Game Impact Theory:
The Five Forces That Are Driving the Adoption of Game Technologies within Multiple Established Industries

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Abstract

The computer gaming industry has begun to export powerful products and technologies from its initial entertainment roots to a number of "serious" industries. Games are being adopted for defense, medicine, architecture, education, city planning, and government applications. Each of these industries is already served by an established family of companies that typically do not use games or the technologies that support them. The rapid growth in the power of game technologies and the growing social acceptance of these technologies has created an environment in which these are displacing other industry-specific computer hardware and software suites.

This paper puts forward a game impact theory that identifies five specific forces that compel industries to adopt game technologies for their core products and services. These five forces are computer hardware costs, game software power, social acceptance, other industry successes, and native industry experimentation. Together these influence the degree and rapidity at which game technologies are adopted in a number of industries. This theory is meant to be useful to managers who must make decisions about adopting, investigating, or ignoring these new technologies.

Games in Society

In his history of the game company Parker Brothers, Philip Orbanes demonstrates the impact that a number of games had on the social practices of the United States in the late 19th and early 20th centuries (Orbanes, 2004). As new games were invented or imported from Europe, they changed the way the population spent its time and changed the definition of leisure activity. Through his new company, George Parker introduced board games like Dickens, Ivanhoe, Chivalry, and Mansions of Happiness. Each of these was a moderate success, but more important to this study is the fact that they defined leisure entertainment as a gathering of four to six people around a game board with colorful pieces, die, and rules of play. In defining leisure these laid the groundwork for the explosive successes of Monopoly and Sorry which would be introduced much later.

Since people were gathered about the dining room table playing his board games, Parker added card games like Pit, Flinch, and Rook, each designed to make card games socially acceptable, rather than the unsavory tools of gambling that they were considered at that time. This same redefinition of leisure activities has occurred with computer games in recent years. Game companies from Parker Brothers to the present have found that it is

important to work within existing social boundaries, but that these are often poorly defined and open to redefinition by the game companies (Orbanes, 2004).

The definition of leisure has continued to occur throughout the 20th century, and has been strongly influenced by the introduction of electronic gaming instruments. Advances in electronics have brought us the radio, television, pinball machines, slot machines, video arcades, home game consoles, and personal computer games. Each of these has become a part of leisure entertainment and each has led to the creation of major corporations. However, the PC game has created products and a set of tools that are spreading far beyond their entertainment roots and are impacting a number of established "serious industries". The technologies from these games are changing the way numerous business activities are being done, from corporate training to scientific data analysis.

Computer Gaming: Business & Economy

In his widely read history of the Nintendo Corporation, Sheff (1999) describes how the computer technologies of the 1960's were turned into the first arcade and console games of the 1970's. Nolan Bushnell's "Pong" game took the pinball arcades by storm when it was introduced in 1972. It began the transition from electrical-physical games to digital-electronic games. Bushnell's Atari Company soon turned Pong into a console device that could be connected to a television and played in the home. This was the first step in turning passive television viewers into active television "finger athletes". It also kicked off the creation of the video game industry. Companies like Atari, Magnavox, Nintendo, Sega, Sony, and recently Microsoft entered the home and began to compete with television, board games, and other forms of leisure entertainment. Since that entry, traditional board and card games have found it difficult to compete with moving three-dimensional action that shouts, explodes, and laughs in beautiful colors and perfectly rendered images.

From the humble beginnings of Pong, Pac-man, Tetris, and video pinball, we have moved to Super Mario Brothers, Wolfenstein 3D, Command and Conquer, Microsoft Flight, Quake, Unreal Tournament, Half-Life, and World of Warcraft. Each of these has provided more realistic virtual worlds and more interactive environments in which to play. As the Internet grew, these also extended themselves through the telephone and network lines to create competitive play with other people around the planet. Games have enabled shared play with complete strangers and defined that as an acceptable form of entertainment.

Not satisfied with small team interactions involving 2 to 16 players, game companies created a new genre known as the "massively multiplayer online game" in which thousands of people can participate in a shared world and can return to that world day after day to see it grow and change in response to their own actions. Multi-User Dungeons, Ultima Online, Everquest, The Sims Online, Second Life, and World of Warcraft have created many alternate communities where players can build relationships, teams, businesses, economies, and a complete working social structure that parallels the

real world. Games have defined what entertainment is, but they are also defining social mores and financial values.

Games as Business

Computer games are a rich and vibrant part of the economy. In recent years, the size of this industry has surpassed that of the movie industry in Hollywood. It is estimated to be over $10 billion annually, compared to Hollywood's $8 billion. It is also a significant driver of the computer hardware and software industries.

Nolan Bushnell, the founder of Atari, pointed out that a number of computer technologies that are now considered standard in business computing were actually invented and applied in computer games. These include raster scan monitors, sprites, real-time graphics, graphical user interfaces, three-dimensional graphics, publicly available computing resources, trackballs, joysticks, sound feedback, collaborative computing, and anthropomorphism (Bushnell, 1996).

Much of this game technology is a direct descendent of military simulator research and development, specifically the Simulator Networking (SIMNET) program sponsored by DARPA in the 1980s and 1990s (Miller & Thorpe, 1995; Dodsworth, 1998). As computers became more powerful, game makers adopted the military theme and style of training as soon as possible. Young programmers like John Carmack created one of the first three-dimensional games for the personal computer, Wolfenstein 3D, and released it as shareware in 1992 (Kushner, 2002).

Like the radio, television, computer hardware, and the Internet, computer games have generated entirely new businesses led by the enthusiasts who jumped in early. These people have also created a number of unique business structures, practices, and partnerships and these are impacting established companies in industries that, at first, appear to be far removed from gaming. But in fact, who share a common technological foundation that the game companies are beginning to exploit. In this paper we explore the economic and social impact that the game industry and its associated technologies are having on industries like:

- Entertainment,
- Education,
- Training,
- Scientific Visualization,
- Scientific Analysis, and
- Exploration.

Games for Business

"The second World War exposed many American servicemen and servicewomen to simulations and games. When they returned to work they began to see the possibilities of learning facts and insights in an experiential way and how that could be used to train staff to keep up with the business expansion, which came post-war." (Lane, 1995).

Games and simulations are not just found in entertainment. As Lane noted in 1995, the simulators and wargames that were used to train military personnel during World War II opened people's eyes to the potential of games and simulations as tools for learning and improving performance. This idea had been growing in military research communities for at least three hundred years, going back to the military game of "Koenigspiel" which was introduced in 1664 by Christopher Weikhmann of Ulam, Germany (Perla, 1990). But those ideas were relegated to the government and military communities and did not propagate out of that community for nearly 300 years.

Post-war companies introduced a number of business training games and incorporated competitive game playing into traditional classroom courses. But, as an industry and a business in itself, this had little impact on the economy or the structure of multiple industries. Like Parker Brothers' games, it was the use of these in entertainment that really generated interest and sufficient revenues to drive invention and innovation. One of the most notable of these was the creation of the hobby board wargame by Charles Roberts in 1952. Roberts was an Army reservist awaiting his commission and sought to create a tool with which to practice his tactical decision-making skills. This desire led him to organize and improve upon the wargaming tools that had been evolving since 1664. In addition to military training tools, Roberts created the Avalon Hill Company which started the entire hobby wargame industry (Perla, 1990).

Fifty years later, "Video games and all related industries generated 220,000 jobs and US$ 7.2 billion in wages in the US in 2000" (Aoyama & Izushi, 2002). Figure 1 illustrates the explosive growth of the game industry since 1994.

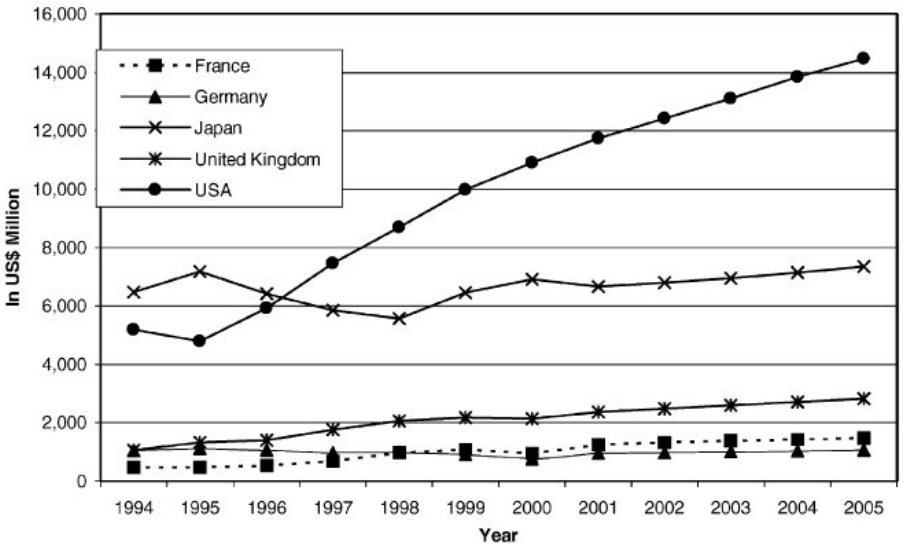

Figure 1. Computer game market trends, 1994-2005.
Source: Aoyama & Izushi, 2002

Some authors see these games as a very limited and bounded product within a single industry. Maier & Grobler (2000) attempted to group all applications of games to learning into a half-dozen simplified categories. This view ignores the continuously changing nature of games, the computer technologies that support them, and the synergistic relationships between the companies that sell them into every market space. They are much more like malleable tools than specialized applications. Their creators will transform them into any form for which a sufficient customer base exists.

