AIR WAR COLLEGE

AIR UNIVERSITY

# IMMERSIVE LEARNING SIMULATIONS

# IN

# AIRCRAFT MAINTENANCE TRAINING

*by*

Joseph J. Rushlau, Lt Col, USAF

A Research Report Submitted to the Faculty

In Partial Fulfillment of the Graduation Requirements

15 February 2010

## DISCLAIMER

The views expressed in this academic research paper are those of the author and do not reflect the official policy of the United States government or Department of Defense. In accordance with Air Force Instruction 51-303, it is not copyrighted, but is the property of the United States government.

## TABLE OF CONTENTS

## Biography

Lieutenant Colonel Rushlau was born in Detroit, Michigan. He was commissioned through the Air Force Reserve Officer Training Corps in May 1989, and he entered the Air Force as an aircraft maintenance officer in December 1989 at Chanute Air Force Base, Illinois. Colonel Rushlau has held a variety of positions including assignments in fighter, reconnaissance, special operations, tanker and test aircraft maintenance. He has also had assignments as a munitions flight commander, managing war reserve material and a tour on the Air Combat Command Inspector General’s Team. Colonel Rushlau has commanded four maintenance squadrons, the 46th Maintenance Operations Squadron at Eglin Air Force Base, the 716th Maintenance Squadron at Duke Field, Florida and two deployed Special Operations Maintenance Squadrons. He has also been commander of the 376th Maintenance Group at Manas Air Base, Kyrgyzstan. Colonel Rushlau holds a Bachelor’s Degree in Wood and Fiber Utilization from Michigan Technological University and a Master’s Degree in Aviation Science from Embry Riddle Aeronautical University.

## Introduction

Training is a huge endeavor and also a huge business. Many different industries spend billions of dollars to ensure they have trained and professional workforces. For the military in particular, training is an essential and recurring part of our daily jobs. Without continual, recurring training military members would lose important skills that they do not have a chance to use in normal, daily activities. Like training, video games are a huge business. The video game industry recorded over $18 billion in sales last year.[1] These games have become a recreational activity for young and old. You can play a standard game on some type of console hooked to your television, or even immerse yourself in a virtual world in one of many online games. Playing video games, particularly the online immersive games, is a hard, long and complex activity that lots of young people pay lots of money to engage in.[2]

What if you could combine the engaging aspects of video gaming with the requirements of a training program? You might just get a training scenario that new and veteran workers enjoy participating in, instead of dreading hours of power point slides and lectures. You might just get a "serious game," or "as proposed by the eLearning Guild, you could get an Immersive Learning Simulation."[3] Quoting the eLearning Guild, Caspian Learning, in a report for the United Kingdom Ministry of Defense, defined an Immersive Learning Simulation (ILS) as "an optimized blend of simulation, game element and pedagogy that leads to the student being motivated by, and immersed into the purpose and goals of a learning interaction."[4] In other words, a video game that trains. This definition of ILS will be used throughout this paper, since discussing serious games has negative connotations. Many people equate the word game strictly with having fun, and certainly not with serious training.

## Purpose

Immersive learning simulation is a relatively new computer based training system that shows great signs of cutting training time in scholastic and other non-technical applications. This paper examines if ILS will save time and money if applied to aircraft maintenance training, while still producing fully qualified maintainers for the United States Air Force. Only openly available information will be reviewed in the attempt to determine if ILS programs are applicable to help train aircraft technicians. This paper will not attempt to develop a new training regimen for any military service or commercial enterprise, it only attempts to discuss available information and draw some realistic conclusions.

Unfortunately, as of writing this paper no simulation for training aircraft maintenance technicians, fitting the definition of an ILS above, has been found to exist. Several companies have developed amazing highly interactive 3-D simulation programs for training military maintainers. Although these 3-D programs do not contain any "game element" as the Caspian definition presents, they are enabling outstanding cost and training time reduction to the organizations that employ them. The actual savings and effectiveness of these advanced training programs are worth discussing, and will enable potential implications of true ILS implementation to be evaluated.

## Significance of this Paper

Simulations in general offer organizations the opportunity to train maintenance personnel at lower cost and lower risk than using actual equipment. According to Web Courseworks, a company that creates serious games and simulations, "virtual machine simulations allow learners to practice complex processes or to operate delicate instruments before they are required to follow the same procedures in real life."[5] As with any simulation, ILS will offer the ability to fail at any maintenance task without negative repercussions. Sometimes failure teaches students more than success, but on the real equipment failure can cost not only money but lives. An ILS will enable instructors to quickly change training scenarios to challenge newly acquired skills and knowledge. Because ILS is computer based, changing scenarios and lessons can be done quickly, enabling students to cover more material in a shorter period of time.

