PRESERVING VIRTUAL WORLDS
FINAL REPORT

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1. Executive Summary

The Preserving Virtual Worlds project is a collaborative research venture of the Rochester Institute of Technology, Stanford University, the University of Maryland, the University of Illinois at Urbana-Champaign and Linden Lab, conducted as part of Preserving Creative America, an initiative of the National Digital Information Infrastructure and Preservation Program at the Library of Congress. The primary goals of our project have been to investigate issues surrounding the preservation of video games and interactive fiction through a series of case studies of games and literature from various periods in computing history, and to develop basic standards for metadata and content representation of these digital artifacts for long-term archival storage. The games included within our case studies were:

- *Spacewar!* (1962) – a space combat simulation for the PDP-1 computer;
- *Adventure* (1977) – one of the earliest of the text adventure games;
- *Star Raiders* (1979) – one of the more popular and complex games released for the Atari 2600 game console;
- *Mystery House* (1980) – the first work of interactive fiction to employ computer graphics as a significant part of the game, and not just text;
- *Mindwheel* (1984) – an interactive fiction work, notable for having been authored by U.S. Poet Laureate Robert Pinsky;
- *Doom* (1993) – the game which popularized the first-person, 3D shooter game;
- *Warcraft III: Reign of Chaos* (2002) – the real-time strategy game from Blizzard Entertainment; and
- *Second Life* (2003) – one of the most successful of the 'social' (i.e., non-gaming) virtual worlds. Given the large amounts of data involved in archiving all of *Second Life*, our project has focused on a small set of *Second Life*'s islands.

Virtual worlds such as these are software artifacts, communities, and commodities. Their preservation is thus intertwined with issues of technology, social relationships and law, and our investigations have touched on issues in all of these realms. Significant problems we have identified for the preservation of these materials are summarized below.

Obsolescence – The most obvious problem affecting these materials is the obsolescence of the hardware and software infrastructures necessary to allow software to run. The earliest game in our case set, *Spacewar!*, currently exists in its original form stored on a punched paper tape intended to be read into the memory of a PDP-1 computer. There is, to the best of our knowledge, only one functioning PDP-1 computer left in the world, at the Computer History Museum in Mountain View, California, and paper tape readers are not exactly common equipment at this time. The fate of the paper tape of *Spacewar!* is the fate awaiting all games without the active intervention of preservationists. A book may pass 50 years on a shelf and still be readily accessible; rapid technological change and the resulting obsolescence of the technology necessary to access software mean that a computer game will not.

Boundaries – Identification of the exact boundaries of the object of preservation is difficult in the case of computer games. While we tend to think of the game as a relatively discrete package of software, the reality is that a *functioning* game involves a web of interconnections

between the game's executable, an operating system, the hardware platform used to execute both, and potentially network hardware and software and a multiplicity of other computer systems (witness the cases of *Warcraft III* and *Second Life*). Even a relatively simple, early game such as *Adventure* possessed a dependency on an operating system library in the source code that the original author, Will Crowther, sent to Don Woods. Games may also come in a multitude of official versions, as well as unofficial modifications (mods), rendering decisions about what to collect, even in the case of a single game, problematic. Determining what constitutes the game, and more importantly, what is necessary to *preserve* the game, can be an extraordinarily difficult exercise.

Intellectual Property Law – Copyright and related issues manifested themselves repeatedly in our studies. The Digital Millennium Copyright Act's prohibition on defeating technological protection measures makes it impossible for a library to create a preservation copy of games employing DRM and anti-copying measures. While obtaining the permission of the rights owner to make a preservation copy offers a potential path around this obstacle, securing these permissions is complicated by the existence of a large number of "orphan works" in the field of computer games, and the great difficulties encountered in trying to track intellectual property rights ownership in an industry as volatile as the game software industry. Intellectual property laws also may pose impediments to the development of emulation technology necessary for continuing access to some games.

Collection Management – As the Open Archival Information System Reference Model makes clear, preservation of *any* object requires the preservation of more than the object itself. Knowledge of how to decode and play back the information (representation information) must also be preserved, as must information which provides an intellectual context for the object to aid in understanding its full meaning and significance. Librarians, archivists and curators dealing with gaming materials must be extremely proactive in their collection management to insure that they are adding the requisite additional materials to their collections. Unfortunately, these types of materials can be exceptionally difficult to obtain in the case of computer games and electronic literature. Many of them may be in the hands of private companies that do not wish to see them released (or belonged to companies that have ceased to exist), and other information may be produced far outside of normal publication channels (e.g., machinima videos created in networked gaming systems and traded among fans), requiring significant time and energy to track down.

Preservation Strategies & Significant Properties – Standard preservation strategies for software entities such as computer games include migration (relatively easy if source code is available), emulation, maintenance of original hardware and operating systems (the 'computer museum' approach), and in cases where these all fail, re-enactment/recreation (the game *Mystery House* is available on modern computing platforms in significant part because of the reimplementation undertaken by the Mystery House Taken Over project, which created a bug-compatible reimplementation of the original). None of these approaches, however, provides a perfect solution to the problem of preservation, and migration, emulation and re-enactment pose significant risks of altering the appearance and performance of games. Our research on emulation in particular shows that significant visual and aural aspects of the work can be strongly affected by running under emulation. Without a clear understanding of which aspects of a game are likely to be considered significant by scholars in the future, it is extremely difficult to choose an appropriate preservation strategy,

and preserving games without any change in their appearance and play may simply not be achievable in many instances.

Despite all of these significant issues, we have identified a number of immediate and intermediate steps that libraries, archives and museums can take to assist in the long-term preservation of games. These include:

- Developing packaging standards for ingest of gaming materials into digital repositories that explicitly include support for application of the FRBR and OAIS data models to insure that the identification of materials and links between them are sufficiently precise and detailed to support preservation activity. We hope that the OWL ontology developed by our project, and demonstrations of its application with METS and OAI-ORE, might serve as the basis for further development in this area.
- Have organizations such as the Library of Congress, the National Digital Stewardship Alliance and others concerned with large-scale collaboration between institutions in support of preservation take a lead role in trying to negotiate the distribution of responsibilities for collection development and management that will be essential to preserve computer games and interactive fiction in a distributed fashion. Given the common need for repositories of representation information and supporting documentation, the Library of Congress may wish to consider starting discussions with the National Institute of Standards and Technology and the Unified Digital Format Registry about the creation of such a repository, focusing initially on data format standards.
- Help develop preservation systems that are accessible by and can accept contributions from the gaming community. The How They Got Game project, as part of the Preserving Virtual Worlds efforts, has established a sub-collection within the Internet Archive's moving image collection called "Archiving Virtual Worlds." It contains video documentation of a large number of virtual worlds, much of it created by those worlds' users. Efforts such as this, that provide a stable environment in which to preserve the contributions of the gaming community and assist them in documenting their own activities and culture, are essential to the preservation of computer games and interactive literature. Moreover, such efforts help promote dialog among librarians, archivists and curators and the larger gaming community, and help build the partnerships essential to preservation activity in this field. The Library of Congress and members of the National Digital Stewardship Alliance should seek out further opportunities for such collaborative efforts with the gaming community. Development of emulators and emulation technology, an area where the gaming community has already invested significant effort, might be a potential arena for collaboration, as might establishing repositories of documentation of hardware platforms, such as the recently launched Maryland Institute for Technology in the Humanities' Vintage Computers website.[1]
- Intellectual property laws as they currently stand represent serious obstacles to preservation of computer games and interactive fiction. The inability of libraries and other cultural memory organizations to make preservation copies of materials employing technological protection measures (TPMs) will certainly doom these

[1] Available at http://mith.umd.edu/vintage-computers/

materials to a rapid demise. The §1201 anti-circumvention rulemaking process, due to the time limitations established on rules allowing circumvention of TPMs, the time and difficulty in coordinating applications for exemptions to the anti-circumvention prohibitions in the law, and the uncertainty of the outcome of any petition, does not provide libraries with a stable legal environment in which to conduct preservation planning. In addition to seeking collaboration with the inhabitants of virtual worlds, libraries, archives and museums need to build relationships with gaming companies to work on legislative changes that will enable preservation of computer games to proceed in a manner that protects the rights of games' creators while insuring that their creations are available to future generations. The ReVAMP symposium discussed in Chapter 9 represents the type of discussion that is necessary if a legal infrastructure conducive to digital preservation is to be forged.

Computer games and interactive fiction form an essential part of our cultural heritage. These virtual worlds are unique forms of art, places for education, socializing, business and entertainment, and seem certain to play an increasing role in people's lives. We hope that the research we report on below will help contribute to librarians', archivists' and curators' efforts to insure that these virtual worlds remain living worlds.

Jerome McDonough
Preserving Virtual Worlds, Principal Investigator

2. Introduction

"This is our history, and just a handful of people are saving it."

> – PixelVixen707, screen name of "Rachael Webster," herself a fictional character in the alternate reality game *Personal Effects: Dark Art*

What is a Virtual World?

Virtual worlds are software artifacts, communities, and commodities. They are places and spaces whose geography and landmarks can be as familiar as your own neighborhood, teeming with personalities that are rich and genuine and multifaceted, but—simultaneously and paradoxically—they are also always finally layers of logical abstractions mediated by the conventions of digital computing. They are also (often) branded media properties capable of generating massive revenues, or else generating very little, a phenomenon not irrelevant to their frequent and sudden demise.

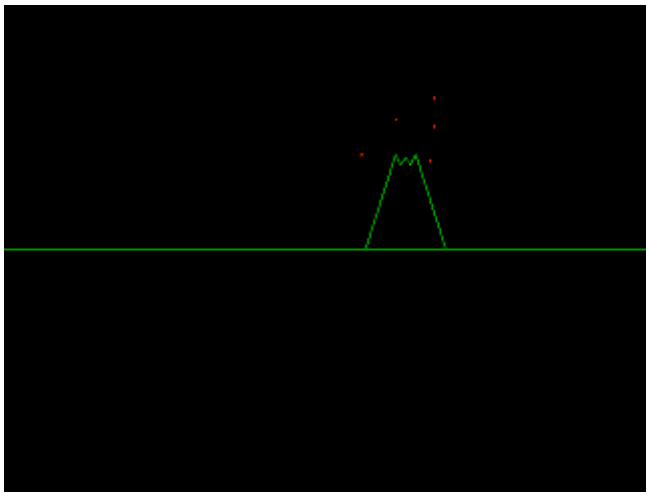
As software artifacts exhibiting complex dependencies on platform, operating system, and network environment, virtual worlds are undoubtedly among the most imperiled forms of interactive digital content. As communities—shared spaces and places—they are defined by no less delicate and idiosyncratic skeins of people, relationships, memories, and folklore akin to those found within oral cultures. Virtual worlds are not virtually—that is, "almost"—real. They are instead, to borrow a phrase from Jesper Juul (2005), precisely *half-real*: they are human products, scripted and engineered out of millions of lines of code written by dozens or hundreds or even thousands of individuals, but they are also focalizers for powerful collective acts of the imagination that rely on the same willing suspension of disbelief that characterizes immersion in other media, like novels and films. Virtual worlds are governed by the non-virtual realities of limitations on processor and rendering speeds, bandwidth, memory, and server technology, but they have also functioned to spur innovation and technical breakthroughs in those very same areas. Most virtual worlds are also buffeted by the inexorable pressures of the marketplace. During the two-year span of our project, no fewer than seventeen virtual world properties winked out of existence, with varying degrees of bang and whimper (see Appendix A). Even when profit-motive is not a consideration and a virtual world is built and maintained out of something like love, it remains vulnerable to the patience, attention span, resources, disposable income, and of course ultimately the inescapable mortality of its founders.

The online journal *Virtual Worlds Review* defines a virtual world as "an interactive simulated environment accessed by multiple users through an online interface." Six essential features are prescribed: shared space (multiple users), a graphical user interface, immediacy ("interaction takes place in real time"), interactivity ("the world allows users to alter, develop, build, or submit customized content"), persistence ("the world's existence continues regardless of whether individual users are logged in"), and socialization, or a sense of community. While presumably capturing what many immediately think of when they conjure the mental image of a virtual world, we find this definition and these criteria limiting. For example, the requirement for a graphical user interface would seem to exclude text-only

Multi-User Dungeons or MOOs (MUDs Objected-Oriented) from the definition of a virtual world. Likewise, *Maze War*, a remarkable 1974 multiplayer game which anticipated the first-person shooter genre would not qualify, since there is no persistence to the game world and precious little in the way of social interaction.

The Preserving Virtual Worlds project has instead taken a deliberately broad and catholic approach to defining its scope and purview. Not all of the virtual worlds in our case set exhibit each of the above properties. This is partly a result of our mandate to explore a variety of different cases and preservation scenarios. However, it is also out of the conviction that no single quality—three-dimensional graphics, multiple users, user-contributed content, persistence—defines a virtual world. For our project, a virtual world means something like a digital setting whose properties are stable and coherent enough to deliver a consistent ludic or interactive experience to two or more users or to the same user over time. A virtual world also, however, inevitably involves some form of imaginative projection based on the promise of inhabitable space. An Excel spreadsheet is thus not a virtual world because despite being capable of producing consistent interactive experiences it fails to create the sense of immersive possibility so crucial to the experience of space and place. We believe virtual worlds thrive on this human craving for possibility.

Perhaps no single example illustrates this more effectively than *Battlezone*, a coin-op arcade tank combat simulator first introduced in 1980 and subsequently ported to the Atari 2600 and numerous other consoles and home computer systems. *Battlezone*, which was also eventually adapted by the US Army for training purposes, presents its players with a sparse and largely empty world, populated by abstract geometric obstacles and an array of hostile tanks, missiles, and spacecraft. The kill or be killed ethos of the game matches this stark, vector-drawn landscape perfectly. There is, however, one unusual touch: on the horizon of this world is a mountain range; peaks and valleys rising and falling like an EKG. Amongst the mountain peaks is a solitary volcano, a distinctive landmark capped off with a few blinking pixels meant to suggest lava or debris.



The Volcano in *Battlezone*

This volcano became the stuff of gamer legend, with the rumor spreading that if you drove your tank far enough you could eventually get to it. And there was more: upon reaching the volcano you could drive up its side, and peer over the rim, and inside was a castle, and inside the castle treasure . . . One commentator puts it this way:

> The attraction of *Battlezone*'s world was so strong that many players wanted to turn their back on the fighting and drive their tank up into the mountains to go exploring. The designers of the game had to put in a routine to send a

> missile after would-be explorers so that arcade owners wouldn't lose money on the peaceful tourists who didn't want to fight. Many great legends emerged from the arcades that centered on finding a way to leave the fighting behind.

This behavior anticipates the appeal of later, much more complex and fully rendered virtual worlds, such as those found in the *Grand Theft Auto* franchise, in which players often engage in "sandbox" mode, foregoing the missions assigned to advance the plot in favor of ... just driving around. (The kind of free-form exploration that Situationist Guy Debord (1956) called a *dérive*.) Such activity is possible because all virtual worlds exist on a continuum between (again using terminology from Jesper Juul, who also discusses the example of *Battlezone* in this context) coherence and incoherence. A virtual world is coherent or incoherent to the extent that the player is able to use the information that is presented to him or her to fill in the gaps and blanks about other aspects of the world that are not literally portrayed. *Battlezone*, for example, gives us nothing with which to conjecture as to why its antagonists are fighting for possession of this barren planet, or how the crews of the tanks (are they even human?) eat or sleep or what they do to pass the time when they're not all busy fighting. But specific details, like the volcano, can become the catalyst for such imaginative projections because they tantalize us with the promise of a more replete world just over the vector limned horizon. Human-computer interaction designer Stan Ruecker (2007) refers to this in a different context as the "aesthetic function," where attention to seemingly arbitrary cosmetic details—in this case, the erupting volcano, with its pixelated lava—has the salutary benefit of capturing a user's attention and engendering trust in the surrounding environment. Virtual worlds, regardless of where they fall on Juul's continuum between coherence and incoherence, exploit and depend on the effects of the aesthetic function on their users.

We draw no hard and fast distinctions between traditional computer games and massive, multiplayer online virtual environments like *Second Life*. Our case set encompasses examples of both, as well as several works of interactive fiction which are at least as much instances of *belles-lettres* as games or entertainment. Steve Russell's *Spacewar!*, programmed in 1961, is thus a virtual world for purposes of our project: indeed, it is a very literal virtual world, with its primitive visualization of a solar system on a screen at MIT (or today at the Computer History Museum in Mountain View). Will Crowther and Don Woods's text-only *ADVENTURE* is a virtual world, its faithful recreation of Kentucky's Bedquilt Cave complex yielding an uncannily accurate world model replete with objects, places, and non-player characters. John Romero's and John Carmack's *DOOM* is a virtual world, an architectural tapeworm enticing users to wonder what lies beyond the vanishing points of its seemingly endless corridors and mazes—precisely the question taken up by those who learned to build their own game levels, as well as early creators of machinima who used the game engine as a platform for narrative. Finally, we might recall the well-known origin story behind Will Wright's landmark game, *The Sims*. Wright was at work on his first game design, a by-the-numbers shoot-'em-up for the Commodore 64 called *Raid on Bungeling Bay*; as he tells it, he became captivated by the idea of using the level editor to design new landscapes and combat zones, eventually finding this activity more compelling than the actual game play. This is the kind of world-making—made up of imaginative projection, social interaction, and unabashed play—that forms the basis for the virtual worlds we examined.

Cultural and Economic Significance

The word "game" comes to us from the Old English *gamen*, itself descended from the Germanic, meaning joy, fun, and amusement. This etymology is consistent with most people's contemporary sense of the term, and so it is not surprising that games are sometimes regarded as trivial, disposable, or at best tangential to those objects of cultural heritage seemingly possessed of more inherent gravitas. Yet even a moment's reflection should reveal the shortcomings of this thinking. Historically, card, tabletop, and parlor games of all sorts have been integral to the human experience across cultures, spanning all levels of social class and caste. Yet as often as games are relegated to the category of the frivolous, they are just as often associated with violence, addiction, and dangerous tendencies. Digital games in particular seem to suffer for their close association with youth culture, and of course debates around violence and militarism in contemporary digital gaming are constantly in the headlines.

This report does not seek to intervene in such debates, other than to point out that the sheer topicality of computer games and virtual worlds at this particular moment in our collective history would seem to make preserving accurate and authoritative records of them an essential aspect of the mission of an institution such as the Library of Congress. Likewise, it is worth remembering that the history of technology reveals consistent patterns of anxiety around new media and new forms of immersive storytelling. Consider the following, for example:

> A whole family, brought to destitution, has lately had all its misfortunes clearly traced by the authorities to an ungovernable passion for novel-reading entertained by the wife and mother. The husband was sober and industrious, but his wife was indolent, and addicted to reading everything procurable in the shape of a romance. This led her to utterly neglect her husband, herself, and her eight children. One daughter, in despair, fled the parental home and threw herself into the haunts of vice…. The house exhibited the most offensive appearance of filth and indigence. In the midst of this pollution, privation, and poverty, the cause of it sat reading…and refused to allow herself to be disturbed in her entertainment.
>
> – 'T. C., ' *The Christian's Penny Magazine and Friend of the People* (1859); Qtd. in *The "Dangerous" Potential of Reading: Readers and the Negotiation of Power in Nineteenth Century Narratives* (Aliaga-Buchenau, 2003).

This warning about the perils of too much novel reading seems instantly familiar, evoking many of the jeremiads about the addictive qualities of gaming one associates with public debates around *Everquest*, *World of Warcraft*, and *Second Life*. The popular pastimes of the present—outright dangerous or at best mere distractions from more wholesome pursuits—are the new cultural norms of tomorrow. Just as it would be very difficult to analyze a painting such as Manet's *Olympia* without reference to Titian's *Venus of Urbino*, it will prove very difficult in the future to discuss games such as *Star Wars Galaxies* without reference to *Spacewar!*. It will also prove difficult to provide a full accounting of our cultural heritage outside the realm of gaming without preserving games as well. In an age where games such as *Tomb Raider*, *Resident Evil*, *Final Fantasy* and *DOOM* spawn media franchises including

films, novelizations, comic books and a variety of action figures and collectibles, and where games such as Microsoft's *Halo* and Blizzard's *World of Warcraft* provide media production platforms for the creation of machinima videos, it is impossible to provide a proper contextualization for much of our existing popular culture without preserving games.

Virtual and gaming worlds also exhibit increasingly complex transactions with segments of society beyond popular entertainment, for example the placement of ads in XBox games by the Obama presidential campaign (GamePolitics.com, 2008). Bainbridge (2007) has noted the potential impact of virtual environments on the research community, both as virtual laboratory spaces and as settings for economic and social research. Increasingly, any complete understanding of modern society and culture requires an understanding of the world of gaming, and if cultural heritage institutions are to adequately serve researchers, we must develop means of preserving these new information resources.

Games have also redefined the social spaces around them: whether it is the coin-op cabinet in a neighborhood tavern or pizza parlor, the video arcade as a new kind of adolescent hangout, the changing dynamics of the family living room—where the TV set takes on a new role as a game-playing device—or the LAN parties that characterize online gaming or cybercafés in Seoul, it is obvious that games have reconfigured physical as well as virtual space.

Economically, computer games have become a significant part of the global economy. Global sales of video games were estimated at $46.5 billion in 2009 (Wu, 2010), and within the United States, direct and indirect employment by the gaming software industry accounts for over 80,000 jobs (Siwek, 2007). Socially, video games have become one of the most popular forms of entertainment within the United States, with 67% of American households playing computer or video games (Entertainment Software Association, 2010), and with online gaming sites in the United States reporting over 190 million visitors in a single month in 2008 (ComScore, 2009).

Challenges to Preservation

Unlike a book in a library, computer games have very poorly defined boundaries that make it difficult to determine exactly what the object of preservation should be. Is it the source code for the program? The binary executable version of the program? Is it the executable program along with the operating system under which the program runs? Should the hardware on which the operating system runs be included? Ultimately, a computer game cannot be played without a complex and interconnected set of programs and hardware. Is the preservationist's job maintaining a particular, operating combination of elements, or is to preserve the capability to produce an operating combination using existing software and hardware? Is it both? Once these questions of the boundaries of the preservation object are addressed, there are a host of other difficulties presenting the would-be preservationist. What information, beyond the game itself, will we need to ensure continuing access to the game? How should librarians, archivists and preservationists go about organizing the body of information needed to preserve a game? What strategy should we adopt to preserve software in a technological environment in which computing hardware and operating systems are undergoing constant and rapid evolution? Given the costs of preservation of normal library

and archival materials, how can we possibly sustain the additional costs of preserving these complex and fragile technological artifacts?

Given that the entire report really revolves around the challenges to preserving and maintaining access to games and virtual worlds, here we simply run down, in abbreviated form, the main problem domains.

- **Hardware obsolescence** – The original console or computing platform used to run the game may cease to be supported or even available in the aftermarket.
- **Software obsolescence** – The original software needed to run the game—operating system, drivers, frameworks—may lose support, cease development, or become incapable of running on future hardware/software configurations.
- **Scarcity** – Some video games are produced in limited quantities and are subject to the dangers of media decay. This is especially likely to be the case for special editions and releases, recalled games, or art games.
- **Third party dependencies** – Currently most emulators are developed by the game community and are of questionable legality. They are also typically created without the benefit of the original specifications and are themselves at risk of becoming obsolete.
- **Complex, proprietary code** – And an associated lack of documentation. Digital games are generally released as compiled binaries with no documentation of the compiling process, or even the programming languages used. Not having access to the source code or language specifications makes migrating or emulating software far more difficult.
- **Authenticity** – The elephant in the digital preservation room, proving that a digital object is what it claims to be, free from tampering or corruption. Digital games enjoy many versions between the first prototype, the official release (on multiple platforms), and cracked or otherwise altered unauthorized editions. Especially for older games, the only extant copy may exist in a fan-run web repository, making the authenticity impossible to establish.
- **Intellectual Property Rights** – The game development industry is highly creative and competitive, leading developers to be conservative with their intellectual property. Most have instituted restrictive shrink-wrap licenses reflecting this. And yet, once a game is no longer actively marketable, they are less likely to respond to inquiries about licensing for it.
- **Significant properties** – What are the significant properties of a game that must be maintained with each transformation/preservation action? What makes Mario Mario? How important are font size and color palette? What about the speed of text scrolling or sprite movement? What about controllers? How faithful must we stay to the original code? Significant properties are essential to define, as they play a major role in determining authenticity.
- **Context** – Although not an immediate threat to the preservation of games, building contextuality is important to creating understanding for future users. This is truer for digital games than many other record types because, as technology advances, game players who have only been exposed to the latest and greatest may be apt to play an older game and say, "so what?" even though the game might have been revolutionary for its time. For example, Sierra's *Mystery House* was the first text adventure to

incorporate graphics. An amazing breakthrough in its day, it seems crude in comparison to today's virtual environments.

About the Project

Preserving Virtual Worlds (PVW) was a two-year collaborative research venture of the Rochester Institute of Technology, Stanford University, the University of Maryland, the University of Illinois at Urbana-Champaign and Linden Lab (2008-10). The project is one of several launched as part of Preserving Creative America, an initiative of the National Digital Information Infrastructure and Preservation Program at the Library of Congress intended to seek novel solutions for the preservation of commercial digital content. Preserving Virtual Worlds has focused on developing methods for the preservation of digital games and interactive fiction through the creation of standards for metadata and content representation.

The PVW project has employed a case set approach in its investigations, choosing a set of games and using those to identify representative types of preservation problems posed by each member of the case set. We have selected a number of games from different periods in gaming history, from different platforms and with different intellectual property status to try to maximize the opportunities for identification of problems. Games, interactive fictions, and virtual worlds within the case set include:

- *Spacewar!* (1962) – a space combat simulation for the PDP-1 computer;
- *Adventure* (1977) – one of the earliest of the text adventure games;
- *Star Raiders* (1979) – one of the more popular and complex games released for the Atari 2600 game console;
- *Mystery House* (1980) – the first work of interactive fiction to employ computer graphics as a significant part of the game, and not just text;
- *Mindwheel* (1984) – An interactive fiction work, notable for having been authored by U.S. Poet Laureate Robert Pinsky;
- *DOOM* (1993) – The game which popularized the first-person, 3D shooter game;
- *Warcraft III: Reign of Chaos* (2002) – The real-time strategy game from Blizzard Entertainment; and
- *Second Life* (2003) – one of the most successful of the 'social' (i.e., non-gaming) virtual worlds. Given the large amounts of data involved in archiving all of *Second Life*, our project has focused on a small set of *Second Life*'s islands.

For each of the games in our case set we have tried to identify specific problems that might impede a library's or archive's ability to preserve the game in the long-term. Identification of these problems has involved content analysis of the games themselves (including documentation provided with the game) as well as research into the various games' intellectual property status. Common problems identified for games in our case set include the unavailability of the original game, content management problems resulting from the complex versioning issues surrounding software, storage media obsolescence and fragility, degradation of game play due to the use of emulation or migration, unavailability of representation information documenting the file formats used in game software, and a number of intellectual property issues.

Based on our investigations into the games in our case set, we have developed a set of requirements for game preservation. We have also implemented a new ontology for game description that draws upon both the Functional Requirements for Bibliographic Records Final Report and Open Archival Information System Reference Model, and successfully used that ontology to create archival information packages for these games in conjunction with existing digital preservation standards such as METS, OAI-ORE and BagIt. We have loaded those packages into preservation repositories at Stanford University and the University of Illinois at Urbana-Champaign.

Project infrastructure included a listserv with all participants subscribed; biweekly conference calls, both project-wide and for the technical team (primarily personnel at Illinois and RIT); several face-to-face all-hands meetings over the course of the project; a public website, including a blog (http://pvw.illinois.edu/pvw); and a wiki, with many (but not all) content areas also open to the public (https://apps.lis.illinois.edu/wiki/display/PVW/Home). Readers are encouraged to consult these online resources, as well as the project partners' publications (see Appendix E) for further information and discussion.

About the Project Partners and Personnel

The University of Illinois at Urbana-Champaign was the lead institution, with Jerome P. McDonough, assistant professor in the Graduate School of Library and Information Science, serving as principal investigator. Project personnel included a diverse array of staff, faculty, and graduate and professional students from Illinois and three other universities, thereby extending the project's demographics to additional information schools, a program in game and interactive media design, a university research library, and a digital humanities center. The team included specialists in game design and game studies, library and information science, archives, digital humanities, intellectual property, and descriptive and analytical bibliography. The participating units within the four partner institutions are further described below.

University of Illinois at Urbana – Champaign (Lead Institution)
Graduate School of Library and Information Science (GSLIS)

The Graduate School of Library and Information Science began as the first library science program in the Midwest, founded in 1893 by Katharine Sharp. More than a hundred years later, it is consistently ranked as one of the very best in the field. The School's faculty believes strongly that librarianship and newly emerging forms of information science must develop together, in order to ensure that libraries resist obsolescence and newer institutions learn the importance of access, privacy, and service. The mission of the Graduate School of Library and Information Science is to provide: graduate education for leaders in research and practice in the fields of library and information science; groundbreaking research to advance preservation of and access to information in both traditional and digital libraries and in the many settings outside of libraries where large amounts of critical information are collected; and useful service to librarians and other information service providers, as well as to the citizens of Illinois.

Rochester Institute of Technology
Department of Interactive Games and Media (IGM), and
B. Thomas Golisano College of Information Sciences and Technology

The Department of Interactive Games and Media is renowned for its innovative approaches to media-centric computing that merge the creative design of the interactive experience with the development of content, technologies, and systems that form the basis of such work. The department will support, wherever and whenever possible, multi-disciplinary work that fuses these elements in pursuit of its academic mission. IGM is comprised of talented and motivated individuals from a variety of academic backgrounds with a shared interest in computing as it relates to interactive and social media, new media, games, simulations, and media-centric systems of all varieties. The department's mission is to provide a sustained educational environment that supports and encourages creative and collaborative academic inquiry by both faculty and students into these areas. The department's programs, coursework, research, and development efforts will provide students with the knowledge and skills to pursue meaningful and rewarding careers in this arena, while simultaneously advancing the field and helping to provide a well-rounded educational experience.

The Golisano College is one of the largest and most comprehensive computing colleges in the nation. The College has garnered accolades and recognition as a premier computing education and applied research facility. Housed in a 125,000 sq. ft. state-of-the-art building, the College showcases cutting-edge innovation and world-class faculty who are passionate about their work. The Golisano College includes the departments of Computer Science, Information Sciences & Technologies, Interactive Games & Media, Networking, Security, and Systems Administration, Software Engineering, as well as the Ph.D. in Computing and Information Sciences program, the research arm of the College. This mixture of applied computing disciplines is unique and allows the College to offer a strong, diverse series of programs centered on computing, from infrastructure to the end user.

Stanford University
Stanford University Libraries and Academic Information Resources (SULAIR)

Stanford University Libraries and Academic Information Resources includes more than 30 libraries and programs supporting research, teaching, and learning at Stanford University. SULAIR acquires and delivers library collections in all formats, establishes policies and standards to guide the use of academic information resources, develops training and support programs for academic uses of computers, and maintains a broad array of electronic information resources, including the online library catalog and several hundred article and indexing databases and electronic journal subscriptions. In each library unit, knowledgeable professional staff provides assistance in locating and using print and online information resources.

University of Maryland
College of Information Studies, and
Maryland Institute for Technology in the Humanities (MITH)

The College of Information Studies, Maryland's iSchool, engages in collaborative, interdisciplinary, and innovative research, teaching, and service. We educate information

professionals and scholars, and we create knowledge, systems, and processes. The iSchool offers Master's degrees in Library Science (MLS), Information Management (MIM), and a doctorate degree in Information Studies. In Fall 2009, 344 students were enrolled in the MLS program, 141 enrolled in the MIM program, and 26 enrolled in the doctoral program. Approximately 70% of the total student body is female. The iSchool has 35 faculty and staff and 33 adjunct faculty representing diverse subject areas in information studies. The iSchool serves the mid-Atlantic region.

The Maryland Institute for Technology in the Humanities is the University of Maryland's primary intellectual hub for scholars and practitioners of digital humanities. On a day-to-day basis, MITH functions as an applied think tank for the digital humanities, supporting faculty fellows and engaging in sponsored research clustering around digital databases and tools, thematic research collections, text mining and visualization, and the creation and preservation of electronic literature, digital games, and virtual worlds. MITH has sponsored over two dozen faculty and graduate student fellows, and serves a community of several hundred researchers and interested members of the public who attend its events.

About this Report

This is the final report of the Preserving Virtual Worlds project, co-authored by the members of the PVW team. While presenting broad ranging and at times in-depth discussion, together with conclusions and recommendations and various supporting documentation in the appendices, it nonetheless cannot claim to be a comprehensive summation of the full range of PVW's activities over the last two years. The principle audience for the report is library and information science professionals at the Library of Congress and other collecting institutions who have already or will soon be developing collections policies for computer games, interactive fiction, and virtual worlds. We also, however, hope that the report will be of interest to game developers and designers, many of whom as yet fail to take even rudimentary steps necessary to ensure the preservation of their own creative legacy and intellectual property; to the academic game studies community, especially those scholars with an interest in understanding the material underpinnings of the platforms and systems they study; and finally, but not least, to the fan and game player communities who have already done so much to safeguard future access to the content they cherish.

3. Games & Interactive Fiction: Collecting for Preservation

Issues of Appraisal & Selection

In *The Study of Games* (1971), an essential treatment of the anthropology of games, Elliott Avedon and Brian Sutton-Smith asked:

> What are games? Are they things in the sense of artifacts? Are they behavioral models, or simulations of social situations? Are they vestiges of ancient rituals, or magical rites? It is difficult and even curious when one tries to answer the question 'what are games,' since it is assumed that games are many things and at the same time specific games are different from one another—but are they? (Avedon & Smith, 1971, p. 419)

We are confronted with a number of questions here. One concerns the essential nature of games. Either games are fixed objects—perhaps authored texts or built artifacts—or alternatively, they are the experiences generated by a framework of rules, codes, or stories and expressed through interaction, competition, or play. Text or performance? Artifact or activity?

Another question is whether there are general structural similarities among all sorts of games. Answering this question fully would be out of scope for our project, which was focused on practical issues of collection and preservation. However, it is worth noting that the authors of *The Study of Games* conclude with "seven elements in games" distilled from studies by psychologists, mathematicians, and others. These structural elements include "procedures for action," "roles of participant," "participant interaction patterns" and the like, taking games away from the notion that they are stable artifacts or texts. These elements underscore the importance of documenting interactivity as a historical phenomenon, something that predated computers (an obvious statement to any player of *Diplomacy* or *Dungeons and Dragons [D&D]*). As fashionable as it has become to discuss games as cinematic or as narratives, let us not forget that actions and responses are fundamental to the nature of interactive games. Games provide a structure within which players do something—whether the game is baseball, *D&D*, or *Myst*—and this structure is not compelled to be a linear narrative. Collections of digital games provide a tailor-made opportunity to document interactivity in ways that are not provided by other media. Any collecting activity thus must consider not only the fixed content of games as authored texts or software, but also examples of game development, game play, and player response and activity that provide a more complete picture of digital games as an interactive medium. We will have more to say about the implications of these considerations later in this report.

Emphasis on both selection and appraisal underlines the diverse nature of the game-related collections, from collections of published games well-suited to selection policies traditionally in the domain of library collection development, to collections of complex software, artifacts, and archives better fitting notions of appraisal and "special" collecting developed in the realms of archives, manuscript divisions, and museums. The common element uniting

selection and appraisal is the intellectual effort of describing collecting and preservation priorities.

Two of the PVW partners have active collecting programs: Stanford in games and virtual worlds, and Maryland in interactive fiction. The Library of Congress asked for our input with respect to the selection/appraisal problem, in order to aid its own eventual collecting activities in the areas of digital games and related forms of interactive software. In this spirit, we offer some thoughts that derive in part from our project work.

With the growth of interactive software as a basis for entertainment and cultural production, it is safe to predict that many libraries will establish collecting programs for digital games and related artifacts, such as hardware consoles and interface devices. The foundation for such a collection in most cases is a library of published console- and personal computer-based games. A collection development policy is therefore a statement of the scope and extent of this library. Based on institution-specific program and patron need, the scope will encompass chronological, technical, and access considerations. A minimal or basic information-level collection, for example, would likely focus on current and recently published games that run on readily available and currently supported platforms (XBox 360, Wii, PS3, Windows PC, Apple Macintosh). With the progression through deeper levels of collecting (instructional support, research, comprehensive collections), decisions need to be made about the acquisition of content and hardware for obsolete platforms, some of which are still supported through third-party vendors (e.g., Atari VCS, Nintendo NES) and others of which are largely unsupported, historical operating systems (e.g., DOS), or titles that involve particular difficulties with respect to security, account management, or patron access (server-based games, handheld games, games distributed by web services such as Steam or XBox Live). Institutions supporting research or comprehensive-level collections will likely need to support multiple access solutions, such as a managed space for use of recent games on currently supported hardware platforms, a "special collections" solution for archival and historical materials, and a digital repository for media migration and long-term preservation, as well as possible future access solutions.

Once the overall scope of the collection is decided upon, the next level of selection policy should cover a mix of traditional library decision points (format, chronological categories, language of publication, country of origin) and categories more specifically tuned to digital games and virtual worlds. With respect to the former, it should be noted that "chronology" in the digital game industry is very closely linked to decisions about platforms of interest; the entire history of *published* digital games currently spans fewer than four decades, yet this history is closely tied to a very strong notion of platform and operating system "generations." Also, the country of origin is a particularly important matter, especially given the historical importance of Asian game publishers, notably from Japan, Korea, and China.

Several criteria for selection decisions are oriented towards specific uses or capacities of digital games. As forms of software, for example, many digital games can be modified or re-used as platforms for activities that are not restricted to the original game content. Some software platforms, such as Flash, console environments (such as XBox Live Arcade) or even "ancient" hardware platforms, such as the Atari VCS, provide a foundation for independent games produced by teams as small as a single designer/coder. Thus a game might be modified from an existing title or created as a one-off project for an art installation,

used to create animated movies, or provide a basis for commentary on current events ("newsgames"). Such uses have come to define entire areas of activity that require special tactics of collection and preservation, such as "art games," machinima, serious games, and so on. These areas, in turn, provide specific foci for collecting activities, depending on local priorities. Thus, a library might well decide, in addition to a broad collection of current titles, to collect a specific type of game, such as art games or "auteur" games as a focused specialization. Defining such areas in a collection policy statement is a more useful approach for collection development than typically applied categories for discussion of digital games, such as genre, because such categories are often loosely applied and may in fact produce artificial divisions of content based entirely on fine distinctions of game-play characteristics rather than inclusive research priorities.

Other important aspects that may figure in a collection policy statement include technological aspects, social or "community" aspects (particularly with respect to network-based games), competitive aspects (digital games as e-sports), surface qualities (graphics, audio, music) and inter-textual or cross-media qualities of games (e.g., games in relationship to literature or cinema). Thus one collection might be differentiated from another by an emphasis on competitive, multi-player games, including documentation of events, tournaments, and "virtual communities" of fans through the collection of websites and replays, or perhaps by a focus on games based on films, which might include a companion collection of films based on games. Finally, with respect to collections based in the United States, it may be important to differentiate regional collecting activities. Designers, developers, publishers, game, and technology companies have historically been concentrated in a few regions, such as Northern California, Washington state, Maryland, and Texas. Thus, Stanford University's game-related collections are closely tied to the older Silicon Valley Archives, and the University of Texas' efforts have thus far emphasized the collection of papers and artifacts from Texas-based designers, technologists, and musicians.

The linkage of game collections and archival collecting efforts raises the related, but separate question of appraisal of game-related collections that consist primarily of documentation, personal papers, corporate records, or other categories we might call archival or special collections material. Appraisal of games as a part of archival practice was not a core issue for investigation by the PVW project. It refers to the process of evaluating collections of records for acquisition, retention or disposition, an assessment made in the context of a particular institution's mission and/or research needs. Richard Pearce-Moses (2005), in the Society of American Archivists' *A Glossary of Archival and Records Terminology,* defines appraisal as "the process of determining whether records and other materials have permanent (archival) value" and notes that it "may be done at the collection, creator, series, file, or item level." In this sense, appraisal is an issue for organizations such as corporate archives in game development companies who must make retention decisions on a regular basis; some of the questions around this issue of corporate stewardship of archival records were addressed in Rachel Donahue's work included in the IGDA's *Before It's Too Late: A Digital Game Preservation White Paper* (Monnens et al., 2009). Academic institutions with active programs in game studies or game development will eventually face similar issues when making decisions about the retention of faculty and project papers in these areas. While PVW was not focused on the appraisal process, we do note that there is a need for careful attention in archival studies to this issue as it relates to game-related archives, particularly with respect to a better understanding of production work-flows, intellectual property considerations, and other

matters as they are specifically shaped in the game industry. We also note that some work has begun in this area, notably by Prof. Megan Winget at the University of Texas.

No single institution can do the work of comprehensively collecting and preserving digital games and their history. Competent institutions must join together to build archives of computer game history. Lay historians of digital games, mostly players and fans, have created websites and entire communities of game players dedicated to the preservation of game content and technology, and have made emulators and collections of game movies available to their communities. Institutions committed to game preservation and history could enlist these pioneers in the effort to create more permanent historical resources, and intelligent collection policies might provide a basis for initial discussion among potential participants. The Digital Game Canon, discussed later in this report, is one example of how such an effort might proceed. Indeed, participation of the game industry, museums, and academic institutions in this project can help to defuse the adversarial relationship between, say, the emulation community and publishers by developing mutually acceptable practices with respect to intellectual property and access. Better communication of collection priorities from libraries and museums working in this area might even provide a solid basis for industry support and participation.

Working with Developers

Preservation of video games and interactive fiction requires preserving not only the games themselves but also contextualizing material necessary to understand games' origin and use. Significant amounts of this type of material can be found in the possession of the software developers and designers who create games and the companies that distribute and support them. Much of this material, unfortunately, is not made public, although in some instances it may end up in archival collections. Our project has attempted to provide an initial classification of materials that those engaged in game preservation might wish to try to collect from developers:

- Source Code & Other Game Assets (including text, still image, audio, video, and 3D files) – As noted in the discussion of FRBR and games as bibliographic objects, a game can have many expressions, and while most users will wish to interact with a binary executable version of the game, obtaining and preserving source code for a video game can serve at least three significant purposes: 1.) it provides information on game production that is not available from the executable version to users interested in the underlying technology of games; 2.) it enables migration as a potential preservation strategy for a game when emulation is not viable; and 3.) it can improve the results of using emulation as a preservation strategy in those cases where producing a faithful rendition of game play requires recompilation of the source. In the case of *Spacewar!*, for example, in order for the online version of the game to run correctly on an emulated version of the PDP-1 computer, minor changes to the original code had to be made (clock speeds on modern computers being somewhat different than a PDP-1). In addition to source code, having copies of draft and final versions of assets used in a game (including text, still image, audio files, video files and 3D models) can ease scholarly analysis and use of these materials.

- Technical Documentation – software and hardware development teams for games will typically accrue a variety of technical materials in the course of game development regarding the underlying technologies necessary to enable a game's use, ranging from documentation of APIs for particular hardware devices, programming language documentation, their own notes on issues like enabling cross-platform compatibility of code, etc. This information may be valuable to scholars wishing to understand game production processes, as well as to preservationists trying to achieve a better understanding of the platforms on which a game was designed to run.
- Production Materials – understanding of the life cycle of a game can also be enhanced by access to materials the game's designers used in its development. This can include design notebooks, storyboards, mock-ups created of game objects, scripts, character profiles, maps of the game's terrain, and similar materials.
- Designer Stories – some of the more interesting material that can be collected regarding games' origins and use does not reside in documents, but in the designers' minds. Interviews with game designers and recordings of designers presenting their work at conferences can be a remarkably rich source of data for those wanting to get a more complete understanding of the history of games' development.
- Records of Interaction with the User Community – Game companies inevitably generate a fair amount of information in the process of interacting with their users, including bug reports on software, records of support calls, discussion forums and wikis. Some of this information may not be available due to privacy issues or other considerations, but it can provide valuable information regarding the game designers' relationship with users as well as the culture of game use.

The game source code, production assets and the technical documentation acquired and generated in the course of game production are likely to have the greatest direct impact on the preservability of a game. The source code and game assets widen the set of potential preservation strategies, and technical documentation regarding the platform on which the game was intended to run is second only to representation information about the game files themselves in terms of its significance for supporting technical preservation activities. Production materials, oral documentation from game designers, and records of interaction with a game's user community are of great value to anyone seeking to understand the life cycle of a game over time.

Unfortunately, game companies may be unwilling or unable to part with all of these categories of materials for varying reasons. While there are exceptions, such as id Software's treatment of *DOOM*, game companies are typically not particularly enthused about publicly releasing their source code, technical documentation or production materials, which might alert competitors to the design processes. Any social scientist who has studied software companies can attest to the fact that getting a programmer or designer to take the time to sit down for an interview is a difficult process, as companies do not wish to sacrifice the valuable time of their employees in an industry which is extremely driven by release dates. They are also disinclined to have their internal operating procedures made public. Records of interactions with users can raise obvious issues of confidentiality and privacy.

This is not to say that game companies will necessarily be unwilling to share these materials, but there are obviously a number of factors working against making them available that

libraries, archives or museums seeking to collect and preserve games must address. The most fundamental issue for any cultural memory organization attempting to collect this material is trust. Many software companies would view sharing something like source code as equivalent to handing over the crown jewels. Assurances that material will be "dark" archived and made available only at some later date or under certain conditions are not of any real significance to a software company unless they already have trust in the individuals and the institution making the promises.

Familiarity is key to building trust, and so cultural memory organizations seeking to collect materials from game designers need to continually engage with those from whom they are seeking materials, and not just as part of the process of negotiating donation of a collection. Librarians and archivists need to be in regular attendance at events that draw the video game design industry, including industry-oriented conferences such as the Game Developers Conference and E3 Expo, gamer-oriented conferences such as PAX Prime and VGXPO and academic conferences such as the International Conference on Computer Games, the IEEE Conference on Computational Intelligence and Games, and the Conference & Festival of the Electronic Literature Organization. Archivists are well aware that personal relationships can be the key to successful acquisition of materials, and maintaining a visible presence in the venues inhabited by game companies is critical to that effort.

