Technology Disruption in the Simulation Industry

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Abstract:

The military simulation industry has been transformed by technological advances multiple times in its history. In some cases those changes have come from within the industry, and in others they have been introduced from outside of the mainstream and have disrupted the established status quo. These external disruptions have traditionally made significant contributions to the state-of-the-art in the field. However, in doing so they have negated millions of dollars in government funding that could have been more valuably applied had the sponsors understood the disruptive forces that were at work. These events have also overturned a number of leading companies in the field and replaced them with upstarts whose technology contained the seeds for future advances.

In this paper, we explore the impact that computer game technologies are having on the simulation industry. These technologies initially provided low-end capabilities for a small niche of the industry. However, over time they have improved to the point that they are more powerful than many of the established tools in the field. This disruption is following the well-established innovation model that was put forward by Harvard professor, Clayton Christensen. Game technologies entered the industry as a "toy" application, but they now offer the foundation upon which the next generation of successful systems will be built. PC game technologies are just one of the waves of disruption that are entering and will permanently change the simulation industry. Future disruptions will arise from game consoles, web-based 3D environments, and wireless technologies. These disruptions will spur the growth of new types of companies and threaten the positions of established companies in the industry. There are technological and economical forces at work in the gaming and military simulation markets that will create a wave of change throughout the industry. This wave will spread cheaper, more powerful and more accessible simulations and simulators across the modern military.

Introduction

Military simulation and training has evolved through a number of different representations of the battlefield. It began as field exercises and miniature maneuvers on sand tables. In 1958 Charles Roberts and RAND Corporation both independently developed the hexagon-based paper board wargame with combat effects tables and random number generators [1]. In the late 1970's these paper maps and tools were being computerized to create some of the first digital battlefield models [2].

Edwin Link introduced pneumatically controlled moving flight simulators in 1938 and other organizations created simulators based on movies of aircraft in flight [3]. The SIMNET project of the late 1980's was a major innovation that really launched the use of computer-driven, 3D immersive, networked combat simulators [4]. For the purposes of this paper, we will treat this innovation as the foundation from which the modern family of distributed simulators have sprung and from which new technologies are now moving the industry into set of solutions. Paul Davis provided an excellent history of the evolution of warfare modeling and simulation in which he points out that the distribution of simulation across multiple coordinated computers was a revolution for the U.S. Department of Defense [5].

Following the introduction of SIMNET, all major simulation systems, both virtual immersive systems and constructive wargames, have been developed as networked devices that can interoperate with other simulations to create a larger and richer representation of the battlespace. This field has often been on the cutting edge of the application of new technologies and is often transformed as new computer technologies emerge from Silicon Valley.

The simulation industry is now on the brink of another transformation. Computer game technology, itself an offspring of simulation projects of the 1980's, has been on a rapid technological rise. The quality of graphics chips, networking infrastructure, user interfaces, physical models, and artistic representation have increased to a level that they can provide a viable training system on a consumer-grade PC for many military customers. The emergence and application of these technologies has been visible for a number of years. The National Research Council Committee on Modeling and Simulation described the convergence of entertainment and defense simulation in their 1997 report [6]. We predict that the trend will continue. In this paper we explore the impacts that this transformation will have on the simulation industry. A number of theorists have developed models of the impacts of innovation on established enterprises. One of the most widely recognized is the disruptive model introduced by Clayton Christensen in 1992 [7]. The entry of gaming technology into the simulation industry seems to be following the patterns that he laid out in *The Innovators Dilemma* [8].

Disruptive Innovation

Technology innovation has often been characterized as either radical or incremental [9]. Incremental innovation refers to changes that "build on and reinforce the applicability of existing technology". These changes strengthen the value of existing technology and the products that use them by making the products more reliable, simpler to use, lower in cost, or accessible to a larger customer base. Most established companies are involved in researching, creating, and marketing incremental innovations to their products. Items as basic as laundry detergent have been with us for fifty years. Tide laundry detergent was introduced in 1946. It was the first synthetic compound to be offered as a detergent against the industry standard of chemical solvents. Tide was a radical innovation at that time [10]. Over the last 60 years, Tide has remained a leading brand and remains a synthetic cleaning powder that is added to the water-based clothes washing process. The

chemical formulation of Tide has changed many times since its introduction and it is repeatedly advertised as being "New and Improved". However, all of these changes to the product have been incremental. They build on and reinforce the value of the synthetic compound. Each is a step along an existing technological trajectory that keeps the manufacturers of Tide at the head of the industry.