In fact, in an ironic turn of leadership, the game industry is now seen as a core source of innovation, technology, and products to drive the military simulation industry from which it originally sprang. Members of a recent government-sponsored study group on entertainment technologies encouraged the military to establish sharing relationships with computer game developers and the movie special effects communities as a means of pulling these technologies into military training to improve its realism (National Research Council, 1997). This recommendation came to fruition when the Army invested $50 million to create the Institute for Creative Technology at the University of Southern California with exactly this mission (Sieberg, 2001).

Key Game Technologies

The power of games stem from the technologies that they contain, their emotional connection to their customers, and the business ecosystems that they have created.

Having evolved from their roots in Pong, Pac-man, Space Invaders, and Tetris, game makers have identified a combination of software technologies that are most effective at winning customers. These have moved from the personal computer, to the television game console, and are entering the cellular telephone as fast as hardware technologies will allow. Figure 2 illustrates these technologies with images. These dominant game technologies are:

- 3D Engine
- Accessible GUI
- Physical Models
- Artificial Intelligence
- Networking
- Persistence

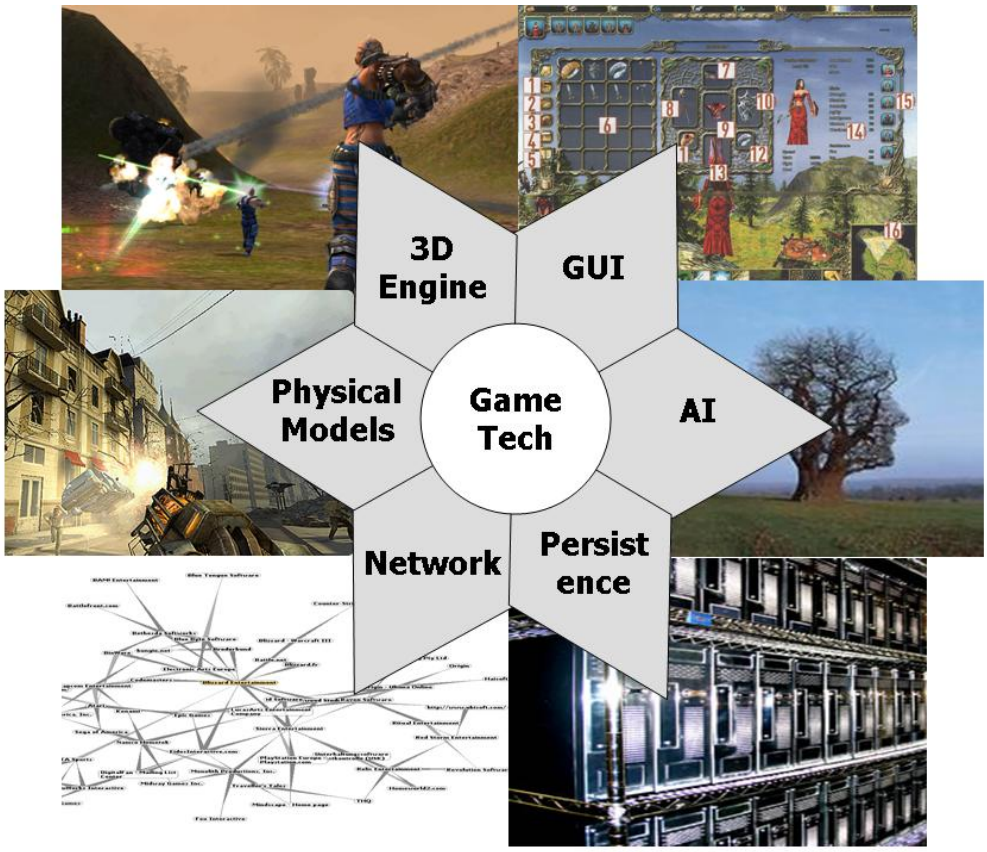

Figure 2. Six key technologies that drive computer games.
Source: Created by the author

3D Engine

Easily the most identifiable part of a game is the three-dimensional engine that creates the graphics that a player stares at for hours on end. These engines are the key component with which vendors compete for market attention. The detail of the characters, the vibrant colors, and realistic explosions all attract players and commercial users from one previously hot game to the next.

Figure 3 provides a side-by-side comparison of the scene generated by Wolfenstein 3D, the first market blockbuster 3D shooting game in 1992, with a comparable scene from the same company's 2005 game entitled Quake 4.

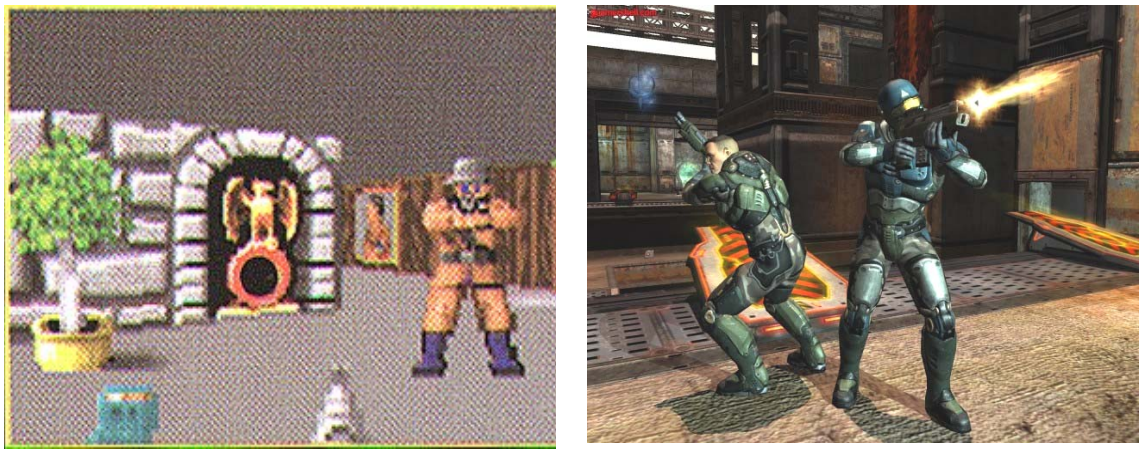

Figure 3. Visual comparison of 3D scenes from 1992 and 2005.
Source: id Software – http://www.idsoftware.com/.

The 3D engine is not just a game technology. There are a number of industries that require this type of capability to visualize information. Most prominently, these include flight simulator training, medical imaging, architecture, and computer aided design. Smed, Kaukoranta, & Hakonen (2002) illustrate the fact that the virtual environments created by a 3D engine are applied in different ways by different communities (Figure 4). Computer games, simulations, and academic virtual environments have significant overlap, but remain unique fields. This picture also illustrates the opportunities that exist for computer games and game technologies to infiltrate these very closely related industries. As we will demonstrate, the number of domains that intersect in this way far exceeds those considered by Smed.

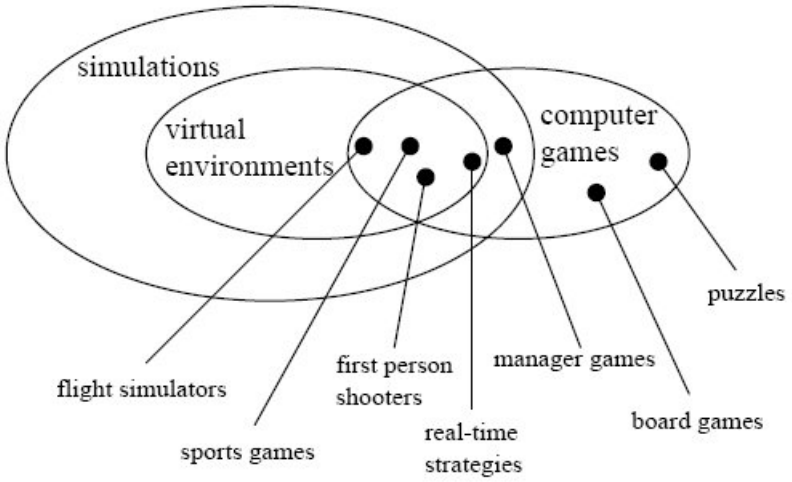

Figure 4. Computer games, simulations, and academic virtual environments share a number of characteristics. These commonalities represent market opportunity for the game industry.
Source: Smed, Kaukoranta, & Hakonen, 2002

GUI

"Why do we put up with the frustrations of everyday objects, with objects that we can't figure out how to use?" (Rosen & Weil, 1995) In their 1995 study, Rosen and Weil discovered that 25% of American adults had never used a personal computer, programmed a VCR, or customized the stations on their car radio. They lay the cause for this squarely at the feet of the complex user interfaces provided by the manufacturer. This is a popular problem for which a simple, non-threatening user interface would find a ready market.

In an attempt to attract and retain as large an audience as possible, computer game developers put significant effort into creating a graphical user interface (GUI) that is easily accessible and understandable. The ultimate goal is to make it possible for a broad audience to play the game without reading a manual. In fact, most games come with a familiarization stage in which the game teaches the player how the controls work and gives them simple tasks to perform to gain and demonstrate proficiency. This expertise in creating an effective human interface can be applied in hundreds of different industries to overcome the issues identified by Rosen and Weil.