Game companies are also more likely to be willing to discuss donations with organizations that they see make active contributions to the world of gaming. Cultural memory institutions that wish to acquire materials from game developers need to have public (and permanent) activities around video games and electronic literature. Points of presence for gaming materials in the library, both physical and virtual (see, for example, the University of Illinois Gaming Collection (http://www.library.illinois.edu/gaming/index.html), Stanford University Library's Stephen M. Cabrinety Collection in the History of Microcomputing (http://sulair.stanford.edu/depts/hasrg/histsci/index.htm), the University of Maryland's Maryland Institute for Technology in the Humanities' Deena Larsen collection (http://mith.umd.edu/larsen/dlcs/), and the Video Game Archive at the University of Texas at Austin (http://www.cah.utexas.edu/projects/videogamearchive/index.html), as well as sponsoring events such as workshops on gaming research and game nights, help the institution promote an image of itself as actively contributing to gaming culture. To the extent that an institution is seen as having goals that align with the gaming industry regarding the importance of promoting games, it will be more likely to be seen as trustworthy by the industry.

Choosing Versions: What's the Difference?

Digital games and virtual worlds are not static or homogeneous entities. Like books with different printings, editions, and translations, like art works with derivatives, prints, copies, and fakes, like films with director's cuts and abridgements, games often exist in numerous different versions. These versions include ports for different platforms, patches and upgrades, user-contributed modifications ("mods"), pirated copies and hacks, and sequels that may prove more or less contiguous to the original. And here we are only talking about the game as a finished product. During development, the game will iterate through alpha and beta versions with greater or lesser availability to the public or to smaller communities of play testers. The constituent digital components of the game, meanwhile, from source code

to graphics, movies and soundtrack, will manifest their own complex hierarchies of variants and version forks on the development tree. Little wonder then that programmers rely on version control repositories to manage these relations as they check code or master files in and out of the object library in the course of their work. Versioning is, in short, a fact of life in the digital world—indeed, one can argue that it is essential to the ontology of the digital at its most fundamental level since (strictly speaking) every time a file is accessed a new copy of it is created.

Libraries and collecting institutions will face constant decisions over which "version" of a game or virtual world to acquire, often also including the question of what source media it comes stored on. Limited resources will inevitably force trade-offs and decision-making. One cannot collect—let alone preserve and maintain access to—everything. Sometimes a particular version of a game will be important to collect since it is the first of its kind, even if it was never widely disseminated. *Adventure* from our case set is just such an example. The version of the game that propagated over the nascent ARPANET, and then to nearly every mainframe and personal computer system in the industry thereafter, was not the "original" programmed by Will Crowther, but rather the expanded version of the game released a year or so later by Don Woods. Anyone who remembers playing *Adventure* on their first computer almost certainly is recollecting the expanded Woods version, not the Crowther original. Yet Crowther's source code has recently been recovered, is now available on the Internet, and has been implemented in a variety of different virtual machines. Which version of *Adventure* does a collecting institution want then, the Crowther original or the version modified and expanded by Woods that proved so influential? The answer, of course, is probably both, but recognizing the difference may not be within the capability of a cataloger or archivist who does not specialize in games research.

Much like an upside down stamp, some versions of games are significant because they contain bugs, so-called Easter eggs, or other anomalies. Sometimes the question of version will be dictated by access: an institution may reach a decision to collect only PC versions of games, because that corresponds with the vintage hardware they have on hand. Sometimes version may be dictated merely by happenstance: what comes into an archivist's hands as the result of an acquisition or what is available that day on eBay. This was precisely the method by which we obtained our Macintosh-compatible copy of *Mindwheel*, a format not even listed in the Moby Games entry for the game (http://www.mobygames.com/game/mindwheel). (It was left on the doorstep of one of the project members, who narrowly avoided stepping on it on his way out.)

We have done considerable work with FRBR as a framework for mapping relationships between different versions, ports, and storage media for games, with *Adventure* serving as our focal point (McDonough et al., 2010). While librarians have long recognized the distinction between a work as an intellectual creation and its embodiment within a particular physical form (and the need to adequately describe both), the publication of the Functional Requirements for Bibliographic Records Final Report by the IFLA Study Group on the Functional Requirements for Bibliographic Records (FRBR) marked a pronounced increase in the level of attention that the library community has devoted to these issues. FRBR proposed a formal model for bibliographic description that recognizes four classes of entities as implicated in descriptive practice: **Works** (unique intellectual or artistic creations), **Expressions** (the realization of Works), **Manifestations** (the physical

embodiment of particular Expressions), and **Items** (single exemplars of a Manifestation). Attributes commonly found in bibliographic description, such as publisher or title, are bound in the FRBR model to one of these four entities.

At first it might seem that all versions of *Adventure* should be grouped under a single "Work," a particular instance of the game (the last version modified by Don Woods, for instance) should be the "Expression," a particular file with a unique MD5 hash should be the "Manifestation," and an individual copy of that file (perhaps on a Commodore 64 664 Block disk) would be the "Item." But what if the text read by the reader is exactly the same, but the underlying code is different? These variants might be simple (a comment added to the FORTRAN source code), peripheral (such as the ability to recognize "x" as a synonym for the command "examine"), or very large (a port of the code from FORTRAN to BASIC). Should these code level variants be considered different expressions? To further complicate matters, what if the FORTRAN code was exactly the same but compiled to two different chips? For example, an IBM mainframe and a Commodore 64 might both have a FORTRAN compiler, but the two compilers will interpret the FORTRAN to a different set of set machine instructions. It might also be the case that two FORTRAN compilers designed by different programmers will generate slightly different machine language. Even the same compiler might generate slightly different machine code from a single source code file depending on the options with which it is invoked. Should these compiled executables, different in their binary structure but based on the same FORTRAN code, represent different "Manifestations" or different "Expressions"?

Finally, even two files with exactly the same MD5 signature participate in a larger software environment at runtime. The drivers that run the display interface, the keyboard, the memory, and the disk drives arguably become part of *Adventure* when the user is playing the game. For instance, the experience of playing the game using the 6507 chip in a Commodore 64 hooked up to a black and white television may be different than the experience of playing the game on the same chip in a Commodore SX64 (the all-in-one machine some felt fit to call "portable"). Should the software environment on which the binary is executed be a part of the classification scheme at all? Would playing the game on a video monitor (which displays only a fixed number of lines at a time) provide a substantially different experience from a session with the same game played on a Teletype (which saves the output indefinitely on paper)?

Such questions are reminiscent of issues and debates that have long been debated in more traditional arenas for cultural heritage, such as literature and textual scholarship. "The root cause of any version is revision," the Melville scholar and editor John Bryant (2002, p. 70) has contended. But what is the threshold by which mere variants in a text promote the text to a new version of the work? Bryant delineates the following characteristics: that versions may be either physical (literally distinct documents) or inferred from the evidence available on one or more extant documents; that a version of a work can always be linked to another version; that versions are revisions of the work, and that they may be initiated, either deliberately or inadvertently, by the author or some other agency like an editor or the public at large; that versions do not depend on the authority of the author to be authorized as versions; that versions are manifest by their degree of difference from other versions; that versions entail some reconceptualization or reimagining of the work in question; that versions are partly defined by their impact on their audiences; and finally, that versions are

constructed critically by virtue of other artifacts in the documentary field, meaning that the existence of a version is always finally arguable. If we step back from this delineation, what we have then is an account of versioning wherein a version itself is always critical, contingent, relative or relational, functional, rhetorical, and perhaps above all, consequential. This seems no less true for digital games and virtual worlds than for the literary and historical documents that concern Bryant. A version is not an inferior derivative of some legitimized and sanctioned work, nor is it simply a collection of observable variants. Versions are, instead (to paraphrase Gregory Bateson) the differences that make a difference.

Our work with *Adventure* and other digital games has highlighted two deficiencies in the FRBR entity-relationship model. The first problem arises from the complex tangle of derivative works associated with any particular game. Neither catalogs as they exist today nor FRBR provide sufficient facilities to ease collocation of these works for users. Computer games provide one of the stronger arguments for the concept of a superwork and adding support for superworks to our bibliographic systems, and to the FRBR model. The second problem is the omission of any mention of intellectual property rights within the FRBR model. While the IFLA Study Group (1997) made it clear that they were not enumerating every attribute of or relationship existing between bibliographic entities, the failure to account for intellectual property relationships between Group 1 and Group 2 entities is extremely problematic for those attempting to describe computer games, and we suspect much other digital material. Alignment of legal theory and cataloging theory regarding the separation between artistic/intellectual creations and their expression in particular forms is, we suspect, a difficult task that will require the input of the both communities.

In sum, there are no easy formulas or checklists to aid in decision-making regarding which versions of a digital game or virtual world to collect. There is no one rule of thumb or absolute heuristic. Bryant's criteria, while compelling, are likely to remain resistant to formal codification. Unraveling the relationships between even the simplest digital works and their constituent elements is orders of magnitude more challenging than for most artifacts in the analog world. That said, these same challenges lend themselves well to visualization and mapping techniques, and one can imagine catalogers and archivists working with increasingly sophisticated tools to articulate and display the relationships between digital objects in their collections. All of this also requires considerable subject knowledge, and here the input of both game scholars and fan communities is likely to be invaluable.

Context Information Reconsidered

Unlike many creative works, video games and virtual worlds are rarely able to stand on their own as time progresses and technological advancements render them obsolete. That which was startlingly innovative in the early 1980s appears simplistic to the modern eye. Take, for example, *Mindwheel* (1984) and *Fallout 3* (2008), two apocalyptic adventures played from a first-person perspective.

(Pinksy & Synapse Software Corporation, 1984)

(Bethesda Softworks, 2008)

Fallout clearly has superior graphics—*Mindwheel* has none and, even if it did, the 16 color graphics of its day would not be competitive. The difference in sound quality is similarly

dramatic. Traversing the world of *Fallout 3* is an instantaneous experience, interrupted only by loading screens for significant changes in setting. In the screenshot above, nearly 20 seconds elapsed between entering the command, "DOCTOR, BEGIN GAME" and the text fully loading. In its simplicity, *Mindwheel's* data barely hit megabytes, while *Fallout 3* occupies several gigabytes.

Games and interactive fiction are not the only works that suffer when viewed after their time. Virtual worlds—from *Second Life* to *Neopets* to *World of Warcraft*—are not experienced in a vacuum. The value and meaning of a virtual world is primarily derived from the actions and interactions of its players. Imagine stepping into *Second Life,* which doesn't even have the benefit of plotlines or non-player characters (NPCs), years after the last user signed off. The world would be empty; interactivity limited to the virtual equivalent of archaeology: examining buildings and prims in an attempt to build a picture of how *Second Life* was lived.

So how do we prove the historical significance of *Mindwheel* or other early video games to a modern gamer? By spending as much effort preserving the context of gameplay as the software that enables it.

Literature & Ephemera

As with any type of history, contemporary publications play a large role in providing an adequate context in which to understand video games. The most relevant of these are documents such as game manuals and press releases, and third-party publications including strategy guides, reviews, and interviews.

A video game's retail package is rarely limited to a copy of the software, especially if it was released before the advent of downloadable content and sophisticated digital rights management (DRM) technology. The box—a valuable artifact itself—typically contains an instruction manual, registration card, and advertisement or catalog at a minimum. Depending on the game, maps, control cheat sheets, posters, and comics or other game related fiction might also be included. *Mindwheel* was bundled with a 93-page novella. Many older computer games required information from these physical materials as a way to prevent illegal copies from being played.

The materials bundled with a game become particularly important if the game itself is no longer playable. Manuals include introductions to plot and characters, screenshots, credits, and explanations of controls. These controller instructions can provide some limited insight into gameplay. For instance, in *Mortal Kombat II*, the character Shang Tsung can transform into any of the other player characters with specific sequences of one to four button presses (or holds). This type of complex button combination for special moves is as intrinsic a part of the fighting genre as the

hardboiled detective is in film noir. If nothing else, this may aid with understanding 'button mashing' in a time when games are increasingly controlled by motions instead of joysticks. In a similar fashion, the keyboard card packaged with Eidos' *Thief: The Dark Project* illustrates the level of thought and detail put into the game's design as well as the difficult controls required by such nuance. When text adventures were the games of the day, players often hand drew maps to keep track of their location; in the golden age of the 16-bit role playing game (RPG), world maps became common pack-ins.

Strategy guides, generally published by third parties, provide a much richer picture of game play than can be gleaned from the materials a game is packaged with. By their nature, these books offer detailed descriptions of game play from beginning to end, and often pair screenshots with the guide text. Strategy guide content may include:

- Screenshots
- Maps
- Concept art
- Tips for mastering difficult game controls
- Puzzle solutions
- Lists of in game items, their purpose, and where to find them
- Cheats, secrets, and Easter eggs

The last item on the list might be viewed as a type of game developer marginalia (or graffiti). Easter eggs are messages, events, or effects hidden by game developers that are typically not encountered during regular game play, or require inside knowledge to catch, if they are. They often contain programmer signatures, homages to earlier titles, advertisements for upcoming games, or genre in-jokes. Sierra On-Line was notorious for using Easter eggs as marketing tools. In particular, the various Quest series all contained references to each other; *King's Quest II* hides a preview of *Space Quest I* in a snake home and a guard in *Space Quest II* asks if you've played *King's Quest* ("Easter Eggs and cheats," n.d.). *DOOM* has a well-known cheat code ("idkfa") which, when typed during game play, gives the player every weapon, full ammo, every key, and full armor. In *Heretic*, another id Software title, typing this code removes all acquired weapons and calls the player a cheater ("Easter egg," 2010).

Promotional materials released by game developers with the launch of new titles can provide important insight into the contemporary state of video game technology. While marketing claims are likely to be exaggerated, they are unlikely to be outrageously overblown. Thus given the fact that both Blizzard's 2010 press release for *StarCraft II* and Activision's 1980 promo reel emphasize graphics, it can be assumed that each of the games is fairly representative of the state of graphics technology at the time of its creation. This is the type of detail that helps with the *Mindwheel* vs. *Fallout* scenario presented above; with it, a modern researcher unfamiliar with the timeline of video game advancement gains a better understanding of the quality of a game at release.

As with literature, game ephemera may include items from both the game developer and licensed third parties. These tie-in items range widely in form and material, from ordinary posters and patches to pocket lint and potions. The table below illustrates some of this variety.

Item	Manufacturer	Year
Small Centipede Poster	**Atari**	**1982**
Dragon's Lair Lunchbox and Thermos	Aladdin Industries Inc	1983
Q*Bert Miniature Figures	Kenner	1983
Mindwheel novel	**Synapse and Pinsky**	**1984**
Packet of pocket fluff (Packaged with *the Hitchhiker's Guide to the Galaxy)*	**Infocom**	**1984**
Nintendo Cereal System	*Ralston Cereals*	*1988*
Breath of Fire Map	**Capcom**	**1993**
Chrono Trigger Key Chains	Bandai	1995
The Book of Atrus (First in a series of novels inspired by *Myst)*	Miller	1997
Trance Vibrator (Packaged with *Rez)*	**Sony Computer Entertainment**	**2001**
DOOM: The Boardgame	Fantasy Flight Games	2004
Yoshi Tag and Run Meter	*McDonald's Happy Meal toy*	*2006*
Master Chief Costume	Rubies Costume Co	2008
Monster Hunter Health Drink	*Bandai*	*2008*
Sonic the Hedgehog Plush Backpack	***Hot Topic***	***2009?***

Key: Developer Third Party [Plain]
Retail Package [Bold]
Limited Edition [Italic]
Nostalgic [Bold Italic]

The meaning constructed by these items is as diverse as their physical forms:

- The lunch kit, Happy Meal toy, and cereal indicate popularity with school-age children.
- The map implies elaborate world building (for the time).
- The pocket fluff appealed to the humors of Douglas Adams fans.
- The *Myst* novels represent a reversal of the usual path of adaptation; book to game (as was the case with *The Hitchhiker's Guide to the Galaxy*) is much more common.
- The board game could imply either outreach to the wider (non-video) gaming community, or greater than average popularity among tabletop gamers.
- The costume speaks to the devotion of the games fans, especially when accompanied by photographs of those fans dressed up for video game or genre themed conventions.

- Nostalgic items like the Sonic backpack, faux vintage t-shirts, and rereleased classic games speak to the lasting influence upon American culture.

In addition to these textual and artifactual materials, soundtracks, movies, television series, audio recordings, and orchestral performances have all emerged from popular video game franchises. While the specific details of ephemera are important for contextualizing games, that some varieties exist at all is a valuable appraisal aid. While any game might be sold with a poster or figurine, only the leading titles are likely to inspire entire lines of action figures or musical arrangements. Certainly, there are many factors other than simple popularity that contribute to a game's enduring value, and not all titles of import come with a large market impact. But, as a history of video games would be incomplete without the blockbusters, some decisions for a large repository are simple.

4. Collections

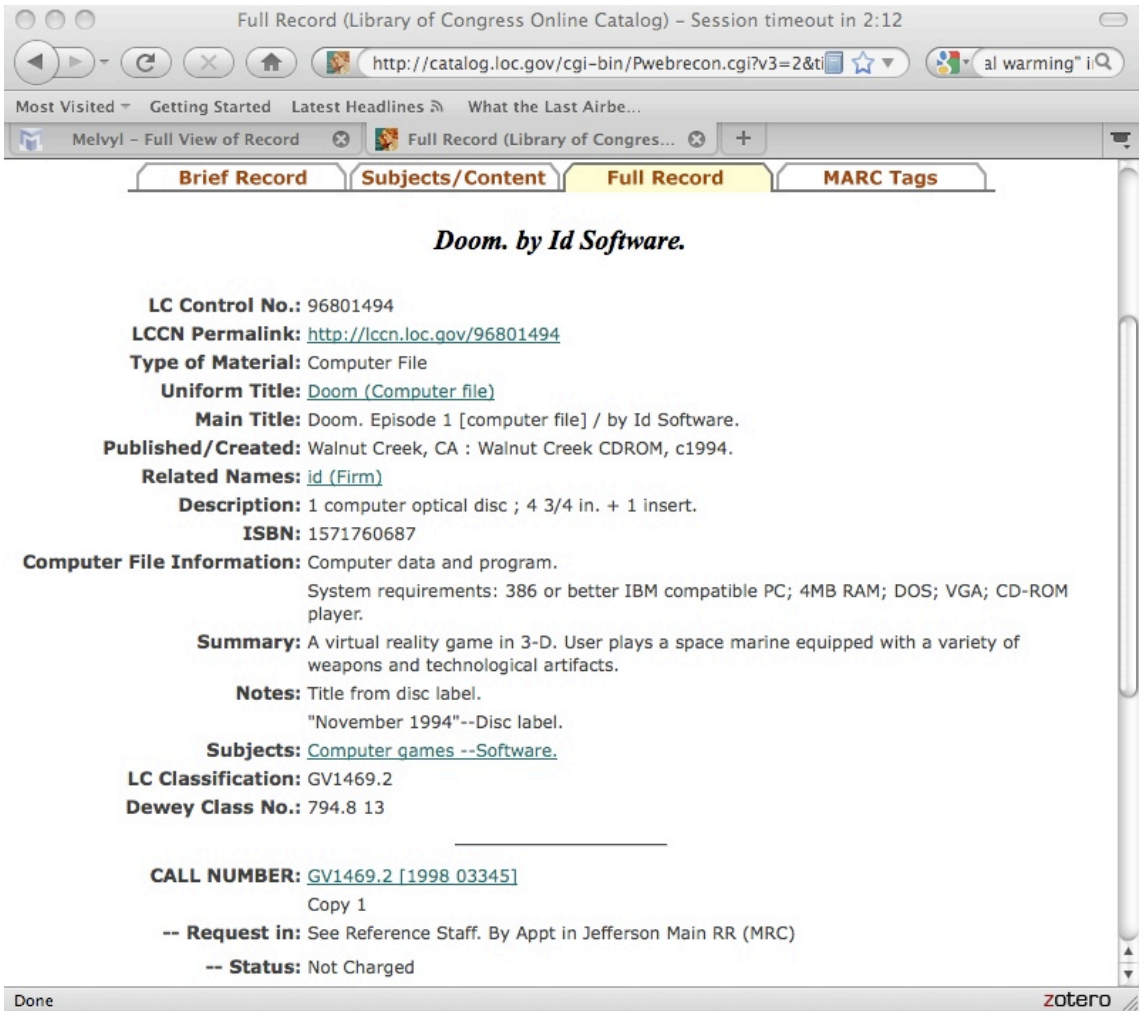
Collections: Bibliographic & Archival Description

Bibliographic records are one of the primary tools that any library has for management of collections. As has been noted with regards to moving image materials (McDonough & Jimenez, 2007), however, catalog records that may serve perfectly adequately as mechanisms to aid access often fail as mechanisms to aid in preservation. In the case of computer games and interactive fiction, traditional bibliographic description may not even prove adequate for purposes of access.

Our project focused on research collections of games, such as those at Stanford University, when considering issues of description for access, and our examination of current practices of bibliographic description was performed with an assumption that our main interest was in determining whether they adequately supported the research activities of scholars concerned with games and related materials. We note that scholars' interests in these materials should not be considered uniform. The needs of scholars working within a program such as the Department of Interactive Games & Media at RIT, which is focused on game design and development, are not identical to those of scholars working within the digital humanities who might be interested in analyzing the rhetorical nature of games (Bogost, 2007).

Another point which is often neglected in library and information science literature is that bibliographic information does not only support the work of patrons; it must also support the work of librarians and archivists. Coyle (2004) has examined the ways in which the current discussions of the FRBR final report and its implications for bibliographic record design have had an unfortunately narrow view of the functions which should be included in "Functional Requirements," particularly with respect to libraries' internal operating procedures. When examining forms of bibliographic description from the point of view of preservationists, we have tried to keep in mind that description must support the work of information professionals as well as that of the research community.

A significant problem with existing practices of bibliographic and archival description from the point of view of scholars interested in computer games and interactive fiction is the lack of detail provided by existing formats and descriptive practices, particularly with respect to the issue of versioning and editions of particular games. Consider this record from the Library of Congress' online catalog:



This record does provide some information regarding the version of the game, inasmuch as it indicates in the title that it contains "Episode 1" of *DOOM* and that the CD-ROM in question apparently dates from November 1994. However, by November 1994, *DOOM* was already in version 1.7a; in fact versions 1.2 through 1.7a were all released during the first eleven months of 1994, and there are significant differences in game play, technical support and capabilities between the different versions. There is also nothing in this record to indicate whether this CD-ROM contains a copy of the shareware version of *DOOM*, or one of the commercial releases. If the shareware version, it would only contain Episode 1, but the mail order releases of the original *DOOM* contained further episodes. For a scholar researching games, this record is singularly unhelpful with respect to the version of the game contained with the Library's collection.

This level of detail, unfortunately, counts as the epitome of service when compared against traditional descriptive practice found in archival finding aids, where item-level description is minimal at best. The finding aid of the Stephen M. Cabrinety Collection in the History of Microcomputing at Stanford University Libraries provides the following information for anyone looking for the game *Star Raiders*:

```
Box 136     Atari, Inc. ST Star Raiders, 1986
            Physical Description: 1 computer disk ; 5 ¼ in. Atari

Box 72      Atari, Inc. Star Raiders, 1982
            Physical Description: computer cartridge Atari

Box 134     Atari, Inc. Star Raiders, 1982
            Physical Description: computer cartridge Atari

Box 142     Atari, Inc. Star Raiders, 1980
            Physical Description: computer cartridge Atari

Box 152     Atari, Inc. Star Raiders, 1982
            Physical Description: computer cartridge Atari
```

Presumably we can depend on the fact that Box 136 contains the version of *Star Raiders* for the Atari ST, but as for the rest, whether the cartridge in Box 142 is intended for an Atari 2600 system or one of the Atari 400/800 systems is unclear, and for the remaining three boxes, the cartridges could be in theory be for the Atari 400/800, 2600 or 5200 systems. And only a scholar with knowledge of the exact release dates for the various editions and platforms would be able to deduce that information from this finding aid.

As discussed in Chapter 3, our project did extensive exploration of the application of the FRBR data model to game materials, and found that it provides reasonable if not perfect support for identification of versions and editions of games. However, FRBR in and of itself is not a solution to the problems of adequate description of game materials. As analysis of the current MARC and Anglo-American Cataloging Rules (Delsey, 2002) shows that the bibliographic format and rules of description employed by the library community already provide support for much of what's contained within the FRBR Final Report. What is needed is a commitment to providing an enhanced level of description necessary to support scholarly work. While clearly there are painful financial ramifications for any library (and even more painful for any archive) trying to create more detailed bibliographic descriptions of these materials, existing practices are not adequate to meet the needs of the scholarly community.

Nor do these descriptions provide anything like the information that would needed by preservationists, for whom the details of version and edition information are equally as vital. The cartridges employed by varying Atari systems (e.g., 400/800, 2600, 5200) differed in the pin-out arrangement used by the cartridge slots to physically interface the cartridge with the rest of the system. While Atari systems are still available on the secondary market today, eventually these systems will cease to function, and any ability to access the information on such a cartridge will be dependent on our ability to read the data off the cartridge and move it into some form of emulator. Without sufficiently detailed knowledge of what types of cartridges are in hand, a library or archive would not even know what additional technical information they might need to collect in order to try to insure long-term access. While the bibliographic record for *DOOM* above indicates that DOS is required to run the software it fails to provide any indication of which version of DOS is necessary.[2] Long-term access to software requires detailed knowledge of the technical environment in which it was designed

[2] The original *DOOM* required MS-DOS version 3.3 or higher.

to execute. Current descriptive practices do not provide anything resembling sufficient information on the technical aspects of software to support preservation activity.

One of our critical findings regarding the preservation of gaming materials is that preservation of a game itself is insufficient; we need to also preserve the information that contextualizes the game and helps researchers achieve a more complete understanding of the game's significance and use. Much of the contextualizing material that we might wish to preserve, however, is archival in nature, existing in relatively few copies. The UT Videogame Archive at the Dolph Briscoe Center for American History at UT Austin, for example, has papers and files donated by Warren Spector, a game designer famous for his contributions to the *Ultima* series of games from Origin Systems, Inc. and *Wing Commander*. These materials are unique, one-of-a-kind contributions, which is to say, the type of material archives specializing in personal papers and manuscripts acquire on a regular basis. A scholar at Stanford University looking at the *Ultima* games contained within the Stephen M. Cabrinety collection would probably be extremely interested in the material held at UT Austin, but bibliographic links between collections held by different institutions are so rare as to count as non-existent. Preservation demands that libraries, archives and museums begin to rethink their practices of bibliographic description and consider the possibility that catalogs and finding aids should help users obtain the information they need regardless of whether it happens to be housed at the current institution. The fact that a catalog provides a valuable service as an inventory of an institution's holdings does not mean that that is the only purpose it should serve.

Problems with linking bibliographic information with databases maintained by other organizations are not limited to the realm of descriptive metadata. One of the basic tenets of the Open Archival Information System Reference Model is that an archival information package for any digital object should contain representation information that allows a user to interpret the bits comprising an object as syntactically valid and semantically meaningful information. As much of this information will be identical for different objects of the same data format, many institutions are hoping that institutions such as the developing Unified Digital Format Registry will become hosts for representation information needed by other organizations. But if this is to occur for games, we need to be able to link the individual files comprising a game stored within an institution's repository systems with representation information stored elsewhere. This will require the addition of linking information that libraries, archives and museums have never had to store previously, as well as the use of standards for linking within a distributed system of repositories, standards that are at best inchoate at the moment.

As the above discussion should make clear, problems with descriptive metadata created within libraries, archives and museums today are not a matter of existing metadata being erroneous; rather it is simply insufficient. Given the increasing costs of generating metadata manually, this is clearly problematic. While some of the forms of metadata described above (e.g., links to representation information) will require decisions by professionals with significant expertise within the preservation field, other forms (e.g., contextualizing information) could be provided by anyone with a strong interest and knowledge of games. Given the number of individuals answering to that description, for games at least, cultural memory organizations should explore how they might enlist the aid of the communities they serve in the creation of metadata necessary to preserve these objects.

Collections: Data and Documentation

Collections of digital games and virtual worlds are, to a large extent, collections of software. Many of the preservation issues faced by repositories holding these collections are therefore problems of software preservation. However, software preservation only addresses one aspect of digital games and virtual worlds; focusing on software preservation was an important aspect of the PVW project, but other equally challenging problems emerged and were addressed by the project investigators.

It is important to emphasize here that virtual worlds are historical in two senses of the phrase: They are worlds of historical interest, and they are going to go away. In PVW, we explored some of the implications of the life-cycle of virtual worlds, especially of their extinction, for thinking about how the history of computer-based "worlds," as well as their use by communities of players or "residents," could be documented. The moment when a virtual world "is history"—when it shuts down—reminds us that every virtual world has a history. These histories of individual virtual worlds are inextricably bound up with the intellectual and cultural history of virtual world technologies and communities. They are also venues for historically specific events and activities. An important part of the historical context for virtual world history is the fact that human beings (through their avatars) fill these digital environments with meaning that emerges from their activities in social spaces, regardless of whether the spaces are synthetic (digital) or physical. So, in addition to preserving the software that provides the technical underpinnings for virtual worlds, our project faced the problem of how to identify, collect and preserve documents that convey events and activities that take place in virtual spaces.

Perfect Capture

Thinking of a game world or a virtual world as historical brings us directly to issues of historical documentation, digital preservation and curation of virtual worlds. What will remain of virtual worlds after they close down, either individually or perhaps even collectively, i.e., when the technology has become passé?

A notion that plays into the preservation discussion is particularly relevant here: namely, that of the potentially perfect reproduction of digital data. Recall that our digital personae, our avatars, and our player characters are ultimately all bits of data on a machine. Death switches count on that. If we can only get access to these data, shouldn't it be possible to copy them forever?

Consider an actual historical case, that of Chris Crosby, a.k.a. NoSkill. Crosby was the first of the highly skilled players of the on-line multiplayer game *DOOM* to be recognized as a "Doomgod." An active player from about 1994 to 1996, the young father was killed in a car crash in 2001. His memorial site on the web, like many others, depicts him in the prime of life, holding his young son, but it also offers a number of files for downloading (NoSkill Memorial Site, 2004). These files are demos recorded from games he played between May 1995 and April 1996. A demo, also called an lmp (from its .lmp or "lump" file extension), is a replay file. It is a recording of a game session in the form of a sequence of commands that correspond to input control states during each frame of the game, or "tic." *DOOM* players

could generate a demo file by simply entering the command "-record" in the console, a command-line interface that could be called up while playing the game. In other words, they could create a script—a sequence of instructions—generated from game data and save it as a demo recording. A recording in this format is much more compact than video captured from the screen. The catch is that the demo data must be run and executed inside a copy of the same game from which it was generated, and even from the exact same version of that game, if the game engine is to render the action correctly.

It is easy enough to download Chris Crosby's demo files from his memorial site and play these files inside the correct version of this old game, originally published towards the end of 1993. Indeed, *DOOM* is in the collection of digital games that have been preserved as part of PVW, so that several versions of the game, including the version Crosby played, will be available in the Stanford Digital Repository, for example. Playing Crosby's replay files is a profound experience. It means nothing less than experiencing a dead (historical) game through the eyes of a dead player, that is, seeing the game as he saw it. NoSkill in this sense comes back to life, as the replay file activates the game engine to carry out the exact sequence of actions enacted by the now dead player. Again, in this first-person shooter, we can see the game action through NoSkill's eyes. The player is dead, but it is now possible for his avatar in some sense to live on through an act of perfect reproduction.

Historians will be unable to help but contrast the potentially infinite repetition and perfect reproduction of NoSkill's game-play to the fading memories of his life … and death. At the same time that we are powerfully affected by revisiting a past experience, we know that what we are seeing may be an historical event, but without documentation it is not history. It is a remarkable act of software and data preservation, but it would be a mistake as we begin to stage early work on preservation of games and virtual worlds to frame these projects like PVW primarily, or even exclusively, in terms of software preservation and the perfect capture mode of game replays. This would be a barren exercise with respect to the documentation of the events and activities—the history—that has occurred in these worlds.

Perfect Loss

This is because future historians and others interested in the history of virtual worlds will not just want to experience what it was like to play a historical game or visit a world like *Second Life,* they will want to know much more about the things people were doing in virtual worlds, why they were doing them, and what their activities meant to them.

So perfect event capture with respect to digital data is possible, and replay offers a paradigm for perfectly reproducing the past, even seeing through the eyes of players who are no longer with us. From a historian's point-of-view, perfect capture is half of a paradox, for it must be placed alongside the very real possibility of "perfect loss" in digital spaces. If we save every bit of a virtual world, its software and the data associated with it and stored on its servers, it may still be the case that we have completely lost the history. To date, the virtual world has not yet been produced that offers vestiges or traces of the past after transaction logs or content have been removed from it. When the data is gone, it's gone. That is not the entire problem, however.

An example might help here. A few years ago, a series of nasty protests in the virtual world *Second Life* led to an attack on in-world buildings owned by the National Front. Reports about this clash appeared in blogs and forums visited by members of the *Second Life* community and others interested in virtual worlds not long after the events had occurred. After reading a witness's account of the events, many readers jumped into *Second Life* to see what was going on, only to find there was absolutely nothing to see. The National Front had already abandoned its Island and deleted all of the content there, essentially stripping the turf of every trace and artifact. The "world" revealed nothing of what had recently been a hotbed of activity and conflict. The only sources left were documents created and stored outside the virtual world itself – blog entries, forum posts, screenshots, etc., on the 2D web.

The historian Timothy Burke has described the difference between game-generated data and historical documentation in terms of what he calls the "proprietary" data of virtual worlds, meaning the data that is owned, or present on the servers that support that world: "... I think the one thing that *isn't* in the proprietary data is the history of unusual or defining episodes or events in the life of particular virtual worlds … The narrative history, the event history, of any given virtual world, may in fact be obscured by the kinds of god's-eye view data that developers have. After all, they often don't know what is happening at the subjective level of experience within communities, or have to react to it after it's happened. (Say, when players stage a protest.)" (Burke, 2006) Thus, focusing on preservation of what Burke calls proprietary data matches up poorly to the likely needs of future scholars of virtual worlds.

Consider another example that illustrates this point. In the first hours after the WTC and Pentagon attacks on 11 Sept 2001, online communities used systems such as massively multiplayer role-playing games as a medium for responding to the attacks. In games such as *Everquest* and *Asheron's Call,* players read news alerts either via in-game text or system announcement, while outside the world but still on-line, other players caught up via player community websites. Of course, others watched television, heard from friends, or even experienced the events up-close and personal. Within hours, players organized candlelight vigils for the victims of the attacks, using glowing weapons or other objects, taking screenshots and posting online to document their in-world activities and discuss what they meant in the context of the dramatic historical events unfolding around them. For a vigil

held on *Everquest*'s Luclin server on 12 September in response to "yesterdays [sic] disheartening display of events," players were invited to "mourn and discuss" on the Everlore website (Lowood, 2008). Players commented on the meaning of this action to them; one of them, with the player name Keeter, argued that, "Just because you are in a game doesn't mean the world outside doesn't effect [sic] you. Many people would like to mourn and share peace along side [sic] people they have battled long and hard side by side with. Yes, I can go to a church to mourn, but I would like to do it with my comrades around the country/world, which is impossible everywhere else. If you don't want to be a part of it, then dont [sic]. You can choose not to do it. But respect the people who would like to. We don't bother people that want to run naked gnomes through the country, so don't bother people that want to gather and discuss something important to us all." Documentation such as this quotation is necessary both for a full description of an event and for a rich interpretation of what the activities associated with that event meant to participants, no matter what kind of world we are talking about.

There are three important points here with regard to a preservation project focused on software and game-produced data. First, inside *Everquest* today there is no trace of these events. Assuming that the game world has not been deleted, erased or remade (untrue), that we are on the right server or shard of the game, and that we are standing on precisely the spot where such a vigil occurred, it is generally not possible to dig beneath the surface, scratch underneath a poster, or find a file cabinet of documents or an old newspaper in a nearby building. There are exceptions, such as a monument on a specific *Asheron's Call* server that commemorated a unique achievement by its players, but such exceptions are rare.

Second, this lack of in-world artifacts and documentation clearly has implications for long-term preservation that focuses on game software and server-side data. Assume that we are able to capture every bit from a virtual world server, everything from 3D models to account information, that we are able to reverse engineer or disable authentication and log-in controls after the original server is no longer live, and that we have received permission from every rights holder ranging from game developers to third-party developers and players to copy, store, and use what they created, show their avatar, or reveal their identity and activities. The chances of all this actually happening are near zero, of course, but assume that it all could be done. Then assume that we can sync up every state or version of the software to the matching states of databases. It might then be possible to run a simulation of the virtual world as an archival time-machine, flying around on a magic carpet in spectator mode but never interacting with events run by the game engine and player data, much like a game replay. Turn the dial to 12 September 2001, and you might find a group of players standing around with brightly colored weapons and wands in their hands. But what are they doing, and what does it mean to them?

The third point then is that the documentation that is a prerequisite for future historical studies of virtual worlds may not be located on game servers at all. The most important qualitative documentation may be somewhere else, on a blog or a wiki, in a player-created database or Flickr screenshots, or a YouTube video. The same may be true for some of the contextual information desired under whatever set of transfer protocols or preservation specifications a project is using, even sometimes for technical aspects such as software dependencies or relationships among objects. Game researchers such as Dmitri Williams have extracted and analyzed a wealth of quantitative data from virtual worlds; they have used

these empirical data to explore social and economic aspects of these worlds. Such research rarely has access to server-side data, but instead relies generally on surveys, participant observation or data harvested on the client side using bots or automated characters. (Williams et al., 2006). The point is that writing the history of virtual worlds on the basis of software and of associated data alone would be a barren exercise. Installing *Everquest* in 2050 will not reveal much about the virtual world that emerged from the software, even if future writers and historians have access to everything needed to run a fully functioning version of the game. Certainly, there are still important reasons for preserving this software, whether as artistic or cultural content, for technology studies, or for forms of scholarship that treat aspects of digital games and virtual worlds as authored texts or artistic objects. Still, we need to think more about virtual world history in terms of events and activities, much as an archivist or historian would in the real world, and attend more carefully to preservation of forms of documentation in digital form that are external to virtual worlds as software environments.

Implications for Collections

One way of characterizing the mix of software preservation and documentation activities necessary to preserve virtual world content and history is to think of the primary collections as a mix of "library" (published digital games and virtual world content) and "archives" (documentation about game/virtual worlds). This is, of course, a familiar model for cultural repositories such as libraries. However, the nature of digital games and virtual worlds as software objects and the particular ways in which events and experiences in these virtual spaces are mediated and reported carry significant implications for collecting strategies as well as preservation.

It is high time to review a few of the issues that have surfaced in the Preserving Virtual Worlds project with respect to collection and preservation of data and metadata. The first issue has already been set up in the discussion of virtual worlds as history. What exactly are we trying to preserve? Specifically, is virtual world preservation focused on the software and server-side data that in some sense defines or encompasses the "world" as a created artifact, or are we looking for materials in digital form that document the activities of players or "residents" of these spaces? There are at least two other ways to shape this distinction. The first is to separate developer-created or -managed materials from those created or managed by players. The second, as already noted, is to distinguish repositories of virtual world data as essentially libraries or museums of created artifacts or texts from archives of documentation about events. However, depicting virtual world preservation as a binary proposition such as developer vs. player or artifact vs. document is ultimately unnecessary and counter-productive. Certainly, there is value in preserving both software artifact and event histories. The most productive approaches to virtual world preservation will be those that integrate artifact and documentation in terms of collecting focus, evaluation of digital content objects, organization of content transfer packages, metadata creation and access strategies.

Consider a problem that might seem to be entirely a matter of treating the essential task of game preservation as software preservation, yet turns out to have crucial implications for documenting player behavior and history: software versions. In the Preserving Virtual Worlds project, we decided early on to limit our attention to a dozen or so representative case studies, rather than a comprehensive collection of software or data. One of our key cases has been the computer game *DOOM*, created by id Software. *DOOM* is a multiplayer, first-person shooter, and while now is not the time to delve into game history, suffice it to say that this game immediately transformed competitive, multiplayer gaming into the leading-edge genre for computer games through the 1990s. There are two other aspects of *DOOM* that are important with respect to preservation. First, it was distributed first and throughout its history in shareware versions that featured a limited number of episodes of the game; the idea was that the shareware version would hook players on the game, so they would then purchase the full version. Second, the developers of *DOOM* openly embraced modification of their software by the player community, and by implication revision of the notion of game authorship, which immediately de-stabilized the notion of a canonical version of the game. Defining a version of the game *DOOM* therefore involves considerable attention not only to a sequence of patches and versions, but also to combinations of developer-produced software, third-party add-ons and player-developed modifications, better known as mods.

De-stabilizing the notion of a fixed version of software is not just a problem when we attempt to determine what versions to preserve and how to account for revisions and

changes. It also raises significant issues that affect the documentation of player activities in the game. A crucially important category of objects that provide this documentation are produced by players' efforts to capture their experiences through replays, screen captures and screenshots. In the case of *DOOM*, we have already seen how NoSkill's demo files make it possible to view the actions of one of this game's earliest and best competitive players. Again, *DOOM* demos were essentially replay files, saved sequences of instructions from a previously played game that, when executed by the game software, would show the same game from the same (first-person) perspective of the original player. In other words, demos are recorded game play sessions that are played by the game engine. The same is true of replay files in later games, such as Blizzard's *Warcraft III*, up to the present day. Unlike video files captured from the screen or video-card output, demos or replays allow different views and settings as permitted by the game software and the best visual quality that the software will produce. However, this all is possible only when a running version of the game engine is available in order to view these replays. Not only that, the version used to view the demo or replay nearly always must correspond exactly to the version that was played when it was created. Therefore, any decision about which version of the game will be preserved determines which replay or demo files will be viewable in the future. Likewise, any decision about which demos or replays are historically significant in terms of game culture or history will presuppose preservation of the appropriate version of the game software. Treatment of the software artifact affects documentation, and selection of documentation affects treatment of the software artifact. At least in the realm of virtual world or digital game history, separation of these treatment decisions into specialized areas or departments may lead to disastrous consequences for future archivists and historians.

A second example with respect to virtual world data and metadata also speaks to the necessity of maintaining contact between collections and their contexts, as well as between projects of software preservation and historical documentation. This example suggests that documentation can also serve as a category of metadata for virtual world data.

An interesting quality of virtual and game worlds is that many of them can be navigated by in-world coordinate systems, much like real-world cartography. Two well-known examples are the "Second Life URL" (SLURL) in *Second Life* and the UI coordinate system in *World of Warcraft*. Just as we can mash up data by attaching GPS coordinates to real-world maps, photographs, and other media, these virtual world coordinate systems might make it possible to match documentation we have assembled in our virtual world collections not only to locations in virtual worlds, but also to each other. In the case of the video collection, however, the metadata scheme based on Dublin Core already provides the "coverage" element for individual objects. As the Dublin Core specifications tell us, this element can be applied "for the use of multiple classification schemes to further qualify the incoming information" such as latitude and longitude or other "native coordinate representations." (Becker, et al. 1997) The Internet Archive's Heritrix-based crawler allows collection curators to input metadata tags at the document level for web pages harvested through crawls; by adding a tag for a specific SLURL, say, to a document describing an event that occurred in *Second Life*, we can thus link documentation to in-world locations.

Using virtual world coordinates might help us bridge the gap between documentation and mute server-side software and data with respect to "event history," perhaps offering a solution to the problem of perfect loss in virtual world history. Here is a specific use scenario. A cultural historian is interested in the use of game worlds for scholarly communication and learns about the first science conference held in *World of Warcraft*, in May 2008 (Bohannon, 2008). She finds videos documenting this event in the Archiving Virtual Worlds collection, but they are a bit grainy and she is curious about the locations chosen for the event. So as part of her "fieldwork," she installs and fires up the game world. Then, using the coordinates conveniently provided by the collection metadata, she ports to the location where the conference was held and, using her avatar, walks the terrain depicted in the video. This scenario will work better in game worlds, where developers maintain relatively stable environments with respect to content, than in virtual worlds such as *Second Life,* where residents such as the National Front are free to delete everything they created. However, if we are able to maintain backups of content as part of a package of data associated with a virtual world, this problem will be alleviated. For now, it is sufficient to observe that, as in the case of *DOOM* demos, useful connections between documentation and data will only be available to historians and other researchers, if curators and archivists work closely along these lines with software preservation specialists.

Examples of Collections and Impact of Preserving Virtual Worlds' Collection-Building Efforts

Currently, there are only a few significant library collections of historical game and virtual world software. These collections also include archival documentation, hardware artifacts (such as game consoles and realia), and print collections related to digital games. They include the Stephen M. Cabrinety Collection in the History of Microcomputing in the Stanford University Libraries (http://www.oac.cdlib.org/findaid/ark:/13030/kt529018f2), the International Center for the History of Electronic Games at the Strong National Museum of Play (http://www.icheg.org/) and the UT Videogame Archive at the Dolph Briscoe Center for American History, University of Texas at Austin (http://www.cah.utexas.edu/projects/videogamearchive/).

The Cabrinety Collection was a resource for the Preserving Virtual Worlds project, as it is held by one of the project partners, the Stanford University Libraries. Stanford's How They Got Game was founded in 2000 to begin work on the history and preservation of digital games and interactive simulations. The founding of the project was stimulated by Stanford's acquisition of the Cabrinety Collection three years earlier. Today, the collection remains perhaps the largest collection of microcomputer history held by a major cultural repository, with approximately 20,000 software titles, roughly 85% of which are digital games, some 75 hardware platforms, publications, ephemera, and archival materials. How They Got Game continued earlier work in software history and archives carried out under the auspices of the Silicon Valley Archives at Stanford, and this activity is closely tied to related archival collections, such as the papers of Steve Meretzky and Hal Barwood, and records of the 73 Easting Simulation and HPS Simulations. The linkage of library and archival collections is similar at both UT Austin and at the Strong Museum.

As part of the Preserving Virtual Worlds project, the How They Got Game group at Stanford has created three collections to document virtual world events using largely player-generated content. The first is the Archiving Virtual Worlds collection (http://www.archive.org/details/virtual_worlds) hosted by the Internet Archive as part of their Moving Image Collections; the second is the Machinima Archive (http://www.archive.org/details/machinima), a curated collection of the emerging medium of game-based moviemaking known as machinima; and the third is a curated collection of websites related to digital games and virtual worlds hosted by the Internet Archives Archive-It service (http://archive-it.org/). The Archiving Virtual Worlds collection is particularly relevant to the discussion of documentation. It consists in large part of video footage made with real-time screen capture tools such as Beepa's Fraps. The "Final Countdown" video that documented the last minutes of *EA-Land* is an example of the content preserved in this collection. The Machinima Archive is dedicated to the academic investigation and historical preservation of the emerging art form known as machinima. Machinima is filmmaking within real-time, 3D virtual environments such as games and virtual worlds, usually made from existing video game engines, whether through editing of replay files ("demo"), video captured from the screen or graphics card, or composited game assets. Machinima "capture" of in-game performance, sometimes called "virtual puppeteering," provides a model for the creation of high-quality video that documents player activities inside a game or virtual world. Last but not least, the How They Got Game project established its subscription with the

Internet Archive's Archive-It service in early 2008 for the purpose of crawling, saving, and making searchable numerous game- and virtual world-related websites. In two Archive-It collections ("digital games" and "virtual worlds"), we have seen to the preservation of videos, weblogs, wikis, player-created websites, maps and many other forms of documentation that provide information about player activities. These activities might include modifying game software, demonstrating skills through superior game-play, commenting on events such as protests or artistic performances, or anything else that someone who has spent time in a virtual world might consider important. A particular emphasis of the documentation activity undertaken through Archive-It has been the preservation of web-based collections of player-created maps, walkthroughs, exploit videos, glitch hunting, and other activities that deeply explore in-game and in-world spaces.