## Terminology

Before jumping into the background and literature review, a few definitions will help the reader understand the terminology in this paper. The phrase "immersive learning simulation," defined above, is used synonymously with the phrases "good video games"[6] and "serious games"[7] in most of the literature regarding video based learning programs. Some programs make use of avatars to get trainees immersed in the program. According to the on-line Encarta Dictionary, an avatar is a character or persona of a player with a graphical representation; a movable 3-D image used to represent someone in cyberspace.[8] Some programs use a "first person" point of view, where trainees will see the simulated scenes through their own eyes instead of watching their avatar move around the simulation. Finally, a simulation itself can be almost anything that reproduces the most important features of an object being trained on or studied. A simulation can involve something as simple as pictures on a PowerPoint slide or as complex as the multi-million dollar flight representations used by the airlines and military in their most immersive flight simulators.

Many different types of simulations and simulators are used to train aircraft maintenance personnel. It is important to describe these systems in order to understand the potential benefits of ILS. One of the most common simulators used is referred to as a training device. These devices are physical training aids that look and work like the actual part of the aircraft or piece of equipment being trained on. Training devices allow trainees to get hands on experience without having to use an operational aircraft. Computer based simulations are routinely used to help train maintainers while avoiding the costs associated with building training devices or using actual aircraft. Exercises can be run in a class room setting to simulate a real world flightline environment to help trainees begin to understand what life on an operational flightline will be like. More recently 3-D graphics based computer simulations have been developed to give the students the opportunity to see and virtually move parts and switches on simulated aircraft. Some of the more advanced 3-D programs allow students to take all necessary repair actions on simulated broke aircraft and then run the aircraft to verify they have corrected the problems.

## Taxonomy of Learning and Transfer of Training

In order to fully determine the benefit of any simulation you have to understand how people learn to become proficient at different tasks. Proficiency is what the Air Force ultimately wants from its maintenance technicians. Even brand new trainees have to become proficient at some simple tasks. In the book *Taxonomy of Educational Objectives* the authors discuss that knowledge must be adaptable, "since each situation is unique, the individual must be able to recognize which essential characteristics of the new situation are related to situations he has already encountered; then he must apply the correct knowledge and method with appropriate modifications."[9] This adaptable knowledge is better known as problem solving. Once a trainee has the basic knowledge of a system's operation then they need to be able to apply that knowledge when the situation changes. For instance, when the system is not working correctly the trainee has to be able to identify what is wrong compared to when the system was working properly, and decide what to do about it. Highly interactive computer simulations like ILS are a tremendous means of teaching not only the system knowledge, but also the adaptability the Air Force needs in its maintenance technicians.

Maintenance training can be very dry, especially if the training consists of just listening to an instructor speak and flip slides. If that same training could be built into the scenario of some computer generated situation, students would be much more attentive. Learning through an ILS will provide the opportunity to incorporate some "positive and negative surprises, or small successes and failures, engaging the student's entire brain. The entire brain becomes engaged because the surprises cause spikes and drops in the brain's dopamine level."[10] Changes in dopamine levels affect the brains ability to focus or pay attention. It is similar to pressing the gas or brake pedal in your car. Regardless of whether you slow down or speed up you are going to pay more attention than if the cruise control is set. An ILS will give instructors the ability to change the scenario on students allowing them to fail without any adverse repercussions. If you fail to complete your maintenance correctly, (i.e. apply your knowledge) you can simply reset the scenario and try again. Failing to complete maintenance correctly on a real aircraft or training device will cost time and possibly money.

In her briefing *Playing With The Brain, Part 2,* Julie Dirksen states that "expertise is formed in any area by repeated cycles of learners practicing skills until they are nearly automatic, then having those skills fail in ways that cause the learners to have to think again and learn anew…[11] Dirksen goes on to state that "good games create and support the cycle of expertise…[12] The game element of an ILS in particular will support "the cycle of expertise." The repetition of learning, then having new information introduced and possibly failing in the application of the newly acquired knowledge will reinforce all of the knowledge the student has learned up to that point. Failure will cause the trainees to apply their new skills and knowledge in different ways. They will have to adapt to the new situations in order to move on to higher skill levels. While this method of learning is possible with physical training devices or actual pieces of equipment, it is much easier with computer based simulations.

