a valuable counterpoint to the thesis.

While there are clearly a host of different approaches that could be taken for more specific, high-resolution studies, the broader range and combination of technical and social focus used here has established a narrative foundation upon which future work can be built. Without this, there would not be sufficiently detailed accounts spanning the proto-VR and VR periods to help structure independent study and future research.

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