Compared to institutional collections of digital games and design archives, collections of player-created documentation relating to activities and events in game and virtual worlds have only begun to emerge in similar institutional contexts backed by preservation solutions. On the other hand, vast troves of such documentation maintained by individual collectors and players, fans and fan groups, and projects (such as MobyGames) have been assembled and maintained. The Archiving Virtual Worlds collection, the Machinima Archive, and the How They Got Game Project's Archive-It collections will all be preserved as part of the Internet Archive's collections, with backup in the Stanford Digital Repository. These collections complement and supplement the project's efforts to work out schemes for long-term preservation of digital game software and assets by documenting in-game and in-world activities and events, player culture, and the efforts made by the player and, to some extent, the developer community to save, preserve and provide access to historical documentation about games and their cultural impact as well as game content.

The Contributions of Game Communities

Prior to recent efforts such as those of the institutional repositories mentioned above and the Preserving Virtual Worlds project, it is fair to say that nearly all of the significant efforts towards collection, preservation, documentation, enunciation and emulation of game content, technology and culture were due to the work of players and fans, or individuals with experience in the game industry. Examples of such efforts include the MAME community on the emulator front, the Software Preservation Society (founded as the Commodore Amiga Preservation Society) on the data migration front, or the work of collectors such as Frank Cifaldi's "Lost Levels" project and website (http://lostlevels.org/).

One of the activities specified by Library of Congress in the award of the NDIIPP grant to the Preserving Virtual Worlds project was outreach. In the project, we emphasized two kinds of outreach with the specific goals of (1) encouraging better contact and communication between communities of players, developers and fans and cultural repositories working in the area of game and virtual world preservation; and (2) opening up channels for the exchange of information among these various groups and institutions.

We believe it will be necessary to encourage more contact between the various communities and individuals with an interest in preserving the history of digital games and virtual worlds and cultural repositories such as museums and libraries building programs for game preservation. The disconnect between active collectors and programmers building software

such as emulators is not unique to game preservation, but is a problem for computer history more generally. An important moment in awareness of the value in forging such contacts was provided, for example, by the "The Attic & the Parlor: A Workshop on Software Collection, Preservation & Access," which took place at the Computer History Museum in Mountain View, California, in May 2006. One of our project members (Curator Henry Lowood at Stanford) was on the organizing committee of this meeting and facilitated the proceedings. The meeting included library and museum curators, corporate archivists, and individuals active in collecting and preserving software, and highlighted the benefits to repositories of working with broader communities, both with respect to collecting and technology.

Preserving Virtual Worlds contacted a number of game companies, collectors, and players throughout the course of our various activities. On the basis of these contacts, we were able to open up channels for exchanging information among these various parties. While we believe that much more work can be done in this area, we can point to two specific examples of our activity as possible models for future projects and programs. The first is our work with the International Game Developers Association (IGDA), specifically, the Game Preservation Special Interest Group (SIG). Quoting from its own website, "The International Game Developers Association is the largest non-profit membership organization serving individuals who create video games. We bring together developers at conferences, in local chapters and in special interest groups to improve their lives and craft" (http://www.igda.org/). While the IGDA serves its mission in many ways, the special interest groups are the focus of member-based activities in a variety of areas, ranging from specific game design areas to quality of life concerns. The Preservation SIG serves as a "meta-resource, hub and community for those interested in digital game preservation and history." The SIG, with roughly 75 members, maintains an e-mail discussion that emphasizes game preservation related news and projects. It has sponsored events at the mammoth annual Game Developers Conference (such as the Digital Game Canon), where it also hosts an annual round-table for members and other interested parties, and aims "towards setting standards and guidelines for assisting industry/academia in establishing preservation efforts."

One of our project members (Lowood) served through the course of PVW as chair of this SIG. Reports on the status and results of the project were delivered to the group and discussed at the annual round-table meetings in 2008, 2009 and 2010. Moreover, several project members (e.g., McDonough, Donahue) joined the SIG and thus participated in on-line discussions of a variety of technical, game, and legal issues via the e-mail forum. In 2008, the SIG launched an effort to raise awareness among IGDA members of the importance of digital game preservation, both as an issue for the industry and as a matter of concern for individual members who collect games or for whom games are an important part of their lives and shared culture. A committee of the SIG began work on a two-part effort to produce easily distributed publications about game preservation. The first is a white paper describing the problem of the possible loss of game content and culture if no action is taken and the challenges facing preservation activities. The second would document best practices after the conclusion of the Preserving Virtual Worlds project. In March 2009, the first white paper was published under the title, *Before It's Too Late: A Digital Game Preservation White Paper,* with publication support provided by the IGDA in the form of a grant to the SIG. It was announced at GDC 2009, where a limited number of copies were distributed; since that

time, it has been available either as a free download or a modestly-priced print publication via Lulu Press (http://www.lulu.com). *Before It's Too Late* includes contributions from PVW. Lowood edited the volume and Donahue distributed two surveys, "Records Management in the Gaming Industry" and "Preservation Activities in the Video Game User Community" as appendices to the white paper. It is anticipated that work will begin on the best practices document in 2011.

A second major outreach activity of the project was the Play - Machinima - Law conference hosted by the Stanford University Law School and the How They Got Game group at Stanford. This two-day conference covered key legal issues associated with player-generated content. The specific focus was machinima, computer-animated cinema that is based on 3D game and virtual world environments, technology, and content. Issues of player-generated content play into many areas of concern to the Preserving Virtual Worlds project as a whole. The specific context of machinima production provided a lens for looking at these issues in detail, while also narrowing the scope of the conference to manageable proportions. Speakers included machinima artists/players, legal experts, commercial game developers, and game researchers; participants from Preserving Virtual Worlds included Lowood, Bittanti and Rojo (as organizers, moderators, and speakers), McDonough and Kraus (as speakers). Topics included game art, game hacking, open source and "modding," player/consumer-driven innovation, cultural/technology studies, fan culture, legal and business issues, transgressive play, game preservation, and notions of collaborative co-creation drawn from virtual worlds and online games. A particular focal point and the main topic of the second day was a document drafted by a team from the Stanford Law School as guidance concerning copyright law for machinima artists. With input from the conference and the IGDA Preservation SIG, that document will be produced as part of the Preserving Virtual Worlds effort and is discussed in more detail elsewhere in this report.

The outreach efforts of the Preserving Virtual Worlds project, both with respect to the IGDA Preservation SIG and the Play - Machinima - Law conference, demonstrated the importance and potential gains from encouraging contact, discussion and collaboration among cultural repositories, the game industry, and the various communities with an interest in game cultures.

Problems/Opportunities in Access

Assume again that we are able to save all the software and server data for a virtual world, game world or simulation and put it into a digital repository in a library. When a historian fires up this virtual world fifty years from now, it will be empty. Moreover, the documentation that will be a pre-requisite for future historical studies of virtual worlds won't be there. It never was. The most important qualitative documentation was somewhere else, on a blog or a wiki, in a player-created database such as Thottbot, in technical documentation, or Flickr screenshots, or a YouTube video. The same may be true when a future repository attempts to fire up some ancient software. If contextual information, such as software dependencies or descriptions of relationships among objects, is not provided under whatever set of transfer protocols or specifications a project is using—and all the retired software engineers are gone—it may be impossible to get old software to run.

We suggested earlier in this report that nobody writing the history of virtual worlds will be

able to do much with software and associated server-side data alone. Installing *Everquest* in 2050 will not reveal much about the virtual world that emerged from the software, how it was built or used, even if future writers and historians have access to everything needed to run a fully functioning version of the game. Certainly, there are important reasons for preserving this software, whether as artistic or cultural content, for technology studies, or for forms of scholarship that treat digital games and virtual worlds as authored texts or artistic objects. Still, we also need to think about virtual world *history* in terms of events and activities, much as an archivist or historian would in the real world, and attend more carefully to preservation of forms of documentation in digital form that are external to virtual worlds as software environments. Software preservation without historical documentation of in-world events will be a barren project.

These considerations bring us to specific *future* use cases and scenarios. Who might want to have a look inside a historical virtual world, and why? And how might future librarians provide access to them? Consider the following hypothetical use scenario:

- A historian is interested in the cultural and social history of virtual worlds. His attention is drawn to vigils that were held in game worlds such as *Everquest* and *Asheron's Call* after the WTC and Pentagon attacks on 11 September 2001. He would like to know more about virtual communities and the meaning to them of such events. However, it turns out that no data other than backed-up chat logs—which soon would be deleted—was ever kept on the game servers. Surviving documentation can only be found via the discussion boards, websites, and screenshots saved by players. Although he is interested in the virtual world's history, his search for documentation depends on web archiving efforts and personal digital collections. Will full-text searching of this vast amount of material yield the documents he needs? Or will finding needles in the web haystack require document-level indexing with specific date, location, or event tags?

The moral of this example? Documenting virtual worlds through software and data preservation *alone* will not do the job. As we have already suggested, there will be no trace of past events inside a virtual world, at least not the present generation of these worlds. We noted one exception earlier (in *Asheron's Call)*, but they are rare. Here is what this means. Assume again that such a world has not been deleted, erased or remade, that we are on the right server or shard of a game or virtual world in which some documented event happened, and indeed that we are standing on precisely the spot where a historical event such as a conference or vigil occurred. We cannot dig, find old documents or inspect traces of the past on the site. Installing *Everquest* in 2050 will not reveal much about the virtual world that emerged from its game software. Nothing of the events that shaped player culture, game politics and relationships between players and developers will remain. Like Ozymandias' giant leg in the desert, the surviving software artifact will tell us nothing about what "once dwelt in that annihilated place." Future researchers will be sorely disappointed if we do nothing to ensure that historical documentation about virtual worlds, but created outside them, is preserved along with software and proprietary data.

Now that we have introduced potential users for our virtual world collections, we will say more about access. Access is perhaps not a core concern for digital preservation per se, and there were no specific project deliverables that involved investigation of an access model or solution. Still, the Preserving Virtual Worlds project, due to its participants and its problem-sets, highlights the importance of finding solutions for problems such as identifying significant digital artifacts or developing standards for metadata. A key element in finding solutions to problems such as these is the collaboration of individuals and teams with different perspectives on software preservation, archives, and history. As a consequence of the Stanford group's connection with a separate project team (led by the former project manager of Stanford PVW effort) concerned with the development of 3D environments for scholarly applications, we roughed out a concept and began development work on an access/delivery environment that might address some future access issues.

Specifically, we began to re-think access to documentation and artifacts from virtual worlds collected in cultural repositories and, with that foundation, begin working on an approach to access that could lead to an alternative model for preservation of 3D artifacts from games and virtual worlds. A collection of such assets would include models, maps, geometries, textures, transactions, and so on. In working on this problem, we have been inspired by Ivan Sutherland's earliest essay on virtual reality, "The Ultimate Display." In this case, however, we are working on an approach to access that may lead to an alternative model for preservation of 3D artifacts built for games and virtual worlds. This work depends once again on collaboration, in this case, on the allied project just mentioned above. Based in the Stanford Humanities Laboratory and the Computer Science Department, this project has been developing next-generation, virtual world platform called Sirikata. Sirikata is a BSD licensed, open source platform. The development team aims to provide a set of libraries and protocols that can be used to deploy a virtual world, as well as fully featured sample implementations of services for hosting and deploying these worlds. An alpha version has been used for a mixed reality performance at the MiTo International Festival of Music in Milan, 12-13 September 2009, and is currently live for an installation at the Bornholm Art Museum in Denmark.

Think about the assets and content that go into the creation of a virtual world: models, maps, geometries, textures, and so on. We are not sure yet how future scholars will visualize, analyze, and understand these artifacts in a digital repository consisting of data files and metadata. In administrator mode, which is what we have today, the Stanford Digital Repository is essentially a file directory. Now think about another model of access to artifacts from an historical world, also largely models and suitable spaces for these models: a natural history museum showing dinosaur skeletons in a set that takes the visitor to a prehistoric savannah. Access to the information preserved there is visual and is reinforced by immersion in the world of the artifacts. It should be possible to do something similar with 3D artifacts from virtual and game worlds.

We are investigating the use of the Sirikata platform for the creation of a new kind of repository, one in which 3D objects are stored, retrieved and investigated as 3D objects. This means that we would like to be able to move original geometry and texture data—archival assets—from their original environments into such a repository. The two cases we are investigating are (1) digital artifacts such as maps or levels from 3D games, beginning with

early titles such as id Software's *DOOM* and *Quake*, and (2) exhibitions created in virtual worlds such as *Second Life* by cultural institutions, including libraries and museums. Can we move these objects into an instance of an open virtual world platform such as Sirikata? If so, might we think of these instances as virtual wings of a library, rather than file repositories, places where the historical artifacts are deposited, preserved, found and investigated in an environment that puts documentation and narrative alongside the artifacts?

Maps are among the most important artifacts in game development and player cultures. Players analyze them, re-create them as mods in games other than the ones in which they were originally created, and build viewers and projections so as to better visualize how to optimize their game-play in these spaces. As artifacts in a digital repository built with virtual world technology, historical maps would not just be artifacts, they might also provide spaces in which to site other objects and documentation—such as models, screenshots, videos, or documentation—that provide information about what took place in these settings. This might be where our future historians goes to check out the locations used for the science conference held in *World of Warcraft*, for example, without having to assemble, install and figure out how to use the original movement and navigation systems of the game's user interface. While further development work is necessary to realize this vision, we have already successfully exported levels (maps) from id Software's *Quake* (1996) to the open VRML format, from which we are able to move unaltered geometries and textures from this historical digital artifact to other environments, whether Maya, 3DS Max, or Sirikata. When the pipeline to the Sirikata-based virtual repository is completed, it will be possible to drop in to Sirikata and see 3D objects with the same geometries and textures they were given in the original game. In fact, these artifacts will be created from certified copies of original game data used to produce them in the first place, utilizing forensics techniques for data extraction and the preservation methodologies worked out in the Preserving Virtual Worlds project. Future access environments for digital repositories will need to consider how to provide scholars with access both to digital artifacts from environments such as virtual worlds and to digital documentation about these artifacts and worlds. Bootstrapping virtual world technology as a means for re-conceptualizing the digital repository as a 3D environment rather than a file system provides a potential solution to this problem and deserves further investigation with the specific goal of developing access solutions for virtual world and game assets.

5. Software Preservation and the Law

Copyright Issues: Complex Ownership and Orphan Works

> *The owner of IP has the right to transfer all rights by assignment, or a portion of the rights by license. The rights may be placed in the public domain, either intentionally, through IP misuse or neglect, or as the result of expiration of a registration. Or the owner may elect to make no use of the IP rights and to prohibit others from use. It has been charged that some patents are procured not to protect the owner's use but to prevent use of the invention by competitors.*
>
> – *Introduction to Game Development*, Ch. 7.5, "Transfer of IP Rights"

Copyright

The most basic preservation action for any digital object is to convert it into a media-neutral format. This is typically done by creating an image of the original media; that is, making an exact, bit-for-bit replica of the disk that can then be mounted from the hard drive or burned to a fresh disk (e.g. an ISO or IMG file). In other words, the simplest and most common preservation process violates reproduction *and* (usually) anti-circumvention provisions in U.S. intellectual property law.

Copyrights held by corporations endure for up to 120 years, and under the DMCA cultural heritage institutions enjoy no special privileges. A video game console generation typically lasts less than a decade. We are currently in the 7th generation of consoles, and personal computers have evolved in equally dramatic ways since Apple II and Commodore 64 began saturating the home PC market. Given the difficulty of identifying and then obtaining permission from the current rights holders of older video games, this translates into libraries risking fines of $200-150,000 per game were they to migrate their collection of classic software from 3.5" floppy disks to images stored on hard drives, an act comparable to rebinding a book or creating an access copy of a manuscript.

Patents

According to Stephen Rubin, video game patents (or at least litigation surrounding them) most often center on game controllers, consoles, and peripherals (Rubin, 2010). As patents have the shortest lifespan of all intellectual property protections, and outside of museums hardware is likely to be discarded in favor of accessing the games on modern computers, they have far less of an effect on cultural heritage institutions. Even so, at least two generations of game consoles have passed by the time a patent expires (20 years from the time of filing) and there is a danger of hardware becoming irreparably damaged after support has stopped, with no legal option to build a replacement.

The Vectrex console, released in 1982, was unique for two reasons: it used vector rather than raster graphics, and it was the first console to offer a 3D peripheral. The Vectrex had a short market life, and the 3D Imager an even shorter one—making it a very rare, and expensive device. The rarity makes the games even more appealing to collectors and, in a display of

typical resourcefulness, someone in the video game community began building 3D imagers from breadboards and portable CD players (Woolff). Because the Madtronix Imagers were produced in 2005, the original patent had expired and Woolff was able to sell them for about $75 each, a far cry from the $700 or more you might pay for one on the grey market, if a functional 3D Imager could even be found to purchase. Without this peripheral, a number of games are rendered unplayable, and preservation is meaningless without access. Although in many cases hardware upkeep is not sustainable, there are instances when the device is unique enough to be worthwhile.

The majority of video game patents may be hardware related, but patents on software, a fairly controversial topic, do exist. Rabin cites Sega, Nintendo, Sony, and Microsoft as all having patents on game play. Patents of this nature serve to strengthen the protections already offered to individual games by copyright.

Trademark

Unlike copyrights and patents, as long as a trademark is used and protected (that is, the owner doesn't look the other way when made aware of infringement), it never expires. Historically, trademarks have simply been logos or other commercial identifiers. With video games, flagship characters become brand identifiers and thus eligible to be registered as trademarks. This could potentially mean that works that would otherwise enter the public domain in a fixed time period could be monopolized by a progression of rights holders for centuries.

Trade Secrets and Licensing

Trade secrets and licensing add further complexity to the web of video game IPR. Trade secret regulations are not as well known or clear-cut as the three major categories of protections. Without even getting into the mire of contract law created by end user license agreements (EULAs), licensed content (for instance, games released with a major motion picture) makes the task of identifying rights holders and obtaining permissions far more arduous. In the book *Challenges for Game Designers*, a great deal of time is spent discussing how to work with licensed content and how to pitch proposals for sequels and other licensed works. Combined with the proliferation of titles on the shelves using characters from Marvel, Disney, and other media giants, this seems to indicate that video games utilizing licensed IP are a sizable chunk of the existing catalog, and so are also likely to be included in any video game preservation projects.

Emulators & the Law

We have argued for a greater degree of collaboration between the gaming community and the preservation community in insuring the longevity of games. The gaming community has been exceptionally active in the creation of emulators to enable access to older games. If emulation is to be used as a preservation strategy for some types of games, then it would behoove the preservation community to take advantage of the large amount of prior work done by the gaming community in creating and disseminating emulators for various platforms and, if possible, contribute to their further development as necessary. If

preservationists are to become actively involved in the creation and dissemination of emulators, however, they need to do so with a full awareness of the legal issues surrounding emulators' creation and use.

In the eyes of the law, the creation of an emulator constitutes a form of reverse engineering, in which an existing computing platform is disassembled and examined for the purposes of replicating its behaviors and operations in a new platform. While generally speaking the courts have found reverse engineering to be a legal activity, the ability to create an emulator can be limited by various laws, including copyright law, trade secret law, patent law, the Digital Millennium Copyright Act (DMCA), contract law, and the Electronic Communications Privacy Act (Electronic Frontier Foundation, 2010). To date, most of the court cases regarding emulators' creation have focused on copyright law, in particular on the extent to which an emulator's creator may examine and use software from the original computing platform when creating the emulator.

Two of the most significant pieces of case law regarding emulators have been the cases of *Sega Enterprises Ltd. v. Accolade Inc.* (977 F.2d 1510 [9th Cir. 1992]) and *Sony Computer Entertainment v. Connectix Corp.* (203 F.3d 596 [9th Cir. 2000]). In *Sega*, Accolade reverse engineered the Sega Genesis console platform by wiring a decompiler to a Sega Genesis system and loading different games on it in order to determine the interface specifications for the console. Accolade used the information obtained by decompiling the Sega Genesis software to create a software specification that they in turn used for creating Sega Genesis compatible games. The Ninth Circuit Court found that Accolade's actions constituted fair use, as they had engaged in copying of the software embedded in the Sega Genesis system only to be able to access the "unprotected ideas and functional concepts embodied in the code," and disassembly of the code was the only means of gaining access to those ideas and functional concepts.

The *Sony* case, however, is the more definitive ruling on the legality of producing and marketing an emulator. In this case, Connectix extracted the contents of a Sony Playstation's BIOS and disassembled it in order to determine its behavior as part of creating an emulator, the Virtual Game Station, that would run Playstation games on Windows or Macintosh computers. As in the *Sega* case, none of the actual code from the Playstation system was used in the Virtual Game Station; Connectix merely studied the original code in order to replicate its behavior. The Ninth Circuit Court found that the extraction and examination of the Sony Playstation BIOS constituted fair use, as in the *Sega* case. The *Sony* decision, however, goes into far more detail regarding the court's analysis of the four factor test involved in a determination of fair use.

The court found that the purpose and character of the use made of the Sony BIOS by Connectix was "modestly transformative," in that it established a new platform on which consumers could play Playstation games, and that therefore this factor favored Connectix. On the second statutory factor, the nature of the copyrighted work, while the court recognized that software deserves copyright protection, it had previously ruled that such protection is less than that offered to "traditional literary works," and found that in this case, the standard set in the *Sega* case, that copying be necessary to access the functional aspects of the software had been met, and this factor also favored a finding a fair use. While the third factor, amount and substantiality of the portion used, weighed against Connectix (inasmuch

as they had copied the entire work), the court also recognized that the copying had occurred as an intermediate step in the production of the Virtual Game Station, and that none of Sony's software had actually appeared in the released product. On the fourth factor, the effect of the use upon the potential market, the court somewhat interestingly found that while the Virtual Game Station might negatively impact Sony's sales of the Playstation, the transformative aspect of the Virtual Game Station meant that the VGS did not simply supplant the Playstation, and that therefore, this factor favored Connectix as well.

The courts to date, then, have found that as long as an emulator does not include software taken from the original system, it does not directly infringe upon copyright. The gaming community has discussed the possibility that the creators of an emulator might be taken to court for contributory infringement, on the theory that by enabling others to play games on a platform other than the original, the creators of an emulator are inducing others to illegally copy game software to enable it to work with the emulator. As far as we know, the courts have not directly addressed this issue. In other cases that have focused on technological devices' role in contributory infringement (see, for example, *Sony Corp. v. Universal City Studios, Inc., et al. 464 U.S. 417* [1984] and *MGM Studios, Inc. v. Grokster, Ltd. 545 U.S. 913* [2005]), the courts have focused on the issues of whether the technology has significant non-infringing uses, whether those responsible for producing the technology were in a position to control the behavior of those infringing on others' copyrights, whether those producing the technology promoted the use of the tool for infringing activities, and whether those producing the technology materially benefited from the infringing activities of others. Any library or archive wishing to become involved in the creation of emulators needs to be aware of these issues surrounding contributory infringement, and avoid any activity that might be seen as encouraging others to infringe copyright or profiting from others infringing activities.

There are a number of other legal issues that may arise with respect to the creation of emulators other than copyright issues. In the *Sony v. Connectix* case, one of Sony's accusations was that Connectix had tarnished Sony's Playstation trademark by the negative associations that would arise in users' minds regarding Playstation games if they played them under the Connectix Virtual Game System and had an inferior experience of the game. While the court rejected this argument, stating that consumers would be able to distinguish between the two platforms and avoid misattributing quality issues to the Playstation brand, the existence of this complaint does indicate that those creating emulators may need to be careful to avoid any appearance of intruding on companies' trademarks.

Contract law and the Digital Millennium Copyright Act may also impede programmers' ability to create an emulation of an existing platform. In *Davidson & Associates DBA Blizzard Entertainment, Inc.; Vivendi Universal Inc. v. Jung et al., 422 F.3d 630* (8th Cir. 2005), Blizzard Entertainment sued the developers of BNETD, a reverse-engineered implementation of the Battle.net online gaming servers that support multiplayer online games from Blizzard such as *Diablo*, *Starcraft* and *World of Warcraft*. Blizzard claimed BNETD's programmers had agreed to the Battle.net end user license agreement and terms of use when they signed up for the service, and the EULA and TOU for Battle.net specifically prohibit reverse engineering. The court upheld the license agreements as enforceable contracts and found BNETD's developers in violation of the EULA. The court also found that BNETD's developers

violated the anti-circumvention provisions of the DMCA by emulating the authentication sequence used by Battle.net servers when establishing communication with a client game.

As a sidebar to this court ruling with respect to emulation, it should be noted that BNETD source code continues to be widely disseminated and that hundreds of servers around the world based on this code are openly operated. This observation raises the possibility that content created on such a private server (replays, machinima, modified assets) might become part of a future archive or collection; indeed, it is likely that some of this content is already evident in a collection such as the Machinima Archive. As part of our collaboration with the Center for Internet & Society at the Stanford Law School, we consulted with legal staff and students at the law school to discuss the specific issue of the liability of a repository (such as the Internet Archive) in such an instance. While in the absence of a specific example or legal action, PVW was not in a position to obtain legal advice and there has been to date no clear legal precedent in this area, it appears that the exposure of an archival repository to legal action due to the inclusion of such content in a video, for example, is likely to be quite small. In the case of an objection to making such a video available for viewing, it is likely that removing public access to the archived content would be an acceptable response. This has been the practice of the Internet Archive, for example; however, the application of such a policy to the case of content produced on a "private server" (as a separate issue from issues of reverse engineering and emulation) has not yet been tested in the courts.

Finally, developers of emulators may find that even if they do not fall afoul of copyright law, they may encounter problems with patents. There has been substantial litigation in recent years regarding patents and emulation technology, most of which has settled out of court. With copyright law providing only a limited ability to restrict the actions of those developing emulators, companies that do not wish to see emulators for their products are more frequently turning to patents as a means of restraining the development of competing technology.

The above issues all relate to the development of emulation technology. There are also legal issues involved in the use of game emulation technology, most notably copyright and the DMCA's anti-circumvention provisions. Most of the copyright issues center on the creation and use of "ROM" files from game cartridges for game console platforms. In *Atari, Inc. v. JS & A Group, Inc., 597 F. Supp. 5*, Atari sued the JS & A Group for copyright infringement and patent infringement, stating that JS & A, in marketing its product *PROM BLASTER* (which allowed users to make copies of Atari 2600 game cartridges), was guilty of contributory copyright infringement. JS & A, citing § 117 of the Copyright Act, stated that the *PROM BLASTER* was intended to allow users to make archival copies of their legally owned computer programs and hence its primary use was non-infringing. The District Court decided that, as § 117 had been rewritten based on the input from the final report of the National Commission on New Technological Uses of Copyrighted Works (CONTU) that states that archival copies of digital media should be allowed "to guard against destruction or damage by mechanical or electrical failure," and since game cartridges as media are not particularly subject to mechanical or electrical failure, making an archival copy of a game cartridge constituted infringement. While this ruling was mitigated somewhat by the case of *Sega v. Accolade*, where the Ninth Circuit found that making a copy of a game cartridge could be fair use if done for the purposes of making an intermediate copy needed to reverse engineer a game system, the case law at the moment is clear that copying a game cartridge

for the sole purpose of being able to play the game using the copy, rather than the original, is copyright infringement.

The DMCA may also inhibit a library's ability to use certain emulation technologies. Some modern computer games employ digital rights management technology, such as SecuROM, which checks for the original installation CD-ROM or DVD-ROM when it runs an installed program. While there are disk emulation technologies, such as Daemon Tools and Alcohol 120%, that claim to be able to create a copy of a protected CD or DVD and mount it in a virtual drive that will enable the game to run even if the original disk is not present, such an action constitutes bypassing a technological protection measure. While the use of such disk image emulation technologies is fairly common among the gaming community, the legality of such an action has not, to the best of our knowledge, been tested in court.

6. Preservation Strategies

Analysis of Hardware Preservation

As part of the preservation of video games and virtual worlds process, it is important to understand how current collectors are faring as part of their acquisition and preservation strategy. To this end, the research team conducted an interview with J.P. Dyson, director of the International Center for the History of Electronic Games (ICHEG), and vice president for exhibit research at the Strong National Museum of Play. The mission of the ICHEG is to collect, study, and interpret electronic and computer games from a number of perspectives, including the cultural impact of games upon society, and how people play and learn from such experiences. Strong and the center have the additional mission of catering to two distinct audiences: the general public and patrons who visit the Strong National Museum of Play, as well as academics and researchers engaged in the study of video games and play experiences.

ICHEG has processed close to 20,000 game artifacts and 100,000 game-related artifacts in the last 18 months. Dyson states that the preliminary focus of ICHEG has been three-fold: acquiring primary artifacts related to electronic games hardware and software, restoration of the collection for both display and interaction, and gathering of ancillary artifacts related to the play experience and documentation of the production process. Acquisition of content is procured through private donation as well as active investigation and outreach by the museum staff.

Restoration processes vary depending upon the type of artifact. ICHEG and Strong rely upon a number of sources for the repair and restoration of electronic game equipment, including internal personnel, experts from the community (from both academia and industry), external paid experts, and others. For arcade cabinets, the process involves either internal specialists or external vendors. Special attention is paid to the type of restoration. In some situations, it is only acceptable for the restoration to occur with original parts (the preferred method). In other situations, original part restoration may be secondary, such as in situations where motherboard components are no longer available. For consoles and computers, ICHEG often acquires multiple copies of the same artifact. In such situations, working components can be selected or reassembled from the duplicates within the collection. When a component does not work, it can be relegated as a display-case sample. Museum personnel have also acquired parts collections that can, in turn, be used to repair broken devices.

Along with parts, the restoration process for an individual component can take a number of forms. Reconditioning may include, depending upon the condition, resurfacing of a CD-ROM and the restoration of magnetic media components. Archival process includes the capture of video and image related to the play experience. For components that find their way into Strong's interactive installations, reinforcement or reconditioning may include processes by which the artifact can be made "bulletproof" for the duration of the exhibit showing. For example, joysticks and other input devices may have to be replaced by versions that can survive the repeated use by patrons of all ages. The museum has used this technique for the Atari 2600 version of *Pac-Man*, due to its overwhelming popularity.

According to Dyson the museum currently focuses on the acquisition and assessment of artifacts. To create the proper experience for the general public and researchers, a number of steps must be undertaken. For consoles, reproducing an experience means coupling hardware with televisions and display devices of the proper era. Dyson has noted that the scarce nature of older televisions coupled with technological problems of newer televisions can cause impediments in re-creating how the game can be experienced in its original form.

Dyson said that ICHEG and the museum are starting to explore the use of emulation and virtualization technologies as a method of preserving game experiences. The Strong National Museum of Play has used emulation technologies in at least two situations where the original artifact was damaged or was too valuable to exhibit for public interaction.

Dyson states that there are a number of challenges looming on the horizon for museums. Currently, ICHEG is concerned about games delivered through technologies such as Steam or the iPhone Apps store. In such cases, the distribution platform is a part of the game experience, and if the distribution channel were to cease operations, the process of capturing the game experience would be exceedingly difficult. Dyson is also concerned about the preservation of experiences related to massively multi-player games and games that exist and persist over a series of distributed servers. Such preservation leads to larger questions regarding the overall preservation of software, firmware, operating systems, and application infrastructures so that an experience can be properly recreated.

Dyson described current efforts of the museum and ICHEG to create a digital collections policy. The policy is intended to determine what it means to collect artifacts that are digital in nature, and is a starting point for the process and for communication related to the preservation of digital artifacts.

Dyson also considers establishing communication between collectors and the companies that produce electronic game hardware and software as one upcoming challenge. With better connections, the potential exists for greater collaboration related to preservation.

ICHEG's long-range plans are to move their processes beyond acquisition, restoration, and presentation. ICHEG and the Strong National Museum of Play are committed to creating plans for large-scale preservation and presentation policies that will require emulation, virtualization, and migration strategies.

In the Preserving Virtual Worlds project, our research team gained insight into the problems that are too often encountered by museums in their quest to provide preservation and access to historical video games.

One such problem dealt with the process of video conversion for both experiencing game play, as well as capturing video of game play for preservation, which first occurred in a case study related to the Atari 2600 *Star Raiders* game. The Atari 2600 utilized a circuit called the "Television Interface Adapter," which output a radio frequency signal. The signal could be received by a standard television set and was treated in a similar manner as an "over the air" transmission. The signal was routed into the television set through a switch block, which allowed the player to select either the game system or a standard television antenna. As part of the Preserving Virtual Worlds research, the team acquired three such Atari 2600 systems

from different eras, including an original Sears Telegames Atari model, an Atari 2600 "Heavy-Sixer" (manufactured around 1977), and an Atari 2600 "Light-Sixer" (manufactured around 1980). In order to create an authentic game experience, the team was able to procure black and white and color televisions from the early 1970s (Sony 1974 Color TV 19", Motorola B&W 13" portable with components dated 1971). Both of these sets were characterized by split VHF/UHF inputs, rotary channel selection and tuning, and a wide bezel to guard against overscan issues related to that era cathode ray tube technology.

Although the team was able to gain a satisfactory play experience from the 1970s television technologies, several problems manifested with progressively newer sets. For example, with televisions from the 1980s through 2009, the team experienced problems such as pixelization of image, fluctuation of brightness (photodiode and photoresistor compensation), problems with signal lock (digital tuner problems), problems with sound reproduction (volume, clarity), impedance conversion (conversion from 300 ohm to 75 ohm), and overscan problems (ghosting, artifacts around image edge). The problems are only exacerbated by newer television technologies based upon the conversion to digital TV signals in the United States. The team was already aware of television technologies that have eliminated the possibility of over-the-air input based upon the lack of analog signal as well as the decrease in popularity of VCRs, game consoles, and DVD players that use a direct RF broadcast signal. In such cases, the television is not even capable of receiving the signal, and as such, nothing is displayed.

The problem also gains new dimensions if the video signal is to be recorded on a digital capture device. In such scenarios, additional signal transformations may have to occur. For example, in order for the team to record screen capture from the Atari 2600 using a digital process, the signal was transformed from an analog RF signal to a composite TV signal (using a VCR to do the transformation) to a digital signal (using a digital camcorder).

The experience gained from the video conversion project was shared with a team of curators and game restoration specialists at the Strong National Museum of Play as part of an extended dialogue that has resulted in a partnership between the museum and the Rochester Institute of Technology, in which students gain cooperative education credit by assisting the museum in video capture and play experience restoration tasks.

A second problem is the conversion of game-related media so that the media can be read and processed by newer technology. Many of the earlier game technologies utilized proprietary formats for their ROM cartridges, magnetic tapes, and floppy disks. As the systems age, it becomes harder to find modern technology equivalents that are capable of processing the information. For example, if a person no longer possesses an original Atari 2600, the only way to retrieve the information from a cartridge is to either purchase an Atari 2600 ROM reader from a third-party company (it cannot be purchased from the average computer or electronics store) or to extract the relevant ROMs from the cartridge's circuit board and process them through a ROM reader. With magnetic media, combinations of media packaging, sizes, capacities, and protection techniques compound the problem. For example, when the research team worked on a case study with *DOOM*, not only did it take some time to hunt down a computer that was still capable of reading a floppy disk, but it was also important to identify a floppy drive that could still process both single as well as double density disks.

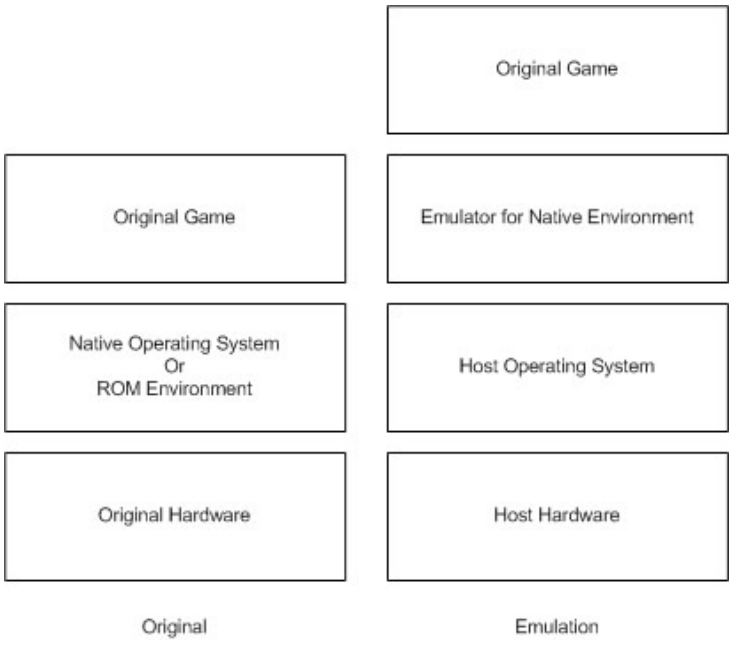
In summary, game museums are at an important crossroads in the preservation process. Curators at such institutions must balance the need to acquire rapidly disappearing artifacts related to the early history of video games while ensuring that their acquisitions will be able to be studied and enjoyed for decades to come. The promise of preservation technologies and their strategies may be able to span the bridge between these two desires.

Analysis of Emulation and Virtualization

As part of the preservation strategy for virtual worlds and electronic games, one must consider options that allow players the ability to experience a game well beyond the availability of a given hardware platform. Ideally, museums and collectors wish to preserve the original experience through maintenance and upkeep, but as hardware platforms age, it becomes more difficult to find repair parts. Furthermore, finding individuals with sufficient knowledge to repair such systems also becomes increasingly difficult over time. In order to augment the preservation of the original game system, techniques of emulation and virtualization can be used to provide game play experiences on newer hardware. This section examines the use of emulation and virtualization techniques as well as their implications for our case study games.

Emulation Overview

An emulator is a software application that is capable of simulating a particular hardware platform, including the hardware and appropriate firmware and support software. Playing through an emulator varies from the original experience because the emulator is designed to execute on hardware that is radically different from the original platform and corresponding system architecture. Emulators are designed to utilize the original executable code from the game. For most emulation systems, this involves extracting and providing a copy of the native cartridge ROM or game CD-ROM.



Over the last several years, the game community has seen a surge in emulation technologies designed to allow users to play many of their favorite, classic console games. In order for an emulator to successfully re-create a play experience, it must address several key areas of the original game environment platform, including the central processing unit, the memory manager, the environment code, and peripherals. In addition, the emulator must have a means of loading and processing the original game code.

- Central Processing Unit – An emulator has to be able to translate CPU instructions and must be able to emulate the functionality of a specific processor. This includes all arithmetic and logical operations, registers, storage modes, addressing modes, interrupt handling, and input/output operations.
- Memory Manager – An emulator must be able to provide the structure and access to main memory that is analogous to the original platform. This includes memory layout and management for system internal ROMs, scratch RAM, system RAM, device-based RAM and ROM (video, audio), and memory controllers (MMUs, DMA circuits).
- Environment Code (ROM/Firmware/BIOS/OS) – An emulator requires the appropriate software framework to operate. For some emulated systems, the firmware is separate from the instructions that are part of the game media. For example, DOS emulators will provide access to BIOS memory and some consoles will provide access to ROMs for common system functions (peripheral calls, math calculations, IO routines). Due to both maintenance and legal reasons, some emulator developers separate the environment code from the rest of the emulation system. Despite potential separation, this code is absolutely required for the emulation system to operate.
- Peripheral Mapping – An emulator must provide mappings from the original system to the target system. For example, in the case of most console systems, components external to code execution include video output, player input (joysticks, paddles), audio, and the game cartridge ports. In many cases, these components were not designed for general use, but were specific to the particular platform. For example, the Atari 2600 provided video and audio through a custom-designed Television Interface Adapter (TIA), which provided a means for the consumer to attach the console to a standard TV. The emulator must provide peripheral translation such that TV signaling can be displayed upon modern video cards and monitors, input devices can be mapped to modern joysticks, mice and keyboards, and ROM cartridges can be mapped to a modern file system.
- ROM/Emulated Software – Target software that can be run on an emulator. Technically, the target software is separate from the emulation environment. However, for most game console emulators, the ROM or Emulated Software must be processed so that it can be properly loaded and executed in the emulator. For example, to run an Atari 2600 cartridge in an emulator, a copy of the ROM code must be extracted with a ROM or cartridge reader and must be formatted in a particular manner such that the emulator can properly parse the resulting file.

The community for emulation development, especially for video games, can be best characterized as a grass-roots movement led by a few dedicated programmers. For most

emulator developers, the process involves reverse engineering the hardware and firmware present in the original systems. Currently, the emulation movement's focus has been predominately on classical console systems, including the Atari 2600, Sega, Playstation 1, NES, Game Boy, and other early platforms. For general computing platforms, classic game-related computers such as the Apple II, TI99/4A, Commodore 64, Atari 400/800, and Amiga have all been the target of emulation development. At one level, the focus on earlier platforms may be based on their simplicity. Earlier platforms consisted of simpler CPUs (6502 series being a popular model), minimal memory management schemes, and limited peripheral detail. At another level, as these platforms age, hobbyists and fans are frantically looking at means to preserve these experiences. As the community often drives emulation efforts, the efforts are in various states of completion. A quick survey of popular emulators for the Atari, Sega, Sony, Commodore, Apple, and Nintendo brands showed that over 70% of the efforts never resulted in a viable emulation environment. In addition, for those efforts that were completed, portions were abandoned for a number of reasons, including developer abandonment and legal confrontation. To make the situation even more difficult, a survey of abandoned projects revealed that their websites were taken over by malicious software (e.g. many of the Apple II emulation sites have been replaced by malware websites as well as virus- and spyware-laden applications).

Emulation Criteria

In exploring emulation environments, the research team compiled a list of factors deemed critical for an emulator that was to be part of a preservation experience. The list of criteria is as follows:

- Source Availability – Is the source code for the emulator freely available?
- Source Maintainability – Is the programming style of the emulator source code readable? How easy is it to maintain the code? How well is the source code documented? Does the source code's architecture make sense? How easy is it to obtain the compilation tools and libraries necessary to rebuild the emulator from scratch?
- Licensing – Does the emulator support a license model that is compatible with preservation efforts?
- Range of Host Platforms and Operating Systems – Does the emulator work on a variety of PC and Apple platforms? Can the emulator run under common operating systems such as DOS, Windows, Apple OSX, and Linux?
- External Documentation – What is the extent of external documentation related to the emulator and the target system, including what is necessary to execute the emulator and related game ROMs?
- Sensory Fidelity – Does the emulator appropriately reproduce the visual, aural, and tactile interactions of the original game?
- Peripheral Emulation – Does the emulator properly reproduce the range of functionality related to the peripheral interfaces? Are the peripherals properly reproduced from a code and experience standpoint?
- Peripheral Expansion – Does the emulator allow for the connection of original peripheral devices (such as gamepad or joystick)?

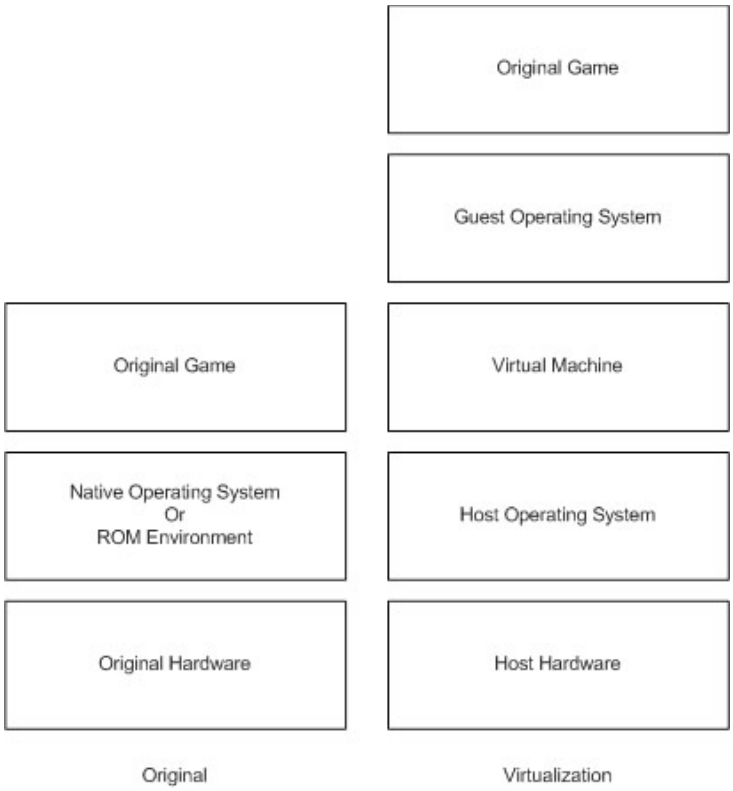
- Performance – Does the emulator run within acceptable parameters on the host operating system? Are there options available to adjust the performance of the emulation software?
- Ease of Use – Is the emulator easy to install and use by someone with a low level of technical proficiency?
- Community Maintenance – Is the emulator actively maintained? How large is the community supporting the emulator? Are there any active or looming impediments to the continuation of the emulator?
- Robustness – To what degree can the emulator execute the original games? If there are still bugs, to what extent do they inhibit playability?
- System Requirements – What does it take to run the emulator? (CPU, memory, RAM, peripherals)
- Emulation Variation – Does the emulator only emulate the standard run-of-the-mill platform or does it emulate the various different manufacturing of firmware differences of a particular series (e.g., does an Atari 2600 emulator have any indicators that there were actually four different production versions of that particular model and does the emulator embody the nuances between these variations?)

For purposes of this research, the team considered an emulator to be "good" if it had the following characteristics:

- The emulator is based upon freely available source code and appropriate licensing.
- The emulator is actively maintained.
- There is reasonable internal and external documentation for the project.
- The emulator interface is easy to use by non-technical players.
- The emulator supports a wide range of performance and tuning options.
- The emulator is robust and provides a believable level of fidelity when compared to the original game experience.