An important aspect of learning through simulation is a concept called transfer of training. Developed by C. E. Osgood in 1949, while studying the effectiveness of flight simulators, transfer of training describes the ability of a skilled behavior that has been learned in the simulator to be carried over, or transferred, to an aircraft.[13] This concept is useful in any type of simulation, not only flight simulation. Transfer can be either positive or negative. In the case of ILS for maintenance training, a positive transfer of training will occur if students can successfully apply the knowledge and skills they learned through the simulation to the actual aircraft or equipment they are being trained to repair.

## Benefits of Simulation

Almost every industry, business, educational institution you can think of and particularly the military uses simulation and simulators to train its personnel. As far as the cost effectiveness that ILS brings to aircraft maintenance training, no actual data was readily available. Since no training programs fitting the accepted definition of an ILS have been found for aircraft maintenance training, other cost data has to be used to deduce potential cost benefits. Existing research regarding simulators, cost per student data from the Air Force's Air Education and Training Command as well as information from the simulation industry can be used to determine some possible ILS cost and savings.

Using actual military aircraft to train maintenance technicians is a very costly proposition. In a 1983 article written for the Royal Aeronautical Society's Flight Simulation Group, airline Captain G.T. Lavery said that the costs of running a modern flight simulator were only about 10 percent of the cost of operating a real aircraft.[14] Using an aircraft for flight training is similar to using an aircraft for maintenance training. When we have to use a real aircraft to train our maintainers we incur fuel costs, the cost of pulling the aircraft off of the flying schedule and the potential cost of repairing anything the trainees break. Thus, not all students will have the opportunity to perform certain tasks because of time and parts consumption as well as wear and tear on equipment. Sensitive test equipment required for aircraft maintenance will also need to be calibrated and is always in short supply in the real world. Since many modern aircraft parts and systems are partly computer based technology themselves, they are ideal for simulation. Finally, although hands-on training is necessary, and will be for the foreseeable future, our current computer systems can provide realistic training that could save substantial time and money.

During the mid-1990s the RAND Institute compiled a report of studies it had conducted for the Army. It looked at different ways to restructure training to save money, without losing effectiveness. One particular study examined the use of a training device based program for training Armor (tank) crewmen. The report stated "A tank is an expensive training device. Using a range of assumptions, the analysis showed that considerable cost savings would occur. Most of the savings resulted from reduced costs for fuel, spare parts and maintenance."[15] The applicability of this study to training aircraft maintenance technicians is clearly apparent. A training device will cost much less than the object it simulates. It can still be a very expensive piece of equipment especially when dealing with something as complex as a military aircraft.

An ILS on the other hand would not require much hardware beyond computer monitors, much like the 3-D programs that already exist.

RAND went on to find through their studies that "the savings are more likely to be achieved, and the improvements in training quality more easily justified, when technology is used to substitute for more expensive capitol or labor (e.g., to replace existing equipment and facilities) rather than enhance existing resources."[16] In other words, more money can potentially be saved if an organization can find or develop some new technology, to replace actual aircraft, training devices and older methods of training. The cost of training has risen dramatically since the RAND study was published. Fuel prices are much higher; aircraft are more expensive and less available due to age and commitments than they were10 years ago. New, more cost effective means of training aircraft maintainers must be developed and implemented to continue to produce qualified maintainers in this fiscally constrained environment.

Immersive learning simulations hold the promise of training our aircraft maintainers for much less money than current methods of training. We may not save as much of our training costs through the use of ILS as Capt Lavery alluded to in his 1983 article; however we could see some substantial savings. NGRAIN, "an industry provider of training and simulation solutions"[17] claims that its highly interactive 3-D simulations have reduced training time up to 60 percent in some instances.[18] The Air Force's Air Education and Training Command is responsible for entry level aircraft maintenance training. They use a variable cost of $302.00 per training day as an estimate of what it costs for each student enrolled in training; this cost includes student pay and travel.[19] This variable cost can be used to determine potential savings of using a highly interactive 3-D simulation, not yet an ILS, compared to current more traditional training methods.

First, assume we have 500 new aircraft maintenance personnel coming into the Air Force in a given year. We probably have more enter the Air Force most years, but 500 will work well in this example. If each entry level trainee has to go through 30 days of training (at $302/day), that would cost the Air Force $4.53 million a year. Using the time savings NGRAIN provides on its website, 60 percent, for training with a highly interactive simulator, our trainees could complete their training in 12 days for a cost of $1.81 million. The savings to the Air Force in this example would be $2.72 million dollars, just for aircraft maintenance trainees. An ILS will potentially save as much time as an advanced 3-D simulation, perhaps more. How could an ILS possibly reduce training time further than the 3-D program? Although an ILS will use the same highly interactive 3-D simulation, the addition of the game element will help to motivate and hold the attention of trainees. Most of the trainees the Air Force will recruit in the foreseeable future will be generation-Y individuals and their affinity for video games and other electronic devices is well noted.