Radical innovation refers to changes that "destroy the value of an existing knowledge base" [11]. Electric lighting is a radical innovation. Prior to its introduction, homes and businesses were illuminated with natural light entering through windows, kerosene lanterns, candles, and gaslights. All of these provided a solution that was sufficient, but also incorporated inconveniences and dangers that created an opportunity for a new approach. The urban distribution of electricity made it possible for homes to replace gaslights and lanterns with easy to use and safer electric lights. This radical innovation destroyed the value of gaslight technology. New and safer types of gas lamps, better gas piping, and automatic lighting mechanisms all became worthless when electric lighting was introduced.

In his 1992 Harvard dissertation, Clayton Christensen introduced a variation to radical and incremental innovation. Instead, he explored the differences between sustaining and disruptive innovations. Sustaining innovations are similar to Dewar and Dutton's definition of incremental innovations. They improve upon established products and technologies by adding to them. However, disruptive innovations are different from radical innovations. They have the value-destroying characteristics of radical innovation, but they work much more slowly and methodically through an industry. Disruptive innovations, at their introduction, actually provide a worse solution than the existing technologies. Their power lies in their ability to meet the needs of small portion of the market that is unaddressed or undervalued by the current leading products and technologies. A disruptive technology often provides a capability that is valuable to a niche of customers who are seen as insignificant to the industry leaders. This lack of significance usually comes from their small size or from the small profit margins that are available from them [8, pp.30-39]. As a result, disruptive innovations do not rapidly destroy the value of established technology. Instead, they gradually erode its value by systematically stealing away customers from the bottom of the value chain. As these disruptive innovations improve their services to customers, they move up the value chain and become a real threat to existing market leaders.

Small volume and low margin customers are the least valued by large market leaders. For this reason, their needs are not the focus of major companies in a field, leaving them to do the best they can with the products available. These customers represent an attractive opportunity to new companies that strive to directly address their needs and accept the lower profits that they generate. In some cases, the solutions that are created for these customers have within them the seeds for tremendous improvements to the products and services that are valuable across the industry. When this occurs, the upstart company has the opportunity to build a low margin business into an industry dominating business. These innovators can displace industry stalwarts to become the new leaders based on technology that was originally "not good enough" for the main body of customers.

Christensen and other authors provide examples of this happening in computer disk drives, hydraulic machinery, steel processing, and aluminum production [8, pp.171-172] [12].

Figure 1 illustrates how this happens. Customers have a wide range of needs for a family of products. These needs vary from the level of performance required at the low end of the market to the level required by the most demanding customers at the high end. Initially, there are no products that meet these needs. However, if the demand remains unmet, entrepreneurs will create products that begin to address them. If successful, these new innovations grow in complexity and capability in an attempt to capture customers that are higher up on the value chain. The line labeled “Progress due to sustaining technologies” illustrates the creation of the first industry leaders in a field. As customers’ needs are met, the customers’ demands on the products grow as well. Therefore, the industry leaders improve their products to continue to meet the demands of the customers they have captured. Over time, a sustaining relationship emerges between the known customer base and a few companies that provide the best solutions to their problems.

However, this cozy relationship cannot remain intact and unassailed forever. There are a number of ways for this position to be challenged. In this paper we are interested in a disruptive assault that begins by meeting the needs of consumers at the lower end of the value chain. At some point, a new technology will emerge that has the ability to meet the needs of the least demanding customers, those least attractive to established industry leaders. Though this product is often seen as inferior and unworthy of the serious attentions of the industry leaders, new upstart companies may be attracted to build a small business based on it. Christensen provides examples in which the industry leaders are actually glad to see the small companies taking some of this low margin business. Industry leaders often view low-end customers as drains on their production capacities and unattractive due to low profit margins. Established companies may allow upstarts to take low-end customers so the established companies can redeploy their assets toward high demand, high margin customers [8, pp.92-93].