Physical Models

When playing a game, characters run, jump, shoot, fall, and explode. Each of these actions is controlled by physical models that estimate how real objects would perform these actions. As games have evolved, the first simple animations of running characters (sprites) have been replaced with physics-based models that calculate how fast a specific vehicle can climb a hill and which objects would impede its progress. The accuracy of these models determines the realism of the world and the pictures that are drawn by the 3D engine.

The most recent advances in this area are the additions of "physics engines" which treat digital objects as if they have mass, weight, volume, stiffness, and joints that operate like real world objects. When movement and interactions occur, the physical properties of these objects interact with each other and with the gravity of the world to generate images that appear to be as real as the physical world we inhabit.

Artificial Intelligence

A game in which only one player exists is very dull. The human player must encounter other characters that are interesting to interact with. These characters possess an artificial intelligence that allows them to perform all of the same actions that a human controlled player would, and to do so in a manner that appears realistic to the human.

The AI techniques created in academic and industry labs have been adopted for games at a very rapid pace. In fact, leading AI researcher John Laird from the University of Michigan commented that the latest advances in AI appear in games long before they show up in more traditional industries (Laird, 2000).

Networking

The Internet connects live players with others around the globe. This means that each person is no longer limited to playing against an artificial opponent on his own computer, but can compete against other people as well. In fact, a player can locate others who have similar skill levels, people who have hours of experience with the game and will play in a unique and unpredictable manner. Like the novels that describe man-hunting-man, this creates the ultimate game of survival in the virtual world.

Networking also enables the creation of a shared community and sub-groups referred to as clans. Those who enjoy the games also enjoy sharing stories and tips within this community. In a networked virtual world, there can be much more to the game than just the software in the box. It can open up an entire alternate community in which to live and build relationships.

Persistence

Until 1997, most networked games created small vignettes in which individuals came together in a dungeon, castle, or fortress to team up and fight each other to the death – over and over and over again. But once the characters left the environment, all remnants of their engagement were deleted from the computer servers and the space was refreshed for the next team that would meet there. But, in 1997, the game Ultima Online changed all of that. The creators envisioned a world that was persistent. It exists before a player enters and after a players leaves. The actions that a player takes in the world persist there as they would in the real world. In this environment, the game becomes an evolving story that changes from one day to the next based on what all of the players do there. The success of Ultima Online led to a number of competitors like Lineage, Everquest, Asheron's Call, The Sims Online, and World of Warcraft. These game worlds can support hundreds of thousands of simultaneous players and evolve over many years. An alternate society that is not mundane and in which a player can create a persistent identity is a powerful attractor for long-term players and long-term customers.

Software Pushes Hardware

These six core software technologies have pushed computer hardware manufacturers to create more powerful equipment. In fact, the game industry has become the primary force driving commercial computer advances – exceeding the demands of business productivity and military applications.

The game community calls for improvements in CPUs, memory, graphics chips and cards, display monitors, network connections, sound generation, user interface devices, and back-end server computers. Advances in all of these benefit all industries that use computers for their products and services, and most significantly, the price/performance ratio enabled by the huge game market. It also builds an industrial computing environment that is capable of running the game technologies listed above when such an application becomes available in their industry.

Game Power: Technological, Personal, Financial, and Social

As stated earlier, the computer game industry has risen from near obscurity to a major industry in just over ten years. It has capitalized on a number of forces in technology, society, and individual preference. When brought together, these forces have been powerful enough to propel the growth of this industry faster than more traditional industries at the beginning of the 21st century. Through consolidation, the largest three companies that are purely in the game software business are Electronic Arts, Namco, and Activision. Though these are significant companies in the game industry, they are dwarfed by the leaders in the industries that are being disrupted by their technologies (Table 1). This size disparity demonstrates the huge growth potential that may lie ahead for games.

Table 1. Largest companies in select industries (by annual revenue in billions of dollars).

Computer Game Software	Entertainment	Defense	Pharmaceutical	Energy
Electronic Arts $3.1	Time Warner $43.6	Boeing $54.8	Pfizer $51.4	Exxon Mobile $339.9
Namco $1.6	Walt Disney $31.9	United Technologies $42.7	Johnson & Johnson $50.5	Chevron $189.5
Activision $1.4	News Corp $23.8	Lockheed Martin $37.2	Abbott Labs $22.3	ConocoPhillips $166.7

Source: Fortune 500 listing for 2006 and game company web sites.

Computer games harness four different forces in order to achieve their growth and the attention they receive from the population and the media. These are technology, personal, financial, and social.

Technological Power

Computer hardware technologies have exploded in the last two decades. They have moved so rapidly that many companies have not been able to take advantage of the power that they offer. Both the developers of software applications and the business consumers of these have usually not required the constant improvements in power that are available.

However, the gaming industry has moved rapidly to create new software that takes advantage of the latest in computer hardware. They have a relatively rapid software development cycle and a low product price. Since they depend on large numbers of customers to purchase their products, each game can be sold at $20 to $50 and still generate significant profits. The constant demand for new games also drives the industry

to create hundreds of new titles every year, with the development time of a single product averaging 18 to 24 months.

Such rapid turn-around allows the industry to experiment with new ideas rapidly and to identify those that work and those that do not. As described for AI earlier, the game industry is often the first place to create a commercial offering of a new software or hardware technology created in a research laboratory.

Thomke (2003) argues that this rapid experimentation with new ideas is an essential part of reducing costs and deployment times. In Figure 5 he illustrates that making more mistakes faster can shorten the product development time and improve the quality of the product. Rapid mistakes reduce the costs that accumulate as a project matures, which reduces the cost impacts when a mistake is found. Making mistakes faster literally makes it possible to make more mistakes and to squeeze more problems out of a product before it is deployed to customers. So, in addition to getting to a product faster, it creates one with fewer embedded errors.

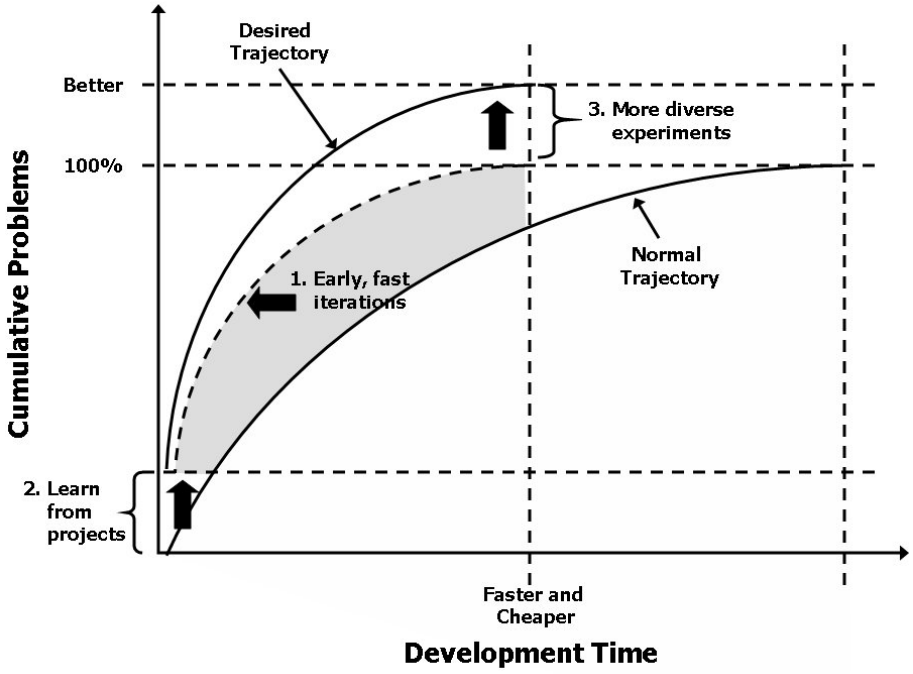

Figure 5. Making mistakes faster can reduce product development time and increase the quality of the product.
Source: Thomke, 2003

Once they discovered the advantages of rapid product development, the game companies themselves pushed this even faster. They began to market their next breakthrough product earlier and earlier, even to the point that they were promoting products that had not begun development yet. They were locked in a leapfrogging arms race to capture the mindshare of customers, even if they had to sell vaporware to do it (Schilling, 2003).

Personal Power

Eric von Hippel of the MIT Sloan School of Management has written a number of papers on the phenomena in which product users become important innovators of new and more advanced products. He and his collaborators have studied industries as diverse as mountain biking, wind surfing, medical equipment, and open source software. In all of these, there is a community of lead users who demand improvements to the current products and who take it upon themselves to create the improvements that they need. This behavior existed long before the current information economy, going back at least to the agricultural era in which farmers had to make most of the equipment they needed because there was little organized industry available to provide it. However, the difference today is that an organized industry does exist everywhere that lead users are innovating. Also, given the current information connectedness of society, the innovations created by one lead user can be shared and duplicated by others around the globe. This network of lead users can make up an alternative, and competitive, source of products (von Hippel, 2005).