## Literature Review

Finding articles, reports and studies regarding ILS is not difficult to do. However, finding any that discuss the possibility of developing a program for maintenance training is more difficult. An article in the periodical Military Training Technology discusses the "rapid growth and expansion of the use of 3-D in maintenance training"[20], and makes a few statements on the possible development of ILS technology. The article begins by explaining three advantages that advanced 3-D technologies bring to maintenance training: "shorter class time due to more rapid learning of training material by students; higher retention of training material learned; and a safer learning environment."[21] These same advantages will occur with ILS, since this technology builds on the 3-D programs by adding a game element further enhancing the pedagogy of the simulation. The article goes on to discuss that in “maintenance training, you tend to be dealing with a lot of younger students. They’ve been raised on video games. It’s how they have learned.”[22] Since these young people are predisposed to learning through games, military trainers need to take advantage of this technology and develop ILS to train aircraft maintenance technicians.

DiSTI® Corporation, an industry leading 2-D and 3-D graphical user interface software developer[23], developed the graphics for one of the most advanced 3-D maintenance training programs currently in use, the U.S. Navy’s F/A-18 simulated aircraft maintenance trainer (SAMT). Although not an ILS according to the definition used in this paper, because it has no game element, the SAMT is quite possibly the most advanced interactive 3-D maintenance trainer available today. Student’s training on the SAMT can “walk around the virtual aircraft, open the aircraft compartments, attach simulated test equipment, diagnose faults, remove and replace equipment and see how the SAMT’s virtual mechanical systems respond in real time.”[24] The SAMT allows trainees to virtually change parts and trouble shoot systems avoiding the costs of actually working on the physical aircraft or equipment. They can also simulate running the system, aircraft or equipment to check if their repair is correct. This is a phenomenal advance in training over many training programs in use today and it saves money. “According to the engineering manager for American Systems, domestic fleets that use computer simulation training typically reduce their training costs by 30 to 60 percent.”[25] With maintenance training ranging from “65-days for an ordinance loader to 185-days for an avionics and weapons system technician,”[26] the Navy stands to save a substantial amount of money through the use of the SAMT. The Air Force will see an SAMT program in the near future, since Lockheed-Martin recently awarded DiSTI the contract to develop a similar simulation for the new F-35.

NGRAIN has developed many different interactive 3-D simulations for the U.S. and Canadian military forces. Although they have not developed an ILS, their advanced simulations provide real life examples of the potential reduction in training costs (time and money) that ILS will provide. The U.S. Army replaced its brake system panel trainers, "estimated to cost $1.3M,"[27] with an NGRAIN developed simulation. "By implementing the NGRAIN solution the Army will also generate an estimated $800,000 in savings over the cost of replacement or the current Universal Maintenance Simulators system."[28] This represents an almost 62 percent savings over replacement of the physical simulator used before. An ILS would most likely cost more than the interactive 3-D program due to the game element of the simulation. If an ILS could be built for this application, a cost analysis would have to be accomplished to determine if all of the savings achieved by the ILS implementation would pay for the program.

When the Canadian Air Force needed to find a more cost effective way to train their maintainers and increase the number of mechanics graduating from the training program using fewer resources, a virtual task trainer was the answer to their dilemma. The Canadian Forces School of Aerospace Technology and Engineering (CFSATE) put together a training program for C-130 propeller system maintenance using an "advanced NGRAIN/CAE 3-D simulation as well as more traditional PowerPoint and technical manual training."[29] The addition of the 3-D simulation enabled the Canadians to decrease their reliance on more costly hardware training devices, while simultaneously supporting a more distributed learning capability. An ILS will enable the same decrease in reliance on expensive hardware training devices, but will have the added benefit of a game element. As discussed earlier, this game element in an ILS will support a cycle of expertise where trainees are "continually tackling challenges that lie just beyond their competence."[30] The virtual world of an ILS coupled with an appropriate teaching strategy will keep students motivated to gain more and more knowledge.

According to an NGRAIN case study, a test of the propeller training program was set up using a group of 16 new recruit trainees. The trainees were given 1 day of training with the new system as opposed to 2.5 days provided in the traditional training program. The results speak for themselves; all 16 students passed the practical exam for the test module, with a 94 percent average. As an aside, the case study also mentions that the students were more accepting and interested in the virtual training than they were of the non-interactive content of the training program.[31] Motivation is a key ingredient in learning, and these Canadian trainees have pointed that out in their learning experiment.