Virtualization Overview

Virtualization is another technique that can be used to help in the preservation process. Similar to emulation software, virtualization software is an application that allows a user to execute code related to a different operating environment from the host system. Unlike emulation, virtualization is performed on CPU and system architectures in which the host and target share similar attributes. In addition, virtualization creates a level of abstraction that does not include the target operating system. Instead, virtualization provides a bootstrapping mechanism in which a legacy or different operating system can be loaded into virtual machine. From there, additional software can be loaded into the virtualization environment.



Virtualization's focus is on providing the appropriate level of abstraction for the hardware environment, including the CPU, memory manager, and peripheral operation. Unlike emulation, virtualization employs a variety of techniques to leverage functionality of the host hardware architecture. For example, virtualization solutions developed for modern PC architectures may employ a technique known as hardware-assisted virtualization. This technique relies upon special processor instructions (Intel's VT-x and AMD's AMD-V extensions) that help accelerate the base assembly instructions. Some experimental systems use a technique called paravirtualization, in which the guest operating system is modified for use with the virtualization process. In either case, the virtualization system must provide access to the following hardware components or provide an appropriate level of abstraction:

- Central Processing Unit (CPU) – Ideally, in virtualization, the native CPU handles every one of the instructions handled by the virtualization system. Unlike emulation, which requires mapping and translation, this means that either the CPU must have the appropriate extensions to handle the virtualization instruction calls or that the target operating system has been modified to allow for code to be context switched from the virtualization environment to the actual CPU.
- Memory Management – The memory management system is a hybrid between the actual hardware and an abstraction process. At one level, the virtualization process must provide the equivalent architectural access to main memory, including multi-user and demand paging techniques used within the system. At another level, the virtual machine's memory space should be separated from any other virtual machines or any processes running on the host system.
- BIOS/Firmware – The virtual machine should have access to the BIOS of the host system. In cases where a legacy operating system requires access to an older BIOS,

the virtualization technology may provide a way of loading such ROM images into a section of RAM memory. When such techniques are utilized, the virtualization system also must account for any potential situations where devices are mapped into the ROM/BIOS memory space.

- Bootstrapper – For native systems, there is usually a process by which an operating system is loaded onto a hard drive. In such cases, BIOS or firmware code is necessary in order to search for peripherals that contain bootable environments. Virtualization systems must contain code to provide an operating system bootstrap for initial configuration.
- Peripheral Mapping – Virtualization technology must provide resource management for peripherals. In some cases, the peripheral is remapped, such as the use of a USB memory stick for a floppy drive as well as a large file for a primary hard drive. In other cases, the host peripheral is utilized in either a shared or exclusive mode, such as CD-ROMS, video, and sound cards.

Unlike the emulation community, the target of the virtualization community is generalized and is often supported by larger corporations. For example, Oracle/Sun Microsystems, VMWare, the RedHat foundation, and other entities that have invested substantial resources into the process are conducting leading efforts in this area.

Virtualization Criteria

The research team compiled a list of criteria for virtualization technologies:

- Source Availability – Is the source code for the machine freely available? If not, is it supported by a commercial entity with significant investment in virtualization technology success?
- Source Maintainability – Is the programming style of the virtual machine source code readable? How easy is it to maintain the code? How well is the source code documented? Does the source code's architecture make sense? How easy is it to obtain the compilation tools and libraries necessary to rebuild the emulator from scratch?
- Licensing – Does the virtualization technology support a license model that is compatible with preservation efforts?
- Range of Host Platforms and Operating Systems – Does the virtual machine software work on a variety of PC and Apple platforms? Can the emulator run under common operating systems such as Windows, Apple OSX, and Linux?
- External Documentation – What is the extent of external documentation related to the virtualization platform?
- Peripheral Emulation – Does the virtualization technology properly reproduce the range of functionality related to the peripheral interfaces? Are the peripherals properly reproduced from a code and experience standpoint?
- Peripheral Expansion – Does the virtualization technology allow for appropriate device mappings? Are there clear interfaces for the addition of shared, exclusive, or simulated device code? Can the process of device inclusion be handled by a programmer with moderate systems programming skills?
- Performance – Does the virtualization technology run within acceptable parameters on the host operating system?

- Ease of Use – Is the technology is easy to install and use by someone with a low level of technical proficiency?
- Community Maintenance – Is the virtual machine actively maintained?
- Robustness – To what degree can the virtualization system run applications? If there are still bugs, to what extent do they inhibit a software experience?
- System Requirements – What does it take to run the virtualization system? (CPU, memory, RAM, peripherals)

For purposes of this research, the team considered a virtualization technology to be "good" if it had the following characteristics:

- The virtualization technology is based upon freely available source code and appropriate licensing. In cases where the source was not available, the virtualization technology was being developed by a company dedicated to virtualization.
- The virtualization technology is actively maintained.
- There is reasonable documentation for the project.
- The virtualization interface is easy to use.
- The virtualization technology is robust and provides a believable level of fidelity when executing legacy software.

Case Studies

As part of this study, the research team selected four game titles from our case set for testing with emulation technology. The game selection included *Star Raiders* for the Atari 2600, *Mindwheel* for the Apple II computer, *Mystery House* for the Apple II computer, and *DOOM* for an IBM PC/MS-DOS environment. For the purposes of the study, the selected software titles were executed on modern hardware with a selection of commonly used operating system software. In all, the team selected ten Intel-based PCs, with Pentium IV processors, at least 4 GB RAM, Nvidia 8800, 9600, and GTX260 video options, CD/DVD ROM drives, at least 320 GB hard drives, integrated Realtek sound solutions, as well as standard mouse and keyboard devices. The systems were configured with a range of host operating systems, including Windows XP 32 bit edition, Vista Ultimate 32 bit edition, Windows 7 Ultimate 32 bit edition (Release Candidate), Windows 7 Ultimate 64 bit edition (Release Candidate), and a variety of Linux variations including Ubuntu, Debian, Arch, Gentoo and Fedora. For Linux installations, additional packages were installed to create an appropriate graphical and audio environment for emulation and virtualization, including X11, Gnome, ALSA, PulseAudio, OpenAL, OpenGL, and other library and application sets. In addition to the PC environments, the team had access to both Intel- and PowerPC-based MacBook Pro computers along with Intel-based Mac G5 systems. These systems were configured with both Tiger OSX (10.4) and Leopard OSX (10.5).

Case Study 1 – Star Raiders

Star Raiders, released by Atari for the 2600 platform in 1982, was a cartridge-based computer game for the Atari 2600, in which the player pilots a fighter spacecraft and engages in battle with opponents known as "Zylons." *Star Raiders* is an instrumental game in video console history for a number of reasons. First, it immersed the player in a first-person, "3D" dogfight environment, which allowed the player to engage enemy craft via a combination of

thrust and rotation interaction. As such, the game is considered to be the forerunner of an entire series of dogfight combat simulators for arcade and home console play, including such classics as *Wing Commander*, *Star Wars*, and *Elite*. Second, the game utilized a non-standard pad controller that allowed for keyboard-style commands on the Atari 2600. The player worked the keyboard controller in tandem with the joystick depending upon the particular phase of the game. The *Star Raiders* cartridge consisted of an 8K ROM, which stored the entirety of the game code.

The target platform for *Star Raiders* included the Atari 2600 game console. Created in 1977, the Atari Game Video Computer System consisted of a MOS 6507 (6502 variant) microprocessor, a MOS 6532 RAM-I/O Chip (128 bytes static memory, timer, and 8 digital I/O ports), and a Television Interface Adapter Chip (TIA). The MOS 6532 was used to buffer the status of console chips as well as buffer the states of the joystick devices. The TIA provided the ability to generate an RF signal that could be received on channels 2 or 3 of a standard television set. The TIA generated both the video and audio signals used by the game system. The console also provided an adapter port for receiving game cartridge ROMs.

In order to ensure emulation accuracy, the research team had access to several original *Star Raiders* cartridges as well as three Atari 2600 platforms, including a Sears Telegames Model, a "heavy sixer," and a "light sixer." As part of emulator testing, the research team selected four emulation systems to test on PC-based environments. The four systems selected included Stella (http://stella.sourceforge.net), z26 (http://www.whimsey.com/z26), PC Emulator (http://pcae.vg-network.com), and MESS (http://www.mess.org).

All four emulation platforms were able to successfully run the *Star Raiders* ROM image. However, based upon the team's criteria for emulation software, all but Stella were eliminated from contention. Specifically, MESS's licensing policy was too restrictive for use as an archival system, and both PC Atari Emulator and Z26 are in an indeterminate state of upkeep, despite the latter's popular following in some segments of the emulator community. In addition, PC Atari Emulator experienced difficulties with clock timings in the first version we evaluated (from a non-authoritative emulator site). The problem proved inconsistent, varying on target PC platform and operating system (problems were experienced on MS-DOS and FreeDOS).

In side-by side comparison, there were several differences noted by the test team. First, there is a perceivable quality difference in the graphical output between the emulator and the original 2600 output for both black and white as well as color televisions (for authenticity, we did some of our testing on 1970s era televisions). The RF/television combination created an experience in which the graphics were not as sharp as the emulated version. Although this might seem as a detriment, the slight blurriness disguised several visual artifacts that distracted players on the emulated systems. Second, the sound quality was also different in the emulated versions. Although the sound approximation of the TIA was acceptable in the emulated version, there were some pitch and timbre variations noted in the audio reproduction when compared to the original experience. In part, this was due to differences in the fidelity when comparing the internal speakers of a 1970s era television versus a modern sound card output to commonly available desktop speakers. To verify the sound quality difference was not due to aging of the speakers, the team attached the Atari console to televisions from the 1980s and 1990s to compare the sound experience. The results

correlated to the experiments performed with the 1970s era television sets. Finally, the mouse and keyboard experience did not properly substitute for the joystick and pad experience of the original. The team later found that an adaptor could be purchased (www.stellaadaptor.com), which would allow the original Atari 2600 joysticks and pads to be interfaced to a modern PC. The adaptor converted the original digital I/O signals from the 9-bin connector to a USB format that could be utilized by z26 and Stella. Despite these issues, the Atari 2600 emulator community has created a robust product that provides an extraordinary level of support for reproducing the original Atari experience. The emulation technology is mature enough to support most Atari cartridges that were produced, and the involvement of the development community has ensured that most emulators support a rich set of tools for both debugging existing ROMs and allowing hobbyists a platform for software experimentation. However, this investigation has also revealed one of the critical weaknesses in the emulator community – as emulators age, they too can fall into neglect and disrepair.

Case Study 2 – Mindwheel and Mystery House

Mindwheel, published in 1984 by Broderbund, was available on a variety of platforms including the Apple II. U.S. Poet Laureate Robert Pinsky designed the game as an interactive novel that allowed the player to explore the thoughts and minds of four deceased characters within the fictional work, with the player trying to solve particular problems in search of a "Wheel of Wisdom." The game was accompanied by a hard-covered instruction manual and a novella that served both as a way to introduce the story line and as an early form of copy protection, as the player was requested to enter words from particular pages and paragraphs in the novella.

Mystery House, an Apple II title published in 1980 by On-line Systems, is a "whodunnit" game in which the player must explore a mansion in search of clues that will lead to the identity of a murderer, who is also locked within the house. The game is based on the tradition of text-based exploration games, but also utilized simple line-based drawings to augment the text descriptions within the game. The game was designed to run on a standard Apple II computer and was distributed on 5.25" single-sided floppy disks for the Apple floppy drive reader.

The target platform for these games was the Apple II/Apple II+ computer system. Based upon the MOS 6502 processor, the Apple II/II+ supported up to 48K RAM, cassette and floppy drives through expansion ports, and a NTSC composite output signal for both monochrome text and color graphics. The support ROM built into the Apple II/II+ provided direct support for Apple's BASIC dialect. Sound was generated through pulsing a speaker. Crude wave generation could be computed on the computer, allowing for low fidelity playback of voice and multi-channel source sound (on a small internal speaker within the computer system).

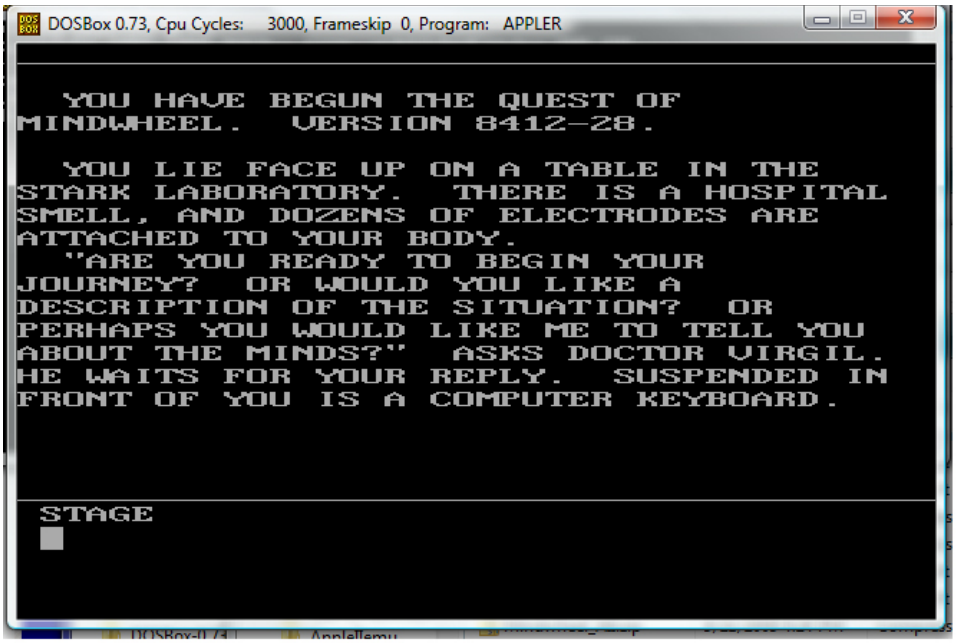
To ensure that the Apple II emulator experience was similar to the original, the team was able to secure time on an original Apple II+ system in order to determine the how well the emulator matched to an original system over a variety of Apple II applications and games.

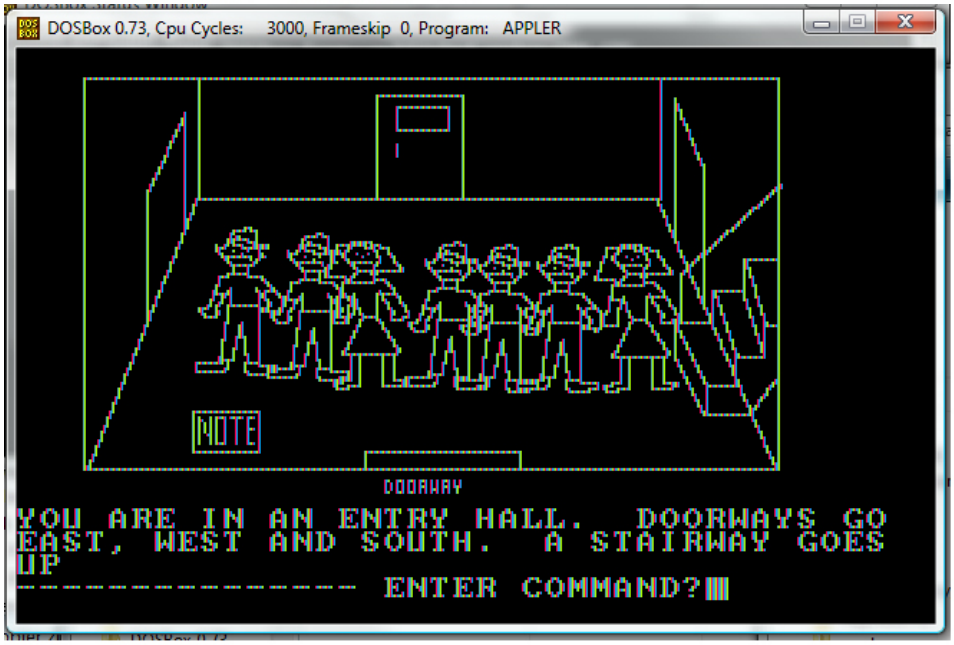
The team discovered a number of emulator systems for the Apple II. The following list includes general observations about each emulation application.

Apple PC (http://www.zophar.net/apple2/applepc.html) emulates the Apple II+, Apple IIe, and Apple IIc computers. The emulator does not include the Apple II ROM, but the user community provides appropriate sources for downloading the ROM images. Apple PC is designed to run on a DOS system, and can run on DOS emulators such as DosBox. The software cannot run on limited DOS environments such as those available in Vista and Windows 7. Apple PC emulates monochrome green and white monitors, and provides sound from the PC speaker, Sound Blaster, or MockingBoard options. The emulation allows for the mouse to substitute as a joystick. Although the software does not require explicit installation, it can be run from a directory on the hard drive. Help is included, and the system includes an integrated debugger. Apple PC uses an inverted capslock scheme, which, when utilized, will persist in lowercase mode appropriate to later Apple models. Backspace and arrow key functions, along with cursor representation, are mapped such that backspace and left arrow move the cursor left. Apple PC is incapable of running *Mindwheel*.

Appler (http://www.zophar.net/apple2/appler.html) is predominantly an Apple II+ emulator, although the README file enumerates several hardware options that span different Apple II class revisions. Appler is designed to run on a minimal 386 system, with at least 1MB RAM memory, 128K EGA graphics adapter capability, and MS-DOS 3.30 operating system. Appler will not run on newer versions of Windows including Vista and Windows 7 without a DOS emulation environment such as DosBox. The emulator includes the Apple II ROM and supports a monochrome white monitor mode for text applications and a color (green, white, magenta) output for graphical applications. Appler supports sound and does not require any special installation. The emulator comes with help and includes an integrated debugger. Keyboard interaction varies with the application. For *Mindwheel*, the backspace and left arrow both perform the backspace, and delete does not perform any operation. In *Mystery House*, backspace and left arrow move the cursor back without erasing

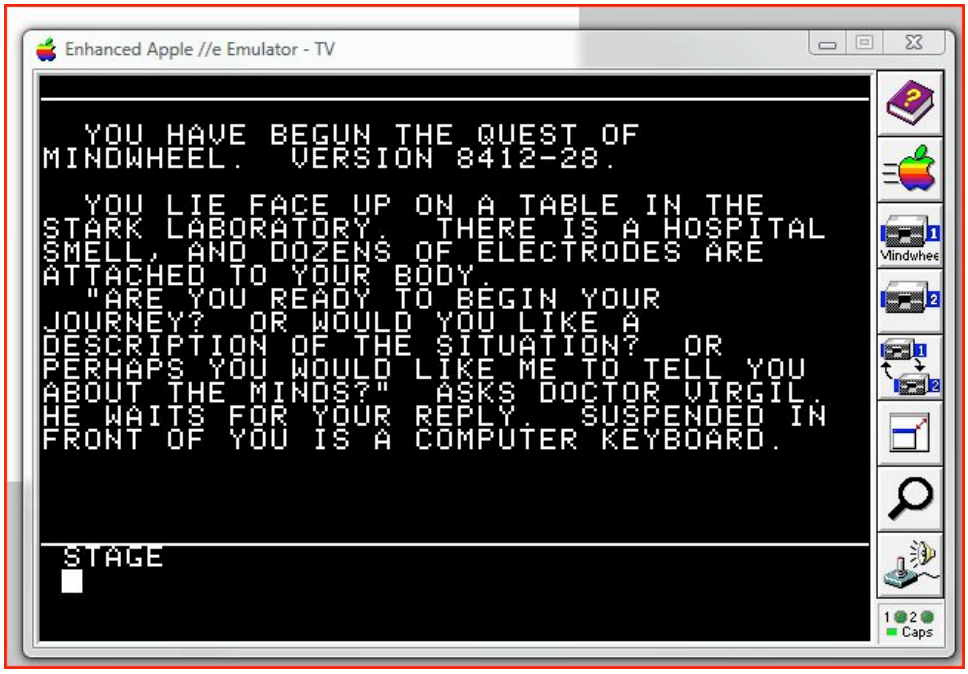
the previously typed text. Appler uses a different font than the standard Apple II character generator. In addition, there are issues with combined text and graphics renderings as well as issues with running *Mindwheel*.



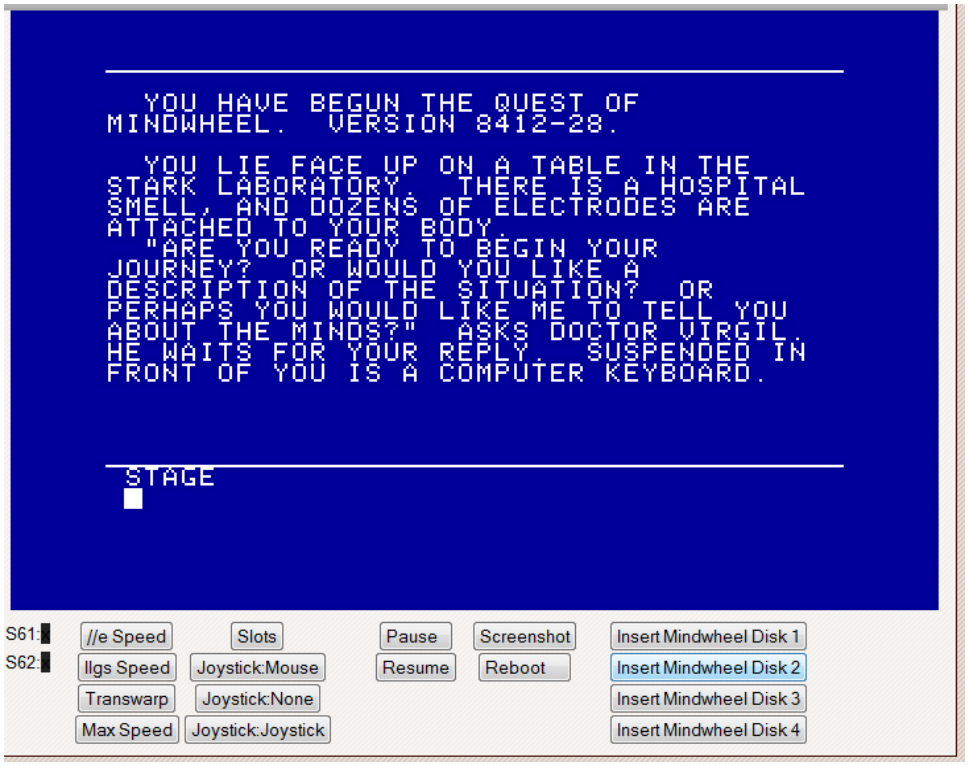


AppleWin (http://developer.berlios.de/projects/applewin/appler) by far was the best Apple emulator tested on the PC platform. Distributed under a GNU license, the emulator supports Apple II, II+, and IIe computers and includes the Apple II ROM. The emulator runs on Windows platforms (tested with Windows XP, Vista, and Windows 7 RC). The emulator supports a wide range of monitor formats, including four monochrome variants (white, green, amber, and custom), as well as color modes (standard, TV, text-enhanced, and half-shift). Sound is available with Mockingboard and Phasor options. AppleWin differs

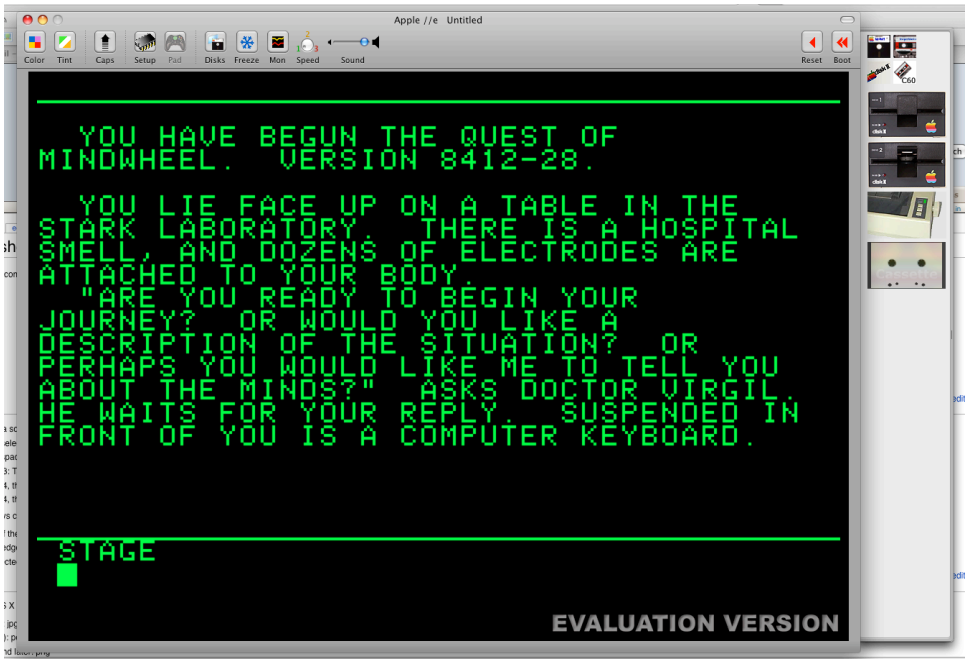
from other emulators in that it has a performance mode that allows for "authentic" timings and run speeds as well as optimized modes that allow it to take advantage of the host hardware. AppleWin requires installation, and includes extensive help, information on the Apple platform, and a complete debugger. AppleWin supports a toggle capslock mode that starts in uppercase. In *Mindwheel*, backspace, left arrow, and delete all perform a backspace. In *Mystery House*, backspace and left arrow both move the cursor left. Delete replaces the highlighted character with a blank and the image of the cursor does not blink.

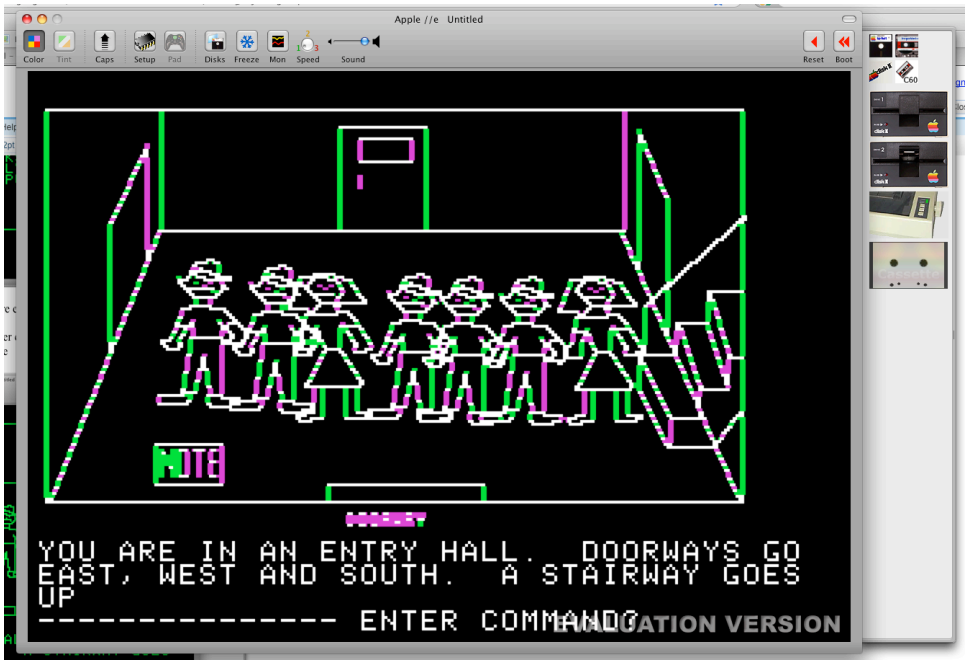


Virtual Apple (http://www.virtualapple.org) is a browser-based emulator. The emulator is capable of executing on both Mac and Windows platforms, and is supported by popular browsers such as Internet Explorer, Firefox, Safari, and Chrome. The application emulates sound and provides two monitor modes – a white on blue for text, and a green, white, magenta mode for images. There is also a Java implementation that can be run from the browser. There is minimal help and no debugging support. Capslock and keyboard reactions are fairly atypical, even when compared to other Apple II emulators.



Virtual II (http://www.xs4all.nl/~gp/VirtualII/) is an emulator designed to run on the Mac platform. The emulator supports Apple II, Apple II+, and Apple IIe computers. It does not come with Apple II ROMs, requiring the user to search the Internet for an appropriate source or to extract the information from their own ROM set. The emulator requires at least the Mac OSX 10.4 operating system. The emulator allows for monochrome and color video, and supports a mode to toggle scan lines on and off. The emulator supports audio including Mockingboard emulations. Options allow for controlling refresh rate as well as CPU speed. Virtual II requires installation, includes help files, and a debugger. To emulate flexible keyboard behavior, Virtual II has the "soft caps lock" option.





By far, the greatest problem the team noted with emulation technology for the Apple II was the inconsistent use of a standard keyboard metaphor when dealing with the Apple II/II+ keyboard. The Apple II/II+ keyboard worked primarily with uppercase encodings, with such machines only allowing key font generation of the uppercase glyphs when typed for certain applications. The inconsistency among emulators leads to inconsistent behavior that is not representative of the original experience. Also, the difference in emulators means that emulator users should explore the keyboard behaviors, or else they could observe unexpected results in the play experience.

Case Study 3 - DOOM

DOOM, by id Software, is universally synonymous with the first-person shooter genre of video games. Developed in 1993 by John Carmack and John Romero, the game story involves a space marine (you, the player), who is dispatched to Mars' moon Phobos, to contain a dangerous situation created by the Union Aerospace Conglomerate, a mega-corporation responsible for processing radioactive waste and supplying the military. The game is known for its graphic nature, supporting a range of weapons as well as stylized violence. The goal for players was to navigate levels searching for keycards, which in turn allow access to additional areas of the game. Along the way, players have to both avoid and fight various monsters with a range of abilities and strengths. *DOOM* was groundbreaking in advancing several techniques for game engine design, including 2.5D game level design, better handling of BSP, complete texture mapping for room surfaces, and non-perpendicular space design. *DOOM* also provided a means by which the game could be experienced in a single-player mode as well as a multi-player mode over a network or a modem.

DOOM was designed to run within an IBM PC environment. Its minimum specifications stated that it could be played on a system with an Intel 80386 or compatible processor, 4MB of RAM memory, a VGA graphics card, and a hard disk drive. The preferred specifications allowed for an Intel 80486 processor, a Sound Blaster Pro or Sound Blaster Pro compatible sound card, and a network card that could support IPX network protocols (with a terminate and stay resident application or DOS network driver stack). Although an operating system is not specified, the README file contained on the distribution media mentions setup issues with MS-DOS 5.0 and before, MS-DOS 6, and OS/2.

With the advent of PC compatible clones in the 386/486 era, there is no standard reference platform for the target system. For this era system, motherboards could support 8MB to 32MB of system RAM, support a PC compatible BIOS, and a number of expansion slots for ISA, VESA, EISA peripherals. Common peripherals included VGA cards that conformed to VESA specification, coax-based Ethernet cards, modems, drive controllers, COM ports, parallel ports, joystick ports, and multifunction IO adaptors for floppy drives and hard disks. Unlike modern PCs, most peripherals required that the user set through jumpers, appropriate IO addresses, memory addresses, interrupt lines, and DMA address channels. Jumper configuration problems could cause unintended consequences, including machine lockups, system crashes, and indeterminate behavior. When running many applications, the user would have to provide known settings for peripherals to the program in order for it to operate effectively.

The team was able to secure an older 486/DX50 system for testing an original *DOOM* distribution (version 1.8 on both Floppy and CD-ROM [Shareware/Retail]).

Before selecting virtualization and emulation technologies, the team examined two different ways of providing an operating system environment for the game. One choice was to use a Microsoft MS-DOS 6.22 distribution from floppy disk. The MS-DOS option is based upon Microsoft's closed source operating system. Although Microsoft does not directly support the sales of MS-DOS, it is still available through the Microsoft Academic Alliance for educational use. The second choice was to use FreeDOS (http://www.freedos.org), an open source alternative to MS-DOS. FreeDOS has GPL licensing and was developed for both modern and legacy systems. FreeDOS can be used to provide DOS functionality for the Windows NT line of operating systems, Windows XP, Vista, and Windows 7. FreeDOS supports such features as FAT32 file systems, disk cache, memory management (EMS and XMS), mouse extensions, and multimedia extensions for CD ROM.

The team worked with a number of virtualization and emulation applications for *DOOM*. The following is an overview of the various systems, detailing what worked and what did not.

Virtual PC 2004 and Virtual Machine 2007 (http://www.microsoft.com/windows/virtualpc) are virtualization systems promoted by Microsoft that provide virtualization support for a Pentium II processor and/or the virtualized CPU of the host platform. Virtualization device mapping provided a uniform peripheral architecture including a S3 Trio 32 VESA card, an AMI BIOS, a Sound Blaster 16, and DEC 21XXX series Ethernet solution. Virtual PC 2004 was able to run on Windows XP and Vista, but not Windows 7 RC. Virtual PC 2007 could run on all the Windows variants that were tested. Both versions of Virtual PC were able to run MS-DOS as well as FreeDOS, and supported the *DOOM* installation process. Video worked nicely in both versions. Sound effects were selectable for PC Speaker and Sound Blaster solutions. Music worked with SoundBlaster, Adlib, and Pro Audio Spectrum selections. For Virtual PC 2007, *DOOM* would tend to freeze on all tested operating systems except Windows 7 RC 64 bit. After several attempts, the team was unable to create a reproducible freeze point: the *DOOM* application would freeze the Virtual PC application at indeterminate points in time.

DOSEmu (http://www.dosemu.org) is a combination hardware virtualization and emulation solution capable of running classic operating systems such as MS-DOS, FreeDOS, and DR-DOS. The program is available for Linux systems and provides a GPL license for its use. DOSEmu provides partial support for sound, with current workarounds for Sound Blaster music compatibility issues. DOSEmu was able to work with all five of the Linux test platforms. The distribution used by the team automatically installed FreeDOS as the target operating system. Although DOSEmu is supposedly capable of mapping to a MPU-401 MIDI card, the testers were unable to reproduce this mapping successfully. Therefore, on all of the host platforms, music did not work. However, sound effects did work in speaker and Sound Blaster mode, except for the Gentoo build, which does not support standard audio device mapping in the base distribution set.

QEMU (http://www.qemu.org) has aspects of both a virtualization platform and an emulation system, and is a contributing component for a variety of other VM solutions,

including VirtualBox, Xen, and KVM. QEMU was deployed on all five of the host Linux systems. In all cases, it was able to install both MS-DOS and FreeDOS, and was able to load the *DOOM* game software. For sound effects, QEMU was able to provide PC Speaker access and Sound Blaster functionality. The sound support did not properly work on Gentoo and Fedora due to audio device mapping. Music was supported for Adlib, Sound Blaster, and Pro Audio Spectrum sound solutions. Fedora had some difficulties mapping the arrow keys in Fedora. Problems with Fedora also led to some situations where the game would manage to get into an unplayable state.

VirtualBox (http://www.virtualbox.org) is a commercial-grade virtualization solution that was offered by Sun Microsystems and was recently acquired by Oracle along with Sun's other operational assets. VirtualBox is distributed in both a commercial version as well as an open source edition. VirtualBox can virtualize a wide range of peripherals and provides native virtual execution, a just-in-time dynamic recompiler, and hardware-accelerated virtualization features. VirtualBox can be run on a wide range of host operating systems. In the testing phase for VirtualBox, the team was able to successfully run the environment under all Windows variants, as well as Ubuntu and Gentoo Linux. VirtualBox was unable to execute under a Fedora base installation due to missing files, and was unable to run under Debian and Arch due to VM initialization problems. Unfortunately, VirtualBox had many problems running *DOOM*: the virtualization process for Windows platforms made the game very slow on Windows variants. To verify this was not a problem with the installation: text-based applications that were run did not experience the same problems as in the running of *DOOM*. Although the Sound Blaster virtualization allowed for sound effects, music selections through the Sound Blaster and other devices were ignored, regardless of the sound card settings.

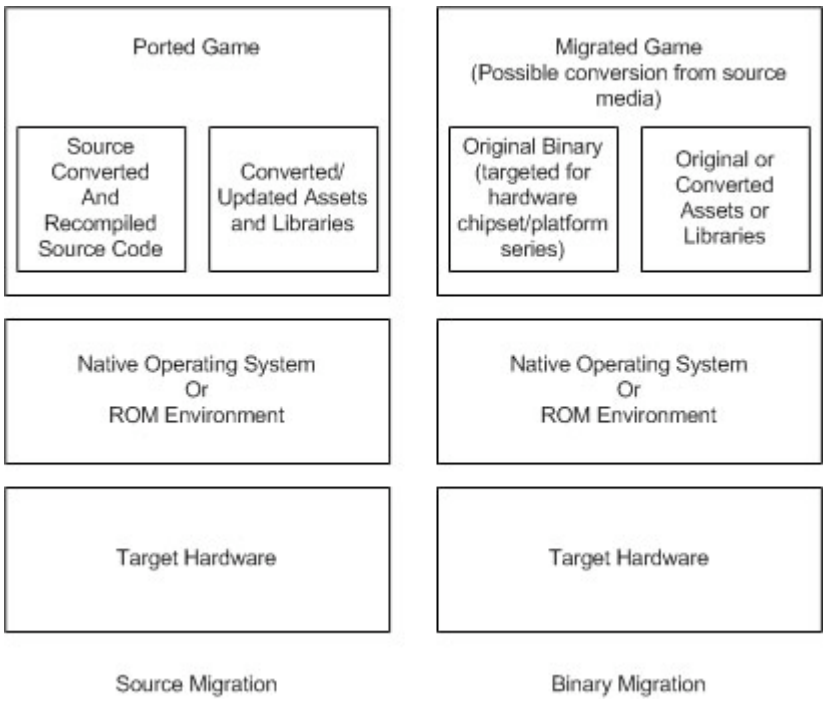
The final virtualization test was with VMWare (http://www.vmware.com), a company dedicated to the creation of virtualization technology. VMWare was used as a baseline to compare the previously tested virtualization solutions. VMWare worked with the various versions of Windows, but worked only with Ubuntu and Debian Linux distributions. Arch, Gentoo, and Fedora were unable to provide re-compilation for the virtualization tools and device mappings. For all distributions, VMWare experienced problems with crashes and issues with sound virtualization. As such, VMWare did not provide a suitable execution environment for *DOOM*.

The final application we tried was Peter Veenstra's DOSBox. DOSBox is actually an emulator that provides an environment analogous to an IBM computer with an MS-DOS execution environment. The emulator provides a wide range of video support, from original Hercules monochrome, through CGA, EGA, VGA, VESA, and S3 Trio 64. For audio, the emulator supports emulation of the PC Speaker, Sound Blaster, MPU-401, Disney Sound Source, Gravis Ultrasound, AdLib, and Pro Audio Spectrum. The emulator has support for network emulation as well as advanced features for screen and movie captures. DOSBox does not require the user to own a Microsoft copy of MS-DOS. As such, FreeDOS is not applicable to this environment. In testing, DOSBox ran within every host operating system the team tried, including all Windows and Linux variations. DOSBox performed the best for the team, having only a freeze problem under Linux with the WaveBlaster sound driver set. By far, DOSBox provided the best experience for *DOOM* compared to the prior technologies.

There were virtualization problems with both MS-DOS and FreeDOS *DOOM* scenarios, including intermittent crashes, freezes, and sound mapping problems. The pure emulation solution created the best experience for the game.

Analysis of Migration

Another important part of the technology of preservation is the process of migration, the process of moving code from one target platform to a newer or better target platform that is capable of running the software application. There are two types of migration that one must consider for the preservation of virtual worlds and video games: source migration and binary migration.



Source migration, or "porting," is possible if one has access to the original source code and assets for a game experience. The process of source migration is usually easier on equipment that possesses similar CPU series and related platform architectures, but can be performed in cases where the source and target architectures differ. To perform source migration, one must possess appropriate tools, such as interpreters, compilers, and assemblers that are capable of not only reading the source programming but also are capable of targeting the new environment. Along with the tools, the re-compilation process requires access to libraries and APIs related to graphics, user input, operating systems and firmware access, math functions, and data parsing. In some cases, source migration may require the original source code for the libraries, as well as the game. In other cases, the operating system of the API set may provide appropriate wrappers for legacy code (e.g. DirectX SDK support for previous versions). If such libraries are not available, one may have to rely upon conversions or library ports from the open source community. Along with the code, digital assets might need some special attention in the source migration process. At the simplest level, the

original code and libraries may be able to use the content directly, and, as such, very little might have to be done. For example, in migrating image manipulation code, libraries will allow for older image formats such as BMP and JPEG to be loaded, but special attention must be paid to elements such as image bit depth, alpha channel designation, bit encoding, as well as file name format and case sensitivity.

Binary migration is possible if one has access to binary and assets of the original game. Binary migration is usually only possible in systems where the CPU series and platform architecture is backward compatible with the legacy system, for example, the execution of a PC compatible Intel 386 binary application on a PC compatible Intel Pentium IV system. Although some binary game applications are self-contained, others rely upon dynamic libraries and modules provided by the target operating system or platform environment. For example, DirectX 9 Games are reliant upon a Windows operating system as well as the presence of the DirectX 9 run-time environment. Such games are often packaged with an integrated or stand-alone installer for the DirectX 9 components. Binary migration can be susceptible to small changes in computer architecture, changes in peripheral devices, CPU optimizations, and changes in BIOS and firmware code.

Another difficulty encountered within the binary migration process is the conversion from original storage and execution media to newer media that can be accessed by modern devices. Since the advent of the personal computer, media storage formats have changed frequently. Tapes were replaced by magnetic disks, which gave way to optical disks and, most recently, to solid-state flash memory. Each format has numerous variants, and each variant requires its own drive connected to a computer through a series of different ports and cables often made obsolete within two years of introduction to the market. As a result, the cultural record of the last 30 years is scattered over a variety of media that cannot be read by humans (or modern computers) without the aid of obsolete and hard to find machinery.

One of our test cases for this project was the preservation of *Mindwheel,* a piece of interactive fiction written in part by U.S. Poet Laureate Robert Pinsky (see also Case Study 2 in Section 6). We obtained a Macintosh copy of this title, but it came to us on the original 400K 3.25" floppy disk. While, as of this writing, USB connectable drives capable of reading 1.44 MB disks are common, these devices are unable to read 800K or 400K. Fortunately, we had access to a Macintosh Powerbook G3 "Wallstreet edition" that had both a floppy drive capable of reading the 800K disks as well as an Iomega Zip drive.

Using this machine, along with an external USB Zip drive, we created an image of the floppy on a Zip disk using the Powerbook, transferred the image to the external Zip drive, and thence to a contemporary iMac. Unfortunately, the disk image was in the now obsolete MFS format and so accessing the individual files via a contemporary machine remained difficult. We solved the problem in two ways: the first involved opening the disk image in the popular MacPlus emulator, vMac, transferring the files to a virtual disk image formatted in HFS (readable by both the emulator and a modern operating system). We later found the "MFSLives" software provided by Apple and were able to open the image within the native operating system.

The chains of transfers from medium to medium and platform to platform described above are common in digital preservation projects, but the fragility of the links that compose them

is palpable. The process described above depended, ultimately, on an aging laptop, available only through serendipity. As the chronological distance between the date of creation and the encounter in the archive grows, accessing old store media will likely become even more difficult. Already, formats even as common as the once ubiquitous 5.25" floppy disk present significant obstacles to preservation and access.

Most scholarly work in born digital preservation to date has focused primarily on the problem of archiving, cataloging, and accessing material that has been transferred to modern hardware. The problem of copying data from older machinery has largely been solved informally on an ad hoc basis. Obsolete drives are pulled out of storage closets and connected to computers old enough to have the requisite ports but new enough to accept more modern connections. Hobbyists build custom-made cables online for connecting old drives to modern computers and sometimes post their schematics on the web, but their documentation is often understandably amateurish and rarely maintained.

There are, however, a few well-supported solutions upon which this project will build. Our experience demonstrates that some computers built at transitional moments in the evolution of media technology can serve as "Rosetta Stone" machines, translating the archaic and forgotten to a form recognizable by the modern. Of these, the Macintosh Wallstreet edition Powerbook G3 is among the best. The laptop, manufactured between May and September 1998, came with swappable CD, DVD, and floppy drives capable of reading 800K and 400K disks. A swappable zip drive could also be purchased for the machine. An Ethernet port further allows data to be transferred from the computer using standard networking protocols, and PCMCIA slots permit the addition of USB ports through a third party card to which an external hard drive or even flash media can be attached. The hardware is capable of supporting older versions of Linux, and with it many contemporary open source software packages. The machine does not, of course, natively support 5.25" floppies or other more archaic formats, but it does serve as an example of the sorts of machines that may prove very valuable to digital preservation laboratories in the future.

One of the best commercial tools produced in the present day for accessing old media is the Catweasel manufactured by the German company Individual Computers. The Catweasel is an internal PCI-card that allows more modern drives to access older formats (including those manufactured by Commodore). Unfortunately, it requires the end user to have an internal floppy drive of

the appropriate size as well as an internal PCI slot, thereby all but limiting the tool to use in desktop computers. Digital archival and recovery work must often be performed using portable workstations that can easily be brought to the archival site. In these purposes, Device Side Data's FC5025 USB 5.25" floppy controller, released in February 2010, provides most of the same functionality as the Catweasel but with an external USB connection.

For 800K and 400K disks, much of the Catweasel's functionality can be replicated with the robust OmniFlop software, developed and released as freeware by Jason Watton of the British company Sherlock Consulting Limited. OmniFlop replaces the default drivers in Windows XP with custom-made software that controls the mechanisms to permit standard floppy drives to read almost any format. Like the Catweasel, it requires a computer with an internal floppy drive (USB floppy drives are not usually compatible with the software).

If one has access to the original machinery, it is sometimes possible to connect early personal computers to a modem (originally used for dialing up bulletin board systems or commercial services like CompuServe or, later, America Online). With the appropriate software, and a working old computer with the appropriate drive and a compatible modem, it is possible to send files to any other computer using what is called a null modem connection. Finding all of the necessary components is often difficult today, however, and one must assume they will become increasingly rare in the future. The procedure is a useful one, then, but not ultimately sustainable.

In January 2009, Nate Lawson, a consultant at a California digital security company called Root Labs, announced a USB connection to a Commodore 1541 drive using what he calls the xum1541 cable. The device is an optimization of the xu1541, originally designed by Till Harbaum in 2007, but later adopted by Spiro R. Trikaliotis of the Institut für Automation und Kommunikation in Magdeburg, Germany. The xu1541 project includes schematics for building a USB connection to the 1541 using components that the author claims will cost less than 5 euros. Lawson's updated xum1541 device is not yet available for purchase, nor are his schematics available online, but a YouTube video gives enough information about the component pieces to suggest an approach for building similar cables for the 1541 and other early 5.25" drives.

