INTRODUCTION

Video Game Styled Training (VGST) has a proven track record for enhanced problem solving, idea generation, human performance, and training cost reduction, and yet the nuclear industry lags behind many government organizations, utilities, and other technical industries in leveraging this proven technology. At best, VGST in the nuclear industry remains a novelty that students use to familiarize themselves on a small topic prior to taking a more comprehensive and cumbersome instructor-led course.

As nuclear power plants strive to improve human performance while maintaining megawatt costs competitive with the dropping price of natural gas, eLearning with VGST offers an extremely viable tool to help meet those goals. Common reservations and misconceptions include cost, development time, a method to ensure the training meets INPO accreditation criteria, and proof of improved knowledge retention and human performance.

Cost – eLearning of any kind accelerates the pace of a training program. Learners are able to move through the material at his/her own pace, thus shortening their gate-to-jobsite on-boarding time. Reductions of individual course completion time from 50-75% are not uncommon. When calculating actual financial cost of developing a complete VGST course, the investment is quickly recovered when targeting high-population, frequent-delivery topics such as General Employee, Safety, Radiation Worker, Basic Systems, SOERs, and E-Plan.

Development Time – The time to develop an instructor-led training course from scratch typically ranges from 10 – 40 investment hours per hour of instruction. A site can expect anywhere from 40 – 160 hours of course development prior to presenting a four-hour accredited training session. This time would generally be spread over a period of 4-8 weeks, as the developer would seldom have his/her time completely committed to developing one lesson plan. In comparison, a contracted VGST company can deliver one eLearning session using a VGST environment within 30 – 60 days, approximately the same time frame as the site developing instructor-led training from scratch.

INPO Accreditation – eLearning uses the same approach to objective-based training as instructor-led training, but it does have unique considerations. Currently, INPO has a draft document titled “Systematic Approach to eLearning – from Analysis to Implementation.” Although not an official ACAD, the 50 page document effectively details how to how implement eLearning into the accredited training process.
Knowledge Retention and Performance Improvement – The value of control room simulators to training nuclear operators is unquestioned. Likewise, “hands-on” labs and OJT/TPE training remain extremely effective for knowledge retention and performance improvement. “Doing” has always been a better learning method than “showing” or “telling.” VGST allows the learner to “do” the work in a virtual environment. A growing body of research shows that interacting within a 3D environment engages the learner in the training presentation more directly, illustrates the effects of failure and success without injury or plant impact, and has a knowledge retention rate of 78%, far exceeding the 20% retention rate when using audio/visual tools.

Misunderstanding appears to be the main hindrance to leveraging eLearning and VGST within the nuclear industry. The deferral of responsibility to course developers or complete dismissal of VGST is usually sourced in a lack of understanding its full potential. Like any major human performance or budgeting initiative, a champion is necessary to create the vision and set goals for the organization. The commitment to using VGST as an innovative, effective, and fiscally responsible learning tool is no exception. This paper intends to provide specific examples of how eLearning with VGST can improve human performance training in the nuclear industry while reducing financial costs.

VGST – A PROVEN TECHNOLOGY

Similar to the format used in entertainment products, VGST employs a computer-simulated, animated environment that contains photo-realistic 3D images of the equipment, the surrounding area, and any necessary tools required to complete the procedures. The steps required to perform the procedure(s) are completed by the learner, using interactive functions which are then graphically represented within the computer-simulated environment.
In 2008, Mark Beckstrom and Phil McCullough of INPO made the following observations: (1)

From a pragmatic perspective, working in an immersive learning environment such as a virtual world provides several benefits that make it an effective alternative to real life:

**Movement in 3-D space.** A virtual world could be useful in any learning situation involving movement, danger, tactics, or quick physical decisions, such as emergency response.

**Engendering Empathy.** Participants experience scenarios from another person’s perspective. For example, the Future of Learning team is exploring ways to re-create the control room experience during the Three-Mile Island incident, to provide a cathartic experience for the next generation workforce so they can better appreciate the importance of safety and human performance factors.

**Rapid Prototyping and Co-Design.** A virtual world is an inexpensive environment for quickly mocking up prototypes of tools or equipment.

**Role Playing.** By conducting role plays in realistic settings, instructors and learners can take on various avatars and play those characters.