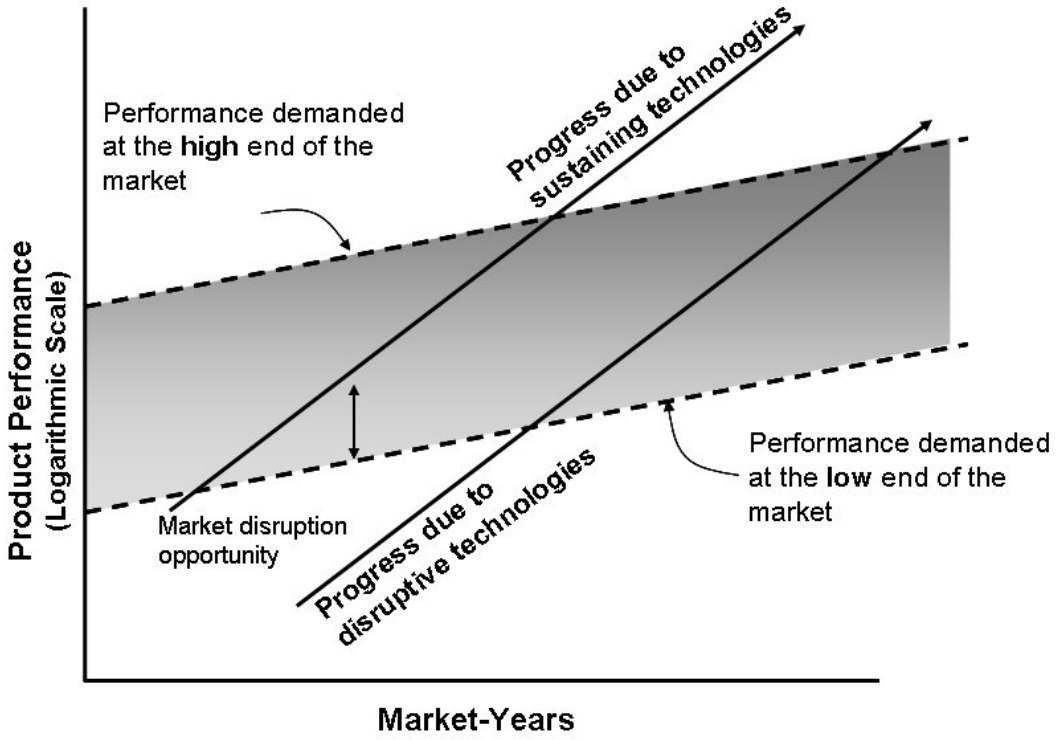

Figure 1. The Impact of Disruptive Technological Change on an Industry.
Source: Christensen, 1997

Ceding the low-end of the market to an upstart with a new, but "inferior", technology can prove to be the undoing of a market leader. As stated above, the inferior technology may have the seeds of great advantage within it. When this occurs, the new entrant begins to make progress up the value chain. They are driving the "progress due to disruptive technologies" shown in Figure 1. Eventually the new technology and the companies that have mastered it will become major threats to established leaders. Unfortunately, by the time this threat becomes clear, it is often too late for the established firms to catch-up. As a result, the formerly upstart companies displace the old leaders to control the market.

Throughout the computer industry, upstarts have used inferior technology to get a foothold in the market and then improve the technology until they are able to surpass all of the industry leaders. This has occurred in personal computers, disk drives, CPU's, engineering workstations, graphics devices, networking, and a host of other components and systems. This same disruption has occurred a number of times in the simulation industry, and is currently occurring again on the back of game technology.

Simulation Disruption

If we treat the introduction of SIMNET as "Disruption Zero" (D_0) in the simulation industry, then we can illustrate how sustaining and disruptive innovations have been and currently are at work in this industry. SIMNET provided a firm foundation upon which a huge portion of the virtual training industry was built. It was not the first exploration into

3D graphics, networking, or team training. But, it provided a low-cost, standardized platform that could be duplicated and networked to allow larger team training to occur. Miller and Thorpe provide an excellent summary of the organization, construction, and deployment of SIMNET [4].