While the amount of preservation work that has been accomplished even under such less than ideal circumstances is remarkable, a formalized and repeatable set of procedures are needed, and needed immediately. With every passing day, the problem becomes increasingly urgent as drives fail and 5.25" disks crumble like papyrus, and with them disappear large swathes of our creative history.

Single density Commodore 1541/Apple II series "flippy" 5.25" disks

According to the 2003 Guinness World Records, the Commodore 64 is the best selling computer of all time. With over 30 million units sold, the machine represented for many an introduction to the personal computer. Although it did not originally ship with a disk drive (plug-in ROM cartridges were the only media that could be used with the machine out of the box), many users quickly purchased the 1541 drive. The drive, similar to the one Apple manufactured for its Apple II computer, could read only one side of the disk at a time, requiring users to physically turn the disk over and reinsert it into the drive to access the other side (hence the colloquial name, "flippy" disks). The drive thus operated differently than later IBM-compatible drives (and for that matter later Commodore drives), which, thanks to the addition of another drive head, could read both sides of the disk at once. Given the staggering number of Commodores and Apples sold, developing an access strategy for the media format is at the top of our priority list.

Double density, IBM-formatted 5.25" disks

Although the Commodore and Apple II enjoyed nearly a decade of dominance in the home markets, business tended to use instead IBM and IBM compatibles. The most common 5.25" drives on these machines could read both sides of a floppy disk simultaneously, and could access a higher number of tracks on a side (hence the designation, double density).

Macintosh 800K/400K floppy drives

The 3.5" drives on early Macintosh computers were formatted slightly differently than those used by DOS/Windows machines and later Macs. Unlike the 1.4MB disks which can be read with a (currently) commercially available USB drive, the disks used by these drives cannot be read using modern equipment. Many writers and artists who used Macintosh computers in the early to mid-1990s have saved their material on these floppies.

3" Amstrad Drives

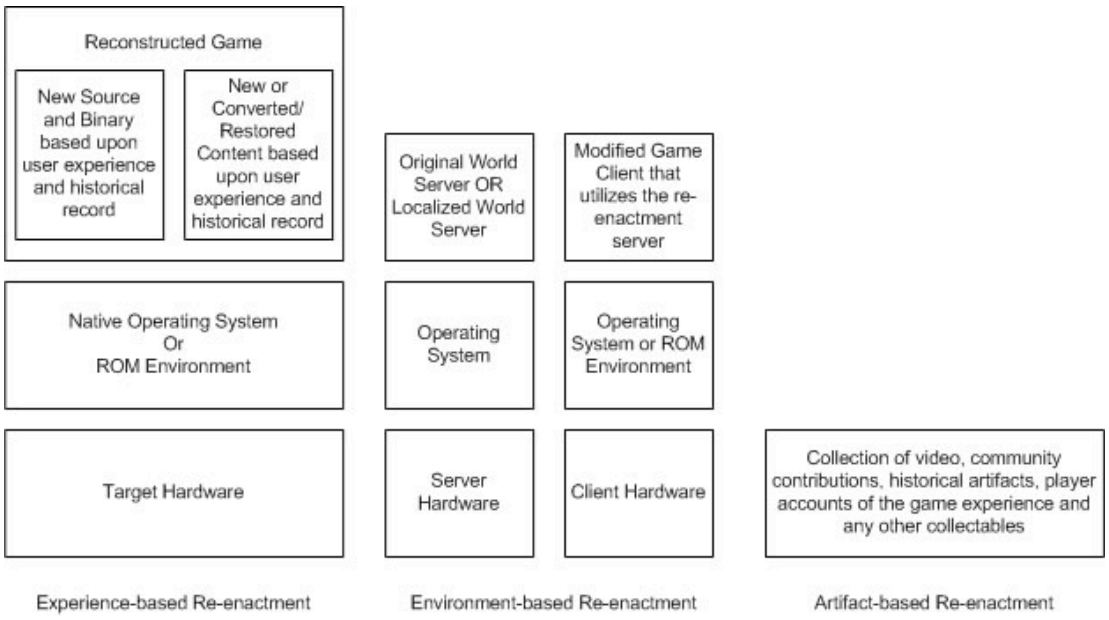
Although never terribly popular in the United States, the U.K.-based electronics company Amstrad produced a series of personal computers, including the Spectrum series, which were very popular in Europe in the 1980s. These machines frequently used a proprietary 3" disk format that is now beginning to appear frequently in the collections of British authors.

SyQuest Optical Disks

In the mid-1990s, a company called SyQuest produced a series of "removable hard disks" that vaguely resembled a compact disk permanently sealed in a plastic jewel case. These disks were read by a special drive that usually connected to a computer via a SCSI port. The drives were most popular with Mac users, and their disks can be found in several publicly held collections of artists' papers. Unfortunately, although connecting a SCSI device to a contemporary machine is not impossible (although still fairly difficult), there are no drivers available for modern computers to control the SyQuest devices.

Analysis of Re-enactment

Another method of preserving a game experience is through the use of technologies that support some level of re-enactment process. In this report, re-enactment covers a range of possible techniques, including the reconstruction of an experience from historical record and game-related artifacts, the reconstruction of the environment through technology, and the documentation of game-related experience through secondary sources, such as community content, advertisements, popular culture artifacts, and other such paraphernalia. In this section, such techniques are examined and the technological impact of the techniques is considered.



By examining such artifacts, two levels of implementation must be reconstructed. At one level, the logic and flow of the game experience must be re-created. This includes navigation related to title screens, credits, game play instructions, game settings, and game play states. It also includes the rules of the game for level presentation, character movement, win and lose states, as well as elements related to play difficulty. At another level, the content of the game must be reconstructed. This includes game art, animation, video, and sound. Fortunately, in some situations, partial information is available that may assist in the reconstruction process, especially in cases where a playable version is available (e.g. games that exist, but due to a loss of technological information, cannot be migrated to a new system). Such re-enactments vary in their accuracy and fidelity in re-creating the original game.

Sometimes re-enactment can be used as an exercise with students who are learning the art of video game development. National programs in the field of game development often challenge students to re-create classic game experiences such as *Asteroids*, *Space Invaders*, and text adventure games so that students can gain greater understanding into the logic and fun of the game development process. Even as recently as this year with Google's "*Pac-Man* in a Browser" experiment, we have seen the impact of experience-based re-enactment.

Another methodology is environment-based re-enactment. This is especially important for games that involve server-based technologies or distributed processing in the presentation of the play experience. For example, games such as *World of Warcraft* require a client-side component (the game world visualization component, input manager, and user interface system) as well as a server-side component (the realm that maintains the object catalog, object instances, and player instances). In such systems, if the server-side technology is no longer available, the game cannot be experienced. As we look back over the last several years, there have been a number of online games that have ceased operation or have changed so significantly that the original play experience has been lost (e.g. what was it like to play during the first three months of the *World of Warcraft* private beta experience?) When server-based games disappear, there are only a few options available to preserve the experience.

Environment-based preservation involves the game development company either distributing the server-side technology to their player base or involves providing the source code to the player community. An example of this approach can be seen with Cyan World's *Myst Online* title, which was based upon the popularity of the *Myst* family of exploratory games. In April 2008, the *Myst Online* servers were shut down. However, in December 2008, Cyan Worlds announced plans to open source the project. Although this process is still ongoing, the possibility of an open source version of the game has re-sparked the player community and has already allowed Cyan Worlds to re-introduce some of the prior technology to the public.

Another form of environment-based preservation involves the underground development community. There have been numerous examples of developers creating their own server-side technology so that a server could be hosted on a local server and a private version of the game (with a small group of friends) could be experienced. Such attempts include the UXO project for *Ultima Online* and the Mangos project for *World of Warcraft*. These projects have resulted in various levels of response from game companies, including active encouragement, non-committal acknowledgement, and legal cease-and-desist responses.

Environment-based preservation can also be accomplished through software designed to process and re-create the environment in a stand-alone application. Such scenarios do not provide the ability for multi-user interactions, but instead allow for an interactive snapshot of what the game would look like at a precise moment in time. The technique involves the capture of game assets as well as information related to the position, orientation, and state of the game objects.

The final methodology is artifact-based re-enactment. This approach involves the use of secondary sources to define the game experience. Key artifacts for this approach include video, images, audio, and first-hand testimonials from players and player communities. In addition, information from trade magazines, conventions, reviewers, commercial outlets, and other sources can supplement critical information. Popular cultural artifacts such as TV commercials, music, spin-off media (Saturday morning cartoons), merchandise, and other items can provide appropriate context for the time period and the experience.

Digital Forensics and Disk Image Analysis

Digital forensics is a rapidly emerging field that encompasses e-discovery, intrusion detection and incident response, data recovery, and the packaging and presentation of digital evidence to standards admissible in various legal settings. As libraries and archives acquire more and more data in born-digital formats, tools, techniques, and workflows from digital forensics offer solutions and technologies for processing this challenging new kind of material. Stanford University Library, along with the British Library and the Bodleian in the UK, are currently applying forensics hardware and software in exactly this role. See Kirschenbaum, Ovenden, and Redwine's forthcoming report (2010) for a more comprehensive introduction to the field.

The bedrock of all digital forensic techniques is the concept of a disk image, a bitstream representation of every *bit* of information originally stored on an instance of physical media.

Bitstream imaging bypasses the file system, thereby allowing an archivist to capture information stored in slack space at the "end" of a file or data clusters flagged for reallocation (the typical fate of supposedly "deleted" material). A technique known as data carving allows an analyst to reconstruct the pieces of a file from the bitstream. File types can be identified by tell-tale headers (if they remain intact), allowing for some reconstruction of the file even it cannot be reconstituted in its entirety. More exotic techniques may allow for the recovery of information from data tracks that have already been overwritten at least once, but these are not within the realm of practicality for libraries and collecting institutions.

Disk images have circulated freely in player communities and various Internet venues, including retro gaming forums and abandonware hubs. Like cartridge-based ROMs, the availability of disk images allows users to run older games via emulators. Sometimes, however, the disk image carries additional freight. A report on a web forum details how one player used an image of an old freeware demo disk to locate source files for the first *Commander Keen* game, an episodic series of side-scrollers published by id Software. Residual data captured as part of the image allowed the player to reconstruct a near-complete running copy of the original game:

> Most of the *Keen* 2 data had been overwritten by the sample games, but to my surprise most of the *Keen* 1 data was still intact and after scratching together the deleted files I managed to get almost a fully running game. Only EGAHEAD.CK1, EGALATCH.CK1, EGASPRIT.CK1, HELPTEXT.CK1 and LEVEL01.CK1 had been completely erased (well LEVEL01.CK1 had about 50% of it's [sic] data there but I didn't bother combining it with the finalized one), so I took these missing files from version 1.0 of the game.
>
> Now I was a bit disappointed that I didn't get the graphics files together (usually graphics are what's most interesting in development versions of games), but it seems the other game files were actually quite different at this point as well. I don't know at exactly which stage the game is in this build but it at least looks pretty close to final with a bunch of minor level design differences in quite many levels.
> The story section is no doubt the most interesting difference, you actually get a scene where a Vorticon comes to your ship and takes the vital parts and then leaves (explaining why these tiles without and with the parts exist in the final game).
> Other points of interest is the lack of the GOD cheat and the fact that you can't complete the game. (http://www.pckf.com/viewtopic.php?t=1211)

Large-scale, systematic analysis of disk images circulating within the player community may therefore provide an important tool for recapturing and reconstituting supposedly "lost" works or versions of works.

Nonetheless, it is important to recognize that even a disk image, while somewhat akin to a "facsimile" in the realm of photographic reproduction, is an abstraction, a projection (or, more precisely, an interpretation) of physical phenomena on the surface of the disk. Creating a disk image is not a homogeneous process, and not all imaging tools will acquire the same data. Some disk image formats, for example, will not indicate the presence of damaged data sectors. It is therefore easy to fetishize a disk image as a more authentic version of the data

than just extracting the files and dumping them on a modern file system. A more useful understanding, however, would be that forensics gives you better documentation about how you reproduced a copy of the original data, not (necessarily) a superior copy.

In one sense, digital games and virtual worlds present no distinct challenges or opportunities for applications of forensics, since the same techniques for data acquisition and analysis that are used with other forms of digital content can be applied just as seamlessly. Whether or not forensic methods are useful in a particular institutional setting will be determined by a cost-benefit analysis of time, resources, specialty training, and the kind of access and services it wishes to provide to its patrons. Techniques for authenticating digital content may, however, have a larger role to play in appraising material collected from the player community. Demos, speed runs, and other forms of player-generated content are occasionally subject to question or controversy regarding authenticity and provenance. In these cases, forensic tools and techniques can prove uniquely useful.

Recommendations on Preservation Strategies

The team has provided several recommendations that must be addressed in the preservation process. These recommendations are not only derived from the emulation, virtualization, and migration processes from the grant, they are also derived from interactions related to the metadata encoding process undertaken by the research team. The recommendations are as follows:

- It is important for museums and other collectors to start the exploration process into emulation, virtualization, and migration techniques as one facet of the preservation process.
- It is important to encode information related to game play based upon original platform, emulation, and virtualization information within preservation metadata.
- There must be a mechanism to encode a testing rubric for virtualization and emulation into a metadata set, such that there is a template for the range of permissible options that is easily searchable and can be indexed. In addition, the testing rubric must contain mechanisms for freeform comments related to the emulation and virtualization process.
- Information related to virtualization and emulation must be extensible and there must be easy mechanisms by which emulation and virtualization information can be updated across collections of metadata. Information update should be updatable based upon the growth and demise of emulation and virtualization community efforts.
- In cases where re-enactment is necessary, there must be means of collecting and indexing metadata and content based upon re-enactment data. Since this information can be more expansive than the original game, there must be mechanisms to minimize repetition and support important artifact derivation.

In looking towards the future, agencies such as the Library of Congress will want to fund exploration in a number of areas if the process of emulation, virtualization, and migration is to be an important part of the preservation strategy. Initiatives should be based upon certain guidelines:

- It is vital to encourage the dissemination of information to help museums and collectors understand the importance of emulation, virtualization, and migration.
- Agencies must help support the development of emulation platforms for the express purpose of emulation. The goal would be to unite various grassroots development teams into a larger community dedicated to the preservation mission.
- Agencies must help larger virtualization companies understand the importance of peripheral virtualization in the preservation stratagem. The effort should include the encouragement of developing adequate video and sound driver solutions, as well as creating avenues for developers to extend the virtualized device specification in an easy to understand format.
- Agencies must help metadata format creators understand the need for a consistent way of encoding emulation, virtualization, and migration data into data set. Standard metadata encoding schemes need to be re-evaluated and extended to support such function.
- Agencies must encourage game engine developers and producers to find technological and interaction solutions to re-enacting and re-scripting typical scenarios within games and engines.

7. When Strategies Fail: The Case of Second Life

Second Life is a virtual world where users create nearly all of the content within the world, and also create most of the social, political and economic activity. While the social, political and economic activities may be the most interesting aspects of *Second Life*, any attempt to preserve those must in part rely on preserving the technological environment providing the context in which they occur. For our project, then, we wished to investigate the feasibility of preserving that environment, and, if possible, doing so in such a way as to avoid relying on the proprietary infrastructure of Linden Lab, if for no other reason than the fact that Linden simply does not possess the resources at this point to serve as a long-term preservation repository for archived states of their own virtual territories (known as "islands"). As we also lacked the resources to try to tackle all of the various islands in *Second Life*, we choose to focus on a subset of five for our archiving efforts:

- Life Squared – A reincarnation of the archive of artist Lynn Hershman Leeson housed in Stanford University Libraries' Special Collections;
- Stanford University Libraries – a virtual library space established by Stanford University Libraries to support online collaboration, education and exhibits;
- Democracy Island – A project of New York Law School devoted to overcoming "some of the difficulties associated with civic participation … in real space";
- International Spaceflight Museum – a virtual museum of spacecraft and space travel managed by a non-profit corporation; and
- Rumsey Historical Maps in *Second Life* – a virtual exhibit of selections from the David Rumsey Map collection.

Problems in Archiving Second Life

Second Life is by far the most technologically complex game (if that is even an appropriate word for it) with which our project dealt, a networked, virtual environment based upon a client/server architecture involving multiple task-specific server components:

- Login Server – manages user authentication and login processes;
- User Server – manages instant messaging sessions;
- Space Server – manages the routing of messages between residents based upon their location in the virtual space;
- Data Server – manages connections to the various databases containing *Second Life*'s data and log information; and
- Simulators – each simulator manages the state of a single region in *Second Life*, including the state of both objects and the terrain and managing the simulation of physics for the region.

Linden Lab has made the client software for *Second Life* available under the terms of the GNU General Public License (version 2.0), with the associated artwork licensed under the Creative Commons Attribution/Share-alike 3.0 license. All software for the server components is closed source.

Second Life is organized into different 256 x 256 meter regions known as islands, or sims (short for "simulators"). A region can be owned either by Linden Lab or by one of *Second Life*'s players, known as residents. The contents of a given region consist primarily of a combination of 3D objects, graphical texture files that can be overlaid on the 3D objects, audio files providing background noises and scripts that enable interactivity with the various objects within a region. All of this content is hosted on Linden Lab's servers, with the different servers managing the interactions between residents' client software applications and the various regions.

Objects in *Second Life* are created by linking various shape primitives (or prims). The primitives comprise eight basic shapes (box, prism, cylinder, sphere, torus, ring, tube and sculpted). Each of these can be further modified from their default shapes. A primitive is more complex than its name might imply, as each prim has an associated inventory that can contain scripts, notecards, textures and other items. Textures (image files applied to the faces of the primitives) give objects the illusion of possessing even more detail. Each object has a set of metadata elements associated with it, including the identity of the individual who originally created the object (the intellectual property rights holder), the Creator, and the individual who has possession of the object, the Owner.

Object scripts, written in the Linden Scripting Language (LSL), are what transform *Second Life* from a beautiful, but static environment into a highly dynamic and interactive one, allowing any object to exhibit a wide variety of complex behaviors and accomplish a variety of functions within an island. Any island can have thousands of script-bearing objects, each object with its own creator and owner. Additionally, textures, scripts and other items in an object inventory may be the creations of someone other than the object creator (and may be impossible to identify).

Preserving such an environment presents several obstacles. There are technological impediments to obtaining access to certain forms of content in *Second Life*. Due to the permissions system employed by *Second Life*, an object's inventory (including scripts) is, by default, not available to anyone other than the object's creator (and so cannot be accessed or copied by any other resident of *Second Life*). As a third party (not Linden Lab and not the owner of an object), we cannot realistically obtain access to the underlying database of object data on Linden Lab's servers directly to make a complete copy, nor can we access the full contents of an island as a user on the system within that particular region.

Intellectual property and contract law present additional obstacles to preservation activity. The Terms of Service agreement covering residents' access and use of the *Second Life* service specifically states "You retain any and all intellectual property rights in content you submit to the service." The Terms of Service also forbid any infringement of intellectual property through unauthorized copying of content available through the service, stating that "You must obtain from the applicable Content Providers any necessary license rights in Content that you desire to use or access" and "You agree that you will not copy, transfer, or distribute outside the Service any Content that contains any Linden In-World Content, in whole or in part or in modified or unmodified form, except as allowed by the Snapshot and Machinima Policy, or that infringes or violates any intellectual property rights of Linden Lab, other Content Providers, or any third parties." The combination of *Second Life*'s contractual framework with copyright law make any effort to make a preservation copy of the contents

of an island without the explicit permission of all of the content creators who have objects present within that island illegal.

One final difficulty with archiving *Second Life* is determining the full scope of what must be archived. If we were to manage to archive all of the objects from a given region, including all scripts, animations and other inventory content that are typically protected, we would, in effect, have managed to archive a ghost town, an empty set of architecture and geography with no information about how the space was used or what its inhabitants were like. A static snapshot of a world such as *Second Life* may in some sense serve as a surrogate for the original, but it is a poor substitute. Part of the fundamental nature of *Second Life* is that it is a living, evolving, dynamic space. An archived copy of a region provides some documentation of what the world was like, but it is hardly a complete set of documentation, and in a very real sense it is not and cannot be a complete version of the original.

Basics of Archiving a World

Despite the issues mentioned above, our project decided that we would try to proceed with an approach that involved making an archival copy of our regions of interest. We decided that our approach should fulfill several criteria. First, it must respect the intellectual property of *Second Life* residents, as well as Linden Lab. It should, if at all possible, produce an archival copy that is not tied to the *Second Life* architecture, but which would allow a copy of a region's contents to be instantiated in multiple different virtual environment platforms. While Linden Lab was a partner in our project, we also decided to approach the issue of archiving a region as a party without special permissions or access, in effect putting ourselves in the position that any library, archive or museum might occupy if they decided to make an archival copy of some region of *Second Life*.

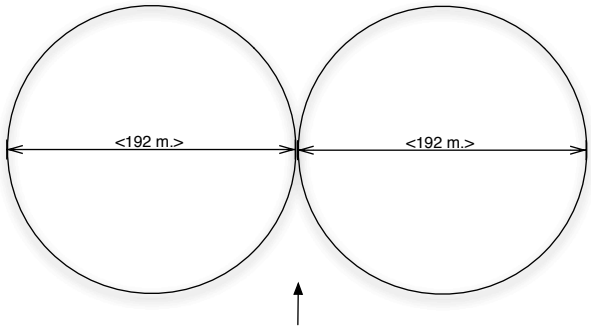
Creating an archival copy of a region in *Second Life* involved a multistage process. First, we created manifests of the various regions' contents and gathered metadata about the objects within those regions. Using the objects' Creator metadata, we next contacted each rights holder for objects in the regions asking for their permission to archive the content they owned. We then downloaded all available information for the objects we had received permission to archive, along with additional information about the island itself, and created a submission information package suitable for loading into repositories at the University of Illinois and Stanford University Libraries containing the complete set of object and region information. Details on our process are below.

Creating a Manifest of an Island

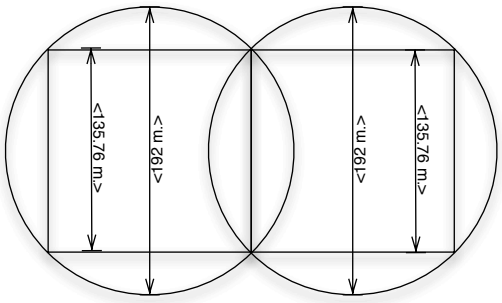
One of the first issues we needed to deal with is identification of the objects to be archived. There are potentially hundreds if not thousands of them on each island, and they may be invisible, at a high altitude within the virtual space or otherwise difficult to identify. Fortunately, Linden Scripting Language (LSL) provides a fairly simple mechanism for detecting objects. However, LSL's limited script memory presented some limitations that required a great deal more thought about algorithm design than was initially imagined.

The primary function for sensing objects in LSL is llSensor() or llSensorRepeat() and the associated events "sensor" and "no_sensor". The llSensor() function can be imagined as a form of virtual radar, sending out a ping, with the event sensor acting as the receptor (no_sensor is triggered when nothing matching the criteria is found). The llSensor() function has a maximum range of 96 virtual meters, so a single ping would sense a sphere with a radius of 96 meters. The spherical nature of llSensor()'s search capabilities presented us with a packing issue, however. If we used llSensor() to detect objects every 192 (2 x 96) meters, there will be gaps between the spheres (imagine packing ping pong balls into a box, and you can visualize the air space that would represent regions we could not detect). Cubes will pack perfectly, so we just compute the maximum size for a box bounded by the sphere and stack the boxes. The diagram below presents a 2D model of the 3D case.

As you can see there are some overlaps in the scan areas when the scans are placed so as to focus our scans on adjacent cubes, rather than spheres, but checking for objects detected twice is straightforward. A more significant problem is that that the sensors only detect the sixteen objects closest to the center of the search sphere. So if there are seventeen or more objects within the space, the probe will not detect any object further away than the sixteenth object detected. In a case where we detect sixteen objects, we will not know whether this is because there actually are sixteen objects, or whether there are more within the space that simply are not being reported by the sensor. We can compensate for this by adjusting the sensor's detection range down until we get less than sixteen objects per scan, but we cannot know what the reduced range necessary to ensure detection of all objects might be.

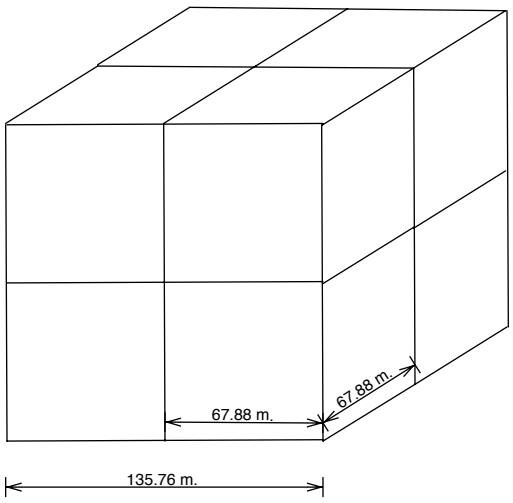


Unscanned space using llSensor() at every 192 meters.



Overlapping llSensor() scans done at ~135.76 metersto scan adjacent cubes

We chose to adopt a method that involves a progressive subdivision of the search space in any case in which a scan detects sixteen objects. If a scan reports sixteen objects within the sensor's range, the sides of the search box are decreased in size by half (so a 136 meter box would become 68) and we essentially stack 8 boxes into the original box with more than 16 objects. We then scan each of those sub boxes. If any of them have 16 or more objects, we repeat the process.



Sensor cube subdivided into small cubes in insure detection of more than 16 objects

There is a potential flaw with this method. It is possible within *Second Life* to put more than one object in the same location. This makes it possible to have 16 or more objects that have the same exact coordinates. In these situations, if our scanning boxes reach a minimum sensor range of 0.01 meter (the minimum shape dimension permitted), we exit the function and our program returns an error alerting the user to the problem. If desired in those cases, a manual inventory of the objects can be performed.

As each object is detected during our scanning process, information about the object's owner and creator is obtained, and our program stores that information in an external MySQL database. Once all of the objects' intellectual property rights holders have been identified, we are ready to embark on the next phase of archiving, obtaining permissions to archive the objects from the appropriate rights holders.

Obtaining Permission

After having created a list of the objects within an island, we can then proceed to contact the creators of those objects to obtain permission to archive their materials. Given the potentially large number of content creators in any given region, we used a semi-automated system to obtain permission to archive objects. The avatar names and UUIDs (a unique identifier given to every asset in *Second Life*) of all content creators from a region are retrieved from our database, and sent to a *Second Life* object that acts as a portal for interaction with *Second Life* residents' avatars. The portal receives the avatar information and sends a notecard within *Second Life* to the creators, describing our project, what we want to do with the objects they created, and including an in-world teleport link they can use to travel to our portal, where they can obtain access to a web interface we have created for granting or denying permission to archive their materials.

At the portal, creators use the object's interface to access the web interface for permissions management. The creators are first asked to set up an account, and then they are presented with a list of all their objects we wish to archive. The creator may choose to allow us to archive all of the objects, some of the objects or none. Creators are also allowed to specify an embargo period during which their content will not be made public. The language for granting permission to archive is based upon a standard archival deed of gift used by Stanford University Libraries that was modified for use on this project (see Appendix G for the language used). Once we have a listing of the objects for which we have been granted permission to archive, we can embark on actually making an archival copy of those objects.

Copying a World

Overview of Building in Second Life

The fundamental building block in *Second Life* is the shape primitive or prim. More complex objects are built by combining prims of different shapes together similar to a set of building blocks or Legos. There are eight prim types used:

- box
- cylinder
- prism
- sphere
- torus
- tube
- ring
- sculpted

Most of these are self explanatory except for sculpted prims, a newer addition that allows builders to create more organic shapes using off-world 3D design software, and then importing them into *Second Life* as 2D UV maps (32 x 32 pixel .tga or .jpg files) that are polar coordinate maps of the sculpted objects. The low resolution of the UV maps limits the details that can be included and display costs associated with sculpted prims continue to make it advantageous to use the other prim types for many applications.

There is a daunting array of parameters that can be used to alter the shape of these prims. Such modifications can often extend to such a degree that they render the base shape unrecognizable. Parameters cover such aspects of an object as its material composition, position, rotation with the coordinate space of the world, size, texture files overlaid on the prim, color, reflectivity and other physical parameters. There are also parameters having to do with ownership, creation, IP issues and contents of a prim's inventory. Prims can contain other things such as other objects, scripts, animations and so on.

Each face of a prim can be textured and colored independently. *Second Life* currently supports .tga, .jpg and .gif files for texturing with a maximum resolution of 1024 x 1024 pixels. Textures can be sized and positioned on a prim face repeatedly as well. You can get the UUID for each texture, and capture the textures using the GLIntercept software.

It is very common to find scripts inside *Second Life* prims. Without scripts, *Second Life* objects would just be pretty (or occasionally ugly) pictures. Prims can contain multiple scripts that function more or less independently of one another. A person can write scripts that allow objects to communication with one another. The Linden Scripting Language actually allows objects to do some surprisingly complex things, and given the ability to use HTTP and XML-RPC to contact off-world web servers, objects can exhibit extremely sophisticated behaviors.

To make more complex shapes or items larger than 10 meters in any dimension, prims are linked together into objects. Linked prims can be moved as a unit and can communicate via scripts a bit more easily than unlinked prims. No more than 255 prims can be linked

together in a single object. Many large buildings are therefore composed of many individual objects, each containing a number of prims. One prim in any object serves as the root prim. All other linked prims can be referred to by their link number. An unlinked prim has a link number of 0, the root prim of a linked set has link number of 1, and the rest are numbered consecutively based on the order they were added or selected. The root prim is important because position, rotation and velocity information for an object are all relative to the root prim. Child prim information is also given relative to the root prim. Additionally, the root prim is generally where the main scripts are placed, although child prims often contain scripts that communicate with scripts in the root prim.

The largest independent building block in *Second Life* is the Island, Sim or Region. A sim measures 256 meters on the *x* and *y* axes. A region is defined by its terrain, stored in a .raw file that gives the height of the ground, ground textures and the water level. The ground textures display somewhat sequentially from lowest to highest terrain height and can be controlled semi-independently by specifying different heights for each corner of the sim. Additionally, there are sim parameters that determine what functions are permissible within the region, and privately held sims often have a covenant that functions like a legal document specifying how the sim is meant to be used. Sims can be divided into parcels that can also have names, descriptions and parameters that determine what is allowable (if the sim parameters allow that for smaller parcels). A standard sim supports a maximum of 15,000 prims (not objects; the number of objects will depend on how prims are linked).

The software we chose to copy the objects in a region is known as CopyBot. CopyBot is a text-based client for *Second Life* developed by a group of griefers (avatars who disrupt others' activities in *Second Life*) known in *Second Life* as the Patriotic Nigras (whose motto is "Ruining Your *Second Life* Since 2006"). The group has a poor reputation in *Second Life* as its primary function was to make content theft and griefing easier. Despite their nefarious reputation, they developed what turns out to be a very useful tool for archiving *Second Life* content, as it allows us to export and import *Second Life* object data to and from an XML file.

The export function downloads all object data into an XML file (see Appendix I for an example). It also downloads all of the textures used on a particular object. There are several important caveats. First, it breaks all links to intellectual property ownership. The names of the content creator and owner do not even appear in the file. Second, it does not gather the contents of an object's inventory, such as scripts, sounds, etc. These have to be collected and inserted back into the objects manually, a process that is only feasible when you have the appropriate permissions to examine the objects' inventories.

Another restriction of CopyBot is that it is designed to download a single object at a time. In order to download all of the objects on an island, we created a program that interacts with our database of objects created during the initial scan of an island. This program obtains the UUIDs for the objects we have permission to archive, and then sends a request via HTTP to a special attachment worn by the CopyBot avatar, directing the CopyBot to move to the object of interest and download it. The management program, combined with CopyBot, allows us to automate the downloading of all the objects we have permission to archive.

In addition to the data for the individual objects, we need to store the information regarding the region and also provide facilities for relating the objects to each other (and individual

information we may wish to store about the island). For this purpose we created an XML schema that stores all of the data required to reinstantiate the objects back into *Second Life*. Having the information stored in an XML document would also allow us to export the information into other virtual world platforms, although this would require some transformation of the data. The XML Schema is broken into six subdocuments and follows this basic structure:

> SLBuild.xsd – the root file for the schema, which stores basic information about the island (e.g., the sim owner, a description of the sim) as well as information on all objects and their composition prims;
>
> SLShapes.xsd – this file defines the parameters that influence the shape of each of the different prim types;
>
> SLPrimFeatures.xsd – this file defines non-shape parameters that may be recorded for each prim type including color, flexibility, drag, the influence of gravity on the object, etc.;
>
> SLPrimTextures.xsd – this file defines the parameters recording the texture information associated with each prim;
>
> SLPrimContents.xsd – this file defines the information set which may be used to record information about the contents of a prim's inventory; and
>
> SLBasicTypes.xsd – this file defines basic element types used in other types in the schema, such as vectors and rotations.

While our process often does not allow us to obtain complete information about the objects in an island (the inventories of primitives in particular are difficult to obtain), the schema does allow us to store a complete record of the contents of an island.

Failures in Archiving

While in theory the mechanisms defined above allow us to archive a fairly complete representation of an island in *Second Life*, separately from the *Second Life* system, and in a form that would potentially allow us to reinstantiate the island in another virtual environment platform, in practice our efforts can only be described as partially successful at best. We encountered a number of difficulties in attempting to archive our test cases in *Second Life* that severely impeded our ability to create a complete record of those worlds.

The greatest impediment was the need to obtain permission from the intellectual property owners before we archived their objects. At its best, our response rate to requests for permission was 10% of the individuals we contacted on one island, and at worst, we received no responses at all. It is reasonable to ask whether an archive that contains only 10% of the objects within an island is worth creating at all; it is certainly not an accurate reflection of the island as it existed at that time. Moreover, some of our responses were actually hostile. Many *Second Life* builders earn a living from creating objects in *Second Life*, and they were not

pleased with the notion that anyone might actually copy their creations and place them in an archive where others would be able to obtain access to them.

In the case of one island, we experienced a complete failure in our attempts to archive not because of intellectual property issues, but due to a technical one. Democracy Island, a project of the New York School of Law, allows any and all *Second Life* residents to build within their island. As a result, the island has been packed with objects to the point where it has actually hit the limit on the maximum number of prims allowed within a given region. Our approach to archiving does require us to instantiate a probe object within an island to perform our initial scan for objects. Because we could not instantiate our probe, we were unable to obtain the necessary information to continue our attempts to archive that island.

Another potential problem exists in that regions and parcels within *Second Life* can be declared 'no script' zones. Any scripts bound to an object in *Second Life* will immediate cease when they enter such an area. Our initial probe to identify objects within an island is a script-based object. If it accidently enters such a region, it immediately fails.

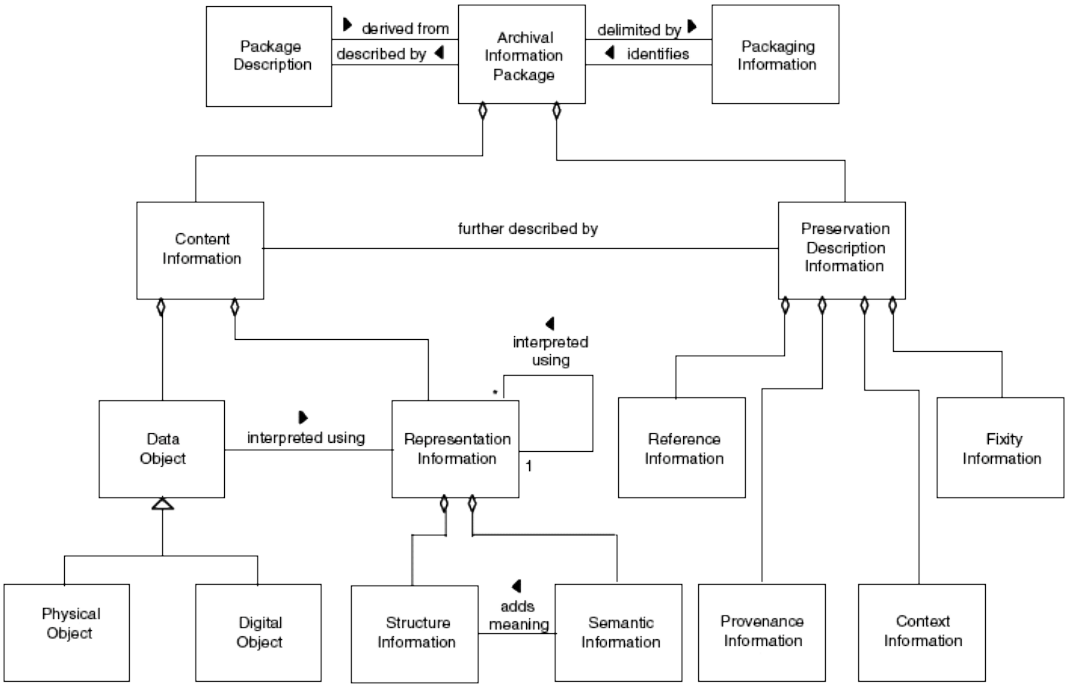
A final major problem is that, as a third party, we have no access to the inventories of objects other than those we have created. While the information we can automatically extract from an island allows us to create a visually complete recreation of the objects in an island, any animations or scripts associated with the objects are lost. All of the behaviors of objects that make *Second Life* an interesting and dynamic environment are gone. While it is possible for the intellectual property owners of the objects to provide us with copies of the contents of the objects' inventories, it was difficult enough to simply obtain permission to archive. The odds of the IP owners being willing to manually copy all of their objects' inventories for us seem remote.

In short, our experiments in trying to archive islands in *Second Life* at best resulted in extremely partial and static representations of the original. While the techniques we've developed may be useful in archiving some virtual world systems, at least in the case of commercial environments such as *Second Life*, there are severe limits to the preservation activity in which a third party can engage. Given the intellectual property and contractual restrictions governing *Second Life*, any hope for a complete archive of a *Second Life* world would rest on Linden Lab's willingness to archive the content itself.

8. Packaging Virtual Worlds

Virtual Worlds and the OAIS Reference Model

The Reference Model for an Open Archival Information System (OAIS) (Consultative Committee for Space Data Systems, 2002) has been accepted as one of the foundations for digital preservation efforts throughout the digital library community. One of the key aspects of the OAIS reference model is the concept of an archival information package, the complete set of content information and preservation description information necessary to maintain a data object as interpretable by the designated community a repository serves over the long-term. The OAIS reference model includes a data model for an archival information package (see the figure below), and later work by the Consultative Committee for Space Data Systems led to an XML packaging format for the creation of archival information packages, XML Formatted Data Units (XFDU) (Consultative Committee for Space Data Systems, 2008).



OAIS Archival Information Package Data Model

While the data model set forth in the OAIS reference model provides a structure that can in theory be applied to information housed in any archive, the OAIS reference model was designed to support the operations of aerospace agencies archives, including data archives. While the Consultative Committee for Space Data Systems (2002) did mention software as a type of content information that might be saved in an archive, the reference model's examples, particularly in the case of representation information, tend to focus on simpler data types. It seems safe to assume that the use cases the OAIS reference model's creators had in mind when designing the model did not include preserving *World of Warcraft* or *DOOM 3*. Our investigations have found that while the OAIS reference model as it stands

today is capable of handling game software as an object of preservation, video games and interactive fiction are extremely complex digital objects, and packaging them in a manner consistent with the OAIS reference model can be a challenge, particularly with regards to the matter of providing adequate representation networks and adequate context information.

The OAIS reference model specifies that an archival information package for digital content should contain the representation information necessary to convert the bit sequences in the digital information into more meaningful information by describing the data format used to encode the digital information. It recognizes that a given piece of representation may reference other pieces of representation information (as when Unicode references ISO/IEC Technical Report 19769 in its discussion of Unicode data types for the C programming language), and that representation information in digital form, as an object of preservation in its own right, may require its own representation information (e.g., if we stored the Unicode standard in PDF file format as representation information for an object, we would need a copy of Adobe's PDF Reference specifying the PDF data format). The full set of representation information needed to ensure a digital object's on-going interpretability can thus form a large and complex representation network.

As an example, consider the game *Mystery House* from our case set. The original source code for *Mystery House* has apparently been permanently lost. Existing versions of the original game are encoded as files embedded within an Apple II disk image file. Our representation information for the game thus needs to start with a copy of *Apple II: The DOS Manual*, the documentation for the Apple II disk operating system. Fortunately, we have a copy of that as a PDF 1.6 file. Obviously, we will then need a copy of the Adobe PDF Reference for PDF version 1.6. The PDF Reference references 33 other documents published by Adobe, the vast majority of them technical documents needed to understand aspects of the PDF specification. It also references 60 documents from other agencies, including a large number of standards documents from agencies including the Institute of Electrical and Electronics Engineers, the International Color Consortium, the International Electrotechnical Commission, the International Organization for Standardization, the International Telecommunication Union, the Internet Engineering Task Force and the World Wide Web Consortium that define technologies relevant to implementation of the PDF specification. Many of these standards documents in turn reference other standards documents. We are well on our way to having a representation network that resembles a small technical library, and we only have the information needed for preservation of the disk image file format; we have not yet considered the files contained within the disk image.

Of course, the size of this representation network could be truncated quite effectively if we keep our copy of *Apple II: The DOS Manual* in print form rather than in PDF format. This requires, however, that the wrapper for our archival information package for this game be able to successfully reference both digital and non-digital material. And that still leaves the issue of the representation information necessary to document the Apple II's binary executable file format, including the documentation for the MOS 6502 instruction set used in the Apple II line.

In addition to complicated representation networks, the games in our case set have shown that games can be extremely reliant on what the OAIS reference model calls "context information" to aid in their interpretation. The reference model defines context information

as "information that documents the relationships of the Content Information to its environment. This includes why the Content Information was created and how it relates to other Content Information Objects." It also provides examples of context information for a software package: a help file for the software, user guides, related software, and documentation on the programming language used. Taken together, these examples indicate that the purpose of context information for software is to aid the individual examining the software to understand its purpose, its operation, and the technical environment necessary to enable the software's use.

All of this information is clearly necessary for the game software we examined in our case set. While we think of games such as *Star Raiders* for the Atari 2600 as relatively primitive in comparison to today's games, players had to understand how to activate and deactivate their ship's shields, how to use the attack computer in targeting enemy ships, how to use the game's galactic map to identify their own location, their starbase location, and the location of enemy ships, how to assess their ship's energy level (and how to recharge it), and how to determine the amount of damage their ship had taken, in addition to basics such as maneuvering and shooting. The game also tracks skill levels of the game players over time as they advance in missions. Without the game manual, it is extremely difficult to interpret the screen displays of the game and understand exactly how game play is supposed to proceed. And a game like *Star Raiders*, designed for an antiquated console platform, nicely demonstrates the necessity of maintaining complete technical documentation on the environment in which it was designed to run if we are to offer continuing access to the game. Without the documentation necessary to produce an emulation of the Atari 2600 Console, the *Star Raiders* game as distributed is useless.

Games, however, may also require context information beyond the forms documented within the OAIS reference model document. Games are not just technical phenomena, they are also social phenomena, and the explanation of "why the content information was created" can be extraordinarily complex in the case of something like the International Spaceflight Museum in *Second Life*. There are entire books devoted to the origins of the Atari platform and games from our case set (for examples, see Montfort [2009], Montfort [2003], Barton [2008], Boellstorff [2008]). If context information is needed to understand why content information is created, then in the case of video games and interactive fiction context information is going to be far more extensive than in the case of a data file from a space mission, and will also involve more extensive links between the digital content information to be preserved and the standard bibliographic universe of published books and journal literature with which librarians have traditionally been concerned.

***Spacewar!* running on a PDP-1. Image courtesy of Kenneth Lu.**

Another obvious, but critical, aspect of games relating to context information is that they are highly interactive. And because they are interactive, the "why" of their creation is not necessarily something established by the game designers, but is constructed on an on-going basis by the games' users. This is particularly obvious in the case of massively multiplayer online systems such as *World of Warcraft* or *Second Life*. The nature of these virtual worlds is constituted in significant part through their use. Without documentation of how players actually engage with these resources, individuals in the future studying these materials will be left with an incomplete answer as to the "why" of their creation. But this is equally true of single-user games. The oldest game in our case set, *Spacewar!*, was developed in part as a mechanism to demonstrate the capabilities of the PDP-1 computer on which it was originally implemented, including the capabilities of the vector graphics display used by the computer (see figure above). Vector graphics display terminals, however, are almost unheard of today outside of a few niche applications. Video or photographic documentation of the game in use on its original platform is also needed if people studying the game *Spacewar!* are to gain a complete appreciation of the "why" of its creation.

Analysis of Packaging Requirements

As the above discussion (as well as the previous discussions on FRBR) should make clear, we have found that, to the extent preservation of computer games and interactive fiction is a metadata problem, it is primarily a matter of structural metadata. More completely, the problem of preserving computer games and interactive fiction is primarily an issue of structural metadata and collection management, insuring that you have the complete set of

representation information and context information necessary to render your content information both accessible and apprehensible, and that all of the necessary relationships between content, representation, and context information are appropriately recorded. Possessing a technical metadata record stating that the file named "star_raiders.bin" contains a binary executable intended to run on a MOS 6502 processor is of limited value for preservation when compared to having copies of the MCS 6500 Family Programming Manual and the MOS 6500 Microprocessor data sheets necessary to interpret the contents of the file. In fact, if we possess structural metadata linking the "star_raiders.bin" file to those documents, and asserting that they provide representation information for it, recording a file format in a technical metadata record is actually somewhat redundant.

Both the relationships described in the *Functional Requirements for Bibliographic Records Final Report* (1997) and the *Reference Model for an Open Archival Information System* (2002) are critical to the successful preservation of video games and interactive fiction. Any packaging mechanism for preservation of these materials must therefore support expression of these relationships between different entities. Moreover, as the relationships that exist in FRBR are specific to particular classes of entities defined in the FRBR report, a packaging mechanism for digital games must allow support, either implicitly or explicitly, the identification of entities described within the package as belonging to a particular FRBR entity class.

Beyond these requirements are ones common to any digital preservation effort. In addition to representation information and context information, a packaging format needs to be able to provide a wrapper for fixity, reference, and provenance information. The digital file format employed for any packaging file for metadata and content should itself demonstrate the sustainability factors identified in the Library of Congress's *Sustainability of Digital Formats* (2007) website.