In a paper titled *Designing Experiential Modes: A Key Focus for Immersive Learning Environments,* Robert Appelman explores the development of experiential modes in immersive virtual learning environments. Basically, he was looking at the development of the building blocks of a training program using immersive learning simulations. Appelman contends that due to the power of modern computers, creative tools and display technology we can develop virtual training with attributes similar to the real world.[32] This is exactly what ILS is and can do for aircraft maintenance training. Appelman also mentions, on a couple of different occasions, that these virtual experiential modes give "the option to blend traditional classroom modes with virtual modes."[33] As an example of blended experiential modes he discusses a history instructor who used *Civilization III,* a video game, as part of his traditional classroom instruction. "A portion of class time was devoted to students achieving certain goals in the game. Students who were not motivated previously even to discuss history, were now excitedly dealing with the strategies used by colonial dictators and the issues raised by negotiating territorial boundaries."[34]

This particular teacher used a virtual world to motivate his students to learn and want to learn more about history. Having young aircraft maintenance trainees motivated and excited to learn more and more about their jobs is a significant benefit that ILS would bring to Air Force training.

Caspian Learning is a leading designer of "serious games and simulations for education, training and engagement."[35] They produced a report for the United Kingdom's Ministry of Defence with the "aim to demonstrate if, how and where the emerging field of serious games or immersive learning simulations (ILS) is of interest to the Defence College of Management and Technology as a component of the Defence Academy…"[36] The report was extremely thorough, looking at where games are currently used in training, the taxonomy of learning through games, as well as listing pros and cons for justifying the use of games for learning. A significant part of the report looked at various ILS from the service industry, military and educational environments and provided an evaluation of their training effectiveness compared to previous methods of instruction.

As part of their report, Caspian Learning listed several key findings as either supporting or barring acceptance of ILS as a training solution within the military. Some of the key findings supporting learning through ILS were "learner demographics and motivation, opportunities for safe failure and enhanced skills practice as well as reduced training costs and time."[37] Barriers to the acceptance of ILS included "generation gaps in awareness and skills, subject matter experts blocking change so as not to give up power and a strong didactic culture of instructor-led learning."[38] The executive summary of the report does not make any concrete statements advocating adopting ILS as the preferred method of training. However, it does make the argument in "that the evidence is already as compelling as that behind the use of traditional CBT (computer based training) or e-learning approaches."[39]

In all of the literature reviewed for this paper several points seem to be reiterated again and again. First, technology has enabled us to develop highly interactive simulations with exceptional graphics. Also, using advanced simulations works best in an environment that is blended with more traditional modes of classroom learning. Another key point, virtual learning environments, such as ILS, add motivation to learning environments and motivation supports the cycle of expertise. We want to develop expert maintainers and ILS will help create the environment to make that possible. Lastly, in addressing more technical applications of ILS, the consensus seems to be that developing the game element to support the training will be a difficult task to accomplish. So, what should the Air Force do if it is interested in exploring the applicability of ILS for training its aircraft maintenance technicians?

## Recommendations

Although no ILS are available for training aircraft maintenance technicians at this time, some valuable information was revealed as a result of this research. The Army's National Simulation Center, the Air Force's Air Education and Training Command and a former Navy Instructor were all helpful sources of information. However, they exposed an apparent lack of communication between the services in regard to ILS use and development. The U.S. military services must get together and share information about the different training programs they are developing for their aircraft maintenance personnel. They could all make use of research and development the other branches have conducted, possibly saving some time and money. The DoD should set up a conference or meeting where the different branches meet and discuss advanced training simulations such as ILS. This may already be occurring for flight simulation, however every career field could benefit from the use of ILS.

Another recommendation based on this research is to further investigate the effectiveness of advanced virtual training simulations through testing. Over the years, in depth research and testing has been accomplished regarding flight simulator effectiveness, but little to no testing has been accomplished on any other simulation's effectiveness. This is not difficult to understand since many fields are just beginning to use simulation. The Air Force has many avenues to complete good, quality testing. The RAND Corporation and Air Force Research Laboratories have completed simulator effectiveness research in the past. Who completes the testing isn't nearly as important as just getting it done. Testing the effectiveness of ILS technology will enable the Air Force to provide empirical evidence that ILS can provide acceptable or better training as compared to traditional methods. Related to effectiveness testing, the Air Force should conduct a cost benefit analysis of ILS implementation. Working with Air Education and Training Command, researchers could determine if the cost of development and implementation of an ILS would save the Air Force money. This study could be accomplished jointly with another service, since this technology will benefit the entire DoD.