Given this environment, many industries attempt to include these lead users in their own internal innovation process. Their goal is to harness the personal energy of these innovators. The game development community exhibits these same traits of user innovation. An entire "modding" community has sprung up which creates new artwork, new game levels, and new software that can be incorporated into a popular game. The game makers have encouraged this trend by making their games more modifiable with each succeeding generation. The modifications by their lead user communities enhance the value of the core product and drives additional sales.

Shankar and Bayus (2002) point out that the market position and growth of a product are derived from at least two equally powerful forces. The first is the size of the installed base. In the case of console games, Nintendo became a powerful player because the large number of installed consoles drove large numbers of game cartridge sales. However, it was overtaken by both Sega and Sony at different times, largely due to the strength of their network of users, which is the second of these two forces. "Strength" refers to the degree to which customers build their own network around a product, discuss it, promote it, and make modifications to it. The PC game community recognizes this value and actively promotes is customer/modder base. Blizzard Entertainment has produced three major blockbuster games for multiple players – Starcraft, Diablo II, and World of Warcraft. Writers have commented that, "Blizzard's products are computer games, but the social dynamics of a networked player population are the backbone of its business" (Herz & Macedonia, 2001).

von Hippel listed three conditions under which lead user innovation is most likely to grow. These are: "(1) at least some users have sufficient incentive to innovate; (2) at least some users have an incentive to voluntarily reveal their innovations and the means to do so, and (3) user-led diffusion of innovations can compete with commercial production and distribution" (von Hippel, 2001). All three of these conditions are met within the game industry.

Financial Power

Computer games resemble movies in more ways than being a form of entertainment. In both industries an average product takes between 18 and 24 months. Each requires a focused team with specific expertise to come together at different times during production – encouraging the use of contract and consulting workers. Each requires the investment of several million dollars in the creation of the initial product, but copies of the final product can be made for a nominal cost. Each relies on an electronic device to run them in the home. Each sells in the marketplace for $20 to $50. Customers are willing to purchase a number of these products during a year. Finally, in both industries it is difficult to determine which ideas will be popular successes and which will be enormous failures.

When a game is successful, there is no limit to the number that can be produced and delivered to the customer and there is no limit on how long the product can continue to be produced and sold. A successful product can generate huge streams of revenue long after it was first introduced into the market.

Kim & Mauborgne (1999) points out that customers purchase products based on the value curve that they perceive. When people choose to play computer games over watching television or participating in sports, it is because these games offer more value at a lower cost. Figure 6 attempts to compare the value curves of television and computer games to illustrate the package of benefits that are driving growth in the game industry. This growth has created a $10 billion industry that gets bigger every year and that is expanding into new forms of revenue generation to include in-game advertising, merchandising, competitions, and movie themes. Together these are generating profits that allow this industry to continually exceed its previous products.

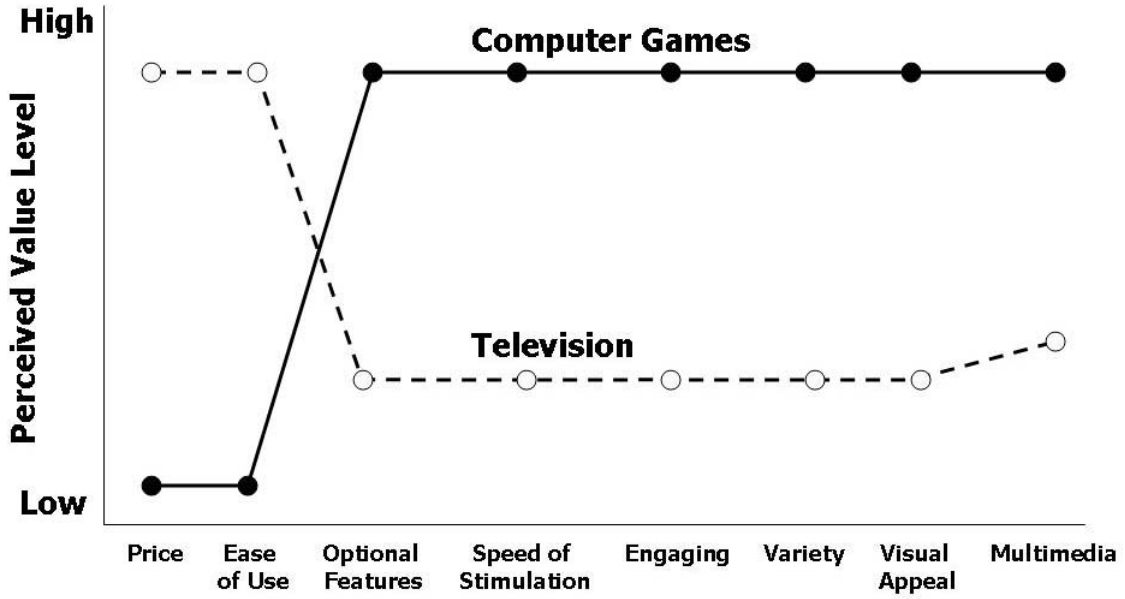

Figure 7. Perceived value of television versus computer games in a number of entertainment factors
Source: Created by the author using the concepts from Kim & Mauborgne, 1999.

Social Power

"This web of relationships between players – competitive, cooperative, and collegial – sustains the computer game industry, no less than the latest 3-D engine, facial animation algorithm, or high-speed graphics card." (Herz & Macedonia, 2001)

21st century computer games have become social gathering points that have created a host of counter-cultures within society. However, these are unique from many previous phenomena, in that the social cultures within these games span the entire Internet-connected world. The popularity of World of Warcraft and Everquest is not an American phenomena, it has attracted a global audience. A group of characters on a quest in either of these games are as likely to come from different countries as they are to come from different states. The only force that still tends to bring together people from the same continent is time. Since the majority of players must balance a job with their game playing, this means that their schedules for entering the game often lineup based on the time-zone in which they live.

To support these social groups a number of open source products have been born which either competes with commercial products like Warcraft or that supplement the experience. Supplemental tools and web sites include newspapers, game asset managers, player tracking tools, team tracking tools, blogs on game events, and trading sites at which players can purchase game items using real money (Hof, 2006).

SourceForge is the dominant repository and collaboration site for open source software development, distribution, and coordination. In that repository, over 25% of all of the applications deposited and openly developed are computer games and supporting tools (Scacchi, 2004). This indicates that people are very eager to invest their time, intelligence, and emotions into the development of game software for which they will receive no financial return. They are eager to express their creativity, develop a reputation, or create a social group interested in their project.

As described earlier, "The effects associated with a customer network are not only a function of network size, but also network strength" (Shankar & Bayus, 2002). Computer game developers can overcome their rivals by creating stronger relationships between the players in their games. The strengths of the relationships in the network make the venture enduring and their enthusiasm for the experience attracts additional players and third party game developers. This personal attraction is one measure of the strength of the social network associated with specific game titles (Scacchi, 2004).

Multi-Industry Impacts

"Having one foot outside your world means you can be less beholden to the people, ideas, and objects that would otherwise bind, and blind, you. Bridging multiple worlds, in

essence, makes you less susceptible to the pressures of conforming in any one because you have somewhere else to go" (Hardagon, 2003).

Game technologies are making this very transition into other industries. After establishing themselves firmly in the entertainment field, many game development companies have begun offering their products and services to a broad set of industries. When these applications are considered "serious business", like defense, medicine, city planning, and architecture, these tools are often referred to as "serious games". At least two recent books have been published under this title and describe a wide variety of applications of games to other industries (Michael & Chen, 2006; Bergeron, 2006). Table 2 summarizes the observations of several authors who have investigated this industry crossover.

All of these activities have been carried out in a different form without the use of game technologies. In most cases, those alternatives did not include a three-dimensional, visual presentation. However, in many cases, the human mind and imagination are not sufficient to visualize what is happening. Jay Forester, the father of System Dynamics, stated that, "The mental model is fuzzy. It is incomplete. It is imprecisely stated. Furthermore, within one individual, a mental model changes with time and even during the flow of a single conversation. The human mind assembles a few relationships to fit the context of the discussion. As the subject shifts, so does the model … Each participant in a conversation employs a different mental model to interpret the subject. Fundamental assumptions differ but are never brought into the open" (Schrange, 2000). This lack of clarity and uniformity presents a valuable opportunity to apply game technologies, particularly 3D visualization and models of dynamic events.

Casti (1997) described the use of a football computer game to study possible final scores for Super Bowl XXIX between the San Francisco 49ers and the San Diego Chargers in 1995. Even though the computer game generated significantly different results from the real football game, this prominent scientist from the Santa Fe Institute, still considered the game to be a useful tool in understanding the dynamics of the Super Bowl performance.

Game companies and their technology did not move simultaneously into all of the industries listed in Table 2. Each industry requires a different level of sophistication for its applications. Therefore, game technologies, which are largely hosted on commercial computer hardware and software, had to wait for that foundation to grow powerful enough to tackle the problems in a new industry. Figure 8 provides a conceptual representation of game technologies moving "up market" into more demanding industries. The shorter shaded rectangles represent a fraction of all applications in that industry that could be impacted by game technology.

Table 2. List of industries impacted by games and game technology.