SIMNET disrupted and displaced a number of systems and technologies that came before it. In Figure 2, we show SIMNET as meeting the low-end needs of Army, tank team training customers in the early 1990's. When it was introduced, SIMNET barely met the needs of a community that expected mechanically accurate devices that replicated the feel of real tanks. But, its innovation was in providing a networked environment in which an entire platoon of tanks could work together as they do in the real world. This changed the basis of competition in the industry from representing the vehicle to representing the shared environment. Successive generations of the product improved on its initial shortcomings and expanded the applicability of the technology beyond tank vehicles, including other ground vehicles and helicopters. SIMNET was poised to be the prototype of all future virtual training devices. Its design and architecture would dominate the market for years to come.

The Close Combat Tactical Trainer (CCTT) was a sustaining innovation from SIMNET. It improved on the computers, visual displays, networking capabilities, physical instrumentation, and all of the tools to build a database and conduct a training event. CCTT was the "Son-of-SIMNET" and remained loyal to its predecessor by keeping the SIMNET solution alive. This program was just one of dozens that extended SIMNET technologies to other vehicles and military systems. By 2000 there were dozens of simulators that had emerged from the SIMNET roots and that could interoperate with each other over a network. These improvements strengthened the position of the design by improving on the original and demonstrating that investments in it lead to better training devices. This approach to the problem and design of a system seemed to be the way simulators would be built from now on.