Finally, while packaging games for preservation is primarily a structural metadata problem, it is clear from both our research (and from the OAIS reference model itself) that archival information packages for video games and interactive fiction will need to make reference to non-digital material (print documentation for software, books and journal literature containing context information, etc.). Such references need to be capable of providing sufficiently detailed descriptions of resources to allow for reliable identification of specific editions of print material.

Metadata & Packaging Recommendations

As noted above, packaging of video games and interactive fiction for preservation is in significant part a matter of making explicit the different relationships that exist between various resources. There are two common web technologies in use today that can both link resources and specify the exact nature of the link between them, and that also provide a wrapper format that we can consider as highly sustainable if evaluated using the Library of Congress's sustainability criteria. The first is the XML Linking (XLink) (World Wide Web Consortium, 2001) standard, and the second is the RDF/XML syntax specification (World Wide Web Consortium, 2004). While these two standards have some significant differences, for our purposes, the similarities are more important. Both provide a mechanism to specify a relationship between two resources. Both provide a mechanism to record a URI that indicates the specific type of relationship between two resources (the predicate in an RDF

triple in RDF/XML, the xlink:arcrole attribute in XLink). Both are capable of asserting relationships between resources when:

- both resources are contained within the same document as the link itself;
- one resource is contained within the document containing the link and the other is external; or
- both resources are external to the document containing the link.

The METS standard employs XLink, while OAI-ORE is expressible within the RDF/XML format; both of these provide the necessary linking mechanisms and do so using common standards. While MPEG-21 DIDL does not explicitly support XLink, its schema allows widespread use of attributes from non-MPEG namespaces (including XLink) and so is capable of encoding the necessary linking information. The XFDU specification from the CCSDS does not, unfortunately, currently conform to either XLink or to RDF, and so we cannot recommend it as a packaging standard at this time.

We believe that a shared, formalized ontology defining the various FRBR and OAIS reference model relationships is the preferred mechanism for enabling the specification of relationships in digital preservation packaging standards. By providing standardized URIs for each of the relationships, ontology provides both the means of indicating the specific relationships between resources and provides a shared language for recording information on relationships between preserved resources that will help promote interoperability between institutions. For the Preserving Virtual Worlds project, we have created an OWL ontology (see Appendix C) that defines the FRBR Group 1, 2 and 3 entities as classes, and defines the various relationships mentioned in both FRBR and the OAIS reference model as properties between these FRBR-based classes.

Having this ontology permits the expression of both FRBR and OAIS relationships between resources in packaging formats employing RDF/XML or that provide appropriate support for XLink extended links. In OAI-ORE, for example, defining a particular aggregation as a FRBR work and associating the work with a piece of context information can be accomplished relatively easily:

```
<rdf:Description rdf:about="http://people.lis.illinois.edu/~jmcdonou/PVW/aggregation/Mysteryhouse/Work.1">
    <rdf:type rdf:resource="http://people.lis.illinois.edu/~jmcdonou/PVW.owl#Work" />
    <pvw:has_context_information rdf:resource="http://www.ifarchive.org/if-archive/solutions/mystery-house.txt" />
    <ore:aggregates rdf:resource="http://www.ifarchive.org/if-archive/solutions/mystery-house.txt" />
</rdf:Description>
```

A similar description is possible in METS:

```
<mets xmlns="http://www.loc.gov/METS/"
   xmlns:xlink="http://www.w3.org/1999/xlink"
   xmlns:pvw=http://people.lis.illinois.edu/~jmcdonou/PVW.owl”>
     <fileSec>
        <fileGrp USE="Data">
           <file ID="F1">
              <FLocat LOCTYPE="URL"  xlink:href="http://www.ifarchive.org/if-archive/solutions/mystery-house.txt"/>
           </file>
        </fileGrp>
   </fileSec>
   <structMap>
       <div xlink:label="W1" LABEL="Mystery House" TYPE="pvw:Work”></div>
```

```
        <div xlink:label="W2" LABEL="Mystery House walk through" TYPE="pvw:Work">
            <div xlink:label="E2" TYPE="pvw:Expression">
                <div xlink:label="M2" TYPE="pvw:Manifestation">
                    <div xlink:label="I2" TYPE="pvw:Item">
                        <fptr FILEID="F1"></fptr>
                    </div>
                </div>
            </div>
        </div>
    </structMap>
    <structLink>
        <smLink xlink:from="W1" xlink:arcrole="pvw:has_context_information" xlink:to="W2"/>
    </structLink>
</mets>
```

While we believe that an approach to game packaging relying on standardized ontologies for the description of relationship types is the best means for encoding the necessary linking information between resources in a preservation environment in a way that supports interoperability, the PVW ontology should be seen as the start of a discussion on standardized ontologies for this purpose and not the end. We do believe that an ontology or ontologies that describe both the FRBR and OAIS models and that integrate the two are an essential component for packaging of computer games and other software. But if ontologies are to become a component of the preservation community's standard toolkit for packaging, development of those ontologies needs to be done in a way that involves the larger community as part of process that would feed into an official standards effort.

With regards to descriptive metadata employed within archival information packaging, we have already mentioned the need for descriptions that are sufficiently detailed to enable identification of specific editions of resources. This is particularly true if we assume a distributed, collaborative preservation environment such as envisioned by the Library of Congress (2002) in their *Plan for the National Digital Information Infrastructure and Preservation Program*. In such an environment, it is conceivable that institutions may rely on copies of representation information and context information being held by other, remote institutions. In such a case, being able to describe a work in sufficient detail in order to enable its identification outside of your own institutional setting is of vital importance.

Dublin Core does not provide this level of detail, and we would recommend against its use in a preservation setting. Description standards such as MARC/XML, MODS, CDWA and VRA Core that enable identification of specific editions of resources should be used instead.

9. Steps for the Future

Library of Congress National Collecting Plan

The Library of Congress has based its collection policy statements on three fundamental principles:

- The Library should possess all books and other library materials necessary to the Congress and the various officers of the Federal Government to perform their duties;
- The Library should possess all books and other materials (whether in original form or copy) that record the life and achievement of the American people; and
- The Library should possess in some useful form, the records of other societies, past and present, and should accumulate, in original or in copy, full and representative collections of the written records of those societies and peoples whose experience is of most immediate concern to the people of the United States.

The Library has a number of separate collection policy statements and overviews for various specific topic fields and in some cases for particular formats. The collection overviews covering special materials and formats include one on computer files (http://www.loc.gov/acq/devpol/colloverviews/computer.pdf), which discusses the computer game holdings of the Motion Picture, Broadcast and Recorded Sound Division at the Culpepper facility. The Collection Policy Statement for Moving Image Materials includes video games within its scope, noting that:

> Video games have become an established, popular medium of moving image entertainment that demand inclusion in the collections of MBRS. The Division is developing new approaches for the more systematic acquisition of video games, including playback consoles and platforms, the multiplicity of formats and their equipment needs, and the technical challenges in preserving the digital source files. The collection will encompass a wide range of examples of video game culture, to allow historians decades hence to fully understand this as a popular phenomenon, and not have simply a few games that seemed significant at the moment of release.

The Collection Policy Statement also states that the collecting level for video games should be at the research level, and that the Motion Picture, Broadcast and Recorded Sound Division "both selects via copyright and purchases video games, their associated hardware, and magazines about them that reflect the breadth and depth of gaming culture."

We strongly endorse the maintenance of a research-level collection of published video games by the Library of Congress. Just as important, in addition to documenting the output of the game industry, the Library of Congress, in collaboration with other cultural institutions, should make a sustained effort to ensure that materials are collected that document game cultures and communities built around digital games within the United States, as well as international cultures and communities that have influenced those in the United States. Based on our research, we would like to recommend some steps that we believe will assist

the Library in maintaining a research-level collection of video games, as well as suggesting some guidelines that might be useful in the selection process for materials relating to video games.

Collection Policy Recommendations

It is perhaps the least surprising of our findings that computer games and interactive fiction are among the most fragile of digital works, due to their extensive dependency and interconnection with computer operating systems and particular hardware configurations. We can safely assume that a PNG image will display equally well on a Mac or a PC, and that an update to a computer's operating system is unlikely to mean that the image can no longer be displayed. Neither assumption is safe for software. Given this fragility, all software, including games, requires an extremely proactive approach to preservation, and this has implications for collection policy.

One of the first implications that should be considered is the necessity of collecting materials other than the games themselves. Both related representation information and context information must be acquired and preserved as part of the Library's collections if games added to the collection are to survive. We address issues around representation information below. Context information is important in two respects. First, it provides understanding of the relationship of specific content such as a digital game to its technical environment. For example, documents such as game manuals, developer-created technical support websites, and contributions by players to discussion forums provide information about hardware and software dependencies that must be understood to install and provide access to game content or instructions on how to operate a game or tools based on it (as in the case of replay or machinima production). Second, information about the context of a game often serves equally well as archival documentation of the technical, player, fan, or creative communities around a game, or about historical events and activities that took place in game or virtual worlds; we discuss historical collections at greater length in section 4 of this report. We note here that contextual information for games and virtual worlds contributes double duty by adding to historical as well as preservation documentation.

With respect to context information generally, our research has shown that preservation of computer games requires an integrative approach to collection development that is not common in libraries, archives, and museums to date. Context information for games can be found in the form of traditional published print material in many forms. The range of published formats for game-related information extends from scholarly books and journal literature such as Montfort's & Bogost's (2009) *Racing the Beam* or Dennis Jerz's (2007) article on the game *Adventure*, through trade and web-based publications such as game guides and magazines and the descriptions of play experiences characteristic of the "new game journalism" (Jim Rossignol's (2008) *This Gaming Life*, or Tom Chick's columns and essays) to ancillary publications and ephemera such as printed game manuals or on-line player reviews. Digital games have been at the heart of scholarly discussion of "trans-media" content, so it should come as no surprise that non-print media also provide contextual information about games. We can start with the growing number of game-based movies such as the *DOOM*, *TombRaider, Final Fantasy*, *Resident Evil, BloodRayne,* and *Mortal Kombat*, game-based machinima and replays, and documentaries on games and gaming culture like *King of Kong: A Fistful of Quarters, Chasing Ghosts: Beyond the Arcade*, *Frag,* and *Second Skin*. Even audio materials such as

game soundtracks and popular music contribute to our understanding of game content. The history of video game music has resulted in significant collections of game music, whether in the form of soundtracks provided with games or produced by fans, or original live performances. Game composers such as George Sanger (The Fat Man, whose archive is preserved at the University of Texas) and Nobuo Uematsu (the main composer for the *Final Fantasy* series) have established game music as a genre. Well-known musicians and bands from several styles of music have contributed to the production of specific soundtracks (such as Nine Inch Nails for id Software's *Quake),* composed and performed specific songs for games ranging from EA's *Fight Night* to music games such as *Dance, Dance, Revolution* and *Guitar Hero,* or licensed songs used within video games (such as the large selection of music available via car radio within the game *Grand Theft Auto IV*, from classics such as Duke Ellington's "Take the 'A' Train" to contemporary music by artists including Ghostface Killah, Sepultura, and Seryoga). Focusing exclusively on materials that might fall within traditional publication chains, we can see that context information that we might collect crosses divisional boundaries within the Library of Congress, such as between book- and media-oriented divisions. Significant coordination on collection policies will be necessary if a comprehensive collection supporting preservation efforts is to be achieved.

Context information for a new digital medium such as games and virtual worlds will often, if not usually, be found outside traditional publication channels. We suggest that the Library of Congress consider web archiving efforts focused on game and game community sites similar to those which can be found in the Archive-It collections we created as part of the Preserving Virtual Worlds project (preserved both at the Internet Archive and at Stanford). Web archiving efforts at the Library of Congress might focus on major sites devoted to gaming and the gaming industry as a whole, or industry-wide issues and movements, whether these sites are created by developers, publishers, trade groups, players, or advocacy groups; specific topical approaches might better be undertaken by collaborating research libraries and organizations deeply engaged with specific games, genres, or research directions (such as the emphasis on game world "cartography" in our project). Examples of significant categories for websites of industry-wide significance might include:

- Portals for information about game development or game publication and history. Examples: Gamasutra (http://www.gamasutra.com), IGN (http://www.ign.com) and Moby Games (http://www.mobygames.com)
- Websites of game industry associations. Examples: the International Game Developers Association (IGDA, http://www.igda.org/) and the Entertainment Software Association (http://www.theesa.com/). It is worth noting here that the IGDA includes a Game Preservation SIG with its own website (http://www.igda.org/preservation); this SIG is chaired by Henry Lowood from our group and was a productive outreach channel for the Preserving Virtual Worlds project.
- Websites devoted to retro-gaming and related attention to historical games and game collecting, including fan-created websites such as the Atari Museum (http://www.atarimuseum.com/mainmenu/mainmenu.html) and Retrogames (http://www.retrogames.com/).
- Various sites devoted to development or support of emulation platforms useful for playing historical games and games from obsolete platforms, such as Stella, and Atari 2600 emulator, and the MAME emulation platform. Examples: the Stella open-

source project site (http://stella.sourceforge.net/), the official site of the MAME development team (http://mamedev.org/) and the Emulator Zone (http://emulator-zone.com).

- Fansites for games, many of which offer not only fan forums and fan-produced content, but also collections of game documentation, such as screenshots, walk-throughs, FAQs, reviews, replays, and videos produced from screen captures and replays. Examples: Koinup (http://www.koinup.com/), SL Universe (http://www.sluniverse.com/php/) and WCR for *Warcraft III* replays (http://www.wcreplays.com/). Blizzard Entertainment offers an excellent collection of such sites on its *World of Warcraft* fansites page, (http://www.worldofwarcraft.com/community/fansites.html).
- Major sites devoted to collecting and distributing machinima provide extensive documentation both of player creativity and of the exploration and content of virtual and game worlds. Examples: Machinima.com (http://www.machinima.com), the Machinima Archive (curated by Henry Lowood and a PVW site for archiving content; http://www.machinima.org), and sites devoted to machinima from specific games or virtual worlds, e.g., *Halo* movies (http://halomovies.org) or *Warcraft* movies (http://www.warcraftmovies.com/).
- Websites devoted to end-user game modifications. Examples: ModDB primarily for console games (http://wwww.moddb.com) or FilePlanet's mod pages primarily for PC games (http://www.filplanet.com/mods) and historical FilePlanet sites devoted to specific games, such as *Planet DOOM* (http://planetdoom.gamespy.com/)
- Websites devoted to alternative games and "art games." Examples: 56KModern (http://www.56kmodern.com/), the Independent Game Festival's Indie Games (http://www.indiegames.com/), the IndieCade festival website (http://www.indiecade.com/), or Gamescenes: Art in the Age of Videogames (http://www.gamescenes.org/).
- Websites devoted to "serious games" and educational uses of games, including military training. Examples: The Serious Games Initiative (http://www.seriousgames.org/), Games for Change (http://www.gamesforchange.org/), or Combatsim.com (http://www.combatsim.com/).

Some of these sites, such as the FilePlanet family of websites, have barely weathered threats to their continued operation or are under duress in terms of their long-term survival. A detailed list of virtual world and massively-multiplayer game websites created as part of the PVW Project in 2008 (see Appendix H) includes many now-defunct websites, only a fraction of which we were able to preserve as part of our ongoing Archive-It crawl.

In addition to electronic resources, media and web-based collections of documents, the Library of Congress might consider collecting in some categories of print materials that are not handled within traditional publication channels. These typically would be collected perhaps under the rubric of "ephemera" in a Special Collections Department; we are proposing that these sorts of materials, along with other categories of near print or "grey" publication play an important role in documenting digital media such as games. Examples include repair manuals and technical schematics for game platforms of many kinds, including arcade consoles; advertising materials for games; and production materials from gaming companies (design notebooks and sketches, development versions of game software and

source code, storyboards, scripts, rule outlines, character descriptions, etc.). Clearly much of this latter material falls within the domain of archival and special collections as a specialized department or area of expertise within most libraries. It should be noted here that in libraries that are currently collecting game-related material (such as the University of Texas and Stanford University), substantial archival holdings are held in such departments, along with published books in circulating libraries and audio and video in media collections. However, we believe that increasingly preservation of digital media of all forms will require eliding the traditional distinctions between library collections and archival collections if it is to be successful. If the Library does not choose to collect such archival material on its own, coordination between its efforts and archival collections at other research institutions committed to documenting the history of gaming and interactive fiction (including Stanford University, the Strong Museum, the University of Maryland and the University of Texas) should form part of the Library's efforts under the National Digital Stewardship Alliance.

With regards to games themselves, obviously the Library will collect a large number of video games through mandatory deposit of published software with the Copyright Office. However, we would caution that, given that registration of copyright fulfills mandatory deposit requirements, and that registration of copyright for software programs does not require complete deposit of the software, it is possible for significant games to be registered with the Library but not actually reside within it. Considering our case set, for example, *Mystery House* from Sierra On-Line, Inc., is registered with the Copyright Office, but the Library does not actually hold a copy of the game. A videotape and textual description were submitted in lieu of the game itself. Given this reality of the copyright registration and mandatory deposit system, the Library will need to survey the games actually present within its collections and determine whether there are additional games which it might wish to add. In addition, the Library may wish to determine whether other classes of supporting materials, such as the above-mentioned video and description of *Mystery House,* should be identified as relevant and important contextual documentation for game preservation and history. These considerations raise questions about the criteria that the Library should use in selecting games for inclusion in their collections, and for evaluating materials already present for reasons such as copyright registration.

In considering both the games in our case set and in the larger worlds of historical and contemporary games considered as a whole, there are a variety of factors that we believe should inform decisions regarding collecting of games:

- Popularity/sales/distribution – popularity, as measured by game sales, should be considered. A game such as *Call of Duty: Modern Warfare 2,* which sold 4.7 million copies on its release day, clearly represents an important piece of popular culture. However, it should also be noted that lists of top-selling titles require careful interpretation; for example, they often are crowded with a limited number of titles, due to dominant series (such as *Madden Football)*, sequels, and titles that appear on multiple platforms. Games with a larger number of release platforms and ports are likely to be among the more popular game titles, to the extent that popular industry "top-10" lists and the like may only provide a narrow view of "hit" titles. A better source of information on popularity and success might be review-based ranking such as Game Rankings (http://www.gamerankings.com/) or Metacritic's game site

(http://www.metacritic.com/games/). Stanford, for example, uses the latter, in its game approval plan.

- Novelty (technical/artistic) – certain games represent significant advances of the state of the art in gaming, either due to technical or artistic innovations. A game such as *DOOM,* which represented a vast leap in the use of immersive 3D graphics, or *Myst,* which influenced the aesthetics of many later computer games, should be considered for inclusion. More recently, specific movements oriented towards independent ("indy") game development, art games, or news games have emphasized the use of games as a platform for creative expression; websites tracking these areas will provide guidance concerning game titles and designers who are influencing these trends in game development.
- Intertextuality – certain games may be of value in understanding and interpreting other games. A game such as David Smith's *The Colony* from 1987, which utilized true 3D for a game involving an off-world colony overrun by bizarre creatures as a result of scientific experiments in teleportation, clearly helps contextualize *DOOM,* which was released six years later (and in fact some of his techniques, such as using ray casting to determine the visibility of objects within the 3D space, were later used by id Software).
- Impact on the Industry – This criterion is closely related to popularity and cultural impact. However, it also calls for collecting games that had a significant impact not just in terms of reception, but also in terms of such matters as marketing, packaging, and distribution. For example, it is important to ensure that a representative collection of games includes examples that introduced specific media (e.g., CD-ROM) or packaging formats (e.g., Electronic Arts' "album cover" packaging). These impacts extend to the introduction of new forms of distribution and game genres, which may also lead to special difficulties in access to games that should be collected. For example, Valve's Steam has had enormous significance as a digital distribution and rights management platform, but the specific nature of its technology will lead to difficulties in collecting games distributed via Steam. Likewise, web-based "social network games" such as *Farmville* have had an enormous impact on casual game design and easily satisfy criteria such as popularity and business impact, but the task of "collecting" such a game is made difficult by its close dependence on social network sites such as Facebook.
- Cultural Impact – some games have a significant cultural impact reflected in their influence on other forms of media or in their ability to spark public discussion and debate. Id Software's *DOOM* has achieved significance by both of these markers. References to the game have appeared in a variety of other media (including episodes of The Simpsons, Friends, and Family Guy, as well as in a song by the Smashing Pumpkins). At the same time, the subject matter of *DOOM* (slaughtering demons in outer space), its moody graphics and audio, and the vocabulary ("shooters," "death match") increased public attention to the levels of violence depicted in computer games. The game was released just as congressional hearings convened by Senators Herb Kohl and Joseph Lieberman were getting underway to examine media violence and its influence on children, and thus its release played a role in the national debate on these issues. In such cases, games become involved in public policy, and the Library should make a special effort to ensure that the games cited in debates such as those around *DOOM* are included within their collections.

- Creator Prestige – A game may also be considered important enough to collect due to the identity of its creator. *Mindwheel* probably would not have received the attention it has were it not authored by U.S. Poet Laureate Robert Pinsky. Games by well-known designers such as John Romero, Will Wright, or Hironobu Sakaguchi may not necessarily always be the best examples of games, but they may still have a significant impact on the game industry. It should be noted that this is a criterion particularly for archival collecting; the collections at Stanford (Steve Meretzky, Hal Barwood) and Texas (Warren Spector) have already begun to collect the papers of noted game designers. Some games are significant due to the prestige of their developers as inventors or innovators, some due to the importance of computer technology and software innovation for this medium. John Carmack's early games (before *DOOM)* are significant for this reason, and the Ralph Baer papers at the Smithsonian Institution provide an example of the impact of this criterion on archival collecting.
- End-user Appropriation – Some games offer features that make them particularly suited to end-user appropriation in various ways. This is a particularly important criterion for considering games not just as authored content per se, but as a creative platform for expression by fans, players, and others. One aspect of this creativity is the alteration of games or their use to create wholly new games. Games like *DOOM* and *Quake* were among the first to provide the means for users to create new maps for game play or make new assets such as creature "skins" and monsters. Such games have since spawned a cottage industry of "mods," modified (in some cases heavily modified) versions of game. Users have also appropriated various multi-user online games (including *Halo*, *World of Warcraft, Second Life* and many others) for the production of machinima, videos created using game technology, assets, or the virtual world of a game as a staging and production platform. Finally, many players have created reputations as "cyber-athletes" by virtue of their creativity in competitive game-play, to the extent that today professional and near-professional e-sports have attained some significance both nationally and internationally. All of these areas—mods, machinima, e-sports—represent activities through which players demonstrate their creativity. Games which have lead to the creation of significant user-produced content should also be given some priority in collecting activity, as should the mods and machinima produced using them, or replay movies that capture important moments in the history of competitive e-sports.
- Impact on Game Design and Technology – Particularly novel games may have a major impact on the development of the gaming industry. The game *Crysis*, for example, established a new benchmark for the whole industry in terms of photorealism in the display of the game world and in the complexity of the physics engine used by the game; the game was so demanding of computer hardware, in fact, that "But can it run *Crysis*?" became a common trope when discussing the capabilities of a new computer platform. The original *Pong* game was obviously not noted for the sophistication of its game play, but it led to the development of the entire console game industry.

In addition to the above issues, there are two other factors that the Library should consider in developing its game collection. Mandatory deposit for copyright will obviously help ensure that the Library has a strong collection of games produced and marketed within the United States. However, the gaming industry (and gaming community) is international, and a

research collection such as the Library's should include significant games from outside the United States. The factors listed above should be considered when selecting games from outside the United States, but the Library might also wish to consider making special efforts to collect representatives of genres of games that are not typical of the U.S. game market (the genres of visual novels and dating sims from Japan, for example), that have achieved prominence within their own countries (such as the various MMORPGs operated by Shanda in China), or that have had significant influence on games or the game industry in the United States. Likewise, the emphasis on collecting games that document creative play might point to documentation of competitive play cultures in countries such as Korea and regions such as Central and Northern Europe. Countries already possessing major video game industries include Japan, Korea, United Kingdom, Canada, Australia, Germany, Sweden, and France, and there are significant industries developing in China, Taiwan, Russia, the Ukraine, Finland, Denmark, and the Netherlands.

On the other hand, game technology and the game industry have also been significantly shaped by the regional concentration of U.S. "high-technology" industry, particularly in computing and web-related sectors. In recent years, the game industry has also been a driver in sectors such as the graphics and audio hardware industries and has influenced mainstream entertainment such as in the movie industry. Thus, it is no surprise that institutions currently active in game collecting activities tend to be located in or near prominent techno-regions or have themselves played prominent roles in producing relevant technologies (Stanford, Texas, Illinois). These comments regarding the collecting implications of both the global and the regional nature of the digital game industry underscore again our conviction that one collecting institution is unlikely to be able to do it all and lead us to conclude this section by noting again the importance of collaborative collecting efforts.

Intellectual Property & Digital Preservation: Widening the Discussion

There is a need for memory institutions interested in establishing video game repositories to support policy positions and offer services that are better aligned with the preservation and use practices of the game community, not only because of the potential for integrating the members of this community into the larger preservation network, but also because their attitudes and values may well influence those of professional archivists in years to come. With their deep curatorial investment in games, players have adopted a versatile set of approaches for collecting, managing, and providing long-term access to these cultural artifacts. While bitstream preservation and emulation are an essential part of the overall picture, so too are re-releases, remakes, demakes, ports, mods, and ROM hacks.[3] As a result, game archives in the wild often reflect notions of authenticity that are different from those

[3] "Remake" and "demake" are game design terms coined by Ian Bogost. As defined by Bogost, remakes "are recreations of earlier works, irrespective of the hardware platform of original creation or recreation." Conversely, demakes are "retro-inspired reimaginings of modern games, as if they had been created on earlier hardware. Demakes are not necessarily created to run on older machines, but their design and behavior are constrained by the real or perceived constraints of vintage systems." See Bogost's spring 2010 syllabus for "Atari Hacks, Remakes and Demakes: Special Topics in Game Design and Analysis," available at http://www.bogost.com/teaching/atari_hacks_remakes_and_demake.shtml.

of memory institutions.[4] While the dominant orientation of archivists is toward the stabilizing of cultural records, gamers can tolerate—indeed embrace—greater variability in the objects with which they interact. The Mario Brothers franchise, for example, has persevered largely because of the consumer appetite for new and altered game levels, power-ups, graphics, characters, and items. As another example, consider the case of *Mystery House*, the first graphical work of interactive fiction ever created. Released into the public domain in 1987, *Mystery House* was recently reimplemented in the Inform programming language by the *Mystery House* Taken Over Occupation (MHTO) Force, comprised of Nick Montfort, Dan Shiovitz, and Emily Short (2004). The project team also commissioned ten contemporary digital artists to mod the game using a specially designed kit for the purpose. The end result is that MHTO oscillates between a preservation project and a remix project. As Jon Ippolito (2008, p. 106) has remarked, new media art "can survive only by multiplying and mutating ... fixity is death." Consequently, there is an argument to be made in favor of preservation strategies that involve reprogramming, reimplementation, and recreation. The "softer" view of authenticity that underlies these strategies operates at what Seamus Ross (2010) would call a "lower threshold of verisimilitude."

What policy initiatives and preservation services might be adopted in response to the needs, practices, and perspectives of players and player-archivists? We propose the following:

Digital Preservation Services: Comparative Methods and Stemmatics

In addition to providing authenticated capture, ingest, hashing, and storage services for archival copies of games, digital repositories might also offer appropriate services for access copies of games in the wild. Because these copies are often modified rather than fixed representations—in line with the "softer" canons of authenticity previously mentioned—repositories could provide users and player-archivists with the means to analyze, document, and measure their inter-relationships using similarity metrics and other approaches. A good example is *Colossal Cave Adventure*, created by Will Crowther in c. 1975, which has the distinction of being the first documented computer text-adventure game. Inspired by Kentucky's Mammoth Cave system, the game inaugurated many of the conventions and player behaviors now associated with the genre, such as solving puzzles, collecting treasure, and interacting with the simulated fantasy world via short text commands (Jerz, 2007). Originally written in FORTRAN, the code has been repeatedly ported and expanded by hackers, fans, and programmers over the years, most influentially by Don Woods (c. 1977). The number of versions of *Adventure* is legion and continues to grow, with players mapping the evolution of the game using tree-like structures showing patterns of inheritance and variation (Dalenberg, 2004 and 2006).

Applying the techniques of digital stemmatics, archivists could help users visualize and interpret these patterns in sophisticated ways. Developed in the 19th Century, stemmatics codified a set of methods for analyzing the filiation of literary manuscripts. Significantly, the tree structures representing these relationships have parallel importance in evolutionary biology and historical linguistics, where they are used to group genomes or languages into families; show how they relate to one another in genealogical terms; and reconstruct lost

[4] "Archives in the wild" is a phrase coined by Jeremy John in the British Library's *Digital Lives* Report.

archetypes (Kraus, 2009). Speculating on the role of digital stemmatics (or phylogenetics, as the comparative method is called in biology) in the context of personal digital archives, Jeremy John of the British Library has postulated that "future researchers will be able to create phylogenetic networks or trees from extant personal digital archives, and to determine the likely composition of ancestral personal archives and the ancestral state of the personal digital objects themselves" (John, 2010, p. 134).

Stemmatic methods have already been applied to board games: Joseph Needham, a pioneering historian of East Asian science, technology, and culture, published a family tree of board games connecting divination, liubo, and chess through a long line of ancestry and descent (331); and biologist Alex Kraaijeveld has applied phylogenetics to variants of chess to help determine its place of origin. The methodology therefore shows great promise for the study of video and computer games in the wild, where variability rather than fixity of representation is often the norm.

Two other tools cited recently by Jeremy John are also relevant in this context:

- ccHost – an open-source content management system developed under the auspices of Creative Commons that can be used to track and document how media content is used, reused, and transformed on the web. (ccMixter, the popular music site for remixing and sharing audio samples, is powered by ccHost.)[5]
- Comparator – a tool developed by Planets (Preservation and Long-term Access through Networked Services), a four-year project funded in part by the European Union. Comparator is designed to measure degrees of similarity between different versions of a digital object.

Stemmatics might also be experimentally applied to the history of platform architectures. The system of hardware documentation developed by Walker Sampson for MITH's vintage computers complements such an approach by modeling the collection "through component pieces and parts" (Sampson, 2010). By decomposing each computer into discrete hardware components—microprocessors, disk drives, input devices, display technologies, and so forth—the documentation isolates possible units of variation. These units or parts can then be grouped together according to hereditary relationships (for example, partial pedigrees have already been constructed on Wikipedia and elsewhere for the MOS 6502 8-bit microprocessor, the ancestor of both the MOS 6510, which was used in the Commodore 64, and the W65C02S, which was used in the portable Apple II). Similar variations and derivations could be established for other processors and hardware components. Perhaps even more significantly, we could begin to model evolutionary degrees of similarity and difference not only between successive lines of personal computers or consoles developed by a single company (e.g., the Apple and Macintosh series), but also between entirely different families or brands of computers (e.g., the Atari ST, nicknamed "Jackintosh" for its obvious mimicry of the original Macintosh. Both machines were also based on the Motorola 68000 CPU). These findings would in turn have potential implications for computer restoration and console modding.

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[5] Information about ccHost and ccMixter can be found online at http://wiki.creativecommons.org/CcHost and http://ccmixter.org/. See also Jeremy John 56 and 156n244.

Digital Preservation Services: Calculating Trust In Fan-Run Game Repositories

Because game archives in the wild cannot usually be authenticated according to standard integrity checks, an alternative method for evaluating the authenticity of their holdings might involve the application of trust-based information. Jennifer Golbeck, for example, has demonstrated how the trust relationships expressed in web-based social networks can be calculated and used to develop end-user services, such as film recommendations and email filtering. Applying Golbeck's insights, archivists could leverage the trust values in online game communities as the basis for judgments about the authority or utility of relevant user-run repositories, such as abandonware sites and game catalogs. Under this scenario, authenticity is a function of community trust in the content being provided. One consequence of this approach is that authenticity and mutability need not be considered mutually exclusive terms; on the contrary, fan-run game repositories that make provisions for transformational use of game assets—such as altering the appearance of avatars or inventory items—might in many instances increase trust ratings.

IP and Public Policy: Reform of Contract Law

While archivists and librarians have for the most part targeted copyright law for reform, gamers have influenced the civil code documents that govern virtual worlds, such as EULAs and TOS agreements. Because this class of documents is frequently updated to reflect the evolving nature of the relationships among different stakeholders (Grimes et al, 2008), gamers have arguably had greater success than archivists and librarians in advancing their goals over a relatively short period of time. *We therefore recommend that archivists and librarians devote more effort to the reform of contract law and its associated document genres.* To the extent that IP is becoming a matter of private policy rather than public policy, managed through licensing and contractual agreements as opposed to federal copyright law, then advocacy efforts increasingly need to be directed at the commercial industry rather than the copyright office or the legislative branch. In many respects—and perhaps somewhat counter-intuitively—the game industry is better positioned than Congress or the courts to respond in a progressive and timely fashion to emerging social, cultural, and technological forces that are radically restructuring the relationship between content creators and users. For example, within the last few years Microsoft and Blizzard have published Game Content Usage Rules that relax the exclusive authorial right of adaptation in order to permit players to generate and distribute machinima, video, and other derivative works of art (2004-2010). These rules in turn provide a nascent legal environment in which remix culture and Web 2.0 can flourish. That such an environment is the product of contract law rather than copyright law bears emphasis: the protracted processes through which copyright law has traditionally been emended increasingly provide inadequate grounds for meeting the challenges of our current cultural milieu, a milieu characterized by rapid technological upheavals that in turn redefine social attitudes toward concepts such as originality, copyright, and creativity. Case in point: the Section 108 Study Group, charged with re-examining the Copyright Act with an eye to updating it for the digital age, took nearly three years to reach agreement on a set of non-binding and comparatively tepid recommendations, which may or may not eventually result in actual policy change upon legislative review. By contrast, the example of Microsoft, in particular, demonstrates how contract law can help legitimate player innovation by rapidly legalizing and codifying it—"rapidly" here being an admittedly relative term.

It is crucial to note, however, that the fluid state of contractual agreements is a double-edged sword: EULAs can just as easily be used to constrict or rescind rights as to expand or confer them. As Microsoft states in its content usage rules, the company may choose to revoke a license "at any time and for any reason" (2004-2010). Although subject to some statutory constraints, it may act self-interestedly, magnanimously, or capriciously as it sees fit. A temporal content analysis would shed light on directional patterns of change: are user rights, once introduced into game licenses, really vulnerable to repeal, or do they tend to persist over time to the point that they become fully naturalized components of the game culture?

Questions and caveats aside, it remains the case that civil code documents, such as EULAs, are more dynamic in nature than the U.S. Copyright Act.[6] Between 2002 and 2007, for example, *Second Life*, the popular 3D virtual world developed by Linden Lab, published at least nineteen different versions of its EULA (Fitz, 2008). Just as revealingly, Microsoft published revisions to its Content Usage Rules less than two months after their initial release based on feedback from the machinima community (Hayes, 2008, p. 570). By contrast, Section 108 of the Copyright Act has been amended a mere four times since it was first published in 1976. The opportunities for citizen intervention into the machinery of contract law is therefore much greater than comparable opportunities for intervention into copyright law.[7]

IP and Public Policy: Layered Licensing Agreements and Archival Endorsements

As a way to address the impenetrability of many software license agreements, Jeremy John has recently proposed a layered approach to their implementation, citing Creative Commons deeds as a relevant model (56, 58). Under this example, the prohibitive length and jargon of many game licenses would be ameliorated by condensing them and restating their salient points in accessible language and machine-readable format. A set of icons would be prototyped as an additional layer encoding baseline user rights and exemptions, again following the CC precedent. The end result would be layered licenses, each layer targeting a different audience: lawyers and experts (original legalese), users (vernacular and visual versions), and machines (RDF version). Applying John's suggestions to game EULAs, Content Usage Rules, and TOS agreements, we recommend that iconic and vernacular versions of these documents be developed and standardized to efficiently communicate the following information:

- Whether or not the user has the right to reproduce game assets
    - The game assets created by the user
    - The game assets created by other users
    - The game assets created by the developers
- Whether or not the user has the right to create derivative works, such as machinima
- Whether or not the user has the right to transfer game assets (e.g., to a public repository)

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6 On the dynamism of civil code documents, such as EULAs, see Grimes et al., 2008.

7 Such intervention is a function of the dynamism of the documents, and is by no means due to their being collaboratively authored by different communities of practice. Machinimists and players influence the content of the documents indirectly rather than directly.

- Whether or not the user has the right to export his or her game assets (or those of others) in an open format
- Whether or not an archival exemption clause exists that allows librarians and archivists to create preservation copies of game assets
- Whether or not the license includes a "competitive endorsement by official or public repositories" (John et al., 2010).

The PVW team or LOC should consider using Appendix A: Virtual Worlds that Died During the Grant to pressure game companies to embrace use policies designed to secure the endorsement of libraries and archives; and to raise awareness among players about the importance of these policies for long-term access to and use of game assets. Additionally, the PVW team recommends convening a working group of librarians, archivists, and researchers to draft an archival exemption clause and conduct outreach events with game developers and players to promote its adoption.

IP And Public Policy: Expanding User Rights In Adaptation

Archivists and librarians have spent most of their political capital in lobbying for legal exceptions to the exclusive authorial right of *reproduction*, largely ignoring the fact that they and their users also have a tremendous stake in limiting the exclusive authorial right of *adaptation*. Gamers, by contrast, have significantly expanded their rights to produce derivative works based on the creative assets of game publishers (Hayes, 2008). *We therefore recommend that archivists, librarians, and game scholars work to expand user rights in the area of adaptation, following the example of gamers.* Section 108 of U.S. copyright law privileges librarians and archivists as a special class of users for whom reproduction is the single most valuable non-exclusive right that may be accorded to them for purposes of preserving the media objects in their care.[8] Conversely, game content usage rules privilege players and the commercialization of primary content, which is potentially supported by the production of derivative works, such as machinima, that boost brand value. Granting the user the right to prepare derivative works is therefore fundamental to realizing what Lawrence Lessig (2008) calls a "Read-Write" (RW) culture. Defined in opposition to a "Read-Only" (RO) culture, which assumes a clear division between creators and consumers, a RW culture sees the two as deeply intertwined: RW creativity is one in which a society's "ordinary citizens" not only passively "read" their culture, but also actively transform it, producing content such as fan fiction, game mods, machinima, and audio remixes.

Within the RW context, it is the right of adaptation, not reproduction, that achieves preeminence among the five established and inter-related pillars of the copyright code (the reproduction, adaptation, distribution, performance, or display of the original work). Moreover, the model of creativity that underwrites RW culture shades almost imperceptibly into an emergent model of preservation. Because players are already an integral part of the preservation system for video games, any adaptation rights they acquire as content creators also helps them in their capacity as content preservers (Kraus, Donahue & Winget, 2009).

[8] The word "reproduce" and its cognates (e.g., "reproducing") appear no less than twenty-four times in Section 108 of the U.S. Copyright Act. Conversely, the word "derivative" never appears at all, nor does any related terminology (such as "adaptation"). Additionally, the executive summary report issued by the Section 108 Study Group makes no recommendations regarding the right of adaptation.

This crossover advantage stems from the fact that the player as modder and the player as preservationist both produce a transformed digital object. In short, because citizen preservation methods that transmit culture via "version streams" are becoming increasingly prevalent,[9] it is essential that archivists, librarians, and curators advocate strongly for the right to prepare derivative works.

Representation Information and Format Registries/Tools

The Library has endeavored in creating its digital preservation systems to ensure that they comply with the Open Archival Information System (OAIS) Reference Model. This carries with it the obligation to ensure that any digital content acquired is matched by the necessary representation information to interpret the digital content. Our research into our case set indicates that the representation information necessary for preservation of software will fall into several major classes:

1. Source Code Representation Information
    a. Structure Information – documentation of text standard (e.g., Unicode) employed by the source code documents
    b. Semantic Information
        i. Documentation of the programming language employed
        ii. Documentation of any OS libraries invoked by the code which may not be part of the standard libraries for a language
        iii. Documentation of any external APIs invoked by the code
2. Binary Executable Representation Information
    a. Structure Information
        i. Documentation of the executable file format employed by the binary (e.g., COFF, ELF, Mach-O, etc.)
    b. Semantic Information
        i. Documentation of the instruction set employed by the processor the binary executable was created to run on (e.g., Intel 64 and IA-32 Architecture reference manuals).
        ii. Documentation of the standard hardware architecture for the computing platform the executable was designed to run on, including information on memory, buses used to interconnect parts of the system, standard I/O devices and any special I/O devices required by the program.
3. Game Data File Representation Information (images, databases, audio tracks, etc.)
    a. Structure Information
    b. Semantic Information
4. Media Representation Information (disk image formats, ROM organization, etc.)
    a. Structure Information
    b. Semantic Information
5. Recursive Representation Information (rep. information for all preceding forms of rep. information)

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[9] "Version stream" is a concept defined by Jon Ippolito, et al., in the context of *The Pool*, an online collaborative environment for designing, sharing, and disseminating variable media art: http://bit.ly/57hhE0.

a. Structure Information
b. Semantic Information

While in many ways the representation information for software is similar to that for any other complex data object which may employ a variety of file formats, there are several aspects of representation information for computer games that we believe deserve highlighting and that suggest possible future steps that the Library might wish to consider.

The first is that the representation information for computer software consists in significant part of standards documents or public specifications created by companies. Standards for character encoding and programming languages form the greatest part of representation information for source code versions of programs (augmented by documentation regarding device specific APIs that might be used in a program). For binary executables, the formats employed for executables on different platforms are well documented, as are the instruction sets for processors for particular machines; companies producing hardware typically have every incentive to provide developers this information in order to encourage them to create software for that platform. While representation information for source code and binary executable formats is typically readily available for modern platforms, it should be noted that this information can be 1) quite voluminous (the documentation for Intel 64 and IA-32 architectures runs to several thousand pages); 2) difficult to obtain once the technologies supporting a particular game become antiquated; 3) unlikely to be found in typical library collections, particularly standards documents; and 4) highly repetitive for different pieces of software.

Given these facts, and given that the OAIS Reference Model suggests that the end points of a representation network for a data object must be decipherable without use of computing equipment, there appear to be clear cost benefits to maintaining a separate collection of printed representation information with the Library of Congress. This would allow information packages that the Library of Congress creates for any games it holds to reference print copies of representation information for these items. Given that so much of this information is in the form of standards documents, there might be grounds for some collaboration with the National Institute of Standards and Technology on the creation of such a collection.

Another crucial point about representation information for gaming materials that should be highlighted is that it may include more information about storage media than might be required for some other forms of data. Some of the games that we have investigated would require an emulation strategy for preservation due to the fact that the original source code was lost or unavailable, and in those instances, the binary executable versions of games that we were able to obtain were contained within a disk image file for the original game platform. Such instances can be seen as examples of the onion-model set forth in the PREMIS metadata dictionary, where one file may contain bitstreams, which may in turn contain further bitstreams, each of which may require separate representation information. For disk images, the representation information will include documentation on the original media format and use.

As noted in the OAIS Reference Model, representation information can itself require representation information, leading to the creation of a representation network. We found

that representation networks for games could quickly become quite large both in terms of the number of works and the byte count of the representation information files, and that the representation information for a game could easily outsize the game itself by several orders of magnitude. In the case of *Star Raiders* for the Atari 2600 platform, the game itself required only 8K of storage, while the representation information for the game consumed over 100 MB. This provides yet another incentive to compile a central store of representation information that information packages for games (and probably other materials) would reference at the Library.

Having the representation information, however, is not enough. One of the aspects of representation networks that has not been sufficiently commented upon in the case of standards documents is that they are stable (at least until a standards document is significantly revised), and that much of the recursively referenced representation information for a standards document will be other standards documents cited in the original standard. A database tracking these representation network links between documents would be of great benefit to the Library and others. At the moment, we do not believe that the data models being proposed for the Unified Digital Format Registry (UDFR) will support recording this type of information linking the pieces of documentation associated with a particular data format. The Library may wish to either work with the UDFR to ensure that support for this type of information is added into the UDFR data model, or consider creating its own database for representation network information.

Digital Game Canon

This outreach activity coincided with the initial development of the Preserving Virtual Worlds proposal. The creation of the Digital Game Canon was undertaken under the auspices of the Game Preservation Special Interest Group (SIG) of the International Game Developers Association (IGDA); Henry Lowood of the PVW team has chaired the Game Preservation SIG since 2006 and organized the original Digital Game Canon activity, namely, the announcement of the initial selection of 10 games for inclusion in the Digital Game Canon.

The goals of the Digital Game Canon are two-fold: 1) recognition for the importance of digital game culture, including raising awareness of the impact and responsibilities of this importance for the game industry; and 2) establishment of a basis for decisions about the historical value of specific game titles that reflect a mix of academic, industry, and journalistic perspectives.

The Canon provides a starting-point for the difficult task of preserving this history inspired by the role of that the U.S. National Film Registry has played for film culture and history. The scope of the Canon has thus far been international. Our argument: We could do worse than to start by making sure these games and archival material related to them are available to future developers, players, and scholars.

At the 2007 Games Developers Conference, five panelists (Matteo Bittanti, Christopher Grant, Henry Lowood, Steve Meretzky, and Warren Spector) revealed and discussed their choices for the first 10 games on this list

(https://www.cmpevents.com/GD07/a.asp?option=C&V=11&SessID=3885). These were the 10 game titles put on the Canon at this event:

- *Spacewar!* (MIT, 1962)
- *Star Raiders* (Atari, 1979)
- *Zork I: The Great Underground Empire* (Infocom, 1980; PDP-11 version)
- *Tetris* (Alexey Pajitnov, 1985)
- *Sim City* (Maxis, 1989)
- *Super Mario Brothers 3* (Nintendo, 1990)
- *Civilization I/II* (MicroProse, 1991-1996)
- *DOOM* (id Software, 1993)
- *Sensible World of Soccer* (Sensible, 1994)
- *Warcraft I/II/III* (Blizzard, 1994-2003)

Full audio and slides from the event can be downloaded from the IGDA Preservation SIG website (http://www.igda.org/preservation/files/dgc_gdc2007/).

The Preservation SIG also maintains a web page for the Digital Game Canon (http://wiki.igda.org/Game_Preservation_SIG/Digital_Game_Canon/). The Gamasutra game design website has commissioned articles on games in the Canon, such as this essay on Spacewar:
http://www.gamasutra.com/view/feature/1433/down_the_hyperspatial_tube_.php. The Canon project was originally conceived as an ongoing project, much like the National Film Registry. Plans have been discussed to revive the project in 2010 or 2011 as a continuing series of annual additions of 10 or so games at a suitable public venue, possibly as a joint venture with a website such as the Joystiq blog community. Just as the National Film Registry is linked to the work of the Library's National Film Preservation Board, we propose that the Digital Game Canon be coordinated in a similar fashion by a board with ties to Library of Congress. If this were of interest to the Library, this would be a topic for further investigation with Henry Lowood and the IGDA Preservation SIG, as well with potential project partners in industry and the player community. It could also provide the basis for future preservation activities based on the work accomplished by the Preserving Virtual Worlds project.