A final recommendation is for the Air Force to find a place to start using ILS. This will entail determining, possibly through a study, what maintenance tasks or actions would most likely benefit from an ILS approach. An infinite number of scenarios are open to develop an acceptable maintenance ILS. For instance, scenarios could be developed where maintainers have to determine airworthiness of broken/damaged aircraft in a combat situation. An individual's score could be based on the number of safe aircraft released for flight versus the unsafe aircraft released. Along the same scenario as the previous example, a simple task such as loading a bomb trailer could be used to develop a maintenance ILS. This loading operation is historically fraught with errors, so an ILS could be developed giving a score for releasing trailers with the fewest errors. The key of this recommendation is to start to develop ILS for maintenance training. Aircraft maintainers have an extremely complex job where compliance/accuracy is paramount. They also possess the ability and drive to make the most of this technology.

## Conclusion

Immersive learning simulations offer great promise for providing exceptional training to aircraft maintenance technicians. Based on the results of past experience with the use of simulation in training, ILS has the potential to provide cost savings, time savings, and increased aircraft and parts availability over more traditional methods of training. In order to take advantage of these potential savings, the Air Force and other services must conduct some cost and effectiveness testing of ILS programs. Each branch of service is interested in developing the highest skilled technicians using the least amount of scarce resources. If the services come together and share their experiences and vision they might progress more quickly and save even more time and money. The learning software industry is standing by to help the Air Force or any other service to develop maintenance training ILS.

The advanced, highly interactive 3-D training programs coming on line in maintenance training offer much more acceptable training environments to our Generation Y trainees. However, ILS will provide the additional stimulation of a game element to keep trainees motivated about their technical training. Immersive learning simulations are not games, even though they may have a "game face." Some people may have trouble getting past the game attributes of ILS, but if testing and evidence from programs already in use can show their effectiveness, than any prejudices can be overcome. We need the most proficient technicians possible in the military; failure is never an option. Immersive learning simulations hold the potential to train technicians more quickly and less expensively than traditional methods, while providing motivation to keep trainees interested in learning. Can we afford not to begin to test this new technology?

---

[1] Seeking Alpha.com, *The Video Game Industry: An $18 Billion Entertainment Juggernaut.* (accessed 2 Nov 2009).
[2] James Paul Gee. *"Good Video Games And Good Learning."* Madison, Wisconsin: University of Wisconsin-Madison, p 1.
[3] Caspian Learning, Evidence that Games and ILSs Work: *Serious Games in Defense Education.* p. 20. (accessed 14 Dec 2009)
[4] Ibid., 20
[5] Web Courseworks, http://webcourseworks.com/simulations_for_training. (accessed 3 Dec 2009)
[6] James Paul Gee. *"Good Video Games And Good Learning."* Madison, Wisconsin: University of Wisconsin-Madison. p 2.
[7] Caspian Learning, *Serious Games in Defense Education,* 19 (See note 4).
[8] MSN - Encarta dictionary, http://encarta.msn.com/encnet/features/dictionary/DictionaryResults.aspx?lextype=3&search=avatar. (accessed 14 December 2009).
[9] Benjamin S. Bloom, ed., *Taxonomy of Educational Objectives: Justification For the Development of Intellectual Abilities and Skills,* (New York: Longmans, Green & CO, 1956).
[10] Julie Dirksen, *Playing with the Brain, Part 2. A Brief Introduction to the Potential Impact of Brain Research on Game and Simulation Design*. Learning and Entertainment Evolution Forum, slide 33-40, 19 June 2009.
[11] Ibid., 18 [All information the same as in the preceding note except slide number.]
[12] Ibid.
[13] J. M. Rolfe and K. J. Staple, ed. *Flight Simulation,* (Cambridge: Cambridge University Press, 1986), 246.
[14] G. T. Lavery, *The Simulator and the Airline Pilot*. Proceedings of The Royal Aeronautical Society's Flight Simulation Symposium: Experience and Needs of Civil and Military Flight Simulator Users, (London, 1981).
[15] John Winkler and Paul Steinberg, *Making Military Training More Effective and Affordable: Lessons from RAND Research*, RAND Report MR-850-A. (Santa Monica, CA: RAND February1997), xv.
[16] Ibid.
[17] NGRAIN, http://ngrain.com/company/index.aspx (accessed 1 Dec 2009)
[18] NGRAIN, *NGRAIN and CAE Help Canadian Forces Increase Training Throughput,* NGRAIN Case Study, (accessed 29 Sep 2009)
[19] Personal e-mail from Richard M. Hutchins, Financial Analyst, HQ AETC/FMAT, 3 November 2009.
[20] Scott R. Gourley, 3-D Models and Maintenance Training, *Military Training Technology,* Vol 10, Iss 4, (2005): 2, (accessed 14 Sep 2009).
[21] Ibid.
[22] Ibid., 4. [All information the same as in the preceding note except page number.]
[23] DiSTI, http://www.disti.com/ (accessed on 30 Nov 2009)
[24] Jim Clark, Maintenance Simulators Gaining Military Acceptance, *Aviation Maintenance Magazine*, 1 November 2008, (accessed 14 Sep 2009)
[25] Ibid.
[26] Ibid.
[27] NGRAIN, *Report On Military Use Of NGRAIN Interactive 3D Equipment Simulations In Training And Operations*, November 2008, (accessed 29 Sep 2009).
[28] Scott R. Gourley, 3-D Models and Maintenance Training, *Military Training Technology*, 3 (see Note 20).
[29] NGRAIN, *NGRAIN and CAE Help Canadian Forces Increase Training Throughput (See Note 18).*
[30] Phillip E. Ross, The Expert Mind, *Scientific American,* Vol. 295, Iss. 2,(Aug 2006): 64-71, (accessed 28 Sep 2009).
[31] NGRAIN, *NGRAIN and CAE Help Canadian Forces Increase Training Throughput (See Note 18).*
[32] Robert Appelman, "Designing Experiential Modes: A Key Focus for Immersive Learning Environments," *TechTrends,* Vol. 49, no. 3 (May 2004): 71, (accessed 14 Sep 2009).