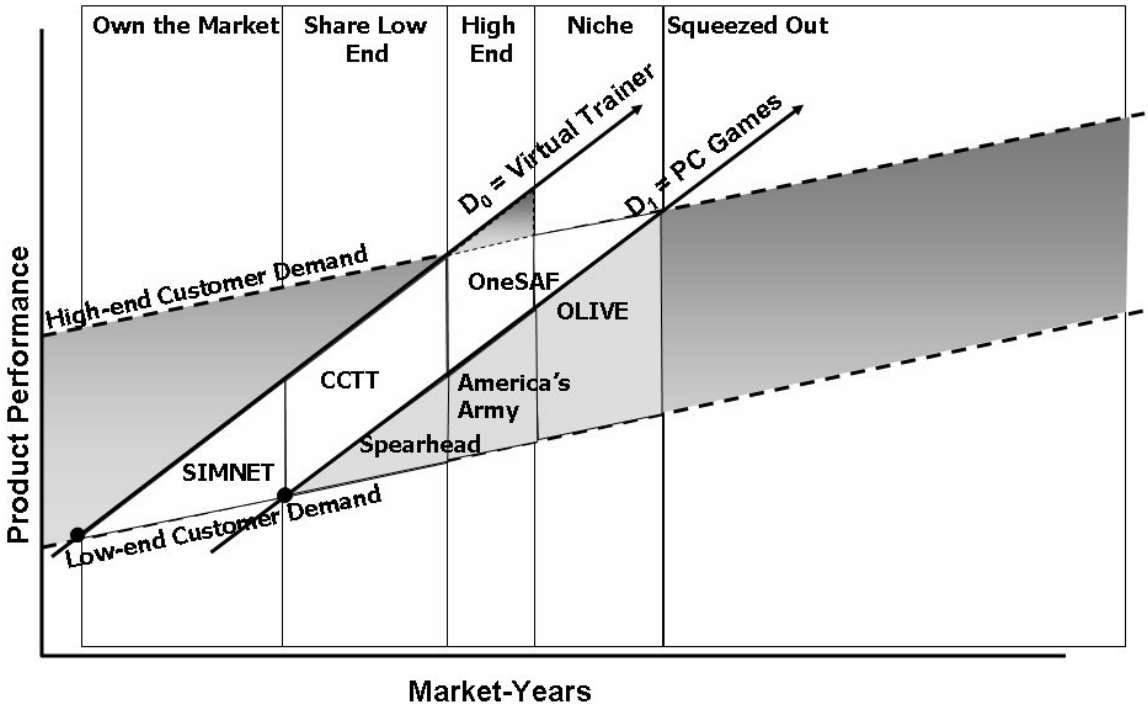

Figure 2. Step-by-Step Disruption of Market Leaders by Emerging Innovators

In spite of the dominance of the immersive simulator, a number of smaller tools were being developed by innovators in the industry. Some of these tools were based on computer game technology, which at that time was considered nothing more than a toy. One example was the game Spearhead that was created by engineers at MAK Technologies in 1998, many of whom has been involved in the original SIMNET project [13]. This game attempted to provide the SIMNET and CCTT experience on a desktop computer. It contained many of the same player positions, instrumentation, and networking that were the foundations of the military simulators. Most people considered it nothing more than a game that civilian and military enthusiasts would enjoy playing in order to feel like real soldiers. However, this was one of the seeds of disruptive innovation in the virtual training industry. Spearhead showed that an average desktop computer could provide some very impressive visuals, physical models, networking, and team training experiences.

Together with projects like Marine DOOM, the training industry began to see that PC-based games could provide training tools for less demanding customers – especially those who were severely financially constrained. This was the beginning of "Disruption One" (D_1) in Figure 2. It took several years and a number of simulators similar to Spearhead, each with an improvement to the system, to convince enough military customers that a PC-based game could provide valuable training. The disruption of the large system training devices had begun.

Christensen explains why the established players in an industry do not fight these disruptive innovations in the beginning, and we see the same trends in the military training industry. First, there exist low-end, low-profit customers that the established

companies are not interested in. Losing these to an upstart is often viewed as a relief on company resources. Second, established companies are dealing with an established customer base that is constantly demanding higher-end improvements to products. These demands cannot be met by the less powerful technology that is serving the low end of the market. Third, the low-end technology is usually not taken seriously. It is often viewed as inferior and beneath the consideration of both serious solution providers and serious customers [8, pp.166-171]. All three of these forces have been at play in the disruption of the military training simulation by game technologies.

The next step in disrupting the industry is the introduction of a platform upon which a large number of simulators can be developed and connected to each other. This platform emerged in 2002 when the Army began releasing "America's Army" as a recruiting tool for new soldiers [14]. Army leaders reasoned that young 18 year-old boys were completely immersed in computer games, therefore, what better way to get their attention than to offer them a free game if they would just pay a visit to a recruiter or the Army's web site. As a recruiting tool, this game did not have to be "good enough" to really train any soldiers. This allowed it to be built quickly and without many of the constraints that are placed on officially sponsored training systems. But, it was soon adopted as a platform upon which real training systems could be constructed. The game is built on one of the best 3D engines in the game industry, the Unreal 2 engine, and has a licensing agreement that allows military organizations to make modifications without paying a licensing fee. This created an environment that encouraged dozens of Army offices to modify the game to represent their own unique systems. It provided a powerful foundation that most projects could not afford to build or purchase on their own, but which they could easily afford to modify for their needs.

America's Army soon became much for than a recruiting tool. It is now a viable competitor to other more official training systems that were built from the ground up as credible and validated representations of military systems and operations. Systems like OneSAF (both the Testbed and the Objective version) and the Joint Combat and Tactical Simulation (JCATS) remain the official training devices within the Army training community. But, in organizations that need high fidelity training devices, there are dozens of America's Army modifications being created that displace the deployment of officially produced systems like OneSAF and JCATS. Just as has occurred in commercial industries, all of the customers for training devices are not purchasing the high-end systems that are produced by the market leaders. Instead they are turning to a tool that is not supposed to be as good, but which fits their needs more closely. Even within an organization like the Army, customers have the freedom to choose their own solutions, and will search for a solution that best fits their budget, facilities, capabilities, need for mobility, and usability of the soldiers.