Industry	Game Technology Impact
Military	Training soldiers and leaders in the tactics and strategies of war. Three dimensional modeling of equipment to illustrate or explore its capabilities.
Government	Ethics training for NASA. Project management training for the State of California.
Education	Augmenting classroom instruction in nearly every subject – English, math, physics, history, etc.
Emergency Management	Training emergency responders, firefighters, FEMA agents, and others to deal with disasters.
Architecture	Visually promoting major hotel, casino, and office spaces to potential clients.
City & Civil Planning	Lay out and experimentation with public services for a population of constituents.
Corporate Training	Orienting people to company products, facilities, and policies. Pilot and safety training.
Health Care	Educating patients on treatments, rehabilitation, and managing anxieties. The next generation of workout videos.
Politics	Presenting political issues and consequences of political decisions. Promoting candidates.
Religion	Interactive versions of sacred texts. Tools to teach religious history.
Movies & Television	Alternative form of storytelling known as “machinima”. Tools for creating animation and 3D worlds.
Scientific Visualization & Analysis	Rapid display of objects under experimentation and physical forces acting on them. 3D display of data collected and analyzed.
Sports	Recreate live sporting events for review and for prediction of potential outcomes. Rehearse for critical “one time” events like Olympic ceremonies. Fantasy sports leagues in 3D.
Exploration	Prepare missions for NASA Mars Lander. Recreate environments around deep sea probes.
Law	Illustrate crime scene activities for judge and jury. Analyze crime scene data.

Sources: Michael & Chen, 2006; Bergeron, 2006; Casti, 1997; Maier & Grobler, 2001

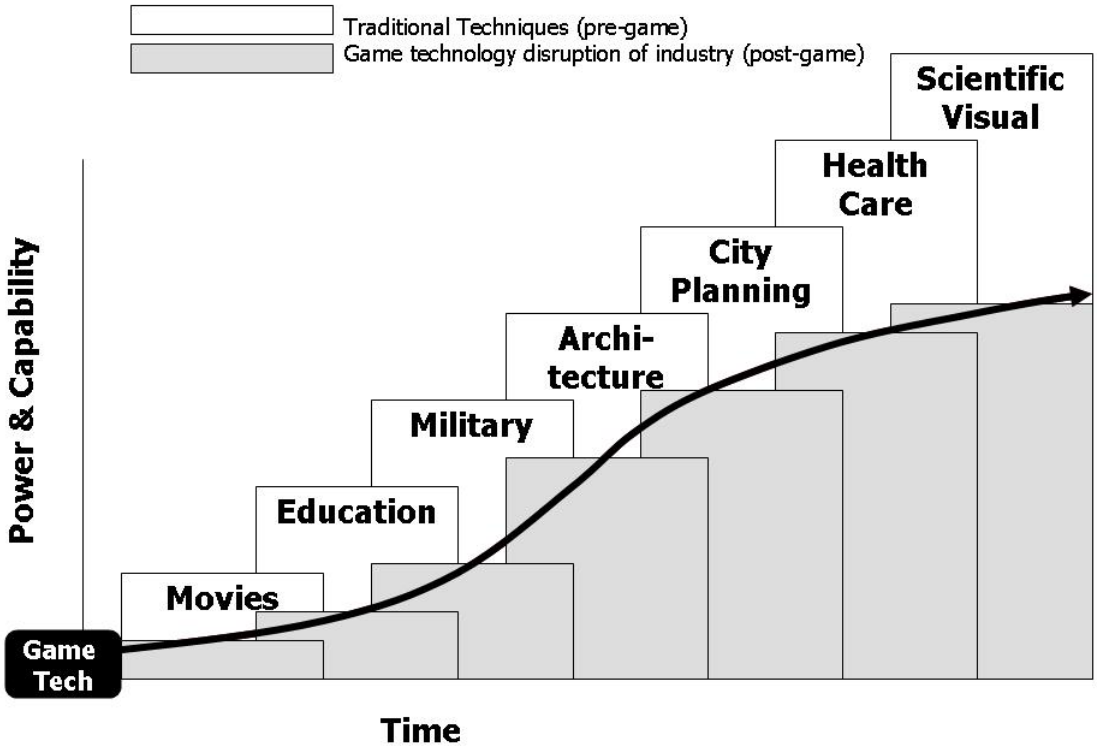

Figure 8. Game technology encroachment into other industries.
Source: Created by the author.

Over time we believe the technologies being delivered by games will fracture into specialized applications and the common reference and root in the game industry will be lost in history. However, the current explosion in both computer and game technologies has allowed them to move so swiftly into so many different industries, that it appears that games are taking over all industries. This is directly parallel to the impact that the Internet had on industries of all kinds in the late 1990's. At that time it seemed that every industry was being turned inside out to become "Internet enabled" or to reinvent itself as an "Internet only" version of its previous identity (Porter, 2001).

Game technology impact is simply a concentrated, short-term transformation of the basic tools that have been under development in multiple industries for decades. Companies have been presented with new technology to improve their competitive position for several decades – small electronics, large computers, telecommunications, the Internet, the World Wide Web, personal computers, and now game technologies. Each of these offers some advantages and each company must determine whether to adopt the new technology. Those that choose the correct technologies will reap the advantages that they confer, and those that do not must continue to compete with the last generation of tools and technologies that they did adopt.

Figure 9 illustrates the adoption of repeated waves of technological advances. Companies that carefully adopt these can continue to improve their productivity, competitiveness, and reputation with customers. The dark shaded, multi-step bar demonstrates the path of

a company that cautiously adopts these technologies. A company can benefit significantly by waiting until the new technology shows promise of displacing the old technology. In fact some authors recommend that companies not adopt new technologies immediately because that is when equipment costs and the level of uncertainty are the highest (Markides, 2005). Assuming that there is always time to catch-up to those who choose first and choose correctly, adopting more slowly can lower the risk of failure, lower the cost of entry, and increase profits. To enable this, a company may invest just enough in a number of new technologies to put itself in a position to leverage them into its products and services if necessary. This is a way to take an option on the technology without bearing the full cost and full risk of adopting it too early (Leonard, 1995).

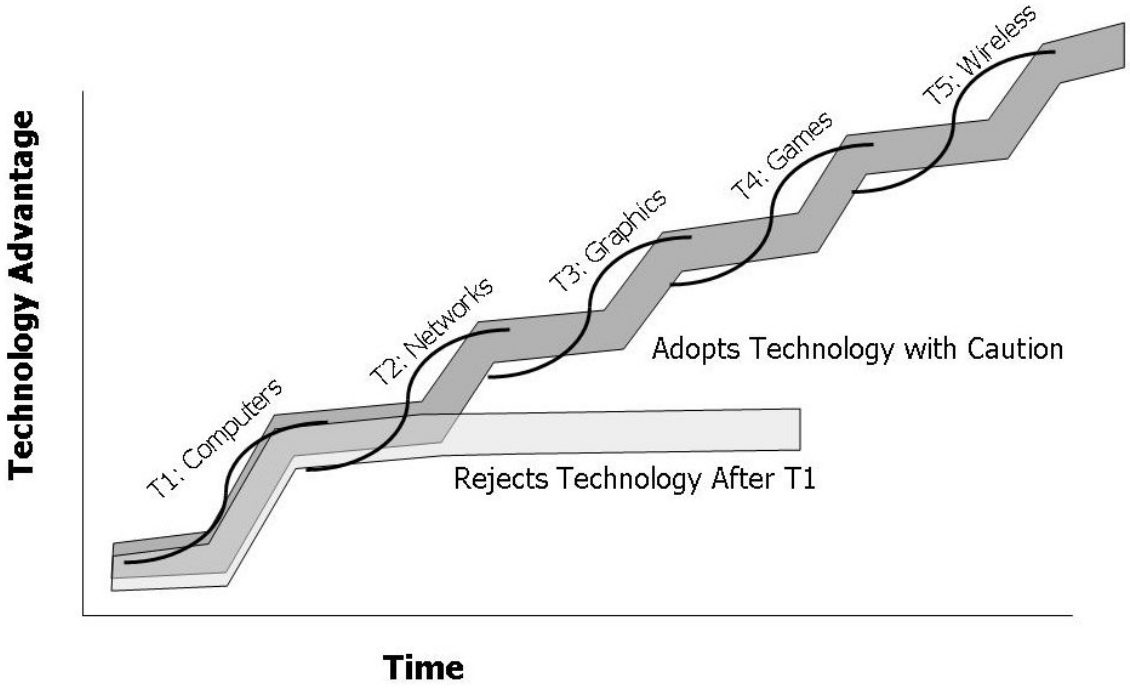

Figure 9. Conservative adoption of successive waves of technology.
Source: Created by the author based on concepts in Christensen, 2004.

However, at the lower end is the lightly shaded bar in Figure 9. This illustrates a company that adopts just one or two waves of technology and concludes that anything after that is not important or valuable. When the ignored technologies do prove to be valuable, this conservative company will find itself competing at a significant disadvantage and potentially unable to survive.

Game Impact Theory

The very nature of games in Western society makes them a disruptive force. As Parker Brothers discovered in the late 19th and early 20th century, games have the power to influence society, but they must fit within societal norms. Today we see computer games extending their influence into the serious business of military operations, medical

education, and emergency management training. In doing this, game technology is jumping the gap between entertainment and work. Throughout the evolution of electronic and computer games, this gap has kept this technology out of business, largely because games were not seen as "serious" tools. Games have been viewed as toys, not at tools for productivity. But the incredible power of the personal computer, graphics cards, broadband Internet connections, intelligent software agents, accurate physics models, and accessible user interface are making it impossible to ignore the potential of these "toys" to be applied to some very difficult problems in the "real business world".