Reimagining Videogame Asset Management & Preservation (ReVAMP) Symposium

The challenges of digital preservation require early intervention -- a requirement that has brought archivists, librarians, information technology professionals, and scientists from a range of fields (notably in the space and geospatial communities) together to find solutions. To date, video game designers have been relatively uninvolved in these collaborations.

Through our work with the Preserving Virtual Worlds project, a survey of game developers, and discussions with game industry professionals, we have realized that there is a large gap of understanding and experience between people in the industry and those in cultural institutions, with scholars sitting somewhere in the middle – perhaps able to act as bridging agents. As video games grow in cultural importance, the need to preserve them and the

materials generated during their development becomes more evident. It is essential that these diverse communities understand each other's goals and perspectives to ensure that future students, scholars, and game developers are able to access the rich history of video games' creation and use. The natural first step in creating such understanding is to bring representatives of each community into one room for discussion.

To impress upon the video game industry the importance of preserving its own history, as well as for the purpose of educating its talent pool, we propose to start with a two-day Symposium styled after the 1960 Conference on Science Manuscripts (Woolf, 1962).[10] The event will bring video game developers, information professionals, and game scholars together to discuss the challenges and value of instituting formal preservation programs through presentations and discussion. It is hoped that such a forum will lead to the development of a roadmap for the future, generate follow-up activities, encourage cross-community collaboration, and motivate the video game developers to take action for preservation. The planning details, agendas, and activity summaries could be used as a model to jump-start preservation and collaboration in other industries that may currently be struggling with (or ignoring) the same issues.

The goal at the heart of our proposal is inspired by the history of science documentation efforts in the United States; we intend nothing less than to instigate an intensive series of meetings and jump-start serious efforts toward the adequate documentation and archival preservation of the many worlds involved in video games: design, technology, business, and culture. To do so, we propose to host a series of symposia styled after the Conference on Science manuscripts mentioned above. The conference could be scheduled around a major industry event, such as the Game Developers Conference (GDC), to ensure maximum attendance. Stanford would be an ideal venue due to its location in the heart of Silicon Valley, the presence of significant game-related holdings in its archives, and its proximity to the GDC site in San Francisco.

We believe that a series of small symposia would be best suited towards influencing key members of the game industry to build support for future preservation work. To accomplish this goal, the first ReVAMP conference will bring together scholars, information professionals, and developers to present and discuss the benefits of preserving game development materials, including providing a general awareness of game history, reuse of game assets, training new developers, preserving culturally important records and artifacts, and building brand awareness. Additionally, we will strive to ease the understandable concerns of business managers and legal offices regarding respect for licenses and intellectual property rights. Attendance at the first ReVAMP conference will be by invitation only, and we expect to include no more than 30–40 individuals.

Ultimately, we seek to partner with the game development industry in the development of one or more disciplinary centers with archival repositories to support all sectors of the video game world in much the same way that the Center for History of Physics (CHP) was established in 1965 by the American Institute of Physics to ensure adequate documentation

10 See also, Joseph Anderson's write up on the development of the Center for History of Physics at the American Institute of Physics, 'Difficult to Document: Physics in Government and Industry.' Available at http://www.bath.ac.uk/ncuacs/FP_Anderson.htm.

and preservation of physics materials. Gaining the support of the creators themselves is a vital first step along this ambitious path, and a conference of this nature represents the best way to open discussion with game developers and get them thinking about preserving their own history. As Joseph Anderson, head of the CHP's archival program has put it, "All the stakeholders in archival records—the people who create them, the researchers who use, and the archivists who preserve them—should work together to decide what can and should be preserved and to develop appraisal guidelines." The ReVAMP conference will represent our best effort to date to create such a consensus among parties concerned with the records of game development, technology, business, and culture. We therefore propose a follow-up symposium, somewhat smaller than the first, for the organization of an appropriate effort to create a disciplinary history center for the preservation of these records.

A Research Agenda for Preservation of Video Games & Interactive Fiction

While the Preserving Virtual Worlds project has managed to answer a number of research questions regarding the issues which make preservation of computer games and interactive fiction problematic, as well as demonstrating the feasibility of building upon existing packaging mechanisms with the digital preservation community for the storage of these unique materials, any such investigation will in turn spark new questions and lines of inquiry to be pursued. Based on research, there a number of questions with respect to the preservation of games and related content that we believe need further investigation.

One of the foremost of these arises out of the work we have done on emulation as a preservation strategy for computer games. As discussed in chapter 6, emulation proved to be only a partially successful strategy. Aspects of the original game which we would, in the best case, wish to preserve (e.g., the music accompanying game play in *DOOM*, differences in graphic output in *Star Raiders*) proved difficult to maintain under emulation, and we expect similar problems to arise under migration approaches. The operation of any piece of software involves a complex interplay with a computer's hardware and its operating system, and changes to any component in this dynamic can have an impact on the software's performance and appearance. To expect software to stay utterly unchanged in the face of changing computing platforms may not be realistic, but we clearly need more research into how emulators might improve their performance, particularly with respect to their ability to successfully reproduce the behaviors of I/O devices.

Preservationists have accepted the necessity of changing the form and appearance of stored information in order to insure its on-going accessibility; newspapers in microform are not identical to the paper copies they replace. But we have little experience to date with users' desires and expectations regarding preserved software, or with their unstated criteria for what constitutes 'good enough' or 'better than good enough' preservation. In the language of the preservation community, we do not know what properties of games our users consider significant. Given that the preservation strategies we have evaluated with respect to computer games and interactive fiction all suffer from some degree of imperfection, a first major research question for the preservation community is 'what are the significant properties of digital games which we should seek to maintain and what are there relative

degrees of importance?' Without this knowledge, we are poorly positioned to select an appropriate preservation strategy from the options available.

As demonstrated by our severe difficulties in attempting to create a preservation copy of islands in *Second Life*, massive, multiplayer virtual environments are extraordinarily difficult to preserve in any meaningful way. Even at the most basic level of creating a complete replica of the physical environment, our efforts were only (very) partially successful. Clearly further research must be undertaken regarding not only how we might preserve these environments, but how we might provide access to what we've preserved. The *How They Got Game* project at Stanford University has been investigating the use of an open source virtual environment software package, Sirikata, as a means of display 3D worlds originally built on other platforms. The project has already managed to export portion of the environment from id Software's game *Quake* and re-instantiate it within Sirikata. Further research is needed, however, not only on how to achieve more complete translation of an original environment in the Sirikata platform (including such features as scripts, animations and other dynamic aspects of the virtual world) but also on how to present a recreated virtual world as part of a virtual museum of 3D worlds.

While our project was able to develop mechanisms for packaging games for preservation that building upon existing standards within the preservation community, our work also revealed the practical limits of using these technologies. Generation of XML packaging files for complex compilations of material such as games is simply prohibitively time-consuming using current technologies. Research and development of tools that speed the process of generating packaging files for such materials, including recording the necessary relationships between content, representation information and context information, will be absolutely critical to the long-term success of the preservation community.

Another recurring theme of our investigations has been that preservation activity surrounding computer games and interactive fiction could benefit significantly from the involvement of the gaming community. Gamers have documentation regarding games' use and history that will be incredibly valuable for scholars in the future; they often possess technical documentation regarding the hardware and software necessary to run a game that the game companies themselves may no longer possess; and they have demonstrated their willingness to invest long hours in the creation of emulators, websites on games and other activities. If this energy could be harnessed by the digital preservation community, it would be of immense value.

Whether this is possible or not, and if so how, are questions that remain to be answered and that we believe deserve further investigation. Some specific questions that have arisen in the course of our research have been:

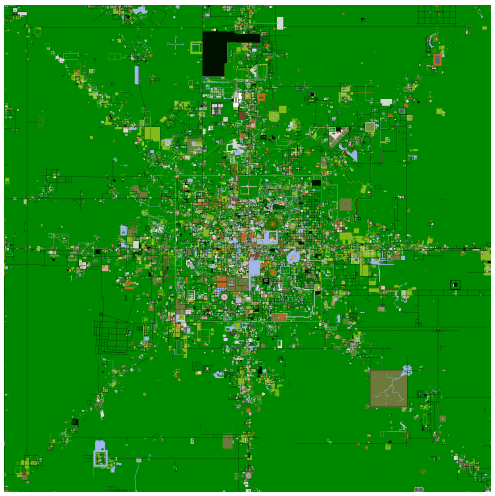
- How might metadata systems run by the cultural heritage sector be opened up to contributions from the gaming community to allow them to provide enhanced description information, as well as context and representation information, for games? Are there legal or social issues that might impede this?
- What legal and social issues might impede libraries collaborating with the gaming community on development and maintenance of emulation software?

- Websites created by the gaming community documenting particular aspects of games have demonstrated the same longevity as other parts of the web, which is to say, they are highly perishable. If the library community were to provide infrastructure for the gaming community for some of this activity, it might help promote the survival of some of this material. What factors might impede this, and how can they be addressed?

Through studying these questions with regards to the gaming community, digital preservationists might also gain further insight into their relationships with other communities of practice.

10. Conclusion

In 1996, as the first generation of online, 3D multi-user virtual environments were becoming increasingly known and popular on the Internet, the VRML Consortium created a working group known as "Living Worlds." The Living Worlds group was to create specifications that would allow the virtual worlds created by different companies to be truly interoperable, with avatars and objects being able to move freely between environments provided by different companies. Through cooperation, the companies involved in the working group hoped to spur further user interest and participation in these evolving virtual worlds.



A map of *Alphaworld*, an early, multi-user 3D world, in 1996

Unfortunately, while draft specifications were developed and some test implementations were performed, the Living Worlds work never really came to fruition. The initial burst of development in multi-user virtual environments died quickly as companies struggled to find a sustainable business model for running a virtual world, and several companies involved in the Living Worlds effort went bankrupt or were acquired by other firms. Later entries into the multi-user virtual environment sphere, such as the early MMORPGs *Ultima Online* and *Everquest*, had little motivation for pursuing interoperability.

There are several lessons that the preservation community can take from the early history of 3D virtual worlds. The first is that without a sustainable business model, any effort to try to keep a virtual world alive is doomed to failure. The second, perhaps less obvious lesson is that involvement of the user community is a vital component of sustainability. While it has struggled financially over the years, ActiveWorlds (the company responsible for *Alphaworld*, a 3D virtual world in operation since 1995) has managed to stay in business, and this may in part be ascribed to the strong community of users that has inhabited the space and their active involvement in its development. It does not seem coincidental that one of the very few companies producing 3D virtual worlds to have survived since 1995 is also the one with many users willing to undertake the expense of traveling to face-to-face annual "Reunion" events. A final lesson is that, given the time necessary for collaborative efforts to develop, it is usually better to start them sooner rather than later.

Our project has documented a number of significant issues impeding the preservation of virtual worlds, including obsolescence of original platforms, difficulties in identification and description of the objects of preservation, problematic rendition of games using common preservation strategies of migration and emulation, and numerous difficulties resulting from intellectual property and contract law. But we have also found several reasons to be hopeful that these problems can be overcome. Existing packaging formats employed by the digital preservation community, such as METS, OAI-ORE and BagIt, can be employed for

packaging game materials for preservation, particularly when supplemented with ontologies which delineate the data models set forth in the *Functional Requirements for Bibliographic Records Final Report* and the *Reference Model for an Open Archival Information System*. While we documented several problems with existing emulation technology's ability to successfully render older games, we also note that there have been successful efforts to modify emulators to enable them to more perfectly reproduce the original experience of game play (Bogost, 2009). Interaction between the gaming community and game companies such as Microsoft and Blizzard Entertainment have resulted in those companies re-crafting their licensing regimes for their MMORPGs to provide machinima creators the legal permissions they need to create new video works using these virtual worlds. Our own collaborations with the gaming community and the Internet Archive have resulted in the creation of a repository of moving image documentation of virtual worlds within the Internet Archive that will allow user-created documentation of worlds to persist within a stable preservation repository.

While these initial efforts provide hopeful signs that the preservation of virtual worlds is, in fact, a tractable problem, continuing work and collaboration by librarians, archivists, curators, game developers, authors of electronic literature, and the communities they all serve will be needed to insure the problem of preserving virtual worlds finds a permanent solution. Libraries, archives and museums need to start long-overdue conversations about how they might more effectively collaborate with each other on collection management, description and preservation of virtual worlds. Game companies and the digital preservation community need to collaborate on changes to intellectual property law that will allow game developers to profit from their work while insuring their work is also known to future generations. Cultural heritage organizations also need to actively engage the gaming community. A good starting-point would be a discussion of how libraries, archives and museums might provide stable, preservation infrastructures that the gaming community might use to document the history and culture of virtual worlds and to collaborative develop tools to insure on-going access to those worlds.

In October of 2007, Linden Lab, our commercial collaborator on the Preserving Virtual Worlds project, and IBM announced their intention to develop open standards to enable the interoperability of 3D virtual worlds. By July of 2008, Linden Lab and IBM were able to demonstrate their first successful case of interoperability, moving avatars back and forth between a *Second Life* Preview Grid and an OpenSim virtual world server. Through their collaboration, the two companies were able to finally realize the dream that sparked the Living Worlds project over a decade ago, and through the collaboration of the cultural heritage community, game companies and gamers, we will be able to insure that virtual worlds remain living worlds in the future.

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Appendix A - Virtual Worlds that Died During the Grant

	Virtual World	Publisher	Description	DoB	Date Died	Cause of Death	Links
1	Aradath/Dragon's Gate	Mythic Realms (when closed)	Gamer's World, AUSI, Genie, AOL, Mythic Realms	1984	10 February 2007		
2	Championship Manager Online	Beautiful Game Studios/Jadestone	Publisher: Eidos. Cancelled by Square Enix after it acquired Eidos.	2005	30 April 2010		http://www.cm-online.com/main/action/forum/thread/23278 http://www.computerandvideogames.com/article.php?id=233969 http://www.edge-online.com/news/championship-manager-online-to-close
3	Cities XL	Monte Cristo Games	a Sim City-esque game with MMO and social networking components.	9 October 2009	8 March 2010	Low subscriber numbers are leading Monte Cristo to pull back the online component and focus on its single-player side.	http://www.virtualworldsnews.com/2010/01/cities-xl-to-close-mmo-due-to-small-subscriber-base.html http://www.massively.com/2010/01/27/citiesxl-to-close-multiplayer-features/
4	EA-Land (AKA The Sims Online)	Electronic Arts	MMOG based on the video game The Sims	17 December 2002	4.35am PST on 1 August 2008	"Widely seen as a failed attempt to port the single-player game to an online, multiplayer environment. Still, EA kept *TSO* running, even as it was eclipsed by other social virtual worlds, and it limped along with a small	http://www.stanford.edu/group/htgg/cgi-bin/drupal/?q=node/239 http://news.cnet.com/8301-13772_3-9931757-52.html http://terranova.blogs.com/terra_nova/2008/04/ea-to-close-ea.html

						membership.”	
5	Faketown	Identity Play	A free MMO created in a pixel art aesthetic, Faketown features drawing and animation tools, along with photo and mp3 hosting, as well as YouTube videos.		23 June 2008	"The site and underlying technology are currently on auction to the highest bidder," said Yeary via email. "We still believe in the product and we are optimistic that someone will see the value in re-establishing the community."	http://www.zazzle.com/rip_faketown_tshirt-235997822793389336 http://www.virtualworldsnews.com/2008/07/faketown-closes.html http://www.virtualworldsnews.com/2008/07/interview-lesso.html
6	GoPets	Zynga	Virtual pet site where owners could customize 3D pets.	4 August 2005	8 November 2009	Chose to focus on Petville instead?	http://en.wikipedia.org/wiki/GoPets http://www.virtualworldsnews.com/2009/12/this-week-zynga-unleashed-its-latest-social-game-petville--as-the-name-implies-petville-is-zyngas-entry-into-the-time-test.html
7	Hellgate: London	Flagship Studios / Hanbitsoft	Fantasy RPG	31 October 2007	31 January 2009	Hanbitsoft has acquired the US/EU territory rights and will be re-releasing back to the US/EU territories with its sequel Hellgate London: Resurrection.	http://en.wikipedia.org/wiki/Hellgate:_London
8	Lively	Google	Web-based virtual environment integrated with YouTube and Picasa.	8 July 2008	31 December 2008	“But we've also always accepted that when you take these kinds of risks not every bet is going to pay off.”	http://googleblog.blogspot.com/2008/11/lively-no-more.html http://www.lively.com/goodbye.html http://arstechnica.co

							m/old/content/2008/11/google-to-shut-down-lively-its-interactive-3d-world.ars
9	The Matrix Online	Sony Online Entertainment	A MMOG developed by Monolith Productions. It was the official continuation of the storyline of the *Matrix* series of films.	22 March 2005	31 July 2009	“doubts about the game circled within the industry, based on the lacklustre reception of the later two *Matrix* films and an overcrowded MMORPG market.” http://en.wikipedia.org/wiki/The_Matrix_Online	http://thematrixonline.station.sony.com/index.vm http://www.joystiq.com/2009/08/04/the-matrix-onlines-final-moments-documented/ http://thematrixonline.station.sony.com/game_basics.vm
10	Meridian 59	Near Death Studios	Sword and Sorcery combat RPG	15 December 1995	Announced 5 January 2010	"Unfortunately, *M59* never really grew," Green admits in his personal blog. "We were lucky that we got a lot of attention for keeping an old game alive from the press. We also had a small and dedicated group of fans willing to keep the game alive. But, the press didn't really care about our attempts to improve the game, and the fans weren't interested in trying to attract new players."	http://meridian59.neardeathstudios.com/ http://www.gamasutra.com/view/news/26677/Meridian_59_Developer_Near_Death_Studios_Closes.php http://www.gamepro.com/article/news/213452/near-death-gives-up-the-ghost-after-nine-years-of-meridian-59/

11	Metaplace	Areae	The *Metaplace* website promises that the platform will integrate smoothly into our current web standards, allowing for integration of Metaplace elements into websites, RSS feeders, and more.		1 January 2010	It just hasn't gotten traction	http://www.raphkoster.com/2009/12/21/metaplace-com-closing/ http://www.massively.com/2008/02/25/gdc08-raph-kosters-reinventing-mmos-a-metaplace-antemortem/ http://www.metaplaceveterans.com/forum/viewforum.php?f=3&sid=3d45064c8a0c864cac00a0cc20fa1812
12	Phantasy Star Online	Sega	On Dreamcast.	21 November 2000	31 March 2007		
13	Tabula Rasa	NCsoft	A MMORPG developed by Destination Games about humanity's last stand against a group of aliens called "The Bane". http://eu.plaync.com/eu/games/overview/tabula_rasa/	2 November 2007	28 February 2009	"Unfortunately, the fact is that the game hasn't performed as expected." http://www.gamasutra.com/php-bin/news_index.php?story=21224	http://eu.plaync.com/eu/games/info/tabula_rasa/ http://www.gamasutra.com/php-bin/news_index.php?story=22510 http://www.gamepolitics.com/2009/05/06/richard-garriott-sues-nc-soft-over-millions-stock-options http://arstechnica.com/gaming/news/2009/03/does-a-game-have-to-fail-to-have-an-ending-tabula-rasa.ars http://en.wikipedia.org/wiki/Tabula_Rasa_%28video_game%29
14	There.com	Makena Technologies	A 3D online virtual world. From home page: "...an	9 January 2003	9 March 2010	Recession: "... at the end of the day, we can't cure the	http://www.prod.there.com/info/announcement

			online getaway where you can hang out with your friends and meet new ones..."			recession, and at some point we have to stop writing checks to keep the world open," says Wilson. "There's nothing more we would like to avoid this, but There is a business, and a business that can't support itself doesn't work."	http://news.cnet.com/8301-13772_3-10462627-52.html http://www.virtualworldsnews.com/2010/03/therecom-shutting-down-on-march-9th11.html
15	Virtual Magic Kingdom	Walt Disney Parks and Resorts Online	MMOG created as part of their 50th anniversary with areas and games based on real park scenery and attractions open to the public daily between 7:00am–10:00pm PST.	23 May 2005	21 May 2008	Created for 50th Ann and promotion ended long after originally planned.	http://www.intercot.com/discussion/showthread.php?t=130548 http://familyinternet.about.com/od/websites/tp/most-influential-virtual-worlds.htm http://www.worldsinmotion.biz/2008/04/disney_closes_gates_to_virtual.php
16	Vivaty	Vivaty	Vivaty is a next generation 3D virtual world in the browser where you can meet new friends and express yourself by dressing up your avatar and personalizing your own virtual scene for free.	March 2008	16 April 2010	“Vivaty.com is a rather expensive site to run, much more than a regular web site, and Vivaty the company has been running out of money for some time.” Jay Weber, Co-founder and Chief Technical Officer	http://blog.vivaty.com/2010/03/31/vivaty-shutdown-party/ http://www.raphkoster.com/2010/03/31/vivaty-is-closing-down/ http://games.venturebeat.com/2010/03/31/vivaty-shuts-down-virtual-world/ http://blog.vivaty.com/2008/03/31/welcome-to-vivaty/

17	Weblin	Zweitgeist	A software that turns the internet into a virtual world where you can chat with people from all over the world		Announced 7 Aug 2009	“Media reports attribute the closure to a lack of funds.”	http://www.virtualworldsnews.com/2009/08/weblin-ceases-operations.html http://www.raphkoster.com/2009/08/08/weblins-closing/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+RaphsWebsite+%28Raph%27s+Website%29

Appendix B – Media Coverage of PVW

Kotaku October 2007
"The Library of Congress Loves Video Games"
http://kotaku.com/313328/the-library-of-congress-loves-video-games

Kotaku November 2008
"On the LOC Preserving Virtual Worlds Project"
http://kotaku.com/5096782/on-the-loc-preserving-virtual-worlds-project

Special Collections 2.0: New Technologies For Rare Books, Manuscripts and Archival Collections 2009
On p. 14: "Creative born-digital works in *Second Life* are also earmarked for long term preservation; the Library of Congress recently provided a grant to several universities, spearheaded by the University of Illinois at Urbana-Champaign, to develop digital preservation standards for Second Life, as part of their Preserving Creative America program."

Crispy Gamer January 2009
"Saved Games: Preserving the New TV"
http://www.crispygamer.com/features/2009-04-08/saved-games-preserving-the-new-tv.aspx

MetaverseTV April 2009
ttp://blip.tv/file/2003603

Blog post: Crispy Gamer April 2009
http://www.crispygamer.com/features/2009-04-08/saved-games-preserving-the-new-tv.aspx

Salon April 2009
"How to Make Machinima Without Getting Sued Blind"
http://www.salon.com/technology/the_gigaom_network/online_video/index.html?section=online_video&blog=/tech/giga_om/online_video/2009/04/28/how_to_make_machinima_without_getting_sued_blind

Kotaku April 2009
"What AJ Learned About Machinima Law Today"
http://kotaku.com/5226851/what-aj-learned-about-machinima-law-today

IEEE Spectrum April 2009
"Stanford Boots Up Machinima"
http://spectrum.ieee.org/sandbox/consumer-electronics/gaming/stanford_boots_up_machinima

Future Tense, American Public Media April 2009
"Machinima lowers barrier of entry to filmmaking, but raises legal questions"
http://www.publicradio.org/columns/futuretense/2009/04/machinima-lower.html

Blog post: Pixel Vixen May 2009
http://www.pixelvixen707.com/?p=1743/#content

Stanford Magazine November/December 2009
"Saving Worlds Preserving the digital and virtual"
http://www.stanfordalumni.org/news/magazine/2008/novdec/farm/news/virtual.html

Voice of America with Art Chimes March 2010
http://www1.voanews.com/english/news/science-technology/Our-World--13-March-2010-87482377.html at ~15:53

Atlantic Monthly March 2010
"Pac Rat"
http://www.theatlantic.com/doc/201003/archiving-video-games

Kojo Nnamdi Show March 2010
http://thekojonnamdishow.org/shows/2010-03-30/preserving-video-games-and-virtual-worlds

University of Maryland Diamondback April 2010
"A Second Life"
http://www.diamondbackonline.com/news/a-second-life-1.1434797
http://thekojonnamdishow.org/shows/2010-03-30/preserving-video-games-and-virtual-worlds

Baltimore Public Radio May 2010
http://stream.publicbroadcasting.net/production/mp3/wypr/local-wypr-899636.mp3
http://mdmorn.wordpress.com/2010/05/03/53102-the-perplexing-task-of-archiving-virtual-worlds/

Ars Technica June 2010
"Saving Virtual Worlds from Extinction"
http://arstechnica.com/gaming/news/2010/06/the-art-of-archiving-virtual-worlds.ars

WILL-AM 580's Sidetrack July 2010
http://will.illinois.edu/sidetrack/program/sidetrackjul10/

USA Today August 2010
"Video Game Hall of Fame Inducting Pac-Man and Pals"
http://www.usatoday.com/tech/gaming/2010-08-05-gamearchive05_ST_N.htm

Christian Science Monitor August 2010
"Video game museum gives arcade classics extra lives"
http://www.csmonitor.com/Innovation/Tech/2010/0805/Video-game-museum-gives-

arcade-classics-extra-lives

This Way Up, Radio New Zealand August 2010
http://www.radionz.co.nz/national/programmes/thiswayup

ABC News Technology site August 2010
"Hall of Fame playing up video games"
http://abcnews.go.com/Technology/hall-fame-playing-video-games/story?id=11328263&page=1
http://stream.publicbroadcasting.net/production/mp3/wypr/local-wypr-899636.mp3