The disruption of the SIMNET-style system is being pushed further by the On-Line Virtual Environment (OLIVE) created by Forterra Systems for the Army. This game-based system brings the capabilities of massively multi-player games to soldiers who are dispersed around the globe. The Sims Online, Everquest, and Asheron's Call are games that allow people to maintain persistent characters in a virtual environment and to interact

with others any time they are able to enter the virtual world. The world is constantly alive and can be entered at any time. OLIVE provides this technology to soldiers through the Asymmetric Warfare – Virtual Training Technology (AW-VTT) project. This means that soldiers do not need to move to a dedicated simulation center to participate in distributed training. They can schedule their own exercises when they can coordinate the people who need to be involved. They are no longer constrained by the availability of a central facility [15].

Spectrum of Customers

The disruption that PC-games are causing within the military simulator community is not without precedent and it will continue because it meets the needs of customers within the Army and the other services. These technologies began as "not good enough" for serious training, but still appropriate for a small niche of customers that needed to learn in a small desktop environment. Improvements in computer, modeling, database, and networking technologies have allowed these systems to grow in prominence. They provide solutions that are significantly lower in cost, both for deployed hardware and development costs. As in other industries, these may never meet the needs of the most demanding customers at the high-end of the market. But, they will displace the lower and medium levels of the market and they will bring new customers into the market so that the size of the market itself is larger. These forces will make these technologies, systems, and companies more prominent and more profitable than the previous generation of systems and companies that they are displacing.

As technology improves, the number of customers who are "over served" by the solutions being created grows larger and larger. The high-end customers push the level of technology higher, but they also push the cost of the solutions higher. As this has occurred in the military simulator industry, it has created a growing opportunity for companies to bring in solutions at the lower end.

These low-end technologies provide solutions that are accessible to communities that were previously "non consumers" of simulation systems. The complexity, infrastructure, support system, and cost of the systems are beyond the reach of many communities who could benefit from smaller and less costly solutions. However, because these needs are at odds with the goals of the major players in the industry who want to push the technology higher in the value chain, the lower end remains unserved. Innovation from new entrants into the industry creates systems that are accessible to these communities and converts them from "non consumers" into customers. This increases the size of the simulation industry and makes it a richer and more robust business.

Multiple Waves of Disruption

The disruption caused by PC-games is just one wave that has entered the simulator industry. This paper describes how that wave is moving through the Army, but is has been just as active in other services and other government agencies. This wave is already being followed by a number of others. Moving simulators to the PC presented a major

cost savings on the hardware platform, lowering it from ten of thousands of dollars for each computer, to two thousand. Moving the simulators onto gaming consoles like the Playstation and Xbox series of machines has the potential of dropping those costs another order of magnitude. Full Spectrum Warrior (FSW) is an Xbox and PS2 based game that demonstrates the viability of these consoles. Just as PC's were initially "not good enough", the game consoles have traditionally lacked some of the features that military training required – such as network playability, local scenario storage, and graphic quality. But, the new systems are making up for these deficiencies and will present a platform that more than meets the needs of many customers for training simulation. This could potentially be "Disruption Two" (D_2) (Figure 3).