**Alternate Means of Online Interaction.** Although users would likely not choose a virtual world as their primary online communication tool, it provides an alternative means of indicating presence and allowing interaction. Users can have conversations, share note cards, and give presentations. In some cases, virtual worlds might be ideal as a remote classroom or meeting place to engage across geographies and utility boundaries.
In 2008, Dr. Rizwan Uddin (Department of Nuclear, Plasma and Radiological Engineering – University of Illinois) made a presentation to the Exelon/INPO sponsored Human Performance Workshop titled: Creating the Foundation for Outage and Online Success. (2) The presentation detailed the methodology of using VGST to simulate radiation fields, thus providing a way to engage learners in virtual rooms to demonstrate excellent radworker behaviors. The presentation cited the following:

Industry Objective: Taking advantage of recent developments in several fields including multi-media, virtual reality and 3D (computer games) representation technology, develop a new set of courses for the 21st century to train personnel with non-nuclear background for work at nuclear power plant sites.

For example, a 3D, interactive and immersive model (that can be viewed on a virtual reality system as well as on regular PCs) displaying neutrons as they scatter, lose energy (neutron color shows its energy level), get absorbed or cause fission leading to new neutrons and fission products can explain the inside of a core much better than a 15 minute lecture.

Concepts of criticality, radiation protection and shielding etc may also be similarly better explained with multimedia, video and virtual models.

The goal is to enhance performance and improve the safety culture at Nuclear Power Plants through better education.

Attention-to-detail is a vital human performance behavior in the nuclear industry. If workers are able to spot discrepancies and correct them before they become larger problems, public and worker safety are improved. Several studies have shown that people who play electronic games have faster reaction times, significantly faster eye-hand coordination, heightened spatial visualization skills, and an increased capacity for visual attention and spatial distribution. One telling example was a study of laparoscopic surgeons who played video games in excess of three hours a week. They had 37% fewer errors and a 27% faster completion of surgery than their non-videogamer peers. (3)

Prompt, conservative decision making in the face of uncertainty is another vital human performance behavior. American, British, Canadian, and Australian military forces have successfully applied VGST to meet a variety of training needs. They have determined that VGST is “a cost-effective means to provide experienced-based learning with emphasis on cognitive and increasingly affective training domains.” (4) In other words, Video Game Styled Training has a proven financial return-on-investment when used as a training tool that simultaneously challenges the learner’s knowledge and skills.
The figure above illustrates why VGST is growing as an effective training tool in industries that require technical and human performance excellence. The “Adoption Pattern” box illustrates how VGST is typically introduced and then accepted by an industry. Initially, it is tested in a niche area, and then expanded into unregulated training, then certified applications, then a recommended practice, and finally it is made a mandatory standard. Currently, the nuclear industry is using VGST in the smallest of niche areas within unregulated spaces. Much of this lag behind other industries is attributable to a lack of vision in adopting VGST as a training tool. Incorporation of VGST is left to developers, who can at best haggle enough funding and technical resources for a small “nice-to-have” training aid. It is clear that the nuclear industry is familiar with the benefits of VGST, but very little progress had been made to
leverage it. The result is a pervasive perception within the industry that “online training” or “CBT” is little more than a boring, self-study PowerPoint presentation. For online training to be successful, it must engage the learner. A well-developed online training session contains higher level asynchronous activities. \(^{(5)}\) Examples are listed below:

Level 1 – “Page Turner” (PowerPoint, online documents, etc.)
Level 3 – Inclusion of “pop-up” boxes
Level 4/5 – Audio and narration
Level 5 – Quizzes and tests
Level 7/8 – Digital Video that illustrates situations and examples
Level 8/9 – Simulations based on real-world situations and have multiple decision paths

“Page turner” presentations, such as an online document or PowerPoint presentation are the lowest level of interactivity and hence, of the lowest instructional value when working with online delivery courses. Excellent online training programs should involve several interactive strategies to keep learners involved and thereby make the content stick when they return to the jobsite.