[33] Ibid.
[34] Ibid.
[35] Caspian Learning, http://www.caspianlearning.co.uk/ (accessed 13 Dec 2009)
[36] Caspian Learning, *Serious Games in Defence Education,* 4 (See note 4).
[37] Ibid., 5. [All information the same as in the preceding note except page number.]
[38] Ibid.
[39] Ibid., 85. [All information the same as in the preceding note except page number.]

## Bibliography

Appleman, Robert. "Designing Experimental Modes: A Key Focus for Immersive Learning Environments." *Tech Trends* Vol 49, Number 3 (May 2004): 64-74. http://www.springerlink.com/content/h66x41v213x28g61/ (accessed 14 September 2009)

Arriotti, Scott, R. (Director Sales & Marketing, DiSTI, Orlando, FL), interviewed by author, 16 November 2009.

Bloom, Benjamin S.(Ed), Max D. Engelhart, Edward J. Furst, Walker H. Hill, and David R. Krathwohl. *Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook 1: Cognitive Domain.* Toronto, Longmans, Greene and Co., Inc., 1956.

Blunt, Richard. Does Game Based Learning Work? Results from Three Recent Studies. *Advanced Distributed Learning.* http://www.defencegaming.org/index.php?option=com_docman&task=cat_view&gid=31&Itemid=54

Bowen, Robert. (Chief TCM Gaming, National Simulation Center, Futures Division, Fort Leavenworth, KS), interviewed by author, 12 November 2009.

Caro, Paul, W. *"Factors Influencing Simulator Effectiveness in the U.S. Air Force."* HumRRO FR-ED-77-18. Alexandria, Virginia: Human Resources Research Organization, 1977.

Caspian Learning, Evidence that Games and ILSs Work: *Serious Games in Defense Education.* http://www.caspianlearning.co.uk/evidence-that-games-and-ilss-work. (accessed 14 Dec 2009)

Clark, Jim. Maintenance Simulators Gaining Military Acceptance, *Aviation Maintenance Magazine*, 1 November 2008, http://www.aviationtoday.com/am/categories/military/27217.html (accessed 14 Sep 2009)

Dirksen, Julie. Playing with the Brain, Part 2. A Brief Introduction to the Potential Impact of Brain Research on Game and Simulation Design. *Learning and Entertainment Evolution Forum*, 19 June 2009. http://www.harrisburgu.net/LEEF2009/

DiSTI, http://www.disti.com/ (accessed on 30 Nov 2009)

Fiorno, Frances. "'E' for Expanding E-Learning." *Aviation Week and Space Technology* Vol 161 Issue 22, (December 2004) [p69 – 69].