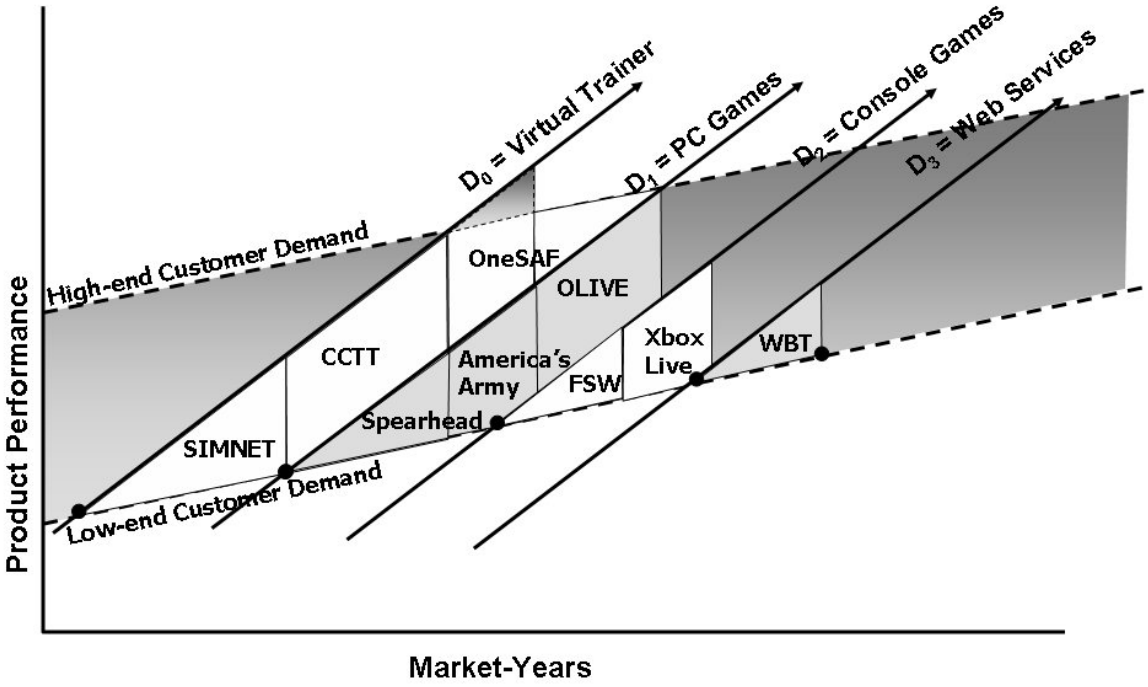

Figure 3. Industries are Transformed by Multiple Waves of Disruptive Innovation

The next obvious step is to remove the simulation from the computer hardware all together and place it on the network, offering it as very rich Web-based Training (WBT) through an improved version of a web browser. Current technology prevents us from delivering really rich simulation content across the network during live play, but this limitation will not stand forever. Technological advances will allow web-based simulators to emerge. At first these will serve the low end of the market, but advances in the technology will move them up-market and turn them into a disruptive force just like the PC-based games – Disruption Three (D_3).

Once this occurs, the connection to the Internet becomes the limiting feature. Everything that has been done through a wired connection will search for a solution that is wireless. This will capture "non consumers" who could not become simulation customers because of the need to have a high bandwidth wired connection. This should lead to the application of wireless tablet PC's, palm devices, cell phones, and other unique forms to the simulation industry – possibly Disruption Four (D_4).

Conclusion

Disruptions bring fundamental changes to an industry. They create opportunities for those who adopt and champion the disruptive technology. But these changes also trickle through the industry and create related changes that are opportunities for improvements. Virtual simulators and virtual worlds created a market for the creation of synthetic natural environments with visual, topographic, and data representations of the real world. Companies have emerged that provide only these products and services. As a result, it is much less common for a team of defense contractors to build all of the hardware and software components of a system themselves. They can more efficiently purchase environmental databases and 3D display systems than they can rebuild them for each project.

The inclusion of game technologies into military simulators is going to further accelerate this use of commercial tools and data to create the software and data within the systems. In the future, simulation systems may be more integrations of commercial tools and data than they are unique creations of these for a single customer. We can see the beginning of this in the new types of defense simulation companies that have emerged. These companies do not attempt to create products entirely from scratch, but instead seek out customers who require modifications to commercial tools with which they are proficient. One company may create the 3D engine, such as Unreal. Three others may specialize in modifying the object models to represent military vehicles. Six others may specialize in creating the digital representation of the environment in which these objects operate. Finally, a few companies will handle the integration of the companies, tools, and data necessary to pull all of this expertise into a working system.

Finally, imagine that due to customer-driven forces, all virtual simulators gravitated toward a common foundation, such as America's Army. Such standardization would be very painful for competitors to that foundation, potentially putting them out of business. But, it would create huge opportunities to provide products that complement and extend that foundation. The MP3 music device market was splintered across dozens of manufacturers who all provided essentially the same capability in a different physical form factor. Because the market was splintered, there was little incentive for third-party companies to create devices to extend the capabilities of the MP3 player. However, when Apple introduced the iPod, it aggregated this business, eventually capturing as much as 92% of the market [16]. This was terrible for competing MP3 manufacturers. But, it created a huge incentive for third-party companies to produce iPod extensions. Today there is an entirely new industry in producing headsets, car adapters, desktop speakers, and dozens of other devices that enhance the iPod product.