Games as a Disruptive Technology

Once the barrier between entertainment and work was bridged, game technologies flooded into all of the areas listed in Table 2. As a relatively mature technology, games entered with a huge disruptive potential to the established players in those fields. Christensen's analysis of the disruptive effects of hydraulics on the steam shovel industry, mini-mills on large steel foundries, and small disk drives on their larger predecessors is a direct corollary to what is happening with game technologies (Christensen 1992 and 1997). These technologies offer significant computer and software power at a much lower price point than the solutions that are used in many industries (Figure 10). Games and serious industries were kept separated by the social stigma that has defined games as toys. This allowed the technology to mature significantly while that stigma dissipated. When it was finally gone, game technologies offered significant power for industry application and have been impacting these industries relatively rapidly.

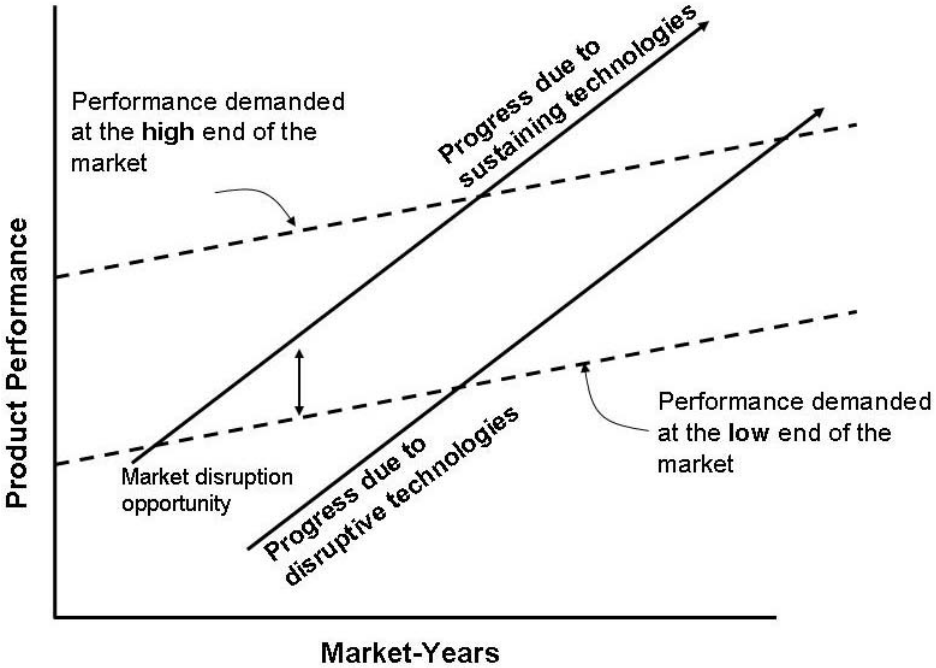

Figure 10. Christensen's theory of disruptive innovations explains how new technologies overthrow established businesses by offering better performance at lower prices.
Source: Christensen, 1997.

Each industry that is assailed by these technologies faces its own set of arguments over whether games can perform serious work. But, those who insist that it is a passing fad are being bypassed by others who experiment with the technology and find a valuable use for it. As we showed in Figure 9, game technologies appear to be a natural next step from the graphics hardware and software that have most recently been adopted by military, medical, architectural, and other "serious" industries.

The power of the 3D graphics, accessible user interfaces, collaborative network connections, and intelligent agents is a persuasive argument. But, lower cost computer hardware and software to apply these technologies is making this technology irresistible and undeniable. In many cases, game applications run on machines that are an order of magnitude less expensive than their predecessors. Rather than paying $20,000 to $50,000 for specialized computer workstations, they can run on a $2,000 to $5,000 personal computer. Morris & Ferguson (1993) have pointed out that low-cost systems always swallow high-cost systems when this type of confrontation occurs.

The military has been one of the first and most avid adopters of game technologies. These games originated from military roots in the 1990's and contain many similarities with the training devices that are used to train soldiers. Therefore, the transition back into serious military applications has been much more direct than in other industries. Figure 11 extends Christensen's traditional graph of disruptive technologies to illustrate the multiple waves of game technologies that are transforming military simulation and training (Smith, 2006).

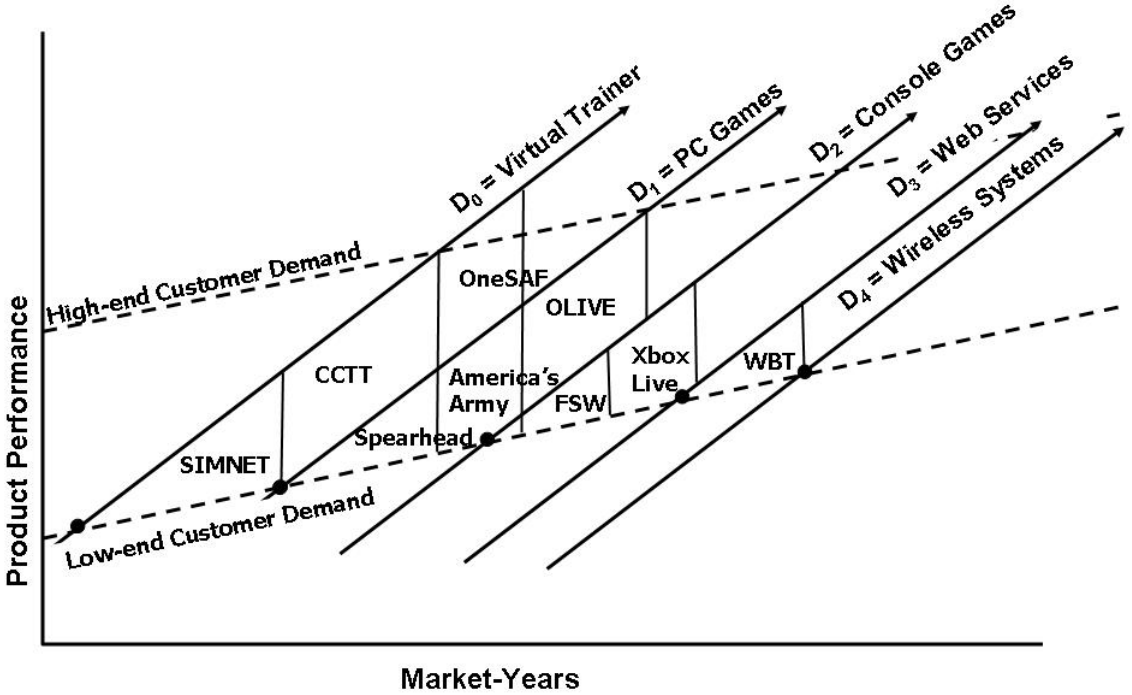

Figure 11. Multiple waves of game technologies that have already or are poised to disrupt the military simulation industry.
Source: Smith, 2006.

The first disruptive wave in Figure 11, labeled “Virtual Trainer”, represents the creation of immersive simulators with three-dimensional graphics in the 1990s. Simulator Networking (SIMNET) and the Close Combat Tactical Trainer (CCTT) replaced a previous generation of devices by providing 3D computer generated worlds and networks to connect multiple training devices into the same world. They capitalized on the early Gould, Harris, and Silicon Graphics computers that brought 3D graphics to the engineering world (Miller and Thorpe, 1995).

The second disruptive wave labeled “PC Games” describes the emergence of SIMNET-like environments on desktop computers. The first set of applications like the game Spearhead demonstrated that PCs were capable of doing this type of work and encouraged other companies and government organizations to investigate new applications (Zyda, 2003; Lenoir, 2003; Mayo, 2005).

The third disruptive wave labeled “Console Games” describes the entrance of game consoles into the military market. These consoles offer yet another order of magnitude of reduction in computer hardware costs, dropping from a range of $2,000-$5,000 to $200-$500. This wave is just beginning in the military and it is not clear whether it will be able to overcome the licensing issues associated with developing a console game for a non-consumer audience.

The forth and fifth waves are speculative in that they suggest that technological advances will make it possible to run military training using game technologies through web-based services and wireless connections and that desktop hardware specifications will become a less important part of deploying these systems. Smith (2006) suggests that the pattern shown by the military adoption of game technologies will be repeated in other industries and that those industries should begin studying this issue themselves.

We suggest that game technologies will continue to move from one industry to the next based on five core forces of the technology and the environment in which it is emerging:

- Cost advantage of hardware platforms,
- Sophistication of software applications,
- Social acceptance of game tools,
- Successes in other industries, and
- Innovative experiments in the adopting industry.

Five Forces Driving Adoption

The five forces that govern the impact of game technologies on serious industries describe the attractive forces of these technologies into new areas (Figure 12). Where Porter’s Five Forces model lists the competitive forces faced by an industry (Porter 1995), the Game Impact model represents the five compelling forces behind game technology adoption.