Simulations are a far superior training method when measured by improvement of performance. The National Training Laboratory (NTL) Institute for Applied Behavioral Science showed that students trained with simulations have a 78% learning retention rate – a retention rate far above other learning methods.\(^{(6)}\)
In terms of interactivity alone, VGST scores highest, engaging the learner in ways that require situational management and problem solving. These higher level activities are the key to quickly introducing a new workforce to the unique challenges presented by nuclear power plants, both old and new. They are also excellent tools for allowing visualization of complex outage projects and highly interactive situations such as E-plan events, SOERs, and security scenarios.

**VGST – A Complete Course**

Since 2008, the advancement of VGST technology combined with the ability to launch online courses and record training completion through a Learning Management Systems (LMS) has advanced the use of VGST simulators from a visual component of training, to that of a complete course. (7)

A VGST simulator is intended to exercise and reinforce the knowledge acquired in the theory / information delivery portion of the training.

A VGST simulator is usually programmed to operate in two modes: learning / practice mode and testing / certification mode. The user interface is designed to be intuitive so that the focus remains on the subject matter and not on complicated computer controls.
Learning / practice mode provides the operator with clear step by step prompts or instructions to complete the procedure in a desired sequence. Procedures, video clips, and other references can be embedded within the VGST environment. If the operator attempts a step out of sequence or an improper step, a warning or correction will appear on the screen and the operator will be directed to try again.

**Step 1: Pick a Scenario**
- Scenario 1: Placing a JSPV circuit breaker in service
- Scenario 2
- Scenario 3
- Scenario 4
- Scenario 5
- Scenario 6
- Scenario 7
- Scenario 8
- Scenario 9
- Scenario 10

**Step 2: Pick your Mode**
- Training
- Testing

**Step 3: Go!**

**Operation Order:**

E.2.2 VERIFY that the OCB is OPEN by observing the position indicator on the OCB.

E.2.2 Step 1: Click on the position indicator to view.
Testing / certification mode does not provide the operator with prompts or instructions. The VGST simulator allows the operator to take steps out of sequence and/or to make improper steps. According to predetermined conditions, specific cause & effect reactions may be programmed into the VGST simulator. In some situations, such as a minor error, the operator may be allowed to proceed with a coaching comment. In other situations, such as a critical error, the VGST simulator could shut down and the operator would be required to start over. In variations of the scenario, events such as equipment failures or other complications can be programmed to occur at random times during a standard procedure. This introduces a troubleshooting element to the training and prevents learning complacency. A count of the operator’s errors will be provided at the completion of each sequence. This provides hard data which can then be used to identify strengths and weaknesses of the individual operator and/or the workgroup.

In both modes, the attempted operation of visible controls that are not associated with the sequence will not be allowed. Typically, a user can complete a training scenario in less than ten minutes. Any number of users can run the VGST simulator simultaneously and at their own speed. An unlimited number of scenarios can be programmed into the VGST simulator using the same environment. This is cost-effective, as the basic environment (e.g., 4KV Switchgear Room, Residual Heat Removal (RHR) Pump Room, etc.) would not have to be recreated to introduce a new training situation.

The following four steps describe a typical deployment plan for a comprehensive eLearning + VGST training solution:

1. Identified students are given access via intranet or internet to the eLearning theory modules for a time-defined period to complete the course. A subject matter expert / instructor is identified as resource to answer questions during this period. Results from the tests are tracked automatically within the Learning Management System.

2. Upon achieving the desired performance in the eLearning theory modules, students are granted access to the VGST simulator. They are allowed to attempt the various scenarios / procedures in a practice mode as many times as they require to become proficient. Built-in prompting and coaching features help guide the students, as well as reinforce industry safety and human performance standards.

3. After the designated practice period, the students are given access to the testing or certification mode of the VGST simulator. In contrast to the learning / practice mode, the students are allowed a fixed number of attempts to complete the required scenarios with a minimum passing score. The results from the testing are tracked either as a pass / fail or as a detailed report providing the instructor with a list of specific errors.
4. Students who achieve a passing score on the VGST simulator advance to the next phase of their curriculum. Students who fail to achieve a passing score are scheduled for remedial training or additional time with instructors.