Standardization on a foundation like America's Army could create this same kind of opportunities in the simulator industry. It would extend interoperability within that community far beyond what has been achievable through standard protocols and services. It would also create a market in which a company could create a scenario generation tool

or an after action review system that could be sold to hundreds of customers without requiring extensive customization.

When disruptive technologies enter a market, they offer a value proposition that is impossible to dismiss. Customers move to the new solutions and change the balance of the industry. Market forces do not operate to maintain the dominance of existing players; rather they move to meet the needs of the maximum number of customers. Disruptive changes are afoot in our industry and will continue. Companies, researchers, system developers, and service providers can choose to ride the wave or fight the wave. But they cannot dissipate the force of the wave of change that is occurring.

References

1. Perla, P. (1990). *The Art of Wargaming*. Annapolis: Naval Institute Press.
2. Allen, T.B. (1987). *War Games: The secret world of the creators, players, and policy makers rehearsing World War III today*. New York: Berkeley Books.
3. Naval Training Systems Center. (1990). *Foundations for the future*. Navy Publication.
4. Miller, D.C. and Thorpe, J.A. (August 1995). "SIMNET: The Advent of Simulator Networking". *Proceedings of the IEEE*. 83(8), pp. 1114-1123.
5. Davis, P.K. (August 1995). "Distributed Interactive Simulation in the Evolution of DoD Warfare Modeling and Simulation". *Proceedings of the IEEE*. 83(8), pp. 1138-1155.
6. National Research Council. (1997). *Modeling and Simulation: Linking Entertainment and Defense*. Washington DC: National Academies Press.
7. Christensen, C. (1992). *The innovator's challenge: Understanding the influence of market environment on processes of technology development in the rigid disk drive industry*. Doctoral Dissertation. Harvard Business School, Boston, MA.
8. Christensen, C. (1997). *The Innovator's dilemma: When new technologies cause great firms to fail*. Boston: Harvard Business School Press.
9. Dewar, R.D. & Dutton, J.E. (November, 1986). "The Adoption of radical and incremental innovations: An Empirical analysis". *Management Science*. 32(11), pp. 1422-1434.
10. Dyer, D.; Dalzell, F. & Olegario, R. (July 12, 2004). "How Tide cleaned up the competition". Harvard Business School Working Knowledge. Accessed on January 14, 2006. http://hbswk.hbs.edu/item.jhtml?id=4254&t=bizhistory
11. Leifer, R.; McDermott, C.; O'Connor, G.; Peters, L.; Rice, M.; & Veryzer, R. (2000). *Radical innovation: How mature companies can outsmart upstarts*. Boston: Harvard Business School Press.
12. O'Neill, P.H., & Bridenbaugh, P.R. (November-December, 1992). Credibility between CEO and CTO – A CEO's perspective; Credibility between CEO and CTO – A CTO perspective. *Research Technology Management*, 35(6), 25-34.
13. Lenoir, T. (2003). "Programming theatres of war: Gamemakers as soldiers". In Latham, R. *Bombs and Bandwidth: The emerging relationship between information technology and security*. New York: The New Press. Draft chapter accessed on January 14, 2006.

http://www.stanford.edu/dept/HPST/TimLenoir/Publications/Lenoir_TheatresOfWar.pdf
14. Zyda, M., et.al. (December 2003). "This year in the MOVES institute". *Proceedings of the Second International Conference on Cyberworlds*. pp. xxxii.
15. Mayo, M.; Singer, M.; & Kusumoto. (December 2005). "Massively multiplayer environments for asymmetric warfare". Proceedings of the 2005 Interservice/Industry Training, Simulation, and Education Conference.
16. Betteridge, I. (November 4, 2004). "iPod market share falls to 87%". *PC Magazine*. Accessed January 8, 2006, http://www.pcmag.com/article2/0,1759,1712064,00.asp

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