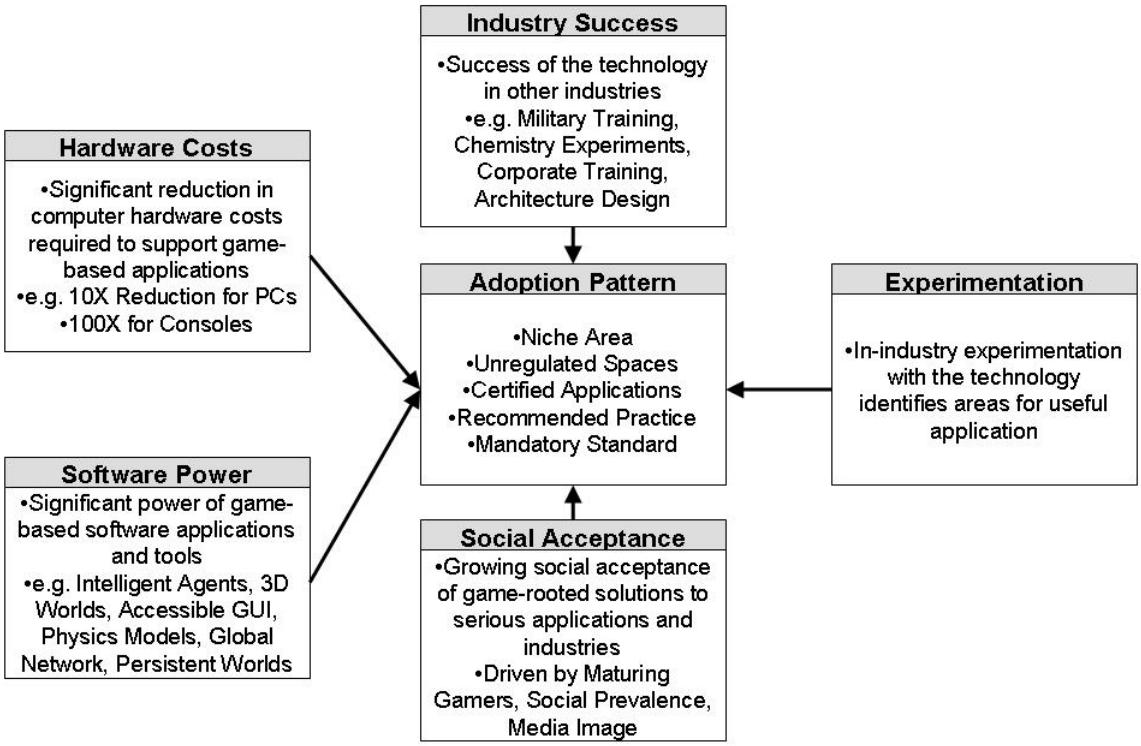

Figure 12. Game Impact Theory: Five forces behind the adoption of game technologies by diverse industries.
Source: Created by the author.

Cost advantage of hardware platforms

Computer games are designed to take advantage of all of the power available on a consumer-grade computer. Their focus is on reaching the most customers based on the hardware that these customers have available. Therefore, unlike serious industries, game companies do not want to create a product that requires a new hardware purchase. As a result, these technologies are designed to be as efficient as possible, maximizing the amount of work that can be done on a consumer-grade computer. These machines are often an order of magnitude less expensive than a professional workstation, dropping hardware costs from the $20,000 to $50,000 range, down into the $2,000 to $5,000 range.

For games that run on the console platform, the hardware costs can drop another order of magnitude into the $200 to $500 range. These hardware savings can be significant for a company that must deploy its “serious applications” to hundreds of employees or customers.

Software Power

Game technologies are conquering some core problems that are shared across a number of industries. The ability to create a user interface that an average employee or customer can understand and operate is critical to a product's success. For a computer game, the goal is usually for the customer to understand how to use the product without ever reading a manual. Any instruction that is required is built into the game itself, allowing the customer to learn while they are using it.

Games also require clever and adaptive artificial intelligence to create game controlled characters that interact with humans in a realistic and engaging manner. Sophisticated AI has always required significant hardware resources and significant expertise to configure and run the system. Games fit this power into a consumer PC and provide scripting languages that allow a customer to change the behavior of the system.

Similarly, the 3D engine, physical models, global networking, and persistent worlds provide power that is impossible to achieve through any competing software products.

Social Acceptance

Games have largely overcome the stigma that they are just toys focused on play. The technology has persuaded most critics that these systems can be applied to serious industries. As the children who were raised with these games have become the leaders inside of companies and government organizations, the level of acceptance has increased significantly.

All of society has become accustomed to seeing 3D representations in courtrooms, medical facilities, museums, building designs, and military systems. After experiencing the advantages of this type of interface, people are much more willing to accept these technologies in serious products and services.

Other Industry Success

The television industry and the military have been two of the first adopters of game technologies. Television shows like Modern Marvels, Nova, National Geographic, and those on the Discovery and History channels have applied 3D visualization and physical modeling to illustrate the behaviors of animals, machinery, and the universe. The clear communications that these game technologies enable motivates other industries to experiment with them as well.

The military has incorporated many of these technologies into its training systems. Training devices for tank crews and company commanders all incorporate the 3D engine, GUI, physical models, AI, and global networking of games. The successes of these lead-users encourage other industries to explore them seriously as well.

Innovative Internal Experiments

As managers, programmers, and artists experiment with game technologies within an industry that is facing adoption, they discover useful methods for studying chemical

reactions, understanding the stresses that occur between an aircraft and the atmosphere, evaluating the visual appeal of architectural designs, or delivering city services in a growing suburb.

When these internal experiments succeed in creating a new product or service, the established projects begin to experiment with the technology and look for ways to improve on their established practices.

Adoption Pattern

At the center of this model is the adoption pattern of the technologies. The adoption of game technologies in many industries may follow a pattern that is similar to that experienced by the military. It will begin in a niche area that is closely aligned with at least one powerful game technology. If successful there, it will be adopted for applications and activities that are not regulated. These are spaces where local groups define their own processes and measures of success. From this position, support will grow for the technology in a number of organizations and geographic areas. This will lead to some form of certified status of game technologies as an acceptable solution to specific problems. Success at this level will lead to it becoming a recommended practice in which the recognized regulating bodies will include it among the proven and preferred approaches to solving a problem. Finally, game technology may become a mandatory standard method of solving problems across the industry (Figure 13).

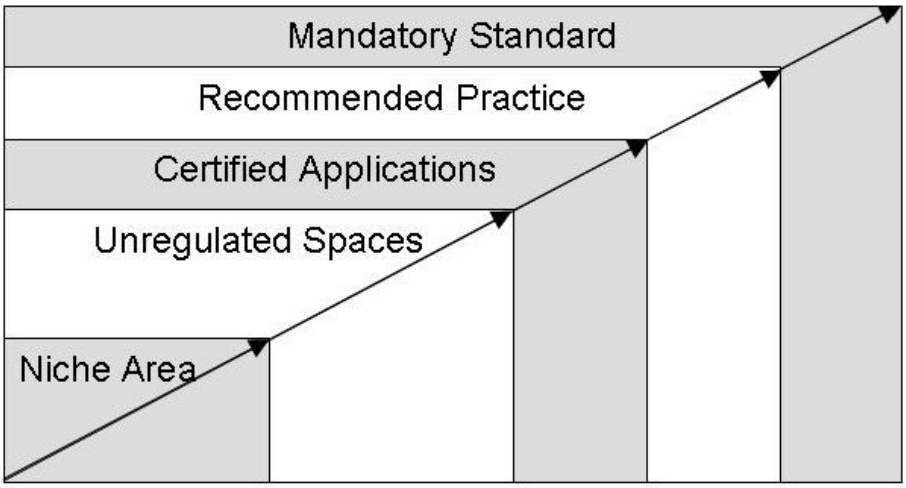

Figure 13. Potential stages of industry adoption of game technologies.
Source: Created by the author

The visual, auditory, and mental stimulation that come with games are often strong motivators for adopting and promoting the technology. Along with the flexibility that is built into the tools by core developers, these come together to create a very energetic lead-user community that contributes advances to the technology. von Hippel described this enthusiasm in the open source software development community (2001), and these forces appear to be even stronger in the game communities.

Seed Out

Being relatively specialized, the game development community is highly interconnected. Even more so among those companies that develop applications for the consoles – e.g. Sony Playstation, Microsoft Xbox, and Nintendo Gamecube. Many small companies get their start by developing exclusively for a single platform, while larger companies develop for one or more platforms (Venkatraman & Lee, 2004). This has created a highly networked community with strong internal ties and that is somewhat insular. Figure 14 illustrates the tight relationships between console and game development companies. The companies that move game technologies beyond the entertainment industry are often outsiders who must fend for themselves in creating a new market. In fact, the companies that create the hardware consoles have shown little interest in and even active resistance to using the game console for non-entertainment applications.