Appendix C – Preserving Virtual Worlds Ontology

```
<?xml version="1.0"?>
<rdf:RDF
    xmlns="http://people.lis.uiuc.edu/~jmcdonou/PVW.owl#"
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:protege="http://protege.stanford.edu/plugins/owl/protege#"
    xmlns:xsp="http://www.owl-ontologies.com/2005/08/07/xsp.owl#"
    xmlns:p1="http://www.owl-ontologies.com/assert.owl#"
    xmlns:owl="http://www.w3.org/2002/07/owl#"
    xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
    xmlns:swrl="http://www.w3.org/2003/11/swrl#"
    xmlns:swrlb="http://www.w3.org/2003/11/swrlb#"
    xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xml:base="http://people.lis.uiuc.edu/~jmcdonou/PVW.owl">
  <owl:Ontology rdf:about=""/>
  <owl:Class rdf:ID="Item">
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:allValuesFrom rdf:resource="#Item"/>
        <owl:onProperty>
          <owl:ObjectProperty rdf:ID="hasReproduction"/>
        </owl:onProperty>
      </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
    <owl:disjointWith>
      <owl:Class rdf:ID="Place"/>
    </owl:disjointWith>
    <owl:disjointWith>
      <owl:Class rdf:ID="Manifestation"/>
    </owl:disjointWith>
    <owl:disjointWith>
      <owl:Class rdf:ID="Work"/>
    </owl:disjointWith>
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:allValuesFrom rdf:resource="#Item"/>
        <owl:onProperty>
          <owl:ObjectProperty rdf:ID="isPartOf"/>
        </owl:onProperty>
      </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:onProperty>
          <owl:ObjectProperty rdf:ID="exemplifies"/>
        </owl:onProperty>
        <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int"
        >1</owl:cardinality>
      </owl:Restriction>
    </rdfs:subClassOf>
    <owl:disjointWith>
      <owl:Class rdf:ID="Object"/>
    </owl:disjointWith>
    <owl:disjointWith>
      <owl:Class rdf:ID="Concept"/>
    </owl:disjointWith>
    <owl:disjointWith>
      <owl:Class rdf:ID="Corporate_Body"/>
    </owl:disjointWith>
    <owl:disjointWith>
      <owl:Class rdf:ID="Expression"/>
    </owl:disjointWith>
    <owl:disjointWith>
      <owl:Class rdf:ID="Person"/>
    </owl:disjointWith>
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:allValuesFrom rdf:resource="#Item"/>
        <owl:onProperty>
```

```
        <owl:ObjectProperty rdf:ID="hasPart"/>
      </owl:onProperty>
    </owl:Restriction>
  </rdfs:subClassOf>
  <owl:disjointWith>
    <owl:Class rdf:ID="Event"/>
  </owl:disjointWith>
</owl:Class>
<owl:Class rdf:about="#Concept">
  <owl:disjointWith>
    <owl:Class rdf:about="#Corporate_Body"/>
  </owl:disjointWith>
  <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >an abstract notion or idea</rdfs:comment>
  <owl:disjointWith>
    <owl:Class rdf:about="#Place"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#Work"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#Object"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#Event"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#Expression"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#Person"/>
  </owl:disjointWith>
  <owl:disjointWith rdf:resource="#Item"/>
  <owl:disjointWith>
    <owl:Class rdf:about="#Manifestation"/>
  </owl:disjointWith>
</owl:Class>
<owl:Class rdf:about="#Object">
  <owl:disjointWith rdf:resource="#Item"/>
  <owl:disjointWith>
    <owl:Class rdf:about="#Manifestation"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#Work"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#Corporate_Body"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#Place"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#Event"/>
  </owl:disjointWith>
  <owl:disjointWith rdf:resource="#Concept"/>
  <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >a material thing</rdfs:comment>
  <owl:disjointWith>
    <owl:Class rdf:about="#Expression"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#Person"/>
  </owl:disjointWith>
</owl:Class>
<owl:Class rdf:about="#Event">
  <owl:disjointWith>
    <owl:Class rdf:about="#Place"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#Work"/>
  </owl:disjointWith>
  <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >an action or occurrence</rdfs:comment>
```

```
    <owl:disjointWith rdf:resource="#Item"/>
    <owl:disjointWith rdf:resource="#Concept"/>
    <owl:disjointWith rdf:resource="#Object"/>
    <owl:disjointWith>
      <owl:Class rdf:about="#Expression"/>
    </owl:disjointWith>
    <owl:disjointWith>
      <owl:Class rdf:about="#Corporate_Body"/>
    </owl:disjointWith>
    <owl:disjointWith>
      <owl:Class rdf:about="#Manifestation"/>
    </owl:disjointWith>
    <owl:disjointWith>
      <owl:Class rdf:about="#Person"/>
    </owl:disjointWith>
  </owl:Class>
  <owl:Class rdf:about="#Manifestation">
    <owl:disjointWith>
      <owl:Class rdf:about="#Expression"/>
    </owl:disjointWith>
    <owl:disjointWith rdf:resource="#Concept"/>
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:allValuesFrom rdf:resource="#Manifestation"/>
        <owl:onProperty>
          <owl:ObjectProperty rdf:about="#hasPart"/>
        </owl:onProperty>
      </owl:Restriction>
    </rdfs:subClassOf>
    <owl:disjointWith rdf:resource="#Item"/>
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:allValuesFrom rdf:resource="#Manifestation"/>
        <owl:onProperty>
          <owl:ObjectProperty rdf:about="#isPartOf"/>
        </owl:onProperty>
      </owl:Restriction>
    </rdfs:subClassOf>
    <owl:disjointWith>
      <owl:Class rdf:about="#Place"/>
    </owl:disjointWith>
    <owl:disjointWith rdf:resource="#Object"/>
    <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
    >the physical embodiment of an expression of a work</rdfs:comment>
    <owl:disjointWith>
      <owl:Class rdf:about="#Corporate_Body"/>
    </owl:disjointWith>
    <owl:disjointWith rdf:resource="#Event"/>
    <owl:disjointWith>
      <owl:Class rdf:about="#Person"/>
    </owl:disjointWith>
    <owl:disjointWith>
      <owl:Class rdf:about="#Work"/>
    </owl:disjointWith>
    <rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:onProperty>
          <owl:ObjectProperty rdf:ID="isReproductionOf"/>
        </owl:onProperty>
        <owl:allValuesFrom rdf:resource="#Manifestation"/>
      </owl:Restriction>
    </rdfs:subClassOf>
  </owl:Class>
  <owl:Class rdf:about="#Expression">
    <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
    >the intellectual or artistic realization of a work)</rdfs:comment>
    <rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:onProperty>
          <owl:ObjectProperty rdf:about="#hasPart"/>
        </owl:onProperty>
```

```
        <owl:allValuesFrom rdf:resource="#Expression"/>
      </owl:Restriction>
    </rdfs:subClassOf>
    <owl:disjointWith rdf:resource="#Object"/>
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:allValuesFrom rdf:resource="#Expression"/>
        <owl:onProperty>
          <owl:ObjectProperty rdf:about="#isPartOf"/>
        </owl:onProperty>
      </owl:Restriction>
    </rdfs:subClassOf>
    <owl:disjointWith>
      <owl:Class rdf:about="#Place"/>
    </owl:disjointWith>
    <owl:disjointWith>
      <owl:Class rdf:about="#Person"/>
    </owl:disjointWith>
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int"
        >1</owl:cardinality>
        <owl:onProperty>
          <owl:ObjectProperty rdf:ID="realizes"/>
        </owl:onProperty>
      </owl:Restriction>
    </rdfs:subClassOf>
    <owl:disjointWith rdf:resource="#Manifestation"/>
    <owl:disjointWith>
      <owl:Class rdf:about="#Corporate_Body"/>
    </owl:disjointWith>
    <owl:disjointWith rdf:resource="#Event"/>
    <owl:disjointWith>
      <owl:Class rdf:about="#Work"/>
    </owl:disjointWith>
    <owl:disjointWith rdf:resource="#Concept"/>
    <owl:disjointWith rdf:resource="#Item"/>
  </owl:Class>
  <owl:Class rdf:about="#Place">
    <owl:disjointWith>
      <owl:Class rdf:about="#Corporate_Body"/>
    </owl:disjointWith>
    <owl:disjointWith rdf:resource="#Event"/>
    <owl:disjointWith>
      <owl:Class rdf:about="#Person"/>
    </owl:disjointWith>
    <owl:disjointWith>
      <owl:Class rdf:about="#Work"/>
    </owl:disjointWith>
    <owl:disjointWith rdf:resource="#Manifestation"/>
    <owl:disjointWith rdf:resource="#Item"/>
    <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
    >a location; encompasses a comprehensive range of locations: terrestrial and extra-
terrestrial; historical and contemporary; geographic features and geo-political
jurisdictions</rdfs:comment>
    <owl:disjointWith rdf:resource="#Concept"/>
    <owl:disjointWith rdf:resource="#Object"/>
    <owl:disjointWith rdf:resource="#Expression"/>
  </owl:Class>
  <owl:Class rdf:about="#Person">
    <owl:disjointWith rdf:resource="#Place"/>
    <owl:disjointWith rdf:resource="#Event"/>
    <owl:disjointWith>
      <owl:Class rdf:about="#Corporate_Body"/>
    </owl:disjointWith>
    <owl:disjointWith rdf:resource="#Manifestation"/>
    <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
    >an individual; encompasses individuals that are deceased as well as those that are
living.</rdfs:comment>
    <owl:disjointWith rdf:resource="#Expression"/>
    <owl:disjointWith rdf:resource="#Object"/>
    <owl:disjointWith>
      <owl:Class rdf:about="#Work"/>
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  </owl:disjointWith>
  <owl:disjointWith rdf:resource="#Concept"/>
  <owl:disjointWith rdf:resource="#Item"/>
</owl:Class>
<owl:Class rdf:about="#Work">
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        <owl:ObjectProperty rdf:ID="hasSupplement"/>
      </owl:onProperty>
      <owl:allValuesFrom rdf:resource="#Work"/>
    </owl:Restriction>
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  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:allValuesFrom rdf:resource="#Work"/>
      <owl:onProperty>
        <owl:ObjectProperty rdf:ID="hasAdaptation"/>
      </owl:onProperty>
    </owl:Restriction>
  </rdfs:subClassOf>
  <owl:disjointWith>
    <owl:Class rdf:about="#Corporate_Body"/>
  </owl:disjointWith>
  <owl:disjointWith rdf:resource="#Object"/>
  <owl:disjointWith rdf:resource="#Item"/>
  <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >a distinct intellectual or artistic creation</rdfs:comment>
  <owl:disjointWith rdf:resource="#Expression"/>
  <owl:disjointWith rdf:resource="#Event"/>
  <owl:disjointWith rdf:resource="#Manifestation"/>
  <rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
  <rdfs:subClassOf>
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        <owl:ObjectProperty rdf:ID="isImitationOf"/>
      </owl:onProperty>
      <owl:allValuesFrom rdf:resource="#Work"/>
    </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:allValuesFrom rdf:resource="#Work"/>
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        <owl:ObjectProperty rdf:ID="hasTransformation"/>
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    </owl:Restriction>
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        <owl:ObjectProperty rdf:ID="hasSuccessor"/>
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        <owl:ObjectProperty rdf:about="#hasPart"/>
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    </owl:Restriction>
  </rdfs:subClassOf>
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    </owl:onProperty>
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</rdfs:subClassOf>
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<rdfs:subClassOf>
  <owl:Restriction>
    <owl:allValuesFrom rdf:resource="#Work"/>
    <owl:onProperty>
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    </owl:onProperty>
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    <owl:onProperty>
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    </owl:onProperty>
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    <owl:disjointWith rdf:resource="#Concept"/>
  </owl:Class>
  <owl:Class rdf:about="#Corporate_Body">
    <owl:disjointWith rdf:resource="#Expression"/>
    <owl:disjointWith rdf:resource="#Work"/>
    <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
    >an organization or group of individuals and/or organizations acting as a
unit</rdfs:comment>
    <owl:disjointWith rdf:resource="#Place"/>
    <owl:disjointWith rdf:resource="#Object"/>
    <owl:disjointWith rdf:resource="#Event"/>
    <owl:disjointWith rdf:resource="#Person"/>
    <owl:disjointWith rdf:resource="#Concept"/>
    <owl:disjointWith rdf:resource="#Manifestation"/>
    <owl:disjointWith rdf:resource="#Item"/>
  </owl:Class>
  <owl:ObjectProperty rdf:ID="hasGamePlayData">
    <rdfs:subPropertyOf>
      <owl:ObjectProperty rdf:ID="hasContextInformation"/>
    </rdfs:subPropertyOf>
    <owl:inverseOf>
      <owl:ObjectProperty rdf:ID="isGamePlayDataFor"/>
    </owl:inverseOf>
  </owl:ObjectProperty>
  <owl:ObjectProperty rdf:ID="isExemplifiedBy">
    <rdfs:domain rdf:resource="#Manifestation"/>
    <rdfs:range rdf:resource="#Item"/>
    <owl:inverseOf>
      <owl:ObjectProperty rdf:about="#exemplifies"/>
    </owl:inverseOf>
  </owl:ObjectProperty>
  <owl:ObjectProperty rdf:about="#hasContextInformation">
    <owl:inverseOf>
      <owl:ObjectProperty rdf:ID="isContextInformationFor"/>
    </owl:inverseOf>
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        <owl:unionOf rdf:parseType="Collection">
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          <owl:Class rdf:about="#Item"/>
          <owl:Class rdf:about="#Manifestation"/>
        </owl:unionOf>
      </owl:Class>
    </rdfs:domain>
    <rdfs:range>
      <owl:Class>
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    </owl:inverseOf>
    <rdfs:subPropertyOf rdf:resource="#hasContextInformation"/>
  </owl:ObjectProperty>
  <owl:ObjectProperty rdf:ID="hasSemanticRepresentationInformation">
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      <owl:ObjectProperty rdf:ID="isSemanticRepresentationInformationFor"/>
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    <rdfs:subPropertyOf>
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  <owl:ObjectProperty rdf:ID="isCreatedBy">
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        <owl:Class rdf:about="#Corporate_Body"/>
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  </rdfs:range>
  <rdfs:domain rdf:resource="#Work"/>
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    </owl:Class>
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  <owl:inverseOf>
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  </rdfs:domain>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:about="#exemplifies">
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  <rdfs:domain rdf:resource="#Item"/>
  <rdfs:range rdf:resource="#Manifestation"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:about="#hasSuccessor">
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    <owl:Class>
      <owl:unionOf rdf:parseType="Collection">
        <owl:Class rdf:about="#Work"/>
        <owl:Class rdf:about="#Expression"/>
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        <owl:Class rdf:about="#Work"/>
        <owl:Class rdf:about="#Expression"/>
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  </rdfs:domain>
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    <owl:ObjectProperty rdf:about="#isSuccessorOf"/>
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</owl:ObjectProperty>
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<owl:ObjectProperty rdf:about="#hasTransformation">
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    </owl:Class>
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  <owl:inverseOf rdf:resource="#hasContextInformation"/>
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  <rdfs:domain rdf:resource="#Manifestation"/>
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  </owl:inverseOf>
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  <rdfs:domain rdf:resource="#Expression"/>
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        <owl:Class rdf:about="#Event"/>
        <owl:Class rdf:about="#Concept"/>
        <owl:Class rdf:about="#Person"/>
        <owl:Class rdf:about="#Manifestation"/>
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        <owl:Class rdf:about="#Corporate_Body"/>
        <owl:Class rdf:about="#Place"/>
        <owl:Class rdf:about="#Object"/>
        <owl:Class rdf:about="#Item"/>
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  </rdfs:subPropertyOf>
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  </owl:inverseOf>
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        <owl:Class rdf:about="#Corporate_Body"/>
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        <owl:Class rdf:about="#Expression"/>
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    </owl:Class>
  </rdfs:domain>
  <rdfs:range>
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      <owl:unionOf rdf:parseType="Collection">
        <owl:Class rdf:about="#Work"/>
        <owl:Class rdf:about="#Expression"/>
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        <owl:Class rdf:about="#Work"/>
        <owl:Class rdf:about="#Expression"/>
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        <owl:Class rdf:about="#Item"/>
      </owl:unionOf>
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  </rdfs:domain>
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  <owl:inverseOf rdf:resource="#hasAnalyticInformation"/>
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</owl:ObjectProperty>
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  <rdfs:domain rdf:resource="#Expression"/>
  <rdfs:range rdf:resource="#Expression"/>
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  </owl:inverseOf>
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        <owl:Class rdf:about="#Expression"/>
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        <owl:Class rdf:about="#Item"/>
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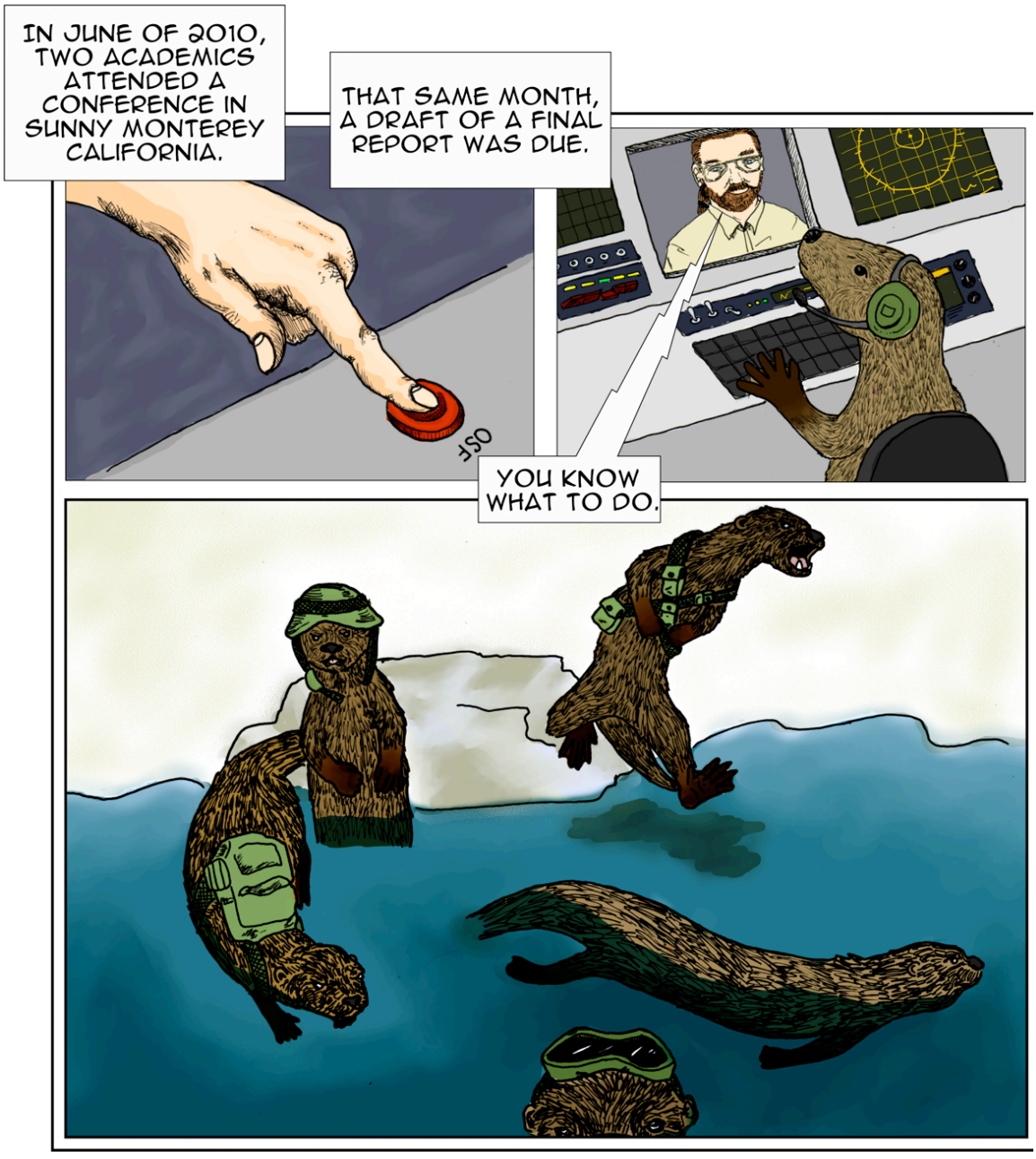
Appendix D – Multi-Institutional Collaboration: Lessons Learned

When partners are slow in providing contributions, enlist a strike force of elite otter mercenaries for encouragement.



Appendix E – Publications

Forthcoming

Kraus, K. " 'A Counter-Friction to the Machine': What Game Scholars, Librarians, and Archivists Can Learn from Machinimists about User Activism." *Journal of Visual Culture* (special Machinima-themed issue guest-edited by the Stanford Humanities Lab), forthcoming spring 2011.

Lowood, H. & M. Nitsche. *The Machinima Reader*. Cambridge, Mass.: MIT Press, forthcoming 2011. (Includes "Video Capture: Machinima, Documentation, and the History of Virtual Worlds, by Lowood.)

Lowood, H., "Memento Mundi: Are Virtual Worlds History?" In: *Digital Media: Interdisciplinary Perspectives on History, Preservation, and Ontology,* eds. Megan Winget and William Aspray. Scarecrow Press, forthcoming 2011.

Lowood, H., "Perfect Capture: Three Takes on Replay, Machinima and the History of Virtual Worlds." *Journal of Visual Culture* (special Machinima-themed issue guest-edited by the Stanford Humanities Lab), forthcoming spring 2011.

McDonough, J. "Packaging Videogames for Long-Term Preservation: Integrating FRBR and the OAIS Reference Model." *Journal of the American Society for Information Science and Technology*. Forthcoming.

2010

Kraus, K. (March 2010). Quoted in "Pac Rat: The Fight to Preserve Old Video Games from Bit Rot, Obsolescence, and Cultural Oblivion." *Atlantic Magazine*.

Kraus, K. & Donahue, R. (May 3, 2010). "The Perplexing Task of Archiving Virtual Worlds." Interview. *Maryland Morning Show* with Sheilah Kast, broadcast on Baltimore's NPR member station, WYPR 88.1 FM. http://mdmorn.wordpress.com/2010/05/03/53102-the-perplexing-task-of-archiving-virtual-worlds/

Lowood, H. (2010). "The Future of Virtual Worlds," (with William Sims Bainbridge, Wayne Lutters and Diana Rhoten," in: *Online Worlds: The Convergence of the Real and the Virtual,* ed. William Sims Bainbridge (London: Springer, 2010): 289-302.

McDonough, J., Kirschenbaum, K., Reside, D., Fraistat, N. & Jerz, D. (Fall 2010). "Twisty Little Passages Almost All Alike: Applying the FRBR Model to a Classic Computer Game." *Digital Humanities Quarterly* 4(2). Retrieved Sept. 13, 2010 from http://www.digitalhumanities.org/dhq/vol/4/2/000089/000089.html.

2009

Kirschenbaum, M. & Farr, E., et al. (October 2009). "Digital Materiality: Preserving Access to Computers as Complete Environments." *iPres 2009*.

Kirschenbaum, M., Tabbi, J., Grigar, D., Tata, M.A., Heckman, D., Gibbs, A. & Angel, M. (December 2009). "E-Ject: On the Ephemeral Nature, Genres, and Criticism of Electronic Objects." *Digital Arts and Culture 2009*.

Lowood, H., ed. (2009). *Before It's Too Late: A Game Preservation White Paper (written by the Game Preservation SIG of the International Game Developers Association)*. Available at: http://wiki.igda.org/Game_Preservation_SIG/White_Paper/Before_It%27s_Too_Late:_A_Digital_Game_Preservation_White_Paper.

Lowood, H., McDonough, J., Frick, C. & Renear, A. (2009). "Digital Curation of Humanistics, Multimedia Materials: Lessons Learned and Future Directions" (Panel abstract), *Proceedings of DigCCurr 2009: Digital Curation – Practices, Promise & Prospects,* ed. Helen R. Tibbo, et al. (Chapel Hill: School of Library and information Science, Univ. of North Carolina, 2009; distributed by Lulu Press): 42-43.

Lowood, H. (2009). "Game Counter," in Fiona Candlin and Raiford Guins (Eds.),*The Object Reader*. Abingdon, Eng., and New York: Routledge: 466-69.

Lowood, H. (2009). "Players are Artists," in Debora Ferrari and Luca Traini (Eds.), *The Art of Games*: *Nuove Frontiere tra Gioco e Bellezza*. Aosta: Regione Auonoma Valle d'Aosta: 190-93. Also in Italian trans. as "I giocatore come artisti," pp. 194-97.

Lowood, H. (Summer 2009). "Putting Politics Into Play: Three Recent Books on Virtual Worlds," *American Journal of Play* 2(1).

Lowood, H. (July-Sept. 2009). "Video Games in Computer Space: The Complex History of Pong," in *IEEE Annals in the History of Computing*: 5-19.

Lowood, H. (2009). "Warcraft Adventures: Texts, Replay and Machinima in a Game-Based Story World," in Pat Harrigan and Noah Wardrip-Fruin (Eds.), *Third Person: Authoring and Exploring Vast Narratives*. Cambridge: MIT Press: 407-27.

Lowood, H. guest editor, July-Sept. 2009 issue of *IEEE Annals of the History of Computing*.

McDonough, J. (2009). "How will we preserve virtual worlds?" in Bart De Nil & Jeroen Walterus (Eds.), *Nieuwe Perspectieven voor Digitaal Erfgoed*. Brussel: Pharo Publishing.

McDonough, J., Kirschenbaum, M., Reside, D., Freistat, N., Jerz, D., Lowood, H., Kraus,

K., Donahue, R. & Winget, M. (2009). "Preserving Virtual Worlds: Models & Community" (panel & paper abstracts). In *Digital Humanities 2009. Conference Abstracts. University of Maryland, College Park. June 22-25, 2009,* pp. 22-29. Available at: http://www.mith2.umd.edu/dh09/wp-content/uploads/dh09_conferencepreceedings_final.pdf.

2008

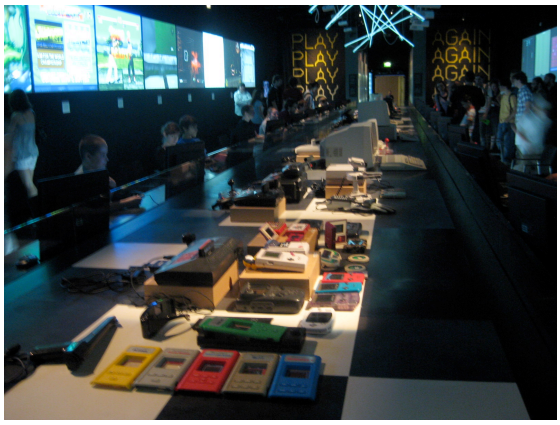
Lowood, H. (2008). "La cultura del replay. Performance, spettatorialità, gameplay," in *Schermi interattivi. Il cinema nei videogiochi, ed. Matteo Bittanti.* Rome: Meltimi: 69-94.

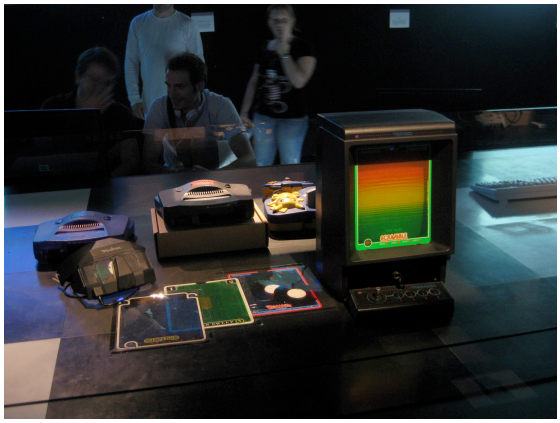
Lowood, H. (Spring 2008). "Game Capture: The Machinima Archive and the History of Digital Games," in *Mediascape: Journal of Cinema and Media Studies.*

Lowood, H. (2008). "Replay Culture: Performance and Spectatorship in Gameplay," in Carlos A. Scolari (Ed.), *L'homo videoludens: Videojocs, textualitat i narrativa interactiva.* Vic: Eumo Editorial: 167-87.

Appendix F – Museogames Exhibit at the Musée des arts et métiers
Implications for Collecting Repositories

The Museogames exhibit—on display from 22 June-7 November 2010 at the Musée des Arts et Métiers in Paris—showcases the history of videogames from the classic arcade games of the 1980s through the sixth-generation console games that became available at the turn of the 21st century. Filling three rooms of the museum's lower level, the exhibit includes home consoles, arcade cabinets, peripherals, miscellaneous game culture documents and artifacts, and recorded interviews with game developers and scholars. The exhibit's main attraction is the game table in the second room, where visitors are invited to sit down and experience retro games and platforms spanning nearly three decades, from the Magnavox Odyssey, the first home gaming console, to Sony's PlayStation 2, the world's best-selling console. Real-time video capture of visitors playing Pac-Man, Super Mario Bros, and other vintage games is projected onto the walls of the exhibition space.





Left: A view of the game table. Right: Magnavox Odyssey game console. Photos courtesy of Matthew Kirschenbaum. July 2010.

For collecting institutions such as the Library of Congress, Museogames serves as an object lesson in managing the underlying tensions between the preservation and access functions of archives, particularly where interactive media are concerned. While many of the works in the exhibition are drawn from the museum's permanent collections, the Musée des Arts et Métiers also partnered with MO5.com, a non-profit French association dedicated to the preservation and public dissemination of digital culture and videogames. Founded in 1996, the association is comprised of a diverse set of stakeholders, including private collectors, hobbyists, journalists, historians, researchers, and gamers. The organization boasts a collection of some 30,000 objects, which run the gamut from antiquated computers, peripheral devices, and other hardware to software, source code, technical manuals, and rare press kits.

In its information leaflets the museum takes pains to distinguish its video game collection from that of MO5.com along two axes: selection and use.

- ***Selection*** – "Toward the end of the 90s, a few private collectors took it upon themselves to safeguard videogame heritage. Their motivation was essentially sentimental and the objective was to keep everything. The approach adopted by the museum is somewhat different. All pieces that join its collections represent a landmark in the history of videogames. The objects acquired by the Musée des Arts et Métiers bear witness to the technical developments of their time; they have played an important role in our economic, social, and cultural history and represent an essential link between the inventions that preceded them and those that were to come after them. *This policy involves selectivity when acquiring pieces for the museum"* ("Two Collections"; emphasis added).
- ***Use*** – "The objective is [for the museum] to preserve [its] collections for future generations. For this reason, unlike the pieces belonging to private collections and which do not have this perenniality requirement, handling of the video games is strictly limited. This difference is illustrated throughout this exhibition with the MO5.com collection *featuring videogames that can be played,* and the collection that belongs to the Musée des arts et métiers, *which is protected for preservation purposes*" ("Two Collections"; emphases added).

These distinctions are visually reinforced throughout the exhibit, with game consoles from the museum's collection sequestered behind wire cages and those from the MO5.com collection set up in the open as game stations.[11] One obvious consequence of this functional division of collections is that the role of the museum visitor changes from that of passive observer to active participant over the course of the exhibition. Likewise, the status of the game artifact itself shifts from one room to the next—from antiquarian relic to source of hands-on entertainment.

Contrasting experiences: on the left Kraus views the museum's collection of game consoles displayed within wireframe cages; on the right, kids play with classic console games lined up in the second gallery room. Photos courtesy of Matthew Kirschenbaum. July 2010.

[11] While we cannot categorically state that every item behind the cages is drawn from the museum's permanent collection rather than MO5.com, this inference is supported by the museum's information leaflet, quoted above. All the games on the game table are from the MO5.com collection.

The example of Museogames prompts two observations with special relevance to collecting institutions:

- In an age of interactive media, archivists and curators need a richer typology of user behaviors with which to work. Access models to cultural heritage have been overly determined by the stewardship of paper documents, with the researcher variously understood as reader, transcriber, or viewer of content. In the case of videogames and variable media art, however, a more accurate depiction of the user might be that of player or interactor.
- In a user-centered milieu, it is especially important that collecting institutions solicit the input and consider the needs and expectations of the user community when developing selection and appraisal models. These expectations need to be thoughtfully and creatively balanced against other archival responsibilities, notably preservation.

With these observations in mind, we propose the following ways MO5.com might serve as a resource and model for collecting institutions:

- An analysis of the scope and diversity of the MO5.com holdings would allow a repository to get a purchase on the publishing, documentary and artifactual universe of videogame production and reception: from concept art and storyboards to marketing materials to vintage software and hardware (and everything in between). Determining the full spectrum of products of videogame culture would pave the way for the archive to adopt a systematic approach to selection and appraisal rather than be disadvantaged by a partial view of the collecting landscape.
- The Museogames exhibition demonstrates the value of establishing strong partnerships with private collectors in order to design interactive game experiences for the public without compromising the preservation mission of the collecting institution. In the absence of a North American counterpart to MO5.com, the Library of Congress might consider facilitating the formation of one, perhaps under the auspices of (or in cooperation with) the IGDA Game Preservation SIG.
- Finally, a collecting institution such as the Library of Congress might consider internalizing some of the practices of MO5.com by adopting a dual-track strategy for collection development. This strategy would entail acquiring and maintaining both preservation and access copies of software and hardware—such as early microcomputers and home game consoles—rather than following the example of the Musée des Arts et Métiers in assuming a noncustodial role with respect to playable versions of games. Such a collection model has been adopted by the International Center for the History of Electronic Games (ICHEG) at the Strong National Museum of Play. As described in the "Analysis of Hardware Preservation" section of this report, the ICHEG collects multiple copies of the same artifact, allowing the museum to source hardware components for installations and exhibits from duplicates in its own collection.

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Museogames exhibition, Paris: Musée des Arts et Métiers, 22 June-7 November 2010. http://museogames.com/

Appendix G – Second Life Deed of Gift

LICENSE AGREEMENT

This is a license agreement between DONOR NAME (Donor) and The Board of Trustees of Leland Stanford Junior University (Stanford) regarding the preservation of virtual property in the Stanford University Libraries' Preserving Virtual Worlds Second Life Archive (Archive).

Donor is the creator and copyright owner of material developed for Second Life, more particularly described to the right of the webpage.

Donor hereby grants Stanford a non-exclusive, royalty-free, irrevocable, worldwide license to preserve the Object(s), and to display and distribute the Object(s) for educational and/or not-for-profit purposes in all media now known or hereafter created, including but not limited to print, audio, electronic, video, optical disk, photographic, digital, and film, subject to the following.

1. Donor warrants and represents that s/he is the exclusive creator of and sole rightsholder for the Object(s) and has the full authority to enter into this Agreement. Donor agrees to indemnify the Board of Trustees of the Leland Stanford Junior University against any claims (including attorneys' fees and court costs) made against the University relating to this Agreement.
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3. Stanford may display and distribute the Object(s) on its own website, and may also share the Object(s) with partner organizations for purposes of display and distribution.
4. Except as set forth herein, copyrights held by the Donor in the Object(s) will remain with the Donor, including the rights to sell, assign or otherwise exploit or dispose of copyrights, subject to this irrevocable license agreement. Donor may commercially exploit the copyrighted materials by any means now known or hereafter known, including but not limited to print, motion picture, audio, audio-visual, visual, electronic, film, internet, or similar means of exploitation and dissemination.
5. Stanford University Libraries is under no obligation to accept the Object(s) or to maintain the Object(s) if accepted. Stanford reserves the right to refuse to accession Objects, and may delete Objects from the Archive at any time for any reason. Stanford is under no obligation to maintain the Object(s) or the Archive. Stanford is in no way liable for third party use of the Object(s).
6. Stanford will provide access to the Object(s) in accordance with its own policies and procedures. The Object(s) will not become accessible to researchers until archival processing has been completed, and the time required for such processing is at Stanford's discretion.

7. Optional: Stanford agrees to restrict access to Object(s) as requested by the Donor below, and will not make the Object(s) available on publicly accessible media until that time. Stanford will, however, preserve the Object(s) in the Archive during that time.

8. This Agreement will be subject to the laws of California and any action arising out of this Agreement will be exclusively heard in a court of competent jurisdiction in Santa Clara County, California.

Appendix H – Gaming Websites Identified in PVW Project

✓ = Archive-It seed has been made

Virtual Words, MMOs, Game Worlds in general

- ✓http://terranova.blogs.com/
  Terra Nova : Collaborative blog on online communities and worlds.
- ✓http://my.binhost.com/lists/listinfo/mud-dev2
  MUD-Dev2 Info Page : discussion list of MUD system design, development and implementation
- ✓http://my.binhost.com/pipermail/mud-dev2/
  MUD-Dev2 archives
- ✓http://www.raphkoster.com/2007/02/02/full-mud-dev-archive-for-download/
  Raph's Website : MUD-Dev1 archive can be downloaded here
- ✓http://mmorpg.qj.net/
  QJ.net : MMORPG blog "24/7 Coverage of Your Favorite MMORPG News"
- ✓http://www.fudco.com/habitat/
  Habitat Chronicles : Chip Morningstar and Randy Farmer
- ✓http://www.dsgames.net/index.htm
  DSGames history, including Qlink.net and Habitat screenshots
- ✓http://www.guildcafe.com/
  Guild Cafe a social network site with blogs and forums, supporting player guilds and clans of many MMORPGs and online games

Second Life:

- ✓http://secondlife.com
  Second Life : official website
- http://mariogerosa.blogspot.com/
  Played in Italy: Curation of History of *Second Life*
- http://second-life.com
  Second Life : tips, tricks, news, and everything you want to know
- http://blog.secondlife.com/
  Official Linden Blog
- http://secondlifeherald.com
  The Second Life Herald : presents the game's events, news, and author's tips
- http://secondlife.reuters.com
  Reuters Second Life News Portal: company portal
- http://lindenlab.com
  Linden Lab : official website of Linden Lab, makers of *Second Life*
- http://secondlifeinsider.com

Second Life Insider : weblog with news and tips about both the players and the game

- http://valleywag.com/tech/second-life/
  Valleywag : gossip rag on *Second Life*
- http://secondlifegrid.net/programs
  Second Life Grid : open source platform used for 3D virtual world development in business,education,and nonprofit organizations
- http://forums.secondlife.com
  Second Life Forums
- http://sundancechannel.com/secondlife
  Sundance Channel: Blogs: Second Life : virtual screening room
- http://edition.cnn.com/2007/TECH/11/12/second.life.irpt/
  CNN Enters the Virtual World of Second Life : CNN to open i-report hub in *Second Life*
- http://secondlifevideo.com
  Second Life Video
- http://wiki.secondlife.com/wiki/Video_Tutorials
  Second Life Video Tutorials : list of video tutorials
- http://crn.com/it-channel/205101362
  Accenture Scientist Predicts Death of Second Life
- http://slurl.com
  SLurl : location-based linking in *Second Life*
- http://somethingawful.com/d/second-life-safari/
  Second Life Safari
- http://slprofiles.com
  Second Life Profiles : online community for residents to meet
- http://getafirstlife.com
  Get A First Life: one page satire of *Second Life*
- http://abc.net.au/services/secondlife
  ABC Online: Second Life : ABC island in *Second Life*
- http://dell.com/html/global/topics/sl/index.html
  Dell Island In Second Life
- http://wiki.secondlife.com/wiki/Main_Page
  Second Life Wiki
- http://slexchange.com
  SL Exchange : *Second Life* commerce
- ✓http://infoisland.org
  Second Life Library 2.0
- http://usd.auctions.secondlife.com
  Second Life Land Auctions
- http://slcc2007.wordpress.com
  The Official SLCC Blog
- http://reperes-secondlife.com
  Reperes : first market research institute on *Second Life*
- http://alpha.cbs.com/primetime/csi_ny/second_life/
  Virtual CSI NY : CSI NY on *Second Life*
- http://secondlla.googlepages.com

Second Life Liberation Army

- http://slnn.com

Second Life News Network

- http://mmorpg.qj.net/category/Second-Life/cid/850

MMORPG News : MMORPG news on *Second Life*

- http://roughtype.com/archives/2006/12/avatars_consume.php

Rough Type : Nicholas Carr's blog

- http://secondlife.vodafone.com

Vodafone

- http://freshtakes.typepad.com/sl_communicators

Business Communicators on Second Life

- http://slgames.wordpress.com/

Second Life Games : blog

- http://sleducation.wikispaces.com

Second Life in Education : wiki

- http://teen.secondlife.com/whatis

Teen Second Life

- http://slvid.com

SLVid : share *Second Life* videos

- http://nonprofitcommons.org

Nonprofits in Second Life

- http://ibm.com/developerworks/spaces/secondlife

Second Life

- http://flickr.com/groups/secondlife

Flickr: Second Life : upload pictures from *Second Life*

- http://2lifeblog.com

Second Life Scripts

- http://massively.com/category/second-life

Posts From The Second Life Category At Massively : the daily news about MMOs

- http://crunchbase.com/company/secondlife

Crunchbase Company Profile

- http://secondlife.intellagirl.com

Second Life Education Research : blog

- http://sldrama.com

SecondLife Drama

- http://web.ics.purdue.edu/~mpepper/slbib

Second Life Annotated Bibliography

- http://secondlifelibrary.blogspot.com

Second Life library 2.0

- http://slpodcast.com

Second Life Podcast : the podcast and blog about *Second Life*

- http://sl-art-news.blogspot.com

Second Life Art News

- http://secondlifenotes.com

Second Life Notes: podcast dedicated to exploring the music, art, and culture of *Second Life*

- http://jira.secondlife.com/secure/Dashboard.jspa
  Second Life Issues
- http://secondlife.blogs.cnn.com
  Second Life I-Reports : news of a virtual world
- http://slfuturesalon.blogs.com/
  Second Life Future Salon
- http://secondlifeupdate.com
  Second Life Update
- http://slcn.tv
  Second Life Cable Network
- http://second411.com
  Second 411 : *Second Life* search engine
- http://iste.org/Content/NavigationMenu/Membership/Member_Networking/ISTE_Second_Life.htm
  Iste Second Life: Iste island on *Second Life*
- http://foureyedmonsters.com/secondlife
  Four Eyed Monsters : blog
- http://taotakashi.wordpress.com
  Tao's Thoughts On Second Life : blog
- http://molotovalva.com
  My Second Life
- http://bloghud.com
  BlogHUD : blogging system for the residents of *Second Life*
- http://rootscamp.org/RootsCampSL
  Roots Camp
- http://secondlife.crowneplaza.com
  Crowne Plaza's Second Life Meeting Room Reservation
- http://apps.facebook.com/second-life
  Second Life Facebook Application
- http://slballet.org
  Second Life Ballet
- http://lists.secondlife.com/cgi-bin/mailman/listinfo
  Second Life Mailing Lists
- http://slcreativity.org/blog
  SL Creativity
- http://slleftunity.blogspot.com
  Second Life Left Unity
- http://secondliferesearch.blogspot.com
  Second Life Research : blog about research on *Second Life*
- http://slambling.blogspot.com
  Ambling In Second Life : blog
- http://secondlifehowto.com
  Second Life HowTo: free guide to content creation in *Second Life*
- http://virtualaloft.com
  Virtual Aloft
- http://sltree.com
  Second Life Tree : the metaverse directory

- http://secondlife.wikia.com
  Second Life Wikia
- http://www.myfirstsecondlife.com
  My First Second Life
- http://secondlife.podcast.com
  Second Life Podcasts
- http://secondlifeproject.com
  Second Life Project
- http://bethssecondlife.blogspot.com
  Beth's Second Life : a teacher's blog
- http://libsecondlife.org
  Libsecondlife : project trying to understand the game from a technical aspect
- http://lindenlifestyles.com
  Linden Lifestyles: unofficial *Second Life* fashion and shopping blog
- http://mynameiskate.typepad.com/secondlife
  Kate's So-Called Second Life : blog
- http://slbusinesscommunicators.pbwiki.com

Second Life Business Communicators Wiki : a collaborative resource for anyone interested in business and communications applications of *Second Life*

- http://sltutorials.net
  SLTutorials.net
- http://blog.secondstyle.com
  Second Style Fashionista : fashionista blog for *Second Life*
- http://mercedes-benz-secondlife-infos.com
  Mercedez-Benz : Mercedes-Benz in *Second Life*
- http://siobhantaylor.wordpress.com
  Sio's Second Life : blog
- http://nwn.blogs.com/nwn/2007/12/second-life-as.html
  New World Notes : Wagner James Au's blog
- http://sweden.se/templates/cs/CommonPage____18195.aspx
  Second Life: The House of Sweden : the official gateway to Sweden
- http://storyofmysecondlife.com
  The Story of My "Second Life" : educator's grant-funded exploration into *Second Life*
- http://slfashionpolice.wordpress.com
  Second Life Fashion Police : fashion faux pas of *Second Life*
- http://slhandbook.com
  Second Life handbook : guide to people, places, and things in *Second Life*
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Second Life .Net Developers User Group: a microsoft.net user community in *Second Life*

- http://www.metaversemessenger.com/

Metaverse Messenger: an SL in-world publication; Tagline: "A real newspaper for a virtual world"

World of Warcraft:

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- http://wow-europe.com
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  Allakhazam's magical realm
- http://bestofwarcraft.com
  The Best of Warcraft
- http://forums.worldofwarcraft.com
  WOW Forums
- http://thottbot.com
  Thottbot : *World of Warcraft* database
- http://worldofwar.net
  World of Warcraft the Unofficial Site : offers news, information, movies, screen shots, forums, journals, live chats, and item database
- http://blizzard.com
  Blizzard Entertainment
- http://wow.warcry.com
  World of Warcraft Warcry
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  World of Warcraft Maps
- http://wowwiki.com
  WoWWiki : guide to the *World of Warcraft*
- http://wowvault.ign.com
  World of Warcraft Vault : *World of Warcraft* news, trailers, screeenshots, previews, reviews, guides
- http://wow.incgamers.com
  World of Warcraft the Unofficial Site
- http://wowguru.com
  World of Warcraft Guru : database
- http://wowhead.com
  Wowhead : database website for *World of Warcraft*
- http://wow.qj.net
  QuickJump : *World of Warcraft* news, announcements, patches, downloads, and videos
- http://wowarmory.com
  The World of Warcraft Armory : vast searchable database of information for *World of Warcraft*
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  WoW World of Warcraft Online
- ✓http://warcraftmovies.com
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- http://almostgaming.com/wow
  World of Warcraft Strategy Guides
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  War3World : contains downloads, replays, maps, and wallpapers
- http://wow.curse.com
  World of Warcraft AddOns, Downloads : *World of Warcraft* news, articles, files, screenshots, and videos
- http://wow.gameamp.com
  World of Warcraft GameAmp: maps, gold, guides, quests, downloads, guilds, demos, and videos
- http://warcraftrpg.com
  World of Warcraft the Roleplaying Game
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- http://wowui.incgamers.com
  WoWUI @ IncGamers : *World of Warcraft* mods, addons, and more
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  World of Warcraft Stratics: news and information coverage for *World of Warcraft*
- http://askapadwe.com
  World of Warcraft Help
- http://worldofwarcraftguru.blogspot.com
  World of Warcraft : blog
- http://worldofwarcraftempire.com
  WoW Empire : information and resources for *World of Warcraft*
- http://wow-europe.com/en/burningcrusade
  World of Warcraft: The Burning Crusade
- http://warcrafthelp.com
  World of Warcraft Community: discussion forums for the *World of Warcraft* gaming community
- http://wowchron.com
  World of Warcraft Chronicles Podcasts and News
- http://freewarcraftguides.com
  World of Warcraft Guides
- http://stormscale.org
  Stormscale : news about *World of Warcraft* from official websites and boards
- http://wowforum.com
  World of Warcraft Forum
- http://worldofwarcraftboard.com
  World of Warcraft Board: discussion forum powered by vBulletin
- http://forum.igsky.com/forum-3-1.html
  World of Warcraft IGSky Game Forum
- http://blizzard.co.uk/wow/forums.shtml
  World of Warcraft Forum

- http://goblinworkshop.com
  The Goblin Workshop: forum
- http://mmotricks.com/forums/world-of-warcraft
  Massive Multiplayer Online Gaming Forum
- http://graffe.com/forums/forumdisplay.php?f=53
  Graffe Forums
- http://forum.ragezone.com
  MMORPG development forum
- http://ubuntuforums.org/showthread.php?t=120615
  World of Warcraft with Wine : forum
- http://broadbandreports.com/forum/wowetc
  World of Warcraft Forum
- http://moncom.net/moncomwow.asp
  World of Warcraft Forum
- http://forums.gameaxis.com/forumdisplay.php?f=236
  The Unofficial World of Warcraft Forum
- http://worldofwarcraft-game.com
  WoW World of Warcraft : description and links
- http://uberwow.com
  Uber WoW Fansite : uber *WOW* fansite; *WOW* forum; *WOW* guides
- http://mmoverload.com
  MMOverload : strategy website
- http://abcwow.net
  ABC World of Warcraft
- http://wowvillage.com
  World of Warcraft Village : "all things world of warcraft"
- http://leeroyjenkins.net
  Leeroy Jenkins
- http://wowfix.com
  WoWFix
- http://www.almostgaming.com/wow
  World of Warcraft Strategy Guides
- http://wowstatus.com
  World of Warcraft Private Server Status
- http://exploitsrus.com/wow.html
  Exploits R Us : wow cheats, gold, and hacks
- http://worldofwarcraft100.com
  World of Warcraft 100 : source for *WOW* sites
- http://worldofwarcraft.bz
  World of Warcraft BZ : free private EMU wow server
- http://frostbolt.com
  Frostbolt : WOW blog
- http://worldofwarcraft.areblogs.com
  World of Warcraft Addict's Blog
- http://hogit.org
  Hogit's Story : blog
- http://wowgrrl.com

World of Warcraft Blog by WoWGrrl

- http://casualwow.blogspot.com
  Casual WoW : blog
- http://world-of-warcraft-gold.com/blog
  World of Warcraft News Blog
- http://1up.com/do/my1Up?publicUserId=5829624
  Legendary Thread : blog
- http://lamthara.blogspot.com
  Lamthara : blog
- http://marama-wow-corner.blogspot.com
  Marama's WoW Corner : blog
- http://the-wow-blog.com
  The World of Warcraft Blog
- http://aeonity.com/wow
  Alliance World of Warcraft Blog
- http://wowguy.wordpress.com
  World of Warcraft Guy : blog
- http://worldofwarcraftblog.wordpress.com
  World of Warcraft Blog
- http://wowdaily.info
  WoWDaily
- http://worldofwarcraftblog.info
  World of Warcraft Blog : tips on gold making and power leveling
- http://wowgold.shoutpost.com
  ShoutPost : blog
- http://wow-gold-reviews.blogspot.com
  World of Warcraft WoW : blog
- http://noggaddicts.com
  Noggaddicts : blog
- http://wow-tips.blogspot.com
  World of Warcraft Tips, Guides, and Exploits
- http://warcraftbot.blogspot.com
  World of Warcraft Bot
- http://aeigelus.com
  Adventures of Aeigelus : blog
- http://warcraft.topplayers.com
  World of Warcraft Blog
- http://squidoo.com/worldofwarcraftblogs
  List of World of Warcraft Blogs on Squidoo
- http://wow.mmodb.com
  World of Warcraft Database
- http://wow.gamepressure.com
  GamePressure Network: database- maps, locations, quests, items, etc
- http://warcraftworlds.net
  World of Warcraft Resource Site
- http://hiddenstuff.com
  World of Warcraft Guides Database

- http://wowecon.com
  World of Warcraft Auction House Price Database
- http://worldofwconline.com/database/items
  World of Warcraft Items Database
- http://warcraftpets.com/wow.pets/index.asp
  Warcraft Small Pets : index of all non-combat pets
- http://wow-item.info
  Wow Item Compare Database
- http://wowdigger.com
  WoWDigger : database
- http://gankbang.com/a/
  Gankbang - Armory data search and ranking
- http://www.wowjutsu.com/world/
  WoWJutsu -- Guild data and ranking
- http://www.blogazeroth.com/
  Blog Azeroth -- forum for WoW bloggers
- http://www.killerguides.com/
  Killer Guides -- strategy guides for MMOs, incl. *WoW* (commercial site)
- http://elitistjerks.com/
  Elitist Jerks -- forums and strategy for *WoW* (guild site)

Lord of the Rings Online:

- http://lotro.com
  The Lord of the Rings Online : official community site
- http://lotro.allakhazam.com
  Allakhazam's Magical Realm : database with quest walkthroughs, item lists, a full bestiary, spells, etc.
- http://lotrovault.ign.com
  The Lord of the Rings Online Vault : *Lord of the Rings Online* news, trailers, screenshots, previews, etc.
- http://lotrmmorpg.com
  LOTR MMORPG : community site; features forums, screenshots, updated news, guild forums, user photos
- http://lotro.warcry.com
  Lord of the Rings Online WarCry
- http://lordoftheringsonline.net
  The Madhouse Tavern : European fansite of the MMORPG *LOTR Online*
- http://lotro.mmodb.com
  Lord of the Rings Online Database
- http://gamespot.com/pc/rpg/middleearthonline/index.html
  Gamespot : news, previews, images, videos, links, and a forum
- http://lotrtalk.com
  Lord of the Rings Online : *LOTR Online* Community Talk
- http://lotronline.com
  Lord of the Rings Online : information database fan site
- http://forums.lotro.com

Lord of the Rings Online Forums

- http://lordoftheringsonlinenews.blogspot.com
  Lord of the Rings Online : blog
- http://lotro.curse.com
  Curse : LOTR Online news, articles, files, screenshots, and videos
- http://lordoftherings.filefront.com
  Lord of the Rings Files : *LOTR* downloads
- http://lotro.us
  Lord of the Rings Online Fansite : information on classes, races, and creatures
- http://guides.ign.com/guides/12112
  Lord of the Rings Online Guide
- http://lord-of-the-rings.org/lotr_game.html
  The Lord of the Rings Online Game
- http://massively.com/category/lord-of-the-rings-online
  Posts from the Lord of the Rings Online Category at Massively
- http://lotronlineguides.com
  Lord of the Rings Online Leveling & More Guide
- http://mmorpg.qj.net/category/The-Lord-of-the-Rings-Online-Shadows-of-Angmar/cid/1905
  QuickJump : MMORPG blog
- http://lordoftherings.gameamp.com
  GameAmp : betas, release dates, maps, guides races, classes and PVP information
- http://games.slashdot.org/games/07/06/01/0816244.shtml
  Slashdot : LOTR Online review
- http://community.codemasters.com/forum/forumdisplay.php?f=417
  Codemasters Forum
- http://lotrovideo.blogspot.com
  Lord of the Rings Online Videos
- http://lorebook.lotro.com
  Lord of the Rings Online Lorebook
- http://gamesites200.com/lotro
  Lord of the Rings Online Top 200 : top 200 sites for *LOTR Online*
- http://lotro.turbine.com/index.php?page_id=73&siid=3
  Lord of the Rings Online Gameplay
- http://arda-online.com/map/
  Lord of the Rings Online Game Database on Google Maps
- http://lotro.tentonhammer.com
  Lord of the Rings Online @ TenTon Hammer : *LOTRO* community site
- http://mapslotro.com
  Lord of the Rings Online Maps
- http://lotro-wiki.com
  Lord of the Rings Online Wiki
- http://lotroedge.com
  LOTRO Edge : lotr online guide
- http://lotrofaces.com
  Character Faces
- http://lotrointerface.com

LotRO Interface : comprehensive site dealing with anything Interface related in *LOTRO*

- http://lotrolife.com
  Lord of the Rings Online MMORPG web comic
- http://lotrorphaven.com
  Lord of the Rings Online Role Player's Haven
- http://lotro.stratics.com
  Lord of the Rings Online Community Resource
- http://lotro.wikia.com/wiki/Main_Page
  Lord of the Rings Online Wikia Wiki
- http://thebrasse.com/lotro
  The Brasse
- http://weathertopradio.com
  Weathertop Radio : podcasts with news and updates on *LOTRO*
- http://lotroalliance.com
  Lord of the Rings Online Alliance
- http://gamertales.com/lotrotales.php
  Gamer Tales : collection of *LOTRO* gaming tales
- http://kismetbp.com
  Kismet Lord of the Rings Online : news and fansite
- http://guildcafe.com/LordOfTheRingsOnline.php
  Guildcafe : kinships, guilds, profiles, screenshots
- http://lotrocraft.com
  Lord of the Rings Online Crafters of Middle Earth : fansite for crafters
- http://lotroguilds.net
  LOTRO Guilds : guild listing, screenshots, videos, interviews
- http://lotronotes.com
  LOTRO Notes : searchable tips database
- http://lotropolis.com
  LOTROpolis : *LOTRO* community
- http://middleearthcenter.com
  Middle Earth Center
- http://virginworlds.com/podcast.php?show=3&ep=15
  Ringcast : weekly podcast covering *LOTRO*
- http://lickanear.com/corcoffee.html
  Lick An Ear : LOTRO related fansite
- http://underthebanner.com
  Under the Banner : information blog
- http://visionsofthering.com
  Visions of the Ring: website for *LOTRO* suggestions, concepts, ideas
- http://arda-online.com
  Arda Online : LOTRO community
- http://lotromovies.net
  Lord of the Rings Online Movies Database
- http://onlinelotr.com
  Lord of the Rings Online : database of quests, deeds, items
- http://lotro-game.com

LOTR Online

- http://www.lotro-game.com/resources/databases
  Lord of the Rings Online Databases
- http://lotrotraits.com
  LotRO Traits : filterable trait database
- http://lotrocrafters.com
  Lord of the Rings Online : crafters forum
- http://pooh.cz/lotro
  Lord of the Rings Online : fansite and blog
- http://lotrovideo.vsocial.com
  Lord of the Rings Online Videos
- http://annonamarth.eu
  Annon Amarth
- http://lotroinsider.blogspot.com
  Lord of the Rings Online Insider : blog
- http://blogtoplist.com/rss/lord-of-the-rings-online.html
  Blog Toplist
- http://lordoftheringsonline.wordpress.com
  Lord of the Rings Online : *LOTRO* blog
- http://lotr-online-leveling-guides.blogspot.com
  Free Lord of the Rings Online Leveling Guide
- http://female-gamer.com/lotro
  LOTRO Insider Blog : female gamer blog
- http://lotroblog.cn
  Lotro Blog
- http://lotro.mmorpgedge.com
  LOTRO Edge
- http://thesafehouse.org/forums/forumdisplay.php?f=64
  The Safehouse Forums
- http://ubuntuforums.org/showthread.php?t=386480
  Lord of the Rings Online : forum
- http://lotroquests.com
  LOTRO Quests : guides, pictures, maps

There.com:

- http://there.com
  There : official site

Sony's Home

- http://www.homebetatrial.com/
  PlayStation Home Trial
- http://www.playstationhome.com/
  PlayStation Home Forums (unofficial)

- http://www.youtube.com/watch?v=oInP2DAa3BA
  PlayStation Home GDC 2007 presentation video

Entropia Universe

- http://www.entropiauniverse.com/
  Entropia Universe : Official website
- http://www.euturnpike.com/
  EU Turnpike : Ore Rates, Crafting Costs, Charts, Maps, guides, tools and more
- http://www.entropedia.info/Page.aspx?page=Main%20Page
  Entropedia : Charts, maps and guides

The Sims Online

- http://player.thesimsonline.ea.com/index.jsp
  The Sims Online : Official website
- http://sims.stratics.com/
  Sims Stratics: Sims Online Community
- http://ea-land.ea.com/
  EA Land: *The Sims Online*, free version, launched in Feb 2008

Digital Games (generally)

- ✓**http://www.mobygames.com/home**
- ✓http://grandtextauto.org/
- ✓http://www.gamasutra.com/
- ✓http://www.ludology.org/
- ✓http://vgmaps.com/

Appendix I – Sample Output from CopyBot

```
<llsd>
    <map>
        <key>120692409</key>
        <map>
            <key>name</key>
            <string>test object 2</string>
            <key>description</key>
            <string/>
            <key>phantom</key>
            <boolean>0</boolean>
            <key>physical</key>
            <boolean>0</boolean>
            <key>position</key>
            <array>
                <real>136.809585571289</real>
                <real>67.7011108398438</real>
                <real>2000.5</real>
            </array>
            <key>rotation</key>
            <array>
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                <real>0</real>
                <real>0</real>
                <real>1</real>
            </array>
            <key>scale</key>
            <array>
                <real>0.5</real>
                <real>0.5</real>
                <real>0.5</real>
            </array>
            <key>material</key>
            <integer>3</integer>
            <key>shadows</key>
            <boolean>0</boolean>
            <key>textures</key>
            <array>
                <map>
                    <key>colors</key>
                    <array>
                        <real>1</real>
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                        <real>1</real>
                    </array>
                    <key>scales</key>
                    <real>1</real>
                    <key>scalet</key>
                    <real>1</real>
                    <key>offsets</key>
                    <real>0</real>
                    <key>offsett</key>
                    <real>0</real>
                    <key>imagerot</key>
                    <real>0</real>
```

```
            <key>bump</key>
            <integer>0</integer>
            <key>shiny</key>
            <integer>0</integer>
            <key>fullbright</key>
            <boolean>0</boolean>
            <key>media_flags</key>
            <integer>0</integer>
            <key>mapping</key>
            <integer>0</integer>
            <key>glow</key>
            <real>0</real>
            <key>imageid</key>
            <uuid>89556747-24cb-43ed-920b-47caed15465f</uuid>
        </map>
    </array>
    <key>volume</key>
    <map>
        <key>path</key>
        <map>
            <key>begin</key>
            <real>0</real>
            <key>curve</key>
            <integer>16</integer>
            <key>end</key>
            <real>1</real>
            <key>radius_offset</key>
            <real>0</real>
            <key>revolutions</key>
            <real>1</real>
            <key>scale_x</key>
            <real>1</real>
            <key>scale_y</key>
            <real>1</real>
            <key>shear_x</key>
            <real>0</real>
            <key>shear_y</key>
            <real>0</real>
            <key>skew</key>
            <real>0</real>
            <key>taper_x</key>
            <real>0</real>
            <key>taper_y</key>
            <real>0</real>
            <key>twist</key>
            <real>0</real>
            <key>twist_begin</key>
            <real>0</real>
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        <key>profile</key>
        <map>
            <key>begin</key>
            <real>0</real>
            <key>curve</key>
            <integer>1</integer>
            <key>hole</key>
            <integer>0</integer>
            <key>end</key>
```

```
            <real>1</real>
            <key>hollow</key>
            <real>0</real>
        </map>
    </map>
    <key>light</key>
    <map>
        <key>color</key>
        <array>
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            <real>0</real>
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        <key>radius</key>
        <real>0</real>
        <key>cutoff</key>
        <real>0</real>
        <key>falloff</key>
        <real>0</real>
    </map>
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    <map>
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        <integer>0</integer>
        <key>gravity</key>
        <real>0</real>
        <key>air_friction</key>
        <real>0</real>
        <key>wind_sensitivity</key>
        <real>0</real>
        <key>tension</key>
        <real>0</real>
        <key>user_force</key>
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            <real>0</real>
        </array>
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        <integer>0</integer>
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    <key>description</key>
    <string/>
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```

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<boolean>0</boolean>
<key>position</key>
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    <real>0</real>
</array>
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    <real>0</real>
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        <real>1</real>
        <key>offsets</key>
        <real>0</real>
        <key>offsett</key>
        <real>0</real>
        <key>imagerot</key>
        <real>0</real>
        <key>bump</key>
        <integer>0</integer>
        <key>shiny</key>
        <integer>0</integer>
        <key>fullbright</key>
        <boolean>0</boolean>
        <key>media_flags</key>
        <integer>0</integer>
        <key>mapping</key>
        <integer>0</integer>
        <key>glow</key>
        <real>0</real>
        <key>imageid</key>
```

```
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    </array>
    <key>volume</key>
    <map>
        <key>path</key>
        <map>
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            <real>0</real>
            <key>curve</key>
            <integer>16</integer>
            <key>end</key>
            <real>1</real>
            <key>radius_offset</key>
            <real>0</real>
            <key>revolutions</key>
            <real>1</real>
            <key>scale_x</key>
            <real>1</real>
            <key>scale_y</key>
            <real>1</real>
            <key>shear_x</key>
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            <real>0</real>
            <key>taper_x</key>
            <real>0</real>
            <key>taper_y</key>
            <real>0</real>
            <key>twist</key>
            <real>0</real>
            <key>twist_begin</key>
            <real>0</real>
        </map>
        <key>profile</key>
        <map>
            <key>begin</key>
            <real>0</real>
            <key>curve</key>
            <integer>1</integer>
            <key>hole</key>
            <integer>0</integer>
            <key>end</key>
            <real>1</real>
            <key>hollow</key>
            <real>0</real>
        </map>
    </map>
    <key>parentid</key>
    <integer>120692409</integer>
    <key>light</key>
    <map>
        <key>color</key>
        <array>
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            <real>0</real>
```

```
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            <real>0</real>
        </array>
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        <key>radius</key>
        <real>0</real>
        <key>cutoff</key>
        <real>0</real>
        <key>falloff</key>
        <real>0</real>
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        <integer>0</integer>
        <key>gravity</key>
        <real>0</real>
        <key>air_friction</key>
        <real>0</real>
        <key>wind_sensitivity</key>
        <real>0</real>
        <key>tension</key>
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    <string/>
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    <key>physical</key>
    <boolean>0</boolean>
    <key>position</key>
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        <real>-1.05799865722656</real>
        <real>0</real>
    </array>
    <key>rotation</key>
    <array>
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```

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    <real>1</real>
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    <real>0.5</real>
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        <key>scalet</key>
        <real>1</real>
        <key>offsets</key>
        <real>0</real>
        <key>offsett</key>
        <real>0</real>
        <key>imagerot</key>
        <real>0</real>
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        <key>shiny</key>
        <integer>0</integer>
        <key>fullbright</key>
        <boolean>0</boolean>
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        <integer>0</integer>
        <key>mapping</key>
        <integer>0</integer>
        <key>glow</key>
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</array>
<key>volume</key>
<map>
    <key>path</key>
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```

```
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            <key>radius_offset</key>
            <real>0</real>
            <key>revolutions</key>
            <real>1</real>
            <key>scale_x</key>
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            <key>scale_y</key>
            <real>1</real>
            <key>shear_x</key>
            <real>0</real>
            <key>shear_y</key>
            <real>0</real>
            <key>skew</key>
            <real>0</real>
            <key>taper_x</key>
            <real>0</real>
            <key>taper_y</key>
            <real>0</real>
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            <real>0</real>
            <key>twist_begin</key>
            <real>0</real>
        </map>
        <key>profile</key>
        <map>
            <key>begin</key>
            <real>0</real>
            <key>curve</key>
            <integer>1</integer>
            <key>hole</key>
            <integer>0</integer>
            <key>end</key>
            <real>1</real>
            <key>hollow</key>
            <real>0</real>
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    </map>
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            <real>0</real>
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            <real>0</real>
        </array>
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        <real>0</real>
        <key>radius</key>
        <real>0</real>
        <key>cutoff</key>
        <real>0</real>
        <key>falloff</key>
        <real>0</real>
```

```
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            <key>flex</key>
            <map>
                <key>simulate_lod</key>
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                <key>gravity</key>
                <real>0</real>
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                <real>0</real>
                <key>wind_sensitivity</key>
                <real>0</real>
                <key>tension</key>
                <real>0</real>
                <key>user_force</key>
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