This format can reduce in-class time by up to 75% while allowing individual students to spend as much time as they require to digest the materials and to focus on areas they find particularly challenging. The logistical costs associated with running a class room training session are reduced accordingly. VGST is also readily adapted to refresher training or as a procedural reference tool in a condensed or accelerated format.
Despite the proven benefits of VGST outside the nuclear industry and the identified application potential within, implementation has been slow to nonexistent. Recurring challenges, real or imagined, tend to fall into the following categories: cost, development time, and integration into accredited training.

**Cost**
In order to validate the return on investment (ROI) of VGST, a cost of instructor-led training has to be established. An American Society of Training and Development (ASTD) study found that 67% of training directors interviewed do not measure the effectiveness of their net-based programs. Although student reaction to the courses was measured, only 3% of the respondents make a real effort to measure the business results of training programs. (8)

A failure to understand the financial cost of delivering instructor training makes measuring the financial gain by conversion to eLearning impossible. Ironically, a simple equation can be used to estimate this cost: (9)

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\text{Total Training Expense Rate (TER)} = (\text{Training Dept. Resource TER}) + (\text{Training Staff Wage TER}) + (\text{Average Class Wage TER})
\]

This equation presumes all training resources ultimately contribute to the presentation of information to students and that all training is instructor-led. An example is described below:
Consider a nuclear utility with the following assets:

- A $2,000,000 annual training budget
- A training staff of 60 at an average salary of $60000/yr.
- An average of 4000 instructor-led training hours per year
- An average class size of 10 students earning an average wage of $50/hr.

Total TER = [($200,000 budget/4000hrs) + (($60,000*60 staff)/4000hrs.) +
[($50/hr.)(10 students)]

Total TER = $500 budget/hr. +$900 staff/hr. + $500 student/hr. = $1900/classroom-hr.

In this example, the utility cost to present instructor-led training runs an average of
$1900/hr for a 10-student class. This extrapolates to $7600 for a typical four-hour
course.

This example illustrates the financial need for VGST to be targeted at courses that have a high population of
students and are presented frequently. However, additional financial savings are realized by:

- Reduction of safety and human performance errors
- More worker time spent at the jobsite, versus in training
- Virtual elimination of paper document control issues
- Low legacy costs, since revisions to procedures can be accomplished in short order, at low cost, and
implemented globally in an instant.
  • Investments in software can be capitalized from an accounting perspective and can be shown on a balance sheet as an asset.

Initial training courses such as basic nuclear systems and human performance techniques, as well as industry-wide courses such as General Employee Training, Radiation Worker Training, SOERs, Foreign Material Exclusion, etc. are ideal candidates for VGST. Each of these courses have a high population of learners, are performed frequently, and result in improved field performance when trained using a VGST simulator versus a PowerPoint lecture or “read-the-slide” online presentation.

**Development Time**

Few, if any, nuclear sites employ the necessary technical talent to develop VGST simulators on-site. It is therefore necessary to contract such projects to professional companies who specialize in VGST. The site training staff is leveraged to provide information to the contracted company. This information includes:

  • Written steps of the specific procedures to be simulated. (Start up, shut down, operation, routine maintenance, etc.)
  • Descriptions and photos of the tools, equipment and virtual environment where the training scenarios will take place. (Job site, maintenance shop, rural, urban, etc.)
  • If possible, a camera capture video of the actual procedure(s) being done.
  • Description of any random actions or responses that are to be incorporated in the training. (Breakdowns, critical errors, etc.)
  • Description of the hardware and operating system that VGST will be deployed on.

A contracted VGST company can usually provide the site with a short project (one eLearning module and one VGST scenario) within 30 – 60 days. More typical projects (two or three eLearning modules and three or four VGST scenarios) take 90 – 120 days. Although expert opinions vary on the time required to develop a new instructor-led training session, estimates of 10 to 40 hours per one hour of classroom presentation are common. Nuclear site expectations that a new four-hour lesson plan be developed and approved within the same 30-60 day time frame is typical.
Integration into Accredited Training

A cultural challenge to implementing new methods of training delivery is how to ensure it will meet INPO accredited training requirements. VGST adds additional pressure because of the time and financial investment required to develop it.

Interestingly, INPO began development of a document titled “Systematic Approach to eLearning – from Analysis to Implementation.” The 50 page document effectively details how to how implement eLearning into the accredited training process. It includes project planning, flowcharts, instructional strategies, objective design suggestions, prototype testing methods, and external resources. Although the document remains in a “Draft” form at the time of this writing, it is clear that VGST can be implemented into an INPO accredited training program, and that an effective groundwork has already been laid.