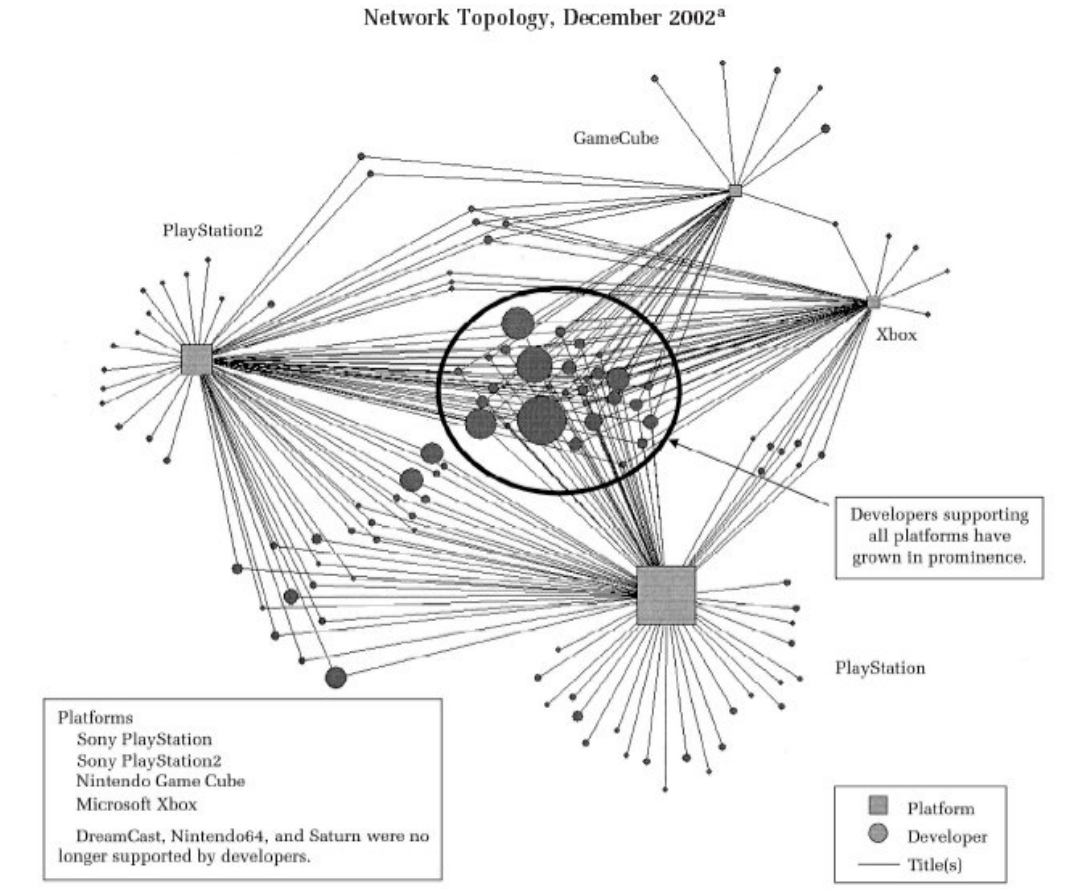

Figure 14. Topology of business relationships between independent game developers and the manufacturers of the leading game consoles in 2002.
Source: Venkatraman & Lee, 2004

This social and business environment is generating splinter companies to serve the military, medical, architecture, and other similar serious customers. Over time, these splinters will become a unique community in their own space and will not be strongly aligned with their gaming origins. This type of relationship previously developed between the early game industry and its military technology parent, and will likely repeat itself as the game industry becomes the technology parent to "serious game" industries.

Determining the strategy for being successful and even dominant in these new splinter businesses will be important to these companies. Observing the key strategy that put Microsoft in control of the PC operating system, Morris and Ferguson have concluded that, "A new paradigm is required to explain patterns of competitive success and failure in information technology. Simply stated, competitive success flows to the company that manages to establish proprietary architectural control over a broad, fast-moving, competitive space" (Morris & Ferguson, 1993).

"Microsoft's insight was to realize that it was in an architectural contest and to take the appropriate steps, including steadily expanding the generality and scope of its systems to come out the winner" (Morris & Ferguson, 1993).

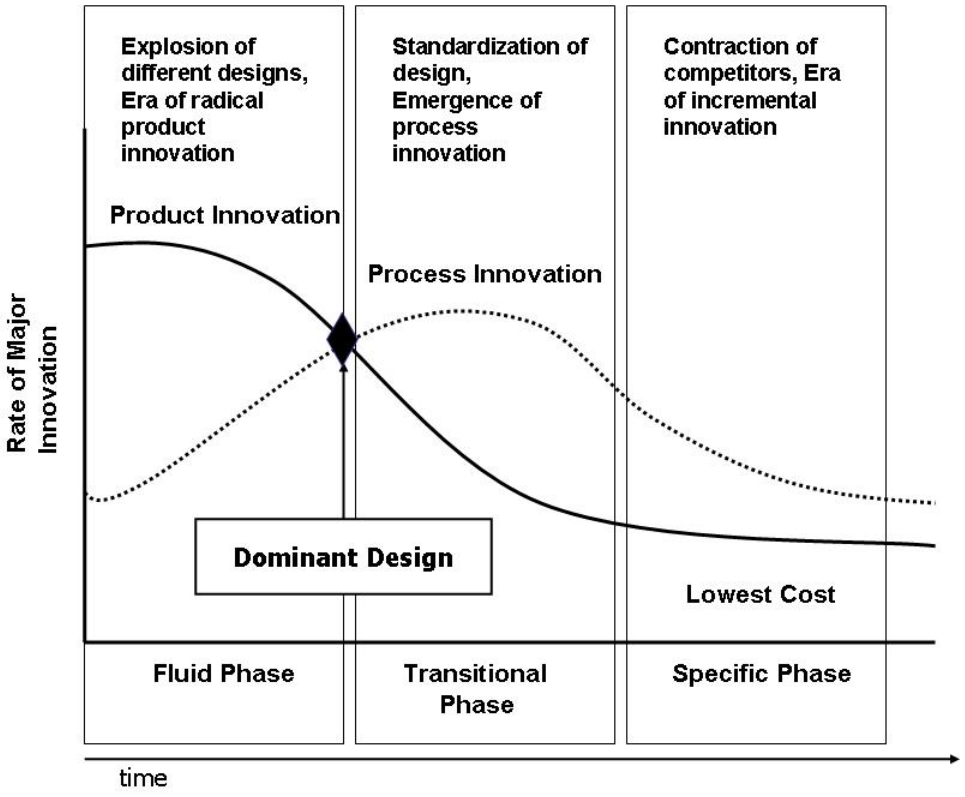

Figure 15. Utterback's model of innovation dynamics differentiates product, process, and cost innovation phases.
Source: Utterback, 1996

These ideas align with Utterback's model of innovation dynamics (Figure 15). In that model he points to the importance of the emergence of a "dominant design". This is a transition point at which innovations in product decline significantly as all companies converge on a standard design created by one of their members. From that point forward, the owner of the dominant design holds a controlling position in the industry. Following this inflection point, companies seek to innovate in the process and production spaces, looking for better ways to create or apply the dominant product design (Utterback, 1996).

Using the five forces identified, we can speculate about other industries that will adopt these technologies in the near future. These might be:

- Television News,
- Sports Leagues (Real and Fantasy), and
- Space Exploration.

The first two can arguably be included in the entertainment category. However, game technology should be able to add more than an entertainment factor to each. Three dimensional animations are already transforming the way in which weather reports are given. Current weather maps and animations are generated by computer programs with similar roots to games. However, these do not go so far as to represent all of the buildings, roads, and social features of a city and to show how the weather will impact these in 3D. Progressive news stations may create a studio that shows the newscaster inserted into a 3D model of the city and its weather prediction. News reports on traffic conditions and road construction are amenable to these technologies as well.

Sports Teams and Leagues can use game technology to display, analyze, and predict the outcome of specific plays and games, just as Casti attempted to do for the Super Bowl. These may come to supplement the use of game films and provide the power to view the scene from any angle, as opposed to the fixed perspective of the film camera. Fantasy leagues can also apply this technology to go beyond the current scoring of fantasy team outcomes. Instead, a fantasy team could actually be created to see how they might have played had they been part of the same team.

Space exploration agencies and companies use 3D representations for design and experimentation with spacecraft. But, these tools are not derived from game technologies, but are industry specific and cost one or two orders of magnitude more than the gaming alternative. 3D worlds are also a natural control environment for missions on Mars. Since a radio signal from Earth takes several minutes to travel to Mars, it is not possible to "drive" an exploration vehicle with a joystick on Earth. But, driving in a local and accurate 3D model of the planet is an alternative way to create a travel path that can be sent to Mars for execution.

Conclusion

Game technologies have the power of technology, personal investment, financial profits, and social change behind them. In this paper we proposed a game impact theory that

describes the forces that are driving the adoption of these technologies in a number of industries. The five forces described by this theory are:

- Cost advantage of hardware platforms,
- Sophistication of software applications,
- Social acceptance of game tools,
- Successes in other industries, and
- Innovative experiments in the adopting industry.

In addition to being technologically powerful, these tools and techniques are becoming more socially acceptable, even socially desirable, as the people who experienced games as children become the next generation of leaders in business, government, and the military.

“Why use simulations and games? An overly cynical answer to this question might be: because they get people enthusiastic and because we all have computers now!” (Lane, 1995). This cynical statement also captures some of the social/cultural forces that are driving this adoption. These technologies are overcoming the same types of resistance that confronted computers as tools for analysis and the Internet as a primary form of communication within business.

“The forces that hone games, and gamers, have more to do with anthropology than code” (Herz & Macedonia, 2001). As with the games introduced by George Parker over 100 years ago, these forms of entertainment test the edge of socially acceptable behavior and the use of one’s time. They impact the social relationships and cultural norms of a generation. The same can be said of business practices. It is the nurture of the individual that creates the current set of practices. As a generation of gamers enters the corner office and the oval office, these technologies will continue to gain acceptance. The five forces of game impact theory attempt to describe why this is happening and provide a framework within which managers and academics can evaluate game technology impacts on other industries.

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