Free Online Library. "Who's Who in Training & Simulation." http://www.thefreelibrary.com/who;s+who+in+Training+&+Simulation-a074440948 (accessed 29 September 2009).

Gee, James, Paul. *"Good Video Games And Good Learning."* Madison, WI: University of Wisconsin-Madison. www.academiccolab.org/resources/documents/Good_Learning.pdf

Gourley, Scott, R. "3-D Models and Maintenance Training." Maintenance Training Technology. Vol 10, Issue 4, 2005. www.MT2–kmi.com (accessed 29 September 2009).

Hutchins, Richard M., Financial Analyst, Air Education and Training Command, HQ AETC/FMAT, e-mail to author, 3 November 2009.

Interaction Media Group. "3-D 'Virtual Task Trainers'." http://articles.directorym.net/3_D_virtual_task_trainers-a878309.html (accessed 29 September 2009).

Lavery, G. T., *The Simulator and the Airline Pilot*. Proceedings of The Royal Aeronautical Society's Flight Simulation Symposium: Experience and Needs of Civil and Military Flight Simulator Users, (London, 1981).

MSgt Gary H. Trejo. (Graphics Branch Manager, 367th Training Support Squadron, Hill AFB, Utah), interviewed by author 17 September 2009.

MSN - Encarta dictionary, http://encarta.msn.com/encnet/features/dictionary/ (accessed 14 December 2009).

NAS Insights, *Generation Y: The Millenials. Ready Or Not Here They Come*, 2006, http://www.scribd.com/doc/2607132/GENERATION-Y-THE-MILLENNIALS, (accessed 12 Oct 2009).

NGRAIN, http://ngrain.com/company/index.aspx (accessed 1 Dec 2009)

NGRAIN, *NGRAIN and CAE Help Canadian Forces Increase Training Throughput*, NGRAIN Case Study, http://ngrain.com/pdfs/CaseStudy-AccelleratingTrainingby60(CanadianAirForce).pdf (accessed 29 Sep 2009)

NGRAIN, *Report On Military Use Of NGRAIN Interactive 3D Equipment Simulations In Training And Operations*, November 2008, http://ngrain.com/casestudies/ (accessed 29 Sep 2009).

Office of Management and Budget, FY 2009 Department of Defense Budget, http://www.whitehouse.gov/omb/rewrite/budget/fy2009/defense.html (accessed 2 Nov 2009)

Orvis, Karin, A., Horn, Daniel and Belanch, James. *Videogame-Based Training Success: The Impact of Trainee Characteristics – Year 2.* Technical Report 1188. Arlington, VA: U.S. Army Research Institute for the Behavioral and Social Sciences, 2006.

Proctor, Paul. "Just-In-Time Training?" *Aviation Week & Space Technology* 144, Issue 22 (27 May 1996): p13.

Roberts, Jeff. "E for Expanding E-Learning: Software Advances Featuring Realistic Scenarios Take Pilot and Technician Training to Another Level." Aviation *Week and Space Technology* Vol. 161, Issue 22, p69. 6 December 2004. http://webebscohost.com/ehost/delivery?vid=10&hid=4&sid=50fe801f-fcff-417b-9...

Rolfe, J. M., & Staples, K. J.. *Flight Simulation*. Cambridge: Cambridge University Press, 1986.

Ross, Phillip, E. "The Expert Mind." *Scientific American* Vol 295, Issue 2 (Aug 2006) 64-71. http://web.ebscohost.com/ehost/delivery?vid=6&hid=107&sid=3bb4f6f6-9388-47b.. (accessed 28 September 2009)

Rushlau, Elton, R., III. (Chief Petty Officer (Retired, 2009), Director of Training, Center for Surface Combat Systems Unit, Great Lakes, IL), interviewed by authored 14 October 2009.

Seeking Alpha.com, *The Video Game Industry: An $18 Billion Entertainment Juggernaut*. http://seekingalpha.com/article/89124-the-video-game-industry-an-18-billion-entertainment-juggernaut. (accessed 2 Nov 2009).

Suite101.com, *Designing Training for Gen Y; Learning Style and Values of Generation Y*, 2007, http://trainingpd.suite101.com/article.cfm/designing_training_for_gen_y. (accessed 12 Oct 2009)

Web Courseworks, http://webcourseworks.com/simulations_for_training. (accessed 3 Dec 2009)

Winkler, John and Steinberg, Paul. *Making Military Training More Effective and Affordable: Lessons from RAND Research*, RAND Report MR-850-A. (Santa Monica, CA: RAND February1997), xv.