Collaboration

One of the priceless assets the nuclear industry possesses is collaboration. Even though each site is owned by a particular company, sharing operating experience, subject matter experts, training materials and methods are commonplace.

A frequent lament within the nuclear industry is the lack of consistent quality in the content and instruction of material that is generic to most sites. VGST is clearly financially viable for site-specific training, but an even greater financial ROI and industry consistency can be achieved through the collaboration of several utilities in the development of common courses such as Radiation Worker, FME, Confined Space, and Basic Nuclear Systems. While INPO has made progress by creating generic NANTeL training courses, adding VGST to create highly-interactive training modules would allow learners to see how systems operate, interrelate, and the impact of their performance upon them. The high interactivity within VGST environments improves learner engagement, thereby improving their long-term knowledge and skill retention. Going a step beyond INPO-developed courses would be the collaboration by several utilities in VGST course development. Such collaboration would not only achieve a lower financial cost per utility, but it would also create a consistent training quality throughout the industry.

Using current technology, VGST can also support multiple users from multiple locations within the same 3D training environment, similar to the Massively Multiuser Online Role Playing Games (MMORPG) like World of Warcraft and Star Wars: The New Republic. The application of VGST technology into outage planning, E-Plan and Security Force-on-Force drills has incredible potential. A wide variety of scenarios can be implemented with each person.
independently moving through the same simulated environment even though they are physically miles apart. Real-time instructor capability and data collection allows continuous monitoring of individual and group performance using both quantitative and qualitative evaluation tools.

Larger utilities with several nuclear sites, the USA Alliance, and INPO are all possible collaboration points where the brightest and best can be brought together in an effort to not simply develop a few VGST courses, but recapture a vision for the future of nuclear training.
“Nuclear power is unique.”

This phrase has been in the nuclear lexicon for many years. It is used to describe the responsibility each employee has to the greater public for safe operation of every nuclear reactor. Since the Three Mile Island accident in 1979, the nuclear industry has pioneered industrial training to achieve remarkable improvements in technical skills, operating experience, and human performance. It is therefore remarkable that a training tool as effective as VGST has made great strides outside the nuclear industry while languishing within.

Returning to comments made by Mark Beckstrom and Phil McCullough in 2008 [1]:

Beyond the initial perfect storm (exodus of the aging workforce) is another set of factors driving the future of learning.

First, consider the need for speed. It has been said that "If you are not learning at the speed of change, you are falling behind."

In his "25 Lessons from Jack Welch," the former CEO of General Electric said, "The desire, and the ability, of an organization to continuously learn from any source, anywhere - and to rapidly convert this learning into action - is its ultimate competitive advantage." Giving individuals, teams and organizations the tools and technologies to accelerate and broaden their learning is an important part of the future of learning.

Second, consider the information explosion - the sheer volume of information available, the convenience of information access (due, in large part, to continuing developments in technology) and the diversity of information available. When there is too much information to digest, a person is unable to locate and make use of the information that one needs. When one is unable to process the sheer volume of information, overload occurs. The future of learning should enable the learner to sort through information and find knowledge.

Third, consider new developments in technology. Generations X and Y are considered “digital natives.” They expect that the most current technologies are available to them - including social networking, blogging, wikis, immersive learning and gaming - and to not have them is unthinkable.

A new generation of workers and a new generation of power plants are entering the industry. “Page turner” PowerPoints are the most primitive of eLearning options. They have little retention value or human performance impact. To remain a competitive energy option, the nuclear industry can no longer afford to keep dreaming about...
“someday” for routinely incorporating 3D technology into its accredited training programs, outage planning, and emergency response plans. Yesterday’s future of learning is now.

The time has come to not only implement VGST within the nuclear industry, but to race back to the front of incorporating all forms of fiscally responsible training that improves human performance, industrial and nuclear safety. The technology exists and is proven. Financial ROI is feasible. The computer infrastructure is in place to develop and deliver the training. Guidance exists to integrate the training into INPO accredited programs. All that remains is for decision makers in the nuclear industry to make it happen.

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